Delayed Asian monsoon onset during the Medieval Warm Period: PMIP3 multi model study

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The Asian monsoon develops over tropical-to-subtropical South and East Asia and is characterized by salient seasonal variation in atmospheric circulation between land and ocean. Long term integrations of climate models on hundred or thousand year timescale reveal that the past variation in seasonal and latitudinal distributions of solar radiation due to orbital parameters forces long-term Asian monsoon variability. Enhanced summertime insolation at the top of the atmosphere (TOA) and resultant warmer Eurasian Continent during the Medieval Warm Period (MWP; 950-1250 A.D.) compared to the Little Ice Age (LIA; 1400-1700 A.D.) reinforces the Asian summer monsoon. The last millennium simulations conducted under the Paleoclimate Modeling Intercomparison Project phase 3 (PMIP3) reveal that the enhanced land-sea thermal contrast and monsoon during the MWP are largely consistent among models. The TOA radiation as a driving factor for the Asian monsoon has its peak anomaly (MWP minus LIA) during July to September (JAS) over the Northern Hemisphere mid and high latitudes. In contrast, the TOA radiation between boreal winter and pre-monsoon period (April to June; AMJ) shows negative anomaly (less insolation during the MWP compared to the LIA). The seasonally asymmetric radiative forcing can result in early/delayed onset of summer monsoon (e.g. Ueda et al. 2011). The current study examines physical relationship between timing of monsoon onset and variation of insolation during the MWP by using results of PMIP3 multi-model archive and idealized sensitivity simulations in a coupled climate model.
PMIP3 multi-model ensemble-mean shows warmer Eurasian Continent and enhanced Asian summer monsoon in JAS but inversely shows cooler Eurasian Continent in AMJ and delayed monsoon onset. Land-sea contrast in tropospheric temperature (between 200 and 500 hPa) can be used as an index for monsoon intensity. Sensitivity experiments performed by MRI atmosphere-ocean coupled general circulation model prescribed with orbital forcing during the two periods can reproduce the above regional anomalies including monsoon. The results of this study indicate that the delayed monsoon onset during the MWP is primarily forced by the orbital parameters and therefore robust feature among climate models.

Reference
Ueda, H., et al. 2011. Clim. Dyn., doi:10.1007/s00382-010-0975-z.

Keywords: Asian monsoon, Land-sea contrast, Medieval Warm Period, Little Ice Age

The cold periods before and after the warmest early Heian era –No existence of Medieval Warm Event in Japan –

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A continuous reconstruction of quantitative paleotemperatures in the Holocene was conducted by using alkenone sea surface temperature (SST) measurements from coastal sedimentary cores because of the strong correlation of SST with atmospheric temperature (AT) in the coastal bay area. Especially during the last three thousand years, the SSTs (ATs) fluctuated by 2.1 degree, with a maximum in 820AD (24.3 degree, 25.9 degree). In addition, the large minimum SSTs (ATs) wa observed at 990 AD (22.4 degree, 24.0 degree). Low temperature was also observed in 560-620AD. The Medieval Warm Period (MWP) in 950-1250 AD (sometimes 1000-1400 AD) is a period of warming by a few degrees that was primarily confined to Europe and North America. The period and affected areas are, however, still open to debate. The IPCC Assessment Reports (2001, 2007) and Mann et al. (2009) discussed the “MWP around 1000 AD”, which may have been local or regional. Bradley et al. (2003) reviewed the evidence and concluded that the warmest medieval ATs were not synchronous around the globe. The MWP was not identified in western Japan because a cold climate prevailed in 990–1150 AD. Particularly low temperatures around 1000–1100 AD can be verified by historical documents from in and around the ancient capital city of Kyoto (Ishii, 2002). It is also confirmed by the evidence that large decrease of SSTs(ATs) was reconstructed in Uchiura (Funka) Bay in northern Japan. Therefore Japanese islands did not experience MWP although MWP has been reported from Europe, USA, and China. Although it is difficult to exactly specify the causes, one plausible mechanism is ENSO. It is suggested that the equatorial Pacific was predominantly in an El Niño phase in 900–1200 AD. Actually, the Southern Oscillation Index (SOI), a proxy for an ENSO event, with negative values corresponded to an El Niño episode. At the modern condition, the Pacific high is weakened, with reduced atmospheric pressure in the western North Pacific in the vicinity of Japan. This results in an enhanced Okhotsk high, which tends to be accompanied by a cold and cloudy/rainy summer in Japan (Meteorological Agency of Japan, 2014).

Keywords: Sea surface temperatures, Atmospheric temperatures, Climatic change, Medieval Warm Period, Japan

Late Holocene flooding history reconstructed from GDGTs in Beppu Bay sediments

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Reconstruction of flooding events is a recent issue of paleoclimatology. We developed the use of GDGT compositions to identify flooding sediments in marine cores and generated a 2900-year long record of flooding in Beppu Bay area, northern Kyushu, Japan by analysing 457 sediments (2-cm interval) of core BP09-3 retrieved in Beppu Bay basin. We also analysed 74 soils in the watershed areas of Oita and Ohno Rivers and 35 estuary sediments for comparison.
Branched GDGTs in soils have less methyl group (higher MBT) and less cyclic structures (higher CBT) than estuary and basin GDGTs. Soil and estuary sediments have more branched GDGTs (higher BIT) than basin sediments. GDGT compositions are, thus, useful to identify the provenance of sediments in Beppu Bay cores.
In core BP09-3, 18 thick and 55 thin event layers were recognized by visual, soft X ray and CT-scan descriptions, and the sediment ages were determined by 42 radiocarbon dates of molluscan shells (Kuwae et al., 2011). Most of major event layers showed higher BIT than hemipelagites. Some of them have high MBT and CBT values which correspond to those of soils. We interpret that they originated directly from the surface soils via Oita and Ohno Rivers, most likely by typhoon-induced flooding. Historical records support this interpretation.
U^{K}_{37}' in the study core showed decadal-scale variation in temperature (PDO). More than two third of flooding events occurred when temperature was rising (transition from positive to negative PDO). These results suggest that the spatial pattern of North Pacific sea surface temperature is a key factor controlling typhoon activity.

Keywords: typhoon, flooding, PDO

Formative Process of varve sediments and recent cyclic change in the Lake Hiruga, Fukusima Prefecture, central Japan

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Lake Hiruga, is one of the Five Lakes of Mikata, is a small lake of less than 1 km^2, which is located in the Japan Sea side of central Japan. This lake is in contact with the Japan Sea by Hiruga channel, and with Lake Suigetsu by artificial Saga Tunnel. Although the salinity of lake water is close to the seawater, the bottom water shows the low water temperature (about 10˚C) in the summer season, and shows the constantly anoxic environments, because the water depth of lake basin is deep (about 38m).
In order to clarify the history of paleoenvironmental change at the Lake Hiruga, the coring was carried out around the center of lake. In this time, we discuss about the formative process of distinct lamina in core top of 50cm, and report to cyclic change.
15HG-2C and 3C cores consist of mud sediments with the lamination at the integrated core length of 251cm. AMS^{14}C dating is carried out in 11 horizons. Based on the results, the age of core bottom is about 3300 years ago. Lake Hiruga was a freshwater lake until AD150, and changed to oligohaline lake from that time. Around the 10th century, the bottom water of this lake became to mixoeuhaline water. Judging from the bottom water exhibits a euxinic environment, it might have had a distinct stratified structure in water column. From the 19th century, the lake basin shows high sedimentation rate, and distinct lamina sediments are formed. It is considered that this is caused by the construction of the Saga tunnel.
In distinct lamina sediments, a lamina with high soft X-ray absorption intensity shows gray color. This suggests that it is a lamina with high precipitation. According to the precipitation pattern in the Wakasa district, the peaks of precipitation are shown snowfall season in winter, and rainy and typhoon seasons in summer. In snowfall season (Dec. to Jan.), the precipitation is the highest. Although the drainage to the lake is large, the current velosity seems to be low, because it accumulates in the catchment area as a snowfield. It is considered that this period contributes to the supply of fine sediments, and forms a lamina with low soft X-ray absorption intensity. In rainy season (Jun. to Jul.) and typhoon season (Aug. to Sep.), heavy rainfall is likely to occur, and the current velosity in lake seems to be high. It is considered that these period contributes to the supply of coarse sediments, and forms a lamina with high soft X-ray absorption intensity. When both events occurred, a lamina with high intensity shows double layer. In this reason, a lamina set with high and low intensity seems to be interpreted as varve.
During the last 200 years, the fluctuation of 5 cycles in total organic carbon (TOC) contents, and the fluctuation of 10 cycles (about 20 years cycle) in total sulfur (TS) contents were recognized. It is considered that the cyclic fluctuation of TS contents is caused by different level of reduced environment due to differences in inflow of seawater with cyclic sea-level change. This cyclic fluctuation seems to be related to the Pacific Decadal Oscillation (PDO). We recognized about 35 years cycle in the TOC contents, and 75 years cycle in the sediment flux.

Keywords: Lake Hiruga, varve, Total sulfur contents, cyclic fluctuation, PDO

Relationship between sedimentary environment and change in type/magnitude/frequency of paleo-hazard history recorded in the sediment of Lake Suigetsu during the late Holocene

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Occurrences of floods and earthquakes could cause the inflow of enormous material to sedimentary basin and consequent deposit of “event deposits (event layers)”. Event deposits could be the recorder of hazard events in the geological past, exceeding the limit of observation and historical record. However it is not easy to distinguish the cause of deposition of event layers and magnitude of each event. In addition, it is also necessary to consider the change of sedimentary environment which could affect the boundary conditions of deposition and scale of event layers. In this study, we tried to reconstruct the record of heavy precipitation and flood events on the last 7000 years using sediment of Lake Suigetsu (SG12 core) based on correlation of observational record and sediment. As a result, depositional processes for recording the occurrence of heavy precipitation and flood events are revealed as below;
1) Flux of detrital material from drainage area increases with the frequency of heavy precipitation (>50mm/day).
2) Light gray event layer is deposited with the occurrence of flood event and its thickness represents the total amount of precipitation in the flood event.
In addition to this result, we reconstructed the flux of sediment components including detrital material from different sources and correlated the result with other environmental record obtained from the sediment of Lake Suigetsu. As a result, local environmental changes described below are revealed.
1) Flux of detrital material would increase and keeps high level in ~100 year time scale occasionally after the deposition of event layers. This could be caused by the increase of erosion rate triggered by slope failures.
2) After the deposition of event layers which are correlated with historically recorded earthquakes, flux of detrital material would increase and keep high level in ~1000 year time scale. This could be the result of topographic change of drainage area caused by fault movements.
Related to this presentation, establishment of proxy for reconstructing heavy precipitation and flood event based on correlation of sediment and observation is presented in H-SC07 session, and correlation of the result of flood event in the late Holocene with regional climate change would be discussed in M-IS 06 session.

Keywords: Lake Suigetsu, varved sediment, flood, earthquake, Holocene

Variation factors of the coastal lagoon environment and ecosystem since the modern period in Hokkaido, Japan

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Although both human activity and natural climate change affect the aquatic environment and ecosystem of lagoon, most previous researches on lagoon eutrophication only discussed the effects of human-induced eutrophication. The effects of climate and sea-level changes have been comparatively less discussed. Thus, we reconstructed the environment and ecosystem changes since the mid 19 centuries in a seasonally frozen lagoon Mokoto-ko locates along the Okhotsk Sea coast in Hokkaido, northern Japan based on multi proxy analyses (CNS, XRF, and diatom) of sediment samples, to discover the impact of eutrophication and climate change on the lagoon ecosystem.
Mokoto-ko is seasonally ice-covered small lagoon, however, has a large 167 times catchment area. At present, Mokoto-ko is an eutrophic lagoon, and anoxic bottom water mass was observed. In January 2009, 1.8 m long sediment cores (09Mk-1C) was obtained from the northern part of basin using a push-in piston corer. There is the clear lamina layer throughout this core. Based on the sediment core analysis, eutrophication of lagoon Mokoto-ko started in late 1950s by phosphorus input, which is probably related with the development of dairy farming in the catchment area. On the other hand, lagoon environment and ecosystem showed drastic fluctuation. A sudden eutrophication and fresh water input of this lagoon has a strong relationship with heavy precipitation in its catchment. In this area, frequency of the heavy precipitation has good correlation with the phase of the Arctic Oscillation, meaning that Arctic Oscillation partially controlled the lagoon environment and ecosystem. In this presentation, impact of climate change on the lagoon ecosystem is discussed based on this periodical environmental change in addition to the impact of human activity.

Keywords: lagoon, Paleoenvironment, Diatom, Anthropogenic effect

Challenges for Millennium Reanalysis

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Our systematic instrumental measurement for meteorological quantities only lasts 100 years at most, so they are too short to analyze recent big climate changes, like Little Ice Age or Medieval Warming Period. In our research group, we have made an offline data assimilation system for stable water isotopes and showed our success to reproduce ENSO changes during 19th to 21st century (Okazaki and Yoshimura, submitted). On the other hand, we have made data assimilation of weather information from old diaries (Toride et al., submitted). Thus, by combining those two data assimilation methods, we are trying to make 1000-year length atmospheric reanalysis product or "Millennium Reanalysis". At the presentation, I'd like to introduce these two new methods and current status of Millennium Reanalysis project.

Keywords: Millennium Reanalysis, data assimilation, stable water isotope

Responses of Antarctic and the Southern Ocean temperatures to changes in annual-mean insolation over the past 700,000 years

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Antarctic temperature record, based on isotope composition of water (δ D), shows close correlation between temperature and atmospheric CO_2. Many studies suggest that a central role of the temperature variation of the Southern Ocean region for global carbon cycle. Deuterium-excess (d-excess = δ D $-8\delta^{18}$ O) provides the information on the ocean surface conditions in the moisture source for polar precipitation. We show a new d-excess record from the 3,035m-depth Dome Fuji ice core (DF2), which was obtained at the Dome Fuji station. The new part of DF2 core (2400m to 3034m depth) extends back to 700 ky BP with high time-resolution. We reconstructed Antarctic air temperature (T_{site}) and temperature at moisture source region (T_{source}) using the new d-excess data. Relationship between T_{site}, T_{source}, and annual mean insolation will be discussed.

Keywords: ice core, d-excess, glacial interglacial cycle

High-resolution reconstruction of climates under the three great famines in the Edo period based on intra-ring oxygen isotope ratio of tree rings and historical daily weather record

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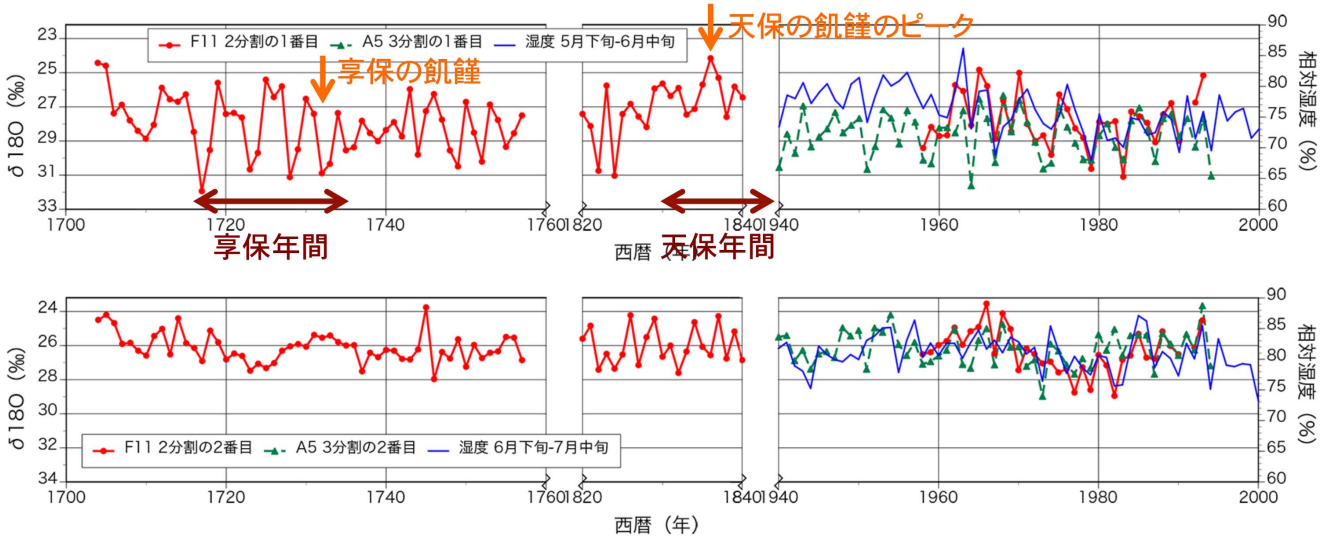
Stable oxygen isotope ratio ($\delta^{18}O$) of tree-ring cellulose is known to reflect well relative humidity at the time of ring formation. In this study we attempt high-resolution reconstruction of climates under the three great famines (Kyoho, Tenmei, Tempo) in the Edo period (1603-1867) by analyzing intra-ring data of oxygen isotope ratio of tree-rings. Tree-ring samples used in this study were taken from two hinoki (*Chamaecyparis obtusa*) trees growing at the Mt.Tanakami site, Shiga Prefecture, central Japan. We extracted cellulose from the wood samples by the “cross-section” method and divided into 12 (or 2, 6, 24, depending on the ring width) segments for each ring using a scalpel. Isotopic measurement was carried out using a continuous flow system with a pyrolysis-type elemental analyzer and an isotope ratio mass spectrometer (TCEA-Delta V Advantage). By comparing measured intra-ring data of cellulose $\delta^{18}O$ and observational data of relative humidity at the adjacent meteorological station for the mid- to late 20th century, intra-ring $\delta^{18}O$ was found to reflect variation of humidity at sub-seasonal (monthly or finer) temporal resolution in the growth season of the tree (May-Jul. or May-Sep. for our samples). According to this result, we reconstructed variations of humidity for the pre- to early Baiu rainy season (May-Jun.) and the mid- to late Baiu season (Jun.-Jul) using $\delta^{18}O$ chronologies of early part and middle or late part of each ring (Figure). For the pre- to early Baiu season, highly variable $\delta^{18}O$ was found in the Kyoho period (1716-1736), implying periodical occurrence of dry early summer caused by delayed onset of the Baiu season. We can also recognize significant decrease in $\delta^{18}O$ (increase in humidity) in the Tempo period (1831-1845), probably due to abnormally early onset of the Baiu season. Contrarily, variability of $\delta^{18}O$ is relatively small for the mid- to late Baiu season.

Keywords: Tree-ring cellulose, Stable oxygen isotope ratio, Intra-ring fluctuation, Relative humidity, The three great famines in the Edo period, Historical daily weather record



初夏～梅雨季前期(上)と梅雨季中～後期(下)に対応する年層内セグメントの年輪酸素同位体比と相対湿度の経年変動

Climate variations in northern Japan as reconstructed from tree ring cellulose $\delta^{18}O$

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Tree-ring cellulose $\delta^{18}O$ is known to be a promising proxy for reconstructing hydroclimate variations in monsoon Asia because the $\delta^{18}O$ is not controlled by ecological factors but by two climatic parameters (i.e., relative humidity and $\delta^{18}O$ of precipitation). In this study, two tree-ring $\delta^{18}O$ series were developed by measuring two individual trees (*Cryptomeria japonica*) growing in Miyagi, northern Japan. Climatic response analyses reveal that the relationship between tree-ring $\delta^{18}O$ and relative humidity is not temporally stable. Also, the tree-ring $\delta^{18}O$ from Miyagi shows complex correlations with other tree-ring $\delta^{18}O$ from Japan, indicating that tree-ring $\delta^{18}O$ in northern Japan is not simply controlled by local hydroclimate. Continued effort toward the development of a dense tree-ring network will shed more light on variability of climate in Japan.

Keywords: Tree-ring cellulose δ18O, Japan

Correlation between two tree-ring d18O chronologies from coastal areas of Pacific and Japan Sea in Hokkaido, North Japan

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We analyzed the tree-ring oxygen isotope ratios (d18O) during last one hundred years for four trees of Picea glehunii in each of North (Teshio) and East (Onnebetsu) Hokkido, Japan. In each of the two sites, there are very good correlations of the tree-ring d18O variations among different tree individuals. However, there is no good correlation between averaged tree-ring d18O variations of Teshio and Onnebetsu, suggesting that the main meteorological factors to determine the tree ring d18O are different between Teshio and Onnebetsu.
We investigated the relationship between the tree-ring d18O and local meteorological parameters. We found that the tree-ring d18O in Teshio has positive correlation with spring temperature and negative correlation with summer precipitation and relative humidity, showing that it can become a good summer precipitation proxy because there is especially large negative correlation with summer precipitation. In contrast, we could not find any significant correlations between the tree-ring d18O in Onnebetsu facing on Pacific Ocean and summer meteorological factors. Because summer hydro-climate in Pacific Ocean side of North Japan is more complex than that in Japan Sea side reflecting the inter-annually varying effects of cold marine fog, we are obliged to conclude that it is difficult to reconstruct paleoclimate using the tree-ring d18O solely in Pacific Ocean side of Hokkaido. However, we found that there are predominant 20-years periodicity in the 11 years sliding correlation between the tree-ring d18O in Teshio and Onnebetsu, which is coincident well with the 11 year running mean of air temperature in Hokkaido. So, the tree-ring d18O in Pacific Ocean side of North Japan can be used as a novel temperature proxy by investigating its correlation with the tree-ring d18O in distant area rather than treating it solely.

Keywords: tree-ring d18O, Hokkaido, Picea glehunii

Climate response of oxygen isotopic compositions in tree-ring cellulose from Java, Indonesia: consideration based on proxy system model

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Oxygen isotopic composition in tree-ring cellulose has been used as paleoclimate proxy. Although Indonesian region plays a key role in global climate system, there are only a few dendroclimatic research using oxygen isotopic composition in tree-ring cellulose. In this study, we investigated climate response of oxygen isotopic compositions in tree-ring cellulose from Java, Indonesia. We checked correlation coefficient between oxygen isotopic compositions in tree-ring cellulose and climate parameter (temperature, precipitation, etc.). In addition, we investigated the dominant factor of oxygen isotopic compositions in tree-ring cellulose from Java by means of tree-ring cellulose oxygen isotope model (proxy system model) in order to improve the interpretation of oxygen isotopic compositions in tree-ring cellulose as proxy.

Teak (*Tectona Grandis*) was used for tree-ring sample in this study. Teak has clear annual ring related to seasonal precipitation change (rainy season and dry season). As for Indonesia, teak is an only species that cross dated tree-ring chronology was established. We collected ten teak disk samples from four plantation area in Java. We measured ring width and cellulose oxygen isotopic composition. All samples were dated by cross dating using ring width and cellulose oxygen isotopic composition.

Oxygen isotopic compositions in tree-ring cellulose have similar inter-annual variation all over Java. This indicate that common climate signals preserved in teak tree-ring cellulose oxygen isotope in Java. Oxygen isotopic compositions in tree-ring cellulose shows positive correlation with precipitation and relative humidity in the last dry season and negative correlation with precipitation in rainy season (growing season). Next, we did analysis using proxy system model. According to the model, oxygen isotopic compositions in tree-ring cellulose is controlled by isotopic composition of source water (the water taken up by roots), relative humidity and isotopic composition of atmospheric water vapor. Our result shows dominant factor of oxygen isotopic compositions in tree-ring cellulose is isotopic composition of source water. In addition, comparison of source water oxygen isotopic composition and rainfall oxygen isotopic composition indicates source water consists of rainfall not only during growing season but also during the several months before growing season.

Keywords: tree-ring, proxy system model, oxygen isotope

An 11.5 Ma paleoclimate record from travertine deposits at Barrancas Blancas in the eastern Atacama Desert, Chile

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Here we survey the potential of spring-related, surface and sub-surface carbonates as an archive of paleoenvironmental change at Barrancas Blancas, located in the broadest and driest sector of the Atacama at 24˚S in Chile. From these deposits we present a new stable isotopic record of paleoenvironmental conditions over portions of the past ~11.5 Ma. U-Pb dates from the carbonates, both surface and sub-surface, demonstrate that springs have discharged at this location over much of the last 11.5 Ma, attesting to the exceptional geomorphic stability of the central Atacama. Many of the sampled vein systems line vertical fissures, and formed within the aquifer before ground water discharged at the surface. Carbonates in such circumstances should not undergo off-gassing and kinetic fractionation prior to formation, simplifying the interpretation of their isotopic composition. Oxygen isotopic compositions of carbonates are genrally high (>-1‰VPDB), and using paleospring water temperatures reconstructed from clumped isotopes, point to strongly (up to 20-30%) evaporated water oxygen isotope values, like those associated with hyperarid conditions in recharge areas today. Carbon isotopic compositions are also high (+3‰ PDB) reflecting a recharge area essentially devoid of plants and dominated by volcanic CO_2, as is the case today. Our isotopic results are very similar to those from the Calama Basin to the north, suggesting that the western face of the Andes between 21-25˚S has been highly evaporative and plantless for much of the last 11.5 Ma. The spring carbonates at Barrancas Blancas strongly resemble those found at Devils Hole and Furnace Creek in Death Valley, USA, and as such warrant further exploration as potential archives of climate change.

Keywords: Atacama Desert, oxygen isotopes, carbon isotopes, travertine, paleoclimate

Preservation processes of paleoflood in stalagmite –case study of Inazumi Underwater Cave, Oita, NE Kyushu,Japan –

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Detrital sediments and mud trapped in stalagmite have been used for reconstruction of frequency of past extreme rainfall events associated with hurricane and cyclone (e.g., Dasgupta et al., 2010 EPSL; Frappier et al., 2014 AGU; Finné et al., 2014 Quat. Res.), yet more efforts should be put in for better understanding of the formation mechanism of so-called “flood layer”. This research presents the features and formation processes of the flood layer using microscopic observation (stereomicroscope, polarized microscope and fluorescence microscope) of the stalagmite’s thin section (SUI-1 and SUI-2) sampled from Inazumi Underwater Cave, Oita, Japan, where experiences episodic cave flooding during summer due to the East Asian Summer Monsoon.

Both of SUI-1 and SUI-2 showed (1) the presence of troughs filled by mud and rock-forming minerals such as augite, magnetite and quartz on the stalagmite’s flank; (2) the presence of numerous microcrystalline $CaCO_3$ on the flood layers; (3) alternating couplets of thick and porous layers on upper part of the stalagmite, which the porous layers were frequently filled by mud, and; (4) that no fluorescence layers were observed.

The (1) indicates that large size suspended solids carried during cave flooding induce physical weathering on the stalagmite’s surface, resulting in formation of the troughs and fill-up by small size suspended mud in the troughs while water level of cave river is decreasing. The large size minerals are considered to be washed away toward the stalagmite’s flank by dripping water. The (2) indicates that the $CaCO_3$ growth was temporarily ceased by the coverage of the suspended solids on the stalagmite’s surface, and that the numerous microcrystalline $CaCO_3$ are the evidence of nucleation and growth competition of newly precipitated $CaCO_3$ from dripping water. The (3) infers that the period of forming the porous layers corresponds to the one of the cave flooding (summer and autumn), and hence seasonality. The (4) indicates that either the concentration of humic substance in the dripping water was too low to provide the fluorescence layers or the humic substance contained in the mud trapped in the stalagmite should be incorporated in the crystal lattice of $CaCO_3$ for the fluorescence.

Keywords: stalagmite, paleoflood, paleoclimate, humic substance, sedimentology

Temperature change since the latest Pleistocene deglaciation stage recorded in carbonate clumped isotopes of a stalagmite collected in Hiroshima Prefecture, Japan

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Stalagmite Hiro-1 from northeastern Hiroshima Prefecture is a valuable material for terrestrial paleoclimate in Japan (Shen *et al*. 2010; Hori *et al*. 2013). However, it is not always easy to separate the temperature and the moisture signals from the stalagmite oxygen isotopic profile. A possible solution for this problem is carbonate clumped isotopes that is independent on isotopic value of water (Ghosh *et al*. 2006) and has been applied to some stalagmites (Affek *et al*. 2014). Carbonate clumped isotopes means the concentration anomaly of mass-47 carbon dioxide generated from the reaction of calcium carbonate and phosphoric acid, and is generally in inverse proportion to the square of the absolute temperature. Here we measured the clumped isotopes for 40 horizons of Hiro-1 stalagmite reacted with phosphoric acid at 70˚C.
The generated carbon dioxide was carefully purified in column cooled at -10˚C, and measured by MAT 253 with applying the baseline correction of He *et al*. (2012). Each value was adjusted on the absolute reference frame of Dennis *et al*. (2011). A typical measuring error was within 0.015 permil (1s) that corresponds to 3˚C in the temperature range of Hiro-1. We applied the temperature equation based on our own measurements of synthesized calcites of known temperatures, which is very similar to the theoretical equation of Guo *et al*. (2009).
After eliminating obvious offsets, the temperatures based on the clumped isotope of Hiro-1 was in 29.7–20.7˚C (24.8˚C in average) during Holocene (11–4 ka), and in 22.4–14.3˚C (18.0˚C in average) during the latest Pleistocene (18–12 ka). These temperatures are likely higher than the real, by considering that the modern temperature of this cave is 10.7˚C. The temperature offset is common between several speleothem studies reflecting Kinetic Isotopic Effect associated with CO_2 degassing (e.g. Affek *et al*. 2014). Although our evaluation involves some uncertainties, we suggest that the temperature difference between Holocene and latest Pleistocene was 6–7˚C. This preliminary estimation is broadly consistent to the 1.5 permil difference in oxygen isotope between Holocene and Pleistocene observed in Hiro-1 (Shen *et al*. 2010).

Keywords: stalagmite, clumped isotopes, temperature change, last glacial period, Holocene

Geochemical analyses of shells of *Gafrarium tumidum* and seawater collected from Tongatapu Island and their application for paleoenvironment and archaeology during the Holocene

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South Pacific Convergence Zone (SPCZ) fluctuation largely affects the climate in South Pacific islands. Current climate models have difficulties in a representation of the SPCZ movement, thus paleoclimate records are crucial to understand SPCZ' s variability. Meanwhile, it is suggested that human migration over the South Pacific islands during the Holocene was influenced by sea level and climate changes, however, they are not evidenced from the quantitative geochemical records. The aim of this study is to reconstruct paleoenvironment of Tongatapu Island, Tonga using geochemical analyses of shells of *Gafrarium tumidum* and seawater. The climate in Tonga is under the influence of SPCZ and this island was a base of South Pacific human migration during the Holocene, thus it is suitable for studying past variability of SPCZ and its relation to human migration. Fossil *G. tumidum* is often excavated from archaeological sites in South Pacific, thus this species is of archaeological importance, too. Bivalve shells which consist of calcium carbonate exhibiting growth lines like reef-building corals are ideal archives of paleoenvironment changes. However, few studies have evaluated potential of *G. tumidum* as paleoenvironmental recorder. Therefore, we assessed it from geochemical analyses of live-caught and fossil shells and seawater collected from Tonga. We measured $\delta^{18}O$ using IRMS (isotope ration mass spectrometry) and trace element/Ca ratio (e.g., Sr/Ca, Mg/Ca, and Ba/Ca) using LA-HR-ICPMS (laser ablation high resolution inductively coupled plasma mass spectrometry) along the maximum growth axis of the shell. Furthermore we calculated a local marine radiocarbon reservoir ages (ΔR) from ^{14}C-ages of fossil shells measured by using Single-Stage-Accelerator Mass Spectrometry (Single-Stage-AMS). We also monitored sea surface temperature (SST) *in situ* for four months, and measured sea surface salinity (SSS) using portable salinometer and $\delta^{18}O$ using Cavity Ring-Down Spectroscopy (CRDS). The results suggested: 1) $\delta^{18}O$ of *G. tumidum* shell can record about 3 yr SST variation in monthly timescales; 2) Sr/Ca of *G. tumidum* shell is controlled by a growth rate, neither by SST nor by SSS; 3) The lagoon of Tongatapu island was isolated from the open ocean between ~2.6 ka and ~1.2 ka; 4) the growth of *G. tumidum* is likely controlled by SSS, not by SST.

Keywords: Calcium carbonate, oxygen isotope, ΔR

Uranium in Corals provide the clue to solve the Quaternary chronology logjam

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Shallow water corals provide only direct way of determining the absolute timing and magnitude of Quaternary sea levels extending back over 600,000 years. Their uranium and thorium abundances and uranium isotope ratios when combined with coral reef elevations help determine sea-levels. Radiocarbon dating is also useful up to ca. 50,000 years but older than that relying on the U-series dating technique. It is relies on the following radioactive decay chain:

238U (4.5x10^9 yr) -> 234Th (24 days) -> 234U (2.5 x 10^5 yr) ->230Th (7.5x10^4 yr)

Deep-sea corals do not provide sea level information but appear to be responsive to ocean circulation changes and continental riverine and ice-sheet meltwater inputs to the oceans (Chen et al., 2016 Science).
In this presentation, we introduce recent debate with regards to uranium isotopes in ocean and discuss the reliable method to conduct U-series dating. Also consequence on the topic related to the phase relations of climate sub-systems are discussed.

Keywords: Quaternary chronology , Coral, Uranium series nuclides

New analytical method of triple combination: gene, morphology, and isotopes, for a single planktonic foraminifer

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Stable oxygen and carbon isotopes of planktonic foraminiferal shells are the most important proxies for paleoceanographic studies. This is because that each (morpho)species of planktonic foraminifers is distributed in a certain area/depth in the world oceans, and their shells are formed under an influence of ambient water condition (i.e., temperature). However, this commonly accepted theory needs improvement, according to the classification of genetically incompatible species (biological species). Molecular phylogeographic studies have revealed that multiple biological species found in a single morphospecies of planktonic foraminifers are differently distributed in the oceans. This improved species concept (biological species) encourage ecological study, and is able to provide novel environmental proxies combing with other basic methods (i.e., morphology and isotope). Although the foraminiferal shells can be preserved after DNA extraction by using the guanidium isothiocyanate buffer, no study has examined the impacts of the chemicals and incubation step with 65–70˚C on the shells. In this study, we carefully tested whether the process of DNA extraction physically and chemically damage to the shells of *Globigerinoides ruber*, one of the most useful planktonic foraminifers, or not. First, we checked the changes of the shell densities in pre- and post-DNA extraction by using the micro-focus X-ray CT (MXCT) scanning. The simultaneous measurement of a sample and the standard material enable us to calculate the accurate CT number, which indicates the density of the shell. As the result, the shell densities showed no significant differences. Second, we prepared three sample sets with: (a) no chemical and incubation as control, (b) incubation in the DNA extraction buffer at 65–70˚C for 40 minutes as standard way, and (c) incubation in the DNA extraction buffer at 65–70˚C for 120 minutes. Stable oxygen and carbon isotopes were measured one by one from these three samples sets by using the microscale isotopic analytical system (MICAL3c). Although the isotope values largely varied among specimens, there were no significant differences among the three sample sets. These data of MXCT scanning and isotopic measurements clearly certified that we define morphological and geochemical features from same specimens after genetic identification. Utilizing our developed method, we compared stable oxygen and carbon isotopes between two different genetic types of *G. ruber*, which were phylogenetically distant. All examined specimens were collected at the same place in the same season. We demonstrated that the isotopic signatures between biological species. Thus, our challenge provide future studies to establish the paleoceanographic proxies in higher-resolution based on the biological species of planktonic foraminifers.

Keywords: planktonic foraminifers, stable oxygen and carbon isotopes, CT scanning, micro-scale analysis

A preliminary result of paleowind variations in Hungary during MIS 19 from loess-paleosol deposits

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Marine Isotope Stage (MIS) 19 is a unique interglacial that occurs around the minimum amplitude insolation variation of eccentricity component at 65 deg N, and thus has been a target for a number of paleoclimate studies. In East Asia, numerous studies revealed detailed paleomonsoon variations for MIS 19 using loess-paleosol deposits in Chinese Loess Plateau (CLP), and discussed continental climate changes. Despite the well-studied CLP, the detailed paleoclimate reconstruction of MIS19 is missing in Europe. The similarities and differences between the characteristic of the East Asian monsoon and the European paleoclimate have not been revealed yet. We analyzed loess-paleosol deposits in the European Loess Belt (ELB) in order to reconstruct detailed inland climate changes in Europe during MIS 19, to evaluate its relation to the global paleoclimate.

Quasi-continuous sampling was elaborated at Paks brickyard, about 150-km south of Budapest (Hungary), where about 60-m thick loess paleosol sequence lies on the right bank of River Danube. The studied sequence is dated back to Early to Late Pleistocene. The Matuyama-Brunhes magnetic polarity transition was reported in various stratigraphic positions around the PD_1 and PD_2 paleosol complex. Oriented samples were collected at 2.5-cm depth intervals from an about 380 cm thick section, ranging from paleosol PD_1 to PD_2. We conducted magnetic and grain size analyses of the samples. Low field magnetic susceptibility (kLF) and frequency dependence of magnetic susceptibility (kFD) show consistent variations, having a large peak in each of paleosol PD_1 and PD_2, and a minimum at the loess horizon between them. We tentatively correlate the lower peak with MIS 19.3, the upper with MIS 19.1, and the minimum with MIS 19.2. The kLF gradually decreases upward from the lower peak, and has a temporal stagnation of decrease on the way at 208~256 cm in depth, that probably lies between MIS 19.3 and 19.2. The result of grain size analyses shows that the median size inversely correlates well with kLF and kFD, namely large kLF and kFD samples have small grain sizes, and vice versa. The relation is the same with the loess-paleosol deposits in CLP. However, we find that the content of fine grains ($< 8\ \mu m$) shows no vertical changes, namely almost constant, while coarse grains ($> 8\ \mu m$) show variations, consistent with median size. We interpret the results as surface winds, carrying coarse grain over short distances, weakened in the warm-moist periods, and strengthened in the cool-dry period, whereas, compare to that winds, the intensity of high altitude winds, carrying fine grain over long distances, such as the Westerlies, has no large variation.

The paleoclimate records from Hungary were compared to those from Lingtai in the CLP during MIS 19. The kLF and kFD of both sites show quite consistent variations. In addition, the characteristic temporal stagnant of kLF decrease observed in Paks is also confirmed in the Lingtai record. The grain size records of both sites show consistent changes that the grain size decreases in the pedogenic zones, and increases in the less pedogenic zone. This record reveals the similarities between the influence of various wind system in the ELB and in CLP: the surface wind (winter monsoon), probably weakened in the warm-moist periods, and strengthened in the cool-dry period. The similarities between the paleoenvironment in ELB and CLP reveal a possible link between Europa and East Asian inland climates during MIS 19.

Keywords: Loess-paleosol deposits, MIS 19, magnetic susceptibility, grain size analyses

High-resolution magneto-climatostratigraphy for MIS 19 loess-paleosol layer in Paks, Hungary

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Detailed paleomagnetic and rockmagnetic investigations of the Paks loess/paleosol succession in Hungary revised the stratigraphic position of the Matuyama Brunhes Transition (MBT).
The first deflections of the virtual geomagnetic pole (VGP) during the precursor phase of the MBT occurs in a well-developed soil horizon. The transit phase of MBT is situated in the upper and transient horizon of the soil mentioned above, and the overlaying loess layer. The transit period is followed by the rebound phase, characterized by instable magnetic field.
The new paleomagnetic results provided evidences for a new detailed terrestrial MIS19 chronostratigraphy in loess, including MIS19.3, 19.2 and 19.1 and revealed a possible link between various terrestrial and marine records from the Atlantic and Pacific area also.

Keywords: Matuyama Brunhes Transition, magneto-climatostratigraphy, pan-European loess

Paleoceanographic change in the western North Pacific during MIS 20-18 based on Mg/Ca-temperature, oxygen and carbon isotope records from Chiba composite section deposited in Boso Peninsula, southeastern part of Japanese islands

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Marine Isotope Stage (MIS) 19 is one of the analogues for the present interglacial period in terms of orbital parameter: low-amplitude precessional insolation variability modulated by the 413-kyr eccentricity cycle. Thus, knowledge of natural climate variability during the time period between MIS 20 to 18 helps to understand the future climate change.
The Kuroshio Current, a western boundary current in the North Pacific, transports warm saline waters from low- to high-latitude and thus plays a crucial role in heat transport in East Asia. Previous studies revealed high SST variability during the last 144 ky off central Japan, with peak SSTs during early MIS 1 and the MIS 5a/4, 5c/5b and 5e/5d transitions, primarily caused by the latitudinal shift of the Kuroshio–Oyashio Currents.
Here, we present Mg/Ca-based temperature, and oxygen and carbon isotope ($\delta^{18}O$, $\delta^{13}C$) records of planktic foraminifers *Globigerina bulloides* and *Globorotalia inflata* in Chiba composite section and reconstruct gradients of surface and intermediate water temperature (ΔT) and vertical $\delta^{13}C$ ($\Delta\delta^{13}C$). Compared to Oyashio water, the Kursohio is characterized by more oligotrophic, stratified with warm surface water. Therefore, the high $\Delta\delta^{13}C$ and ΔT with warm surface water suggest the increase in the Kuroshio influence. The results indicate that both $\Delta\delta^{13}C$ and ΔT increased during the transition from MIS 20 to 19, which suggests the increase in influence of the Kuroshio water. The $\delta^{18}O$ of *G. bulloides* shows low values with high amplitude still in the late MIS 19, suggesting the warm surface water. This further suggests the strong influence of the Kuroshio water, which is also supported by relatively high $\Delta\delta^{13}C$, ΔT and microfossil assemblage. A recent study based on grain size analyses from Loess- palaeosol sequence in northern China suggest weak East Asian winter monsoon and Siberian High during late MIS 19, triggered by a very weak precessional insolation minimum leading to warm summer conditions unfavorable to Northern Hemisphere ice-sheet build-up at the inception of each of MIS 20, MIS 18. This study suggests that the strong Kuroshio Current during late MIS 19 might have played a crucial role in enhancement of poleward heat transport that helped to warm up the middle to high latitude and suppress the development of Siberian High.

Keywords: Chiba composite section, Kuroshio, East Asian winter monsoon

Paleoceanographic change through the Marine Isotope Stage 19 in the Kuroshio-Oyashio subarctic boundary, the northwestern Pacific, based on benthic and planktic foraminiferal oxygen and carbon isotope records

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Orbital configuration during the Marine Isotope Stage (MIS) 19 are characterized by weak eccentricity-precession forcing and the obliquity maximum, and they have occurred at around the precession minimum as well as MIS 1, the present interglacial period, although the both absolute values of obliquity are different (Tzedakis, 2010; Tzedakis et al., 2012). Thus, MIS 19c, the one of sub-stages during MIS 19, is assumed as the close analogue for the present interglacial and will suggest the timing of the next glacial inception in the future excluded anthropogenic influences.
Here, we report foraminiferal stable oxygen and carbon isotopic records from the Chiba composite section, and the Higashinagata Formation, Toyofusa Group in the Boso Peninsula, and the CHOSHI-1 core drilled through the Yokone Formation, Inubo Group, at Choshi city, northestern part of Chiba. The Chiba composite section is one of the candidates for the middle Pleistocene GSSP (Global boundary Stratotype Sections and Points). We carried out stable oxygen and carbon isotopic analyses by using benthic foraminifers, *Bolivinita quadrilatera*, *Cibicides* spp. and *Uvigerina* spp., and planktic foraminifers, *Globigerina bulloides*, *Globigerinoides ruber* and *Globorotalia inflata*. Stable isotope measurements were performed by a Finnigan-MAT253 Isotope mass spectrometer coupled with a Kiel IV carbonate preparation device installed at the Department of Geology and Paleontology, National Museum of Nature and Science. In order to develop age models, the resultant $\delta^{18}O_{benthic}$ curves were correlated to the sea level equivalent curve (Elderfield et al., 2012).
$\delta^{18}O_{planktic}$ and $\delta^{18}O_{benthic}$ curves basically represent synchronized changes in the glacial-interglacial cycle scale. Especially, $\delta^{18}O_{G.\ bulloides}$ curves show millennial scale oscillations from the peak of the MIS 19 to MIS 18 superimposed on the glacial-interglacial cycles in both of the Chiba composite section and the CHOSHI-1 core. However, the $\delta^{18}O_{G.\ ruber}$ curve from the Higashinagata Formation, in which the isotope data yielded only through the late MIS 19, exhibits a slight oscillation in contrast to those of the Chiba composite section and the CHOSHI-1 core during the same interval. This implies that since the Kuroshio front facing to the Kuroshio-Oyashio subarctic boundary was placed at near the latitude of the present Choshi region, the Chiba composite section and the CHOSHI-1 core were commonly affected by sea surface temperature (SST) changes associated with a latitudinal shift of the Kuroshio front during the MIS 19 –MIS 18 transition. In contrast, the Higashinagata Formation was less affected by the SST changes since the Kuroshio front have not reached down to the southernmost part of the Boso Peninsula during the interval.

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Keywords: Marine Isotope Stage 19, Foraminifera, Oxygen isotope, Carbon isotope, Kuroshio front

Pliocene planktonic foraminiferal assemblages of IODP Site U1338 in the equatorial Pacific: implication to the closure of the Central American Seaway

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Modern oceanographic settings of the equatorial Pacific is characterized by an East-West asymmetric structure of thermocline caused by the closure of the Central American Seaway in Pliocene. IODP Site U1338 was placed in the eastern part of the equatorial zone from Miocene to Pliocene. Therefore, this site is suitable to examine paleoenvironmental changes related to the closure of the seaway. In this study, we investigates planktonic foraminiferal assemblages from 5.5 to 2.2 Ma at Site U1338.
As a result, 79 species belonging to 19 genus of planktonic foraminifera were detected from 42 samples of this interval. The planktonic foraminiferal fauna is dominated by tropical to subtropical species such as *Globorotalia tumida*, *Globigerinita glutinata* and *Menardella menardii*. According to a Q-mode factor analysis of the samples, planktonic foraminiferal assemblages can be divided into three zones, namely, Zone A (5.5--4.5 Ma), Zone B (4.5--3.1 Ma) and Zone C (3.1--2.2 Ma). Zone A is characterized by cyclic changes of subtropical subsurface components, tropical subsurface components and surface components. In turn, Zone B is characterized by alternative changes between subsurface and surface tropical components. Zone C is dominated by tropical subsurface components. These faunal changes suggest that the shoaling of thermocline in the eastern equatorial Pacific might start at approximately 4.5 Ma followed by stepwise weakening of the western Pacific oligotrophic water.

Keywords: planktonic foraminifera, Pliocene, eastern equatorial Pacific, IODP

History of the equatorial Pacific thermocline during the early to middle Miocene

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The evolution of the equatorial thermocline is essential in understanding climate changes in the tropical Pacific. Multispecies analyses of planktic foraminifera provide a way to examine temperature distribution thus equatorial thermocline. Although the secular development of the thermocline can date back up to the late Miocene, the early to middle Miocene interval has been rarely examined. In addition, causal relationships with dynamic Antarctic ice sheet and closing low latitude gateways remain unclear. Here we investigate vertical thermal gradient at Integrated Ocean Drilling Program Site U1337 in the eastern equatorial Pacific (EEP) throughout the early to middle Miocene. The gradient increased (surface water warmed) over the Miocene Climatic Optimum (16.9 to 14.7 Ma), whereas it decreased (surface water cooled) across the East Antarctic Ice Sheet Expansion (EAIE: ~13.9 Ma). Comparison of the EEP record with the western equatorial Pacific (WEP) counterpart (Corfield and Cartlidge, 1993) suggested that changes in sea surface temperature were relatively stable in the WEP than in the EEP through the early to middle Miocene (18.8 to 11.9 Ma). We further estimated thermocline depth and tilt from the two diagonal gradients between the EEP and the WEP records: shoaling of thermocline from 16.7 to 15.7 Ma and weakened thermocline tilt between 16.5 and 13.8 Ma. Closures of low latitude gateways (the Indonesian Throughflow and the Central American Seaway) (~17 to 15 Ma) might trigger thermocline shoaling, and the reduced Antarctic ice sheet volume (16.4~13.9 Ma) would affect thermocline tilt. Thermocline depth from 18.8 to 11.9 Ma was likely much deeper compared to the Pliocene to modern condition.

Keywords: eastern equatorial Pacific, Miocene, thermocline, planktic foraminifera, oxygen isotope ratio

Stratigraphy and paleo-environmental study of Paleogene sequences in Hokkaido, Japan

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Paleogene period is characterized by the transitional interval from warm greenhouse period to cool icehouse period in the climate history of earth. Although detailed stratigraphic and paleo-environmental studies of Paleogene sequences have been carried out in the Atlantic, Indian oceans and Tethys Sea, while little is known about the paleo-environmental change in the northwest Pacific Ocean.
Thick Paleogene sequences are exposed in the central and eastern Hokkaido, Japan. These sequences were accumulated in the fore-arc and/or intra-arc basins in the northwestern Pacific Ocean. In this study, we analyzed U-Pb ages of tuff beds and carbon isotope, benthic foraminifera and dinoflagellate cyst fossils of the Paleogene sequences of the Nemuro, Poronai, Urahoro and Onbetsu groups. Based on our U-Pb ages and carbon isotope stratigraphy and previous work of calcareous nannofossil biostratigraphy, the middle-upper parts of the Nemuro, Poronai, Urahoro and Onbetsu groups are correlated with Danian to Ypresian, Lutetian to Rupelian, Bartonian to Rupelian and lower to middle part of Rupelian, respectively. Four major environmental events are identified in the studied sequences as below.
(1) Danian-Selandian: This period is characterized by eutrophication of surface ocean, represented by prominent increase in P/G ratio of dinoflagellate in the Nemuro Group. This interval corresponds to the warm-climate period of early Paleocene.
(2) PETM: No significant faunal change is identified around this period in the Nemuro Group. Since exposure around this horizon is quite poor, there is a possibility that exact PETM horizon is not exposed in this studied section.
(3) Middle Eocene Climatic Optimum (MECO): This interval is correlated with the basal part of the Poronai Formaiton. On set of deposition of the Poronai Formation might reflect the sea level rise in this period although tectonic subsidence might have been the major contribution of the Poronai basin formation.
(4) Bartonian cooling: In the middle part of Poronai Formation is marked by occurrences of glendnite. This interval yields abundant benthic foraminifera of *Bullimina*. These evidences suggest that cooling and increased primary productivity occurred in this region.
(5) Eocene/Oligocene boundary: Prominent sedimentary facies change from hemipelagic mudstone to shallow-marine sandstone occurred across the boundary between the Poronai and Momijiyama formations. These facies change may reflect sea-level fall around the Oi-1 glaciation. The same horizon is identified in the upper part of the Urahoro Group.

Keywords: Paleogene, stratigraphy, dinoflagellate

Utility of apatite trace-element for tephrochronology

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Apatite is a common accessory mineral in intermediate and felsic igneous rocks. Because apatite has a wide range of trace-element compositions as well as strong resistance to diagenetic alteration, the trace-element composition of apatite has been used for tracing petrogenetic processes of plutonic bodies as well as the tephrochronology of Paleozoic tephras. We studied apatite trace-element compositions of representative Quaternary ignimbrites and their corresponding co-ignimbrite ashes in Japan. The results demonstrated following three points.
1. Trace-element compositions of apatite phenocrysts are useful for discriminating and correlating tephras and ignimbrites. Even different tephra deposits and ignimbrites derived from the same caldera can be distinguished.
2. Trace-element compositions of apatite phenocrysts are not affected by welding, making them valid for correlations between densely welded and non-welded tuffs.
3. In successive ejecta of each eruption cycle, the Cl, Mg, Mn, Y, and Ce contents of apatite phenocrysts generally are constant throughout successions except for the uppermost parts, whereas Fe contents vary from horizon to horizon. This compositional stratigraphy makes it feasible to identify the eruptive stage at which co-ignimbrite ash was ejected by correlating apatite trace-element compositions between ignimbrite successions and co-ignimbrite ashes.
Given the resistance of apatite to diagenetic alteration, this correlation method is a promising tool for correlating pre-Quaternary volcanic and volcaniclastic rocks and identifying their source volcanoes. In order to apply this method to tephrochronology of pre-Quaternary tephra, we examine Miocene and Cretaceous tuffs in Japan (Kinone Formation in Chiba and the Yezo Group in Hokkaido). Our result demonstrated that pre-Quaternary tuffs can also be used for wide-correlation of tephra as well as identification of source caldera.

Keywords: apatite, tephrochronology, caldera

Dramatic oceanic sulfur-isotopic shift event at the Early Eocene

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Oceanic sulfate is a huge reservoir of sulfur on the earth surface with its residence time as long as >10 myr. Paytan et al. (1998: Science) showed temporal variation of sulfur isotope value ($\delta^{34}S$) of oceanic sulfate that was summarized based on the analytical results of pelagic barite from deep sea sediments. They revealed conspicuous positive $\delta^{34}S$ shift (17 to 22‰) within a short period of time (~1 myr) across 50 Ma.
Ogawa et al. (2009: EPSL, 285) reported continuous deposition of pyrite-rich sediments through 55 to 45 Ma from ACEX core (IODP EXP. 302) and suggested deposition of vast quantity of pyrite on the sea floor of Arctic Ocean during Eocene that could explain 3‰ of positive $\delta^{34}S$ shift of entire ocean. However, it was still inconsistent with the enigmatic positive shift mentioned above from the standpoint of its duration and size. The temporal variation of oceanic sulfate is also required to be verified through this interval.
The objective of this research is to clarify the global temporal variation of $\delta^{34}S$ of oceanic sulfate through Early-Middle Eocene and discuss the inconsistency between duration and magnitude of positive $\delta^{34}S$ shift between $\delta^{34}S$ fluctuation shown by Paytan et al. (1998) and that expected from ACEX data.
Continuous $\delta^{34}S$ record of pelagic calcareous ooze or micritic carbonate collected by ODP, IODP is obtained from analyses of CAS (carbonate-associated sulfate). We tried to acquire $\delta^{34}S$ values of both barite and CAS from identical sample but it could be achieved only from single sample of equatorial Pacific. Enough CAS data have been obtained from ODP Sites 1258, 1259 (Equatorial Atlantic) and Sites 1262, 1263, 1265, 1267 (South Atlantic) to draw a temporal variation of $\delta^{34}S$ with CAS for Early-Middle Eocene. The fluctuation exhibited considerable decoupling with that of Paytan et al. (1998) showing gradual shift over >5 myr with the magnitude smaller than 5‰ instead of abrupt change as large as 5‰. The time interval for $\delta^{34}S$ shift is concordant with that for pyrite deposition on Arctic seafloor and well explained by outflow water from Arctic discussed by Ogawa et al. (2009). Abrupt $\delta^{34}S$ shift at 50 Ma shown in Paytan et al. (1998) could reflect local heterogeneity of sulfur isotopic composition of oceanic sulfate around eastern equatorial Atlantic during this period.

Keywords: sulfur isotope, Eocene, sulfur, sulfate ion, barite

Characterization of Carboniferous sulfate mineral deposits in central Thailand

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We present petrographic and geochemical data of sulfate mineral deposits in northeast Nakhon Sawan, central Thailand, and provide new constraints on their age and depositional environments. The deposits are made up of a layered anhydrite in the lower part, and strongly deformed nodular and massive gypsum in the upper part. They are intruded by andesitic dikes that contain Middle Triassic zircons (ca 240 Ma). These dikes are probably part of the regional magmatic activity of the Sukhothai Arc during the Early to Middle Triassic. Sulfur ($\delta^{34}S$) and strontium ($^{87}Sr/^{86}Sr$) isotopic compositions of the sulfates range from 15.86‰ to 16.26‰ and from 0.70810 to 0.70817, respectively. Comparisons with the Phanerozoic seawater isotopic evolution curve indicate that those values are best explained by precipitation from seawater during the Serpukhovian (ca 326 Ma) in the Late Mississippian epoch of the Carboniferous period (Kuroda *et al.*, 2017). This is consistent with previous studies of calcareous fossils in the limestones that crop out around this site (Ueno and Charoentitirat, 2011). Our interpretation is that evaporitic gypsum was originally precipitated from hypersaline seawater on a shallow lagoon or shelf on the Khao Khwang Platform during the Serpukhovian, and that this gypsum changed to anhydrite during early burial. The anhydrite was then cut by andesitic dikes during the Middle Triassic, and more recently the upper part of which was rehydrated during exhumation to form secondary gypsum near the surface. In the presentation we will also discuss the relationship of this sulfate mineral deposits with that in the northeastern Thailand (Surakotra *et al.*, 2017).

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Keywords: Carboniferous, sulfate evaporite, strontium isotope, sulfur isotope

Implications for paleo-oceanographic oxygen conditions during the Cretaceous OAEs: Results from laboratory culture experiments

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The oceanic redox state is a critical determinant of the evolutionary history of life on Earth, and “anoxic events” have been proposed as one of the causal mechanisms for mass extinctions. During the mid-Cretaceous, oceanic anoxic events (OAEs) occurred several times with substantial turnover of planktonic foraminiferal species. However, the direct effects of the anoxic condition on planktonic foraminifera remain obscure. In this study, we cultured 6 species (n = 31) in all at three treatments: ~2 mg hydrogen sulfide (H_2S) L^{-1} (H1 treatments), ~9 mg H_2S L^{-1} (H2 treatments), and control (without H_2S). All planktonic foraminifera could not survive more than 48 hours. Furthermore, gametogenesis ratio of each H_2S treatments showed considerable low value (8% and 17%), and time to gametogenesis was also very short (less than one day) under H_2S occurrence. It revealed that foraminiferal biological response of anoxic with the presence of H_2S should be fundamentally different from that of the dysoxic (i.e., low dissolved oxygen; ~0.7 mg O_2 L^{-1} or ~22 μmol O_2 L^{-1}). Our results also proposed the species-specific tolerance for H_2S and that if harmful influence of H_2S restricted in relatively short time (i.e., less than 24 hours) such as tidal cycle, some foraminifera (e.g., *Neogloboquadrina dutertrei*) might have the potential to survive even under the episodic/temporary occurrence of H_2S. Complete disappearance of planktonic foraminifera at Cretaceous OAE2 could result from the photic-zone euxinia (free H_2S), and presence/absence record of planktonic foraminifera could contribute to examine the detailed oceanic redox state in the photic zone around anoxic events.

Keywords: oceanic anoxic events, hydrogen sulfide, Planktonic foraminifera

Behaviors of marine primary producers during ocean anoxic events

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At the Ocean Anoxic Events (OAEs) during the Phanerozoic, biomarkers of cyanobacteria and green sulfur bacteria have been found, which suggests depletion of nitrogen and euxinic water condition in the euphotic zone (so-called "euphotic euxinia"), respectively. However, conditions to cause the depletion of nitrogen and the euphotic euxinia have not been known yet. We do not know well the behaviors of primary producers in the surface ocean when the ocean becomes anoxic. Here we investigated marine biogeochemical cycles of C, P, N, and S to understand these conditions and behaviors of primary producers quantitatively with a surface ocean biogeochemical cycle model. The results showed that nitrogen tends to deplete in the euphotic zone owing to net denitrification when the climate is much warmer than it is today. Under such conditions, cyanobacteria become dominant as a primary producer. When the upwelling rate is high in addition to the warmer climate condition, euxinic water upwells to the euphotic zone, hence green sulfur bacteria becomes dominant as a primary producer. We also found conditions for coexistence of eukaryotic algae, cyanobacteria, and green sulfur bacteria together within the euphotic zone, which could have been caused at coastal upwelling areas during the OAEs in the past.

Keywords: Ocean anoxic events, euphotic euxinia, biomarkers, marine biogeochemical cycle modeling

