

Fire activity in Japan influenced by spring temperature and vegetation type

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In Northeast Asia, the climatic effect on natural fire activity is poorly understood. We analyzed charcoal particles in Lake Biwa sediments, central Japan, deposited for 150,000 y to evaluate the climatic effect on fire activity. Between 130,000 and 40,000 y ago the charcoal concentration is mostly consistent with spring insolation on site driven by orbital forcing or the oxygen isotope ratio of worldwide marine sediments. Meanwhile, the variation of charcoal concentration related to vegetation change; the peak of the charcoal concentrations were in the periods with dominance of the conifer forest. This findings indicate that fire activity was controlled by spring temperature with the influence of vegetation type.

Keywords: fire activity, charcoal particle, spring temperature, spring insolation, vegetation type, Lake Biwa sediments

Chronology of Lake Biwa sediments: integration of radiocarbon ages, tephrochronology and environmental magnetism

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The Quaternary sedimentary sequence of Lake Biwa, located in central Japan, provides continuous terrestrial records of past climate changes in East Asia including detailed records of Asian monsoon activity from the Middle Pleistocene to the Holocene. We constructed a common chronological framework for multiple sediment cores from Lake Biwa for the past 50 kyrs. An age-depth model of a 18.42-m long piston-core (BIW07-6), recovered between Takashima and Okinoshima Island in central part, was constructed under the age constraints of thirteen AMS radiocarbon dates of terrestrial macrofossil and six known-ages of widespread tephra layers. Using this age model, we estimated the model ages of ten horizons at which characteristic features were observed in the time series of anhysteretic remanent magnetization (ARM). ARM is a measure of fine ferrimagnetic mineral flux into the sediment, representing a proxy of hydrological changes around Lake Biwa. Therefore the characteristic features of the ARM variation serve as tie-points of core-to-core correlations in Lake Biwa, as well as the horizons of tephra deposits. We thus obtained age-depth curves for other core samples, which were well constrained with the tephra ages, the ARM events and additional radiocarbon dates from each core. The integrated age model has an acceptable accuracy to assess terrestrial environmental changes in millennial scales and can be adapted for paleolimnological studies in other regions.

Keywords: Lake Biwa, age model, last glacial period

Oxygen isotope analysis of speleothem water inclusion: glacial temperatures reconstruction

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Speleothem inclusion water isotopic compositions are promising new climatic proxies. The applicability, however, is limited by low water content and challenging analytical difficulties. We have developed a precise and accurate isotopic technique based on cavity ring-down spectroscopy with a low sample-amount requirement of 20-260 nL of inclusion water from only 77-286 mg of stalagmite deposits in Gyokusen Cave, Okinawa Island, Japan. The 1σ reproducibility is ± 0.24 permil for $\delta^{18}\text{O}$ and ± 1.8 permil for δD . The isotope values of inclusion water samples from the two most recently layers are within the expected range of isotopic monitoring data for drip water and rainwater at the island.

Keywords: stalagmite, speleothem, fluid inclusion, oxygen isotope, CRDS

Centurial-scale cycle observed in oxygen isotope of Holocene stalagmite from central Japan

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Oxygen isotope of stalagmites records local climatic conditions via the meteoric isotope values in water recharge area. Previous studies in China and Japan have revealed that variations in stalagmite oxygen isotope likely indicate variations in intensity of the Asian monsoons. We here present U-Th age and oxygen isotope of two stalagmites collected from the central Japan, which appear prominent centurial-scale cycle. Uppermost 5.3 cm of stalagmite OT02 from Gujo City (Gifu Prefecture) exhibit 9 cyclic changes in its oxygen isotopic values in a period of 8.5-2 ka. Estimated ~650-yr wave length broadly conforms with that of solar activity reconstructed based on radio carbon anomaly. Temperature change was unlikely responsible for the stalagmite isotope because the phase unmatched with the solar activity. The oxygen isotope was low during the cold phases of lower solar activity. The oxygen isotope of OT02 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 owing to the Rayleigh distillation that occurs in water vapor mass from the Japan Sea. The records of OT02 can be the change in the winter proportion of meteoric water. This would have increased the stalagmite oxygen isotope during colder periods. A similar ~650-yr cycles appear in the Holocene stalagmite from Odai (Mie Prefecture). The periodicity is also conformable with historical climatic periods, such as Little Ice Age and Medieval Warm Period. We suggest that such cyclic change can be extended back to 8 ka.

Deep ocean circulation and water temperature variation in Late Cretaceous based on carbon and oxygen isotopes of benthic

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Oceanic anoxic event 2 (OAE 2) occurred by global climatic warming in the latest Cenomanian to earliest Turonian. Global climate was gradually getting cool just after OAE 2. In the North Atlantic, deep water called NCW (Northern Component Water) was formed (Frank and Arthur, 1999; MacLeod et al., 2011; Martin et al., 2012), and oxygenated bottom water was flowing into North Atlantic by opening of Central Atlantic Gateway (CAG) between South Africa and South America in the early Turonian (Poulsen et al., 2001). Otherwise, climatic cooling from the early Campanian had affected SCW (Southern Component Water) forming in Southern high latitude and this deep water had flowed into Pacific (Brady et al., 1998; Huber et al., 1995; Murphy and Thomas, 2012; Robinson and Vance, 2012; Robinson et al., 2010).

It is cleared that deep water was sourced from high latitude during cooling time from the Campanian to Maastrichtian. However, deep ocean circulation before the Campanian has not yet clarified: especially, deep-water source during the warming periods. In this study, we reconstruct deep-ocean circulation during the late Cretaceous. We selected epifaunal species of benthic foraminifera from core samples in North Atlantic, South Atlantic, Southern Ocean, and Indian Ocean, to analyze carbon and oxygen isotopes in Kochi Core Center in Japan. We report new findings on deep-sea circulation and water temperature changes from the Cenomanian to Maastrichtian by compiling analyzing data and previous literature data.

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Keywords: Cretaceous, Deep ocean circulation, carbon isotope, benthic foraminifera

Response of terrestrial climate to Cretaceous OAE2 observed in a sequence of Canadian Pacific coast

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Abstract

Across the Cretaceous Cenomanian / Turonian (C/T) boundary interval, a short-term event characterized by sediments rich in organic matter dominated over extended area of various oceanic setting around the world. This pronounced oceanic event is called Oceanic Anoxic Event 2 (OAE2). Considerable disturbance of global surface carbon circulation has been suggested during the event. Across the OAE2 interval, carbon isotope ratios of sedimentary organic carbon and carbonates show unique positive excursions, which are identified throughout the world. On the other hand, influence on the terrestrial environment during the event associated with the carbon cycle disturbance has been less discussed.

To understand the possible terrestrial climatic response related to this carbon cycle perturbation, Haida Gwaii, Pacific coast of western Canada, was studied. Limited macrofossils and carbon isotope stratigraphy well indicate the OAE2 interval through the section. Concentration of polycyclic aromatic hydrocarbons (PAHs) through continuous sequence in Haida Gwaii was evaluated as proxies for the terrestrial environment in the period of OAE2. Likely origin of PAHs in the sedimentary rocks is wildfire; terrestrial vegetation and/or soils can be the source. On the other hand, they can potentially be generated from thermal maturation. In the studied section, gradual increase of PAHs (pyrene, benzo(e)pyrene, benzo(a)pyrene, benzo(b)fluoranthene and benzo(ghi)perylene) content was observed within the OAE2 interval. Based on comparison of this increasing pattern with other thermal maturation indices (MPI-1, CPI), wildfire is concluded as the main origin of the PAHs. Increase of PAHs associated with OAE2 suggests the climate of the North American Pacific coast gradually turned into condition that is prone to induce frequent wildfire during the period of OAE2.

Haida Gwaii, presumably located around 35°N during the period of OAE2 (Ward et al., 1997) was dominated by the prevailing westerlies (Upchurch et al., 1999) whereas the latitude is seasonally controlled by subtropical high pressure belt (SHPB) at present. Hasegawa et al. (2013) suggested expansion-shrinkage oscillation of Hadley Cell associated with global climate during Cretaceous. Haida Gwaii located near the northern edge of SHPB could be a region sensitive to such Hadley Cell oscillation. Our observation of PAHs from the studied section could provide important information for discussion on Hadley Cell expansion under declining trend of climate associated with OAE2.

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Keywords: Oceanic Anoxic Event, Cenomanian Turonian Boundary, Hadley Circulation, Subtropical High, Polycyclic Aromatic Hydrocarbon (PAHs)

Detailed age determination of Cretaceous shallow marine - non-marine strata

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Introduction

It is very difficult to determine detailed age of pre-Quaternary shallow marine and non-marine sequences because they are usually very poor in age diagnostic fossils. However, age determination of such sequences is important to demonstrating past sea level changes as well as evolution of terrestrial fauna and flora. Since the shallow marine and non-marine sequences contain abundant wood fragments, carbon isotope stratigraphy is appropriate method for determining the age of those strata. This study attempted to determine the detailed age of the Cretaceous shallow marine?non-marine sequence of the Kuji Group using carbon isotope stratigraphy and U-Pb ages of tuffs.

Geologic outline of the Kuji Group

The Kuji Group is about 800-m-thick sequence exposed in the eastern coast of Iwate Prefecture. This group overlies unconformably the Jurassic accretionary complex (Rikuchu Group) and is unconformably overlain by the Paleogene non-marine sequence (Noda Group). The group consists mainly of sandstone and conglomerate with subordinate amount of coal and coaly mudstone, and is composed of the Tamagawa, Kunitan and Sawayama Formations in ascending order.

Since the Kuji Group yields abundant well-preserved plant and terrestrial vertebrate fossils such as dinosaur and reptiles (e.g., Hirayama et al., 2010), detailed age determination of this strata is critical for reconstructing terrestrial fauna and flora of the Cretaceous East Asia. The group also intercalates a lot of felsic tuff beds throughout the sequence which provides good anchor points for correlation of carbon isotope curves between the Kuji Group and other marine sequences.

Method

About 500 sandstone and coaly mudstone samples for carbon isotope analysis and 8 felsic tuff samples for U-Pb dating were taken from the sections of the Tamagawa coast, Edanari, Osawada, Natsui and Sawayama streams. For the tuff samples, zircons were separated using heavy liquid, and zircons of 50 grains randomly by a handpicking were pressed into soft PFA sheet, and their surfaces were polished using 3- and 1- μ m diamond paste. The U-Pb isotopic age of zircons were determined using LA-ICP-MS at the Nagoya University. For the carbon isotope analyses, wood fragments were picked up from the disaggregated sediments, and the carbon isotope of the wood fragments of the sample was then measured using a mass spectrometer (IsoPrime) in line with an elemental analyzer EuroEA3000.

Result and discussion

The U-Pb isotopic ages of tuffs from the Kuji Group range from 95 to 80 Ma, and the carbon isotope ratio of the fossil wood fragments of this group changes between -27.0?-20.9 ‰. We correlated the carbon isotope curves among the Kuji and the Yezo groups and the English Chalk with the help of many anchor points of the U-Pb isotopic ages and several macro fossils. As the result, we identified exact Cretaceous stage boundaries of the Cenomanian/Turonian, Turonian/Coniacian, Coniacian/Santonian and Santonian/Campanian in the Kuji Group. The bone bed containing dinosaur in the Osawada stream is assigned to be lower Coniacian.

Keywords: Cretaceous, Carbon isotope, U-PB age, tuffs

Orbital influence on productivity and bottom current in the western equatorial Pacific: environmental magnetic approach

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The Western Pacific Warm Pool (WPWP) has highest water temperature in the global ocean, and its spatiotemporal variations have significant impacts on large-scale atmospheric circulation and global hydrology. An environmental magnetic study was conducted on sediment cores of late Pleistocene age taken from water depths of 2500 to 4500m in the West Caroline Basin (WCB) offshore northern New Guinea to understand better the paleoceanography in WPWP. Sediments in the southern part of WCB are deposited under the influence of relatively strong bottom water currents parallel to the New Guinea Trench; this is evidenced by sediment grain-size spectra, anisotropy of magnetic susceptibility, and 3.5 kHz sub-bottom profiling records.

Magnetite dominates magnetic mineral assemblages of the sediments. This is evidenced by that isothermal remanent magnetization (IRM) acquisition curves are mostly explained by a low-coercivity component, and that the Verwey transition is obvious in low-temperature measurements. Existence of the sharp central ridges on first-order reversal curve (FORC) diagrams and transmission electron microscopy indicate the occurrence of biogenic magnetite, in addition to magnetostatically interacting pseudo-single-domain and multi-domain magnetites of probably terrigenous origin.

The ratio of anhysteretic remanent magnetization susceptibility to saturation IRM ($k_{ARM}/SIRM$, a proxy of biogenic to terrigenous magnetic mineral component) and acid solvable component (~carbonate content) are synchronous with northern-hemisphere summer insolation; peaks of the former two correspond to the insolation maxima. This suggests that in WCB ocean productivity and then population of magnetotactic bacteria are higher when the Australia-Indonesian summer monsoon is stronger at the insolation maxima. The precessional frequency is visible in volumetric magnetic susceptibility (k) variations at sites shallower than the carbonate compensation depth (CCD), but the eccentricity frequency becomes dominant in carbonate-free mass susceptibility (χ_{cf}). Sediment redistribution by bottom water currents, whose strength and paths may vary with glacial/interglacial changes, may be responsible for the eccentricity frequency in χ_{cf} .

On the Ontong-Java Plateau (OJP) to the east of WCB, on the other hand, the precessional frequency appears in k , but the eccentricity frequency dominates $k_{ARM}/SIRM$ variations. This suggests that the $k_{ARM}/SIRM$ ratio at OJP could be influenced by a terrigenous supply via the Equatorial Undercurrent, but not by the strength of the monsoon.

Keywords: environmental magnetism, Western Pacific Warm Pool, West Caroline Basin, paleoceanography

M-B boundary age constrained by high-precision U-Pb zircon dating of a widespread tephra in a sedimentary sequence

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Geomagnetic polarity reversals, including the Matuyama-Brunhes boundary (MBB), are critical markers in age calibrating sedimentary sequences with volcanic rocks. Most age determinations for the MBB use marine astronomically-tuned benthic and planktonic foraminiferal oxygen isotope records to date the mid-point in the transition of the virtual geomagnetic pole (VGP). During the MBB and other reversals, the Earth's geomagnetic field intensity dropped significantly, resulting in the increased production of cosmogenic radionuclides, including ¹⁰Be, in the upper atmosphere. Hence, the MBB has also been recognized as a positive spike in the ¹⁰Be flux recorded in marine sediments and an Antarctic ice core.

The MBB has a frequently cited age of 780 ka, which derives from astronomically-tuned benthic and planktonic oxygen isotope records from the eastern equatorial Pacific. This marine astronomically-dated MBB age is supported by ⁴⁰Ar/³⁹Ar ages of Maui lavas at 781-783 ka, revised by the recent reference age of Fish Canyon Tuff sanidine (FCTs) standards. However, an understanding of post-depositional remanent magnetization (PDRM) processes shows that lock-in of the geomagnetic signal occurs below the sediment-water interface in marine sediments, which then yields ages for geomagnetic events that are too old. Because this age offset is influenced by sedimentation rate, those records with higher sedimentation rates should minimize the PDRM lock-in problem. In fact, younger astrochronological MBB ages of 772-773 ka have been reported from high sedimentation rate records. These MBB ages are consistent with records of cosmogenic nuclides in marine sediments and an Antarctic ice core, although they are not supported by radiometric timescales.

Here, we present a high-precision U-Pb zircon age of 772.7 ± 7.2 ka from a marine-deposited tephra just below the MBB in a forearc basin in Japan. Because the U-series dating is relatively free from issues about standardization and decay constants, this U-Pb zircon age coupled with a newly obtained oxygen isotope chronology yields a highly accurate MBB age of 770.2 ± 7.3 ka. Our MBB age is consistent with those based on the latest orbital-tuned marine sediments. We provide the first direct comparison between orbital tuning, U-Pb dating, and magnetostratigraphy for the MBB, fulfilling a key requirement for calibrating the geological timescales.

Abrupt intensification of North Atlantic Deep Water formation at the Nordic Seas during the late Pliocene transition

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Southward flow of dense North Atlantic Deep Water (NADW) and northward flow of warm surface water constitute the Atlantic Meridional Overturning Circulation (AMOC). The AMOC is an important component of the present climatic system because it plays a major role in controlling the northward transport of heat and moisture [Ramstorf, 2002]. In order to understand the evolution of the climatic system during the late Pliocene transition (LPT), during which the global climate changed from warm and relatively ice-free conditions to a colder and more glacial climate in the Northern Hemisphere [Lisiecki and Raymo, 2005], it is crucial to reveal changes in the NADW. However, details of the past evolution of the NADW during the LPT are still poorly understood because of the lack of suitable paleoceanographic proxy data.

Here, we developed a new rock-magnetic method to determine constituent of sediments and report on the evolution of NADW during LPT. North Atlantic deep-sea sediments drilled at the Gardar Drift (Integrated Ocean Drilling Program site U1314) were used for rock-magnetic measurements. We measured isothermal remanence (IRM) acquisition curves of 252 samples collected from 199.3 to 299.2 mcd of the core, which correspond to ages between 2.22 and 2.91 Ma at an average resolution of 3 kyr.

First derivatives of the IRM curves were decomposed into two end-member components. Consequently, residuals of the decomposition were sufficiently small throughout the study interval, thus confirming that the Gardar Drift sediments represent a mixing of the two end-member components: high-coercivity and low-coercivity components. Changes in the components agree well with those of the LR04 oxygen isotope data of benthic foraminifera [Lisiecki and Raymo, 2005]; the fraction of high-coercivity component periodically changed with the interglacial?glacial cycle. Variation trends of the sediment constituents drastically changed at ca. 2.68 Ma. Average values of the fraction of high-coercivity component increased after ca. 2.68 Ma from $38 \pm 13\%$ to $68 \pm 22\%$ because of the increase in high-coercivity component during the interglacial period.

Fraction changes of the high-coercivity component represent variation of the Iceland-Scotland Overflow Water, a branch of NADW formed at the Nordic Seas. The drastic increase in the high-coercivity component during the interglacial period suggests that intense NADW formation at the Nordic Seas abruptly started at ca. 2.68 Ma.

Keywords: North Atlantic Deep Water, Iceland Scotland Overflow Water, Nordic Seas, Late Pliocene transition, IODP Exp. 306

Reconstruction of changes in marine primary productions by biomarker analysis of sediments from the Gulf of Cadiz during

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The Gulf of Cadiz (GoC) has been regarded as an important area for investigating water exchange through the strait of Gibraltar. Particularly, change of Mediterranean Outflow Water (MOW) circulation was evaluated by contourite depositional pattern in the GoC (e.g. Hernández-Molina et al., 2014). The Azores Front (AF), which is known as northeastern margin of the subtropical gyre and regional upwelling area, is located at around the Canary Islands. Although the AF is not penetrated into the GoC at the present, microfossil records suggested penetration of the AF and enhanced productivity during the last glacial period (e.g. Rogerson, 2004). Thus, the GoC is sensitive to change of Atlantic ocean circulation, and can be key region of mid-latitude paleoclimatic and paleoceanographic circulation. However, sediment core samples prior to the Pleistocene had not been recovered until IODP Exp. 339 (2011 Nov. to 2012 Jan.), and paleoceanographic records have been hardly reported. Hence, we performed biomarker analysis on the sediment samples recovered by IODP Exp. 339 to reconstruct variations in marine primary production and paleoceanographic change around the GoC from late Miocene to late Pliocene.

We detect C₂₇ to C₂₉ sterols (eukaryotic algae biomarker), long-chain alkenones (haptophyte biomarker), dinosterol (dinoflagellate biomarker), and long-chain alkyl diols (eustigmatophyte and diatom biomarkers) from all studied samples. The C₂₈ and C₃₀ 1,14-diols are known as *Proboscía* diatoms biomarker, while eustigmatophyte are assumed as the main origin of C₂₈ and C₃₀ 1,13-diols and C₃₀ 1,15-diol in marine sediment. Recently, upwelling indices based on diol composition such as Diol Index 1 and 2 (DI1 and DI2) were proposed (e.g. Rampen et al., 2014). Concentrations of long-chain alkenones and C₂₈ sterol to total organic carbon (TOC) increased at ca. 4.2 Ma. The C₂₈ sterols were mainly composed of brassicasterol, which is the major sterol alkenone-producing haptophyte. Thus, these results suggest increase of haptophyte production. While, consecutive contourite sediment was found after 4.5 – 4.2 Ma. Hence, we cannot eliminate possibility that the increases of these biomarker concentrations are attributed to efficient preservation of sedimentary organic matter due to development of contourite depositional system. On the other hand, the 1,14-diol concentrations as well as DI1 and DI2 values increased during 3.4 – 3.2 Ma, which indicates high contributions of *Proboscía* diatom to marine production. Benthic foraminiferal $\delta^{18}\text{O}$ records indicate that global climate was thought to be colder during 3.4 – 3.2 Ma even in the warm Pliocene epoch (Lisiecki and Raymo, 2005). Particularly, local maximum of foraminiferal $\delta^{18}\text{O}$ values was observed at cold period of the MIS M2 (ca. 3.35 – 3.24 Ma). Thus, increases of diatom productions in the GoC might be explained by ocean and wind circulation changes caused by global cooling. Furthermore, sea surface temperature (SST) estimated in the IODP U1313 site (mid-latitude Atlantic Ocean) indicated that the North Atlantic Current (NAC) was weakened and glacial-like ocean circulation was established from 3.4 Ma to MIS M2 (Naafs et al., 2010). From these results, it is concluded that diatom productions increased as results of penetration of the AF into the GoC permitted by the glacial-like ocean circulation and enhanced vertical mixing during 3.4 – 3.2 Ma.

Keywords: North Atlantic Ocean, Pliocene, MIS M2, Biomarker, Diatom, Mediterranean Outflow Water

Marine tephra as an important tool for paleoceanography and paleoclimatology

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Tephra is a product of volcanic eruption, and volcanic ash, which is thought to be geologically synchronous, is an important key bed to connect the events found in lacustrine and marine sequences. Tephra grain is an important component of marine sediments, especially around the volcanic islands such as the Japanese islands. Tephra grains have been supplied to marine environments not only directly by the volcanic eruptions as fall tephra, but also by erosion of terrestrial and marine beds. Fall tephra is an important tool to identify relationship among the environmental changes found in terrestrial, lacustrine and marine environments. Exact correlation of regional climatic events is extremely important to understand global climatic changes. Comparison of terrestrial and marine radiocarbon ages of the same tephra provides us information on the local reservoir effect. Because the local reservoir effect is influenced by ventilation and ocean circulation, regional reconstruction of local reservoir effect is useful for understanding the three dimensional ocean circulation changes in the glacial and deglacial oceans.

Keywords: tephra, marine sediments, marine reservoir effect, environmental change, key bed

Absolute paleomagnetic intensity and tephrochronology: Absolute calibration of relative paleomagnetic intensity stacks

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Absolute geomagnetic paleointensities (APIs) have been estimated from igneous rocks, while relative paleomagnetic intensities (RPIs) have been reported from sediment cores. These two datasets have been treated separately, as correlations between APIs and RPIs are difficult on account of age uncertainties. We present a procedure for directly correlating APIs with RPIs of a RPI stack. Correlations between APIs and RPIs were conducted with virtually no associated age errors using both tephrochronologic correlations and RPI minima. Using the stratigraphic positions of tephra layers in oxygen isotope stratigraphic records, we directly compared the RPIs and APIs reported from welded tuffs contemporaneously extruded with the tephra layers. In addition, RPI minima during geomagnetic reversals and excursions were compared with APIs corresponding to the reversals and excursions. The comparison of APIs and RPIs at these exact points allowed a reliable calibration of the RPI values. In this study, we applied the Tsunakawa-Shaw method to 20 welded tuffs to increase API dataset. We obtained mean paleointensities for 16 of the 20 welded tuffs. Since eight of the 16 welded tuff units were correlated with the oxygen isotope stratigraphy, they can be added to the API data used in the correlation procedure. Combining these API data with the reported data, we correlated API data with RPIs from the PISO-1500 stack. For 13 correlation points, RPIs of the PISO-1500 stack showed a linear relationship with virtual axial dipole moments (VADMs) calculated from the APIs, indicating that the PISO-1500 stack has a linear relation to the axial dipole moment. The correlation procedure with increased API data can contribute to constraining the relation between RPI of a RPI stack and API and calibrating a RPI stack to absolute values.

Keywords: welded tuff, widespread tephra, absolute paleointensity, relative paleointensity, oxygen isotope stratigraphy

Hydroclimate variations in southwestern Japan over the past 1500 years inferred from oxygen isotope ratios in tree rings

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Oxygen isotope ratios ($\delta^{18}\text{O}$) in tree-ring cellulose have been widely used to reconstruct hydroclimate variations and atmospheric circulations over monsoon Asia. However, most of previous reconstructions based on tree-ring $\delta^{18}\text{O}$ cover only the past several hundred years, and therefore millennium-scale reconstructions are yet to be developed. Here we present a well-replicated 1500-year tree-ring $\delta^{18}\text{O}$ chronology that was constructed using living and fallen dead trees (*Cryptomeria japonica*) in Yakushima Island, southwestern Japan. First of all, core or disk samples were absolutely dated by matching ring-width patterns among different trees. Then a total of 14 trees were selected for isotopic analysis. We employed the 'plate method' to isolate cellulose component directly from a 1.0-mm wood plate. Each annual ring of cellulose was separated using a razor blade. Finally $\delta^{18}\text{O}$ of individual ring was determined using a continuous flow isotope ratio mass spectrometer coupled to an elemental analyzer. The $\delta^{18}\text{O}$ time series were highly correlated with one another, suggesting that common climatic signals are preserved in all the sampled trees. Because the $\delta^{18}\text{O}$ series did not show prominent age-related trends, all the series were simply normalized to have the same mean during the overlapping segments. The normalized series were then averaged to construct the final chronology. Response analysis using ambient climate records for the last 50 years indicates that tree-ring $\delta^{18}\text{O}$ is mainly governed by summer relative humidity. We therefore interpret this record as a proxy of hydroclimate related to East Asian summer monsoon. Low-frequency variations in our chronology are similar to those of a Northern Hemisphere temperature reconstruction. More specifically our reconstruction shows a relatively dry (wet) condition during the Medieval Warm Period (the Little Ice Age). Centennial-scale fluctuations of sea surface temperatures in the equatorial Pacific may play a role in modulating long-term hydroclimate changes in southwestern Japan.

Keywords: Tree rings, Oxygen isotope, Yakushima Island, Monsoon

The change of sedimentary environment for past of 350 years in the Lake Mokoto, Hokkaido, Japan

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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. Especially, the Okhotsk brackish-water lake group around Abashiri City is constituted by major lake in Japan such as Lake Abashiri, Lake Mokoto, Lake Tofutsu, and Lake Notoro. In this study, The change of sedimentary environment in Lake Mokoto is discussed by sedimentologic and geochemical high-resolution analysis of the cores collected from Lake Mokoto.

Mokoto has two-layer structure of intermediate salinity surface waters and high salinity bottom water. The bottom water in Lake Mokoto shows the anoxic conditions in summer season.

The 09Mk-2C cores collected from Lake Mokoto shows the length of 3.87m. In Lake Mokoto, there were the Ta-a tephra (AD 1739) at the 3.5m depths and Ko-2c (AD 1964) at the 3.87m depths.

The cores collected from Lake Mokoto consist of organic mud with the lamination in all cores. In 09Mk-2C core, the core top 185 cm shows the black (L value: ca 5), and it seems to indicate the seasonal anoxic environment as present. The organic mud below 100cm depth shows black (L values: ca 13-15). In the observation by the soft X-ray photograph, the cyclic lamina set is observed in the core from Lake Mokoto. It is considered that this cyclic lamina set is the verve.

Phosphorus contents in 09Mk-2C core show the relatively high values (ca 0.1wt%) above 192cm depth. However, Phosphorus is not detected below this horizon up to 290cm depths. Same Trend was observed to 09Mk-1C core. According to result of this core, the increasing of phosphorus contents may be caused by drainage of pollution from stock farm. The horizon of phosphorus increasing is estimated to AD1957 from the number of cyclic lamina set. In report, domestic animal increased at AD1955 in the drainage basin. This timing is consistent with phosphorus increasing. The thickness of lamina set is about 7mm before late 1960s for the age of cyclic lamina set. After that, the thickness of lamina set is about 25mm. It is suggest that Lake Mokoto is aggrading by sediment from drainage basin under high sedimentation rate.

Keywords: Coastal Lagoon, Lake Mokoto, lamina, Ta-a tephra, Ko-2c tephra, anoxic

Centennial-scale variability in lower trophic level productions off Tomakomai, Hokkaido

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Nutrients in the surface marine waters support lower trophic productivity and fisheries productivity through food webs. In the latter of 20th century, nutrient levels represented by PO₄ showed a decreasing trend in the western North Pacific (Limsakul et al., 2001; Minobe, 2013; Tadokoro et al., 2009). This decreasing trend is the largest rates in the world ocean; decreases in productivity of lower trophic levels have also been reported in this area (Boyce et al., 2010; Tadokoro et al., 2009). The decreasing trend of nutrients may be attributed to intensification of subtropical gyre circulation and Kuroshio-Oyashio Extension due to global warming; the effect extends basin-wide (Minobe, 2013). Heretofore, it is unclear that this nutrient decreasing trend results from global warming or is in case of natural variability. Understanding to what extent nutrient depletion due to natural variability contributes to this decreasing trend is important to predict oligotrophication in the North Pacific in the 21st century. However, only 40-year records from observations of nutrients have prevented us from unraveling patterns of long-term natural variability and its amplitude. Here we present long-term record of nutrient levels in the Coastal Oyashio region, western North Pacific, by using proxies of lower trophic levels which sensitively responds to nutrient levels, in order to elucidate long-term natural variability of nutrients and its amplitude.

Results of biogenic opal, algal- and zooplankton-derived pigments showed centennial- or millennial-scale variability for the last 3000 years. Based on flux of biogenic opal, chlorophyll a + derivatives and SCEs, the centennial-scale variability caused depletions from a peak to a trough by 19-42%, 12-19% and 11-65%, respectively. This indicates that diatom productions have substantially varied on centennial timescales. Assuming that amplitude of the diatom production variations was directly attributed to nutrient levels, the depletions on centennial timescales is as large magnitude as that in PO₄ (23%) in the late 20th century. The biogenic opal flux is low level at present and the decreasing trend since 19th century is considered to be part of centennial natural variability. Similar centennial-scale variability is also found in the sardine fossil scale records from Japan and off California, records of salmon abundance from Alaska, and PDO index reconstructed from tree ring width from the North America. Centennial climate changes over the Pacific may be associated with the centennial variability in the biological productivity in each region of the North Pacific and PDO. Further studies on this centennial natural variability, including a network of more productivity reconstructions in the western North Pacific and the driving mechanisms, are needed for long-term predictions of nutrient level and fisheries productions.

Keywords: centennial variability, lower trophic level production, Coastal Oyashio, nutrients, PDO

Intensity variation in ocean circulation with iceberg surges after intensification of Northern Hemisphere glaciation

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Ice sheets linked with ocean circulation play an important role in global climate change. Here we show millennial-scale rock magnetic records together with ice rafted debris (IRD) counts indicating links between ice sheet collapse and ocean circulation after the intensification of Northern Hemisphere glaciation (NHG). We report an abrupt variation in the activity of water circulation associated with an IRD event in Marine Isotope Stage (MIS) 104 weakened to a similar degree to that occurred in MIS 100, the first pronounced glacial period in which widespread glaciation occurred in the northern hemisphere at the intensification of NHG.

We analyzed a sediment core IODP Site U1314 in the Gardar Drift in the North Atlantic. In this study, we analyzed sediments from 239.5 to 245.5 mcd (m composite depth) at 2 cm resolution, which corresponds to the age between 2.58 and 2.62 Ma according to the age model by Hayashi et al. (2010). This interval includes MIS 104, which is a prior glacial interval to MIS 100. We compare the result in MIS 104 to that in MIS 100 in the preceding study (Ohno et al., 2014, JpGU).

We sieved 0.5 g sediments and counted IRDs larger than 150 μm . As a result, two IRD events were confirmed at about 2.602 Ma and 2.610 Ma. Magnetic hysteresis parameters, S-ratio ($M_{r-100mT}/M_{r1T}$) and IRM (isothermal remanent magnetization) acquisition experiments were done by using an Alternating Gradient Magnetometer (MicroMag 2900, Princeton Measurement Corporation).

Rock magnetic records showed 2 types of variation: a long-term variation with glacial-interglacial cycle and a short-term variation associated with an IRD event. The IRM acquisition curves in all samples were well explained by a mixture of two components (of high and low magnetic coercivity, respectively). The variation in the proportion of two components are interpreted as variation in the content of basaltic sediments transported by North Atlantic Deep Water. Therefore, the variation in the proportion of two components indicates the variation in the intensity of deep water circulation. Increase in the component of high magnetic coercivity indicates active deep water circulation at interglacial period. In contrast, increase of the component of low magnetic coercivity indicates inactive circulation at glacial period.

In addition to the long-term variation in IRM acquisition curve during 2.58-2.61 Ma (for thirty thousand years), short-term variation associated with an IRD event occurred at 2.602 Ma and 2.610 Ma. The component of high magnetic coercivity in IRM acquisition curve decreased by 68% (from 73% to 5%) within about a thousand years at 2.602 Ma. Succeedingly, it increased to the same proportion as before the event within a time interval of 10 thousand years. In addition, another short-term variation occurred without IRD event at Gauss-Matsuyama geomagnetic polarity transition.

In our previous study in MIS 100, we reported repetition of sudden decrease and gradual increase in component of high magnetic coercivity associated with IRD events. It is well known that the continental ice sheets grew much larger in MIS 100 compared to in MIS 104. However, our study suggests that the comparable level of decrease in deep water circulation occurred at not only in MIS 100 but also in MIS 104.

Keywords: ice rafted debris, rock magnetism, ice sheet collapse, deep water circulation, North Atlantic Deep Water

Rapid sea-level fall during the earliest phase of Marine Isotope Stage 19 in Osaka Bay, Japan

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Marine Isotope Stage (MIS) 19 is climatologically important as an orbital analogue of the Holocene, besides its stratigraphic importance as a candidate for the Early-Middle Pleistocene boundary. We conducted diatom analyses of marine clay sediments in the 1700-m core of the Osaka Group to estimate sea-level changes during MIS 19. The marine condition and diatom assemblages in Osaka Bay are strongly affected by eustatic sea-level change. The homogeneous fine clay sediment and its high average accumulation rate (63 cm/kyr) can yield millennial to centennial scale sea-level changes. Variations in diatom assemblages are classified into four ecological categories ; marine, marine-brackish, brackish, and freshwater. Marine taxa define marine zone, ranging in depth from 405.60m to 390.62 m. Diatom assemblages clearly show precession-related signals for two sea-level highstands correlated with MIS 19.3 and 19.1, and a lowstand with 19.2, respectively. In addition, we found a rapid sea-level fall event in the earliest phase of MIS 19. This event suddenly began at a depth of 403.88 m with rapid decrease in marine-planktonic diatoms, and strong increases in marine-benthic and freshwater-planktonic diatoms, followed by a relatively gradual recovery to the pre-event levels at a depth of 403.27m. An astronomical age model shows its duration of 783ka-782ka. We examined benthic marine oxygen isotope records from deep-sea and coastal marine sediments, some of which have a signal comparable to the sea-level fall event in the earliest MIS 19, suggesting the temporal expansion of global ice sheet. The rapid sea-level fall during the period concerned may reflect a global event.

Keywords: sea-level change, Marine Isotope Stage 19, Middle Pleistocene Transition, diatom, Osaka Group, Matuyama-Brunhes Transition

High-resolution climate variation during marine isotope stage 11 from a core of Osaka Bay, southwest Japan

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Climate of marine isotope stage (MIS) 11 has been investigated by many researchers, regarded as an analogue for the Holocene. MIS 11 is a super-interglacial characterized by its high sea-level and long duration. To reveal millennial to centennial scale climate changes of this interglacial in comparison with sea-level variations shown by diatoms, pollen analyses were conducted on a 1700-m core of Osaka Bay over a depth range from 162 m to 222 m. The core has an average sedimentation rate of about 60 cm/ka, dated with a linear age model based on the orbital tuning, reinforced by tephrostratigraphy and magnetic polarity stratigraphy. Cold climate shown by dominance of coniferous tree taxa in the latest stage of MIS 12 was replaced by cool climate dominated by deciduous tree taxa mainly composed of *Fagus*, a cool proxy, in the earliest MIS 11. The vegetation in MIS 11 was gradually dominated by deciduous tree taxa. The proportion of *Quercus* (*Cyclobalanopsis*), a warm proxy, increased with sea-level rise and reached its maximum at sea-level highstand of MIS 11.3. After the thermal maximum, *Quercus* (*Cyclobalanopsis*) gradually decreased with fluctuations and coniferous tree taxa such as *Cryptomeria* and *Sciadopitys* increased, both indicating cooling and wetting. After MIS 11.3, the climate shows clear precession-related signals correlated with changes in the diatom sea-level proxies. Pollen taxa, especially *Alnus* and non-arboreal pollen, also show environmental changes. From the latest stage of MIS 12 to the earliest MIS 11, a marsh environment was dominant during the post-glacial sea-level rise. In the early stage of MIS 11, the post-glacial warming is clearly shown by the rapid increase of *Quercus* (*Cyclobalanopsis*), and the warming is interrupted by a short-term cooling that ranges in age from about 416 ka to 413 ka based on the linear age model. The temporal cooling almost coincides with the sea-level fall or stagnation suggested by the diatom sea-level proxies. A similar cooling event has been reported from Europe, Lake Baikal and the Antarctic. Therefore, the cooling event in the early MIS 11 may be global and accompanied by an ice volume increase.

Keywords: Marine Isotope Stage 11, Paleoclimate, Paleovegetation, Pollen analysis, Osaka Bay sediments

High-resolution climate variations during the last interglacial period from an Osaka Bay core

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The last interglacial period is characterized by an extremely high sea-level and warm climate. To reveal detailed features of climate for this period, pollen analyses were conducted on a sedimentary sequence in a 1700-m core from Osaka Bay. At least 400 tree pollen grains were counted for each sample. A marine sediment layer correlated with the last interglacial ranges in depth from 73.6 m to 61.4 m, with the highest sea-level at 69.5 m according to diatom assemblage data. An average sedimentation rate of 0.548 m/ka ($R=0.999$) is calculated with nine age control points above marine isotope stage (MIS) 17 in the core. A linear age model using the average sedimentation rate and calibrating the sea-level peak to the MIS 5e highstand (Rohling et al., 2008) suggests the marine layer spans in age from 130 ka to 108 ka. The time span almost agrees with that of MIS 5e. The climate change based the age model is as follows. Before 130 ka, *Picea* is dominant, indicating a cold climate during MIS 6. From 130 to 125 ka, the proportion of cool-temperate deciduous broadleaved taxon *Fagus* gradually increases, suggesting gradual warming, coinciding with the postglacial sea-level rise that is shown by the gradual increase of pelagic diatom *Thalassiosira* spp. After 125 ka, *Fagus* turns to decrease, while *Quercus* including warm-temperate evergreen broadleaved taxon *Quercus* (*Cyclobalanopsis*) gradually increases and reach a maximum. The thermal maximum occurs slightly after the highest sea-level. After 115 ka, temperate conifers *Cryptomeria*, *Sciadopitys* and *Taxaceae-Cephalotaxaceae-Cupressaceae* begin to increase, suggesting a gradual wetting. The wet climate continues even after MIS 5e. Subtropical taxon *Lagerstroemia* occurs throughout the last interglacial. These climate variation features seem to be consistent with those of the last interglacial climate from Lake Biwa.

Keywords: Last interglacial, Paleoclimate, Osaka Bay, Pollen analysis

Pliocene paleoceanographic reconstruction off the Kumano based on planktonic foraminiferal modern analogs

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The Modern Analog Technique (MAT) is a powerful method to reconstruct paleoenvironment by means of a modern dataset (Hutson, 1979; Overpeck et al., 1985; Prell, 1985). In this method, a paleoenvironmental property for a fossil assemblage is calibrated by nearest modern assemblages. Therefore, this method is completely rely on the size and coverage of the modern dataset. According to previous multi-technique studies, the MAT is more sensitive than the Imbrie-Kipp transfer function method.

A global modern database of planktonic foraminifera has been well established by international projects. However, the global dataset is based on specimens in different test size (>150 micrometers) from that of Japanese workers (>125 micrometers). As a Japanese regional dataset, Imbrie-Kipp factor loadings were presented for 81 surface sediment samples along the Pacific coast of Japanese Islands (Takemoto and Oda, 1997). We newly developed a FORTRAN program of the MAT using the square chord distance (SCD) based on Imbrie-Kipp factor loadings of a given sample and the modern 81 samples of Takemoto and Oda (1997). We applied this program to Pleistocene 147 samples obtained from IODP Sites C0001 and C0002 drilled off the Kumano region, northwestern Pacific. As a result of this, vertical temperature changes (0-300 m in depth) of both winter and summer seasons for the last 1.8 million years were reconstructed successfully with low SCD values (less than 0.25). The depth gradient of the summer water temperature in the reconstructed profile indicates stepwise increases around 1.59 Ma (MIS 54) and 1.01 Ma (MIS 28).

Keywords: Planktonic foraminifera, Pleistocene, Modern Analog Technique, Kumano, IODP

Salinity change in the tropical western Pacific at 5.2 ka when an abrupt tropical climate change occurred

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It has been reported that an abrupt mid-Holocene climate event that marked the transition from early Holocene (pre-5,000-yr-B.P.) conditions to cooler, late Holocene (post-5,000-yr-B.P.) conditions was widespread and spatially coherent through much of the tropics. This abrupt event was occurred around 5,200 yr ago and was coincident with structural changes in several civilizations. While these evidences are obtained from ice core records and/or lake levels, little has been discussed using marine data. Especially, obtaining accurate estimate of the past $\delta^{18}\text{O}$ (salinity) distribution in tropical surface waters is crucial to establishing the role of the tropical oceans in global climate change. In this study, Sr/Ca ratios and $\delta^{18}\text{O}$ values in a fossil coral collected from Vanuatu were measured to reconstruct past sea surface temperature (SST) and salinity. The age of the fossil coral is 5212 ± 10 based on the precise U-Th dating method. Sr/Ca and $\delta^{18}\text{O}$ were then analyzed with an approximate time resolution of 2 month. XRD analysis and SEM observation revealed that skeletal material was composed of only aragonite. As a result, slightly higher mean SST and about 0.5 per mil enrichment of $\delta^{18}\text{O}$ relative to modern seawater have shown from 5.2 ka coral. The result is corresponding to the previous study from Great Barrier Reef which has suggested that the temperature increase enhanced the evaporative enrichment of $\delta^{18}\text{O}$ in seawater.

Keywords: coral, Holocene, abrupt climate change, salinity

Reconstruction of Andaman Sea coastal environment during the past 500 years

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The Andaman Sea is a semi enclosed marginal sea in the northern Indian Ocean. Marine sediment of Andaman Sea is supplied not only from Ayeyawady - Salween river system but also from surface current from the Bay of Bengal driven by Indian monsoon. Although the change of coastal sediment environment in Andaman Sea is important for understanding climate system associated with livelihood, their reconstruction remains unclear. In this study, a marine sedimentary record sampled at a water depth of 75 m (core length: 450cm) in coastal environment of the Andaman Sea (15°N, 96°E, southwestern Myanmar) was used to reconstruct the paleo-environmental change over the past 500 years. We find the evidence from ¹⁴C ages that the sediment rate decreased between about 150~170 cm bsf (1600~1750 cal yr A.D) of the core. Moreover, grain size analysis reveals finer between about the 150~170 cm bsf part. Therefore, our results suggest the reduction of sedimentary supply into Andaman Sea coastal area from rivers around 1600~1750 cal yr A.D. There is a possibility that these results were reflected various environmental changes (e.g. onshore precipitation).

Keywords: sedimentary condition, Andaman Sea, grain size analysis