

The sedimentary process and distribution of tsunami deposits in coastal lakes: a flume experiment

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A series of flume experiments were performed to examine the sedimentary process and distribution of tsunami deposits in coastal lakes. In the experimental program, a fixed slope of 1/20 and terrestrial area including a pool as a coastal lake were installed, and tsunami-like solitary wave was generated. The tsunami flow transported sediments from a sand bed placed on the slope, and deposited them on the terrestrial area. When the tsunami flow irrupted into the pool, hydraulic jump was occurred. In the area where the hydraulic jump made turbulence, little sediment deposited. Thus, the distribution of the tsunami deposits in the pool did not always show the thinning-landward trend in the present experimental series. The dependence of the amount of sediments on magnitude of tsunami waves was more pronounced in the pool than the land area.

Keywords: tsunami deposit, flume experiment, coastal lake

Variations of terrigenous organic carbon content in flood and slope failure sediments

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In this study, we analyzed the stable organic carbon isotope of sea floor sediments, which were deposited by the modern large floods with typhoon and the slope failure with earthquakes. Stratigraphic variations of terrigenous organic carbon content in the flood sediments were different from those of slope failure sediments.

Sediment cores KH-11-9-FB12 and FB14 were corrected from the deep-sea floor off the Kumano River mouth, which is located on the Kii Peninsula. The sediment cores contain flood-induced sediments by large typhoon in September, 2011, the largest 20th century typhoon, and the large 19th century Totsukawa flood (Ikehara et al.,2012). These flood-induced sediments have high terrigenous organic carbon content. The base of turbidite, which include wood fragments, has highest peak of terrigenous organic carbon content. On the other hand, terrigenous organic carbon content of the lower part of turbidite mud are lower than those of the middle and upper parts of turbidite mud. The stratigraphic variations of terrigenous organic carbon content is not recognized in the middle and upper parts of turbidite mud.

Sediment cores 95A and 104A were corrected from the shallow depression on shelf off the Saru River mouth, Hokkaido, in 2007. These cores contain the sediments by the severe flood with typhoon in August, 2003. The shallow depression on shelf, which is thought to be the old river path during lowstand of the last glacial age, was suitable for preservation of the flood-induced sediments (Katayama et al., 2007). The lower part of the turbidite mud has low terrigenous organic carbon content and the middle and upper parts have high terrigenous organic carbon content. The stratigraphic variations of terrigenous organic carbon content is not recognized in the middle and upper parts of turbidite mud. The turbidite mud off the Saru River mouth have same characteristics as those off the Kumano River mouth. These results suggest that the lower part of flood-induced sediments were formed by erosion and deposition of sea-floor sediments during the early stage of flood. The middle and upper parts were considered to be formed by continuous supply and deposition of terrigenous materials from river mouth during the flood.

The sediment core BP09-6 was corrected from the Beppu Bay. The sediment core contains the slope failure sediments by the large earthquake in 1596 (Keicho-Bungo earthquake; Kuwae et al., 2013). The slope failure sediments are characterized by upward decreasing of terrigenous organic carbon. This result suggests that the turbidity currents were caused by collapse of delta slope sediments, which contain both terrigenous and marine organic materials.

Stratigraphic variations of terrigenous organic carbon content might be important information, when we investigate the records of paleo natural disasters with sea-floor sediments.

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Keywords: turbidite mud, hemipelagites, organic carbon, natural disasters

Quartzose sand and kaolinite-dominated mud derived from felsic plutonic rocks in intense weathering condition

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In the Upper Miocene - Early Pliocene time, Japanese island had a warm and subtropical climate. The mineralogical and chemical compositions of sand and mud of the Upper Miocene Tokiguchi Porcelain Clay and the Early Pliocene in the Kobiwako Group were examined for sedimentary petrography and geochemistry to clarify the influence of the warm climatic condition on sediment composition. Both sediments are considered to have been produced from felsic crystalline basement provenance. These sediments are characterized by the deposition in warm and humid climate on the basis of plant and diatom fossils.

The humid tropical climate produced quartz rich sand and kaolinite rich mud. The Upper Miocene sediments indicate that mafic silicates and feldspars were destroyed so that the sand ranges from arkoses with plagioclase rich sand to subarkoses with dominant of K-feldspar. The Upper Miocene mud show kaolinitic clay mineral composition and aluminous chemical composition. In contrast, the Pliocene sand is arkosic to litharenitic with abundant of feldspars and accessory minerals. In the Pliocene mud, an increase in the relative abundance of smectite accompanies the breakdown of volcanic fragments and volcanic glass is detected.

The intense weathering, rare earth elements (REE) are concentrated in mud. The Miocene sand shows the REE concentration less than one of PAAS level, whereas the Miocene mud display similar level of concentration in PAAS. In many samples, the REE concentration is mostly by biotite and zircon evidenced by HREE concentration.

The intense weathering condition, such as high temperature with humidity, affects the sand and mud compositions with selective destruction of minerals and newly formation of clay minerals. The relative increase of HREE, which is mainly housed in durable minerals, and mineral assemblage of sand and mud probably provide quantitative estimation of weathering degree for the sediments derived from felsic plutonic rocks.

Keywords: Miocene, sand composition, mud composition, REE composition, weathering

Depositional environment of the recent Yangtze Delta sediment deduced from the natural gamma-ray spectroscopy of YD13-G2

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The Yangtze River has transported approximately 500 mt/yr of sediments which formed a well-developed tide-dominated delta on its mouth during the Holocene high-stand. Sediment transport is dominant in rainy summer season or during flooding events, and the 40% is deposited in the estuary and the remaining sediments are transported offshore by tide forming a submerged delta or re-transported southward during stormy winter season. Due to these seasonally contrasted and event driven feature of sedimentation, spatial distribution of the accretion and erosion of the delta body is highly heterogeneous.

The Holocene subaqueous delta sediment has been also used as good sediment archives of the history of the Yangtze discharge and flooding due to its high sedimentation rate and good coverage of the Late Holocene. We also performed drilling of the delta sediment and collected two ~30 m drilling cores and four gravity cores in order to reconstruct the flooding history and the associated change in the detrital provenance. The drilled site (YD-13) is located on clayey bottom with the water depth of 40 m. The top 10 m of the sediment core consists of homogeneous clay with rare sand patches, which could be formed during the Holocene high stand. One of the gravity core (YD13-G2) recovers the 140 cm of surface sediments, and we decided to examine the natural gamma-ray spectrum and stacking pattern of this gravity core at 1 cm resolution in order to stationarity of sedimentation.

Since Cs-137 was not detected from the YD13-G2 sediment, even the surface material was judged to be older than 1950. Pb-210 is detected from the top 50 cm interval, which suggests the near-surface sediments were deposited during these ~100 yrs. However, the vertical profile of Pb-210 shows highly variable from zero to 25 Bq/kg with zigzag shape, which suggests repeated intercalation of old materials. Th-234 / K-40 and Ac-228 / K-40 ratios varies consistently suggesting some varieties in the provenance or grain size. Further examination is necessary to resolve potential event sedimentation and the apparent age of the related sediments.

Keywords: Yangtze Delta, Depositional environment, natural gamma-ray spectroscopy

Provenance changes of Yangtze Delta core sediments and their implications for precipitation changes during the Holocene

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Understanding the complex evolution of the natural environment in response to changes in climatic boundary conditions is a major challenge. Changes in frequency and magnitude of flooding of the Yangtze in association with the variations in East Asian Summer Monsoon (EASM) precipitation during the Holocene is one of such examples. The Yangtze River catchment is particularly sensitive to periodic flooding and droughts caused by temporal and spatial variations in the seasonal precipitation regime.

As a joint research project with Nanjing Normal University, we conducted Yangtze Delta drilling to reconstruct temporal and spatial changes in precipitation within the Yangtze River drainage during the Holocene. Core YD13-1 (31°02' 59.9250" N, 122°50'00.2538" E) was recovered from Yangtze subaqueous delta at a water depth of 37 m, its penetration depth is 39.5 m, and probably covering the entire Holocene. The project focus on decadal/centennial-scale variability of river discharge and its provenance in the lower Yangtze reaches, deltaic system and East China Sea (ECS). It includes the study of the reconstruction of the flood history, the variability of fresh-water input and redistribution of Yangtze-derived sediments and Holocene floodplain development in these areas.

A new tool that use of electron spin resonance (ESR) signal intensity of the E1' center and the crystallinity index (CI) of quartz is introduced to characterize the provenance of the Yangtze River Delta sediments, which were derived from various parts of the Yangtze River drainage, and its temporal changes that should have reflected the spatio-temporal changes in precipitation and flooding. The result will contribute to a more accurate understanding of the changes in spatial precipitation pattern associated with rapid climatic changes, of evolution of the lower Yangtze river-delta-shelf system, and of the environmental and climatic conditions under which the process took place. Our previous research result from the mudbelt core in ECS suggests possible scenarios for the response of the Yangtze catchment to the changes in monsoon intensity and extreme events. New analytical result of the provenance proxy for core sediments from Yangtze River Delta will be presented and possible scenario will be discussed.

Estimating mixing ratio of the sediments from tributaries in the sediments from Yangtze River mouth

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Yangtze river is the largest river in eastern Asia. The rain front is accompanied with the development of summer monsoon, and moves within the Yangtze drainage, bringing heavy rain. Thus, the spatial fluctuation is also important for understanding the behavior of summer monsoon.

A paleoclimate record is needed for reconstructing the distribution of precipitation before metrological record. In Yangtze, over 95% of yielded sediment is suspended particle matter(SPM). The precipitation in drainage is proportional to water discharge, and water discharge is also proportional to suspended sediment concentration.

In this study, as a basis for reconstructing the past distribution of rain in Yangtze drainage, 1) analyze the ESR(Electron Spin Resonance) signal intensity of each tributary, 2) confirm that ESR values can explain the mixture of sediments in the mainstream, 3) discussing how large flood can be detected as a change of ESR values in the river mouth.

The sediments from major tributaries of Yangtze shows different ESR values each other. Using ESR values of each tributary as end members, the modern ESR value at rivermouth is estimated. The estimated value is consistent with the analyzed ESR value of sediments near rivermouth. So, ESR signal intensity can be used for estimating mixture of sediments.

We also calculated how large ESR value at rivermouth can change on the assumption that the flood occurs in specific tributaries. As a result, the flood can be detected as the change of ESR value at rivermouth when the sediment yield increases 5 times than usual.

Evaluation of chemical weathering and sediment flux for several drainages within the Yangtze River basin

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Chemical weathering is closely coupled with erosion and driving landscape evolution. Silicate weathering plays a major role of fixing atmospheric CO₂ in the carbon cycle in time scales longer than 10⁵ years. Therefore, quantitative estimation of chemical weathering rate and evaluation of its controlling factors are critical to understand its role on landscape evolution and controlling the carbon cycle on a long time scale. Researches on evaluating controlling factors of the weathering rates have been conducted using various methods and on various temporal and spatial scales, including theoretical approaches based on mineral dissolution experiments, empirical approaches based on analyses of river water, suspended material and sediments, and numerical modeling approaches to synthesize these data. Although empirical formulations of the chemical weathering and physical erosion rates specific to a certain river have been presented, processes of weathering and erosion should be considered together both from physical and chemical aspects in order to obtain more generalized formulas. Besides, in order to reconstruct the past processes of chemical weathering and erosion from the knowledge of the present processes, it is necessary to establish methods for reconstructing chemical vs physical weathering processes by using sediments which are the end products of weathering and erosion.

Toward the objective above, this study aims to explore the present processes of chemical weathering and erosion in the Yangtze River drainage as an example. Yangtze River is the longest river in Asia with the great water discharge and sediment flux. Hence, the river's role on material cycle on Earth's surface is significant. In addition, water and meteorological data are accumulated for long time period by many gauging stations and meteorological stations in the basin.

Mineral and chemical compositions of suspended particles and sediments as well as chemical composition of dissolved matter are analyzed for water samples and river bank sediments obtained from Yangtze River and its tributaries in the summer of 2011. Using these results, together with river discharge data and dissolved/suspended load concentrations, the fluxes for each element are calculated, and then the inputs from each watershed are obtained. Then, the relative contribution between chemical weathering and physical erosion is estimated. The calculation revealed that chemical weathering rate increases downstream but the relative contribution between chemical weathering and physical erosion in the uppermost part is the maximum in the upper, erosional part. In the lower, depositional part, dissolved carbonate is diluted after the main stream has merged with Poyang Lake, and then increased again toward the river mouth. The processes of chemical weathering and physical erosion in each watershed and their possible controlling factors will be discussed.

Underwater topographic survey for inaccessible water areas, and its applications to submarine and sublake landslides

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Landslides, volcanoes, active faults and other hazard related topographies exist on the sea floor or lake bottoms. It is important to investigate them for assessing future hazard potential. But investigations for these underwater topographies are not so easy because it needs quite high cost, and its heavy weight equipment also requires a ship big enough to hold it. These days, dramatically advanced leisure-use fish finders enable us to investigate underwater topographic survey from shallow to several hundred meters deep. These fish finders are low cost and light weight, so can be equipped on inflatable rafts that is accessible into ultra shallow area of 0.5 - 20 m deep that is usually inaccessible for usual scientific research vessels. Thus the investigating method using the fish finder and an inflatable raft is more versatile than other technical ways. Some advanced fish finders have a side-scan sonar system that obtains 2D image of acoustic reflections, and it can identify bottom materials and underwater structures. Now we are trying to apply for studying submarine and sublake landslides in water areas that have not been surveyed. This presentation shows successful examples of our conducted investigations for the sublake landslides in Lake Kussharo and the 1923 Nebukawa landslide that a part of the landslide dived into the sea. These results have contributed the innovative discussion in generation of tsunamis on the lake, and revealed unknown submarine ruins that landslide devastated.

Keywords: fish finder, submarine landslide, underwater landslide, bathymetric survey, side-scan sonar

Development of a monitoring system of bathymetric change and related sediment transport using optic fiber cables

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A development of monitoring system is important for understanding more detailed process of the bathymetric change and sediment transport. At the nearshore zone, to monitor the nearshore features such as sand ripple migration, and the sediment suspension processes, optical back-scatter sensors (Downing et al., 1981), rotary sidescan sonar system (Traykovski et al., 1999), and sand ripple profiler (Masselink et al., 2007) were developed and used. Those systems can provide the very high-resolution morphological change and transportation, but not suitable for investigation of large-scale sediment erosion and deposition generated by high-energy waves in the surf zone. Where change in water depth is large (e.g. more than 1 m) in short span, the systems will be destroyed, lost, or submerged.

In the present study, we developed a new instrumentation for the monitoring of bathymetric change and related sediment transport in the high-energy shallow marine environment using optic fiber cables. The system consists mainly of four components: (1) an array of optical sediment sensors (OSSs); (2) a support structure (steel pipes); (3) an electronics unit that transmit and receive the LED through the optic fiber cables; and (4) a digital data acquisition system. The OSSs are mounted in a vertical steel pipe, 2 m long; and the spacing between the sensors is 10 cm. The steel pipe with OSSs was embedded to the seafloor at two places beneath a pier (427 m long) of Hazaki Oceanographical Research Station (HORS) owned by the Port and Airport Research Institute (PARI) at Sudahama Coast facing the Pacific Ocean, Japan. Both the electronics unit and the data acquisition system were installed in an observation room on the pier. In addition, those points of measurement are aligned perpendicular to the coastline in water depth approx. 4-5 m. Since active sediment transport that creates and deforms the longshore bar have been observed in this area (e.g., Kuriyama, 2010), detailed process of change in the cross section will be acquired by the present systems. In this presentation, we will show the system and data, and discuss those availability and future plan.

Acknowledgment: We would like to thank Dr. Satoshi Nakamura and Mr. Masayuki Banno belonging to the PARI for understanding and support of using the HORS, and MIKUNIYA Construction Co., Ltd. for installation work of the pipes. We wish to express our deep gratitude to the above-mentioned individuals and organizations.

Keywords: monitoring system, bathymetric change, sediment transport, optic fiber cable

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New insight of tsunami excitation mechanism and its recordable evidence in deep-sea

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Not yet

Keywords: Japan trench, 2011 Tohoku-Oki earthquake, Tsunami, Earthquake, Sediments, Submersible

Deposition and preservation of fine-grained turbidites around the Japanese islands

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We will report the sedimentological characteristics of fine-grained turbidites occurred around the Japanese islands such as off Sanriku, off Kumano, Suruga Bay, Beppu Bay, Japan Trench and off Hidaka. Some of these are thought to be formed in relation to the slope failures by the earthquake-ground shaking. Sometimes, subaqueous debris flow deposits were observed below the fine-grained turbidites. Agitation of the shelf floor by the tsunami waves is another mechanism to create the fine-grained turbidites. Third mechanism is the hyperpycnal flows related to the flood events. Preservation potential of the fine-grained turbidites will be discussed based on the repeated surveys of surface sediments off Sanriku region after the 2011 Tohoku-oki earthquake and its related tsunami. Based on these observation, we will discuss on the depositional processes of the fine-grained turbidites and preferable setting to preserve them as the geological records.

Keywords: turbidite, earthquake, tsunami, preservation potential, sedimentary structure, depositional process

Comparison between the Tidal Zone Deposits and the Terrace Deposits Emerged in the 1703 and 1923 Kanto Earthquakes

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Recurrent giant earthquakes at the plate boundary along the Sagami Trough have been considered as one of the greatest thread of the Tokyo Metropolitan area. At the southwestern tip of the Miura Peninsula, in south of Tokyo, the tide gauge station records the coseismic uplift amount of 1.4 m and the interseismic subsidence amount of 0.3 m in and after 1923 earthquake, respectively. It is effective to reveal evidences of the past coseismic uplift to know the future earthquake.

Wave-cut benches which emerged in 1923 are widely distributed along the rocky coast. Higher wave-cut benches, good indicators of coseismic uplift prior to 1923, are also recognizable. It is, however, often difficult to spatially compare one another due to the erosion.

We investigated the distribution of the tidal-flat deposits and the 1923 wave-cut benches at two small bays in the southwestern and southern parts of the Peninsula. The aggradation of the coastline associated with the 1923 uplift was identified by the comparison between the 1:25,000 topographic maps before and after the 1923 earthquake. Observations of outcrops and drilling cores at the 1923-formed marine terrace showed that the tidal-flat deposits consist of shelly sand and gravels. The elevation of tidal-flat deposits indicates the coseismic uplift in 1923 and the interseismic subsidence after 1923. The uplift amount was estimated approximately 0.9 m and 2.1 m at the southwestern and southern parts of the Miura Peninsula, respectively. The uplift amount inferred from the tidal-flat deposits is concordant with that inferred by the wave-cut benches.

Keywords: Kanto Earthquake, Paleo-earthquake Record, Terrace Deposits, Tidal-flat Deposits

The paleosols and topography of sedimentary basin relationships in the upper Miocene Clay deposit, central Japan

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The Tokiguchi Porcelain Clay Formation is fluvial deposit distributed in central Japan in middle to late Miocene period. The sedimentary facies analyses were carried out in this formation. Those studies, however, were insufficient to reconstruct fluvial environment, because the fluvial deposit essentially have been bounded by short hiatuses due to sub-aerial erosion and paleo-surface formation. In this study, therefore, we focused on paleosols so as to reconstruct the weathering environment during the hiatuses. In general, paleosol formation in the fluvial sediments also depends on the supply of detritus and drainage conditions. Consequently it is very useful to research paleosol features for reconstruction of the topography in the small sedimentary basin where Tokiguchi Porcelain Clay Formation was deposited.

The clay-dominated sediments, which are interpreted to have been deposited in small sedimentary basin within a radius of 2 kilometers, were examined in two mines, Hishiya and Nakayama mines, across Toki and Tajimi Cities in Gifu Prefecture. The sediments in Hishiya mine shows the deposition in proximal area of the sedimentary basin, whereas those in Nakayama mine displays the facies formed in marginal area of the basin. On the sedimentary facies analysis, 13 facies are recognized in the formation. The sedimentary facies associations indicate the deposition mainly in backswamp environment with minor channel incision. Furthermore the coarse-grained sediments which were deposited as channel-bar and levee deposits intercalating debris flow deposits, with high accumulation rate, were particularly deposited in the marginal area of the basin. In contrast, the fine-grained sediments which were deposited with low accumulation rate in lakes and swamps, were particularly distributed in the proximal area of the basin. For this result, the fluvial system with lakes and swamps was developed near mountain slope side. In the whole are of the basin, approximately 20 paleosol horizons were founded in the lake and swamp deposits within a thickness of approximately 30 meters. In the proximal of the basin, these paleosol horizons range sparser. These paleosol horizons, with various pedogenic features, such as root with approximately 150 centimeters length and trunk traces with approximately 50 centimeters wide, pedogenic concretions, ped structures and microfabric of clay minerals, are formed thickly and developed clearly. In addition to, abundant siderite nodules covered with bright clay are present in lake deposit in the proximal area of the basin.

As a result the characteristics of the sedimentary facies could depend on the sedimentation rate depending on variation of the distance from the rim of the sedimentary basin. Besides the characteristics of the paleosol features could be affected by the drainage conditions due to morphological variation related to the location in the sedimentary basin. The characteristics of the sedimentary facies and paleosol features, however, suggest the large change of water level in the whole sedimentary basin. Concretely the redox condition had shifted from reductive condition in lakes or swamps to oxic condition in bushy grounds. The plausible cause for this change of redox condition in the sedimentary basin could be responsible for water-level change which was frequently occurred by damming of rivers formed from debris flow deposition.

Keywords: paleosols, Miocene, terrestrial environment, Tokiguchi Porcelain Clay Formation, sedimentary facies analysis

Applications of a method to detect varved sediments

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Studies of lacustrine deposits, especially on varved sediments, have further clarified the high-resolution record of paleoenvironments. Varved sediments are very useful for these studies because they are expected to contain annual records of depositional environments. In order to obtain annual records such as annual thickness, color tones, and chemical compositions, at the very least, it is necessary to detect the boundaries of annual bands. In addition, the detection and measurements should be reproducible.

Methods to measure boundaries of varved sediments are divided into two main categories: (1) measurement by visual judgment and (2) measurement by image analyses. The latter method uses photographs of the sediment, soft-X ray images, element maps, and so on. In order to detect boundaries, a threshold value, wavelet analysis, and wave analyses of the gray value of images have been previously used. While the visual judgment method has the disadvantages of human error and criteria, the image analysis method also has limitations as follows: one threshold value cannot be used for all locations in successive images; this method is dependent on the resolution of images, and it is affected by noise in the image-values.

In this study, we used a new method to detect the boundaries of banded deposits using the following procedure: (1) smooth the images, (2) calculate the inclination of "gray-value map" of the images, (3) calculate a mid-value in one wavelength of the "gray-value wave" in the map, and (4) detect a boundary as a point of the maximum inclination around the mid-value. The result obtained using this method shows well-defined "boundary map" of the bounded deposits, similar to the result obtained by visual judgment. Using this method, internal information, such as the transmittance value of soft-X ray in a lamina, can also be digitized like a lamina thickness. Since a time-series of lamina thickness and internal information of the lamina can be calculated based on this method, lamina-by-lamina facies analysis, such as that performed for detection of flood deposits, can be employed in studying varved deposits automatically and quickly.

Keywords: varved sediments, image analysis, time-series, soft-X ray, diatomite

Depositional cycle and flood and slope-failure events in an 8,000-yr varve of Pleistocene Hiruzenbara Formation, Japan

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Paleoenvironmental changes can be reconstructed from varve deposits. The Middle Pleistocene Hiruzenbara Formation, which is distributed in the Hiruzen Highland, Maniwa city, Okayama Prefecture in Japan, is composed of mostly pure lacustrine diatomite that contains finely-laminated varves. From these varves, researchers have found decadal-scale depositional cycles that are thought to correspond to solar activities (Ishihara and Miyata, 1999), and intercalated flood- and slope-failure events have been detected. However, the relationship between the solar cycles and hydrogeological events remains unclear. In the present study, we sampled the finely laminated varves in the Hiruzenbara Formation, and obtained an 8,000-yr time-series of varve-thickness, gray-values for each lamina, variance of the gray-values, and deposits of flood- and slope-failure events using image analysis methods. Wavelet analysis and a fast Fourier transform (FFT) were applied to these time-series data to evaluate event-cyclicities.

In the time-series of varve-thickness, a long-term cyclicity of 1,000 - 2,000 yr was recognized. The upper parts of varves were light-green in color, and these were likely deposited during the winter season. Clear increases in thicknesses of the light-green parts were observed from the lower to upper parts of the analyzed section. Results from frequency analyses using the FFT and wavelet analysis of the time-series of varve-thickness data suggest that periods of 8 to 12 yr, 20 yr, and 30 to 35 yr dominate in this region. These periods were also found by Ishihara and Miyata (1999) and Masuda et al. (2004) in other sections of the formation. The periods in varves of 8 - 12 yr and around 20 yr correspond to solar activity, and a 35-yr periodicity of lake environmental change has been reported previously. In this study, however, these periods were not stable in the analyzed section, which is similar to the results obtained by Ishihara and Miyata (1999) and Masuda et al.(2004) who measured varve-thickness using a microscope.

One hundred-forty seven flood deposits were identified in the 8,000-yr record. Portions of the high-frequency parts and low-frequency parts were repeated in the analyzed section. Mean thickness of the flood beds was around 2 mm. Thirty-three deposits from slope failures were found in the section. These deposits were rare in the upper and lower most parts of the section, but were dominant in the lower part. There was no repetition of domination for the deposits that were observed during the flood events. Mean thickness of the slope-failure deposits was around 5.5 mm.

In the sections where flood deposits dominated, the mean varve-thickness tended to thinner without exception. In the upper part of the analyzed section, which lacked flood event signatures, the mean varve-thickness was generally greater. These trends suggest that climate conditions and the frequency of flood events might have affected the productivity of diatoms (thickness of the lamina). In addition, the periods detected by frequency analyses were not clear in the flood-deposit dominated sections. Results showing that dominations of slope-failure deposits were not related to the varve-thickness and the gray-values suggest that the slope-failure events were influenced by local phenomena related to lake development.

Keywords: Banded diatomite, Varve, Image analysis, flood deposit, slope-failure deposit, Solar activity

Subsidence and a change of depositional environment by the 1662 Hyuganada earthquake in southern Miyazaki Plain

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The Miyazaki Plain, southern Kyushu Island, have been damaged repeatedly by a number of great earthquakes (measured or estimated to be >M7-8) occurred in not only the Nankai trough but also the Hyuganada coastal region. A total of six great earthquakes happened in the Hyuganada coastal region in the range of AD1909 to 1984. Historical documents indicate such great earthquakes had also occurred in AD1662, 1769 and 1899. Furthermore, the great earthquakes in the Nankai trough, such as the 1707 Hoei Nankai earthquake and the 1946 Showa-Nankai earthquake, had also attacked the plain with terrible tsunamis (Usami *et al.*, 2013).

Recently, the Nankai trough has received extensive attention as hypocenter of great earthquake attacking the Miyazaki Plain, because the Central Disaster Management Council (2012) proposed a new source model of the earthquakes including the Hyuganada coastal region. On the other hand, previous geological and seismological studies about past Hyuganada earthquakes are much less than the Nankai trough despite of their high seismic activity indicated by historical documents.

For example, historical documents shows that the 1662 Hyuganada earthquake brought about serious social and natural damages to the plain (Hatori, 1985). Especially, around the estuaries of the Oyodo-gawa River and the Kaeda-gawa River in southern area of the plain, the tsunami with about 4-5 m height and ~1 m subsidence occurred. This coseismic subsidence made a coastal lagoon around the estuarine area of the Kaeda-gawa River (Shimayama region). After buried by riverine debris, this lagoon was reclaimed and became paddy fields (Miyazaki-city, 1978).

The purpose of our study is to clarify depositional changes around the Shimayama region including coseismic geomorphological change. A multiple geological borings were carried out in the study area. Depositional environments were reconstructed inferred from paleontological, geochemical analyses. Depositional ages of core sediments were estimated by radiocarbon ages. The surface geology was divided into four layers mainly (layer A, B, C and D) in ascending order. The layer A was composed of alternate layers of grayish sand and silt with many angular pumices and organic materials. The layer B consisted of alternate layers of gray or grayish brown mud and sand including numerous well-preserved molluscan fossils. The bottom of the layer B, which covered the layer A above ~1.5 m T.P. with 10 to 40 cm thick, was black or dark gray muddy fine sand with bioturbation including rip-up clasts, shell fragments and volcanic rocks with >1 mm diameter. The layer C was composed of gray silt with several thin layers of fine to medium sand and plant fragments. The layer D consisted of silt to fine sand layers and surface cultivated sediments with ~20 cm thick overlying them.

Result of some analyses showed their quantitative differences corresponding to depositional facies. The main diatom components of the lower part of the layer A was fresh water benthic species such as *Cymbella turgidula* and *Gomphonema parvulum*, and the upper was few diatom fossil. On the other hand, the layer B showed abundance of brackish to marine water species such as *Cocconeis scutellum* and *Thalassionema nitzschioides*. In addition, absorbed water analysis of the core sediments showed that K, Ca, Na, Mg and SO₄²⁻ concentration, which are rich in sea water, were few in the layer A but increased drastically at the bottom of the layer B. And grain size and molluscan fossils species were also different between the layer A and B.

These results indicate that depositional environment changed drastically from fresh water marsh or shallow pond to tidal or inner bay. Depositional ages of the layer A, B and C were estimated from radiocarbon ages to be AD1445 to 1595, AD1549 to 1771 and AD1651 to 1771 respectively and suggest that the depositional environment between the layer A and B correlate to crustal deformation by the 1662 Hyuganada earthquake.

Keywords: Hyuganada earthquake, Miyazaki Plain, depositional environment