

Characteristics of tsunami origin sediments sampled from Hirota and Toni bay around the Sanriku coast, Japan.

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The recent 2011 Tohoku tsunami strongly affected the coastal area of the Pacific coast of Tohoku. Tokai University and JAMSTEC team investigated the Tohoku coastal area as a part of Tohoku Ecosystem-Associated Marine Sciences (TEAMS). We got the knowledge of distribution of rubble, bottom sediment environment and tsunami information in the local area.

We researched using acoustic equipments (Multi beam echo sounder, Sub bottom profiler and Side scan sonar), bottom sampler and ROV. And, we have interviewed about situation of damage at the local area.

Characteristics of submarine topography

Toni and Okirai bay have the scattered irregularity bottom surface (Okirai 15-20 m and Toni 17-25 m). This irregularity bottom surface relative height is 20-100 cm at Okirai. Rubble was seen in the coast side from this irregularity bottom surface. And, from SBP data, a record to scraping underlying layer was seen. We were able to estimate that submarine topographic signature (erosion surface) made by undertow at Tsunami event.

Surface sediments

SBP data was seen signature reflecting (20-50cm down from seabed), and able to estimate the reflecting surface to depth of approximately 40 m at Hirota bay. In the Toni and Okirai bay, SBP data was seen signature reflecting (20-100cm down from seabed), and able to estimate the reflecting to depth of approximately 50 m. These reflecting characters have large lateral change in each bay.

Columnar core

Almost each core, first layer (approximately 0-10 cm) of core was seen grading structure (middle to coarse) of sand sediment, but second layer (from 10 cm underlying layer) was different facies from center area to side area of each bay. Especially at the center area of axial, bottom part of second layer (contain woodchip and shell piece) was scraping underlying layer. Thus, we were able to estimate upper zone from second layer was tsunami origin sediment.

The longest 2 m core at Hirota bay was divided into two more parts under the second layer, such as, 3rd layer with fine sand to massive silt sediment zone, and 4th layer (140-200 cm) with middle to coarse sand sediment zone. So, we think that underlying layer sediment (from 130 cm underlying layer) has possibility of palaeo tsunami origin sediment.

Keywords: Tsunami origin sediment, Sanriku coast

Influence of the 2011 Tohoku tsunami to the surface sediments on the Sendai shelf

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Huge tsunami by the 2011 off the Pacific Coast of Tohoku Earthquake inundated coastal areas of the northeastern Japan. Because friction velocity at sea floor by the tsunami wave became larger at shelf, the tsunami might agitate and resuspend the shelf sediments in the Sendai Bay. However, we have only a little knowledge on characteristics of the shallow marine tsunami-related deposit. To understand the tsunami influence on sea-bottom environments, we conducted two surveys to collect the surface sediments of the Sendai shelf in summer 2012. Comparison with the pre-earthquake surface sediment dataset suggested that bottom sediment changes occurred at least several locations on the shelf. Mud deposition was most characteristic change at the northern and southern mid shelf. Resuspension and redeposition of shelf mud might occur on the shelf. Occurrence of muddy turbidite on the outer shelf suggested that a part of resuspended mud might be transported as turbidity currents toward offshore. Generation of the turbidity currents might play an important role on the long-distance transport from shelf to slope. On the other hand, no clear change on bottom sediment grain size and sedimentary structure found on the sandy shelf located central-southern mid shelf. Although the detailed comparison should be necessary, no large and long-distance transport might occur on the sandy mid shelf.

Keywords: tsunami, surface sediment, Sendai Bay, shelf, 2011 Tohoku earthquake tsunami

Origin of submarine event deposits by the 2011 Tohoku earthquake and tsunami: from benthic foraminiferal assemblages

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Tsunami by the 2011 off the Pacific Coast of Tohoku Earthquake brought significant damage along the northeastern Japan coast. We conducted a marine survey cruise (KT-11-17) to clarify the influence of earthquake/tsunami to sea bottom environments, off Sanriku, northeastern Japan, July-August, 2011. As the results, we found the 2011 earthquake- and/or tsunami-induced turbidites at 13 sites from outer shelf to trench slope off Sanriku. At two sites from slope (893 m and 1446 m in water depth), the turbidites have sharp erosional bases, and upward-fining graded structures started from very fine sand-coarse silt.

The surface layer of the turbidite mud at the shallower site (893 m) includes the major foraminiferal species in the outer shelf (*Uvigerinella glabra* and *Elphidium clavatum*). The possibility of inflow from outer shelf to the site by earthquake- and/or tsunami-induced turbidity currents is inferred from the benthic foraminiferal assemblages. The Basal sands of the turbidite at the deeper site (1446 m) include abundant *Takayanagia delicata*; and the turbidite mud include abundant *Stainforthia apertura*. Both species are reported by previous studies on living benthic foraminifera off Sendai as dominant species in water depth 550 m - 900 m. It is suggested that the sediment was transported from several-hundred meters shallower water depth than the site.

Keywords: event deposit, earthquake, tsunami, turbidite, marine sediment, foraminifera

High contribution ratio of tsunami deposits for alluvium in the Masaki coast, northern Japan

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Several tsunami deposits were recognized in the alluvium in the Masaki coast, Iwate prefecture, northern Japan. These tsunami deposits showed a high contribution rate for alluvium.

Keywords: tsunami deposits, alluvium

Magnetic anisotropies for tsunami deposits: Application to the 3.11

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Tsunami deposits consist of well-sorted fine sand intercalating with non-marine black organic mud. It is difficult to reveal a transport direction of the deposit if the deposit showed no sedimentary fabrics, such as ripples. The proxy of anisotropy of magnetic susceptibility (AMS) appears to be a promising tool for the study of flow fabrics in recent-tsunami deposits such as Sumatra tsunami (Wassmer et al. 2010). The AMS fabric might allow us to reconstruct transport directions of unconsolidated tsunami sediments during emplacement because AMS provides a cryptic alignment of ferromagnetic and paramagnetic minerals. Such cryptic minerals, such as magnetite or phyllosilicate minerals, would behave as a different emplacement mode in a different hydrodynamic condition. In the AMS fabrics of volcanic rocks, there are large discrepancies between the magnetic lineation and the framework-forming silicate linear fabric. This suggests that the uncorroborated use of bulk AMS to detect flow fabric in tsunami deposits has risks. In this article, we show that the anisotropy of anhysteretic remanent magnetization (AARM) may resolve the difficulties. The combination of inundation eye-witness, SEM, AMS, and AARM confirms the flow pattern of recent- and paleo-tsunami deposits from the geoslicer sampling at Rikuzen-Takata city, Japan during 2011, 11th March Tohoku tsunami. We determined if the sandy deposits are of tsunami from these magnetic anisotropies.

Keywords: tsunami deposits, paleomagnetism, anisotropy of magnetic susceptibility, anisotropy of anhysteretic remanent magnetization

Sedimentary features of the 2011 Tohoku-Oki tsunami on coastal lowland behind a lagoon in Matsukawaura, Fukushima

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In this paper we describe the sedimentary characteristics of the 2011 Tohoku ? Oki tsunami deposit in Matsukawaura, Fukushima Prefecture, Japan. Matsukawaura is paddy field lowland with a 1.5 km wide of semi-enclosed lagoon. This study area provides opportunity to examine the effects of lagoon for tsunami deposition on the coastal lowland behind a lagoon. Total of eleven sites along a transect were examined and sampled for thickness, and sedimentary analysis (grain size, mineralogy and foraminifera analysis). Thickness of the deposits is ranging from 8 to 26 cm and showing a fining landward trend. The deposits are mainly composed of well sorted to poorly sorted of coarse to very fine sand which covered by mud layer. Medium to fine sand dominated the deposits and is nearly similar with lagoon grain size. The foraminiferal assemblages in the tsunami deposit dominated by lagoonal ? intertidal species (*Elphidium Matsukawauraense*, *Ammonia tepida*, and *Rotalia beccarri*). The mineral composition of the tsunami and lagoon deposits was almost similar, with only the percentage of each mineral differing between types of deposits. Based on the sedimentary structure, settling out of sediment from suspension was the dominant process of deposition. Our observations and analyses suggest that lagoon was the main source of the deposits. Our results indicating that the depositional characteristics of the 2011 Tohoku-Oki tsunami appeared to have been affected mainly by local effect. The findings of our study are of considerable importance in interpreting paleotsunamis in coastal lowland behind lagoon.

Keywords: the 2011 Tohoku-Oki tsunami deposit, Matsukawaura, Lagoon, Grain size, Mineralogy, Foraminifera

Measurement of precise grain size and morphological characteristics of tsunami sand particles

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Morphological characteristics such as circularity, convexity, aspect ratio, intensity, particle size of the 2011 Tohoku-oki tsunami deposits are measured by a grain image analyzer (Morphologi G3S, Malvern). The tsunami deposits, beach sand, coastal dune sand, and basal layer (aeolian sand) beneath the tsunami deposit were collected from Misawa coast, northern Tohoku just after the tsunami inundation. We could analyze the particle size with 1/32-phi-precision by using the machine and it shows that the tsunami deposit is slightly but significantly finer than the coastal dune sand. It was also confirmed that the basal layers contain a significant amount of silt and clay fractions, whereas the tsunami deposit is poor in mud contents (<1%). Circularity and aspect ratio of the tsunami sand particles are similar to those of the coastal dune sand, but dissimilar to those of basal layers. Precise measurement of particle characteristics of sandy and muddy tsunami sediments will be useful not only to identify the possible source of tsunami sediment but also to identify thin sandy layers or sandy patches of paleo-tsunami origin in soil.

Keywords: Tsunami deposit, Precise grain size analysis, Morphological characteristics, Morphologi G3S, 2011 Tohoku-oki tsunami deposits

Paleo-tsunami records in Tonankai area and future issues of paleoseismological studies along the Nankai Trough

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It became widely understood after the 2011 Tohoku Earthquake that geological records of thousands of years are needed to know possible largest magnitude of earthquakes and tsunamis in a region. Though the Nankai Trough has been the focus of many paleoseismological studies, it becomes more important to understand diversity of earthquake magnitude and recurrence intervals within longer time scales.

To reveal tsunami history of thousands of years, we conducted hand coring and drilling survey at 27 study points. These coring exposed at least 9 paleo-tsunami layers in the sedimentary succession deposited between 4500 yrBP and 500 yrBP. All of the paleo-tsunami layers contain bioclasts of marine and brackish water organisms such as gastropod, bivalve, calcareous algae and foraminifera. In most cases, these layers are few centimeters thick and have sharp basal contacts. Soft x-ray imaging shows that some of the sand layers includes rip-up clasts and are composed of two or more sub-layers of paired sand and silt. Radiocarbon ages of selected materials indicate that the younger three layers were deposited by the historical tsunamis in AD 684, 1096 and 1498 respectively. These layers were deposited by past tsunamis which provably occurred in the Tonankai and/or Tokai areas. Historical documents tell that the 1854 Ansei Tokai Earthquake Tsunami inundated the study site and left sands on ground surface. On the other hand, wave heights of the AD 1946 Showa-Nankai earthquake tsunami occurred in the Nankai area and the AD 1960 Chilean tsunami were 1.0 m and 1.5 m respectively, and lower than the barrier spit that separates the study site from the sea.

There is no historical documents of the AD 684 earthquake tsunami in Tonankai area, but our result supports archaeological studies, which suggest that the rupture of the earthquake extended to the Tonankai area. We do not see traces of the AD 887 and 1361 earthquake tsunamis that are thought to have occurred in the Nankai area.

Interregional correlations of geological records based on detailed dating results will become increasingly important to know the lateral extent of past rupture zones. In addition, examinations of uplift/subsidence occurred simultaneously with tsunami sand deposition by paleontological and geochemical analysis will provide more precise information about diversity of vertical crustal deformation along the Nankai Trough.

Keywords: tsunami deposit, Nankai Trough, Tonankai area

Estimation and sensitivity of fault parameters from distribution of tsunami deposit

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Comparisons of distribution of tsunami deposit with computed tsunami inundation is a useful method to estimate fault parameters. Sawai et al. (2012, GRL) assumed 14 different fault models of the AD 869 Jogan earthquake, and compared the computed tsunami inundation areas with distribution of tsunami deposit in Ishinomaki and Sendai plains, and Odaka lowland. The 14 fault models include outer-rise normal-fault earthquake associated with the 1933 Showa Sanriku earthquake, tsunami earthquake on shallow plate interface near the Japan trench such as the 1896 Meiji Sanriku earthquake, active-fault earthquake in Sendai bay, and interplate earthquakes with various fault depths, widths, lengths, and slip amounts. They showed that an interplate earthquake of 200 km long and 100 km wide with 7 m slip can produce tsunami inundation to cover the distribution of the tsunami deposit.

Nanayama et al. (2003, Nature) surveyed tsunami deposit along the Pacific coast of Hokkaido, and concluded that unusual tsunamis occurred along the Kuril trench with an average interval of about 500 years. The most recent tsunami is dated in the 17th century. Satake et al. (2008, EPS) assumed the fault models including "Giant fault model" with depth range of 0 km to 85 km, tsunami earthquake, and interplate earthquakes. They showed that an interplate earthquake of 300 km long and 100 km wide, and slip of 5 m and 10 m in the north and the south, respectively (Mw8.5), can produce tsunami inundation to cover the distribution of the tsunami deposit.

Sensitivity analyses of computed tsunami inundation to fault lengths and slip amounts are also helpful to estimate these fault parameters. We examined the sensitivity to fault lengths and slip amounts of the AD 869 Jogan earthquake. We assumed various interplate fault models with four different lengths (100, 200, 300, 400 km), three uniform slip amounts (6, 9, 12 m), and two top depths (15, 31 km). Fault width is fixed at 100 km (Uniform Slip Models). We also assumed variable slip models using slip distribution of the 2011 Tohoku earthquake (Satake et al., 2013, BSSA) (Variable Slip Models). Tsunami inundation distances were computed on the 869 topography in Ishinomaki and Sendai plains in Miyagi prefecture (Sawai et al., 2012, GRL) and Odaka (Sawai et al., 2012, GRL) and Ukedo (Imaizumi et al., 2010, internal report) in Fukushima prefecture, and compared with maximum transportation distances of sandy tsunami deposit on 10 transects.

As a result of Uniform Slip Models, the fault model of the 869 earthquake requires the fault length of at least 200 km and the slip amount of at least 9 m to completely inundate up to the tsunami deposit on the 10 transects. For Variable Slip Models, we found that fault length of more than 200 km is also needed. However, when fault length exceeds 200 km with slip amounts of more than 9 m in Uniform Slip Models, or when fault length exceeds 200 km in Variable Slip Models, the computed inundation distance increases very little. This indicates the following two points. One is that we cannot judge whether the fault length is 200 km or more, and field studies of tsunami deposit are necessary on the northern part or the southern part. The other is that inundation distance does not simply increase with fault parameter but saturates due to topography. The computed tsunami inundation areas show that the margin between the calculated inundation limit and upland, which is defined as altitude more than 10 m (T.P.), is small and it is difficult for tsunami to inundate for a longer distance except for two transects in Sendai plain.

Geological studies after the 2011 Tohoku earthquake (e.g. Goto et al., 2011, Marine Geology; Abe et al., 2012; Sedimentary Geology; Sawai et al., 2012, GRL) reported that the tsunami inundated more extensive than the tsunami deposit. However, it is difficult to apply a simple relationship to estimate the accurate magnitude of the 869 earthquake, because of the saturation problem.

Keywords: tsunami deposit, fault model, the AD 869 Jogan earthquake, tsunami computation, inundation distance

Paleotsunami investigations in the Primorye region, Russia, for assessing tsunami hazards around the Sea of Japan

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Information from tsunami deposits is most important for assessing tsunami and earthquake hazards in areas where recurrence interval and size distribution of historical and pre-historical tsunamis are not known or poorly recorded. Northern coast of the Sea of Japan is one of these areas. Recent earthquakes such as the 1983 Nihonkai-chubu Earthquake and the 1993 Hokkaido Nansei-oki Earthquake provided severe damage along the coastal communities, where we have no knowledge about the past events. The 1983 and 1993 tsunami inundated not only in the Japanese coast but also in the Primorye region, Russia, along the other side of the Sea of Japan and caused some damage there. We carried out reconnaissance along the Primorye coast to find the historical and pre-historical tsunami evidences, as there are many natural lowlands facing sandy beach that are suitable for tsunami deposit reservation. The surveys were done in summer of 2010, 2011 and 2012 as a joint research project with Hokkaido University and the Russian Academy of Science. As a result, we could find candidate tsunami deposits in some sites. The deposits are continuous sandy layers buried in the peat. Some of them are probably correlated to be 1940, 1983 or 1993 tsunami. Tsunami heights of them are recorded to be more than 4 m. We also found possible pre-historical tsunami deposits beneath the B-Tm tephra (ca. 1000 AD) at Kit Bay.

Keywords: tsunami, paleo-tsunami, tsunami deposit, Sea of Japan, Primorye

Late Holocene record of tsunami events from coastal wetlands, Okushiri Island, off southwestern Hokkaido

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The 1993 off the southwest coast of Hokkaido Earthquake provided a cause of the tsunami that damaged on the Coast of Okushiri Island. Many offshore active faults are distributed along the eastern margin of the Japan Sea and some of them triggered large earthquakes. In the historical record at Hokkaido, the oldest tsunami hazard around the west coast of Hokkaido was induced by the volcanic avalanche of Oshima-Oshima in 1741AD. Hitherto known events in the sedimentary records are resulting from the investigation of submarine turbidite (Ikehara, 2000) and tsunami deposits on Holocene marine terrace (Kawakami et al., 2012; Hirakawa et al., 2012). The shallow CCD in the Japan Sea and slow sedimentation rate of terrace deposition have been complicated correct estimation the event occurrence age. We investigated event deposits formed by tsunami to reveal occurrence age, in coastal lowlands in the Okushiri Island.

Surface deposits were extracted at two coastal lowlands (Hatsumatsumae and Wasabiyachi-gawa) located behind the dunes over 10 m high in the south coast of Okushiri Island. The sediment of the lowland consists of peat and peat mud. Several sand beds are intercalated in the normal peaty sediment. There are three event layers in Hatsumatsumae lowland and five layers in Wasabiyachi-gawa lowland. The event layers indicate some typical features of formed by tsunami running over a coastal sand dune (Takashimizu, 2012). The features are decreasing bed thickness toward inland, massive or faint parallel lamina, erosional contact at the base and including rip-up clast. Therefore, we interpreted the event sand bed as tsunamiite. The ages estimated from ¹⁴C, of five events occurred are 11-13 centuries, 6-7 centuries, about 2,300 cal yBP, 2,600 or 2,700 cal yBP and 3,100 to 3,300 cal yBP, respectively. These tsunami events corresponded to the events deposits in the event on the Holocene marine terrace. The past tsunami events that we found occurred every about 300 through 1000 years. The calculated mean interval is approximately 650 years.

The event ages from the sedimentary record in the isolated island inside of the tectonic belt of the eastern margin of the Japan sea are important for correlations of another tsunami events in the nearby earthquake source area.

Keywords: tsunami deposit, eastern margin of Japan sea, coastal lowland, correlation

Geological study on tsunami deposits in the Pacific coast of Aomori, northern Japan

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We studied paleotsunami deposits in the Pacific coast of Aomori Prefecture. The study area is facing to northern edge of the Japan Trench, where the 2011 Tohoku earthquake raised concerns about future large earthquake (Simons et al., 2011). However, there are few historical and geological records to evaluate long-term earthquake history around north of the Japan Trench. We found unusual sand sheets interbedded with fluvial mud and peat, beneath coastal lowlands in Higashidori, Rokkasho and Misawa. Some sand sheets contain brackish-marine as well as freshwater diatoms, such as Fragilariaceae spp. (e.g. *Staurosira* spp. and *Staurosirella* spp.). The diatom assemblages of sand sheets indicate that they were transported from seashore.

In Higashidori site, five sand sheets were found between 1.5 and 3.5 m in elevation. Three of them are 3-10 cm thick, quartz-rich and wide-spread. They show normal grading and sharp contacts with underling peat. ¹⁴C date of plant microfossils just above and below the sand sheets show that they deposited after 1500 AD, ca. 4,500 cal BP, ca. 5,000, ca. 5,300 cal BP and ca. 5,800 cal BP.

Keywords: tsunami deposit, diatom, Aomori, Japan Trench, Kuril Trench

Coastal paleo-environment changes and tsunami deposits from Kanto earthquakes in Ena bay, during the past 4000 years

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Interplate earthquakes and subsequent tsunamis often leave geological evidence such as tsunami deposits in coastal regions, therefore studies of coastal paleo-environment changes and tsunami deposits from paleo-earthquake by microfossil analysis are important for long-term earthquake forecast because these data provide information on earthquake occurrence time and environmental changes during co-seismic and inter-seismic periods.

The average recurrence interval of the great interplate earthquakes along the Sagami Trough, Taisho-type Kanto earthquake, is estimated to be 200-400 years. However, earthquake histories prior to the 1703 Genroku Kanto earthquake have not been revealed from historical literature although some candidates were proposed. Miura Peninsula has been uplifted during the previous Kanto earthquakes and attacked by the tsunamis (Hatori et al., 1973). Shimazaki et al. (2011) conducted Geo-slicer surveys in Koajiro Bay of Miura Peninsula and suggested that the 1293 earthquake causing destructive damage in and around Kamakura was the Kanto earthquake prior to the 1703 Genroku earthquake. On the other hand, Kaneko (2012) reported the possibility that the tsunami accompanied by the Kanto earthquake in 1495AD might strike Ito on the east coast of Izu Peninsula from archeological and historical records. However, geological evidences and historical records of Kanto earthquake are still not enough to reveal the recurrence interval. Also, there are hardly natural coastal wetlands that would preserve tsunami deposits, because the natural environments were collapsed by revetments in Kanto.

The object of this study is to reveal the histories of Kanto earthquakes through identification of tsunami deposits and a reconstruction of paleo-sea depth changes using diatom, grain size and C/N analysis in Ena bay. Ena bay is a small bay on the south coast of Miura Peninsula and salt marsh is formed innermost of the bay. In May and November, 2009, and February, 2011, we conducted 3 m length handy Geo-slicer surveys at Ena bay. We have basically analyzed 5 cores (ENA-C, ENA-E, ENA-F, ENA-I and ENA-2a) and some modern surface sediment samples collected in the bay.

As a result, three (in ENA-C), four (in ENA-E and ENA-I), five (in ENA-F) or six (in ENA-2a) coarse layers including shell fragments and gravels are recognized. Each of these event deposits have sharp lower contact indicating that they accompanied with a strong current. Rarity and poor preservation of diatoms are recognized from these event deposits, indicating long-distance transport by a high-energy flow. On the other hand, changes in diatom assemblage show an increase or a decrease of relative abundance of marine species, suggesting a paleo-sea depth changes. Namely, marine benthic species gradually decrease prior to the deposition of tsunami deposits indicating coastal subsidence, and benthic species increase above tsunami deposits indicating coastal uplift. It is revealed that Miura Peninsula uplifted about 1.4 m at the time of the 1923 Kanto earthquake and now subsides with a rate of about 3.7 mm/year from tide gauge record at Aburatsubo. The diatom analysis suggests that environmental changes corresponding to these co-seismic and inter-seismic crustal movements. Based on the sedimentological features and environmental changes, we conclude that the event deposits, named as T1, T2, T3, T4, T5 and T6 unit from the top to the bottom, are transported by tsunami from the previous Kanto earthquakes. The T1 unit is the tsunami deposit from the 1923 Taisho Kanto earthquake based on Pb-210 dating. Radiocarbon ages indicate that the T2, T3, T4, T5 and T6 unit deposited about 2000, 3000, 3300, 3700, and 4000 cal. BP, respectively. These dates are consistent with records of previous Kanto earthquakes inferred from marine terraces in Boso Peninsula (Shishikura, 2003). In addition, it is revealed that geological records during 1000-2000 cal. BP are hardly remained in Ena bay.

Keywords: Kanto earthquake, Tsunami deposit, Diatom analysis, Paleosea depth, Ena bay

Tsunami deposit survey at Zaimokuza, Kamakura City, Japan (a progress report)

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The Kanagawa Prefectural Government has been conducting its first Tsunami deposit survey on the shore of its territory since 2011. Here we will give an interim report on our research at Kamakura, where has been attacked by several tsunamis as known from historical literatures.

The survey was held in Zaimokuza area, which is known as a port developed behind the beach ridge in the Middle age. We excavated ten boreholes in four localities in the area. The depths are 5-6 meters. The general stratigraphy obtained from the investigation is summarized as follows in ascending order.

The lowermost stratum obtained in our investigation is silty fine sand (Unit A). This layer is highly water-bearing, bluish gray colored and massive sand containing molluscas that represent sublittoral environment such as *Macoma* sector, *Veremolpa* micra or *Rhinoclavis kochi*. The facies and the Mollusca assemblage implies this layer is formed in more closed bay than the present bay.

Unit A is overlain by a series of sediments that include river gravels, sand, and silty sand (Unit B). The gravels are rounded but not flat and composed of mudstone and kawarake or ancient earthenware. The mudstone was widely quarried around edge of the ancient Kamakura to spread the habitable area to hillside and fill the low ground. This series of deposit is interpreted as deposit of a wetland, which is documented and mapped in ancient literatures. The uppermost layer is landfill formed in the modern age, approximately 1910s.

The deposit of historical wetland created in the calm environment was expected as the host of event deposits that include tsunami deposit; however, we recognized it is highly affected by current of river. This means that the area is not ideal for tsunami deposit research. However we are still due to evaluate each layer, since deposit processes of some layers are not certain. We will also give some data in the session to deepen discussions on geology of this area.

Keywords: Kamakura, Zaimokuza, topographic development, Tsunami, wetland

Preliminary study for evidence of tsunami deposits from Holocene sediments in the southern of the Izu Peninsula

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This study conducted stratigraphic and paleoenvironmental research on Holocene deposits based on a new outcrop and sediment cores in the lowland of the southern of the Izu Peninsula, central Japan, examining the evidence for tsunamis during the past few thousand years. Until now, we did not identified any evidences for mega-tsunamis.

Keywords: tsunami deposits, Holocene, southern of the Izu Peninsula

Tsunami deposits from Shimizu Plain, Shizuoka Prefecture

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This study reconstructed the Holocene sedimentary environment and researched the distribution of possible tsunami deposits in Shimizu Plain, Shizuoka Prefecture from 11 sediment cores.

Based on the sediment and molluscan fossil records, the Holocene sediments are divided into four facies: lower sand (LS), middle mud (MM), upper sand (US) and uppermost sand (UMS) layers. Except for UMS, these sand and mud layers are interpreted as delta front and prodelta deposits in bay, respectively. UMS is interpreted as fluvial and dune sediments.

Transition from LS to MM occurred at 9500-8600 yr BP which corresponds to period of eustatic sea-level rise with 10-20 m. While transition from MM to US or UMS occurred after 4000 yr BP which Elevation and 14C dating of the upper limit of the marine deposits show that the total coseismic uplift has exceeded 20 m total interseismic subsidence during the last 8800 years.

Based on elevation and 14C age of marine deposits, coseismic uplift of AD 1854 Ansei-Tokai earthquake is estimated to be at least 1.5 m. This value confirms the coseismic uplift value in historical document.

Six event deposits were identified in sediments after 6000 yr BP when sea level reached and maintained its present elevation. These deposition ages are estimated to be about 200, 550, 1300, 3400, 4300 and 5600 yr BP. The youngest event deposit seems to be flood deposit. It is likely that the event deposit at 550 yr BP was caused by tsunami associated with AD 1498 Meio earthquake. The event deposit at 1300 yr BP may be formed by tsunami of either AD 684 Hakuho or AD 887 Ninna earthquakes. There is possibility that event deposit at 3400 yr BP correlates with any tsunami deposits reported from Shimizu Plain (3500 yr BP), in Lake Hamana (3300 yr BP) and coastal plain around the lake (3400 yr BP). Since the event deposits at 4300 and 5600 yr BP contain rip-up clasts, they are probable tsunami deposits.

Keywords: Shimizu Plain, tsunami deposits, Holocene, sedimentary environment

Tsunami deposits at the Iwafune lagoon and the Kamo lake, Niigata Prefecture

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Tsunami damage has occurred in the past, in the Sea of Japan, it is necessary to understand the history of the tsunami. We studied tsunami deposits in the Iwafune lagoon of Murakami city, and the Kamo lake of Sado city, Niigata Prefecture. The Kamo lake is a lagoon that is separated by sandbank about 2 ~ 3m elevation. The Iwafune lagoon developed behind the coastal dunes. We made the core drilling at three sites each of the Iwafune lagoon and Kamo lake. We certified sediment facies observed events, and a grain size analysis. Results of core observation, and brackish waters since about 9000 years ago, the sedimentary environment of Kamo lake, coastal sandbar was established about 7000 years ago. In Iwafune lagoon, the depositional environment of the bay has been continued until about 3000 years ago. Sand layer that extends to the inner bay environment of both regions, it may be caused by event deposits such as the tsunami event. Grain size, From consideration of the facies-change and grain size etc., these deposits are brought by the tsunami. The depositional age of 5 to 8 events in the lagoon sediment of the Iwafune and Kamo lake are matched. Certification of tsunami deposits, it is necessary to consider in more detail. Event deposits in the Iwafune lagoon and Kamo shows the history of the tsunami that occurred in northern waters in the Sea of Japan about 9000 years.

Keywords: tsunami deposits, Japan sea, Niigata, Kamo lake, Iwafune lagoon

The distribution of benthonic foraminifera in paleo-tsunamis sediments on Ishigaki islands

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In the last 250 years, the Ryukyu subduction zone had no known thrust earthquakes with $M_w > 8.0$. Because of the lack of large thrust earthquakes, a common idea that the Ryukyu trench is unlocked was commonly accepted. However, a large tsunami struck Ishigaki and Miyako islands with the wave height of up to 30-35 m in 1771. The source of this earthquake was suggested to be a tsunami earthquake with $M_w=8.0$ that occurred near the trench axis (Nakamura, 2009). In addition, slow-slip events at depths of 30km (Heki and Kataoka, 2009) and very-low frequency earthquakes at shallow depths near the trench axis (Ando et al., 2012) have been identified in the western Ryukyu trench. These findings suggest that the Ryukyu subduction zone should be locked and has the potential to generate large thrust earthquakes.

In order to estimate the size and recurrence intervals of paleotsunamis along the western Ryukyu trench, the excavation surveys of the deposits at 6 sites in Ishigaki Island was undertaken on November 2011, October 2012 and February 2013. The excavated sites are located on the lower Holocene marine terraces and implemented using a geoslicer or backhoes. According to the results of stratigraphy and C14 dating data, two tsunami events (1771 and one between 8 C. and 11C.) in this island were identified. Furthermore, comparing with shallow beach sand, the deep ocean benthonic foraminifera were found in the tsunami deposits and the value of deep/shallow species ratio were much higher than the sediments without tsunami events. Based on these results, through the analysis of benthonic foraminifera in the deposits could gain information on sediment source and depositional style. In addition, it also could provide more reliable evidence for the tsunami identification.

Keywords: tsunami deposits, benthonic foraminifera, Ryukyu trench, 1771

Characteristic of surface sediment left by 2011 Tohoku earthquake, case study of Hirota bay

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The recent 2011 Tohoku tsunami strongly affected the coastal area of the Pacific coast of Tohoku. The result of onshore features for tsunami impact is well-reported, but offshore is only a few researches.

In this presentation, we will show about distribution of tsunami deposit left by 2011 Tohoku earthquake at Hirota bay. We researched about tsunami origin sediment using acoustic equipments (Multi beam echo sounder, Sub bottom profiler and Side scan sonar), bottom sampler and ROV.

Hirota bay have a few fairways at coast side that from between submerged breakwater to valley by submarine topography data. East side of this bay (around Kesen-river) have strong reflected intensity depending on SSS image, and lead up to offshore (depth approximately 17m) from river side. Distribution of surface sediment is mainly sand, gravel where locally-distributed near the river side by grain size analysis, and a few sediments with woodchip, shell piece etc.

SBP data confirmed surface sediment characterized by inside reflecting at the valley axis of bay, and clearly different from lower sediment layer.

Sand to silt sediments layer with grading (fine to medium) structure observed at the top of the columnar core (0-40 cm) sample. The lower part of this layer consists gravel and shell fragments, and has contact the unconformable relations with the lower sediment layer. Underlying layer is massive sediment with fine sand to clay (40-70 cm) materials. We assume that denudation is boundary of previous or after tsunami sediment and upper layer is tsunami origin sediment. This boundary has continuity reflecting surface by SBP data and confirm distribution of this reflecting surface and thickness. We were able to estimate tsunami origin sediment distributed with thickness approximately 20-50cm, and high thickness was distributed to the fairway.

Keywords: Tsunami origin sediment, Sanriku coast

Characteristic of submarine topography and sediment left by 2011 Tohoku earthquake, case study of Okirai and Toni bay

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The recent 2011 Tohoku tsunami strongly affected the coastal area of the Pacific coast of Tohoku. The result of onshore features for tsunami impact is well researched, but offshore is only a few researches.

In this presentation, we will show about characteristic of submarine topography and tsunami origin sediment left by 2011 Tohoku earthquake at Okirai and Toni bay. We researched about tsunami origin sediment using acoustic equipments (Multi beam echo sounder, Sub bottom profiler and Side scan sonar), bottom sampler and ROV.

We got the submarine topography data at Okirai (water depth: 2-105 m) and Toni bay (2-112 m). Both bay have valley in valley (Okirai 75 to 90 m and Toni 70 to 90 m) and scattered irregularity bottom surface (Okirai 15-20 m and Toni 17-25 m). This irregularity bottom surface height is about 20-100 cm at Okirai. In SBP survey, this signature topography has a feature of non-bedding with strong reflector surface.

Characteristic of columnar core have thin lamina layer (0-16 cm) with woodchip, grading structure (fine to coarse) of sand sediment with shell piece (16-65 cm) have observed. Underlying layer of sand sediment is reddish brown clay and it has erosion structure between sand sediment (16-65 cm) and this layer. It was guessed that erosion structure was made by turbidity current by tsunami activity. This erosion boundary has continuous reflecting surface by SBP data, and confirm distribution of this reflecting surface and thickness. We were able to estimate the reflecting surface to depth of approximately 40 m. And, it was estimated that tsunami origin sediment was distributed with thickness around 20-100cm.

Keywords: Tsunami origin sediment, Sanriku coast

Characteristics of tsunami origin sediments sampled from Hirota and Toni bay around the Sanriku coast, Japan.

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The recent 2011 Tohoku tsunami strongly affected the coastal area of the Pacific coast of Tohoku. Tokai University with JAMSTEC investigated the Tohoku coastal area as a part of Tohoku Ecosystem-Associated Marine Sciences (TEAMS). We got the columnar core samples for give an account of bottom sediment environment and got the character of tsunami origin sediment.

Hirota bay is typical rias coast characterized by narrowing of bay size from bay entrance (6 km) to closed-off section of bay (3 km) and axial angle is northwest to southeast. Toni bay size is comparatively small (east to west angle 6 km and bay entrance 4 km).

The high-resolution sub-bottom profiling shows wide variety of sedimentary facies layer by each bay. These layers are distinguished clearly from basement (underlying) layers.

We got the columnar core using vibration bottom sampler at Hirota (6 station, max length approximately 2 m) and Toni bay (6 station, max length approximately 1 m).

By the result of Hirota columnar core sample, it was seen grading (fine to medium) sand sediment contain the woodchip and shell piece at the surface zone (0-10 cm). Underlying layer (10-50 cm) was seen coarse to medium grained sediment with woodchip and shell piece, and lower part of this layer eroded out the underlying silt layer. We supposed the surface-grading layer with medium to fine sand (0-50 cm) was tsunami origin sediment. The longest (2 m) core was seen coarse to gravel sediment contain woodchip and shell piece (0-20 cm), and it was scraping underlying massive silt to fine sand layer. From 130 cm underlying layer was seen middle to coarse sand sediment again. So, we think that underlying layer sediment (from 130 cm underlying layer) of 2m core has possibility of past tsunami origin sediment.

Characteristic of columnar core at Toni have lamina with woodchip (0-16 cm), grading (fine to coarse) sand sediment with shell piece (16-65 cm). Sand sediment of underlying layer is reddish brown clay, and has erosion between sand sediment (16-65 cm) and this layer.

We were able to estimate that the surface layer with grading structure (fine sand at the surface and coarse sand with gravel from lower part) of columnar core was the sediment gravity flow caused by the tsunami activity.

Keywords: Sanriku Coast, tsunami origin sediment

Numerical investigation of the relationship between tsunami hydrodynamic features and the distribution of the deposits

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Considering about the magnitude, inundation and damaged area of the paleo-tsunamis is important for evaluating the risks of the low-frequency large-scale earthquakes and tsunamis that might occur in the future (Imamura and Goto, 2007). Sandy tsunami deposits extended to inland is used as evidence of minimum inundation limit of the paleo-tsunami (e.g. Sugawara et al., 2010; Satake et al., 2008) to estimate the earthquake magnitude and focal mechanism of the paleo-tsunami wave source. However, the source model of the 2011 Tohoku-oki tsunami showed unusual fault parameters (i.e. 50 m slip around the trench axis (Geospatial Information Authority of Japan, 2011)) in comparison with the AD869 Jogan tsunami source model. This suggests that if we use the landward extent of the sandy deposits as the minimum extent of the inundation distance of the 2011 Tohoku-oki tsunami, the results may underestimate the actual (observed) inundation distance (Hashimoto et al., 2013). Reconsidering the estimation accuracy such as the tsunami wave source model using tsunami deposits distribution is critically important for future tsunami risk evaluation.

Takashimizu et al. (2012) said that it is important to confirm the relationship between tsunami flow depth and the thickness of the tsunami deposits, so that they investigated the 2011 Tohoku-oki tsunami deposits distribution and flow depth to study relationship of them. Hashimoto et al. (2013) studied the relationship between the distribution of the tsunami deposits, and calculated tsunami hydrodynamic features (maximum flow depth and velocity). However, maximum flow depth and velocity are not necessarily the sole parameters to explain the sedimentation process of the tsunami deposits.

In this study, we reconsider the relationship between the distribution of the tsunami deposits at Sendai Plain and hydrodynamic features such as flux, integral value of the velocity or Froude number.

Keywords: Tohoku-oki tsunami, Tsunami deposit, Sendai Plain, Numerical simulation

Numerical simulation of tsunami deposition by the 2011 Tohoku-oki earthquake in Sendai Plain

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Geological research on paleotsunami events is essential for reliable evaluation of risks from infrequent large-scale earthquake. Numerical simulation of tsunami sediment transport will give aid for quantification of the inundation area, hydraulic character and wave source of the past tsunamis. A lot of numerical studies have been carried out during the last decades, taking modern examples into account, such as the 2004 Indian Ocean tsunami. The 2011 off the Pacific coast of Tohoku (Tohoku-oki) earthquake may offer a valuable opportunity to enhance the utility of tsunami deposits and its numerical simulations, on the basis of abundant datasets such as densely-measured tsunami trace heights, high-resolution digital elevation model (DEM) and tsunami records from tide observations.

Numbers of previous studies have reported sedimentological feature of the 2011 Tohoku-oki tsunami deposits in the Sendai Plain (e.g. [1]). The tsunami deposited sandy to muddy sediments up to 30 cm in thickness, and distributed them up to several kilometers inland. It is notable that the maximum inland extent of the sandy tsunami deposit reached only 60-70% of the inundation distance, and the thickness of the sand layer showed significant variations across shore-normal transects [1][2]. Quite minor contribution from sea-bottom sediments to the onshore tsunami deposit have been confirmed through the grain-size, microfossil and geochemical analyses [3][4], implying that most of the onshore tsunami deposits are originated from the shallow sea closed to the coast, beach and inland areas. It is highly likely that the flow condition and also sediment transport would have been affected by natural and anthropogenic topography, such as dikes installed on the top of sand dunes, roadways on elevated mounds. Numerical simulation of the tsunami sediment transport in the Sendai Plain should incorporate the effects from such kinds of topographic features.

A numerical analysis on sedimentation by the Tohoku-oki tsunami is performed in the present study. The tsunami source is based on the fault model proposed by Sugino et al. [5], which reasonably reproduce the terrestrial geodetic data and tsunami records from offshore and nearshore tide stations. The tsunami propagation is calculated using a numerical code based on the shallow-water theory (TUNAMI-N2; [6]), and the tsunami sediment transport model by Takahashi et al. [7] is coupled with it. A high-resolution DEM (dx = 5 m) and land use map with same resolution are used to incorporate the effects from complex topographic features and land covers.

The preliminary result showed that entrainment of sediments from the beach and massive erosion around the engineering structures mainly accounts for the origin of sand layer deposited inland. Shore-normal distributions of the calculated thickness of sediments reasonably agree with the distribution trend and local variation of the tsunami deposits observed in the field. There are many issues to be resolved for direct comparison of numerical result and field data. In this presentation, applicability and limitation of the current tsunami sediment transport model is examined, and desirable strategy for data correction in the field will be discussed.

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Keywords: tsunami deposit, numerical simulation, sediment transport, The 2011 Tohoku-oki earthquake tsunami

Thickness and grain size fluctuation of the 2011 Tohoku-oki tsunami deposit in Sendai and Joban coasts, Japan

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In general, tsunami deposits thin and fine landward, although local microscopic topographic features give strong effects to the distribution trend of the deposits. For instance, post-tsunami field surveys after the 2011 Tohoku-oki event revealed that the thickness and grain-size varies significantly because of the small-scale undulations (Nakamura et al. 2012), redistribution of the vented sediments from liquefaction (Goto et al. 2012) and scouring at the lee side of engineering structures (Takashimizu et al. 2012). Investigation of local variability of thickness and grain-size of modern tsunami deposits are a key to better understand of the formation process of the tsunami deposits. However, it is usually difficult to consider such local effects in case of paleotsunami events. Therefore, it is rather important to clarify the characteristics of general thickness and grain-size trends and the physical formation process of tsunami deposits from modern examples. Such findings can be applied for estimating the size and hydraulic behavior of paleo-tsunamis.

In this study, the 2011 Tohoku-oki tsunami deposits were investigated along twelve shore-normal transects on the coastal lowland in Miyagi and Fukushima prefectures, northeast Japan. Inundation distances at each transect ranged from 0.6 to 4.1 km. Trench surveys of the tsunami deposits were conducted at over 500 sites from April 2011 to November 2012. Deposit thickness, grain-size and sedimentary structures were documented and samples were retrieved from each site. Grain size of the tsunami deposit was measured using settling tubes.

Total thickness of sand and mud, and thickness of sand layer generally showed a landward thinning trend in each transect. Between 1.5 and 2 km inland from the shoreline, the total thickness was less than 10-15 cm, and farther inland (over 2-2.5 km) it was thinned below 5 cm. The sand layer was less than 10-15 cm in thickness between 1.5 and 2 km inland, less than 5 cm from 2 to 3 km inland, and <0.5 cm at further inland (more than 2.5-3 km from the coastline). The thickness of mud layer was less than 5 cm at each location and there was no obvious landward trend. Mean grain size showed a landward fining feature up to 2 km inland, but it showed a fluctuation ranging from 1.5 to 2 phi. Meanwhile, the grain size rapidly fined landward down to 3 phi at 2-2.8 km from the shoreline.

We found a general landward thinning trend of the total thickness of the tsunami deposits. However, the thickness was largely varied in a zone up to 1.0-1.5 km inland. In this area, the thickness was likely to be sensitive to the local undulation of topography. According to the grain size analysis, bed-load transport might have been dominated in this section. Along short transects (< 2 km), there was no remarkable difference in the thickness of sand layer near the coastline and at the inundation limit. Hence, it is likely that the sediment-transport capacity of the tsunami was well maintained at least 2 km inland. Besides, absence of the thick tsunami deposits (>0.5 cm) between 2 and 3 km inland may explained by the following reasons: (1) limited sand supply from the source (i.e. sand dunes developed within 0.5-1 km from the coastal line; Szczucinski et al. 2012), (2) decreasing in sediment transport capacity because of reductions of the flow speed and depth during tsunami inundation.

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Keywords: 2011 Tohoku-oki tsunami, tsunami deposit, thickness, grain size

Effect of topographical and hydraulic features on distribution range of the 2011 Tohoku-oki earthquake tsunami deposit

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Effect of topographical and hydraulic features on distribution range of tsunami deposit was investigated after the 2011 Tohoku-oki earthquake tsunami. We visited coasts located from Misawa city in Aomori Prefecture to Sammu city in Chiba Prefecture and investigated 19 coasts which had been clearly inundated by the tsunami. We confirmed tsunami deposit in 18 coasts with a slope of less than 0.08 and tsunami deposit reached near the limit of the tsunami inundated area in 15 coasts though the run-up height of the tsunami is less than 10 m in some coasts. The detail analysis of the obtained sample and estimation of hydraulic features of the tsunami inundation using a numerical simulation are still ongoing. We are going to show more data in the presentation.

Keywords: tsunami deposit, the 2011 Tohoku-oki earthquake, field investigation, numerical simulation

Taphonomical process of sandy tsunami deposit based on field observations at 1 year after the 2011 Tohoku-oki tsunami

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Deposited tsunami sediment immediately begins to experience the effects of physical, chemical weathering, and bioturbation, and is altered into the *fossil* tsunami deposit. This study discusses alteration and preservation process (i.e. taphonomy) of tsunami deposit on the basis of field observation of facies, thickness, distribution, and covering layer of the 2011 Tohoku-oki tsunami deposit one year after the tsunami event. The 2011 Tohoku-oki tsunami caused severe damage to the coastal regions of eastern Japan and left a sediment veneer over affected areas. The tsunami deposit thickness tapers landward from 56 cm to few millimeters across a gentle slope lowland. At 1 year after the event, thin tsunami deposit around the run-up limit is hardly distinguishable because it has been eroded or mixed with humic soil. On the other hand, the relatively thick deposit, more than 2 cm in general, has preserved original depositional structures and thickness. In the forest, the tsunami deposit has been covered with organic debris or partially decomposed organic debris layer. The tsunami deposit beneath the covering layer seems to be well preserved. Because the thin tsunami deposit has been lost in one year after the event, the area where the 2011 deposit can be observed has become smaller than the tsunami inundation area. Therefore, inundation area and flow height which have been estimated from distribution of paleo-tsunami deposit is tend to be underestimate. Knowledge on the alteration process on tsunami deposits, tsunami-taphonomy, increases the potential precision for paleo-tsunami researches.

Keywords: Tsunami deposit, Taphonomical process, Weathering, 2011 Tohoku-oki tsunami

Distribution and origin of the 17th century tsunami deposit in the Iburi coast, Shiraoi district, central Hokkaido

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Pacific coast in Hokkaido is frequently suffered tsunami disaster caused by earthquakes associated with the Kuril Trench subduction. The 17th century tsunami deposits are discovered in eastern Hokkaido (Nemuro-Kushiro), central Hokkaido (Iburi coast) and western Hokkaido (Uchiura bay). But the tsunami deposits in the Iburi coast have unconfirmed trigger of tsunami yet. Conceivable candidates of its trigger are 1640 Hokkaido Komagatake eruption, 1611 Keicho-Sanriku earthquake and earthquake along the Kuril subduction zone occurring 300-500 years interval. We surveyed Shiraoi district in the Iburi coast, blank area of research, and studied distribution and origin of the tsunami deposits. We draw 4 survey lines perpendicular to shoreline, and investigated by a handy boring method.

Shiraoi district reaches back marsh behind sand dune, and is characterized by flat to gentle slope topography toward shore. Shikotsu pyroclastic flow deposits distribute inland. The Stratigraphic units of the Shiraoi district are divided into Us-b (1663) tephra, tsunami deposits (with thin peat at most upper part), peat, B-Tm tephra (20cm lower part from tsunami deposits), in descending order. The tsunami deposits are distributed with 14km length along the Iburi coastline and 0.6-0.9km width to landward. The deposits rapidly decrease in thickness at half inland of the deposition, and indicate a thin sheet-like distribution to the landward. The finer grain size distribution and increasing pumice grain to landward. Diatom fossils in the tsunami deposits include marine species of 18%. Constituting particles are similar grain sizes and assemblages to beach sand and dune sand. These results suggest that the deposits are transported from seaside, and correlate to the 17th century tsunami deposits distributed widely along the Iburi coast, Tomakomai and Mukawa.

Vertical sedimentary structure of the deposits near the coastline indicates inverse grading (lower unit), normal grading (middle unit) and normal grading (upper unit), in ascending order, which suggests at last two tsunami inundation events. Grain-fabric analysis of the each unit indicates that these deposits were formed by inflows with NNW paleo-flow directions. Distribution scales, a distance from the seacoast and a highest altitude of the deposit, in comparison with other 17th century tsunami deposits from the Iburi coast, are more larger at eastern Mukawa area than western Shiraoi and Yufutsu areas, which suggests the deposits are attributed to the eastern Kuril Trench origin earthquake.

Keywords: Tsunami deposit, Hokkaido, 17th century, Grain size analysis, Grain-fabric

Tsunami deposits survey around Japan Sea coastal area, Hokkaido

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At the eastern margin of Japan Sea, many large-scale earthquakes, such as "The 1993 off the southwest coast of Hokkaido Earthquake" have occurred, and accompanied "Tsunami", that damaged around the Japan Sea shoreline of Hokkaido. However, because of the absence of reliable historical records in Hokkaido, high-density geological survey would be needed, especially the recognition of "Tsunami deposits".

Historical disaster This Tsunami deposits survey have conducted by our group and Hokkaido local government. We survey around whole shorelines from Wakkanai to Matsumae, and especially Okushiri Island. In the Okushiri island, we recognize several event deposits accompanied Tsunami. Event deposits, such as sand bed with gravel are intercalated in peat or silt. The ages estimated stratigraphic and radiocarbon age are 1741 (accompanied with the Oshima-oshima volcano eruption), 11-13 centuries, 6-7 centuries, 2.3ka, 2.6-2.7ka, 3.1-3.3ka respectively.

At the Japan Sea shoreline area of Hokkaido, sand and gravel beds could recognized at 7 sites in 2011 survey, 26 sites in 2012 survey, respectively. mainly southern area and northernmost area. Geological, geographical and geochemical detailed work would be needed.

Keywords: Hokkaido, Tsunami, Earthquake, Debris avalanche, Geological Hazard

Tsunami Deposits Survey in the Bishamon Bay at the Southern Tip of the Miura Peninsula, Central Japan

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Tsunami Deposits Survey in the Bishamon Bay at the Southern Tip of the Miura Peninsula, Central Japan

Keywords: Tsunami Deposits, Kanto Earthquake, Miura Peninsula, Bishamon Bay

Detection of tsunami deposits: utilizing benthic foraminifera of the former Hojozu Lagoon, Imizu City, Toyama Prefecture

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This research aimed at discovering any marine event-sediments, such as tsunami deposits and storm-sediments, by utilizing the ore samples of drillings performed in Hojozu Lagoon by means of benthic foraminifera.

Using box-cored sediments recovered from the bottoms offing the river mouth of Kurobe River, the present distribution of benthic foraminifera in the Toyama Bay was examined under a stereomicroscope, with the reference of the depth distribution of benthic foraminifera and contrast with correspondence water reported by the previous research.

In order to extract benthic foraminifera, the core samples of Hojozu Lagoon were also examined under a stereomicroscope, and a marine event-sediment was detected in comparison with the water mass corresponding to depth distribution of a marker foraminifera.

As the result, it became clear that benthic foraminifera of Toyama Bay including *Ammonia ketienziensis* are as available for a marker species judging for a tsunami deposit.

From the core samples of Hojozu Lagoon, before the end of the Yayoi Period (ca. 1,900 yr B.P.) after the Middle Jomon Period (ca. 5,000 yr B.P.) in age, a probable marine event -sediment of either tsunami or storm and also a possible tsunami deposit were discovered.

The characteristic feature of the former marine sediment is coarse-grain sand included, and that of the tsunami deposit is content of many pieces of sea shells and from medium-to coarse-grained sands. Roundness and degree of sorting of both those sediment particles are low. Moreover, as for the source of supply of sediments, it is presumed that the former is not deeper than the middle sublittoral zone, and that the later is not deeper than the outer sublittoral zone.

The foraminifer method used in this study is expected to be a promising tool for discrimination of tsunami deposits from storm-sediments from marine-event sediments.

Keywords: tsunami deposits, storm deposits, hojozu lagoon, holocene

Preliminary results of a paleotsunami study by hand coring in coastal lowlands, eastern Kyushu

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The AD1662 Kanbun Hyuga-nada, AD1707 Hoei, AD1769 Meiwa Hyuga-nada and AD1854 Ansei Nankai tsunamis that occurred along Nankai Trough and Hyuga-nada all struck the east coast of Kyushu (Hatori, 1985). In particular, the AD1662 Kanbun Hyuga-nada tsunami inundated the extensive Miyazaki Plain, and based on the historical documents Hatori (1985) estimated that the inundation height was 4-5 m. The fault rupture area of the AD1707 Hoei earthquake is thought to have extended to the west of the Cape Ashizuri (Furumura et al., 2011) with the resultant tsunami being about 3-4.5 m high at the northeast coast of Kyushu, although it was thought to have been comparatively small in the southeast (Hatori, 1985). However, if the rupture area of an earthquake was to extend further west, a higher tsunami could strike the southeastern coast of Kyushu.

Paleotsunami deposits in stratum provide helpful information for disaster risk reduction such as the inundation area and recurrence intervals of paleotsunamis that have no historical records. However, studies of paleotsunami deposits do not cover all of the Pacific coastal lowlands of Japan at the current moment. In eastern Kyushu, sandy paleotsunami deposits were reported from Ryujin Lake in Oita Prefecture (e.g., Matsuoka and Okamura, 2008), but there has been no detailed study of paleotsunami deposits in the south of the Miyazaki Prefecture. The purpose of this study is to reveal the tsunami history over thousands of years in eastern Kyushu by using paleotsunami deposits.

We started a preliminary research of paleotsunami deposits by hand coring coastal lowlands in Kagoshima, Miyazaki and Oita prefectures in March 2012. In this presentation, we mainly discuss geological data obtained from coring at Kushima lowland, Miyazaki Prefecture. This 550 m wide drowned valley lowland faces Shibushi Bay and is surrounded by 10-30 m high hills. We conducted core logging at 19 study points along 300 and 450 m shore-perpendicular transects and collected samples for radiocarbon dating and diatom analysis.

The 4-6 m sedimentary successions of these study sites are composed from bottom to top of fine to medium dark-gray sand with granular, green-brown organic-rich silt, black-brown organic-rich peaty silt, blue-gray clay and agricultural soil. Several sand layers was found in the organic-rich peaty silt and blue-gray clay at many study points. Marine and brackish diatoms were found from sand layers at around the boundary between the lower green-brown organic-rich silt and the upper organic-rich peaty silt. This indicates a possibility that these sand layers were transported inland from sea area by a high energy flow. Although they could have been deposited by paleotsunamis, more criteria such as lateral consistency in the sedimentary succession are needed for identification of these layers as paleotsunami deposits. Using diatom analysis, we will also examine the environmental changes that might have occurred simultaneously with deposition of the sand layers.

Keywords: tsunami deposit, Kyushu, Miyazaki Prefecture, Nankai Trough, Nankai earthquake, Hyuga-nada earthquake

A Study of Paleo-Tsunami along the Coastal Area of Miyazaki Prefecture, south-western Japan

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Tsunami is the most destructive natural disaster on the coastal area. Eastern Kyushu along the Pacific coast has been suffered by tsunamis, such as the 1662, 1769, and 1984 tsunamis. Recently, tsunami deposits have been reported from various areas and environments in Japan. However, paleo-seismological study based on the tsunami deposits has not been reported from along the Hyuganada. We report a study of paleo-tsunami along the coastal area of Miyazaki Prefecture. These results will be presented in this session.

Keywords: Miyazaki prefecture, tsunami deposit

Subaqueous Tsunami Deposites from southern part of Okinawa Island of Naha city

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Since the interplate coupling is assumed to be weak along the Ryukyu Trench, the occurrence of large interplate earthquakes is assumed to be unlikely. However, locally coupled area is observed near Okinawa Island in the central Ryukyu Trench (Nakamura et al., 2010). Furthermore, the core-sampling research detected the anomalous layers which contain corals and open-sea shells in the Haneji Naikai Bay and Shoya Bay, northwestern Okinawa Island (Haraguchi et al 2012). The thicknesses of the layers are 5-10 cm. Since the coral and open-water shells live in the outside of the bay, they would have been transported by the tsunami. Distribution of tsunami sediments is important to constrain the source area of the tsunami. However, the distribution of the tsunami sediment in Okinawa Island is still unknown. Therefore, we employed coring survey to detect tsunami sediments in the southwestern Okinawa Island.

We carried out the tsunami sediment investigation in Manko of Naha city. I used Russian style Pete sampler for a sampling. Sample R1 and R2 gathered the depth of 310cm and 260cm. I divided the sample into every 5 cm. Then we measured the water content of the samples. Then the samples were sieved in a mesh-size of 63 micro. After then we calculated the mud contents. Then we measured the particle size of the samples using sieves (mesh: 2mm, 1mm, 0.5mm, 0.25mm, 0.125mm). Finally, the depth of the core was converted to age using the sedimentation ratio of 1.4 cm/yr, which was estimated from the Pb210 isotope analysis.

The core sample R1 almost consists of mud from top to bottom. From surface to the depth of 100 cm, sand content is higher. The grayish white coarse sand is included in the depth of 0-25 cm. The grayish white medium-grained sand with patch-like inclusion of fine sand is included in the 30-45 cm. The fragments of wood are concentrated in the depth of 60-100 cm, which correspond to the age of WWII and postwar population growth, reclamation. We assumed that the concentration of fragment of wood and sand would have been caused by these events. The concentration of the sand could not be found in this core. This suggests that remarkable tsunami events did not arrived in the lake-Manko area for about 300 years.

Keywords: Manko, Tsunami Deposites, Okinawa, southern, Naha City

A survey of tsunami sediments in Miyako Islands

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The 1771 Yaeyama tsunami (Meiwa-tsunami) was possibly M8 class interplate earthquake in the Ryukyu Trench (Nakamura, 2009). The transport ages of tsunami boulders, which were moved from coral reef to land by tsunamis, concentrate to five periods for 3000 years (Kawana, 1994). This suggests that the mega-tsunami occurred frequently in the south Ryukyu Trench. Thin sand layer overlying the basement of buried old house has been reported in the ruin of the Miyako-Yaeyama region. They has been interpreted as the tsunami deposit. However, there is no evidence for the tsunami deposit since the origin of the sand is unclear. Then, we employed the trench-surveys in the Miyako Island and investigated the origin of the sand layers using the analysis of foraminiferal. The survey was conducted on the day of 18-21 June 2012 at Tomori (Miyako Island), Ikema Island, and Irabu and Sawada (Irabu Island). We digged a trench about from 1m to 3m depth and observed. The silt layer with sand is distributed at the depth from 30 cm to 50 cm in Tomori. We collected 8 samples from 15cm to 110cm depth including this layer. Since layer consists of muds from 0 cm to 160 cm in Ikema Island, we could not find sand layer. In this site, we collected samples from 45cm to 155cm depth. A medium grain sand is distributed at the depth from 80 cm to 115 cm, and brown-colored fine grain sand or silt is distributed at the depth from 120 cm to 200 cm in Irabu. We collected 6 samples at the depth from 80cm to 160cm. In Sawada, the sand layer with grading from medium to coarse is distributed at the depth from 170 cm to 290 cm. We collected 9 samples from 190cm to 290cm depth. Next, we washed mud . Then, the samples separate by 2mm mesh, 1mm mesh, 0.5mm mesh, 0.25mm mesh, 0.125mm mesh and 63um mesh and we pick not more than 150 foraminiferas by from 0.5mm mesh to 1.0mm mesh at a microscope. If sample's amounts are increasing, we divided for simple divider. In foraminifera, we divided into priority species (Calcarina, Hispida, Baculogypsina, Elphidium) and the others. In addition, we observe species for inhabiting sediment in the others. The mud content is lower and the layer contains coarse sand at the depth from 115 cm to 150 cm in Irabu. From the foraminiferal analysis, sample of 150cm depth contains

Eponides sp., Pseudorotalia sp., Lenticulina sp., Ammonia sp. and A. bicirculata. These five species live in the sediments of reef and lagoon (Uchida, 2007; Shiba, 2012). Furthermore, Lenticulina sp., Ammonia sp. and A. bicirculata were not included in Toguci Beach's samples. This suggests that the sand at the depth of 150 cm in Irabu is transported from reef, lagoon and beach. The sand would have been tsunami sediment because the sand of reef and lagoon could not be transported to the site by the storm wave. The sand originates from sand of reef, lagoon, and beach also suggest the sand is tsunami sediment. The grading structure at the depth from 170 cm to 290 cm in the Sawada suggests that the layer is tsunami sediment. Furthermore, the bottom of the grading layer includes Ammonia sp., Cibicidoides sp., Anomalina, Eponides sp., Pseudorotalia sp. and Ammonia sp.. In addition, Cibicidoides sp., Anomalina, and Eponides sp. was not included in Sawada Beach's samples. In addition, at this depth's sample was a result of a large number of individuals that live in the shallow-water zone inside Elphidium. I mean, I can guess it deposits due to the tsunami because the sand of the beach sand and lagoon and reef are mixed and sand location where waves are difficult to reach are transported to land. Even more, sand from 290cm depth's sample was a result of a large number of individuals that live in the shallow-water zone inside Elphidium, too. In addition, we also observed planktonic foraminifera and Ammonia sp. . We suggest to tsunami trace, too.

Keywords: tsunami sediments, foraminiferal analysis

Movement of boulders by tsunamis or typhoon waves in the Lanyu Island, Taiwan.

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The eastern Taiwan region is convergent plate boundary where the collision of Philippine Sea plate and Eurasian plate is ongoing. Occurrence of M 7.5 earthquakes are estimated from the distribution of the sea floor active faults. Seismic potential for interplate earthquakes in the western Ryukyu Trench is M 8.5 (Lin et al., 2012). Few damages by historical tsunamis were reported in the old documents in Taiwan, whereas folklore about tsunami damage remains in the east part of Taiwan and Lanyu Island, southeast of Taiwan. Large boulders, which consist of fragments of coral reef and are moved by inundation of tsunamis or storm waves, are distributed on the shore of Lanyu Island.

We surveyed the distribution of boulders in the shore of Lanyu Island, and investigated whether the boulders are moved by tsunami or typhoon wave. The survey was carried out from August 31th to September 4th of 2012. Just before the survey, the typhoon 14 (TEMBIN) approached the island and caused severe damages to the infrastructure of the island. We surveyed the distribution of boulders in the western coast of the Island. The maximum run-up heights of the storm wave were 11 m in the western coast of the Island. Although the boulders whose diameters were within 2.0 m were not moved by the storm waves, the boulders whose diameters were over 2.0 m were transported by the typhoon wave. This suggests that the boulders whose diameters are over 2.0 m would be transported by the storm wave whose maximum heights were over 11 m.

The boulders are distributed in the north and east coast of the Lanyu Island. The maximum size of boulder is 6.4m x 6.1m x 2.9m. We calculated the minimum inundation depth that can transport the boulder using the formula by Kennedy et al. (2007). The calculated minimum depths by tsunami and storm waves are 3.4 m and 12.9m, respectively. The coral reef-lagoon topography does not develop along the Lanyu Island, and the distribution of the boulders is limited within 100 m from shore and within the heights of 10 m. this area corresponds to the storm area. The boulders in the Lanyu Island would not have been transported by the tsunamis but have been moved by the storm waves.

Keywords: Taiwan, tsunami boulder, typhoon, Lanyu Island