Field Survey of tsunami deposits in Noda Village, Iwate prefecture

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Large tsunamis had frequently affected to the Sanriku coast according to historical and observation records (Utsu, 2004). It is essential to collect information of paleo-tsunami deposits for understanding nature of low frequency large tsunamis in the past. However, there are few reports of paleo-tsunami deposits along the Sanriku coast (Yagishita et al. 2001) nevertheless that the coastal region is broad. Thus, more geological data should be collected to better estimate timing, recurrence interval, and size of historical and pre-historic tsunamis along the Sanriku coast.
Goto et al. (2014) performed preliminary survey at Noda Village of Iwate Prefecture in Northern Sanriku and reported several gravelly sand layers. They also reported presence of the AD 915 Towada-a tephra (To-a) and AD 946 Baegdusan- Tomakomai tephra (B-Tm) above the gravelly sand deposit. On Sendai and Ishinomaki plains (Sawai et al. 2007, 2008), Otsuchi Bay (Torii et al. 2007), and Koyadori in Miyako City (Ishimura and Miyauchi, 2015), the 869 Jogan tsunami deposit has been identified based on the stratigraphy that the To-a tephra layer was deposited just above the tsunami deposit. Noda Village locates far north from the area where the 869 Jogan tsunami deposit was reported. Therefore, if we can identify the 869 Jogan tsunami deposits in this area, it will be useful to constrain the tsunami source model. However, correlation of gravelly sand layers and identification of their tsunami origin should be further evaluated. Thus, we conducted detail field survey at Noda Village in order to correlate gravelly sand layers among each survey pits and to identify their origin.
We set a survey line and observed sediments with approximately 5 m to 10 m interval for the most parts. As a result, we found at least 4 gravelly sand layers and identified them as the event deposits based on sedimentary features (event layers I to IV in ascending order). We then correlated these deposits pit by pit to understand the continuity of each event deposit. We also used chronological data for correlation of event deposits because the survey area is an artificial terrace topography for agricultural work so that correlation by lithological observation only was sometimes difficult. Based on grain size analysis and numerical simulation of storm surge and wave, we evaluated the origin of the event layer III, which is deposited continuously and widespread area. The event layer III was formed by the sediments that were transported landward by strong current, because of rounded shape of particles, landward fining and thinning features, and upward fining trend. Our numerical modelling revealed that the landward extent of the event layer III could not be explained by the storm surge/wave even if we assume extremely large size. Based on these results, we identified the event layer III as tsunami deposits. Similarly, we identified all other event layers (I, II, and IV) as tsunami deposits because their landward extents are further than the inundation limit of extremely large storm surge/wave. In this way, the numerical simulation of storm surge and wave can be a useful method to distinguish tsunami deposits from storm deposits.
Our results imply that four large tsunamis had occurred during 1600 years from around 1100Cal BP to 2700Cal BP. Considering the landward extents of each tsunami deposit, local sizes of these tsunamis might have been large equivalent to the 2011 tsunami or the 1896 tsunami.

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Historical and paleo-tsunami deposits on the Pacific Coast of Iwate Prefecture

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Iwate Prefecture is advancing examination for future tsunami hazard based on scientific knowledge such as historical records and tsunami deposits. As a result of the field survey, we identified tsunami-like layers at 13 sites along the Pacific Coast. Before 2011 Tohoku-oki tsunami, tsunami deposits were reported at several sites along Sanriku Coast, but the distribution and their correspondence with historical tsunamis were not clear. Recent studies including our survey provide several data about these assignments.

We identified tsunami-like layers at Harashinai site (Hirono Town), Noda lowland (Noda Village), Masaki site (Taro coast), Ohtahama site (Miyako Bay), Funakoshi lowland (Yamada Town), Kirikiri lowland (Otsuchu Town), Okirai Bay, Goishi Coast (Ofunato City), and several lowlands around the Hirota Peninsula. At most site, tsunami-like layers consist of well-sorted sand with erosional base and distributed in peat. Several layer shows laminae, rip-up mud clasts and grain size grading. At Masaki site, beach gravels are buried in talus deposits and soils.

Radiocarbon dating results suggest that the several layers are correlated with 1611 Keicho Oushu (Sanriku) tsunami and 869 Jogan tsunami. At Noda lowland and the Hirota Peninsula, a sand layer is deposited just below tephra layer that is identified as Baitoushan-Tomakomai tephra (B-Tm) that was deposited in early to middle 10th Century or Towada-a tephra (To-a) of AD915. The horizon of this sand is similar to the Jogan tsunami deposits reported in the Sendai Plane.

Our survey data probably contains the history of large (mega) tsunamis during last 4,000-6,000 years along the Pacific Coast of northeastern Japan.

Keywords: tsunami deposit, historical tsunami, Jogan tsunami, Keicho Oushu (Sanriku) tsunami, Iwate Prefecture

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Characteristic of the diatom assembles in Hirota bay, Iwate, Japan

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The recent 2011 Tohoku tsunami strongly affected the coastal area of the Pacific coast of Tohoku. Many of the damage caused by the tsunami around Hirota bay, Iwate. Tsunami origin sediment over a wide range are distributed. We will show about characteristic such as lithofacies description, a grain size composition and diatom assembles of the columnar core sampled from Hirota bay.
Result of this study, the core consist of Unit1(U-1) and Unit2(U-2). U-1 was sand to silt sediments layer with grading, and has forms the erosion surface structure at the bottom of this layer. U-2 was massive sediments with fine sand to silt layer characterized by bioturbation. We assume that U-1 is 2011tsunami deposit and U-2 is normal sediment in this bay.
On the 13HV2 core which sampled near the coast, freshwater species from Unit1 dominate but marine diatom from Unit2 dominate. On 13HV3 core which sampled near the coast, marine species from Unit1 dominate but freshwater diatom from Unit2 dominate. U-1 and U-2 which near the coast shows the characteristics diatom assembles is reversed to be dominant species. On the 13HV8 core which sampled near the Kesen river, U-1 and U-2 are both freshwater diatoms dominated. On the 13HV4 core and 15HV8 core which sampled the central portion of the bay, U-1 and U-2 are both marine diatoms dominated.
The diatom assembles of 2011tsunami deposit shows the separate characteristics near the coast, the Kesen river and in the central portion of the bay.

Keywords: diatom, tsunami, deposit

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Constraining depositional age of tsunami deposit using rip-up clast

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Depositional ages of tsunami deposits are important for estimating recurrence interval of tsunamis. Correlation of tsunami deposits in the wide area are usually conducted based on dating results of tsunami deposits in many area. The ^{14}C dating method is commonly used for dating of tsunami deposit. In general, ^{14}C dating are conducted using organic matters in the sediments from above and below the tsunami deposit. The depositional age of the tsunami deposit is assumed to be within these ages. However, the estimated depositional age of the tsunami deposit may be older than the actual age by this method because tsunami can erode bottom sediment. If we identify any materials that were eroded by the tsunami and incorporated into the tsunami deposit, the depositional age may be further constrained by the dating result of such materials.

In case of dating using materials within the tsunami deposit, shells and plant fragments are commonly selected (e.g., Bondevik et al., 1997; Clark et al., 2011). However, ^{14}C dating results of individual materials often have large statistical errors due to wiggles in the calibration curve. Instead, rip-up clast, which is considered to have been eroded from the ground sediment by the tsunami and incorporated into the tsunami deposit, has an advantage because sequential ^{14}C dating can be performed. In this study, we tested sequential measurement of ^{14}C dating of rip-up clast to better constrain the depositional age of tsunami deposit.

Study area is the Rikuzentakata City, Iwate prefecture. In this area, we observed a tsunami deposit with abundant rip-up clasts in few centimeters in size. Presence of rip-up clasts indicates strong basement erosion during the tsunami flow. We performed ^{14}C dating using samples taken from above and below the tsunami deposit and rip-up clasts within the tsunami deposit. Results of sequential measurement of ^{14}C dating were constrained by the stratigraphic order and depth information using OxCal ver.4.2.4 (Bronk Ramsey, 2008; Bronk Ramsey and Lee, 2013). The depositional age of the tsunami deposit is AD 681-1184 if we only use dating results from sediments above and below the tsunami deposit. On the other hand, the age of the youngest part of the rip-up clast was AD 776-887. The age obtained from the rip-up clast can be used to constrain the limiting maximum age of the tsunami deposit. In this case, depositional age of the tsunami deposit is AD 776-1184.

As stated above, rip-up clast can further constrain the depositional age of the tsunami deposit. This results in turn suggest that the depositional age of the tsunami deposit sometimes be older than few tens to hundreds of years due to the basement erosion by the tsunami flow if we only use dating results from sediments above and below the tsunami deposit.

Keywords: tsunami deposits, rip-up clasts, OxCal

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Classification of tsunami flows on Ria coast based on 'source-deposit' contained in tsunami deposit

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Tsunami deposit sometimes includes land-originated particles that were eroded and transported by tsunami. We can reveal the tsunami behavior of erosion and deposition, and reconstruct the behavior of past tsunamis by investigating the source deposits contained in tsunami deposit layers. To reveal the characteristic sedimentary features of tsunami deposits in rocky coast, we first mapped source deposit of the 2011 Tohoku tsunami deposits in Numanohama, Miyako City in Iwate Prefecture. High tsunami run-ups (>30 m) of the 2011 Tohoku tsunami were measured in this valley (Tsuji *et al*., 2011, 2014). On the basis of these source deposits, we then tried to reconstruct the flow of past tsunamis using particle components of event layers in geological samples.

The sedimentary features of the 2011 Tohoku tsunami deposit in a narrow valley along the Sanriku coast (e.g., Yamada *et al*., 2014) were quite different from those of sandy layer which was observed at Sendai plain, Miyagi Prefecture (e.g., Fujiwara and Tanigawa, 2015). The difference is attributed to the topographical conditions. We examined the depositional conditions in a valley, and classified source deposit into beach, riverbed, and slope. We focused on gravels with the diameter of > 2mm and investigated their features such as rock type, diameter, roundness, and sphericity. We found that the combination of rock type and roundness was the best indicator to represent the characteristic features of each source deposit. 'Source deposit [marine]'; marine beach-originated source deposit, has a high roundness (0.8-0.9) regardless of rock types. 'Source deposit [slope]'; slope-originated source deposit, is composed of angular particles with a low roundness (0.1-0.2) regardless of rock types, and is distributed in slope area with altitudes of >5 m. 'Source deposit [riverbed]'; riverbed-originated source deposit, is composed of granite with an intermediate (0.4-0.5) roundness, which was originated from mother rock in the upper stream.

In order to understand the behavior of past tsunamis, we classified each event layer into four types. Type A; the layer which includes all of the above source deposits, Type B; the layer which includes source deposit [marine] and [slope], Type C; the layer which includes source deposit [riverbed] and [slope], Type D; the layer which includes none of the above source deposits. We used these four types as an indicator of water flow during the event. Type A suggests the high inundation and strong run-up and return currents. Type B shows high inundation and strong run-up current which transport marine pebbles landward. Type C shows high inundation and characterizes strong return flow.

We have identified 12 event layers (S1-S12 from top to bottom) from a 5.7m-long geological sample at the survey site (Goto *et al*., 2015; the 2015 SSJ Fall Meeting). The S1 layer is probably the trace of the 2011 Tohoku tsunami. The sedimentation ages of the other layers were estimated as follows; S2 (AD1961-), S3 (AD1947-1997), S4 (AD1910-1950), S5 (AD1769-1904), S6 (AD1713-1889), S7 (AD1682-1852), S8 (AD1609-1820), S9 (AD1476-1728), S10 (AD1469-1617), S11 (AD 1461-1600), and S12 (AD271-1390).

Among these, layers S1, S4, S5, S7, S8 and S12 were classified into Type A, two layers (S2 and S10) were Type B, the only one (S3) layer was Type C, and three layers (S6, S9 and S11) were Type D. On the basis of their sedimentary ages and historical records, other five layers of Type A (S4, S5, S7, S8, and S12) can be correlated with historical tsunamis as follows; the 1933 Sanriku-Oki, 1896 Sanriku-Oki, 1763 Aomori-Oki, 1611 Sanriku-Oki, and 869 Jogan tsunamis. In a similar way, we

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could construct the behavior of past tsunamis for the other types; hence, source deposits are useful as an indicator reconstructing behavior of each tsunami.

Keywords: tsunami deposit, Ria coast, Sanriku coast, historical tsunami, source deposit

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Event deposits recorded in coastal lowland on the middle-northern part of Akita Prefecture, the eastern margin of Japan Sea

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Tsunami is the most destructive natural disaster on the coastal area. North-eastern Japan along the Japan Sea has been suffered by tsunamis, such as the 1833, 1983, and 1993 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 coastal area of Akita Prefecture. We report a study of paleo-tsunami along the coastal area of Akita Prefecture. These results will be presented in this session.

Keywords: Akita Prefecture, eastern margin of Japan Sea, tsunami deposit

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Tsunami deposits and preservation potential of them in Onuma, Minami-Sanriku Town, northeast Japan

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Preservation potential of tsunami deposits (Szczucinski, 2012; Spiske et al., 2013; Fujiwara, 2015) is significant for deciding study site, identifying tsunami deposits and assessing interval and frequency of them. One of the factors of preservation potential is topography and depositional environment. Therefore, we reconstructed paleoenvironment during Holocene for assessing preservation potential, and then identified paleo-tsunami deposits.

Our study site is Onuma, Minami-Sanriku Town, Miyagi Prefecture, at the southern part of the Sanriku Coast. Based on geomorphic interpretation, study site had been kept marsh or swamp closed by sandbar and sand dune, and is appropriate for paleo-tsunami study. Thus, we conducted three kinds of methods for obtaining subsurface sediments and identifying tsunami deposits, and used two kinds of analysis for estimating paleoenvironment. As a result, marsh or swamp environment was constructed in 6 ka (just after the fall of To-Cu tephra) and existed until 1 ka. This indicates high preservation potential of tsunami deposits. In this presentation, we will report age and magnitude of paleo-tsunami based on tsunami deposits.

Keywords: tsunami deposits, Sanriku Coast, preservation potential, reconstruction of paleo-environment

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Characteristics of Tunami origin sediment at Onagawa Bay, Miyagi Prif.

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By the Tohoku Region Pacific Coast Earthquake generated on March 11, 2011, a tsunami occurred in the wide range of the Pacific coast and was able to bring serious damage. Tokai Univ. carries out general marine geological investigation for the purpose of the debris mapping at a part of TEAMS around the Iwate area with JAMSTEC. From 2014,we started an investigation to clarify bottom of the sea environment including debris mapping and the surface sediment in Gulf of Onagawa.
Gulf of Onagawa is the typical rias type gulf that opened in the east Pacific among Oshika Peninsula existing to the south and Izushima located to the north. It is only Onagawa River to pour into the Onagawa, and there are few sediment supplies from the river. In the Onagawa bay area, the sandy beach does not exist except East Side Coast area from the Gobuura-bay, and most are reef level. It is pointed out that the quality of sea-bottom environment of the Gulf of Onagawa became the nature of the mud superiority by a tsunami more. The characteristic of this change is totally different from the characteristic (sandy sediment covers the sea-bottom in many gulfs) of the Sanriku Coast area that Tokai University clarified until now.
We succeeded in gathering three columnar geological samples from depth of the water 17m to 24m in Gobuura-bay. As a result of columnar sample (15ONV2-2, 23m in WD) observation, fine sand to silt sediment layer (U-1) observed the top (0-10cm) where the coarse sand layer developed in the bottom, and silt sediment (U-2) with many shell fragment was confirmed in lower part of columnar section (10-120cm). The coarse sediment is not confirmed in the U-1 layer in other columnar samples(15ONV1,15ONV3), and the grain size does not change with the U-1 layer and the U-2 layer.
In the Gulf of Onagawa with a little sabulosity sediment, sea-bottom mud sediment is stirred by a tsunami activity, and is estimated that the muddy sediment deposit on the sea-bottom surface again. The small amount of sand sediment that observed the bottom of U-1 layer from 15ONV2-2 is derived from the beach around the Gobuura-bay.

Keywords: Tunami origin sediment, Onagawa Bay

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Preliminary GPR study on the effects of topography on the preservation of paleotsunami deposits

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In order to better understand the paleotsunami record at any one location it is important to choose places where deposits are likely to be thickest and best preserved (Sawai, 2012). However, even when apparently appropriate study areas have been selected, tsunami deposits may not be present. For example, studies in the marshes of the Sendai Plain have shown that there is considerable variability over even a few tens of meters (Sawai et al., 2008). This is largely because the plain consists of a prograding beach ridge topography with numerous ridges having no surface expression because they are now buried beneath surface peats. The preservation potential of tsunami deposits on the Sendai Plain therefore seems likely to vary with the thickness of the peat relative to the undulating subsurface beach ridge topography. Indeed, while the 2011 Tohoku-oki tsunami deposits showed a thinning trend inland, it also varied markedly in thickness depending upon local variations in topography (Goto et al., 2011; Yamada and Fujino, 2013). In the case of the 2011 event, this was further exacerbated by artificial topographic variations such as roads, although for most paleotsunami deposits this would not be the case.

Given the recognized control of deposit preservation/thickness imparted by the contemporary paleo-topography it is preferable to obtain as much information about subsurface structures as possible during the early stages of any research project in order to more effectively identify the appropriate study sites for ongoing work. In this study we report on a Ground Penetrating Radar (GPR) survey carried out on Ishinomaki plain to help clarify the relationship between paleo-topography and tsunami deposit preservation/thickness. GPR transects were measured along 10 profiles within a 50 ×30 m grid. The non-invasive data collected by GPR was validated by studying the deposits preserved in a series of trenches or cores taken at each transect intersection point. Using these data we recreated the three-dimensional paleo-topography dated to around 3,000~3,500 yr ago that currently underlies the contemporary peat surface throughout the study area. This reconstruction included the spatial distribution and thickness of tsunami deposits, beach ridges and peat sequence.

In summary, we found that tsunami deposits were well preserved/thicker where they are associated with paleo-topographic depressions, and are overlain by a relatively thick peat sequence. Conversely, the peat is thin and tsunami deposits are either non-existent or difficult to distinguish from beach ridge deposits when associated with paleo-topographic highs. While this work in essence concurs with findings from historical events, it highlights the value of GPR surveys for identifying the best paleotsunami study sites based upon an understanding of subsurface paleo-topography. This will greatly enhance the success of future paleotsunami fieldwork.

Keywords: paleotsunami deposits, paleo-topography, GPR

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The characteristics of tsunami deposits at Idagawa polder, Minami-soma City, Fukushima Prefecture.

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In the Tohoku region along Japan Trench, great earthquakes often occur with large tsunamis before the 2011 Tohoku-Oki earthquake. In particular, a historical tsunami with 869 Jogan earthquake caused serious damage, and the estimated magnitude was Mw 8.4 or larger (Sawai *et al.* 2012). The results of tsunami deposit surveys in Sendai plain show tsunami deposit between 869 Jogan and 2011 Tohoku-Oki earthquake might correspond with 1454 Kyotoku or 1611 Keicho earthquake, and average recurrence interval of large tsunamis were estimated about 500-600 years (Sawai *et al.* 2015).
We carried out the tsunami deposit survey to investigate the tsunami deposits with 869 Jogan and 1454 Kyotoku or 1611 Keicho earthquakes at Idagawa polder, Minami-soma City, Fukushima Prefecture. The sedimentary environment was stable, because there was the inner-bay or lagoon of fresh-blackish water until the 1921 and there was no massive river in this area. Although there were several previous studies around this area, the number of survey and analysis locations was too few (Aoyama and Goto, 2005, Oikawa et al. 2011 and Oota and Hoyanagi, 2014). In this study, we took the 13 cores of length 2.0-2.5 m in the 11 locations 0.6-2.7 km away from the coast. We will discuss about these results for the elemental analysis by using the X-Ray Fluorescence (XRF), grain-size analysis and radiocarbon age measurement.
Ordinary deposits were consisted of the inner bay silt and the median grain size was about 15 μm. The 5 continuous event layers (EV1-EV5) were found in ordinary deposits (Goto et al. 2015, Kusumoto et al. 2015). These layers were consisted of the coarse, median and fine sand, and the weak elements (Na, K and Ca) and strong elements (Si, Fe and Al) for the chemical weathering were more abundant than ordinary deposits. However, the top event layer (EV1) and about 10 cm of ordinary deposits under EV1 showed the increase for the oxides of phosphorus and the decrease for the oxides of sulfur, and these trends differ from the others. They may indicate the closure of inner-bay and the beginning of the reclamation.
The most of event deposits had sedimentary signatures like tsunami deposits, such as the significant erosional contacts, multiple graded beddings and rip-up clasts (e.g. Dawson and Stewart, 2007 and Switzer and Jones, 2008). In addition, the median grain size of these event deposits is about 0.28 mm. Only the second event layer (EV2) shows a bimodal distribution that it has the peak both the median sand and silt. If it is assumed that the sources of all event deposits are the same, the phenomenon of EV2 may be weaker than the others.
Being a result of radiocarbon age measurement, the sedimentary age of EV2, EV3-EV4 and EV5 were estimated AD1520-AD1920, AD130-AD1440 and 140BC-AD130, respectively. Compared with tsunami deposits in Sendai plain, EV2, EV3-EV4 and EV5 may correspond to tsunami deposits with 1454 Kyotoku or 1611 Keicho, 869 Jogan and the older earthquakes, respectively.
Acknowledge:we thank a lot of advices and partnerships of Professor Minoru Yoneda, Takayuki Omori, Hiromasa Ozaki and the others of laboratory members in Laboratory of Radiocarbon Dating, The University Museum, The Univ. of Tokyo.

Keywords: Tsunami deposits, The 869 Jogan earthquake, historical tsunamis in the Tohoku region

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Geological evidence for tsunamis and earthquakes from Lake Hamana and Fuji Five Lakes

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Great earthquakes have repeatedly occurred along the Nankai Trough, the subduction zone that lies south of Japan’s heavily industrialized southern coastline. While historical records and geological evidence have revealed spatial distribution of paleo-earthquakes, the temporal variation of the rupture zone is still under debate, in part due to its segmented behavior. Here we explore the potential of the sediment records from Lake Hamana and Fuji Five Lakes as new coherent time series of great earthquakes within the framework of the *QuakeRecNankai* project.
We obtained pilot gravity cores form Lake Hamana and the Fuji lakes Motosu, Sai, Kawaguchi, and Yamanaka in 2014. In order to image the lateral changes of the event deposits, we also conducted reflection-seismic survey. Based on these results, potential coring sites were determined and then 3–10 m long piston cores were recovered from several sites in each lake in 2015. The cores consist of 2 m long sections with 1 m overlaps between the sections allowing us to reconstruct continuous records of tsunamis and paleo-earthquakes. In this presentation we introduce the progress of *QuakeRecNankai* project and discuss the potential of the lakes as Late Pleistocene and Holocene archives of tsunamis and paleo-earthquakes.

Keywords: Tsunami deposit, paleo-earthquake, Lake Hamana, Fuji Five Lakes

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Tsunami events of Nankai Earthquake recorded in lacustrine sediments along the eastern coast of the Kii Peninsula, southwest Japan.

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We studied on tsunami sediment from lacustrine sediments along the Nankai Trough for the reconstruction of prehistoric tsunami record. Total 27 cores were collected from the three lakes named Ashihama-ike, Zasa-ike and Usuzuki-ike, which located on behind coastal ridge along the southeastern coast of Kii Peninsula. Ashihama-ike records two major events, 2000-2300 yBP and about 1000 yBP through last 4500 years interval. Six events are detected in Zasa-ike, which are about 6500, 3500, 2000-2300, 1300, 1000 and 800 yBP through the interval of 7500 years. Usuzuki-ike cores have only one event of 2000-2300 yBP in last 4500 years sediment. The similarity of recurrence time and relative size of events in these three lakes suggests that sediments in these lakes preserve good prehistoric records.

Keywords: Nankai Earthquakes, tsunami sediments

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Preliminary report on paleotsunami study in the coastal lowlands of Toyo, Shimanto and Kuroshio towns, Kochi Prefecture, western Japan

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Kochi Prefecture has been struck repeatedly by large tsunamis generated by subduction zone earthquakes along the Nankai Trough. Historical records through approximately 1,300 years indicate great earthquakes (M ~8) basically occurred at intervals of 100-200 years along the Nankai Trough. However, because historical documents are relatively sparse before the 16th century, it is difficult to evaluate magnitudes and rupture areas of earthquakes during this period. Tsunami deposits provide basic data for reconstructing not only the long-term earthquake history but also the magnitudes and the rupture areas. Therefore we studied tsunami deposits in Kochi Prefecture. We obtained cores and geoslices from coastal lowlands of Toyo Town, Shimanto Town and Kuroshio Town. We found some exotic sand layers interbedded in silt and clay beneath the each lowlands. We present initial findings following the preliminary results of radiocarbon dating and fossil diatom analysis for some cores.

Keywords: tsunami deposit, Nankai Trough, Toyo Town, Shimanto Town, Kuroshio Town, Kochi Prefecture

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Sedimentary reconstructions of coastal flooding in the Bungo Channel by the 1707 CE Hoei tsunami

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A tsunami generated by the C.E. 1707 Hoei earthquake is largely thought to be the flood event of record for southwestern Japan, yet historical documentation of the event is scarce. This is particularly true within the Bungo Channel, where significant inconsistencies exist between historical records and model-derived tsunami heights. To independently assess flooding from the Hoei tsunami in this region we present complementary reconstructions of extreme coastal inundation from three back-barrier lakes in the northern Bungo Channel: Lake Ryuuoo, Lake Amida, and Lake Kamega. At all sites the most prominent marine overwash deposit of the past ~1,000 years, as defined by grain size, density, and geochemical indicators, is consistent with the timing of the 1707 tsunami, providing strong evidence that the event caused the most significant flooding of the last millennium in this region. At Lake Ryuuoo, modern barrier beach elevations and grain sizes in the tsunami's resultant deposit provide ~4 m as the first physically based height constraint for the 1707 tsunami in the northern Bungo Channel. A newly developed rupture and tsunami simulation for the 1707 event produces inundation patterns more consistent with historical and sedimentological observations in the Hyuga-nada area, including flows over the Lake Ryuuoo barrier capable of transporting the maximum grain size observed in the lake’s 1707 deposit.

Keywords: Bungo Channel, Nankai Trough, Coastal Flooding, Inverse Modeling

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Study of tsunami deposits along northwest coastal area of Kyushu, Japan

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Tsunami deposits caused by big earthquake are studied in many localities around the Pacific and the Sea of Japan. However, only few coastal areas are studied in northwest to west Kyushu along East China Sea. Several researches on tsunami deposits are reported from west coastal area of Kagoshima Prefecture (Oshima et al., 2014). In this paper, researches of tsunami deposits in northwest coastal area in Kyushu are summarized.
Many core-samples from eight sites located in following three northwest coastal areas are studied; Genkai-cho and Karatsu City in Saga and Iki City in Nagasaki. Basis of variant examinations such as X-ray CT imaging, radiocarbon dating, sedimentary facies, fossil shell and microfossil analysis, regional sedimentary environments and events are studied. Those show several sedimentary events have been occurred at two sites of Minato-machi and Hamatama-machi in Saga.
In Minato-machi, event-sediments are recognized at two sites. From the radiocarbon dating data, two events ages are estimated to about 6,200 and 3,800 years ago. Those are composed of shell fragments in the intertidal-subtidal sedimentary environments of inner bay. 6.2 ka event sediment occurs imbricated fossil shell lived in the intertidal zone under the slightly deep water conditions. 3.8 ka event sedimentary structure is estimated to be a part of ripple-dune structure.
In Hamatama-cho, three event-sediments are recognized. From the radiocarbon dating data, three events ages are estimated to about 7,100, 2,200 and 2,200 years ago or later. Those are composed of following deposits in the intertidal-subtidal sedimentary environments of inner bay; shell and charcoal fragments, shell fragments-mixed coarse sand and gravely medium sand. Those are consisting of poor sorted silty medium sand, imbricated shell fragments and three normal grading layers each. Marine fossils and flow structures suggests all event-sediments have been formed by marine events. Because no simultaneous sediments in these events are identified at surrounding areas, those were local events probably. Currently, additional researches are continuing under the considering of the effects on depositional gaps and bioturbations.
In this presentation, additional data will be showed, the correlation of each regional event deposits will be discussed. And the comparison with previous works such as wash over deposits of 2,500 years ago in Kajikurihama ruin, west of Yamaguchi (Ichihara et.al, 2012) near the northwest costal area of Kyushu will be focused.
Acknowledgment : X-ray CT imaging was used the machine of Central Research Institute of Electric Power Industry.

Keywords: Tsunami deposits, Event deposits, Northwest coastal area of Kyushu

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The generation of tsunami deposit resulting from the 7.3 ka Kikai Caldera eruption along the Ishizaki River of northern Miyazaki Plain, southern Kyushu, Japan

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Many researchers have noted that the coast of southern Kyushu may have been struck by a huge tsunami before the Koya pyroclastic flow at the time of the Kikai Caldera eruption about 7.3 ka (Maeno et al., 2006), but there is currently no clear evidence of this. In 1996 Dr. Shinji Nagaoka created a large stripped sample during improvement along Ishizaki River, northern Miyazaki Plain, and Miyazaki Prefecture Museum of Nature and History have been kept it. According to Nagaoka et al. (1991), we analyzed Holocene stratigraphy near the Ishizaki River lowland using sedimentological, volcanological and micro-paleontological methods. Also we dated them using radiocarbon and tephrochronological methods. We already got some information about this tsunami event as bellow.
(1) The 7.3ka tsunami deposit is 28cm in thickness and consists of medium to coarse sand grain. This layer shows the high flow regime bedform like an antidune. Its base has a clear erosional surface, and covers the estuary mud layer. Pumice is at the bottom of the sand layer to be compared to Koya pumice is, on the other hand on the top include wood fossils are numerous. Sand layer is covered in reworked sediment in the water of the K-Ah volcanic ash. Thus the 7.3 ka tsunami struck Miyazaki coast only once between falling stages of Koya pumice and K-Ah volcanic ash. This event can be contrasted to the first of the earthquake events of the Akahoya period (Naruo and Kobayashi, 2002).
(2) K-Ah volcanic ash layer is 44cm in thickness, and convolute lamination is observed over the layer. As the cause of liquefaction, the second earthquake events of the Akahoya period (Naruo and Kobayashi, 2002).

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Keywords: 7.3 ka Kikai Caldera eruption, tsunami, tsunami deposit, Koya pamice, K-Ah volcanic ash, Miyazaki Plain

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Detection of tsunami sediment layers in southeast of Taiwan using Ground Penetrating Radar

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Surveys of tsunami sediments are important to reveal the history of paleo-tsunamis in Taiwan where damages by tsunamis have been rarely recorded in the old documents. Recently, investigation of the tsunami sediment has been made progress in the southeast of Taiwan (Ota, 2013; Lallemand et al., 2015). The regional distribution of the tsunami sediments would inform the run-ups of paleo-tsunami and sedimentary condition when the tsunami was inundated. However, large-scale trench survey is generally difficult to be carried out because of expensive cost and difficulties of agreement from residents. The remote-sensing survey method is required to trace the tsunami sediment layers nondestructively. We employed the Ground Penetrating radar (GPR) to detect the regional distribution of the tsunami sediment layers.

The GPR survey was carried out at Chenggong (north of Taitung) and Lanyu Island from August 27 to September 2, 2015. We surveyed using GPR equipment and carried out drilling using hand-auger to refer the layers. Used frequencies of GPR equipment are 500 MHz and 1 GHz. The maximum penetrating depth is about 1-2 m for the wet mud condition.

In the Chenggong, we carried out the surveys at middle terrace (asl. 18 m). From the survey at the terrace out of the Chenggong town, we could detect the undulation of boundary (between soil and mud layer) with the depressions of 20 cm at the depth of 50 cm. The fragments of the corals and shells deposited densely at the bottom of the depressions. These fragments could be detected by GPR profile as the diffracted body.

The GPR survey was carried out at Lanyu Island. We surveyed at northwest of Yayu village, southeast of Hongtou village, near the Yeyin village, and northwest of Langdao village at Lanyu Island. In the northwest of Yayu, we have set two long survey lines along the shore and four short survey lines perpendicular to the shore at the talus deposit near the shore. This site consists of three layers. The top layers consist of medium-grained sand with corals. From the previous study, the bottom of the first layer composed of the sand which was transported by typhoon or tsunami waves (Sakai 2015BS). The middle and bottom layer consist of mud and mud with gravel, respectively. The 3-D imaged boundary between first and second layer using the GPR profile shows that the boundary inclined gradually seaward.

In the southeast of Hongtou, we carried out the GPR survey at the talus (asl. 10 m) between coral terrace and mountain slope. We could detect the boundary among soil layer, sand layer, and the basement. Moreover, we could detect the diffraction by pebbles or gravels in the sand layer.

The results suggest that the detection of the tsunami sediments layer would be possible if the layer contains fragments of corals and shells.

Keywords: tsunami sediments, Taiwan , Ground Penetrating Radar

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Sedimentary characteristics of tsunami deposits made in wave flume

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The large-scale experiments on the formation of tsunami deposits was conducted in CRIEPI. This experiments is characterised by the very high-speed horizontal flows and the hydrological condition is more similar than that of previous experiments. We obtained core samples and peel samples from tsunami deposits. These samples show clear cross-shore variation of sedimentary structures of tsunami deposits.

In this presentation, we are going to show some actual peel samples and discuss local depositional characteristics of deposits observed in these peels.

Keywords: Tsunami deposit, Laboratory experiment, sedimentary structure

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Identification process and criteria of tsunami deposit

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Identification of tsunami deposit has frequently been discussed in many papers (e.g., Morton et al., 2007; Goff et al., 2012). This is because sedimentary features of tsunami deposit are usually similar to those of other deposits formed by storm and flood events. In this study, we compiled identification criteria and process of tsunami deposits based on the review of previous publications specifically from Japan. According to the previous papers, at first, the tsunami geologists usually identify an event deposit, which is defined as a deposit that was instantaneously formed during geological event (group X). Then, they further investigate whether any evidence of tsunami origin can be observed in the deposits. Based on the evidence, the deposits can be further classified into 5 groups (groups C, B, A1, A2, and S). Once the event deposit is recognized, presence of characteristic sedimentary features such as basement erosion and upward grading is evaluated (group C). Although these sedimentary features are not necessarily definitive evidence of tsunami deposit, they are typically observed in the recent tsunami deposit. The deposit is further evaluated if there are any materials that are characterized by landward sediment transport from the sea (group B). The deposit may show evidence of distinctive tsunami origin in some cases (group A1). For example, the deposit sometimes contains marine microfossils that were derived from the sea floor below the storm wave base (e.g., Uchida et al., 2010). Numerical modeling would also be strong tool to exclude the possibility that the deposit is formed by storm impact, although such analysis has rarely been conducted. Historical record is another useful tool to correlate depositional age of the deposit and historical tsunami (group A2). Such simultaneity in age are typically used to identify historical tsunami deposits especially in Japan since there are long historical records. Identically, the deposit can be identified as tsunami deposit if both geological and historical evidences are sufficiently collected (group S). Although identification criteria may be expanded in the future due to the progress of the research, the current compilation would be useful to consider the validity of tsunami origin of the deposits.

Keywords: tsunami deposit, identification criteria

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