Japan Geoscience Union Meeting 2014
(28 April - 02 May 2014 at Pacifico YOKOHAMA, Kanagawa, Japan)

MIS23-P07 Room:Poster Time:May 2 16:15-17:30

Historical tsunami deposits in Numanohama on the Sanriku coast, Japan

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We conducted tsunami deposit survey in a small valley along the Sanriku coast, Japan, just north of Taro (Miyako city, Iwate prefecture), where the 2011 tsunami heights from the Tohoku earthquake ranged from 17 to 34 m. We identified six tsunami deposits during the recent 500 yrs from the 3-m long Geo-slicer sample. The uppermost one is located on or just below the ground surface and probably from the 2011 Tohoku earthquake. The ^{210}Pb and ^{137}Cs dating analyses indicated that the 2^{nd} to 4^{th} uppermost tsunami deposits can be correlated with historical tsunamis: the 1960 Chilean tsunami, the 1933 and 1896 Sanriku tsunamis. According to Japanese historical documents, other candidate tsunamis since the 15^{th} century are from the 1793 Miyagi-oki earthquake, the 1763 and 1677 Aomori-oki earthquakes, the 1677 Boso-oki earthquake, and the 1611 Sanriku earthquake. Other trans-Pacific tsunamis includes the 1700 Cascadia tsunamis severe damage along the Sanriku coast and these tsunami deposits may be also preserved.

After the 2011 Tohoku earthquake, many surveys for tsunami deposits have been conducted in Sendai plain (Goto *et al*., 2011, Marine Geology; Shishikura *et al*., 2012, Annual Report on Active Fault and Paleoearthquake Researches). There are few reports of tsunami deposit studies along the Sanriku coast. Furthermore, depositional ages of many identified tsunami traces along the Sanriku coast were estimated to be several thousand years before present. The reasons for absence of recent tsunami deposits include that the Sanriku coast is a ria coast characterized by sawtooth-shaped coastline. Because of the steep-sloped valleys, alluvial deposits are very limited and tsunami traces are difficult to be preserved. Around the survey site, however, a marsh is separated from open sea by a beach ridge of $\sim$ 4m high. In this marsh, well-decomposed peat has been developed. The sand deposits were brought by large tsunamis over the beach ridge and preserved in the marsh peat. Our study is the rare case that the geological evidence of recent historical tsunamis was continuously identified.

To identify tsunami deposits, we sketched the sedimentary structure, measured the distribution of grain sizes, and analyzed the microfossils. Depositional ages of tsunami deposits were estimated on the basis of radiocarbon (AMS) dating and ^{210}Pb, ^{137}Cs analysis. The ^{210}Pb dating is useful to determine the depositional rate during the recent 100 years because of its short decay time (the half life time is 22.3 year). The ^{137}Cs dating is useful to judge whether the depositional ages are before or after the start of atmospheric nuclear experiments in AD 1954.

Peat and sand layers are alternated with their thickness of several centimeters to several tens centimeters. Each sand layer consists of beach pebble and sand or rock pieces from host rock in this area. The sand layers have structure characteristic to tsunami deposit: erosional contact, alternation of normal- and inverse-grading, lamination and thin mud layer sandwiched between two sand layers. The sand layer can be traced continuously along the landward transect. Abundant marine microfossils in the sand layers indicate that the sea water flow into the marsh with the tsunami sand.

The ^{14}C result shows that peat at around 3 m depth deposited after the 15^{th} century. The ^{210}Pb decay curve indicates that the deposition ages of the upper four tsunami deposit layers are during recent 100 yrs. The 2^{nd} uppermost tsunami deposit can be correlated with the 1960 Chilean tsunami because ^{137}Cs was detected down to this layer.

Acknowledgment
We thank Kazuomi Hirakawa and Javed N. Malik for giving useful comments and suggestions in the field. We also thank Jun Muragishi, Ryutaro Naruhashi, Satoshi Kusumoto, Akira Takigawa, Tsuyoshi Yamaichi and Ravi K. Parabhat for helping the field survey.

Keywords: Tsunami deposit, Sanriku coast