Urgent research on the impact of tsunami on the coastal geology: experiences and challenges of international research

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The purpose of the post-tsunami survey is to record the influences of the tsunami on society and the natural environment, in addition to the behavior of the tsunami such as wave height and inundation distance. The impact on the natural environment includes coastal erosion and sediment movement caused by the tsunami, and associated ecosystem changes. Among them, tsunami deposits composed of the various sizes of materials, which remain on the surface after the tsunami receded can become traces of the tsunami that will remain until later generations. Tsunami deposits provide a basis for knowing the recurrence feature of earthquakes accompanied by tsunamis and are also useful for long-term evaluation of giant earthquakes that cause low-frequency catastrophes. However, the identification of paleo-tsunami deposits is not easy. The reason is that not only the behavior of the tsunami on land is complicated, but also the distribution and sedimentary characteristics of the tsunami deposit depend on the topography, geology, vegetation of the coastal area, and season at the time of the tsunami. Besides, it is affected by weathering from the formation of the tsunami deposit until it remains in the soil. During the years when tsunami traces remain on the surface, they are exposed to rain and wind and are disturbed by flora and fauna. Also, after they are buried in new soil, chemical properties of groundwater and soil can cause the disappearance of microfossils which are valuable evidence that they are marine sand. For a reconstruction of the long-term history of the tsunami and earthquakes based on a small part of the tsunami deposit, we have to understand these processes and also know the conditions under which no trace of a tsunami remains. Therefore, it is important to collect information about modern tsunami deposits around the world, which are formed under various environments and are subject to weathering. I've been involved in 14 tsunami field surveys over the past 25 years. In some cases, we examined multiple locations with different environments for the same event, and sometimes we visited the same location repeatedly to observe the preservation and disappearance of the deposit. In the presentation, I introduce case studies, including the insights from surveys of the

Krakatau eruption tsunami in Indonesia in December 2018. Here, tsunamis of the same height form completely different sediments on the coral reef shore and the sandy beach near the river. The preservation potential of the tsunami deposit is confirmed to be very high in the forest. And following the modern tsunami deposits in the forest, traces of the 1883 tsunami that caused the worst volcanic tsunami disaster in the world have been found.

Significance of fundamental datasets for tsunami numerical modeling

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Tsunami numerical modeling has been playing a key role to evaluate tsunami hazards, such as wave height along the coastlines, inundation area and run-up height. The tsunami modeling is able to simulate sediment erosion and deposition, by means of coupled modeling of tsunami hydrodynamics and sediment transport. Such tsunami modeling can be used to assess the damages to the coastal environments and communities and to prioritize areas for emergency response and post-tsunami field survey.

Data on bathymetry, topography and sedimentary environments is the foundation to generate useful simulations. Since the tsunami can totally alter coastal environment, the data must be acquired prior to a tsunami event. Behavior of tsunamis is quite sensitive to the coastal bathymetry and topography, which often results in significant local variation in the wave heights. This is most evident in rocky indented shorelines, such as the southern Sanriku Coast. Preferable spatial resolution of the modeling may be less than ten meters, in order to reproduce tsunami run-up in narrow valleys. In case of a flat coastal plain with sandy beaches, such as the Sendai Plain, micro-topographies like beach ridges, swamps and artificial features sometimes give considerable effects to the processes of sediment transport and resulting morphological changes. To account for the effects from the micro-topography, sedimentary environments must be included in the model, in addition to high-resolution topography data. The sedimentary environments includes information on initial distribution, thickness and property of sediments and type and density of vegetation. Most important sediments property is the grain size.

The tsunami modeling requires such kind of data as indispensable inputs. Thus, high-resolution, accurate topography data with relevant information is required to generate meaningful simulations for assessing the tsunami impact. The Light Detection and Ranging (LIDAR) technique provides onshore topographic data with a horizontal

resolution of ~1 m and a vertical accuracy of ~0.1 m, which are being common for recent tsunami numerical modeling. It enables tsunami modelers to reproduce detailed spatial variation of tsunami height and inundation area, as well as distribution pattern of tsunami deposits. Availability of high-resolution bathymetric data, on the other hand, is limited typically in the neighborhood of major bays or harbors. If not available, the tsunami modeling inevitably employs accessible coarse bathymetric data with interpolation technique, which may introduce uncertainties in the simulations. Lack of information on the sedimentary environments is the additional source of uncertainties.

This calls for development of the fundamental dataset for the tsunami modeling, which combine coastal bathymetry and topography and sedimentary environments. The dataset will enhance our ability to assess tsunami impacts. Note that natural and anthropogenic processes, such as coastal sand drift and construction works, may alter the topography and sedimentary environments. Maintenance of the dataset with newly-acquired data is needed for the emergency use at the time of tsunami event.

Importance of post-tsunami geological survey for the future progress of paleotsunami research

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Paleotsunami history and size based on the geological studies provide us useful information for the hazard assessment of low frequency but large tsunamis. Moreover, it is important to know extreme tsunamis through the Earth's history which contributes to understand the nature of causative events such as asteroid impacts. Based on these motivations, many researchers have studied paleotsunami deposits worldwide. However, researchers always confronted the difficulties on the identification of paleotsunami deposits and the interpretation of their sedimentary process, because these are similar to those deposited by other water-related events such as storm surge and flood. To overcome these issues, understanding the sedimentary features and process of recently formed tsunami deposits are very important. Therefore, post-tsunami geological survey, which is conducted soon after the tsunami event, is a key to develop future paleotsunami research. Also, geologists can contribute recovery process and future tsunami risk assessment through the post-tsunami geological survey. In order to perform efficient survey within the limited time and ability during emergency situation, it is important to prepare a kind of manual about the survey procedures. In this presentation, current situation and problems of both paleotsunami and post-tsunami geological surveys are reviewed. Then, importance to prepare the manual for post-tsunami geological survey and its possible contents will be discussed.

Seismicity and Potential Seismic Hazard of Thailand: The need of high quality research work along the mountain slopes in Thailand.

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Thailand is surrounded by major plate boundaries but have been encountered with relatively small amount of moderate earthquakes in the past. Still, only a moderate earthquake can cause a major damage to the communities. For example, a magnitude 6.2 earthquake that occurred in Chiang Rai province in the Northern Thailand on 5 May 2014 caused damages to more than 15,000 building with degrees from minor damages to total collapse and yielded a total damage of US$300 million. Overall, the northern Thailand and the western Thailand have relatively higher seismic hazard compared to other regions. In addition, as most the mountain ranges are located in the northern and western Thailand, these areas are susceptible to the effect from the earthquakes occurring in the region especially slope stability during the rainy season. There is a need for high quality research work along the mountain slope in Thailand to make local communities safe and ready for landslides and flashfloods. Southern Thailand also have potential hazards for landslides in the mountains, moderate earthquakes and tsunami.

This talk will cover for seismic hazard and active faults studies and the earthquake mitigations of Thailand along with seismicity and major historical seismic events in Thailand. Overviews of other natural geological hazards such as landslide and land subsidence will also be included. The talk will also cover a case study of the hazard in the mountain for the case of Tham Luang Cave Rescue Operation in 2018 when the Thai boys soccer team and their coach were trapped in Tham Luang Nang Non cave in Chiang Rai Province, Thailand to show how important geoscientists from various fields can assist the society during the natural crisis.