# White paper for Geohazard (Submarine landslides and mass movements) at INVEST09 from Japanese research group

A submarine landslide team of The Japanese planning group for Geohazard science at IODP*

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## Abstract

The aim of this white paper is to decipher the fundamental formation processes of submarine landslides and mass movements (SLM) associated with earthquakes (and other reasons, e.g. gas hydrate melting, tectonic movements etc.). Our working hypothesis is that topography of slope, pore fluid pressure and physical properties of sediments are only three factors to generating the earthquake-related SLM. It means that all earthquake-related SLM do not need necessarily predefined weak planes before sliding. Materials of SLM before sliding include natural heterogeneity such as strata, discontinuities, and deformation structures. When the fluid pressure increases and exceeds the shear strength in sediments on account of earthquake shaking, consequently fluid migration increasing of pore fluid pressure beneath a low permeability layer, the materials slide along one of such surfaces if the slopes were just before gravitational instability. In this hypothesis, heterogeneity in sediments strongly constrains the very locality of the horizon of high fluid pressure and slip surfaces. The seismic vibration may also significantly reduce the cohesion along the surfaces and elicit weak planes as result. Topography of slope plays important roles in 1) shear force along the slip plane and 2) size of submarine landslides. This hypothesis may also be applied to additional mechanisms of submarine landslides to methane hydrate decomposition, sedimentation loading, erosion processes and so on, which are believed to be common elsewhere.

## Overall eight Questions:

### What are the major hypotheses and unanswered questions in your topic? Describe the global relevance of those questions.

## Major hypothesis

**[Pore fluid pressure, physical properties of sediments, and topography are only three factors to form submarine landslides]**

Rock body that constitutes slopes includes discontinuity and heterogeneity (e.g. bedding, fracture and fault planes) without exception. If earthquakes occur, the existing discontinuity would be weakened due to liquefaction and/or redistribution of pore fluid derived from earthquake shaking. Increase of pore fluid pressure occurs decrease of frictional resistibility in the existing discontinuity. One of the existing discontinuities may be developed into a slip plane in the rock body, and consequently the rock body would slide gravitationally.

Kokusho and Takahashi (2008) proposed that if pore fluid pressure increases rapidly in the strata due to earthquakes or other triggers, pore fluid would concentrates beneath low permeability layers. In a horizon beneath the low permeability layer, the pore fluid pressure should increase drastically, and the horizon is linked each other to be a water film (Kokusho and Takahashi, 2008). The water film having high pore fluid pressure could be a slip plane of the submarine landslide. Thus, slip planes of submarine landslides are probably formed due to increase of pore fluid pressure.

The horizon of the water films is constrained by physical properties of sediments, particularly permeability of sediments. Location of low permeability layers decides the location of slip planes. Topography plays an important role in shear stress on the slip plane. Also topography is constrained size of the submarine landslides. Amount of gravitational unstable materials before sliding are dependent on strongly topography.

## Major unanswered questions

What is a major trigger of submarine landslides?
What determine sizes of submarine landslides?
Where do submarine landslides occur?

These questions were discussed at the Geohazard Workshop 2007, in Oregon, but still not answered clearly.

## Which of these represent the highest research priorities that can realistically be achieved in the next decade?

A trigger (or triggering mechanism) each submarine landslide needs to be understood. Previous studies have proposed several triggering mechanisms to make submarine landslides, such as earthquakes, wave loading, tides, sedimentation, gas, loading due to glaciations, erosion and diapirs (Locat and Lee, 2002). Our hypothesis is “slip surfaces are initiated by increase in pore fluid pressure”. We want to understand how the pore fluid pressure responds to these triggering mechanisms by long-time monitoring of pore fluid pressure. We choose carefully monitoring horizons on the basis of slope stability analysis and/or computer simulation methods to seek candidates of slip planes. Weak planes in a rock body may be one of interests on monitoring. Long-time monitoring of pore fluid pressure using boreholes will bring answers to the hypothesis (see Fig. 1).

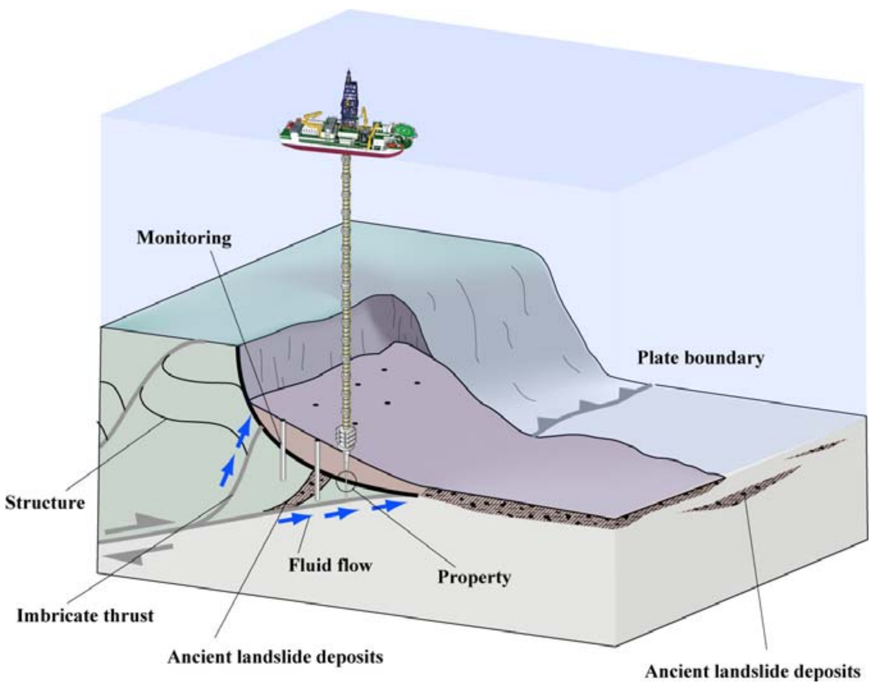


Fig. 1. Deep-sea drilling and submarine landslides, at deformation front of an accretionary prism.

What drilling, sampling, experimental and site characterization strategies are required to achieve your goals?

In order to monitor the pore fluid pressure, we need to install sensitive pressure gauges and pressure-resistive tilt meters into boreholes. At some giant submarine landslides (Hawaii Island), target depths to set the tools may be deeper than 1000 mbsf.

Detailed site survey plays an important role in study about submarine landslides. The site survey data give us exact location of scarp of submarine landslides, depositional basin and its forms of mass movements. Since the Nankai region is the most well-studied subduction margin in the work and has finished 3-D seismic surveys, a number of single channel seismic surveys, series of drilled core studies, massive piston coring surveys, and systematic submersible surveys, this region should be the highest research priority area that can realistically be studied in the next decade. Despite the site survey is expensive and funding from the IODP and other organization is limited, we need many case studies including surrounding site survey dataset to understand mechanisms and processes of formation of submarine landslides.

Furthermore, the Nankai trough where repeats subduction great earthquakes historically, and accretionary prism is developed. The balance between sediment accretion and surface landslide is important factor for accretion tectonics to keep prism shape in critical taper model (Davis, et al., 1983). Many submarine landslides are observed at toe of the Nankai accretionary prism. If a basal fault of the landslide connect with the plate boundary fault, the landslide may happen concurrent with plate subduction earthquakes. The understanding of timing, structure and distribution of ancient landslide will contribute not only disaster evaluation but also accretion tectonics in plate subduction zone.

## What are your platform and technological needs?

In general, non riser drilling may work. In case of coastal submarine landslides, mission specific platform may be called for shallow water drilling.

## What mix of long-term projects and single expeditions will best answer these questions?

A series of single expeditions in different regions is required for comparative study to understand basic mechanism of submarine landslides. Each expedition should consist of a series of drill holes at a large slide and surrounding smaller slides under the same geologic environments.

## How can the future drilling program interact with other science programs and with industry to achieve your goals?

1) Submarine landslides play an important role in formation of tsunamis as shown in Fine et al (2005) and other studies. Around Japan, however most of the submarine landslides tend to be in small size, probably because small-scale slope failures have occurred frequently due to repeated earthquake shaking, thus tsunami may not have occurred by single submarine landslide. Submarine landslides, however, can enlarge the size of tsunami if their timing is synchronized with the ocean floor motion. Thus, we have to collaborate with research groups of tsunamigenic deposits on land and also groups of computer simulations.
2) Information between continents strongly depends on submarine cables (e.g. internet, e-mail, economic business, social security and so on) thus the cables are one of the basic infrastructures in our society. Submarine landslides have repeatedly broken submarine cable systems in several places. An earthquake of 26/Dec., 2006 in Taiwan (M =7.0 and M = 7.1) generated submarine slope failures and subsequent turbidity currents, broke submarine cable systems (Soh and Machiyama, 2007). In 1929, turbidity currents cut cables in Grand Bank, New foundland, after a slope failure triggered by a large earthquake M=7.2 (Heezen and Ewing, 1962). Protection of the submarine cable

systems is of a highly demand for cable companies and governmental organizations, thus there is potential to collaborate with them.

## What hot topics can be highlighted to be used for outreach and raising the public's interest?

Answers of this question are same as the previous questions. In Japan, tsunamis caused by submarine landslides may have large impact, because our country has been damaged by large Tsunamis in the past. Nowadays we have mega cities, nuclear power plants, airports, and many structures in the coastal areas. Protection of such structures has high priority in disaster mitigation.Protection of submarine cable system is another topics of large impact. Our society significantly depends on submarine cables and conservation of benthic ecosystem is also important (see above).

## How are your science goals relevant to society?

When we understand the basic mechanism of submarine landslides with our hypothesis, i size, timing and location of future possible submarine landslides could be assessed. These must be of high interests of the public.

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