Seafloor instability processes and products on the active Hikurangi margin

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Submarine landslide complexes and mass-transport deposits (MTD's) occur widely across active margins affected by many forcing factors including earthquakes; sediment loading; gas hydrates; tectonic deformation and slope undercutting. The Hikurangi Margin is no exception, reflecting the tectonically dynamic nature of the margin and a voluminous terrigenous sediment supply during both glacial and interglacial stages. Documented slope failures range in size from the margin scale Ruatoria collapse at 10^{12} m^3, widespread failures in submarine canyons with volumes as low as 10^5 m^3, to discrete earthquake-triggered turbidites only centimetres in thickness. The products of submarine slope failures – MTD's – are widely preserved in slope basins imaged with seismic reflection data.

Landslides have a role in margin evolution, influencing canyon development, cross-slope sediment transfer activity and accretionary processes. Studies indicate that landslides pose a potential hazard to New Zealand coastal populations, particularly where submarine canyons encroach across the shelf to within close proximity of the coastline. Current seafloor instability research addresses key aspects of the spectrum of global questions relating to submarine landslides. 1) What are fundamental processes that control slope mass movements? 2) What is the hazard to coastal populations from submarine landslides? 3) What information can the downslope deposits from submarine landslides (turbidites) contribute to the paleoseismic record?

Analysis of submarine landslides and related processes link to the *New Zealand Primary Site GeoPRISMS Implementation Plan* directly in terms of *Section 2.4.4/D* for paleoseismic studies, and indirectly in terms of the wider efforts to understand upper plate stratigraphy and climate influences. Seafloor instability processes are likely to be a significant ancillary topic based on datasets collected for other purposes (e.g. 3D multichannel seismic reflection data to image the Hikurangi subduction thrust). In the following paragraphs we outline ongoing research that links with several active and proposed international initiatives.

To address process controls on mass movements, a comprehensive effort is in motion to understand the role of gas hydrate in slow moving or creep slope failures – a new mechanism of submarine slope instability as yet only identified on the Hikurangi Margin. Downslope creep-deformation of ice-sediment mixes occurs widely on earth as rock glaciers, and has been proposed for other planets. In the submarine environment such processes are unknown, and to date few examples of slowly-deforming sediment bodies have been documented; however there is strong evidence that gas hydrates cause "creeping" in a well imaged, slowly deforming submarine landslide off the east coast of New Zealand's North Island (Figure 1). This constitutes a fundamental shift for the role of gas hydrates in seafloor stability as hydrates are directly weakening the seafloor on short timescales, as oppose to the widely cited model of temperature controlled dissociation causing failure on a glacial-interglacial time frame. To investigate this mechanism several field campaigns are proposed. 1) 3D P-Cable seismic reflection data across the landslides in collaboration with Geomar and the University of Kiel. 2) Coring using Marum's MeBo robotic drilling technology to sample and analyse landslide debris and adjacent sediments. 3) An APL to IODP proposal 781A (which is proposed adjacent to this landslide complex) will be submitted to collect in-situ hydrate samples from the landslides, and to undertake LWD to characterize the failed sequence.

Towards the southern margin, two initiatives are currently underway focused on landslide-generated tsunami hazards. In the Cook Strait, a multi-year project is focused on quantifying the probabilistic landslide tsunami hazard from landslides within the shelf indenting canyon to the coastal areas of central New Zealand. Initial modeling of previous events shows that landslide-tsunami can generate waves up to 5 m in populated coastal areas. This work addresses major questions related to the hazard from landslides in complex submarine terrain. Whereas many landslide-tsunami models allow landslide debris to run down an infinite slope, our results show that interaction with opposing canyon walls significantly affects tsunami generation and focusing. Submarine canyons are the principal means by which large scale seafloor slopes approach the coast around the globe – Cook Strait's Nicholson Canyon occurs 10 km off Wellington airport and drops from 100 to 500 m water depth. To the south, Kaikoura Canyon is another major canyon system which is incised to c. 0.5 km from the coast. A 0.25 km^3 incipient earthquake-triggered failure in this canyon head has been modeled to generate waves up to 13 m high and, with a very high littoral zone sediment input, may reoccur on c. 200 yr timeframe. Work is currently in progress applying state-of-the-art geophysical and sediment analysis techniques to understanding the actual nature of the unstable sediment. Depending on these results, proposed future work includes in-situ geotechnical analysis, stability modeling and a re-evaluation of the tsunami hazard and risk related to the sediment failure scenario.

At many active continental margins, off-fault submarine paleoseismic records have been interpreted from turbidite sequences recovered in cores. The application of turbidite paleoseismology techniques is ideally suited to continental margins where turbidites have been emplaced into a steadily depositing background sequence of hemipelagic or pelagic sediment, and where tests can be drawn for regional event synchronicity, sedimentology, and correlation with existing earthquake records. Identification of turbidites from high-resolution stratigraphic records, their chronology and provenance allows tectonic and climate signals to be deciphered. For the eastern North Island, there are no paleo-earthquake records unambiguously originating from a rupture along the Hikurangi subduction zone, but paleotsunami deposits and co-seismic uplifts associated with upper plate earthquakes have been recognised. On the Poverty continental margin, 67 synchronous turbidites were described by Pouderoux et al. (2012) that span the last 18,000 yrs resulting from earthquakes, with a mean return time of ~230 yr, with a 90% probability range from 10–570 yr. The earthquake chronology indicates cycles of progressively decreasing earthquake return times, from ~400 yr to ~150 yr at 0– 7 kyr, 8.2–13.5 kyr, 14.7–18 kyr. The two 1.2 kyr-long intervals in between (7–8.2 kyr and 13.5–14.7 kyr) correspond to basin-wide reorganisation of the Poverty slope seascape, reflecting the emplacement of two large MTD's. These and other buried MTD's form the greater percentage of mid-slope basin fill at this location highlighting the important role mass failure processes have in margin building and large scale cross-slope mass flux.

The Hikurangi margin exhibits a hugely varied range of mass-transport and seafloor instability processes and large scope exists for increasing understanding of globally relevant fundamental landslide processes and hazard implications. There is significant scope to develop new collaborative projects, and also to integrate with complementary proposals that will collect data relevant to landslide, MTD and turbidite-paleoseismicity research.

References:

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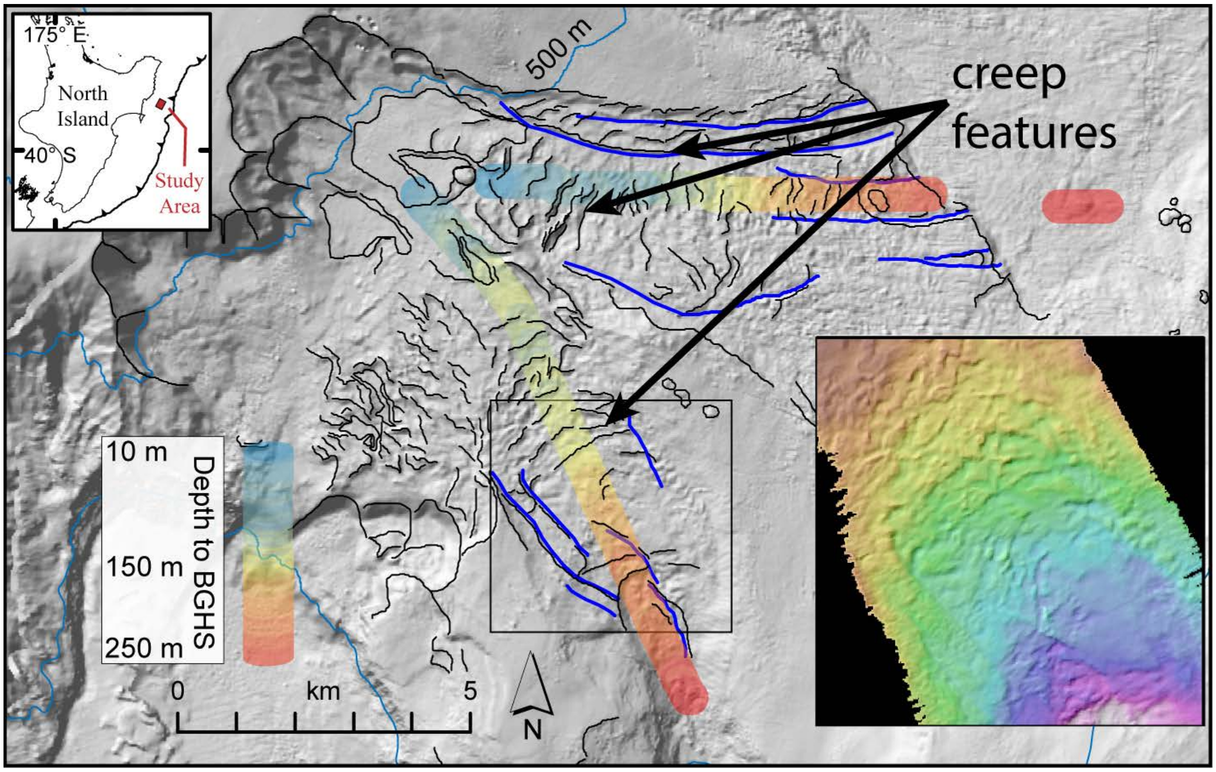

Figure 1. Creeping slope instability complex on New Zealand's East Coast. The slow deformation of this landslide is proposed to be controlled by gas hydrate occurring within the landslide debris. After Mountjoy et al. (in review).