Part I

Submarine Landslides and Tsunamis

Introduction by Roger Urgeles[1], Paolo Mazzanti[2], and Jacques Locat[3]

1) Dept. Geologia Marina, Institut de Ciencies del Mar (CSIC), Barcelona, Spain
2) Dipartimento di Scienze della Terra, "Sapienza", Università di Roma, Rome, Italy and Università di Roma, NHAZCA S.r.l., spin-off "Sapienza", Rome, Italy
3) Dep. de geologie et de genie geologique, Université Laval, Québec QC, Canada

Submarine landslides are as common as their subaerial counterparts, yet they might be orders of magnitude larger. Because of the lack of direct observations and inaccessibility of the marine environment, little is known of recurrence rates, trigger mechanisms, pre- and post-failure geotechnical conditions, and the role of landslide processes in delivering sediments to deep water. Nevertheless, increasing development of seafloor-based (offshore platforms, telecommunication and energy transport facilities, . . .) and coastal infrastructures ask for better knowledge of seafloor stability conditions, submarine landslide processes and subsequent effects such as tsunamis. Session L22 at the second World Landslide Forum presented recent advances on our understanding of submarine landslides in-line with the objectives of the UNESCO-IUGS' project IGCP585 (http://www.igcp585.org).

Modern Marine Geophysical and Mapping Techniques

The session showed how modern marine geophysical and mapping techniques might be useful in identifying the variety of features associated with offshore slope failure and associated mass transport deposits, some of them affecting areas of high ecological and environmental value such as the Great Barrier Reef (George et al. 2011). Examples from Uruguay and the NW African Margin (Krastel et al. 2011) and the Northern Sicilian margin (Sulli et al. 2012) show how changing environmental factors couple to control the styles of submarine slope failures and derived tsunami hazard. Extensive mapping efforts do not only show the distribution of previous landslides; they may also give indications on destabilizing conditions as pockmarks, steep slopes and signs of erosion. Detailed seafloor maps provide an important framework for susceptibility mapping and for further landslide hazard and risk assessment (Hansen et al. this volume). Furthermore, detailed mapping maybe the "reference level" for future monitoring of seafloor changes.

Offshore Failure Catalogues

Mapping efforts provide the base for establishing offshore failure catalogues. These are useful to understand the role of the geological structure (or setting) in controlling the patterns, frequency and magnitude of submarine slope failures. An example of catalogue for the Mediterranean Basin showed that most submarine landslides originate in water depths exceeding 2,000 m on slopes of less than 2° indicating that the continental rise, at least in this region, is a place of increased slope instability (Urgeles et al. 2011). The little constraints on ages of most events suggest that a large number of them occurred during the Holocene, indicating that climate induced stress changes (sea level and bottom temperature changes and their effect on gas hydrate and gas systems, sedimentary load,. . .) have had a major role in triggering slope failures (Urgeles et al. 2011). A second example with historical landslides from Norwegian fjords and lakes showed that in this environment landslides are often triggered by human activities (L'Heureux et al. this volume). In this setting the time of occurrence frequently corresponds with periods of unfavorable groundwater conditions (e.g. heavy rainfall, snow melt, and tidal drawdown; L'Heureux et al. this volume).

Pre-conditions and Trigger Mechanisms

The marine environment requires dedicated attention because some of the pre-conditions and trigger mechanisms are unique to this environment. In volcanic ocean islands, the physical and geomechanical characteristics of submarine hyaloclastite materials forming the base of the emerged volcanic edifices have low strength and high deformability properties (Ferrer et al. this volume). These rocks therefore play a fundamental role on the stability of the island flanks. Lafuerza et al. (2011) also showed how Quaternary sea level variations were possibly at the origin of gas exsolution, increased pore pressure and submarine slope failure initiation in gas-rich marine sediments.

Modeling the Motion of Submarine Landslides

Modeling the motion of submarine landslides is of critical importance to understand their extremely long runouts, their impact on seafloor structures and tsunami generating potential and to highlight defense interventions and remediation strategies. Results presented at the session indicate that the permeability of the matrix in subaqueous rock avalanches plays a key role in their dynamics (De Blasio this volume). Analysis of past deposits also shows that subaqueous rock avalanches are not as mobile as subaqueous debris flows (De Blasio this volume). Also the presence of larger blocks plays an important role in the dynamics of subaqueous rock avalanches. A model for the rock mass disintegration during flow in the two environments (subaerial/submerged) shows the importance of fragmentation in controlling the propagation phase of rock-avalanches (Mazzanti and De Blasio this volume). Laboratory experiments are also useful to understand the impact of submarine landslides and derived gravity flows on offshore installations such as cables and pipelines (Wang et al. this volume). The session showed numerical approaches to post-failure evolution using cellular automata (Avolio et al. this volume) and finite element modeling codes (Crosta et al. this volume) for coastal and lacustrine landslides and impact on the corresponding water bodies (Crosta et al. this volume).

Coastal/Submarine Landslides and Tsunamis

In this regard, understanding the relationship between coastal/submarine landslides and tsunamis is critical to mitigate the risks. Indeed, results presented at the session indicated that three tsunamis in eastern Sicily and southern Calabria were all chiefly initiated by earthquake induced mass failures (Billi et al. 2011). Establishing landslide scenarios is critical to understand the characteristic of the generated tsunami (i.e. travel time, periodicity, first signal polarity, wavelength) and their relation to coastal geohazard (Planinsek et al. 2011). When submarine slope failures have occurred in historical times, such as the 1888 shoreline landslide and tsunami in Trondheimsfjorden, central Norway (Glimsdal et al. this volume), they might be useful in validating models of landslide dynamics and tsunami initiation for older events or as benchmark for future scenarios.

Conclusion

The session highlighted that the threats posed by submarine landslides to human require an integrated approach taking into account all of the aspects highlighted above (Vanneste et al. this volume). In particular further research and development is needed to improve technologies for imaging the sub-surface as well as geotechnical data on high-quality soil samples. Long-term measurements that can capture pore pressure, deformation and other transients in underwater slopes are also necessary. Improved understanding of submarine landslides dynamics is required for developing numerical models that are also a key to improved tsunami modeling (Vanneste et al. this volume).

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