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Earthquake-induced submarine slope-failure in the Cretan Sea, eastern Mediterranean

F. Strozyk (1), M. Strasser (1), S. Krastel (2), A. J. Kopf (1), A. Förster (1), and K. Huhn (1)

(1) MARUM, Centrum for Marine Environmental Sciences - Cluster of Excellence: The Ocean in the Earth System, University of Bremen, D-28359 Bremen, Germany (strozyk@uni-bremen.de), (2) IFM-GEOMAR, Leibniz Institute of Marine Sciences, Cluster of Excellence: The Future Ocean, Christian-Albrecht-University Kiel, D-24148 Kiel, Germany

Large-scale gravitational mass-transport processes are of significant interest as leading agents for submarine landscape evolution, sediment mass-transfer and the evolution of sedimentary systems. In active tectonic environments, subaquatic mass-transport deposits (MTDs) also can be used to make inferences regarding the impact of triggering mechanisms (e.g. earthquakes, rapid oversteepening) and pre-conditioning factors (e.g. sedimentation, long-term slope steepening) on slope failure initiation. This study aims on the conceptual understanding of the frequency and associated triggers of gravitational mass transport at an active continental margin in the eastern Mediterranean. We investigate geophysical data and gravity cores retrieved during R/V Poseidon cruise 336 in 2006 (CRESTS) in the southern Cretan Sea. Here, we identify several large-scaled MTDs and their head-scars along the north-eastern Cretan mid-slope and compare their recurrence to the impact of neotectonic activity of the surrounding Hellenic subduction zone.

Accumulation rates from core data of draping sediments, overlying the youngest MTD, indicate it to be older than 50 ka B.P., while recurrence intervals about 50-300 ka are estimated for older landslides. Therefore, slope failure events occur less-frequent in comparison to the high repetition rate of earthquakes in this area. Geotechnical tests on gravity cores reveal a generally mud-rich, consolidated, cohesive sediment column with high shear strength. Steep and sharp headwall geometries and gliding of intact blocks at head-scars indicate high cohesion also in deeper strata. In contrast, several imbedded sapropels with slightly reduced shear strength and ash-layers with a potential for liquefaction can constitute preferred glide planes of landslides. To reconstruct the observed slope destabilizations and to quantify the influence of seismic ground acceleration, measured data are implemented into a pseudo-static limit equilibrium model, which is used for back-analysing slope stability under seismic loading conditions. Results reveal high Factors of Safety, and thus stable conditions for the upper 75 m of the sediment column under static and moderate seismic loading conditions. Triggering of failure requires high ground accelerations of at least 27%g from a high-magnitude earthquake. The rare occurrence of such ground accelerations in combination with the mechanical characteristics of slope sediments may explain the slope's long-term stability in between massive landslide events. We postulate that casual slope over-steepening due to regional fault activity in combination with spontaneous weakening of one of the assumed sapropels or ash-layers in depth during a high-magnitude earthquake event are the most likely triggering mechanisms of observed slope destabilization.