Sediment failure of St. Pierre Slope: new insights of failure mechanisms and slope instability due to the 1929 Grand Banks Earthquake

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The 1929 Grand Banks submarine landslide was triggered by a Mw 7.2 strike slip earthquake on the southwestern Grand Banks of Newfoundland. Studies following the event by several decades were the first to recognize that slope failure can cause tsunamis. These studies identified St. Pierre Slope as the main failure area and showed widespread, shallow (<25 m-thick), translational and possibly retrogressive sediment failures occurred predominately in >1700 m water depth (mwd). It seems unlikely this style of failure in deep water generated a tsunami that had >13 m of run-up along the coast of Newfoundland. The objective of this study is to identify possible alternative tsunami source mechanisms and pre-conditioning factors that may have led to sediment instability. These objectives are addressed using a comprehensive data set of multiscale 2D seismic reflection, multibeam swath bathymetry and laboratory geomechanical test data. Results show numerous reflection offsets within the Quaternary section of the slope underneath modern seafloor escarpments (750-2300 mwd). These offsets appear down to 550 m below seafloor (mbsf) and are interpreted as low angle (~17°), planar-normal faults of <100 m-high vertical and ~330 m of horizontal displacement. The faults are interpreted as part of a massive (~560 km³) complex slump with evidence for multiple décollements (250 mbsf & 400-550 mbsf) and slumping in at least two directions. Infinite slope stability analysis using peak ground acceleration (PGA) indicates that a combination of earthquake loading and the presence of geomechanical weak layers are needed to explain the slope failure. At St. Pierre Slope, the analysis of sediment cores shows that geomechanical weak layers form as a consequence of underconsolidation in connection with excess pore pressures that are related to: 1) high sedimentation rates, 2) instantaneous deposition of mass transport deposits (MTD's) and sandy turbidites, and 3) the presence of gas. The décollements of the slump are associated with MTD's and sediment waves that likely form weak layers. The layers of sediment waves are assumed to consist of sorted silts or fine sands and are therefore likely to be susceptible to excess pore pressure development during earthquake loading. Excess pore pressure development results in reduced effective stress and higher potential for instability. It is interpreted, therefore, that the 1929 earthquake triggered displacement of a 550 m-thick slump with ~100 m of vertical seafloor displacement. This
instantaneous displacement of the slump in 750 mwd with a seafloor volume displacement of 70 to 130 km² is likely a more effective source for tsunami generation than the translational, shallow (<25 m) failures in deeper water.