Analyse of the Tarapaca paleolandslide (North Chile) using generalized Newmark approach and implications on present-day large scale landslide

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Landslides much larger than today's are not uncommon in the geological record, and are observed in arid or hyperarid areas where a good preservation allow detailed analyses of their geometrical and mechanical characteristics. Should such large-scale landslides be possible today, much larger devastations than caused by the present-day's greatest registered events could be expected. One way of checking this possibility is to determine the magnitude and site-to-source distance of the seismic event necessary for the landslide to form using Newmark permanent displacement analysis (see e.g. Jibson & Keefer, 1993). One of the limitations of the conventional Newmark's method is to consider ground acceleration as parallel to the slope, and downslope. A generalized Newmark analysis (Ingles et al., 2006) has been developed where ground acceleration is not slope-parallel and the ratio of vertical to horizontal acceleration depends on the seismic situation of the slope (magnitude, earthquake source distance, style of faulting). As a consequence, the seismic horizontal critical acceleration is in most cases lower than Newmark's critical acceleration and the displacement greater than calculated from Newmark analysis. The difference may be considerable and result in significant consequences, particularly for low-angle slopes with potential deep shear surfaces that are located close to the source of large earthquakes. Therefore, Arias intensity and the magnitude of earthquakes necessary for large-scale landslides to occur may be lower than expected from the traditional Newmark approach.

This approach has been applied to a large-scale paleo-landslide, the Tarapaca landslide, observed in the Atacama Desert, northern Chile, which is one of a series of large-scale landslides formed on the forelimb of a $\sim$400 km long west-vergent thrust fault-propagation fold known as the Moquella flexure (Darrozes et al., 2002). The landslides postdate the initiation of a well-preserved drainage network dated of 4.5 Ma. The triggering mechanism of the Tarapaca paleo-landslide was studied by constraining the mechanical and physical characteristics of rocks, slope value, climatic changes and seismic activity.

This analysis combined with that of the tectonic context indicates that the greatest probability of landslide formation requires either high-magnitude shallow earthquakes situated along the Moquella thrust zone not seismically active today (moment magnitude Mw 7.3 at $\leq$15 km to the landslide) or very high magnitude earthquakes situated along the still active subduction plane (Mw8.4 to Mw9.2 at 50 to 120 km to the landslide). As a comparison the conventional Newmark analysis would have given moment magnitudes of Mw 7.8 and Mw 8.8 to 9.6, respectively, and unrealistically high Arias intensities.