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Landslide mechanism, geomorphic change and surface process: evidence from earthquake-triggered Tsaoling avalanche

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The Tsaoling rock-and-soil avalanche is the largest landslides triggered by the Chi-Chi earthquake (Taiwan, 1999). Beside of the Chi-Chi earthquake event, four giant landslides have been historically documented since the late 19th century in this area. Because of its unique geological conditions and periodic reoccurrence of gigantic slides, instruments installed and aerial photo scans regularly around the Tsaoling area. In addition to detail and extensive field observations, several Digital Elevation Models (DEMs) generated from sets of aerial photos before and after landslide have also been utilized to document and measure the coseismic and post-seismic geomorphologic changes.

The major sliding surface is situated between two massive sandstones by a metric friable fine layer composing of fine layered shale, silty mudstone and interlayered beds, and is characterizing by a smooth, gentile and planar surface. The major slid mass situated on the upper slope, is an isolated hill and been daylighted. The estimated volume of the initial rocke avalanche is about 125.5 Mm3 and 138 Mm3 for the depleted and accumulation zones, respectively, indicating an increase in volume due to fragmentation. The average thickness was about 150 - 170m, up to 195m thick of the slid mass. Whereas about four fifths of the slid mass transport across the river and deposit around the Taochiashan hill. The hill, composed of rock debris generated by the previous events, is about 140m higher than the Chinshui riverbed before the earthquake. The transported debris was about 30 - 90m thick, covered on the preexisting debris deposit hill and around the river channel. The debris formed a dammed lake, with a maximum volume of 45 Mm3.

The landslide debris merged the river channel and forming a dammed lake. Due to high annual rainfall, several severe impacts by typhoons and abundant landslides upstream, the subsequent topographic evolution is a more dramatic phenomenon on this site. On the slid area, much of the debris rested onto the sliding surface transported down slope. The minor scarp line retreat upslope-ward up to 120m and generates land erosion about 2.7 Mm3, thicker than 30m, in a relatively small area. On the deposit area, the strong river erosion affects the area by an overall volume over 72 Mm3 around the river channel. However, soon after the lake was filled, small river channels developed on the surface of the sediment and became incised. On 2009, the Chinshui stream demonstrates the power of river incision which affected the filled lake, with a river channel deeper than 50m. It is worth noting that a flat river terrace was generated by the incised river course. The formation of the river terrace as part of the evolution of a landslide dam is thus different from the general concept related to tectonic uplift. The above-mentioned dramatic surface processes demonstrate high denudation rate and landform evolution in an active orogenic belt.