

## **Distant, delayed and ancient earthquake-induced landslides**

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On the basis of a new classification of seismically induced landslides we outline particular effects related to the delayed and distant triggering of landslides. Those cannot be predicted by state-of-the-art methods. First, for about a dozen events the 'predicted' extension of the affected area is clearly underestimated. The most problematic cases are those for which far-distant triggering of landslides had been reported, such as for the 1988 Saguenay earthquake. In Central Asia reports for such cases are known for areas marked by a thick cover of loess. One possible contributing effect could be a low-frequency resonance of the thick soils induced by distant earthquakes, especially those in the Pamir – Hindu Kush seismic region. Such deep focal and high magnitude ( $>7$ ) earthquakes are also found in Europe, first of all in the Vrancea region (Romania). For this area and others in Central Asia we computed landslide event sizes related to scenario earthquakes with  $M > 7.5$ .

The second particular and challenging type of triggering is the one delayed with respect to the main earthquake event: case histories have been reported for the Racha earthquake in 1991 when several larger landslides only started moving 2 or 3 days after the main shock. Similar observations were also made after other earthquake events in the U.S., such as after the 1906 San Francisco, the 1949 Tacoma, the 1959 Hebgen Lake and the 1983 Bora Peak earthquakes. Here, we will present a series of detailed examples of (partly monitored) mass movements in Central Asia that mainly developed after earthquakes, some even several weeks after the main shock: e.g. the Tektonik and Kainama landslides triggered in 1992 and 2004, respectively. We believe that the development of the massive failures is a consequence of the opening of tension cracks during the seismic shaking and their filling up with water during precipitations that followed the earthquakes.

The third particular aspect analysed here is the use of large ancient landslides for paleoseismic studies. As Central Asian mountain regions are marked by a relatively high ratio of seismically versus climatically triggered landslides, they represent a prime test area for such studies. This observation is contrasting with known landslide activity in Europe where by far most landslides are triggered by climatic factors, besides for some seismically active regions in the Eastern Alps, around the Mediterranean Sea and in the Carpathians (Vrancea, Romania). We will discuss how we may identify such earthquake-triggered landslides and how we may distinguish them from rainfall-induced slope failures.