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Empirical correlation between earthquake magnitude and the volume of the largest landslide and its application for paleoseismicity study and estimating earthquake induced topography changes

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The evolution of paleoseismological studies clearly demonstrates that in order to properly understand the seismic potential of a region, and to assess the associated topography changes, extensive studies are necessary to take full advantage from the geological evidence of past earthquakes. A major line of paleoseismic investigation is detailed study of coseismic effects in the natural environment and quantitative assessment of the topography changes depending on earthquake magnitude.
So far most of research has focused on coseismic fault motion. The seismically induced landslides have been used mainly for establishing epicentral zones and the timing of old earthquakes. But earthquake triggered landslides are one of the major contributors to the damage and causalities associated with earthquakes. Seismically induced landslides are especially important agents of denudation in tectonically active zones. They are also great sources of information about seismic event. On the other hand earthquakes are one of the major causes of landslides. So it is desirable to quantify the landslide-earthquake association.
A first step in this way was taken by Keefer (1994) who obtained an empirical relationship between earthquake magnitude and the total volume landslides triggered by this earthquake. Next significant contribution was done by Malamud et al. (2004) who extended Keefer's quantification on the basis of analyzing of the complete landslide inventories. They suggested the general frequency-area probability distribution function which allows to calculate some dependences on earthquake magnitude of landslide parameters (such as total area and volume of triggered landslides, area and volume of the largest landslide).
Largest earthquake induced landslides are the most interesting target for paleoseismisity study in mountain provinces. In this paper we report empirical correlation between earthquake magnitude and the volume of the largest landslide. So the empirical and theoretically calculated relationships can be compared. It shows a good correspondence and can be practically used after regional verification (which is necessary for each particular active area).
It should be noted that different parameters of earthquake triggered landslides are not simply a functions of magnitude. There are additional factors related both to geomorphic and earthquake mechanism considerations such as roughness of topography, rock type, hydrological conditions, earthquake type and depth, direction of energy focusing, regional morphotectonic structure and so on. But in spite of the fact that all of them play important role in seismic triggering of landslides as soon as landslide event has occurred the statistical approach appears to be the most promising tool. It gives universal laws for landslide events and allows correlating different parameters irrespective of their functional links.
Using parameters of the largest seismically induced landslides we have estimated magnitudes of prehistoric earthquakes, calculated the total volume of earthquake triggered landslides, the contribution of landslides caused by aftershocks and erosion rate due to seismically induced landslides. We tested this approach for the mountainous, seismically active SE part of Russian Altai where there are many large Holocene seismically induced landslides and the 2003 Chuya earthquake (MS = 7.3) took place.
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