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Landslides triggered by the 2002 Denali fault, Alaska, earthquake: What do they tell us about the strong shaking?

R. Jibson

U.S. Geological Survey, Golden, CO, USA (jibson@usgs.gov / Fax: 1-303-273-8600 / Phone: 1-303-273-8577)

Shaking from the **M**-7.9 Denali Fault earthquake of 3 November 2002 triggered thousands of landslides from the steep slopes of the Alaska Range and surrounding areas. The earthquake consisted of three distinct subevents, which had distinctive seismological characteristics and which apparently triggered distinctive distributions of landslides. Triggered landslides ranged in size from rock falls of a few cubic meters to rock avalanches having volumes as great as 20 million cubic meters that were triggered from steep rock slopes bordering large valley glaciers. The large majority of landslides were shallow rock falls and rock slides involving failure of the uppermost few decimeters to meters of slope material.

One unusual aspect of the landslides triggered by this earthquake was their narrow concentration along the fault rupture. Normally, an earthquake of this magnitude would be expected to trigger landslides over a very broad region extending perhaps 350 km from the fault and covering an area of about 30,000-100,000 km^2. In this earthquake, virtually all of the landslides clustered in a narrow band about 30 km wide that straddles the fault for more than 300 km (area $\sim$10,000 km^2). The largest landslides clustered at the western part of the fault zone between subevents 1 and 2, and landslide concentration decreased eastward along the fault zone.

Another unusual aspect of the landslides triggered by this earthquake was their relative scarcity. Analysis of data on landslides triggered by earthquakes worldwide suggests that a **M-**7.9 earthquake might be expected to trigger about 80,000 landslides. Although no detailed inventory was compiled for the Denali Fault earthquake, the number of triggered landslides appeared to be at least an order of magnitude less than this. Likewise, landslide concentrations on the steep slopes near the fault were not as great as what has been seen in other recent earthquakes of smaller magnitude.

Several inferences about the strong shaking can be drawn from analysis of the distribution of triggered landslides, and these inferences have since been confirmed independently by various seismological studies: (1) The low concentration of landslides in the near field suggests that the earthquake was deficient in high-frequency energy and attendant high accelerations. (2) Accelerations high enough to trigger landslides extended relatively short distances, only about 15 km, from the zone of fault rupture. (3) The clustering of large rock avalanches within the areas of the first two subevents of the earthquake is consistent with these subevents containing the highest accelerations and greatest amount of high-frequency energy of the earthquake record. No large rock avalanches were present in the area of the third subevent, which generated the largest fault displacements but relatively lower accelerations and less high-frequency energy. (4) Landslides extended only short distances to the west of the epicentral area of the earthquake whereas to the east they extended for more than 300 km along the zone of fault rupture, presumably because of eastward directivity of shaking that attended the eastward propagation of fault rupture.

In areas where near-field strong-motion instruments are absent or sparse, analysis of the distribution of shaking-induced ground failures can play a key role in interpreting—even if only with a broad brush—near-field ground motions.