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The "shattered landscape": intense ground failure produced by the great Southern Peru earthquake of 2001

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The Southern Peru earthquake of 23 June 2001 (M_w 8.2-8.4) was probably the largest earthquake to occur in the world since 1965. It produced widespread landslides and other ground failures throughout a region of at least 400 km by 100 km. Near the southern end of the fault rupture, where much of the energy release and the largest aftershock (Mw 7.6) took place, was a zone of particularly intense ground failure.

This region is part of one of the driest deserts on earth. Main geologic features in the area are a Coastal Cordillera, which rises to 1600-1800 masl, a series of alluvial fans drained by incised channels, which are dry most of the time, and a narrow coastal plain. Ground-failure effects were concentrated in the alluvial-fan areas and along the channels that drain the fans and the foothills of the Coastal Cordillera. The severity and variety of these ground-failure effects have led us to coin the term "shattered landscape" to describe their consequences.

The "shattered landscape" effects include abundant landslides, pervasive ground cracking, microfracturing of surficial hillslope materials down to the millimeter scale, collapse of drainage banks over long stretches, widening of hillside rills, and lengthening of first-order tributary channels. Effects were particularly intense and well preserved where soils consisted of a crust of desiccated aeolian sand underlain by heavily structured organic soil. This soil formed in areas of "lomas" vegetation that draws its moisture from the pervasive coastal fog.

In addition to the short-term hazards associated with such landscape shattering, long-term consequences are inferred to include increased run-off and sediment transport

during post-earthquake rainstorms. This inference was confirmed during the first post-earthquake rainstorm in this desert region, which occurred in June and July of 2002. Greater amounts of rainfall in this desert region have historically been associated with El Niño events. Previous studies of an unusual paleoflood deposit in this region have concluded that it is the product of El Niño-generated precipitation falling on seismically disturbed landscapes about 500 years ago. The effects of the 2001 earthquake and 2002 rainstorm support that conclusion. The "shattered landscape" may be a phenomenon associated with the largest earthquakes, ($M > 8$). Ground-failure effects have been studied in detail so far for only a few such earthquakes.