

Three major natural disasters caused by flow-type landslides involving massive entrainment along their paths (Khait, Tajikistan 1949; Huascaran, Peru 1962 and 1970)

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Entrainment of material along their paths by rockslides and rock avalanches has been recognized as an important mechanism in long run-out landslides and in transforming initial rockslope failures into mobile flows. We show that the process was a key element in the development of three catastrophic landslides in Tajikistan (1949) and Peru (1962 and 1970). The total death toll in these events is estimated at 40,000 people. In the 1949 Khait, Tajikistan case a rockslide, triggered by a M7.4 earthquake, was transformed into a highly mobile rockslide-loess flow by the incorporation of a significant volume of saturated loess from the valley floor and steep valley sides of the Obidara River. The landslide ran out a total distance of 11 km over a vertical distance of only 1500 m and the total volume of the flow is estimated to be 40 Mm³. The flow buried the towns of Khait and Kusurak with a total death toll that we estimate in the region of 17,500 people. In the Cordillera Blanca, Peru, falls of ice and rock from the North Peak of Huascaran in 1962 and 1970 were transformed into high-velocity debris flows by entrainment of snow from the surface of Glacier 511, and massive entrainment of surficial materials from an area downslope from the glacier margin. Entrainment significantly increased initial failure volumes. In 1962 the initial fall had a volume of 3 Mm³ whereas the final volume of the destructive highly fluid debris flow that overwhelmed Ranrahirca was in the order of 13 Mm³. Loss of life was approximately 4,000 people. In 1970, the initial fall from the same North Peak was triggered by a M7.9 earthquake and had a total volume of about 7.5 Mm³. The final volume of the highly destructive flow which split into two lobes (one of which overwhelmed the town of Yungay) and swept into the Rio Santa was in the order of 50 Mm³. The velocity of the event was extraordinary, with a mean velocity estimated to be 75 m/s. Approximately 18,000 people lost their lives in the 1970 flow. Both the 1962 and 1970 events continued downstream as very rapid distal debris flows/debris floods. In 1970 the distal flow reached the Pacific Ocean, 160 km downstream. The three case histories illustrate the role of entrainment in transforming initial rockfalls/rockslides into high-velocity, highly destructive flows that have the potential to overwhelm communities at some distance from the source instability.