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Giant landslides from the inside

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Despite the growing literature on catastrophic long-runout landslides, few studies have systematically examined sedimentary and petrographic characteristics of the interior of large landslide deposits, which yield valuable insights into dynamics during motion and final emplacement. We summarize petrographic evidence of dynamic rock fragmentation, internal sliding surfaces, and basal frictional melt that together allow constraining the dynamics and emplacement mechanisms of nine giant (> 1 km^3) landslides in the Alps, the Himalayas, and the Tien Shan. We find that the fractal particle size distribution in some of these rock-avalanche deposits is similar to that found for fault-zone rocks, deforming glacial tills, and volcanic debris avalanches, suggesting a strong link through a formational mechanism consistent with confined comminution models. We propose a model in which giant landslide sedimentology evolves during runout, from initially intact, discontinuity-defined rock slides with shear focused at the base, to the final stratified fragmented sand and gravel deposits. Mature deposits show shear distributed throughout the mass with near equal probability of fragmentation across all clast sizes with additional zones of concentrated shear related to weak lithologies. We argue that exposures of micro-breccias and frictionite (=hyalomylonite) in the debris and at the basal shear planes are indispensable as a tool for identifying giant landslides and distinguishing them from superficially similar Quaternary glacial deposits. Recognizing these tell-tale petrographic indicators is crucial, in particular where the scarcity of geomorphic evidence typically used for detecting large landslides (e.g. displaced ridge lines, cirque-shaped detachment scars, hummocky terrain, flow lobes, and impounded sediments) may lead to grave underestimates of both the recurrence and residence time of giant slope failures.