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Controls of gravitational mass wasting on the geomorphic evolution of headwaters: The 'Lluta collapse', northern Chile

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The 'Lluta collapse' is a prominent geomorphic feature in the landscape of the western escarpment of the Andes of northern Chile that resulted from probably one of the oldest recognizable landslide ($>$ 2.5 Ma) in a continental setting, and from subsequent modification of the landslide scar by backward erosion. The combination of geomorphic and geological information from the 'Lluta collapse' and sedimentological observations from the landslide deposits imply that a total of 25 km^3 of mass was displaced by landsliding. Subsequent modification of the landslide scar occurred by backward erosion, resulting in the establishment of a dendritic drainage network and the removal of an additional ca. 24 km^3 of material. It appears that this mass was produced by mass wasting in the headwaters, and exported by high-concentrated debris flows in channels.

The source area of the 'Lluta collapse' is bordered by an amphitheater-shaped scarp. This scarp-line – corresponding to the first-order geometric length-scale in the landscape – is made up of coalescing units of lower-ordered length-scales that also display concave geometries, and that have resulted from hillslope mass wasting. It appears, therefore, that the geomorphic evolution of the 'Lluta collapse' and the establishment of a dendritic geometry in the headwaters have been governed to large extents by mass wasting processes of different length-scales. In contrast, high-concentrated flows have controlled the export of mass, which, in turn, has allowed the base-level to lower to sufficiently low magnitudes to initiate further landslides. Hence, the data suggest that whereas the geometrical development of the 'Lluta collapse' has been controlled by gravitational mass wasting, the rates of the development of this geomorphic unit have

been limited by the export rates of mass and hence by the transport capacity of the flows.