

## **Rapid ice-rock avalanches versus gradual glacial processes? Implications for the natural hazard potential in the Karakoram Mountains (Pakistan)**

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There is a growing concern about extreme mass movements from combined ice-rock avalanches in glaciated environments areas in the light of increasing settlement activities in mountains and their forelands. Recent devastating events, such as those from Huascarán (Peru) in 1970 or Kolka (Caucasus) in 2002, have been an eye-opener in terms of the large run-out-distances and their hazard potential. At the same time there is a variety of topographic settings and distinct triggers of ice and rock failures, which leads in turn to a broad spectrum of multi-phase processes, such as the possible propagation of rock-ice-masses onto glacial surfaces with subsequent debris flows. These events are often not directly observable, and a sound interpretation of the sedimentary record is needed. However, the origin and process dynamics of giant debris accumulations in different mountain regions of the world is discussed increasingly controversially. In the last decade a lot of debris accumulations, which were classified formerly as moraines, were reinterpreted as products of mass movements.

In this context, the study presented here, focuses on a case example from the upper Chapursan Valley at the Afghan-Pakistan border (Karakoram Range, Pakistan). The Chapursan Valley floor and the adjacent sediment cones are covered with an outstanding hummocky debris landscape over a length of about 10 km and a width of up to 1 km with individual hummocks reaching about 10 m in height. These landforms overlap with the zone of permanent settlement. According to local legends and reports of early travelers in this region, one of the largest settlement concentrations formerly occurred in the upper Chapursan Valley and was destroyed by a natural disaster. Geomorphological field investigations, sedimentological studies, a comparison of satellite images, an analysis of historical data and interviews with the local inhabitants were carried out to unravel the origin of the hummocky terrain. The results show that complex geomorphological processes, consisting of a glacier advance and followed by glacier lake outbursts and ice avalanches, contributed to the formation of the hummocky debris landforms. The Kit-ke-Jerav and Yishkuk Glaciers in the upper Chapursan Valley seem to have experienced extraordinary fluctuations in historical and recent times.

The new findings on past processes forming large-scaled debris accumulations have wider implications for the recent hazard potential of settlements located in glaciated high mountain regions, especially in seismic active regions.