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Landslide morphology of the Batote area, Jammu & Kashmir, NW Himalaya: Implications for the age of prehistoric debris slides

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ABSTRACT

Identification of morphological elements is pre-requisite to understand the landslide behavior and composition. The relative age determination of the identified prehistoric debris slides depends on the subtle preservation intensity of surficial geomorphological features, topographic elements, and drainage evolution. The land use land cover along the western slope of Chakwa and Mogu *Nalas* show predominance of cultivation and forest area over a thick overburden material. The field-based mapping of intrinsic factors revealed the presence of prehistoric debris slide features such as thick debris material, water escape structures in debris material, large slabs (4–6 m) of bedded shale-mud sequence of Murree Formation, subtle rolling topography, slope-top benches, smoothened steep crest slopes with elliptical to amphitheater shape, and reversal of contours. Such features were used to determine the relative age of six identified prehistoric debris slides along the western slope of Chakwa and Mogu *Nalas*. Three prehistoric debris slides along the Mogu *Nala* are much smaller but have preserved comparably better morphological features and, therefore, are younger. In contrast, the prehistoric debris slides along the Chakwa *Nala* show tell-tale signs of steep smoothened scrap, dense vegetation, and rolling topography with streams flowing off the main slide body. The smoother nature of these features along with drainage deflection and dense vegetation indicates prehistoric debris slides activity along the western slope of Chakwa *Nala* to be very old of Early Holocene in age or older about 5000–10000 years.

1. Introduction

The Kashmir Himalaya, forming part of the NW Himalayan fold-thrust-belt, is under constant landslide threat attributed to its inherent high relief, steep gradient, highly deformed terrain, and fast ca. 4.5 mm/year upliftment (Jehan and Ahmad, 2006). The area also experiences frequent moderate to major earthquakes, heavy rainfall, and snowfall, acting as triggering factors for the landslide occurrences (Nanda et al., 2023; Mir et al., 2024, 2025; Sana et al., 2024; Paul et al., 2025; Habib et al., 2025). In addition, during the last two decades, developmental activities have tremendously increased in the Himalayan region, which many times are at the cost of fragile geo-environment like reactivation of prehistoric landslides.

Morphological and topographic elements/features of a landslide are distinct and well discernible in recent mass-wasting scenarios (Mohan et al., 2020). However, prehistoric landslides are quite challenging to identify from the ground as well as from aerial and satellite imageries, due to the loss of their distinctive landslide morphology through sub-aerial aggradation processes and anthropogenic activities with time (Mather et al., 2003; Garriss, 2019). In addition, the identification of such features in prehistoric, and/or palaeo-landslides in inhabited hilly terrains, although challenging, is very critical/ crucial for landslide hazard mitigation and risk reduction.

In potentially hazardous areas, the record period of the prehistoric landslides is short, typically < 200 years, therefore its identification is important for determining the risk (Clague, 2015). For the recognition of prehistoric landslides, evidence from morphological, topographical, and landform characteristics needs to be identified (Moore et al., 1991; Riley et al., 1999). Globally, several characteristic features and geomorphic markers from the topographic/ terrain/ slope maps, and field-based techniques have been utilized for the recognition of prehistoric landslides (e.g., Mather et al., 2003; Duman et al., 2005; Ardizzone et al.,

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