Landslide Mechanism Triggers Dir Upper, Khyber Pakhtunkhwa Pakistan: The Impact of Geochemistry and Geotechnical Properties

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The 83.5 kmr Chukyatan-Kumrat Upper Dir road is vulnerable to regular landslides caused by hydrometeorological risks, especially after the heavy rains and flooding in 2010. The landslide zones are composed of meta-volcanics, basaltic andesites, meta rhyolites, ignimbrites, volcanic ash, granodiorites, and spotted slates covered in residual soils. This study examines the geological features, geotechnical characteristics, and rock weathering of these regions. The study shows that large amounts of loose, weathered rock debris have accumulated due to the presence of the nearby Dir fault, and the exposed slopes exhibit polygonal stress fractures, joints, and fissures with steep inclinations exceeding 40° and heights exceeding 100 m. The slope material has a relatively low internal friction angle (28.520°–31.930°) and cohesiveness (4.154-5.95 kPa), while the bedrock's unconfined compressive strength (UCS) ranges from 10.75–41.51 MPa, indicating a weak to moderate-strong rock classification. The pH of the soil ranges between 3.1 and 4.2, and the presence of clay minerals suggests that the weathering conditions there encourage landslides. The hydrothermal alteration during low-grade metamorphism of the meta-volcanic rocks in the region has led to the creation of chlorite, smectite, monmorillonite, and zeolites as a result of chemical weathering, according to thin section and X-ray diffraction analysis. In addition, the content of quartz has increased due to physical deterioration. The study comes to the conclusion that a number of landslide incidents in the Chukyatan-Kumrat area are caused by the slope geometry, low shear strength of slope materials with strain-softening properties, and environmental factors like rainfall, snow melting, freeze-thaw activity, and slope base cutting for road development. Massive loading in the form of houses also plays a role in these events. The study's conclusions could useful in creating preparedness and mitigation plans that are suitable for slope protection in the study region and its environs.