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Paraglacial Cirque Headwall Instability - Regional Scale Assessment Of Preconditioning Factors

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Cirques are characteristic landforms in high alpine environments with flat cirque floors flanked by steep headwalls. From a rock-mechanical perspective, rock walls are assumed to adjust over time according to their internal rock mass strength, which is determined by a number of factors including e. g. intact rock strength and fracture system characteristics. However, temperatures permanently below freezing as well as glacier coverage keep cirque headwalls stabilised so that slope inclination can evolve during glaciation that is far beyond strength equilibrium. When cirque headwalls deglaciate, the relative importance of rock mass properties increases drastically as they precondition rock slope instability. Cataclinal headwalls, where major fracture sets dip out of the slope, are rated as unstable and usually respond rapidly to glacier retreat. Anaclinal headwalls with in-dipping fracture sets in contrast respond delayed and probably less drastically. To date, a systematic assessment of the predisposition of cirque headwalls for rock slope instability following deglaciation is lacking. We aim to tackle this lacking by a systematic regional analysis of predisposition factors using GIS tools.

For the central Hohe Tauern Range, Austria, regional datasets are available for the most important preconditioning factors including topography (digital elevation model), geology (digital geological map), glacier extent (digital glacier inventory), and permafrost distribution (PERMAKART 3.0). We combined geomorphometric analyses with geotechnical data to locate and evaluate the sensitivity of glacier headwalls to rock slope instability using GIS and object-based analysis techniques.

Our results show that a vast majority of the headwalls identified can be divided by a significant convexity in the slope profile curvature into a larger, upper and a lower, steeper headwall section (> 60°). The lower limit of the steeper section is marked by a significant concavity in the slope profile curvature, which is commonly known as the schrundline. Assuming that the convex transition between steeper and flatter headwall section constitutes the upper limit of enhanced headwall retreat e. g. by periglacial weathering inside the bergschrund, we further address this headwall section as the schrundwall.

Geotechnical data (foliation dip and direction) has been digitalised and interpolated in a yet oversimplified manner, to distinguish headwalls into cataclinal, anaclinal and orthoclinal slopes. Slope inclination and foliation dip has been interrelated to identify e. g. particularly sensitive overdip slopes. First results show that anaclinal and orthoclinal as well as cataclinal headwalls are quite common features in the study area. However, overdip slopes with steeply (30°-60°) outdipping foliation are almost exclusively found in schrundwall sections.

The persistence of steep overdip schrundwalls may be related to permafrost occurrence, which is subject to further analysis. Our approach, applied to modeled subglacial topography, may be of great value to anticipate future paraglacial instabilities in glacier headwalls.