Rock slope instability along the Isfjorden coastline and the impact of climate warming

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The archipelago of Svalbard is one of the fastest warming arctic regions. The mean annual temperature at Svalbard Airport increased by 3.7 °C during the last 118 years, which is about three times the estimated global warming during the same period. This rapid rise in temperature, combined with negligible human influence, makes Svalbard an ideal laboratory to study the relationship between mass movements and climate warming.
For this purpose, two study areas, the west-facing Forkastningsfjellet and the east-facing slopes of Garmaksla were selected, both characterized by postglacial landslide activity but differing in terms of litho-structural setting, deformation history and slope exposition.
Field mapping, GPS- and temperature measurements and bathymetrical surveys were performed to reveal the controlling factors and deformation mechanisms that drive the rock slope instabilities. Successive UAV surveys acquired between 2019 and 2023 document the spatio-temporal development of the landscape.

A 175.000 m³ rockslide affected the coastal cliff of Forkastningsfjellet in August 2016 and concluded an 80-year period of relative stability along this coastline. A back-analysis of the rock slide revealed that slope instability initiated along a pre-existing listric block fault that was inherited from the postglacial Forkastningsfjellet rock slide. Slope failure was attributed to a strength decrease of weak Jurassic shales, permafrost degradation and increasing water pressures. Since then, rapid surface alterations could be documented.

Thermokarst settlements, sinkhole and subsurface channel formation in combination with redirection of surface water runoff finally lead to a second rock slide event (volume ~500.000 m³) in November 2022. dGPS data revealed the highest displacement velocities on the block that failed and acceleration was detected on that block the year before. Drone-based visual observation of the main scarp documents the cryogenic-structural setting and evidences thermo-erosional gullying and permafrost thaw governing rock mass dilation and slope failure.

The east-facing slope of Garmaksla at the western margin of Billefjorden is also characterized by a huge postglacial rock mass instability, which affected a strong sandstone/mudstone and overlying limestone/dolomite sequence of Devonian-Permian age.
The rock slide is delimited to the west by the Balliolbreen Fault, an important pre-existing fault that accommodated multi-phase deformation since Devonian time and served as the main rupture surface. It is explained by a compound rock slide model in which displacement is governed along shallow out-of-slope dipping bedding planes and weakness zones.
During the observation period, the area showed no signs of reactivation processes of large slide blocks, surface runoff or seepage spilling out of the coastal cliff was not observed. However, thermokarst structures and ALDs were first noticed on the water-saturated northern slopes of the rockslide area in summer 2023, demonstrating permafrost thaw and an increase in the active layer thickness as well.
The findings in both landslide areas show that unfavourable litho-structural settings and climate warming correlated permafrost thaw and increasing water availability are likely first order controls on the stability of the rock slopes. With regard to Forkastningsfjellet, it can be predicted that the coastal blocks will be affected by accelerating rock slide activity.

For future research and to better understand the effects of climate warming on landslide activity, it would be helpful to initiate a long-term monitoring project that collects and evaluates future landslide activity along the Isfjorden.