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Frost wedging and rockfalls on high mountain rock slopes: 11 years of observations in the Swiss Alps

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Field measurements were undertaken on alpine rockwalls in the Upper Engadin towards understanding (1) seasonal and interannual variations in frost wedging on the rock face and (2) contribution of pebble and boulder falls to the rockwall retreat. The study sites are Murtèl (schist), Büz (shale) and Trais Fluors (limestone), where active rock glaciers develop below the rockwalls. All rockwalls face north and lie near the lower limit of mountain permafrost (2900 m ASL). Automated monitoring of crack movement and temperature over 5-11 years shows three kinds of major movements: small opening-closing associated with short-term freeze-thaw cycles, moderate opening-closing with annual freeze-thaw cycles, and occasional significant opening during seasonal thawing. Whereas the first two only slightly contribute to net widening, some of the third events lead to interannual net widening at Murtèl rockwall: the net widening cumulated to 0.6 mm during the first 5 years but thereafter diminished. Manual collection of rock debris detached from painted rock faces ($0.25\ m^2$) shows that the rockwall retreat rate due to pebble falls varies interannually with a maximum of about 2 mm/yr, but the average rate for 17 sites is only 0.1 mm/yr. The average retreat rate shows also a large spatial variation, partly reflecting joint spacing. The rockwall retreat rate due to pebble falls accounts for only 10 % of the Holocene average retreat rate estimated from the volume of Murtèl rock glacier. In contrast, a large boulder fall happening during seasonal thawing provides a total rock debris volume equivalent to the long-term average rate. These results indicate that surficial freeze-thaw action constantly produces pebble falls but rarely contribute to the growth of rock glaciers, whereas occasional large boulder falls, mainly associated with deep seasonal frost (or thaw) penetration, virtually control the rockwall retreat and rock glacier development.