Using combined quantitative geophysical methods to delimit physical properties of low porosity permafrost bedrocks

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Degradation of mountain permafrost poses an increasing hazard to the stability of high-alpine infrastructures, which are predominantly located in low porosity bedrocks. Considering the dramatic climate change-induced temperature increase and the recent tourism expansion in these regions, safe long-lasting constructions and maintenance of infrastructures at high altitudes requires a complete process understanding of these permafrost systems.

Non-invasive, geophysical measurements such as Electrical Resistivity Tomography (ERT) and Seismic Refraction Tomography (SRT) are the state of the art today in permafrost research due to their capability to distinguish between frozen and unfrozen medium. Thanks to their complementary sensitive records, it is common to combine electrical and seismic data sets by using petrophysical relations. Several multimethod approaches were already successfully applied in ice-rich conditions, however quantitative studies in ice-poor bedrock characterized by different physical properties are rarely investigated.

In this study, we present a quantitative multimethod approach for long-term monitoring of low porosity permafrost bedrock. ERT and SRT data sets were recorded between 2010 and 2021 at the Zugspitze crest (Germany, 2.885 m asl) and in the Hanna-Stollen at the Kitzsteinhorn (Austria, 3.029 m asl). Both locations are visited every day by thousands of tourists, present infrastructure founded in bedrock with porosity of 0.2 to 5.0 % and are affected by degrading permafrost, although showing different lithologies. A combined analysis of resistivities and p-wave velocities, supported by their laboratory temperature calibrations with water-saturated samples from the field, allowed us to quantitatively estimate site-specific permafrost changes. The preliminary results show a clear warming of the permafrost core and a thickening of the active layer, well in agreement with other long-term permafrost observation at the Zugspitze summit and at further alpine sites (e.g. Scandroglio et. al, 2021).

In summary, our quantitative multimethod analysis for ice-poor bedrock provides fundamental contributions for planning and maintenance of permafrost-founded infrastructure under the influence of climate change. In the future, we aim at developing a new benchmark approach for hazard potential assessment of high-alpine infrastructures with foundations and anchoring in
thawing permafrost.