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# Application of 2-D geoelectrical resistivity tomography for mountain permafrost detection in sporadic permafrost environments: Experiences from Eastern Austria

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Mountain permafrost covers some 2000 km$^2$ of the Austrian Alps which is less than 2.5% of the national territory. Delineating the altitudinal lower limit of permafrost in the mountains of Austria is difficult due the complex topography, the rather sparseness of field verification data and the lack of long-term permafrost monitoring data. Such monitoring data should cover different slope aspects, different elevations, different substrates and different mountain regions of Austria. In this study it was attempted to delineate the lower limit of permafrost at two study sites in the Tauern Range, Austria, applying two-dimensional geoelectrical resistivity tomography (ERT). In addition, multi-annual ground temperature data collected by miniature temperature datalogger (MDT) were used to validate the results. At the study site Hochreichart (maximum elevation 2416 m asl), located in the Seckauer Tauern Range, 14 ERT profiles (lengths 48-196 m; electrode spacing 2, 2.5 or 4 m) were measured at elevations between 1805 and 2416 m asl. Measurements were carried out at two cirques (Reichart, Schöneben) and at the summit plateau of Hochreichart. Results at this site indicate that permafrost lenses are detectable at elevations down to c.1900 m asl at radiation-sheltered sites. Furthermore, at the summit plateau permafrost only occurs as rather small lenses. The ERT-based permafrost pattern is generally confirmed by the MTD data with negative mean annual ground temperature values at only a few monitoring sites. However, the possibility of air-filled cavities causing higher resistive zones faking permafrost existence cannot be excluded because coarse-grained sediments (i.e. relict rock glaciers and autochthonous block fields) are widespread at this study site. At the second study site Kögele Cirque (maximum elevation 3030 m asl) located in the Schober Mountains 12 ERT profiles (lengths 48 m; electrode spacing 2 m) were measured at elevations between 2631 and 2740 m asl. Spatially, the 12 profiles are well distributed over the entire cirque. At this site permafrost was detected as up to 5 m thick lenses at SW-facing slopes and at 2740 m asl. Several permafrost lenses were found at a terminal moraine complex dating to the Little Ice Age (LIA) influenced by thermokarst at about 2635 m asl. At one profile a >8 m thick massive debris-covered glacier remnant (resistivity values >100.000 ohm.m) was identified. However, no large permafrost bodies have been found. Consequently, no clear transition zone between permafrost free to more discontinuous permafrost was detected at this cirque. Summarizing, neither at the Hochreichart site nor at the Kögele site a clear altitudinal lower limit of permafrost was detectable by ERT and MTD. At the first site only small patches of permafrost exist today mostly at coarse-grained sediment sites. At the latter site patches of permafrost can be found in LIA-terminal moraines and at higher parts of the cirque. The remnants of a former cirque glacier are well preserved under a thin veneer of debris which is, however, so far thinner than the active layer thickness. More continuous permafrost areas presumably only exist at north-facing areas above c.2800 m asl.