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Applicability of quasi-3D Resistivity Imaging at a Permafrost Site with blocky Surface and complex Geomorphology

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Two-dimensional electrical resistivity tomography (ERT) has been established in the previous decade as a widely applied tool for the mapping and characterization of permafrost in the shallow subsurface of mountain environments. Using the marked increase in electrical resistivity at the freezing point, this method delivers information about subsurface structures that contain ice and furthermore allows for first estimates of the ice content, the origin of ice and the thermal state of the substratum (aggradation, degradation).
Recently, this approach has been refined in periglacial research in alpine terrain by a collation of several parallel ERT-profiles and perpendicular tie-lines to gain a quasi-3D image of the subsurface.

The study presented here applies the quasi-3D ERT at a permafrost site in the Upper Engadin with a coarse-grained and blocky surface and solely small patches of finer debris. Its aim is to map permafrost within a complex geomorphology – composed of lateral moraines, settling of debris, rock glacier- and lobe-like structures and talus slopes – in the glacier forefield beneath Piz Murtèl and the mountain range Furtschellas at 2800 m a.s.l.
23 two-dimensional ERT profiles were measured during the summer of 2009, 11 in longitudinal direction and 12 in transverse direction. Each profile was arranged with a 3 m electrode spacing in the direction of measurement and with a threefold offset of 9 m in parallel direction using both, the Wenner as well as Wenner-Schlumberger electrode configuration. To obtain a reasonable coupling between the electrodes and the ground surface soaked sponges were clamped between the steel rods and the ambient boulders at several points.

Our measurements show a large contrast between the resistivity values, indicating a permafrost body (> 200.000 kohm.m) that underlies the measurement-grid encircled by an area with low resistivity values (< 1.000 kohm.m). Differences in debris cover and size of detritus at the surface coincide well with the resistivity contrasts. The reliability of ERT measurements has been validated using a 10 m deep borehole that contains a thermistor probe with 10 sensors at variable depth and BTS measurements. The borehole, installed in the summer of 2008, shows an active layer thickness of approximately 2.2 m and a permafrost body downwards to the lower end of the borehole. The temperature at the bottom of the snow cover was measured in the winter of 2009. Temperatures below -3°C indicated probable permafrost occurrences in the whole glacier forefield.

We conclude that quasi-3D ERT is a valuable tool for the mapping of permafrost extension and subsurface characteristics in mountain environments. Even in coarse and blocky debris a good coupling between electrodes and ground was possible and yielded reasonable results.
Our study confirms the potential of quasi-3D imaging that is due to an improved resolution in lateral and vertical direction of subsurface conditions compared with 2D ERT. Data acquisition and data preparation, however, are much more time-consuming than with simple 2D ERT. A further validation of quasi-3D ERT with methods such as BTS, temperature measurements or seismic refraction tomography remains a prerequisite.