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Quantitative electrical imaging in permafrost rock walls

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Several authors provided indications of the changing stability of permafrost rockwalls in different high-mountain environments. Anticipation of the hazard induced by permafrost rock slope failure requires monitoring of thermal and hydrological regimes inside the rock mass and quantitative geophysical methods could theoretically provide certain information on both.

Electrical resistivity tomography (ERT) in frozen rockwalls could become a key method for such investigations since freezing and temperature changes induce significant and recognizable changes in resistivity. Inferring reliable thermal state variables from ERT images, however, requires a quantitative approach involving calibrated temperature-resistivity (T-) relationships as well as an adequate resistance error description in the ERT inversion process. Testing T- relationships from a double-digit number of low-porosity sedimentary, metamorphic and igneous rocks from Alpine and Arctic permafrost rockwalls in the laboratory, we found evidence that exponential T- paths developed by McGinnis et al. (1973) do not describe the resistivity behaviour of hard rocks undergoing freezing or melting correctly, as freezing occurs in confined space. We hypothesize that bilinear functions of unfrozen and frozen T- paths offer a better approximation. Separate linear approximation of unfrozen, supercooled and frozen T- behaviour could help to provide more accurate temperature estimates from the resistivity of permafrost rocks. Utilizing a T- relationship in an imaging framework requires a quantitative ERT approach (Krautblatter et al., 2010), where the correct description of data errors and the right degree of data fitting are most crucial issues. Over-fitting the data (corresponding to underestimating the data error) should be avoided, because this typically leads to artefacts in the images – often mistaken as evidence of high spatial resolution –, as should under-fitting (overestimating the data error), which results in images with non-optimal resolution and contrast.

We provide examples from repeated measurement campaigns from 2006-2011 in permafrost rock walls at the Zugspitze (Germany), the Aiguille du Midi (France) and the Steintaelli Crestline (Switzerland) to demonstrate the potential of quantitative, temperature-calibrated electrical resistivity tomography. We believe that the method will play an increasingly important role in permafrost rockwall characterization and monitoring.

Krautblatter, M., Verleysdonk, S., Flores-Orozco, A. and Kemna, A. 2010. Temperature-calibrated imaging of seasonal changes in permafrost rock walls by quantitative electrical resistivity tomography (Zugspitze, German/Austrian Alps): J. Geophys. Res.-Earth, 115, F02003, doi:10.1029/2008JF001209.

McGinnis, L.D., Nakao, K. and Clark, C.C., 1973. Geophysical identification of frozen and unfrozen ground, Antarctica. In: F. Sanger (Ed.), 2nd International Conference on Permafrost, Northamerican Contribution, Yakutsk, USSR, 136-146.