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Active layer and bedrock mapping in permafrost with Electrical Resistivity Tomography and Induced Polarization – A case study from Svalbard

Asgeir Kydland Lysdahl[1], Sara Bazin[1,2], Andreas Olaus Harstad[1,3], and Regula Frauenfelder[1]
[1]Norwegian Geotechnical Institute, Oslo, Norway (aol@ngi.no)
[2]Now at: Institut Universitaire Européen de la Mer, Plouzané, France
[3]Now at: Skanska Norway AS, Oslo, Norway

Design and construction of infrastructure in frozen permafrost soils demands for detailed investigation of the ground characteristics prior to the construction process. Variations in ground temperature affect the physical properties of permafrost, such as amount of unfrozen water content and ice content. In addition, aggradation and degradation of permafrost induce changes of its physical properties. Ground-based Electrical Resistivity Tomography (ERT) and Induced Polarization (IP) surveying can be used to characterize near-surface ground conditions to a few tens of meters depth, especially when calibrated by boreholes.

Measured electrical resistivity is temperature-dependent, which makes ERT a suitable tool in permafrost investigations. The temperature dependence is most pronounced for temperatures below freezing point. Electrical resistivity rises exponentially during freezing, when unfrozen water content within a substrate decreases. The electrical resistivity is, thus, very sensitive to phase changes between water and ice and we usually observe a lack of resistivity contrast at lithological interfaces. Direct translation from resistivity to lithology is, therefore, seldomly possible in permafrost. While ERT is successful for mapping the active layer, further interpretation of resistivity profiles is thus impeded by the lack of resistivity contrast within the permafrost. Indeed, the lithological structures are hidden by the strong resistivity of the frozen layer. By adding complementary information, IP measurements can help separate effects due to freezing and lithology. The IP effect can be measured in the time-domain, simultaneously with the ERT measurements, and with the same equipment. The IP effect occurs after abruptly interrupting the current flow between the current electrodes. The voltage across the potential electrodes does not drop to zero instantaneously, but decays exponentially. The decay time can be used to estimate the chargeability of the ground.

Here, we present three examples where combined ERT- and IP-surveying was used to detect the interface between sediments and bedrock within permafrost soils, and to investigate potential environmental hazards related to run-off paths from existing and planned landfills. Study sites were an active landfill near the town of Longyearbyen, and two potentially new landfills near Longyearbyen and Barentsburg, respectively (the latter one for surplus masses resulting from coal mining). As permafrost traditionally had been seen as a natural flow barrier for such landfills, understanding its degradation owing to climate change was considered key in the planning of future sites. Eight profiles were carried out in September 2018, when expected active layer thicknesses were at their maxima. Two-dimensional inversion was performed with the commercial software RES2DINV for the resistivity data and Ahrusinv for the chargeability data.

The results of our case studies show the benefit of simultaneous ERT- and IP-measurements, to both map active layer depths and determine sediment depths in permafrost areas. They also gave valuable insights in understanding potential environmental hazards related to run-off from the landfill, as a consequence of water entering the landfill in the summer period. ERT/IP surveys are flexible and relatively easy to deploy. The technique is non-destructiv and is, therefore, also suitable for maintenance studies in vulnerable arctic Tundra environments.