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Verification of Geophysical Models of the Permafrost Distribution within an Alpine Talus Slope Using Borehole Information, Valais, Swiss Alps

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In order to determine the spatial extension and the characteristics of the permafrost within alpine talus slopes, thermal and geoelectrical measurements were carried out in several sites of the Swiss Alps (Lambiel 2006, Pieracci *et al*. 2008). The observations and the measurements carried out at the study sites allowed proposing a model of the permafrost distribution in talus slopes located within the Alpine periglacial belt (Lambiel & Pieracci 2008). According to this model, permafrost appears likely in the lower part of the slope, whereas it is generally improbable upslope. In order to validate the model, in the Attelas talus slope (Verbier area, Valais Alps, 2600-2800 m a.s.l., west-facing flank of the Mont Gelé) a fix Electrical Resistivity Tomography (ERT) profile along an upslope-downslope transect composed by 48 electrodes (4 meters interval) was installed in summer 2007, and three boreholes were drilled along the ERT profile in autumn 2008.

The Attelas talus slope is a cone-shaped landform, composed by paragneiss and affected by solifluction processes in the upper-mid part of the slope. A protalus rampart at the foot of the talus suggests the presence of creeping permafrost in the lower part of the slope.

The ERT of July 2008 shows a difference in resistivities between the lower and the upper part of the slope. A resistive body with values higher than 25 kΩm and a thickness of about 15 meters is present in the lower part of the slope, as imaged by both apparent and inverted resistivities. In the central part of the slope, a layer of 15-20 meters with lower resistivities (<10 kΩm) is superposed on a resistive body (12-20 kΩm) found at greater depth. Finally, in the uppermost part of the profile, the resistivities are lower than 4 kΩm. To determine the lateral extension of the resistive body in the lower part of the slope, another ERT was executed perpendicular to the upslope-downslope profile.

If we consider the good connection between resistivities and ground surface temperatures (GST), the resistive body in the lower part of the slope, which corresponds to the coldest GST, can be interpreted as a permafrost lens. The second resistive body in middle of the profile can be interpreted either as low-resistivity permafrost or as porous sediment, whereas the low resistivities and the GST close to 0°C in the upper part of the slope indicate the absence of frozen sediments.

The stratigraphy of the boreholes is known thanks to direct observations and movies recorded with a hand-made borehole camera. Borehole B1 (lower part of the talus slope, 26 meters depth) presents 3.5 meters of unfrozen sediments and 20.5 meters of ice and blocks. The bedrock is located at a depth of 24 meters. Borehole B2 (middle of the ERT profile, 21 meters depth) presents 4.5 meters of unfrozen sediments and 13.5 meters of ice and blocks. The bedrock is located at a depth of 18 meters. Finally, borehole B3 is 15 meters depth and does not present ice. The stratigraphy of the three boreholes is confirmed by the thermal profiles measured the 10 November 2008. B1 presents a frozen ground up to the base of the borehole, with the coldest temperature (-1°C) at a depth of 15 meters. B2 is weakly less cold than B1, with a temperature of about -0.5°C between 10 and 20 meters depth, whereas the temperatures recorded in B3 are widely positive.

Two main conclusions can be drawn from observations at the study site:

1. All the data confirms the model of the permafrost distribution in talus slopes located within the Alpine

periglacial belt: the presence of permafrost is probable in the lower parts of the talus slope, whereas it appears to be generally improbable in the upper parts. This permafrost distribution pattern is conform to the measurements carried out in other alpine talus slopes (e.g. Delaloye & Lambiel 2005, Otto & Sass 2006, Pieracci et *al*. 2008)

2. The borehole data (observations, movies, thermal profiles) allow us to validate the stratigraphy obtained from the ERT, both for the distribution of frozen sediments in the talus slope and for the depth of the detected structures.

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