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Surface and borehole geophysical measurements for detecting water infiltration paths within fissured clay sediments

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The Trièves area is a large depression located within the French alpine foreland 40 km south of the town of Grenoble. It coincides with the position of a 300 km^2 palaeolake created by the damming of the Drac River by the Isère glacier during the last maximum glacial extension (Würm period, 45000 yr BP). The lake was progressively filled by clays resulting from the erosion of the surrounding crystalline and limestone massifs. These clayey formations which can reach 250 m thick overlay an irregular palaeotopography made of compact alluvial layers and mesozoic marly limestones. After the glacier retreat (10000 to 15000 yr BP) the rivers cut deeply into the geological formations, triggering large landslides in the clay deposits.
In the north of the Trièves area, the left bank of the NS oriented artificial Monteynard lake is affected by several large adjacent landslides. Our study is focused on the translational Avignonet landslide which affects a surface of about 1x106 m2 with a global eastward downslope motion towards the lake. This earthslide exhibits a heterogeneous sliding velocity distribution, from a few cm/yr to 15 cm/yr in the more active zones. One of these actives zones (50 m by 100 m in size), which is bounded by a major scarp and affected by numerous fissures at the surface, was chosen as a test site for studying water infiltration. The high fissure density probably results from the presence of shallow slip surface and from the swell/shrinking phenomenon in the superficial clay layers. The site was investigated by 5 boreholes drilled to a depth of 20 m. Electrical and seismic measurements at the surface and in boreholes were conducted to image this deformed zone and to monitor changes in the mechanical and hydrological parameters down to 10 m. Geophysical prospecting was initiated in September 2008 with a monthly period and high to medium spatial resolution (0.5 and 1 to 5 m). Simultaneously, meteorological parameters (rainfall and air temperature) and shallow ground parameters (temperature, water table level, soil moisture and water flow) were locally continuously recorded. Periodic hole logging (neutron-neutron, gamma-gamma) provided high spatial resolution (0.3 to 0.2 m) measurements of water content and density along vertical profiles in the ground. Finally, in-situ physical parameters were calibrated with laboratory analyses performed on cored samples.
Initial seismic and electrical images combined with hole logging showed the geological and hydrogeological structure of the deformed zone, with the presence of a shallow water table (2 to 3 m depth) and of two slip surfaces at about 5 and 10 to 14 m depth. Electrical data were temperature-corrected to take into account seasonal variations. Time-lapse electrical measurements have imaged the evolution of the shallow water table with time, as well as the presence of a near-vertical narrow low-resistivity anomaly. This latter is located below a scarp mapped at the surface and is interpreted as a preferential water infiltration path with a higher water content.
These results are in agreement with a previously proposed hydrogeological scheme for the clays in the Trièves area and highlight the interest of geophysical techniques for monitoring water conditions and infiltration in such disturbed medium.