Geological Survey of Austria

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# ABSTRACT

## Structures of deep-seated slope failures at Gschliefgraben recognized by complex of geophysical surveys

Supper R. [1], Baron I. [1], Seren S. [2], Ottowitz D. [1], Pfeiler S. [1], Jochum B. [1], Römer A. [1], Winkler E. [1], Motschka K. [1], Moser G.[3]

*(1) Geological Survey of Austria, Neulinggasse 38, 1030 Vienna, Austria*
*(2) Zentralanstalt für Meteorologie und Geodynamik, Hohe Warte 38, 1190 Vienna, Austria*
*(3) Münzfeld 50, 4810 Gmunden, Austria*

*Contact: robert.supper@geologie.ac.at, ivo.baron@geologie.ac.at*

Different geophysical methods could provide diverse information about the subsurface. Especially in the case of deep-seated slope failures, information coming from different methods is required, e.g.: for determining different lithological units, porosity, water saturation or geometry of slip surfaces and zones of detachment. Therefore a complex interpretation of geophysical methods was performed at the Gschliefgraben site in Upper Austria.

The Gschliefgraben site is one of the most prominent and extensively studied slope failures in Central Europe. It comprises a large spectrum of geologically controlled slides, earth flows, topples, rockfalls and deep-seated gravitational deformations (DSGSDs) in the Gschliefgraben valley and along the slopes of the Northern Calcareous Alps. In late November 2007, an earth flow of about 3.8 million $m^3$ of colluvial mass was reactivated in the central and western parts of the valley. The displacement velocity was up to 4.7 m/day at the beginning. Consequently, in frame of the first emergency measures, 55 buildings had to be evacuated. Recently, the Gschliefgraben landslide has been a test site of the European FP7 project SafeLand where new techniques have been tested for rapid mapping, monitoring and effective early warning, consisting of, e.g., airborne and ground-based geophysical surveys and the GEOMON4D (continuous geoelectrics) and DMS (automatic inclinometer) monitoring systems. Ground Penetrating Radar, resistivity profiling and a multiparametric airborne (helicopter-borne) geophysical survey was applied to investigate the subsurface and to test those individual techniques. Additionally, a comparison with results of seismic tomography provided by Millahn et al. (2009) is discussed.

The geoelectric resistivity survey proved that it is a reliable method to investigate the structure of the landslide and bedrock in shallow and deeper portions (depending on the length of a profile). Complicated subsurface structures, which were identified in the Gschliefgraben valley, resulted from the complex deep-seated mass movement.

The GPR survey was performed on the active earthflow. Despite the GPR survey has quite limited depth of penetration (max 15-20 m in the case of the Gschliefgraben site) it provided very good information on the limit of different lithological units and the geometry of shallow slip surfaces. The main limit, however, was the artificial re-modelling of the active landslide due to remedial works which partially masked the original landslide structures at most of the landslide.

Airborne geophysics is a new promising method for landslide investigation. The big advantage of airborne geophysical measurements is that large areas can be surveyed within relatively short survey times. Although the use of helicopters seems to be quite expensive, the method is very effective since several different sensor systems can be combined at the same time. The Airborne electromagnetic survey is the only remote-sensing method which is able to investigate also geological structures below the ground surface down to several hundreds of meters. It recognizes lithological units with different clay content, porosity and water content at different depths. Radiometry, in general, investigates the radioactive content in the soil at the ground surface and it could be applied for reconstructing source areas of mass-movement deposits (U, Th, K), identifying open

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joints and cracks in hard rock (Th), fault zones in bedrock (U) or degree of chemical weathering (K). Material removal and wash-out was effectively indicated by the Caesium (Cs) survey. Besides that, ground resistivity and soil moisture could be new parameters for landslide susceptibility assessment and mapping. The method is suitable for large landslides, earthflows, and DSGSDs for investigating their structure and substrate.

Thrust structures were interpreted within the zone of pressure ridges along the NC Alps margin (within Ultrahelveticum mostly) by the seismic tomography. Different detached rock bodies and detachment zones were identified in deep portions up to 100 m below the ground surface and they resemble thin-skinned nappe structure. Those structures developed due to tectonic thrusting of the Eastern Alps and also most probably due to DSGSDs. Those results are in agreement with the resistivity survey and they are supported by unexplained displacements in the deep part of the D.M.S. inclinometer, open cracks, toppled rock towers or by pseudokarst crack caves with strong air blow.