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Monika Tessadri-Wackerle

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Structure and kinematics of the Niedergallmigg – Matekopf mass movement (Tyrol, Austria)

W. Chwatal[1], H. Kirschner[2], E.Brückl[1] & C. Zangerl[1]

1 Institute of Geodesy and Geophysics, Vienna University of Technology, Austria
(wchwatal@luna.tuwien.ac.at)
2 alpS GmbH Zentrum für Naturgefahren Management, Austria

The Niedergallmigg - Matekopf mass movement is one of the largest deep-seated landslides in the Alpine region. Morphologic features, in particular the extent of the head scarp, indicate a total displacement of about 180 m. The slowly creeping rock mass shows a difference in elevation between the toe and the main scarp of about 1400 m. Results from geodetic measurements show average surface displacements in the range between 5 to 10 centimetres per year.

The mass movement is situated in the Silvretta crystalline complex and in the Landecker Quarzphyllitzone. Phyllitgneises, phyllits and amphibolites cover the lower to middle part of this area where the upper part is built up by paragneisses and two-mica schists of the Silvretta crystalline basement. The dominant tectonic structures are oriented in approx. E-W direction (e.g. joints, shear faults), parallel to the main structural lineament of the E-W striking Inntal. Conjugated N-S striking joint systems are also observed. The main foliation, which dips steeply (65° to 90°) towards SSE, forms a northvergent anticline-structure, which is characterized by intensive internal folding.

The mass movement started with a creeping phase after the retreat of the Alpine glaciers at about 14,000 years BP. Due to the sedimentation of the river Inn at the toe, the mass movement became almost stable after undergoing an irregular sequence of large deformations („stick slip"). Nowadays the most important question is, whether this stable kinematic state will persist in the near future or if there will be a change into a non-predictable rapid slide, which may result in catastrophic events in the case of human settlement. The kinematic state is influenced by precipitation, ground water and erosion at the toe of the slope. Thus the determination of the structure and the characterisation of the kinematics will lead to a better understanding of this mass movement and in particular the foundations for a prediction of an instability.

The mass movement can be separated into two moving segments, a smaller eastern a part and a larger western part, on which we focus. A 3-D seismic survey was carried out to explore the thickness and internal structure. 373 seismic stations were deployed along 4 cross-lines, with a total length of 7,5 km. 41 shots were recorded simultaneously by all receivers. The seismic data indicate a vertical gradient of the P-wave velocity for the creeping rock mass and a nearly constant velocity for the underlying compact rock. Therefore, a combination of tomographic inversion and standard refraction seismic methods was applied. The results show P-wave velocities in the range of 1000–2000 m/s near the surface, 2000–3000 m/s at a depth of 25–150 m and 3000–3500 m/s below the depth of 150 m for the creeping mass. The velocity of the compact rock, which can be interpreted as the basal surface of the mass movement, varies in the range of 4800–5200 m/s. The maximum thickness of the creeping rock mass is about 320 m. A model of the basal surface has been constructed by using the boundaries of the actual movements (e.g. scarps) and the seismic results. In areas with no seismic data, particularly in the upper region, a reasonable interpolation technique was used. The volume of the creeping rock mass was determined as 0,43 km^3.

A retro deformation was applied to reconstruct the pre-failure topography (initial state) of the mass movement. The constraints were the present surrounding geomorphology (scarps, edges etc.), the conservation of the mass, the initial geomorphology (e.g. smoothness of terrain, gradient of the slope) and the dilatation during the creeping phase. To determine the amount of the dilatation, the average present porosity (0,21) was calculated from the seismic P-wave velocities and the average pre-failure porosity (0,06) was estimated from the thickness of the mass movement.

Constraints on the kinematics are derived from the seismic structure and the geodetic observations. Geodetic measurements show dip angles of the surface displacements of 34°, 25° and 17° in the upper part, in the middle part and in the lower part of the mass movement. These values correspond to the dip angles of the basal surface and lead to the conclusion that the whole volume of the sagging belongs to the currently moving rock mass. Therefore a rotational slider block model, which assumes that the whole mass movement is advancing as a single block along a circular shaped sliding plane, was adapted. The calculated dip angles of this model, which fit to the dip angle of the geodetic measurements, confirm the applicability of this model.