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# Present structure and prefailure topography of the giant landslide of Köfels


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**INTRODUCTION:** The Köfels landslide (Ötztal, Tirol, Austria) is recognized as the largest landslide in the crystalline Alps. This event took place about 8700 years ago according to radiocarbon dating. The geoscientific community became more interested in this event, when pumice and fused rock was found at this site. The findings gave rise to numerous theories about the cause of the landslide. The hypothesis of a volcanic event has been discarded presently, however, impact theories and purely geomechanical theories are still under consideration (Heuberger, 1994). Structural maps of the landslide and the topography of the valley before the event are a prerequesit for a decision between these theories.

**SEISMIC INVESTIGATIONS:** Based on the results of earlier seismic investigations (Heuberger and Brückl, 1993) and the information coming from drillholes and a reconnaisance gallery (Amperer, 1939, Klebelsberg, 1951), reflection and refraction seismic lines with a total length of 3.1 km were measured in 1997. These lines covered both the landslide area and the valley sediments up- and downstream the landslide (Fig. 3a). An accelerated weight drop source and a 96-channel recording system was used. The station interval was 1 m for line 97/5, 5 m for line 97/1 and 6 m for the other lines. All lines were processed according to refraction seismic principles (Brückl, 1995). Refraction seismic P-wave velocity models were established down to a depth of about 100 m. Reflection seismic processing was applied to the lines 97/1 - 97/4 using the ProMAX 2D programme package. A penetration depth of about 0.5 s two-way traveltime was achieved by the reflection seismic method. As an example the stacked and migrated sections of the lines 97/2 and 97/3 together with the interpreted horizons are shown in Fig. 2.

**INTERPRETATION of the STRUCTURE:** The deepest reflection seismic horizon was interpreted as the erosional base of the valley or the sliding plane of the landslide. This discontinuity covering the whole investigation area was mapped integrating the information from the former seismic investigations, the drillholes, and the reconnaissance gallery. A second horizon was found below and downstream of the landslide mass. We correlated it with compacted sediments which are older than the event and thus overthrusted by the sliding rock mass („old valley fill"). A third discontinuity was interpreted within the landslide mass and correlated with an internal sliding plane and associated with the findings of pumice and fused rock. The results of these interpretations are shown in the following figures:

- Fig. 3b: present day topography including the boundary of the visible landslide mass and the outcrop of the internal sliding plane
- Fig. 3c: top of the compact rock corresponding to the erosional base of the valley and the sliding plane including the boundaries of the whole landslide mass and the escarpement area
- Fig. 3d: similar to Fig. 3c, but with „old valley fill".

**RECONSTRUCTION of the PREFAILURE TOPOGRAPHY:** The present day topography of the landslide mass is imprinted by a gourge eroded by the river „Ötztaler Ache" after the event. Therefore, as a first step in reconstructing the prefailure topography this erosion was compensated for (Fig. 3e). The original volume of the landslide after the event was calculated as 3.88 $km^3$ and the erosional losses as 0.46 $km^3$. An estimate of the porosity can be made on the basis of the P-wave velocities observed within the landslide mass. The quantitative basis of this estimate is shown in Fig. 1. The porosity was calculated from the P-wave velocity applying a relation given by Watkins et al. (1972).

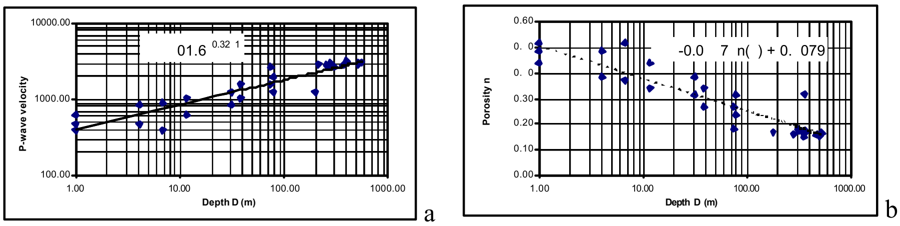


Figure 1: Relations between the thick-ness of the over-burden D and the P-wave velocity Vp (a) and the porosity n (b)

From these relations a mean porosity of n = 0.23 was derived for the landslide mass. To compensate for the rock disintegration during the mass movement the porosity of the landslide mass was reduced to n = 0.09, corresponding to a volume of 3.28 km3. Under this reasonable constraint the reconstruction of the orginal topography resulted in a crest continuously ascending from North to South and therefore following the regional trend (Fig. 3f). The horizontal and vertical displacements of the centre of the landslide mass are 2090 m and 676 m respectively, resulting in an energy release of about 5*1016 Joule. A longitudinal and a transverse section through the landslide area and the valley are shown in Fig. 4a and 4b. The reconstruction of the erosional base of the valley along the longitudinal section includes the results of seismic measurements carried out at the Tumpen landslide about 6 km downstream of the Köfels landslide (Poscher and Patzelt, 1996).

CONCLUSION: Based on the results of seismic measurements and the information coming from drillholes and a reconnaisance gallery, models of the present and prefailure structure of the Köfels landslide area were constructed. The most prominent morphological feature is the deepening of the erosional basis of the valley by 300 m just at the southern boundary of the landslide area. In conjunction with the steep slope of the reconstructed crest this morphology results in relatively high stresses. Therefore our results give strong support to purely geomechanical theories of the cause of this landslide.

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