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Kinematics of a long run-out rockslide: a case study from the Fernpass-region (Northern Calcareous Alps, Tyrol, Austria)

C. Prager (1, 2) and C. Zangerl (1)

(1) alpS - Centre for Natural Hazard Management, Grabenweg 3, A-6020 Innsbruck, Austria (prager@alps-gmbh.com) and (2) Institute of Geology and Paleontology, University of Innsbruck, Innrain 52, A-6020 Innsbruck (christoph.prager@uibk.ac.at)

One of the largest alpine mass movements is the fossil Fernpass-rockslide in the Northern Calcareous Alps (Tyrol, Austria), showing enormous mobility with unusually long run-out distance. The complex accumulation path is characterised by two channelled "sturzstroms" up to 16 km length. The release of the Fernpass-rockslide is assumed to date about 3500 uncal. yrs BP, controlled by the polyphase interaction of lithological - structural vulnerabilities, seismic activity and climatically controlled water pressure changes (Prager 2005, this session).

The debris, comprising a volume of approx. 1 km^3, originates from a deeply incised, wedge-shaped scarp, built up by a thin-bedded alternation of dolomites, limestones and marls of the Seefeld Fm (Norian, Upper Triassic). Rheology and bedding conditions, but above all, complex intersection of fault systems and fracture zones control the formation of sliding planes and the block size distribution. According to established doctrines, the subdivision of the debris into two branches resulted from an oblique impact against the opposite mountain slope. Whereas the run of the northern branch fits into a kinematical coherent model, the strong deflection of the southern branch causes fundamental difficulties in process understanding. Therefore also the possibility of temporal and spatial different failure events should be considered.

The internal structure of the rockslide is characterised by varying block-size separation and fragmentation. Upper parts of the proximal depositional facies feature a bulky framework of coarse debris, occasionally containing slabs of 100´s metres in side length. At the apex of the Fernpass a maximal thickness of the rockslide of approx. 250 metres is assumed. Medial to distal areas are built up by angular blocks of different size (centimetres to decametres) mixed with abundant fine interstitial material. Analogue to observations published by Pollet & Schneider (2004), this chaotic depositional facies characterises unconfined zones at the top or lateral margins of rapid moving landslides. Unfortunately the basal sliding plane of the Fernpass-rockslide, supposed to show fine attrition-breccias, is not exposed.

Occasionally medial to distal rockslide-debris is mingled with fragments of moraine and quaternary terrace sediments. But more common, relictic layers of fluvial-glacial terrace sediments are situated right on the top of the rockslide debris. Presumably they have been transported from the source area piggy-back on the failed rock mass, indicating a laminar flow of the superficial parts of the rockslide.

In contrast, window-like outcrops of underlying moraines and the local absence of rockslide deposits cannot be the primary features of a high energy sturzstrom. This and observations of extension and normal faulting (Abele 1972, 1997) suggest movements at a lower kinetic energy level.

So based on this rockslide characteristics, a new conceptual model for the kinematics of catastrophic landslides surging on low permeable and water-saturated valley-fillings was established: (1) initially the rapid moving rockslide (i.e. sturzstrom) and subsequent (2) the creeping mass movement (i.e. gravitational spreading). The high mobility of the translational slide was favoured by the huge rock-mass volume and channelling effects. But the crucial processes lowering the shearing resistance are the dynamic disintegration and the increase of pore water pressure. Abrasion due to penetrative internal shearing has generated attrition breccias with (egde-) rounded clasts and silt- to sand-sized particles as secondary matrix. The high content of newly formed fine-grained matrix, especially in combination with mobilized groundwater, causes a significant reduction of the dynamic coefficient of friction and a change from sliding to flowing mechanism, enabling unexpected long run-out distances (Hsü 1975, Legros 2002 and references therein). But these fine particles also raise the cohesion between the rockslide fragments, enabling the subsequent dispersion and gravitational slip of the debris at a lower kinetic energy level.

In addition to dynamic disintegration, rockslide-motion was favoured by undrained loading. The abrupt increase of pore pressure in the water saturated, low permeable substrate (lacustrine sediments in the south, moraine in the north) caused a reduction of effective stresses. Subsequent to the rapid sturzstrom movement the rockslide-debris, and presumably also the uppermost parts of the incompetent substrate included, was effected by creeping processes and gravitational spreading. This resulted in further disintegration of the rockslide mass and generation of the present morphology characterised by the well-known Toma-hills and several lakes in depressions.

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