Analysis and prediction of the runout of rock slides and rock avalanches

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A rock slope failure leads to the detachment of a rock mass consisting of a mass of blocks. During the last few years continuum mechanics as well as discontinuum mechanics numerical codes have been developed for modelling the runout of these masses. The study presents two important models of these categories, the Distinct Element Model PFC (Itasca Consulting Group) and the continuum mechanics numerical code DAN3D (McDougall & Hungr, 2004).

Whereas DAN (Hungr, 1995; McDougall & Hungr, 2004) is a numerical code explicitly developed for the runout analysis of rapid, flow-like landslides (e.g. rock mass fall and debris flows), the DEM (Cundall & Strack, 1979) code PFC3D is designed for a broad range of application and has to be modified for runout modelling. In particular, the default local damping (proportional to acceleration) has to be replaced by a viscous damping activated at each particle-contact and an additional rotational damping has to be implemented to prevent extensive runouts.

The main difference between the two approaches depends on how the heterogeneous and complex landslide material may be considered. DAN and DAN3D is based on the concept of "equivalent fluid", defined by Hungr (1995) and used

tacitly by a number of other workers (e.g. Sousa & Voight, 1991; Rickenmann & Koch, 1997). In this framework, the heterogeneous and complex landslide material is modelled as a hypothetical material, which is governed by simple internal and basal rheological relationships that may be different from each other. The internal rheology is assumed to be frictional ("equivalent fluid" is therefore somewhat of a misnomer) and is governed by only one parameter, the internal friction angle. The shear resistance at the base of the flow is modelled by means of an open rheological kernel, which allows the use of frictional (with constant pore-pressure ratio), plastic, Bingham, Voellmy and other rheologies.

By contrast, PFC models the moving mass as an assembly of discrete particles. Although the particle assemblies used in PFC are closer to the nature of a fractured rock mass, the material is, however, hypothetical. For example, it is typically necessary to perform an upscaling of the block size distribution of the landslide material to a computable level. Therefore, both approaches re-

Text-Fig. 1.
Prediction of the runout of potential rock slides at Rotes Kögele (Hallstatt) using the Particle Flow Code (PFC) (Mair am Tinkhof, 2007).
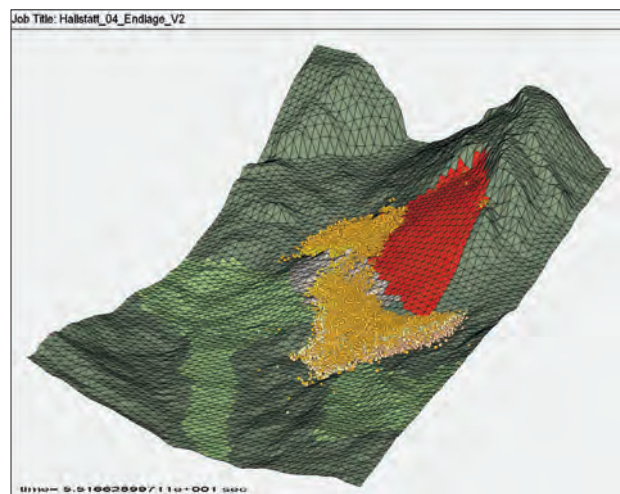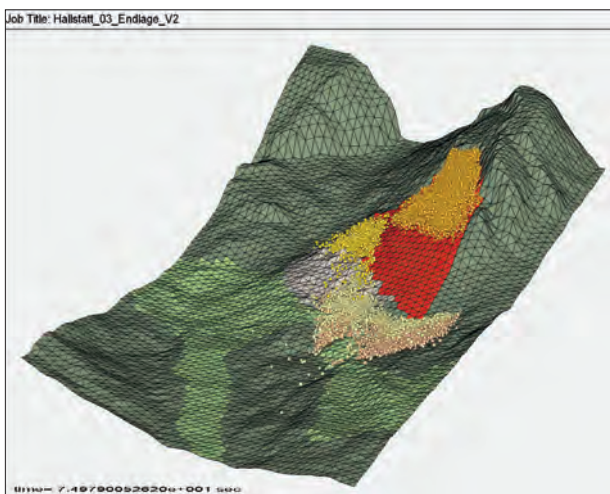
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Text-Fig. 2.
Back-calculation of a rock mass fall at
Mount Plassen (Hallstatt) using DAN3D.
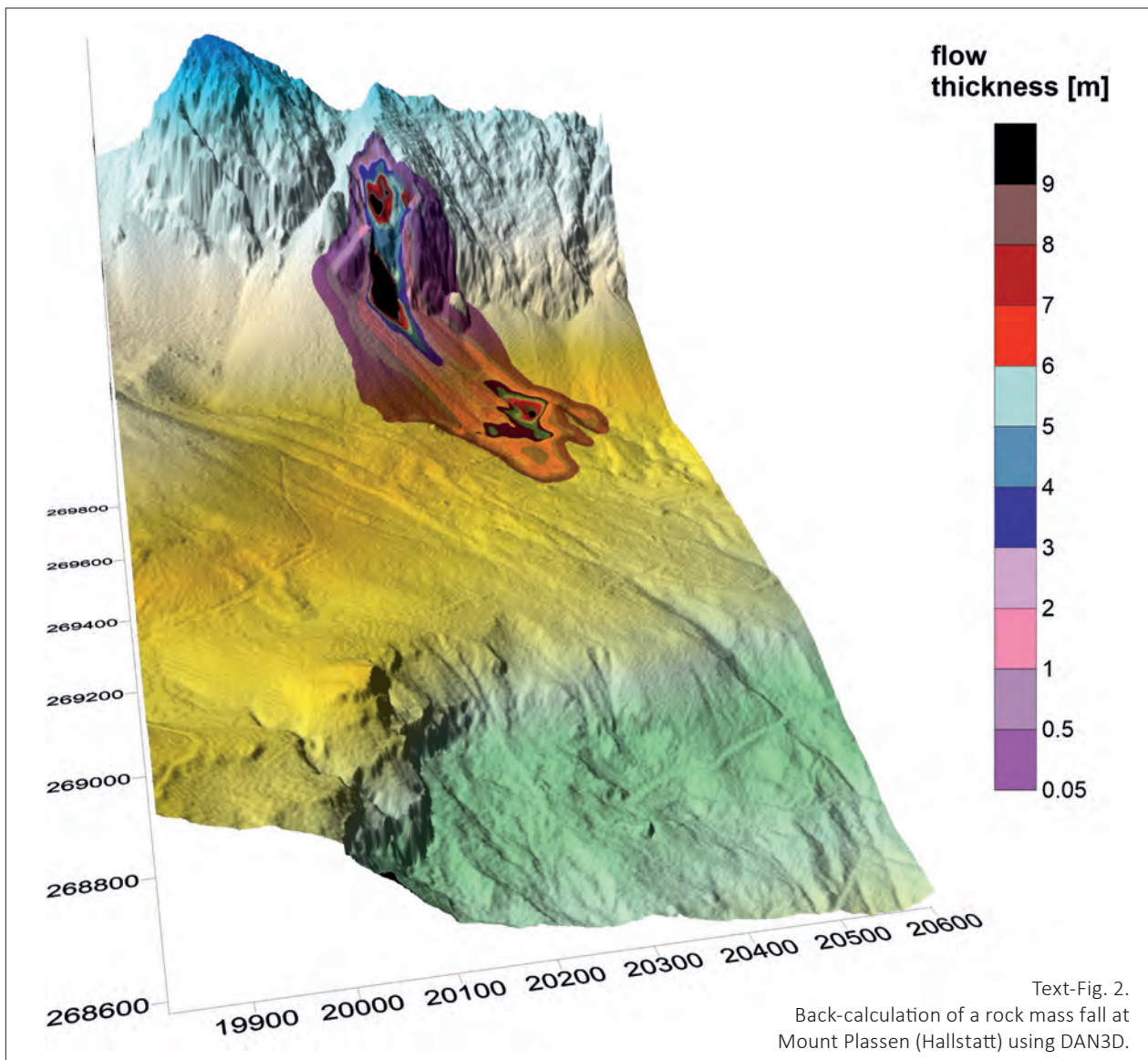
quire an empirical calibration procedure, in which actual landslides of a given type are subjected to trial-and-error back-analysis. The results are judged in terms of their ability to reproduce the bulk external behaviour of a prototype event, including the travel distance and duration and the spatial distribution of velocities and flow/deposit depths. The calibrated parameters are considered as apparent, rather than actual, material properties.

Two typical case studies are presented to demonstrate the capabilities of the two calculation approaches. The prediction of the runout of potential rock slides at Rotes Kögele (Text-Fig. 1) and the back-calculation of a recent rock mass fall at Mount Plassen (Text-Fig. 2).

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