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Reconstruction and back-calculation of the Banjarnegara landslide, Indonesia

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On December 12, 2014, the Banjarnegara area, Central Java, Indonesia, was hit by a landslide, leading to 98 casualties and destruction an area of ca. 125.000 m2. The landslide ocurred in weathered and hydrothermally altered andesitic rocks, beginning as a rotational slide, which spread out, leaving a central spur intact. At the western side of the spur, it developed into a mudflow, which caught onlookers by surprise and lead to the majority of casualties. The slide was triggered by rainfalls of 112 mm/d and 101 mm/d on the two preceding days. The initial sliding surface was predetermined by a clay layer, which is a hydrothermal alteration product of the andesitic and basaltic country rock, and has an approximately slope-parallel attitude (volcanic slope layering). Our study aims at understanding the complex mechanism of the formation as well as the movement of the slide, where several processes typical for slides in the province are combined.

In a first step we reconstruct the geometry of the landslide by approximating the pre-event topography and slip surface in 3D, based on an array of longitudinal and transverse sections. The present topography is well defined by photogrammetric data, while assumptions have to be made concerning the original topography and the slip surface, where it is covered by debris. The calculated volume of the slide mass is 130.338 m3.

In a second step, back calculation with the RocScience program Slide and the GRASS GIS r.slope.stability module is used to evaluate if measured geotechnical and reconstructed geohydraulic properties can represent ground conditions at the time the slope failed. Here we use a deterministic approach, and iteratively adjust the target parameters until equilibrium is reached (factor of safety = 1).

In a third step, we investigate the downslope flow of the slide mass, using the GRASS r.avaflow module, a novel GIS-based open source simulation framework for two-phase mass flows. We apply this to the comparatively slow movement of the eastern part of the slide, which did not exhibit liquid behavior, as well as to the mud flow of the western part. Thereby, we explore not only the sensitivity of the model outcomes to selected key parameters, especially basal friction angle, internal friction angle, and solid fraction, but also the possibilities of r.avaflow to model complex slides such as this, with strongly varying properties. We demonstrate the general ability of r.avaflow to reasonably reproduce the observed and reported spatio-temporal evolution of flow heights, volumes, and velocities as well as travel times of the mass flow. The optimized parameters further contribute to a set of guiding parameter values that will be useful for conducting predictive simulations on possible future landslides of comparable characteristics and magnitude.