Peculiarities of Large Landslides' Morphology and Internal Structure: Constraints of Their Motion Modelling

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Abstract

Set of natural constraints critically important for rockslides and rock avalanches modelling, both physical and numerical, can be provided by detail description of various large-, medium- and small-scale features typical of the deposits of the historical and past events. It allows developing models reproducing physical and mechanical processes that really take place during large landslides formation and emplacement, which is necessary for reliable hazard assessment. Evidence of abrupt changes of rheological behaviour of rockslides' debris during their emplacement and of the laminar flow-like debris motion and their possible causes are discussed.

Keywords

Bedrock landslide • Rock avalanche • Rheology • Laminar flow • Modelling

300.1 Introduction

Large bedrock landslides represent high hazard due to their extraordinary mobility, so that they can endanger areas quite distant from the mountains feet. Numerous mechanisms aimed to explain such mobility have been proposed. Since reliable physical modelling of such gigantic phenomena is problematic due to scale effect, their reconstruction is performed, most often, by the numerical modelling (Hungr 2011, Crosta et al. 2011). However, rheological models reproduced by these codes seem to be not always in line with the peculiarities of the phenomena in question observed in the field. In such cases the attempts to get best fit of the modelled deposits' shape or runout to those observed in nature could turn out into "playing of coefficients".

Two peculiarities typical of the real rock avalanches based on case studies from the Central Asian region mainly, i.e. evidence of abrupt changes of rheological behaviour of rockslide debris and of its laminar flow-like motion that can provide constraints in their numerical modelling are discussed.

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300.2 Evidence of Abrupt Changes of Rockslide Debris Rheological Behaviour

Analysis of along-way rockslide debris distribution shows that in some cases practically all collapsed material accumulates at the distal part of its path. Such slope failures were ascribed to the so called "Primary rock avalanche" type (Strom 1996, 2006, 2010). They could move either down-valley with distinct lateral confinement and form long-runout rock avalanches, or across-valley producing high natural dams with the impressive runup in frontal part and the proximal lowering. Numerous examples could be found in various mountainous regions, in Central Asia in particular (ibid.). Similar morphology is typical of the mobile parts of "Secondary rock avalanches" (ibid.) with compact accumulations at the feet of the collapsed slopes and long runout avalanche-like "tongues" (Fig. 300.1).

Despite evident lack of rockslide debris at the proximal parts of the travel path there are the trimlines clearly visible several dozens (sometimes more than hundred) meters above

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Fig. 300.1 Trimlines (T) above the *upper part* of the Mingteke rock avalanche in the Central Tien Shan

the top of the rockslide deposits at the debris-free part of the rock avalanche path where lateral confinement prevents its sideward spreading. These trimlines show that moving rockslide was very thick at the initial stage of its motion and, likely, moved as a relatively rigid (or highly viscous) body.

At the central part of debris path such high level of trimlines decreases rather sharply allowing assumption that at some stage of motion properties of moving debris changes drastically and it moved further as a granular flow. It looks as if rockslide debris liquefied and flue out leaving small patches on slopes much above the resultant surface. At several long runout rock avalanches one can observe evidence of such super-elevation at the bends along the lower part of debris path too.

In those cases where rockslide moved across relatively narrow gorges such flow-like motion of debris result in the significant runup as if viscous pseudo-liquid had passed an equilibrium point and "froze" at the opposite slope of the valley forming dams with distinct proximal lowering. It can be exemplified by several existing and breached rockslide dams—the 1911 Usoi in the Pamirs, the Köfels in the Alps, the Mini-Köfels, Djashilkul and Aksu in the Tien Shan. Sometimes, as, for example, at the Avalanche Lake rock avalanche in Canada that had risen over very steep and high opposite wall of the valley evidence of backward debris motion was observed (Evans et al. 1994).

Such conversion of debris motion style could be explained as the transition from sliding of the more or less rigid body at the initial stage of rockslide motion to flow-like spreading at the following stage (Shemiakin 1993, 2002; Staron and Lajeunesse 2013). It could be hypothesised that such conversion occurs when the process of debris fragmentation reaches some threshold value resulting in rapid and significant decrease of the angle of the internal friction of debris. Lateral confinement typical of most of such case studies prevents sideward thinning of the moving rock avalanche body and, thus, facilitates fragmentation due to higher lithostatic pressure. The exact mechanism of such increasing fragmentation could be due to dynamic fragmentation proposed by Tim Davies and Mauri McSaveney (Davies and McSaveney 1999; McSaveney and Davies 2006), or due to combination of the lithostatic loading and shearing tested experimentally (Dubovskoi et al. 2008; Strom and Pernik 2013). Unlikely that such effect could be caused by decrease of friction coefficient just at the base of sliding rock mass. The latter should result in acceleration of the entire sliding body but not in the observed effects of its rheological behaviour changes.

300.3 Evidence of a Rock Avalanche Debris Laminar Flow

An important point in the numerical modelling of rock avalanche motion is the correct selection of the flow-like motion equations. They must correspond to the processes that really take place during rock avalanche emplacement. These constrains could be also derived from the observations on the internal structure of rock avalanche deposits (Dunning and Armitage 2011). Analysis of numerous case studies from different parts of the World, from the Central Asian region in particular (Strom 1994; Abdrakhmatov and Strom

Fig. 300.2 Unmixed "layers" of debris in the frontal part of the Ornok rockslide in the Central Tien Shan. *White arrow* indicates the position of the outcrop shown on Fig. 300.3

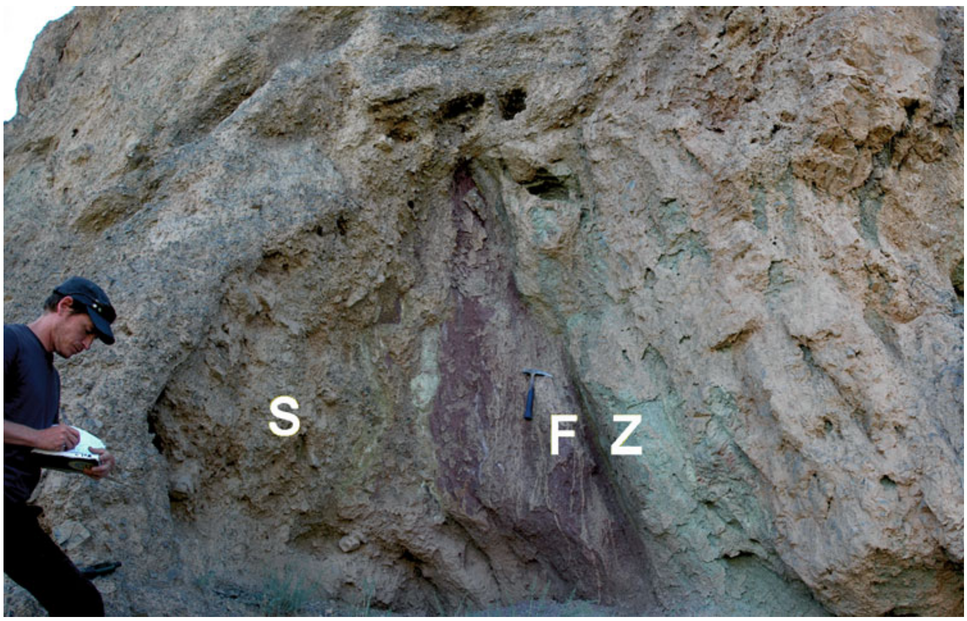

Fig. 300.3 Mylonitized Palaeozoic rocks of the fault zone (FZ) thrusted over the quaternary scree (S) within the displaced block in the *lower part* of the Ornok rockslide body. Estimated distance from the original position of this tectonic contact exceeds 1 km

2006) show that if the rockslide source zone is composed of different lithological types of rocks, especially varying in colour, mutual position of debris units that had originated from different parts of the source zone retains and they form pseudo-stratified bodies without any mixing (Figs. 300.2, 300.3) and, thus, without evidence of turbulence during rockslide motion.

Thus use of the equations describing turbulent flow even if they allow to model resultant shape of rock avalanche deposits during back analysis of the historical case studies, seems to be inadequate, as far as rock avalanche motion differs significantly from motion of debris flows with high water content where distinct evidence of turbulence have been observed by eyewitnesses and could be revealed from the study of debris flow deposits (Stepanov and Stepanova 1991).

300.4 Conclusions

Possibility of changing of the mechanical properties of moving debris that results in qualitative transformation of its rheological behaviour as well as absence of mixing of debris originated from different lithologies (or from different parts of the source zone) (Strom 1994, 2006) indicating laminar rather than turbulent flow-like motion of rockslide debris provide significant constraints in their modelling, both physical and numerical. Numerical simulation of such features should provide reconstruction not only of the resultant morphology of rockslide deposits but also of the basic peculiarities of their internal structure and thickness of moving debris at the consecutive stages of its emplacement.

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