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Towards a numerical run-out model for quick-clay slides

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Highly sensitive glacio-marine clays occur in many relatively low-lying areas near the coasts of eastern Canada, Scandinavia and northern Russia. If the load exceeds the yield stress of these clays, they quickly liquefy, with a reduction of the yield strength and the viscosity by several orders of magnitude. Leaching, fluvial erosion, earthquakes and man-made overloads, by themselves or combined, are the most frequent triggers of quick-clay slides, which are hard to predict and can attain catastrophic dimensions.

The present contribution reports on two preparatory studies that were conducted with a view to creating a run-out model tailored to the characteristics of quick-clay slides. One study analyzed the connections between the morphological and geotechnical properties of more than 30 well-documented Norwegian quick-clay slides and their run-out behavior. The laboratory experiments by Locat and Demers (1988) suggest that the behavior of quick clays can be reasonably described by universal relations involving the liquidity index, plastic index, remolding energy, salinity and sensitivity. However, these tests should be repeated with Norwegian clays and analyzed in terms of a (shear-thinning) Herschel–Bulkley fluid rather than a Bingham fluid because the shear stress appears to grow in a sub-linear fashion with the shear rate. Further study is required to understand the discrepancy between the material parameters obtained in laboratory tests of material from observed slides and in back-calculations of the same slides with the simple model by Edgers & Karlsrud (1982).

The second study assessed the capability of existing numerical flow models to capture the most important aspects of quick-clay slides by back-calculating three different, well documented events in Norway: Rissa (1978), Finneidfjord (1996) and Byneset (2012). The numerical codes were (i) BING, a quasi-two-dimensional visco-plastic model, (ii) DAN3D (2009 version), and (iii) MassMov2D. The latter two are quasi-three-dimensional codes with a choice of bed-friction laws. The findings of the simulations point strongly towards the need for a different modeling approach that incorporates the essential physical features of quick-clay slides. The major requirement is a realistic description of remolding. A two-layer model is needed to describe the non-sensitive topsoil that often is passively advected by the slide. In many cases, the topography is rather complex so that 3D or quasi-3D (depth-averaged) models are required for realistic modeling of flow heights and velocities. Finally, since many Norwegian quick-clay slides run-out in a fjord (and may generate a tsunami), it is also desirable to explicitly account for buoyancy and hydrodynamic drag.