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Evolution of the 1963 Vajont landslide (Northern Italy) from low and high velocity friction experiments

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The final slip at about 30 m/s of the Vajont landslide (Northern Italy) on 9th October 1963 was preceded by a long creeping phase which was monitored over about three years. Creep was localized in cm-thick clay-rich (50% Ca-montmorillonite + smectite + illite + vermiculite, 40% calcite and 10% quartz) gouge layers. The velocity results in thermoviscoplastic model of the landslide (Veveakis et al., 2007) suggested that during creep, compaction and frictional heating released water from the clay-rich layer and, by increasing the pore-pressure in the slipping zone, determined the final collapse of the landslide. Here we investigated the frictional evolution of the clay-rich layers and the transition towards the final collapse.

Experiments were carried out on the clayey gouge from the slipping zone at atmospheric humidity conditions ("dry") and in the presence of excess water ("saturated"). High velocity friction experiments were performed in a rotary shear apparatus at 1 MPa normal stress (about the normal stress at the sliding surface of the Vajont landslide), velocity v from 0.006 m/s to 1.31 m/s and displacements up to 34 m. The 1 mm-thick clayey gouges were sandwiched between marble cylindrical specimens (24.95 mm in diameter) and confined by Teflon rings to avoid gouge expulsion during the experiments. The fluid release during the experiments was monitored with a humidity sensor. Low velocity friction experiments were performed in a biaxial apparatus at 5 MPa normal stress, v from 1.0 10E-7 m/s to 1.0 10E-4 m/s (within the range at which the slide became critical, 2.0 10E-7 m/s, Veveakis et al., 2007) and displacements up to 0.02 m.

In dry experiments, friction is 0.43-0.47 at v < 1.0 10E-4 m/s and decreases to 0.21 at 1.31 m/s. Velocity-step runs evidenced a velocity-weakening behaviour with a (direct effect) – b (evolution effect) = -0.005 to -0.008. In saturated experiments, friction is 0.18 at v < 1.0 10E-4 m/s (in agreement with the experiments by Tika & Hutchinson 1999 performed on the Vajont clays), and decreases to 0.03-0.05 at v > 0.006 m/s.

At dry conditions, dilatancy was observed for v > 0.7 m/s suggesting fault pressurization by water release due to smectite-to-illite decomposition. Decomposition occurred at temperatures above 300°C, as confirmed by the breakdown of the Teflon ring and by the emission of H2O from the sample assembly. SEM observations show that deformation was localized in 200 micron-thick slipping zone at the contact with the marble cylinders, and that the gouge includes concentric aggregates of sub-micrometer clay + calcite + quartz grains wrapping nuclei of calcite, quartz or clay fragments. All these features suggest that rolling lubrication was concomitant to thermal pressurization. At saturated conditions, dilatancy and H2O emission were absent, deformation was diffused in the slipping zone and no concentric structures were found: these features suggest that the H2O liquid-vapour transition was not achieved, though the actual lubricating mechanism has not been fully understood yet.

Our experimental data indicate that the frictional behaviour is velocity-weakening in both dry and saturated conditions and determined by the clay fraction within the gouge and it. The presence of free water in the slipping zone reduces friction to almost zero, explaining the high velocity achieved by the slide during the final collapse.

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