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The Super-Sauze Flowslide (Alpes-de-Haute-Provence, France) Triggering Mechanisms and Behaviour

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SCIENTIFIC PROBLEM
Complex landslides, evolving into flows, are frequent in the "Terres-Noires" of the French Prealps. In the Barcelonnette basin, several of these flowslides are active, localized mostly to torrential basins submitted to an intense erosion (Antoine & al., 1995 ; Flageollet & al., 1998). They have a characteristic morphology : blocks and panels which break away from the crown, by retrogressive plane ruptures, accumulate by dislocating in one or several gullies, and constitute, after their progressive deconstructuring, a heterogeneous debris-flow. To understand and model the behavior of these type of flowslides, this article, based on the studied Super-Sauze flowslide, describes first the mechanisms and modes of triggering of these structural landslides through an analysis of the recent rupture of a marly crest, and then the modes of evolution of the debris-flow.

A FAVOURABLE MORPHO-STRUCTURAL CONTEXT
The Super-Sauze flowslide (in the Roubines area) lies in the superior member of the callovo-oxfordian black marls, and develops in a torrential basin gullied in bad-lands. Between 80 and 500m in length, the naked interflues (crests), sharp, very steep, more or less parallel and coalescent, are spaced 40 to 50m apart. They individualize gullies, of variable depths, marked mostly by seasonal, more rarely, by perennial run-offs. Beginning in the 60's, the flowslide now stretches over approximately 800m between 2105m at the crown and 1740m at the basis of the flow (Fig. 1). The marls present a facies of clayey schists, black or gray, finely laminated, alternating with small calcareous beds. This microstructure, which partly accounts for their erodability and their susceptibility to mass movements, results from the conditions of sedimentation in successive layers (Awongo, 1984) and the tectonic history of the region. Broken and deformed by important tectonic events, the Roubine marly mountain presents a faulted and strongly jointed macro-structure, and strong variations of dip. Moreover, the microtectonic plays an essential role, by constituting potential sliding surfaces and by guiding the fragmentation and the weathering of the marly panels. The morphometry of the clasts, which results from their spalling (allonged or platy parting), depends on the orientation of the bedding joints, of the schistosity and of the carbonate content of the marls (Alexandre, 1995). Thus, after a phase of gullyng, the structure and the morphology of the site work towards the development of gravity-driven mass mechanisms (slidings, rockfalls, falls of blocks, mudflows, debris flows, ...) that fossilize a drainage channel (Flageollet & al., 1998).

CONDITIONS TRIGGERING THE SLIDINGS
There was no direct observation during the initiation and extension phases, of the 1960's slidings (the first investigations began in 1991). Nevertheless, it is possible to reconstitute the

conditions (favourable factors) triggering slidings in such torrential basins, on the strength of an analysis of the rupture of a crest situated on the western flank of the flow (Fig. 1) that occurred at the beginning of 1997. This crest stretches over more than 80m, between heights of 1840m and 1910m. Its average slope reaches 35°, while the slope of the initial topographic surface must have been closer to 40°. In October 1997, several dislocated blocks separated by small strike-slip faults are edged by large and deep quasi vertical open fractures. On the surface, these blocks are fragmented over several decimeters while they are coherent and less destructured in depth. The main scarp reaches 7m in height. Fracturation planes, small calcareous beds (30cm thick), schistosity planes (inclined to 32-35° downstream) and many sliding scratches are visible. The structural fracture openings were caused by the combined effects of gravity and decompression. Moreover, ochre deposit traces on the main scarp and on the fracturation planes suggest poor water circulation along these discontinuities. By May 1998, the rupture has clearly increased and eight blocks can be identified. Along the length of the crest run two fracturation planes, one inclined to 58° on the south flank and the other inclined to 38-40° on the north flank, delimiting blocks which are more or less dislocated and
Figure 2. Morphological evolution, kinematic and mode of rupture of a marly in-situ crest.

broken. The shape and the position of the surface of rupture are obtained, by prolonging these fracturation planes in depth, according to the method of intersections (Van Asch, 1984). The surface thus obtained is rectilinear, situated on average 8-9m under the current topographic surface, inclined 33° downstream, and therefore appreciably parallel with the schistosity
rheological behaviour of the flow. The covered paleotopography individualizes compartments with different kinematic, mechanic and hydrodynamic characteristics (Flageollet & al., submitted). The vertical structure of the flow displays two superimposed units. The first, 5 to 9m thick, is a very active and very wet viscous mud formation (rate of movement superior to 5m/year, semi-pervious material with groundwater fluctuations between -0.5 to -1.5m, plastic or visco-plastic behavior), while the second, with a maximum thickness of 10m, is a stiff
compact rigid/plastic and stable formation (impervious material, "dead" body, ...).

CONCLUSIONS
In such strongly gullied marly basins, rock block slides happen in down the dip sectors, when the dips reach values close or superior to those of the angle of internal friction, because of the reduction of the cohesion, linked to the decompression, and possible overpressure linked to infiltrations in the different discontinuities and interfaces. As it evolves, this sliding material forms into a debris-flow which progresses by fossilizing the torrential basin. The dynamic behavior of this type of flowslide has to be modelled (PhD thesis J.-P. Malet, under way), in connection with meteorological and hydrodynamic conditions, to evaluate the induced risk of rapid transformation, into muddy fluid flows or into torrential lava. Similarly, a good understanding of how gullying and the triggering of mass movements are interrelated is essential if we are to be able to deal effectively with such torrential basins.

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REFERENCES.