Morpho-structure and triggering conditions of the Laval landslide developed in clay-shales, Draix catchment (South French Alps)

M. Fressard & O. Maquaire
CNRS UMR 6554 LETG, University of Caen Basse-Normandie, Caen, France

J.-P. Malet
CNRS UMR 7516, School and Observatory of Earth Sciences, University of Strasbourg, France

S. Klotz
Cemagref, Grenoble, France

G. Grandjean
BRGM, Planning service and natural hazards, Orléans, France

ABSTRACT: Black marl hillslopes in the French Alps are strongly affected by mass movements. This paper presents the methodology used in order to characterize the geometrical and geotechnical structure of the Laval landslide (Draix, Alpes-de-Haute-Provence, France). The methodology has consisted in combining geomorphologic techniques, geotechnical test (dynamic penetration tests) and geophysical seismic survey. The results indicate that the combination of the three techniques is well suited to characterize shallow landslides structure developed in black marls.

1 INTRODUCTION

The callovo-oxfordian black marls of Draix (Alpes-de-Haute-Provence, France) are known for their susceptibility to weathering and erosion, and show many examples of active structural landslides. These landslides generally present a morphology composed of a main scarp with straight ruptures and controlled by the bedding and the discontinuities.

The material that failed from the main scarp forms accumulation zones composed of reworked marls and blocks of heterogeneous sizes. The reworked soils are largely exposed to the high intensity rainfalls observed during summer storms and strongly contribute to the high sediment yield observed in the basins. The Laval largest landslide, which occurred in January 1999, has surprised many observers by its size and the volume of mobilized materials. The study area extends on 4000 m^2 from 875 m to 935 m elevation.

2 GENERAL OBJECTIVES

The objective of this study is to characterize the internal structure of the Laval landslide and to identify the conditionning and triggering factors. The methodology consists in combining aerial photo-interpretation techniques, geomorphological observations and measurements, geotechnical measurements and a seismic survey. A qualitative model of landslide development is proposed, and the landslide geometry is defined.

Several morphological mapping and topometric measurements have been carried out on the site (Huser, 2001). It is instrumented since 2006 in order to characterize the water circulation inside the accumulation zone (Garel et al., 2008). A water infiltration experience has been leaded in October 2007 (Grandjean et al*.,* in press).

3 MATERIAL AND METHODS

The acquisition of geophysical and geotechnical data in the accumulation zone allows to identify the boundary between reworked materials and intact bed rock. The dynamic penetration tests have been applied to the recognition of marly bedorock by Flageollet et al. (2000) and Maquaire et al. (2002). This method allows to obtain information on the geometry and structure. About 50 drilling have been done from January 2007 to March 2008. Seismic surveying has been applied by Grandjean et al. (2006). The method of continuous imagery has shown good results for the characterisation of marly landslides structure. The results are interpreted along nine cross sections distributed on the site. A qualitative model is proposed according to the geomophological aspects observed *in situ* which evolution is estimated by the comparison of the georeferenced photographs taken before and after the landslide triggering (Fressard, 2008).

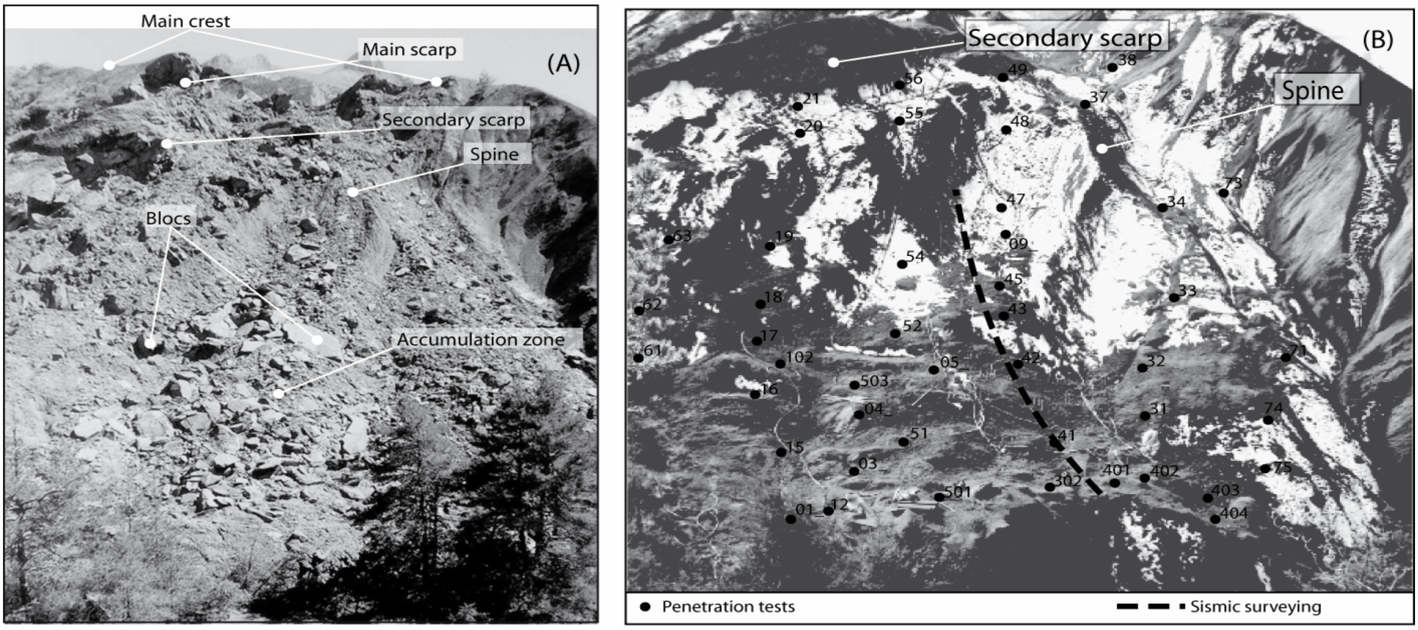

Figure 1. View of the Laval landslide: (A) May 1999; (B) March 2008 with the penetration tests and seismic survey location.

In order to characterize the predisposition factors, the morpho-structural measurement have been completed with fault and stratigraphy scanline observations. These data have been combined to GPS and terrestrial laser scanning realized in July 2007 in order to integrate the information in a GIS database. It permits to propose interpretative sections that suggest the predisposition conditions according to the iso-volumes and the marls expansion coefficient (Klotz, 1998).

4 RESULTS

In the accumulation zone, the materials thickness is variable from approximately 1 to 6 m (Fig. 2-3). The materialis composed of reworked marls and blocks of various sizes. The interpretation of the cross-sections shows that the paletopography overlaid is in accordance with the observations from the aerial photographs prior to the triggering. The limit between accumulation and ablation zone is clearly established, and constitutes a first stage towards the understanding of the triggering conditions. Morpho-structural measurement will allow us to go further into that question.

The section 1 (Fig. 2) indicates that cracks have a major influence in the geometry of the rupture. The massif failed in many dihedrons with two degrees of freedom according to two components of a moving vector with a general North orientation (Fig. 4):

(a) the first component is principally controlled by the main crack N90°-50°N. This component is orientated North-North-West, and supplies the most important volume to the accumulation zone;

(b) a second component controlled by the bedding is orientated North-North-East. This displacement of the failed material along this component seems to have occurred slower because the mass has moved in a homogeneous way.

Few damages are visible except a few open cracks. These two components of a major moving vector (North direction) have been validated by the observation of the movement of two young pines over the main scarp. These trees are visible on the georeferenced pictures taken before and after the main rupture.

The volume of the accumulation zone is estimated at 8.000-10.000 m^3, corresponsing to a volume of ca. 4.500-5.600 m^3 of compact marls. This figure has been calculated according to the 'expnasion coefficient' calculated by Klotz (1998). This iso-volume estimation shows that the material of the accumulation zone (relatively thin) is supplied with shallow landslides which base altitude has been estimated at around 900 m. Thus the "pre-landslide" topography has been reconstituted according to the observation of the aerial photographs taken before and after the triggering date.

5 CONCLUSION

The combination of geomorphologic and geotechnic methods has premised to identify the structure and the geometry of the accumulation zone, and then to understand the structure of the main scarp and the triggering conditions. ..

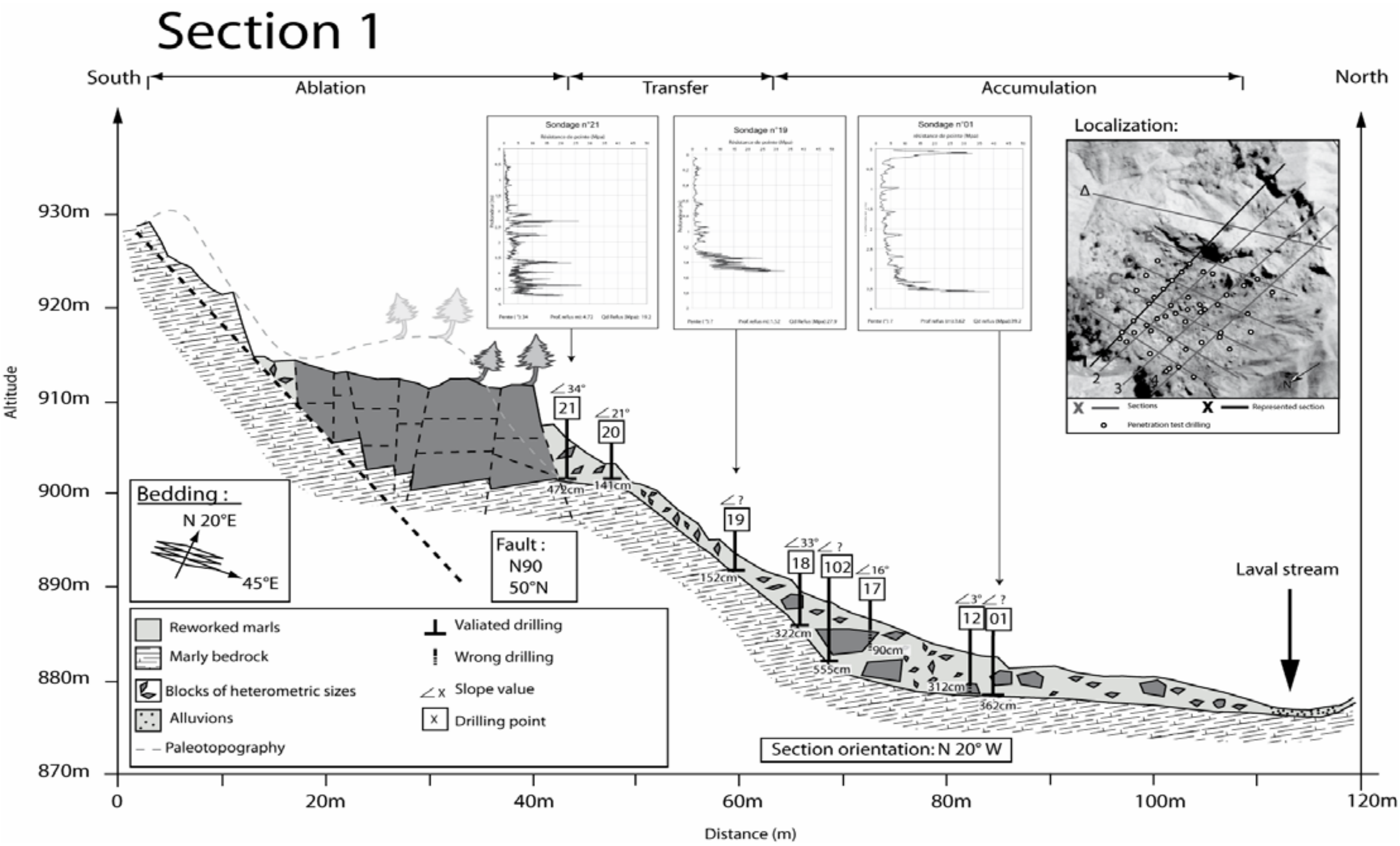

Figure 2. Longitudinal section of the Laval landslide.

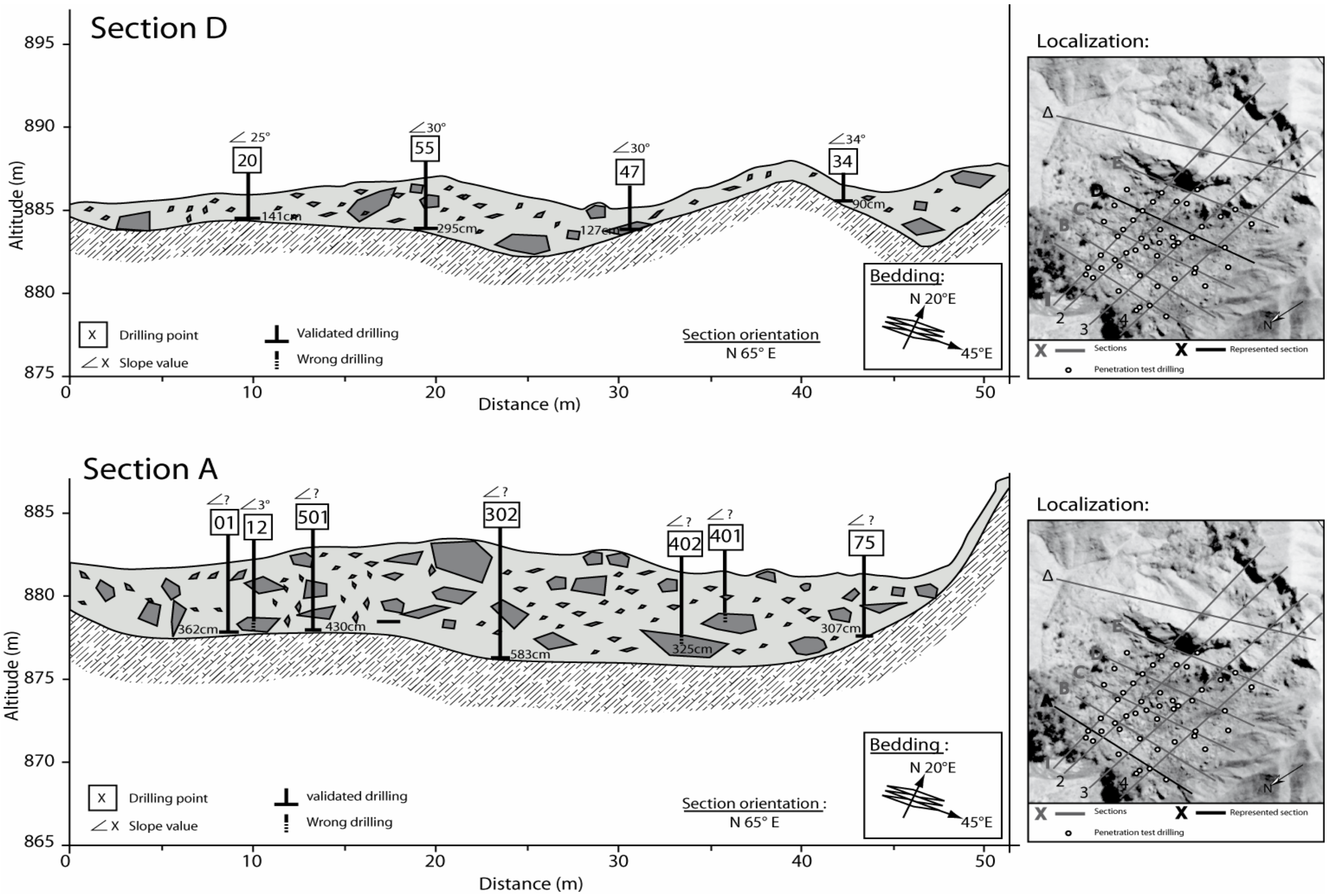

Figure 3. Transversal sections of the Laval landslide.

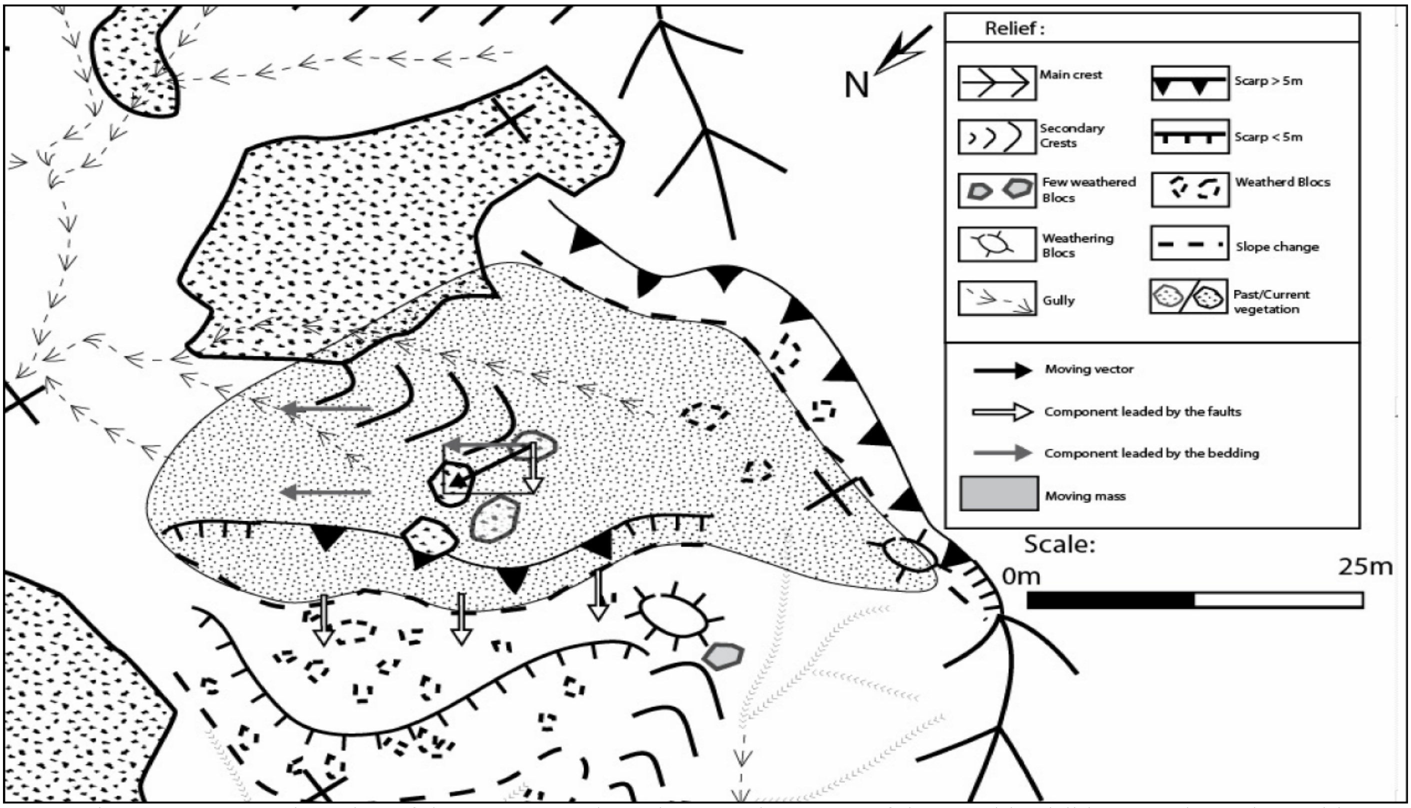

Figure 4. Major components orientation of the movement along the secondary scarp of the Laval landslide. Note down the position of the pines position before and after the movement.

This conceptual model has shown its interest for the characterization of those phenomenons We have thus been able to define precisely the limit between the accumulation and the ablation zone, recognize the morphology of the paleotopography and estimate the volume of materials in the accumulation zone

The structural measurements and the in situ observations have premised to characterize the internal structure of the ablation zone. This landslide seems to be wildly commanded by the structural factors of the massif. A numerical and hydro-dynamical modeling will soon validate those results.

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