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Characterization of the fissure system of landslide. Integration of seismic azimuth tomography, geotechnical tests and geomorphological mapping.

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In the past, seismic methods have been successfully tested to investigate the structure of unstable slopes, particularly for localizing bedrock geometry. These methods allow direct and non-intrusive measurements of acoustic (P) wave velocity, an essential parameter to define the properties of reworked moving materials. Such measurements were carried out at the Super-Sauze mudslide, located in the Barcelonnette Basin (French South Alps). This mudslide has developed in Callovian-Oxfordian black marls, known as “Terres Noires”. The mudslide kinematics which comprises velocities of 0.005 to 0.3 m.day-1, is controlled by variations in water flows and the consecutive building of positive pore pressures.The slope surface is highly irregular and affected by kinematical tension cracks and fissures of 0.5 to over 1.0 m deep as well as by surficial swelling/shrinking fissures. The geometry and structure of the fissure system, which controls part of the water circulation, has to be characterized in order to better understand the mechanics of the mudslide. A method is proposed to map the fissure system by combining non-invasive geophysical measurements, geotechnical penetrations tests and geomorphological mapping from high resolution air photographs and fieldwork. Geophysical measurements performed on the Super-Sauze site were adapted to characterize the structure of the mudslide in terms of fissure intensity by using seismic first-breaks azimuth tomography. These measurements involved

48 channels seismic equipment featured by 40 Hz geophones and a handy-hammer source. Geophones sensors were set at the surface, around a circle of 12 m in diameter, in a plot where deformation markers were observed. The source was activated in the centre of the circle and seismic arrivals recorded at each sensor. First-breaks traveltimes were afterwards inverted using the JaTS software coupling an eikonal solver to a SIRT (Simultaneous Iterative Reconstruction Technique) algorithm. As qualitative results, P-wave inverted velocity map shows velocity anomalies in relation with the main directions of fissures observed in the surface. For a quantitative demonstration, fissure density and depth were characterized from field measurements and near surface aerial photographs A 1*1 m2 raster was drawn over the test area and measurements of fissure depth and estimations of fissure density were made. Both observation were summarized into three classes and interpreted in terms of fissure type. Together with a sketch of the fissure structure, near surface aerial photographs were made with the NESCAFE system at an altituder of 8 m above surface. Estimation of the compacity and resistance of the soil was also performed from several geotechnical penetration tests (limited to a depth of 3 m) with a penetrometer of variable energy within the circle. Geotechnical resistance maps were calculated at several depths by kriging the value of the soil resistance over the entire circle. The distribution of P-wave velocities seems to be correlated to some of these parameters, indicating that this method could be used as a new potential technique for analysing the spatial distribution of fissure systems of active landslide without intrusive technologies. This innovative technique should be at the basis of future and more systematic studies of high hazard zones, in conjunction to fissure parameters mapping.