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Deep-seated slope deformations in the Northern Apennines: integrated analysis and monitoring of the Berceto landslide (Parma, Italy)

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Introduction

In the Northern Apennines, large slope instability is almost exclusively related to slow/very slow - moving mass movements that rarely develop into catastrophic failures. Nonetheless, they cause a relevant impact on socio-economic activities since they often affect areas that are inhabited from historical times, and that can suffer severe losses in relation to reactivation events or continued creeping movements. This study is aimed at defining the developmental movement of Berceto landslide, a large ($5\ km^2$) an deep (150 m) mass movement, that can be classified as a rotational and translational rock slide, that locally develops into falls and earth flows-slides. This landslide causes damages and deformations on houses and infrastructures in the village of Berceto, counting about 3000 inhabitants, in other minor hamlets and in the E33 highway (A15 Parma – La Spezia).

Geologic and Geomorphic setting

The landslide affects a sequence of rock masses characterised by the overlapping of sandstone formation on clay formations that are dipping downslope, and by the presence of high-angle normal faults that separate the sandstone slab into blocks. The sandstone slab is characterized by brittle behaviour and secondary fracture permeability, while the clay formations is characterized by plastic and viscous behaviour and primary permeability. The gravitational evolution of the slope has produced a slope topography characterized by scarps alternated to either low acclivity zones or to tilting zones and extension trenches or deep gullies.

Methods

This study has focused on the acquisition and the analysis of geologic and structural data, geomorphologic data, geotechnics and geomechanics data, radiocarbon dating data and instrumental monitoring data, these latter provided principally by Autocamionale della Cisa SpA (inclinometers and GPS) or generated during this research by means of space borne radar interferometry (DInSAR).

Results

Radiocarbon dating of organic rest found through boring made in a tilting zone located in the uppermost part of the slope, that coincides with the position of small lake now completely drained out artificially, has proved that the mass movement started developing prior to 30.000 yr BP. The cores, that contained other organic matter dated to more recent times, have also proved that the progressive tilting of the block has taken place intermittently and more frequently during periods coinciding with worsening of climatic conditions.

Cores from more than 30 boreholes have permitted the reconstruction of the rock stratigraphy involved into the mass movement. Data from the associated inclinometers, have allowed the geometry and the depth of the presently active slide surfaces to be defined between 92 m and 4 m.

The GPS monitoring, started in November 1998 and comprehensive of six cycles of measurement on about 16 benchmarks located prevalently around the E33 highway, has helped defining the extension the lowermost rock or earth slides and displacement rate in the lowermost part of the phenomenon, that has proved to be in the range of 2 to 20 cm/year (although some non monitored earth slides are probably even faster).

The differential interferometry, based on images obtained between January 1996 and January 2001 by ERS1 and ERS2 satellites (operating in C-band), has permitted to detect and quantify movements especially in correspondence of the village of Berceto, that represents the uppermost part of the mass movement. This data is highly valuable since no other monitoring system is installed in this zone, except for a few inclinometers located in some superficial deformations, and that are probably been drilled to shallow to detect deep seated slope deformations. Interferometry has, in fact, evidenced a more or less continue ground deformation in the order of mm/year, that on the long term might be considered responsible for the damages suffered by some buildings and roads, especially in some portion of the village located over huge disarranged blocks of rock masses.

Conclusion

On the basis of data acquired and analysed during the research, the zone of major risk can be outlined: they surely include the highway E33, that represents a linear element across the lower part of the landslide, but also other zones in the upper and intermediate slope, especially where scarps subject to retrogression are found, or nearby trench zones or upon isolated disarranged blocks. This is the case for part of the village of Berceto, built on a landslide area that, this study has proved, shows a continuous, although extremely slow, deformation.

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