The Ligosullo (UD, Italy) Landslide, Revisiting of Past Data and Prospects from Monitoring Activities

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Abstract

The paper focuses on the analysis of a landslide, located in the northern sector of the Friuli Venezia-Giulia Region (North-Eastern Italy) affecting the village of Ligosullo. Field surveys, geophysical investigations and interferometric analyses, financed by the Geological Survey of Friuli Venezia-Giulia Region in the last 15 years let to recognize a sliding surface up to 70 m deep, causing the mobilization of 7 millions m^3 of material. A new phase of studies including geological and geomechanical surveys and monitoring activities has been recently undertaken by the University of Padua (Department of Geoscience) and NHAZCA S.r.l. (Spin-off of "Sapienza University of Rome"). The first results we obtained and the future goals are discussed in this paper.

Keywords

Landslide • Interferometric analysis (SAR) • Terrestrial interferometric (TInSAR) surveys • Displacement • Monitoring

34.1 Introduction

The aim of this work is to improve the knowledge about the Ligosullo landslide by combining geological and geomechanical surveys with monitoring data. The huge interest is due to the presence of the village of Ligosullo in the area affected by the landslide. Terrestrial Interferometric (TInSAR) surveys (Bozzano et al. 2011) and topographic surveys have been planned and already partially realised in order to define the displacement field affecting the slope and its relation with the seasonal regime. Moreover, advanced Satellite SAR Interferometric (A-DInSAR) analysis will be performed in order to detect the historical displacement trend of the landslide (Mazzanti et al. 2011).

34.2 Geological and Structural Setting

The study area belongs to the Carnic Alps, which are a range of the Southern Alps. They extend from east to west for about 100 km, and form the border between Austria and Italy. The geology of the area around Ligosullo involves the sedimentary rocks of the Permo-Anisic Succession (Venturini 1986, 2006), that locally shows a moderate (50°/60°) SE dipping stratification (Fig. 34.1). In particular the main lithologies are represented by the Bellerophon Formation, with dark grey/white saccharoidal laminated gypsum

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(evaporitic lagoonal deposits) and the Val Gardena Sandstone with reddish breccias and conglomerates. The structural setting of the area is characterized by the presence of an important E-W oriented belt system and the associated faults (mainly reverse faults or thrust), which strongly influences the morphology of the region (Fig. 34.1).

Major valleys are set, in fact along these faults. In the area reported in Fig. 34.1, the Pontaiba-Minischitte Line is an important structural element trending E-W associated with many secondary faults mainly oriented N–S (Fig. 34.1) (Selli 1963). In the southern part of the map of Figure 34.1 the Val Gardena sandstone mainly constituting the Ligosullo

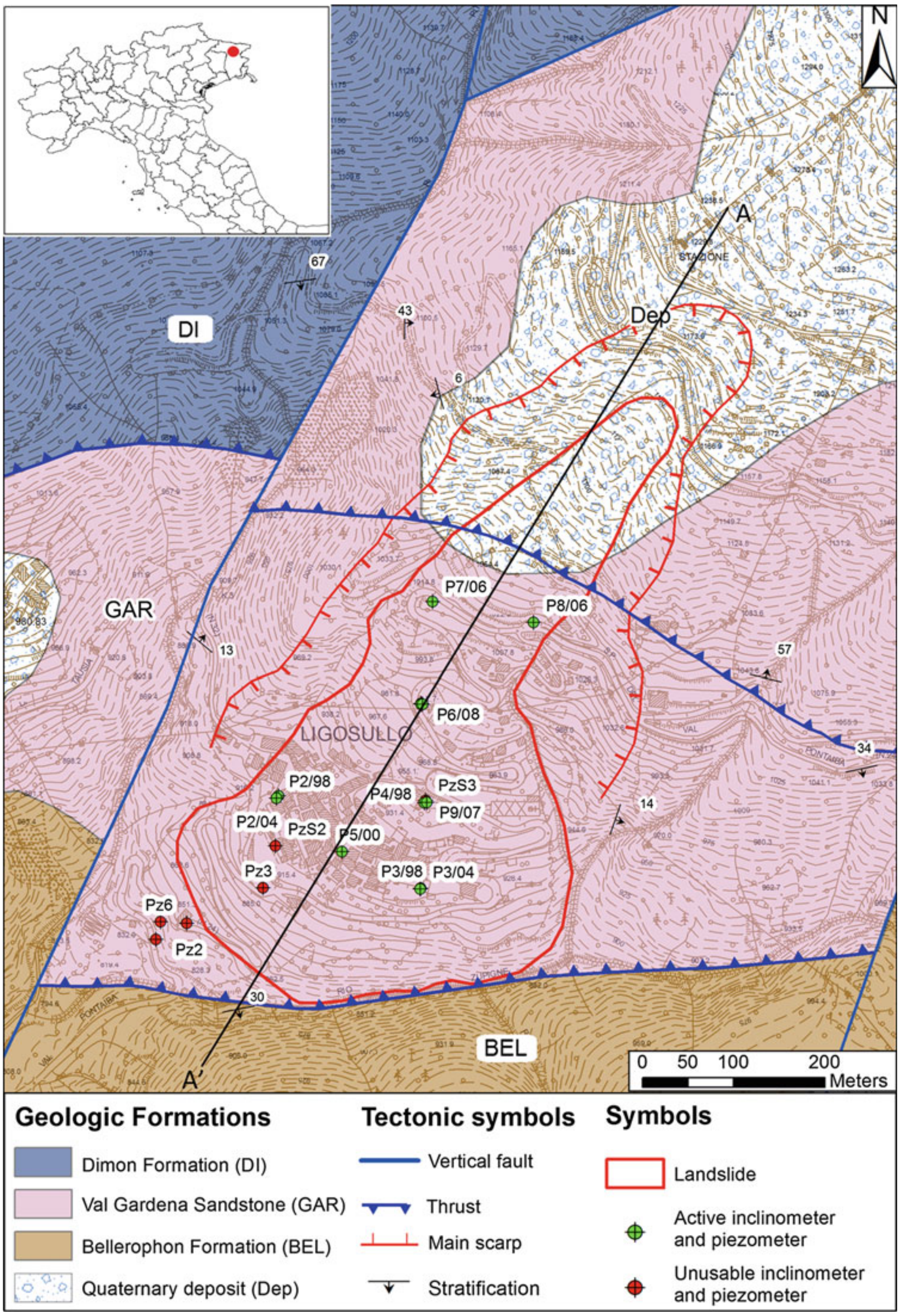

Fig. 34.1 Geologic map of the study area

landslide slope and the Bellerophon Formation are in contact along the Pontaiba-Minischitte Line.

34.3 The Landslide: Monitoring and Analysis

34.3.1 Landslide Characterization: State of Art from Previous Investigations

By means of the geological reconstructions, the landslide body is resulted as mainly composed by the Val Gardena Sandstone. Geomechanical surveys carried out during the summer 2013 stated the intense weathering and jointing conditions of the landslide rock mass. Field surveys, geophysical investigations and the inclinometric monitoring of the landslide financed by Geological Survey of Friuli Venezia-Giulia Region since 1998, allowed us to hypothesize a sliding surface up to 67 m deep. This surface is located in correspondence of the contact between the Val Gardena Sandstone and the Bellerophon Formation. Moreover, some secondary shallow sliding surfaces were reconstructed. A volume of about 7 millions m^3 of mobilized has been computed. The slope movement has been classified as a structurally-complex landsliding (Fig. 34.2).

Inclinometer monitoring showed that the main direction of movement (195°N) is in accordance with that one of the maximum slope angle. An average rate of 18 mm/y is resulted (Ramella et al. 2010). During the year, the phases of activity have been associated to the precipitation events. Considering that the average precipitation of the area is very high, 1,736 mm/yr, a seasonal behaviour of the Ligosullo landslide has been therefore to be taken into account. The piezometric data set showed an homogeneous behaviour in term of time of the mechanisms of groundwater recharge.

Rock mass is characterized by an high degree of jointing, responsible for its high permeability. Due to topographic conditions, the depth of the water table varies considerably. Beneath the town of Ligosullo, a great depression of the water table, which reaches 897 m a.s.l compared to 925 m a.s.l of the ground surface, has been registered while above the village, the piezometric data showed a rise up to 969 m a.s.l compared to 981 m a.s.l of the ground surface. This element was behind the choice of the best location for the construction of the new drainage wells provided by the monitoring program (Ramella et al. 2010).

34.3.2 Monitoring Activities

In order to improve the knowledge about the dynamic behaviour of the landslide, the following monitoring activities have been planned and designed:

- *TInSAR monitoring* four surveys on 2013 and 2014 in different seasons will be performed in order to measure the widespread displacement trends and entities (also by comparing data with atmospheric parameters), thus allowing to detect and perimeter the most active sectors of the landslide.
- *A-DInSAR monitoring* historical displacement analysis from 1992 to 2010 will be performed by satellite SAR images collected by ERS1–ERS2 and Envisat satellite. The activity aims to reconstruct the historical displacement evolution trend of the slope thus allowing for the analysis of the triggering factors and factors affecting the dynamic behaviour of the landslide.

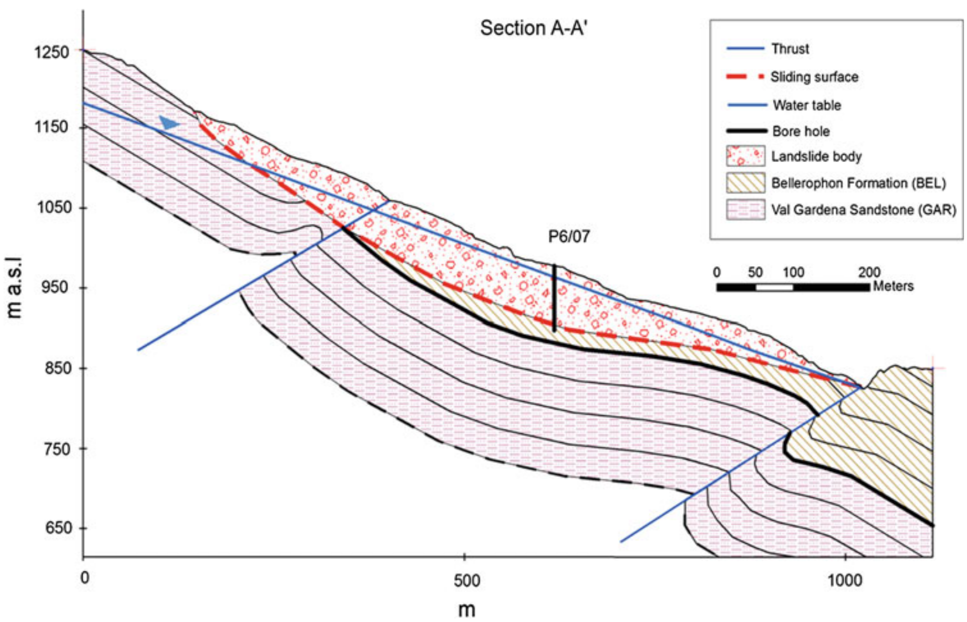

Fig. 34.2 Longitudinal section of the Ligosullo landslide

- *Topographic monitoring* twelve surveys on 2013 and 2014 in different seasons will be performed from a single measurement point (near the TInSAR monitoring platform), mainly concurrently with TInSAR surveys. The aim of the activity is to detect very low values of 3D displacements referred to some restricted areas in order to assess the underestimation of TInSAR data (due to the measurements along the Line of Sight) and to have data redundancy for a robust interpretation.

At present the following activities have been performed:

• *TInSAR monitoring*

TInSAR monitoring platform was materialized on June 2013 in front of the Ligosullo village, thus allowing a widespread view of the study slope. The IBIS-L interferometric sensor was installed on a specifically designed and developed iron modular basement on the SP32 street (Murzalis, UD) thus allowing the optimal orientation of the sensor. Instrumental start-up and calibration have been performed. The monitoring platform was also equipped with a 28 channels GPS sensor (in order to verify the stability of the monitoring system during survey period) and with a professional weather station (in order to collect weather parameters data for TInSAR data filtering). Three corner reflectors (passive devices characterized by very high radar signal reflectivity) have been temporary installed on some strategic sectors of the scenario in order to get the radar coordinates in the local geographic system and perform TInSAR data georeferencing.

The first monitoring survey was performed on June-July 2013 thus collecting 1.634 SAR images in 29 survey days.

Data processing is at present in progress, so no results are yet available (Fig. 34.3).

• *Topographic monitoring*

The topographic net was materialized on April 2013. 22 optical targets (monitoring targets) were installed in the landslide area while 6 additional targets (reference targets) were installed outside the landslide area for the instrumental calibration. The monitoring point was materialized near the TInSAR platform. A wood structure anchored to the ground was installed for such purpose, thus allowing the exact repositioning of the sensor (total station) in the periodical surveys. The topographic net georeferencing was performed through GPS measurements on some sample targets.

Data processing is at present in progress, so no results are yet available.

Fig. 34.3 **a** Ligosullo landslide; **b** topographic monitoring platform; **c** topographic target; **d** TInSAR corner reflector; **e** TInSAR monitoring platform

34.4 Concluding Remarks and Outlooks

According the geological model here proposed, the Ligosullo (UD) landslide is a large and deep structurally-complex landslide involving about 7 millions m^3 mainly constituted by the Val Gardena sandstone locally intensively jointed and weathered. It is supposed that this landslide mass is sliding on the Bellerophon Formation, constituted in its turn by saccharoidal laminated gypsum, along their contact surface. The remobilizations or acceleration phases of the slope movement has been strictly related to the precipitation regime. Monitoring activities were planned and designed, aiming to get information about the present (through Terrestrial SAR Interferometric monitoring and topographic monitoring) and past (through Satellite SAR Interferometric analyses) dynamic evolution of the landslide. The achieved results will be interpreted from a geological and geomorphological point of view in order to identify the best strategies for hazard mitigation.

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