GEOPHYSICAL AND GEOLOGICAL INVESTIGATION IN THE AREA NE OF MENFI (SOUTH-WESTERN SICILY):

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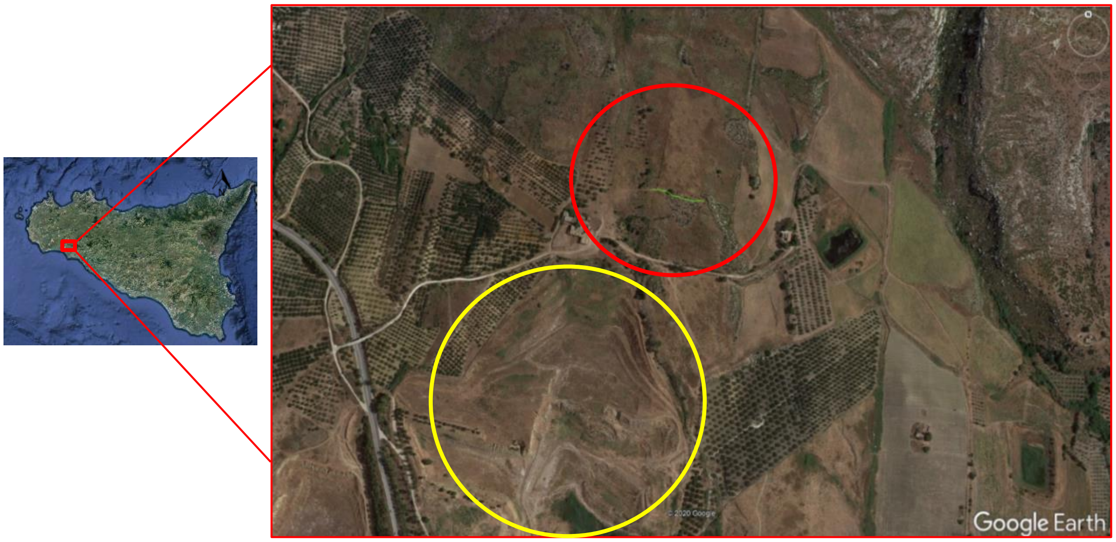
Introduction

Following the seismic events that occurred from January to June 1968 in the Belice Valley, numerous geological studies have been conducted by various authors in south-western Sicily. Before these seismic events, which partially or totally destroyed some inhabited centers, the area was regarded as aseismic.
Within this area we identified numerous morphostructural features consisting of open fractures, which compose a single main feature with WSW-ENE trend. Two other featuresm, orthogonal to these, have NNW-SSE trend. They are visible on Google Earth frames from 2014 to 2017 and they were subsequently filled by human activities. In 2019 July a seismic swarm has again affected the area and following this event a reopening of the fractures occurred.
The aim of this study is to understand the role of seismicity in the transformation of the territory, which may have created trenches and/or fractures of both tectonic and landslide nature.

The study area

The study area is located in southwestern Sicily, precisely NE and 5 km away from Menfi (Fig. 1).
The territory is characterized by a hilly landscape. The topographic features are closely linked to the combination of endogenous (tectonics, lithology) and exogenous (climate, vegetation) factors which allow to identify two sectors characterized by different evolution (Fig. 1):
a) the sector to the south of the main morphostructural feature, where the "Bertolino" quarry is located, characterized by Pleistocene silty-sandy clays. The slope is constantly evolving due to the erosive action of rainwater and the accumulation of erosion products;
b) the sector including the area of the morphostructural features, characterized by soils with a lithoid consistency (marly limestone, calcarenites). In this area, the erosive action is less incisive.



F*ig.1 – Location of the study area. Yellow circle: area where the "Bertolino" quarry is located; red circle: area in which the morphostructural features are present; green lines: main morphostructural features.*

Materials and methods.

The characterization of the morphostructural features was carried out with a multidisciplinary approach, by using the following techniques: geophysical investigations such as Multichannel Analysis of Surface Waves (MASW) surveys and microtremor recordings, particle size and morphological analysis of soil samples, morphological analysis by observation in situ and through Google Earth, and analysis of the displacement of the earth's surface using satellite interferometry technique (INSAR).

45 microtremor measurements (Fig. 2a) were carried out using Tromino® and these were analyzed with the HVSR technique (Nakamura, 1989; Bonnefoy-Claudet et al., 2006) and processed with the "GRILLA" software. A MASW acquisition (Fig. 2a) was also considered. This survey, consisting of a spreading with 12 geophones, intergeophonic distance of 2.5 m and offset of 5m, was processed using the winMASW® software.

In order to observe the displacements of the earth's surface and the ground deformation, the SBAS (Small Baseline Subset) interferometric technique was used (Ferretti at al., 2007; Pepe and Sansoti, 2005). 91 satellite images, captured by the Sentinel 1-A satellite (both of the ascending and descending orbits) in the time interval from 9/10/2016 to 9/10/2019, were processed using ENVI 5.4 and SARscape 5.4.1 software.

Particle size analysis was performed on 22 soil samples, according to the protocols (Boggero et al., 2011) (Fig. 2b). Approximately 100 grains were isolated from each sample and observed under a light microscope for morphoscopic analysis (Powers, 1952).

The morphological analysis was carried out through preliminary observation of images extrapolated from the historical imagery of Google Earth. Only images from 2014 were taken into consideration because the previous images have a poor resolution. Subsequently, the observation was made in situ at different periods of the year and the dimensions of the open fractures were measured.

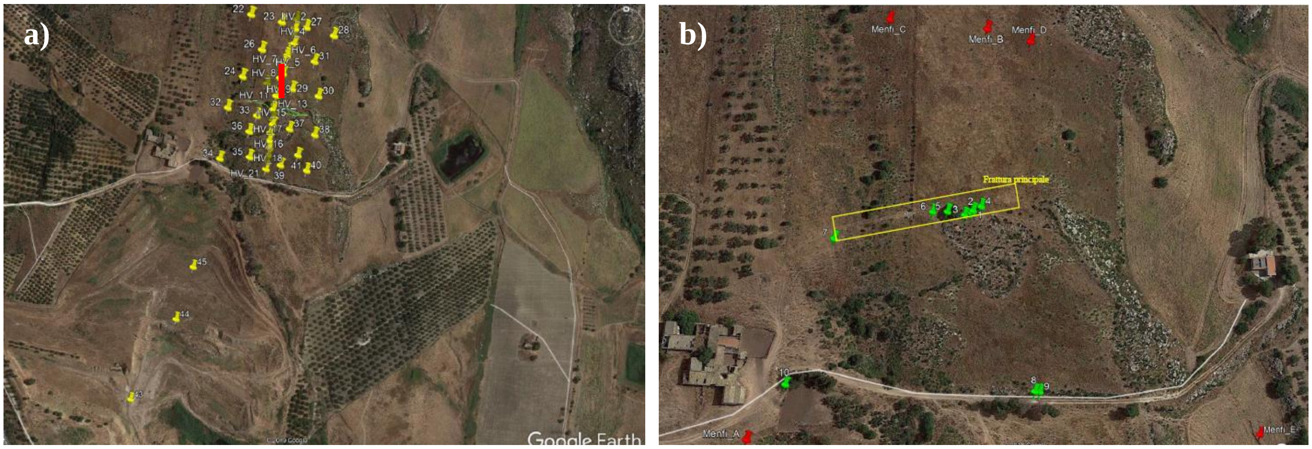


Fig. 2 – a) Location of microtremor measurements., red line: MASW location,; green lines: main morphostructural features; b) location of soil sampling.

Data interpretation and discussion

In the study area evidence suggests that the reopening of the fractures is connected to the seismic events that occurred in July 2019.

The Google Earth morphological analysis shows that until the end of 2018, the fracture is not open. From the in situ investigations, following the seismic swarm of July 2019, instead it becomes open again (in Fig. 3a an example of one of the fractures). We therefore hypothesized that the reopening of the fracture is a seismic-induced ground movement. The size and depth of these fractures supporting this hypothesis, considering that they remain almost the same from August 2019 to January 2020. In fact, in this period, strong rain events occurred but they did not cause significant changes. Therefore, the infiltration of rainwater was not charged as the cause. Sand samples were taken along the main fracture and have been analyzed in the laboratory. Furthermore, the morphoscopic analyses evidenced quartz grains of clear marine origin and therefore cannot be current continental deposits.

These sands, in addition to being aligned along the fracture and limited in circular shapes, are found in correspondence of depressed areas with respect to the surrounding morphology. Based on these data, we hypothesize that these sands come from the subsoil. The uprising of these sands could be a signal of a seismic-induced structure and could be due to the fluidification of the soil linked to the seismic shaking and / or to the uprising of sandy material due to density difference caused by compression.

From the seismostratigraphic section, obtained from the MASW and HVSR inversions and joint-interpretation, an abrupt slope break of layers is noted (Fig. 3b). Two contributing causes have been hypothesized for this slope variation:

1: An inherited morphology and therefore a paleo-structure that produces unconformity between the first layer and the underlying one;

2: The presence of a discontinuity in the subsoil that is not visible on the surface.

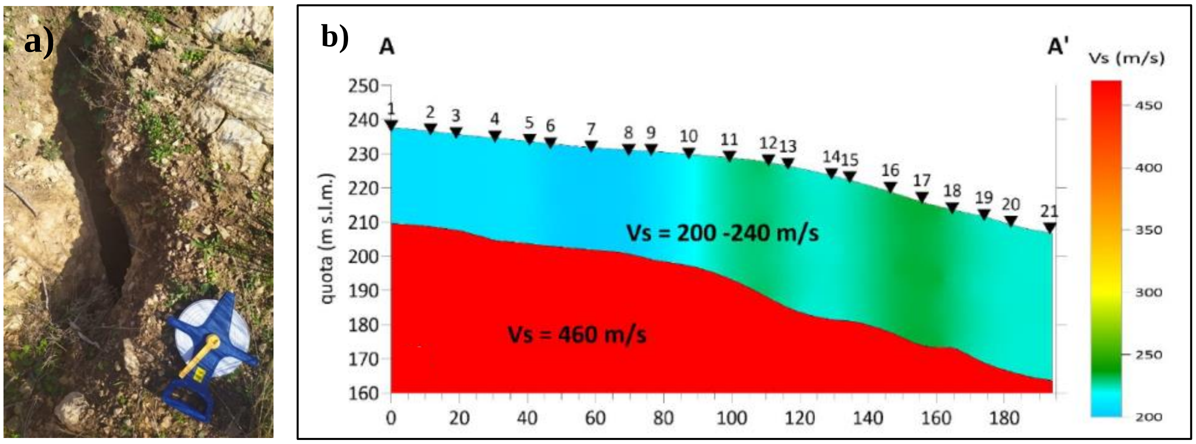


Fig. 3 – a) Example of one of the fractures; b) Seismostratigraphic section.

The multi-temporal interferometric analysis show excessive displacement velocities. These results were not considered reliable as, with the values obtained, there should be much larger fractures than those observed in situ. The unreliability of the products is due to a limitation of the interferometric technique, or the difficulty of operating in a predominantly natural area.

Conclusion

This multidisciplinary study suggests that the genesis of open fractures in the study area is directly or indirectly related to the seismic activity. Each single technique used highlighted elements that, in order to be proven, had to be compared with all the results.

Evidence of gravitational phenomena, absent in the official Italian hydrogeological database (P.A.I.), were observed, which should be considered in assessing the hazard of the area. Furthermore, the different seismic responses of the area upstream and downstream of the main morphostructural feature should be taken into consideration for any engineering works to be carried out within the area.

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