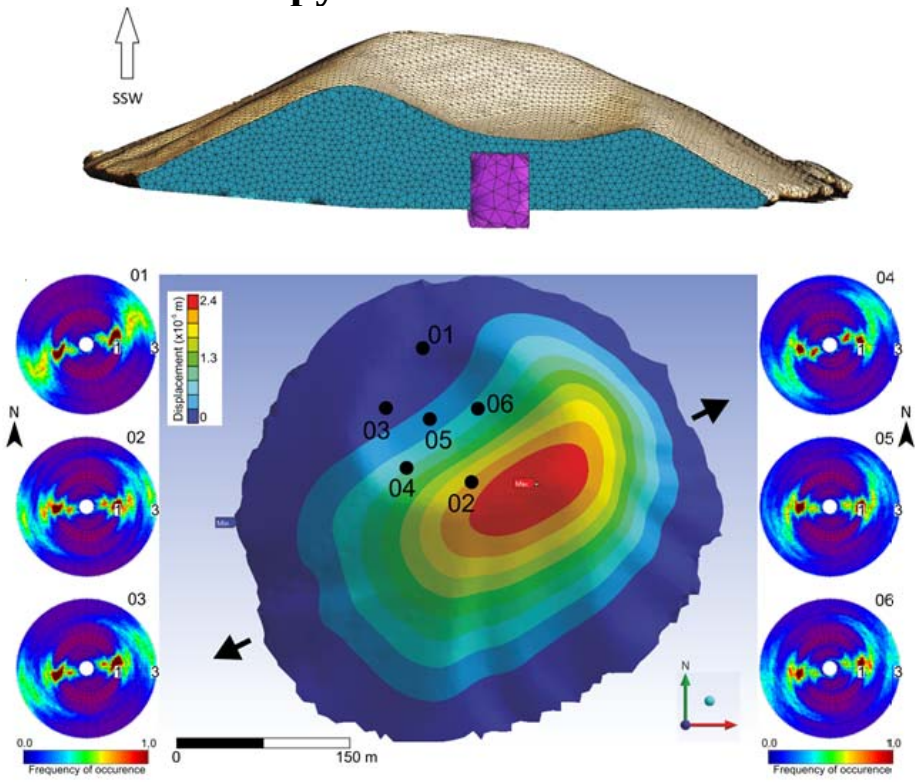
COST Action ES1301

"Impact of Fluid circulation in old oceanic Lithosphere on the seismicity of transfOrm-type plate boundaries: neW solutions for early seismic monitoring of major European Seismogenic zones (FLOWS)"

Use of geophysical techniques and 3D modelling to investigate mud volcanoes and extinguished pyroclastic cones



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ABSTRACT

This report describes the main results of the Short Term Scientific Mission (STSM) carried out in collaboration with University of Catania (Department of Geology).
The main goal of the STSM was to investigate:

- mud volcanoes site in the vicinity of Mt. Etna. Data were also acquired and the integrated with previous ones. Finally a 3D surface model has been derived and will be in the near future integrated with the 3D reconstruction model of the subsurface inferred from the study.
- Geophysical date from "salse di Nirano" were analized and preliminary results obtained
- A 3D modelling of the Mt Vetore (Etna) was constructed. Finite Element simulations were carried out to match the experimental data. Results are going to be submiited to Geophysical Journal international

1. Purpose of the STSM

The main goal of the proposed Short Term Scientific Mission (STSM) was to investigate mud volcanoes site in the vicinity of Mt. Etna. In particular, a microtremor survey aiming to obtain information on the Salinelle area (Paterno') subsoil structure was performed and new data were collected. The STSM served also to better plan some further campaigns during which several different kind of data (e.g. ERT, geochemical survey, and drone survey) will be collected. Similarly, we analyzed data related to the mud volcano "salse di Nirano" in Northern Italy.
During this Short Term Scientific Mission geophysical data were also acquired on extinguished pyroclastic cones located on Mt. Etna (Mt. Vetore). The ambient vibrations survey helped to collect high quality data and derive useful information about the subsurface structure of Mt.Vetore pyroclastic cone. In both cases a 3D digital model was constructed.

2. Description of the work carried out during the STSM and main results

The Salinelle area (Figure 1) is characterized by emissions of muddy and salty water which create specific pseudo-volcanic edifices. The method has been successfully applied in the case of Lusi hydrothermal system (Panzera et al. 2018a). The main goal was to identify important stratigraphic discontinuities aiming and try to locate the reservoir location below the mud-structures and combine results with ones inferred through geochemical data. New data were acquired using portable seismometers as well as array of vertical geophones (Figure 1). An example, of processed data is given in Fugure 2. We combined data from previous survey aiming to better reconstruct the subsoil structure and to understand, combining also geochemical data, the fluid migration from depth to the surface. During the STSM a detailed 3D model of the area was constructed (Figure 3) and in the near future a 3D model of the subsurface will be added in order to have an outline of a comprehensive model of the area.

We analyzed also data previously collected in the “Salse di Nirano” area (northern Italy (Figure 4). In this study we applied the HVSR method, which is a common tool used for site effect investigations to assess fundamental frequency of sediments. It is based on the ratio of the horizontal to vertical components of ground motion and it generally exhibits a peak corresponding to the fundamental frequency of the site. Although experimental data peaks usually fit quite well the resonance frequency of the theoretical curves, they are less reliable as regards to their amplitude. Nevertheless, the HVSR curve contains valuable information about the underlying structure. These peaks could be interpreted as related to the velocity contrast at depth between alternating shale and sand overlaying a velocity anomaly.

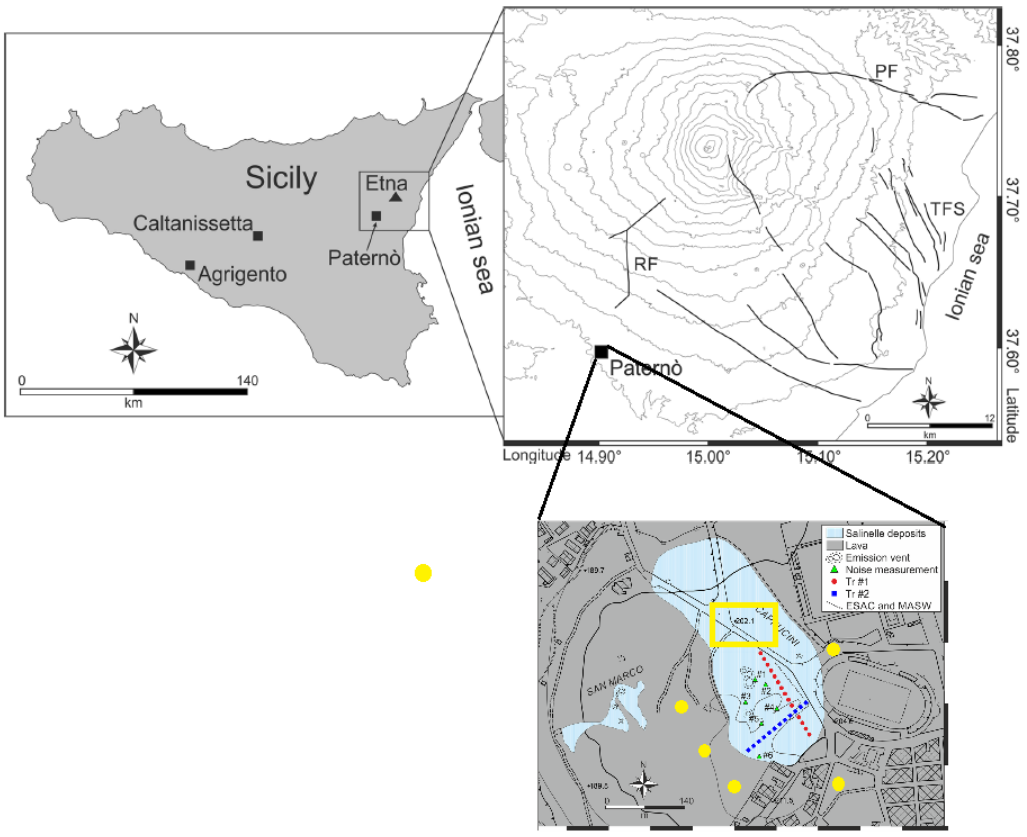

Figure 1: Geographic location of the study area (left panel) and main structural features of Mt. Etna (right panel; RFS Ragalna fault system, TFS Timpe fault system, PF Pernicana fault). Lower panel shows simplified geologic map of the Salinelle area as well as the location of the taken measurements. In yellow are indicated the location of the new acquired data.

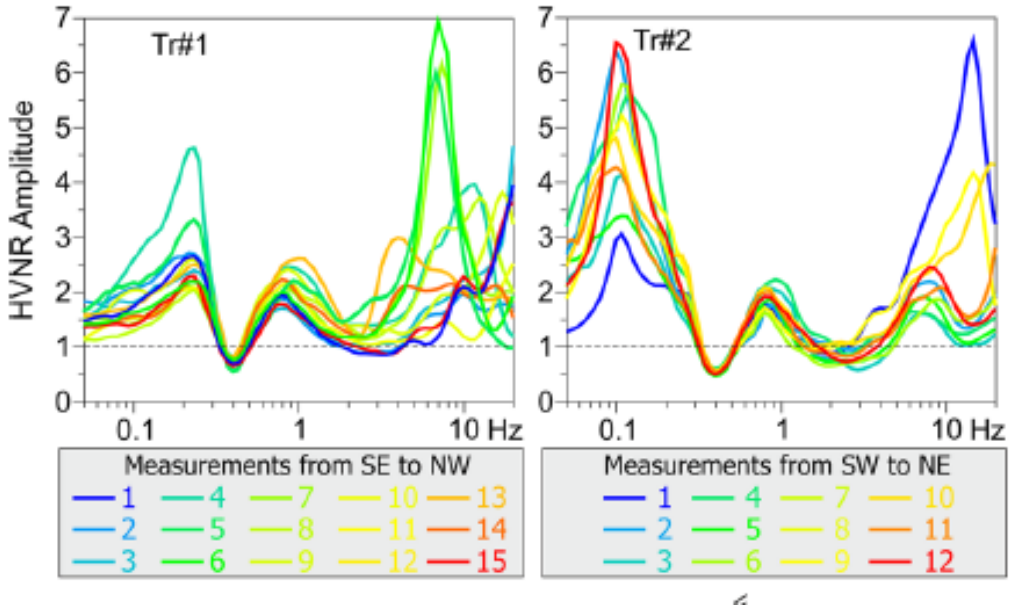

Figure 2: HVNRs computed at each site along the Tr#1 and Tr#2 profiles (from Panzera et al. 2016).

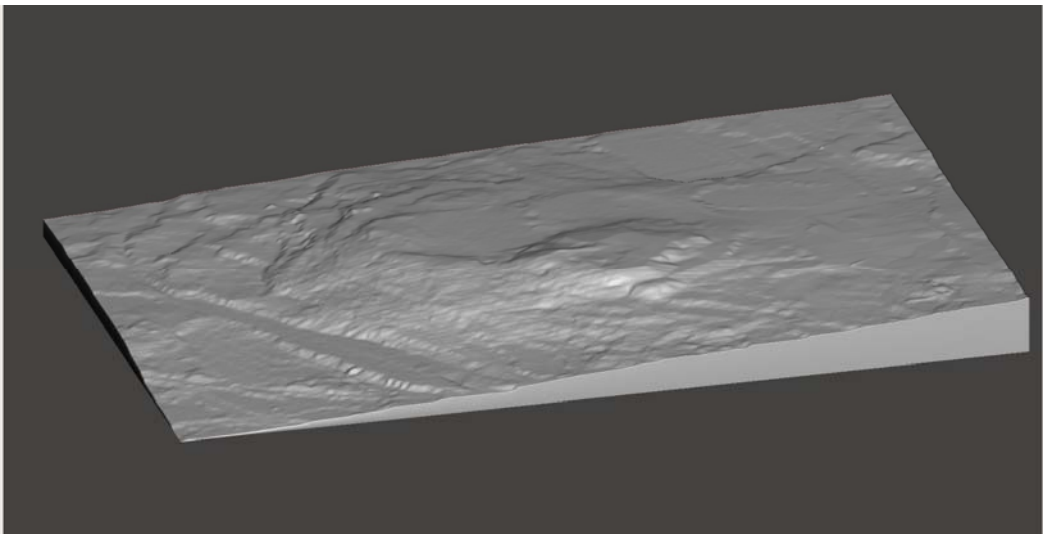

Figure 3: 3D model of the Salinelle area.

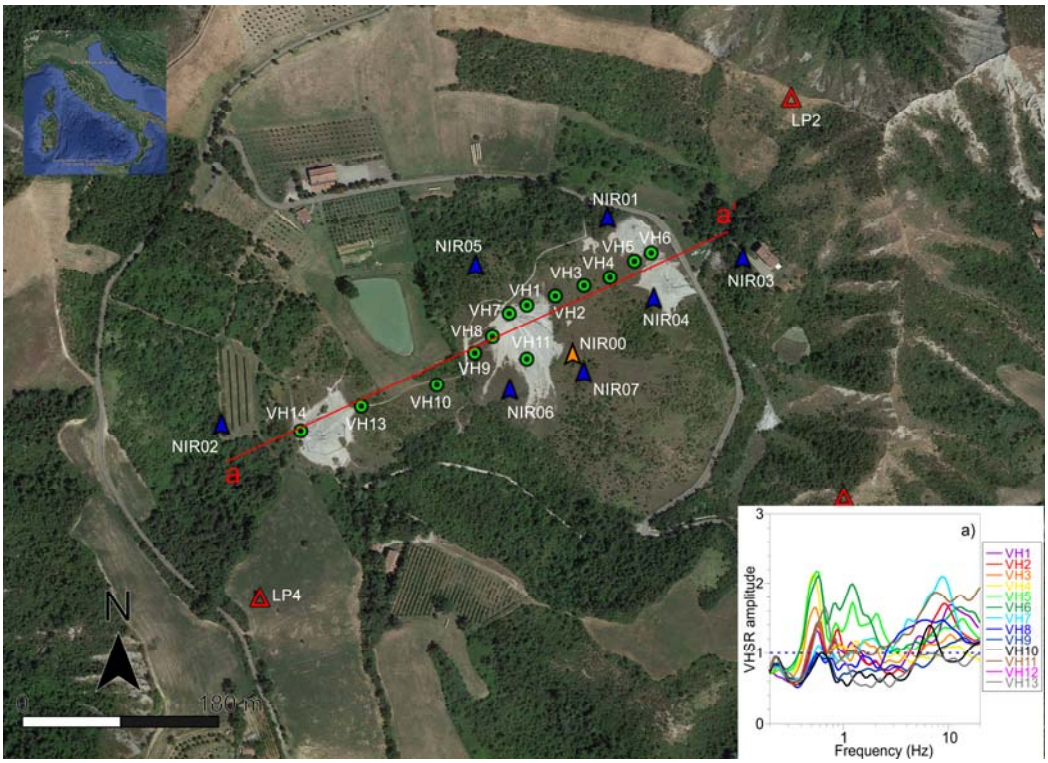

Figure 4: Salse di Nirano study area reporting the acquisition point data. Inset shows preliminary results.

During the STSM data acquired on Mt Vetore (Etna, Sicily) were analyzed. Mt. Vetore is a pyroclastic cone (Corazzato and Tibaldi, 2016) located on the flank of Etna (Figure 5). Parasitic volcanic cones is an important marker especially in volcanoes characterized by lateral activity. Their distribution and orientation is an important marker to obtain information on the maximum horizontal compressional stress that act on a volcano. A geophysical survey on Mt. Vetore pyroclastic cone was performed to obtain important information on its structural setting and to support the usual morphometric analysis. Results highlighted an evident peak at 1.0 Hz inside the cone, which is attenuated away from it. Random decrement method was applied to this peak to compute damping and then to exclude a link with anthropogenic sources. Moreover, time-frequency polarization analysis revealed that ambient vibrations are strongly polarized in a narrow frequency band centred at frequency of 1.0 Hz, with a preferred oscillation azimuth almost 70°-90° N. Array measurement of ambient vibrations was also used to obtain shear wave velocity profile and then to retrieve the main interfaces with high seismic impedance. The results suggest a cone structure having a feeder pipe consisting of about 50 m of fragmented rocks surrounded by piroclastics laying on a high velocity substrate. Finally, a 3D model of Mt Vetore was built employing the Finite Element method to reproduce the first experimental modal frequency of the cone. The numerical results reproduced quite well the first experimental frequency as well as the oscillation direction observed during the geophysical survey.

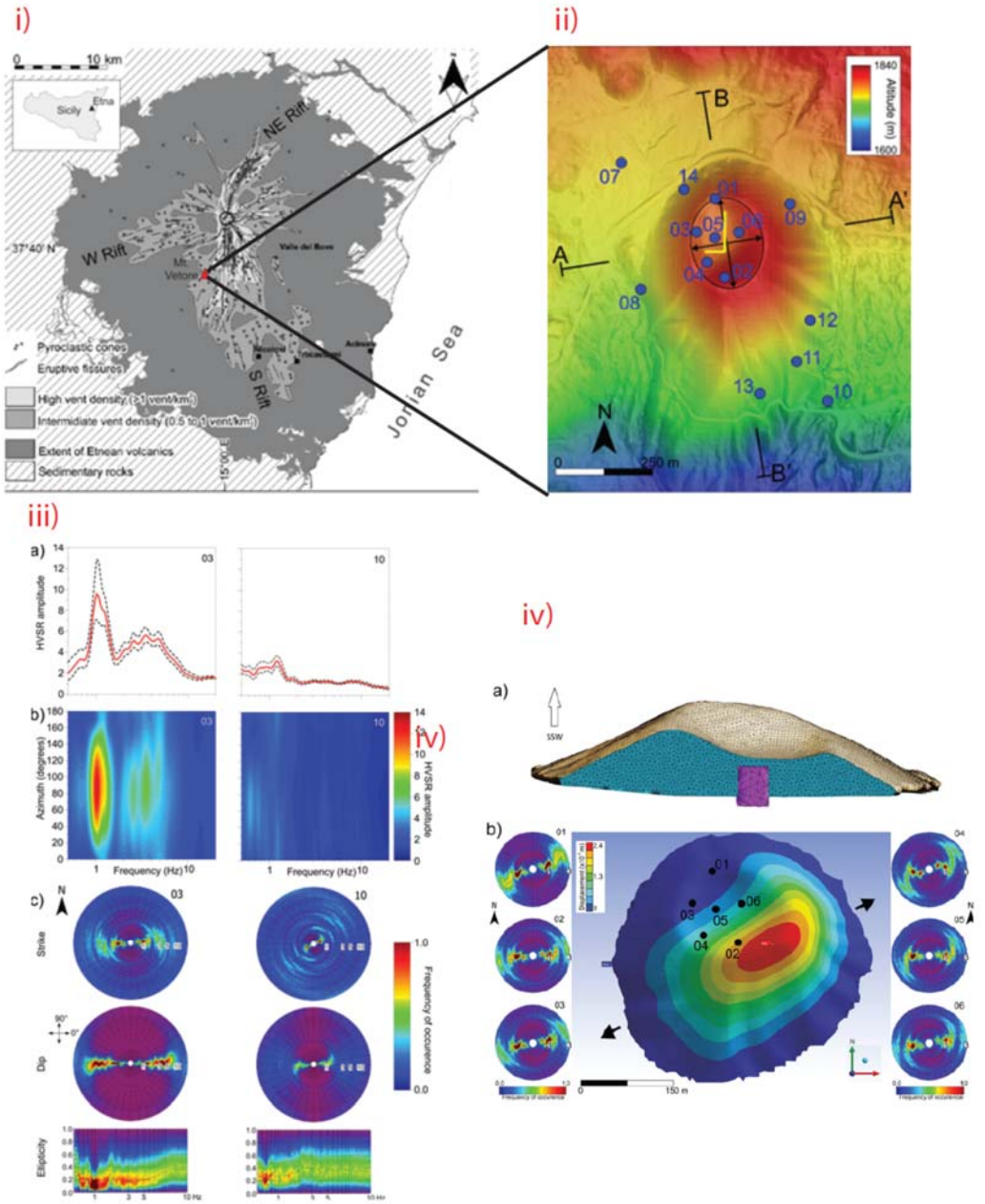

Figure 5: i) study area; ii) Altitude map of Mt. Vetore; iii) a) Examples of HVSRs obtained at the investigated sites and corresponding contours plots (b) TF analysis results for the selected sites (c). iv) a) Sections of FE model of Mt. Vetore in purple the dike and in light blue the pyroclastic material. b) Pyroclastic cone displacement for the first experimental modal frequency, in which black arrows show the oscillation direction (continuous animation of this is available as animations S1 and S2 of the auxiliary material). Black point indicate the experimental ambient vibrations measurement sites inside the cone, for which are reported polar plots of the polarization strike. The contour scale represents the relative occurrence frequency of each value and the distance to the center represents the signal frequency in Hz (modified from Panzera et al. 2018b).

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References:

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Panzera F., Sicali S., Lombardo G., Imposa S., Gresta S., D'Amico S., 2016. A microtremor survey to define the subsoil structure in a mud volcanoes area: the case study of Salinelle (Mt. Etna, Italy). Environ. Earth Sci., 75:1140, DOI 10.1007/s12665-016-5974-x

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4. Future collaboration with the host institution

The two Institutions involved in this STMS intend to submit a common research proposal. In particular, the authors are considering the calls explicitly designed and directed to facilitate Italian-Maltese scientific collaborations. On this framework we are going to propose a project that deals with innovation technologies and multidisciplinary survey to study the subsurface. Independently from this, we hope to have many future occasions to perform integrated studies and improve the ongoing collaborations.

5. Foreseen publications/articles resulting from the STSM

At the moment, the next occasions for publishing part of the data are the next ESC were two abstracts were submitted. One related to the Salinelle area and the other related to the result on Salse di Nirano. Results about Mt Vetore have been submitted as a paper to Geophysical Journal International.