

Combined geophysical measurements off the coast of Ischia Island (Southern Tyrrhenian Sea) as a contribution to the natural hazard assessment

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Abstract – The COSMEI survey was conceived and carried out in the wake of the emergency following the Casamicciola earthquake in 2017. The geophysical investigations were targeted towards two main objectives, i.e. identify possible active structures and to dimension the debris avalanche deposit on the northern offshore of the island. Single- and multi-channel seismics, differential-magnetic and resistivity, MBES geophysical data were acquired in December 2017 on board the Minerva Uno oceanographic vessel. The first results ensuing the processing phase, allowed to gather further information on the seismic-stratigraphic characterization of the north-western sector of the island of Ischia, and the identification of shallow resistivity and magnetic volcano-tectonic anomalies.

I. INTRODUCTION

The oceanographic cruise "COSMEI" (Italian acronym of Ischia Electric Magnetic Seismic Oceanographic Campaign) was planned consequently to the seismic event of Mw 3.9 that occurred on the 21st of August 2017, with epicenter 1 km southwest of Casamicciola Terme [1,2]. The aim of the marine survey was to provide further insights into the identification of active volcano-tectonic structures in the northern marine sector of the island of Ischia and to constrain the Northern Debris Avalanche deposit (NDA) [3-6]. The CNR-DTA, in agreement with the Centro MS (Center for Seismic Microzonation and its applications), prepared a plan of investigations at sea for the reconstruction of potentially hazardous tectonic and volcanic structures. Within this framework, the COSMEI survey gathered a set of geophysical data (mono/multichannel seismic data, bathymetric data, gradiometer magnetic data and resistivity data) to outline the stratigraphy and the structural features offshore. The multichannel seismics allowed a penetration of the seismic signal down to 0.6 s TWT and a CDP spacing (Common Depth Point) of midpoint resolution of about 1.56 m. The geoelectrical

and magnetic data revealed the presence of local anomalies north of the Ischia harbor. Finally, geoelectrical methods were adopted to determine the electrical resistivity values in the subbottom. The knowledge of the resistivity values, for different types of materials below the seabed is crucial for the identification of areas with high thermal gradient. This survey provided the opportunity to test the best instrumental configuration.

In this note we report on the measurements performed at sea and on the very first outcomes of each dataset.

II. GEOLOGICAL SETTING

The Ischia Island is the subaerial portion of a much larger volcanic complex that has been active since at least 150 ka B.P. and mainly consists of an upraised structure interpreted as a resurgent block (Mount Epomeo volcanic horst) [7,8]. The resurgence followed the caldera formation, 10x7 km wide, which in turn had followed a large explosive eruption at the origin of the Monte Epomeo Green Tuff (MEGT), some 55 ka ago [9,11]. It has been lasting intermittently since about 33 ka, possibly due to the magma pushing [12-14]. The edges of Mount Epomeo are marked by a system of sub-vertical faults, with NW-SE, NE-SW, N-S, and E-W strike [10,15]. The northern part of the block, dislocated by roughly ENE-striking normal faults that dip 60°–85° N, has produced a Holocene graben structure in the hanging wall [10], where the source area of the historical seismicity could be located [1,2,16]. A general subsidence of as much as 1 cm yr⁻¹ has been affecting some sectors of the island since Roman times, as documented by historical remains, GPS and DInSAR measurements [17-20]. The steep flanks and the mechanical properties of the weathered Green Tuff have favored the instability of the slopes, resulting in shallow mass movements and in large rock and debris avalanches south, west and north to the island [6,21-23]. The largest failures have displaced huge amounts of material in the marine settings, up to several kilometers behind the present-day coastline [3-5,24,25]. The

definition of the mass movement volumes entering the sea is of primary importance for risk assessment issues [26-27].

III. METHODS

The COSMEI campaign was held onboard the Minerva Uno O/V (29.11.2017-06.12.2017), equipped with the DGPS and SEAPATH positioning system (FUGRO static link), single beam and multibeam sonars, subbottom profilers, and sediment samplers.

A. Seismic survey

A dense net of seismic lines were recorded by means of a GeoEel Solid™ digital marine streamer, 24 active channels, 75 m total length, and acquired with the Geode seismograph. A Sparker Geo-Resources 1500j was used as seismic source. Data was recorded by a PC running an applicative code for setting the field acquisition parameters and storing the seismic data in seg-2 format. A total of 26 seismic lines were recorded, which on the whole covered a total length of about 200 km (Fig. 1). The investigation was aimed at defining the geometrical features of the Northern Debris Avalanche (NDA) [20-22,24,29] and the elastic properties of the terrains by analyzing the seismograms and the wave shapes.

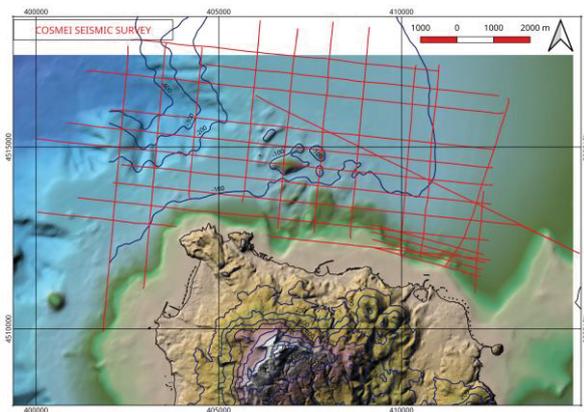


Fig. 1. Navigation tracks of the multichannel and single-channel seismic survey.

Contextually, the Chirp Sonar acquisition was performed by using the hull mounted CAP 662 Datasonic system, included in the vessel's equipment. This survey focused on the definition of the shallow stratigraphic geometries and on strategically locating the sites for the sampling sites of rocky outcrops.

B. Magnetic survey

The magnetic field prospection was realized by using a gradiometer Overhouser SeaSpy2 by Marine Magnetics. A total of about 38 magnetic profiles for a total length of 160 km were recorded over the northern offshore (Fig. 2), and differently spaced. North of the Ischia harbor a denser net of acquisition was performed to accurately

investigate the anomalies occurring at that site. In Fig. 2 the recorded profiles are shown.

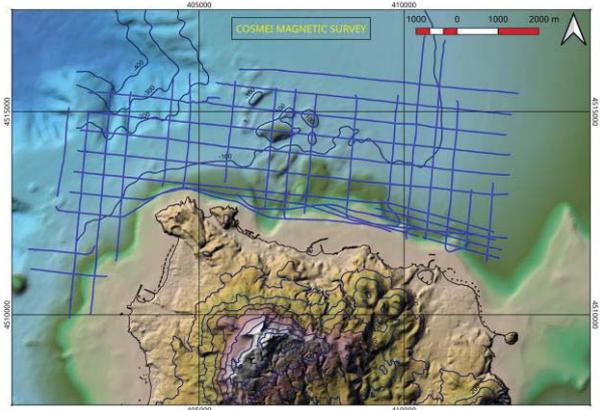


Fig. 2. Navigation tracks of the magnetic survey.

C. Geoelectrical survey

The geoelectrical profiles (fig. 3) were acquired by applying the resistivity method and the induced polarization method. The survey was carried out using the SYSCAL-Pro Switch georesistivimeter equipped with orange PUR marine cable. Thanks to its 10 reception channels, the Syscal Pro allows simultaneous collection of 10 resistivity data points corresponding to 10 depth levels. The short current injection time allows recording of a set of 10 resistivities at about every 2 seconds; it makes this tool very efficient for this type of survey. A ruggedized streamer with 13 graphite takeouts can be supplied. Electrode spacing is 5 m. Depending on the depth of the water column, the streamer can either be floated near the water surface or submerged near the seabed. GPS system is connected directly to the SYSCAL Pro unit thanks to a serial data port; thus, the position of the electrodes for each measurement point is accurately known.

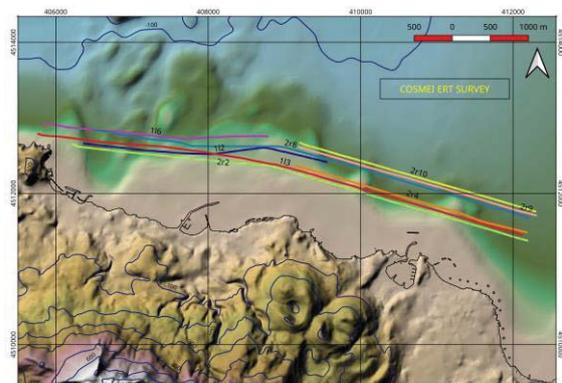


Fig. 3. Navigation tracks of the geoelectrical survey.

The data, recorded by the SYSCAL Pro, are continuously

transferred to a laptop by a serial communication. Simultaneously, the resistivity values are displayed in real time, numerically and graphically (2D section of resistivity). The apparent resistivity was measured with reciprocal Wenner array.

D. The MBES survey

In line with to the previously described investigations, a bathymetric survey was also carried out using the multibeam RESON 7160 MBES, since the frequency of the emitted signals did not interfere with the other equipment. Therefore, a very accurate DEM of the seabed was realized over the entire area (fig. 4).

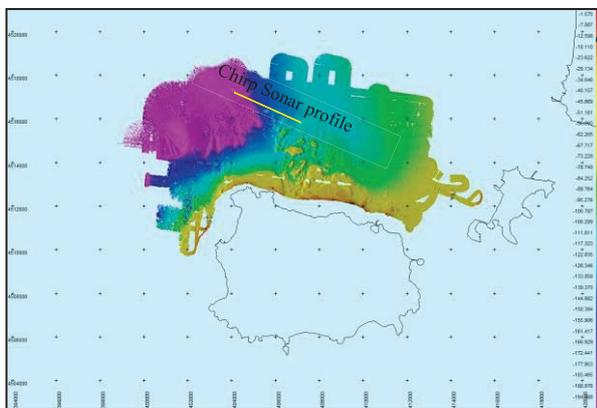


Fig. 4. The MBES acquisition.

IV. PRELIMINARY RESULTS AND DISCUSSION

Even though the processing phase has not been completed yet, some important achievements have been obtained by the integrated geophysical acquisition.

A. Single and multichannel seismics

Figure 5 depicts an example of a multichannel shot gather and the corresponding F-K spectra. 1 ms of time sampling interval, 12.5 m spacing of shot points and a record length of 1.5 s were employed. These parameters were selected to ensure the capture of all high-frequency energy.

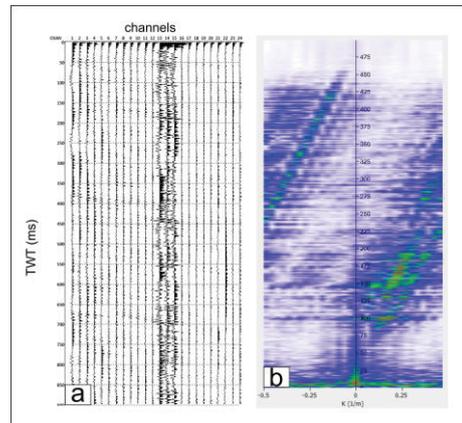


Fig. 5. a) Representative raw shot gather. b) Shot Gather F-K filter: The useful frequency range goes up to about 350 Hz

Several conventional pre-processing steps were applied (Fig. 6a); these permitted the signal enhancement (noise suppression and increasing the overall signal-to-noise ratio), allowing to detect a reflected signal (Figs. 6b,6c) to a depth of about 0.6 s TWT (Fig. 6d).

The multichannel seismic survey allowed the detecting of

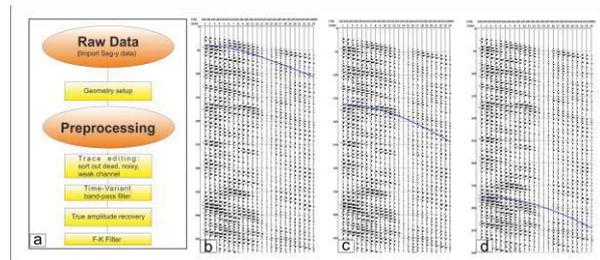


Fig. 6. a) Overview of the data pre-processing sequence; b,c,d) shot gather after the processing steps; the blue line identifies the reflection hyperbola.

clear unconformity below the NDA, which seems to be continuous and almost horizontal (Fig.7).

This basal unconformity, ones defined all over the area, could possibly allow the evaluation of the volume of the displaced material.

The Chip Sonar records concur in this calculation, delimiting the post-failure drape and the base of the thin portion of the mass slid deposits (Fig. 8), which are unresolvable at the multichannel-seismic scale.

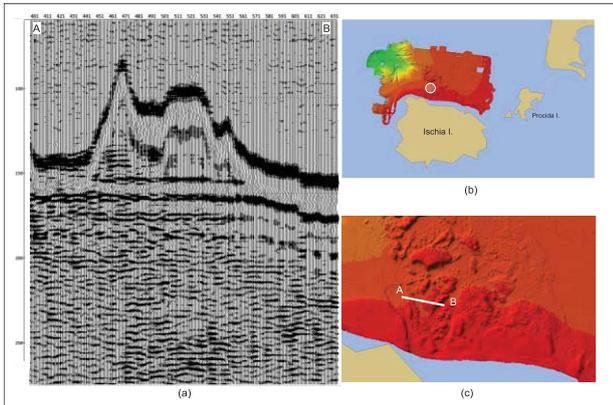


Fig. 7. a) The portion of the multichannel seismic stack section depicts the shape of the NDA and its basal unconformity; b) MBES map with the surveyed area (white circle) displayed in (a); c) MBES map with the projection of A-B seismic section.

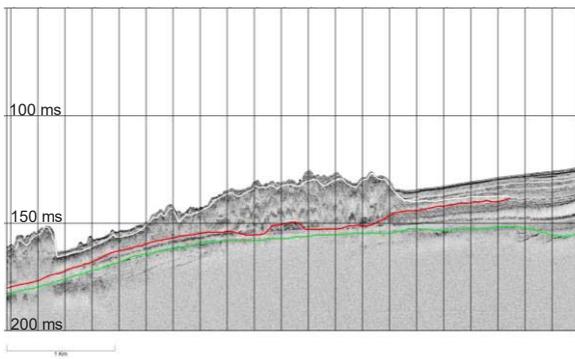


Fig. 8. Chirp Sonar profile: the green line is the top of the prograding wedge; the red is the base of NDA; the white is the top of NDA. Location in Fig.4.

B. Magnetic survey

The magnetic survey allowed to realize a detailed magnetic map (Fig. 9) offshore north-western sector of the Island of Ischia, highlighting the occurrence of some relevant magnetic anomalies. The investigated area shows high amplitude magnetic anomalies probably associated to shallow-buried volcanic structures. The first step of processing data, concerned quality control, position estimates and magnetic signal noise reduction. Then all spurious effects, outliers and inconsistent values of the magnetic field were eliminated by removing spikes and dropout values. Subsequently, after filtering operations (necessary, for example, to attenuate the noise associated to the not constant speed of the vessel combined with the sea state), a spline interpolation of the data was conducted to achieve the magnetic map.

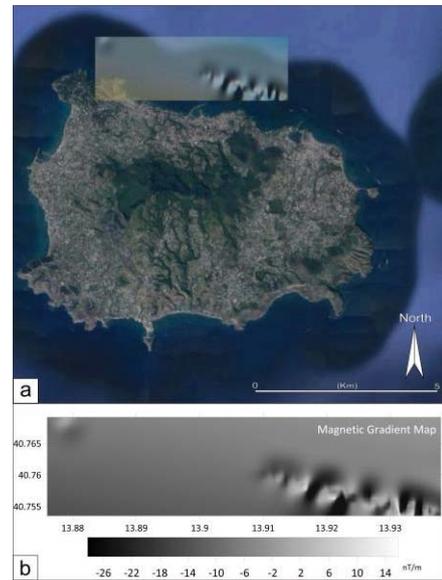


Fig. 9. Part of the magnetic survey. a) location of the magnetic anomalies in the north marine sector of the island of Ischia; b) shaded relief magnetic map

C. Geoelectrical Survey

Electrical resistivity techniques are used extensively in the geophysical exploration to locate subsurface cavities, fault and fissures, permafrost, mineshafts, etc.

In this study we used the marine ERT survey to explore 1) the very shallow bottom beneath the seabed; 2) the resistivity variations and the self-potentials in the sea water vs. depth. In reference to the latter, a new acquisition technique was used during the COSMEI survey. In particular, our experiment envisaged the acquisition of electrical data by placing the electrode cable vertically so that the resistivity values and the self-potentials were referred to depths between -45 to -95 m. Figure 10 shows an example of measuring self-potentials (SP) by positioning the electrode cable vertically. A stratification in terms of electric field is very clear, and is most likely due to a different salinity. In fact, the electrical conductivity of the water is particularly sensitive to the salt content. Upper picture of Figure 10 shows the SP measured at different depth (white spot). The SP value is not constant but it is variable in the water blade between -45 m and -95 m. The resistivity and the induced polarization are also variable. These variations in sea water, considering ordinary conditions and shallow depth, should not exist. Therefore, these changes could be attributable to local seepages.

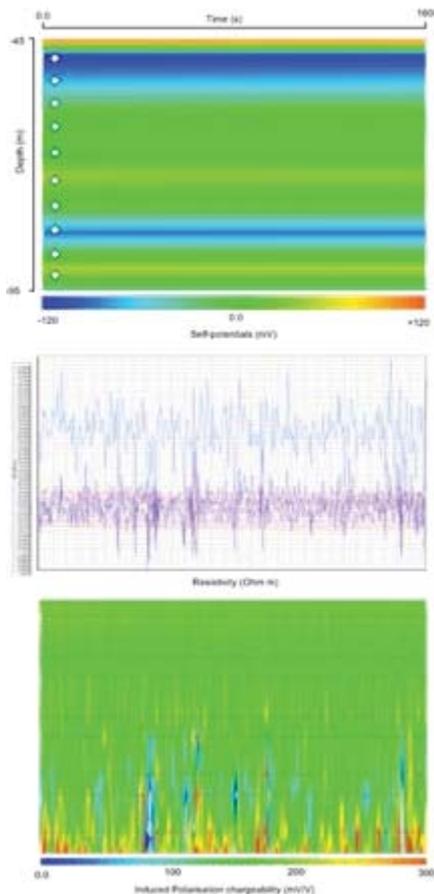


Fig. 10. Self-potentials, electrical resistivity and Induced polarization obtained by the vertical cable mode acquisition.

D. Bathymetry

The 4D acquisition (DEM repeated after a number of years), is a frontier in marine geomorphological analysis as it allows the comparison of the topography of the seabed and the identification of any changes through the creation of residual maps. To this aim, we have compared the most recent bathymetric survey (2018, this study), to the one performed in 2003 some 15 years ago [3,24,28-29], by matching the grid cell dimensions (i.e. 5 m x 5 m). No significant variation was recognized seaward of -30 m, in this time span.

V. CONCLUSION

The quality of the geophysical data is, overall, very good. The geophysical profiles were acquired both parallel and perpendicular to the coastline in order to obtain data to be processed using 2D and 3D techniques. Data acquired during the survey included: approximately 200 km of high resolution multichannel seismic lines and Chirp Sonar lines; - about 160 km of differential magnetic lines; - about 50 km of geoelectrical lines; multibeam surveys over the entire navigated area. The

preliminary processing of the acquired data allowed us to advance one step further in the reconstruction of the stratigraphy of the subsoil with the main objective to detect faults, fractures and the basal unconformity of the NDA. Resistivity and magnetic data, highlighted the presence of local anomalies. All these findings call for further analysis since they are relevant in terms of volcanic risk assessment in the island. The integration of these data with high resolution morpho-bathymetry (Multibeam) and superficial seismic-stratigraphy (Chirp) may improve the knowledge of the north-western coastal sector of Ischia Island.

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