Campi Flegrei active seismic experiments waveforms compilation

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Abstract: A new experiment called SERAPIS (**SE**ismic **R**eflection/Refraction **A**cquisition **P**roject for **I**maging complex volcanic **S**tructures) has been planned and carried out, based on off-shore seismic energization and data acquisition on land and on sea-bottom. The experiment was performed in September, 2001 during which the vessel NADIR of IFREMER (equipped with 12, 16-liters air-gun) produced more than 5000 air gun shots recorded at a sea-bottom seismograph array of 72 OBS and 62 stations installed on-land. Active seismic refraction DSS (Deep Seismic Soundings) acquired during the surveys conducted in 1980 and 1985 were recovered jointly with seismic data acquired in the Campi Flegrei area in the framework of the MareVes97 (an experiment devoted to the definition of the structure of the Somma-Vesuvio complex) offshore survey. The data set acquired during the SERAPIS experiment has been successfully used to infer 3D images of the volcanic structures of Campi Flegrei and Neapolitan bay. Active seismic waveforms and related P-picks (more than 90000 data) from the SERAPIS experiment are also available in the project data server.

Introduction

One of the tasks of the project "Integrated seismic methods applied to the investigation of the active volcano structure: an application to the Campi

Flegrei caldera", concerns the recovering of previous active seismic data acquired in the Campi Flegrei area.

In particular we refer to the Deep Seismic Soundings (DSS) performed in the Thyrrenian sea. We perform the recovery and homogenisation of old data of DSS seismic experiment, available at Istituto di Ricerca sul Rischio Sismico (now department of Istituto Nazionale di Geofisica e Vulcanologia). In particular, the Deep Seismic Sounding data, acquired in the 1985 during a Campi Flegrei micro-array sub-experiment, were digitised and archived.

In addition, with the aim to provide new insight on the caldera structure and to investigate its feeding system, a dense and extended marine active seismic survey called "SERAPIS" has been performed during September, 2001 in the gulfs of Naples and Pozzuoli. SERAPIS provided a dense 3D seismic coverage of the Gulf of Pozzuoli, the coastal part of the Campi Flegrei caldera, as well as a partial reacquisition of the western sector of the Gulf of Naples. During the field operation about 5000 shots, at 125 m distances, produced by a battery of 12, 16-liters synchronized air-guns mounted on the oceanographic vessel NADIR (IFREMER), have been recorded at a network of 72 sea bottom receivers and 62 3-component on shore seismographs. The oceanographic ship covered a total of 620 km along dense grid-lines oriented N-S and E-W in the Gulf of Pozzuoli, and along a few grid-lines in the Gulf of Naples The SERAPIS experiment provided an additional (and originally not expected) active seismic data-base, consisting of more than 92,000 traces, whose structural informative potential has been partially explored during the project, which essentially used the first P-pick data set.

Merging the Serapis 2001 and MareVes 1997 data-sets allows for the covering of the whole gulf of Naples from the Sorrento peninsula at East to the Ischia and Procida islands at west. The whole data set consists of more than 650000, three component records, acquired by 72 sea-bottom seismographs and 84 onland stations installed in the Campi Flegrei and Mt. Vesuvius volcanic areas. First P-arrival times have been manually picked on pre-processed common receiver sections. The used P-picks for seismic tomography consist of about 65000 data relative to sea-bottom stations and 25000 data from on-land stations. The data base has been integrated with re-picking of the MareVes seismic section (5000 pickings)

SERAPIS PROJECT

SERAPIS experiment, carried out in September 2001, consisted in to record at dense submarine and on land 3C seismic network, installed in the bays of Naples and Pozzuoli (Figure 1), the waves radiated by a battery of 12, 16-liters synchronized air-gun sources mounted on the ship NADIR, owned by the French company Ifremer. The source and receiver arrays cover an area of more than 50x50 km^2. 62 three-component stations have been installed on-land in

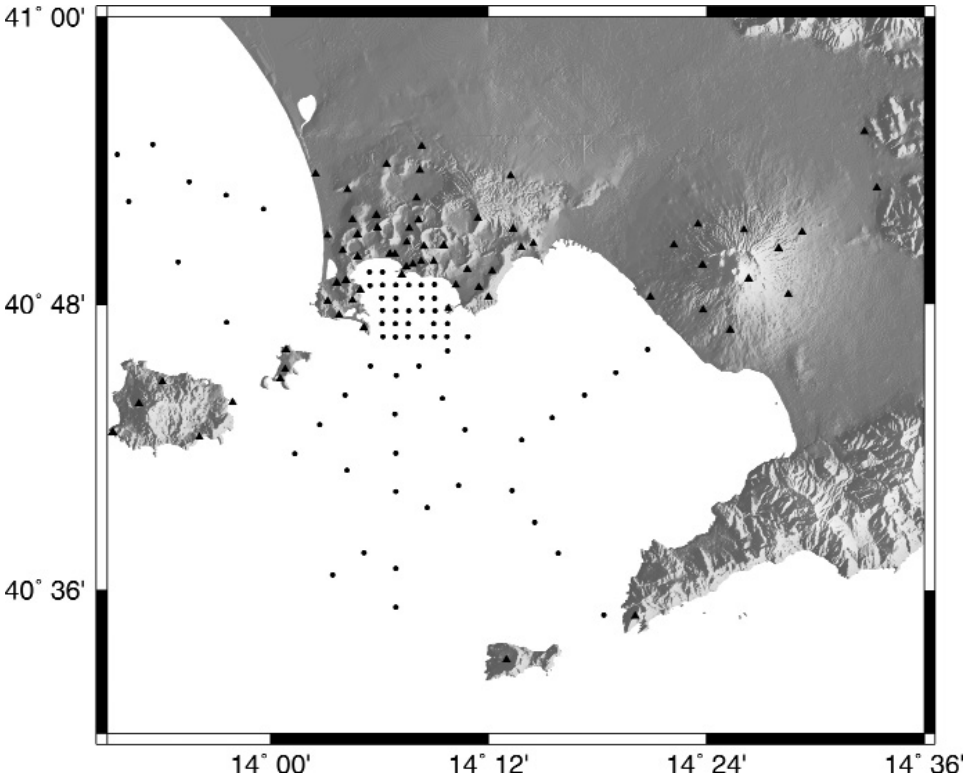

Fig. 1. Map of the area investigated during the SERAPIS experiment. Black lines traces the path of the vessel during the campaign. Red and blue circles display the position of OBS and seismograph during the experiment.
You can see this figure in color on page 210.

the areas of Campi Flegrei, Mt. Vesuvius and on the islands of Ischia and Procida. 72 sea bottom seismographs (OBS) have been installed in the gulfs of Naples and Pozzuoli by the University of Hamburg with the logistic support of private companies Geopro (Germany) and Geolab (Italy). The OBS were equipped with 4.5 Hz 3C sensor and a continuous recording device, while almost all on land station were equipped with 1 Hz 3C sensor. The permanent stations of Osservatorio Vesuviano were also set to record the experiment. A denser 2D network of 35 OBSs has been deployed in the bay of Pozzuoli aimed at detecting and modeling reflected/converted waves from the possible shallow to deep discontinuities beneath the Campi Flegrei caldera.

Over a two week period a total number of about 5000 air gun shots have been fired during the experiment, with an average spatial spacing of 125 m, for a total ship travel path of 620 km. All of the seismic lines were re-sampled at

least twice, using a staggered configuration, which results in a smaller source spacing (less than 65 m). The acquisition layout was designed to provide a very high data density in Pozzuoli Bay (about 2500 shot were performed inside the Bay) for an explored surface of 5x5 km^2. The other shots were performed in the Bay of Naples along some 10-20 km long profiles.
The horizontal OBS ray sampling of the area investigated in the present study is shown in the Figure 2. This corresponds to more than 40000 ray paths.

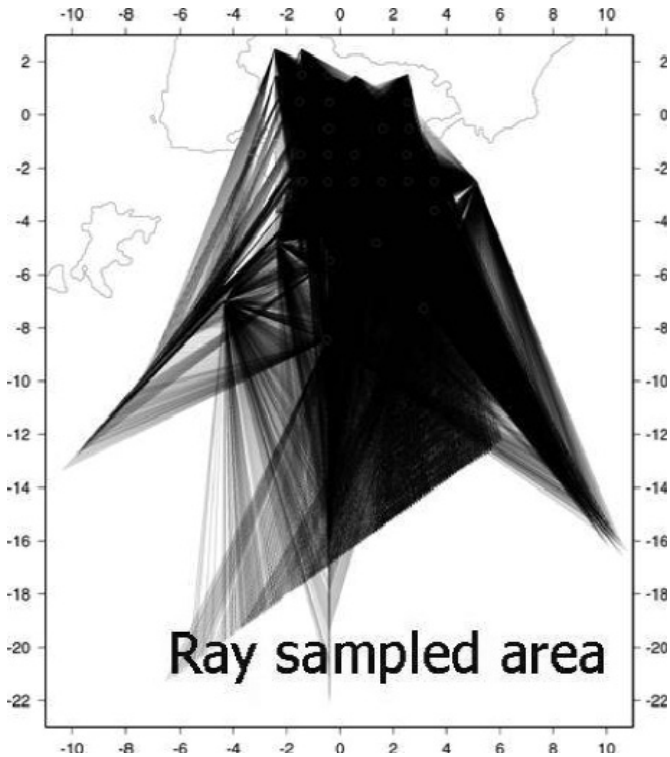

Fig. 2. Horizontal ray sampling of the area investigated during the SERAPIS experiment.

Due to dense urbanization of the area and the night time selected to perform shots trying to reduce noise problem, only six air-guns were operated near the coastline and in the Pozzuoli Bay, while offshore all 12 air-guns were used. The latter allowed the recordings of high energy P waves at distance of > 40 km. An example of recorded data bandpass filtered (5-15 Hz), amplitude equalized (AGC window of 1 s) and plotted in a time reduced scale, using a reduction velocity of 6 km/s, is shown in Figure 3.

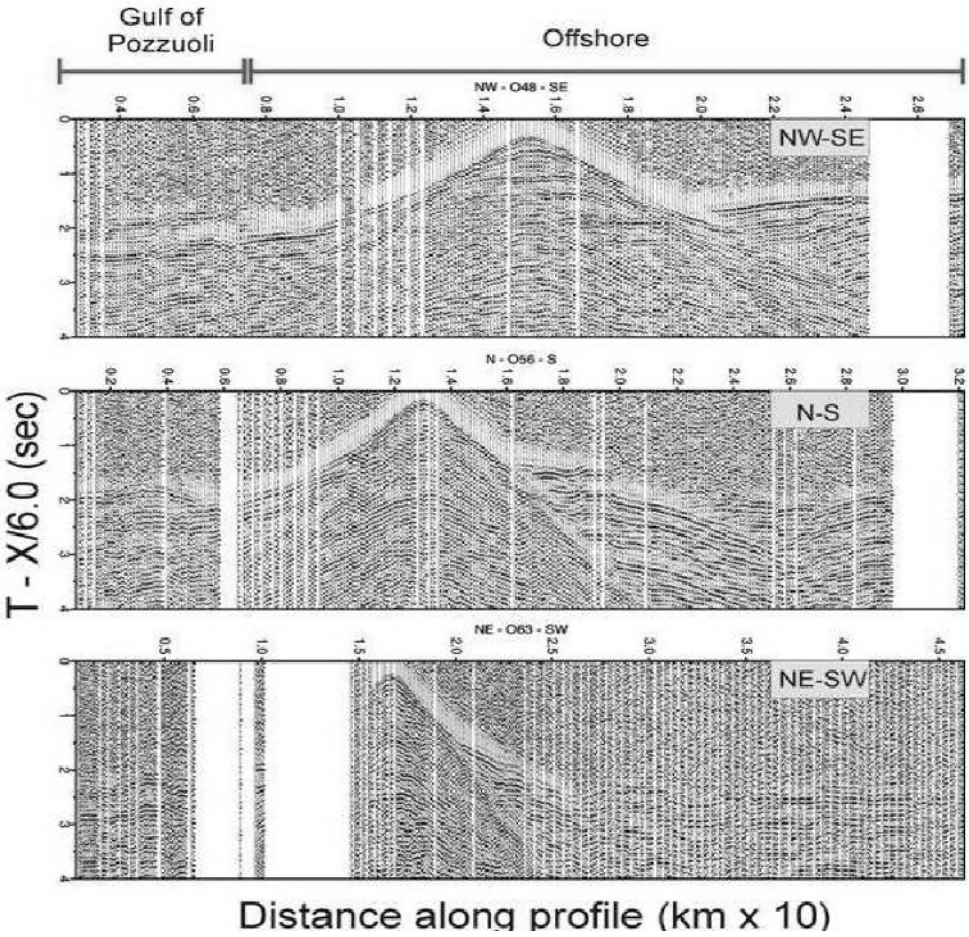

Fig. 3. Examples of common receiver seismic section along NW-SE (upper), NS (centre) and NE-SW (bottom) direction, through the Bay of Pozzuoli towards offshore.

All the recorded traces were arranged in a complete three-component seismic waveform archive, distributed to all participants to the project. This seismic waveform archive joint to a similar one containing data from several hundreds microearthquakes occurred on 1983-1984 at Campi Flegrei (Capuano et al., this issue) represent an unique collection of waveforms produced by passive and active seismic sources in a complex volcanic area, recorded on land and on the sea bottom, that can be very useful to better understand caldera structure.
Once the SERAPIS waveforms dataset was realized, manual reading of the first P wave arrivals has been performed. All the waveforms were band-pass filtered between 5 and 15 Hz in order to work in the frequency range were the phase and amplitude response of the instruments deployed were the same. Picking

was performed on the pre-processed traces, arranged as common receiver gathers (CRG). The SERAPIS data set processing consisted of examining 300,000 OBS waveforms and 400,000 waveforms from stations on land, providing 65,000 and 25,000 P wave first arrival times, respectively. The number of high-quality waveforms recorded by land stations was rather low as compared to the OBS due to the high cultural noise level in the studied area. In all, and considering also the integration of the data from the MareVes97 investigations, the dataset used included ca. 95,000 picks of P-wave first arrivals.
Aster and Meyer (1988, 1989) determined hypocenter location and velocity structure of the caldera using a segment of the passive data recorded in 1984. Vanorio et al., 2005, using the new passive dataset performed a more confident re-analysis of velocity structure and location. SERAPIS data allowed the realization of 3D tomographic images that cover also the Bay of Pozzuoli and part of the Gulf of Naples, evidencing the buried rim of the Campi Flegrei caldera, as shown in Figure 4 (Zollo et al., 2003; Judenherc and Zollo, 2004).

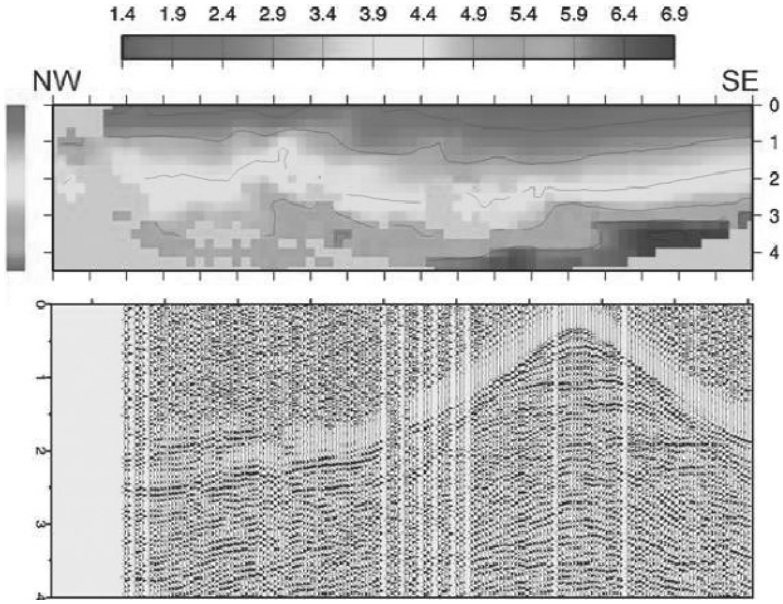

Fig. 4. Example of P-velocity depth section in the Campi Flegrei bay area.
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DSS WAVEFORMS

We perform the recovery and homogenisation of IRRS old data of DSS seismic experiment. In particular, the Deep Seismic Sounding data, acquired in

the 1985 during a Campi Flegrei micro-array sub-experiment, were digitised and archived. The data were acquired using sea shots (Figure 5) and deploying 20 analog stations along a dense micro-array (about 100 m spacing, length 2.5 km) in the Caldera area (Figure 5 panel inset).

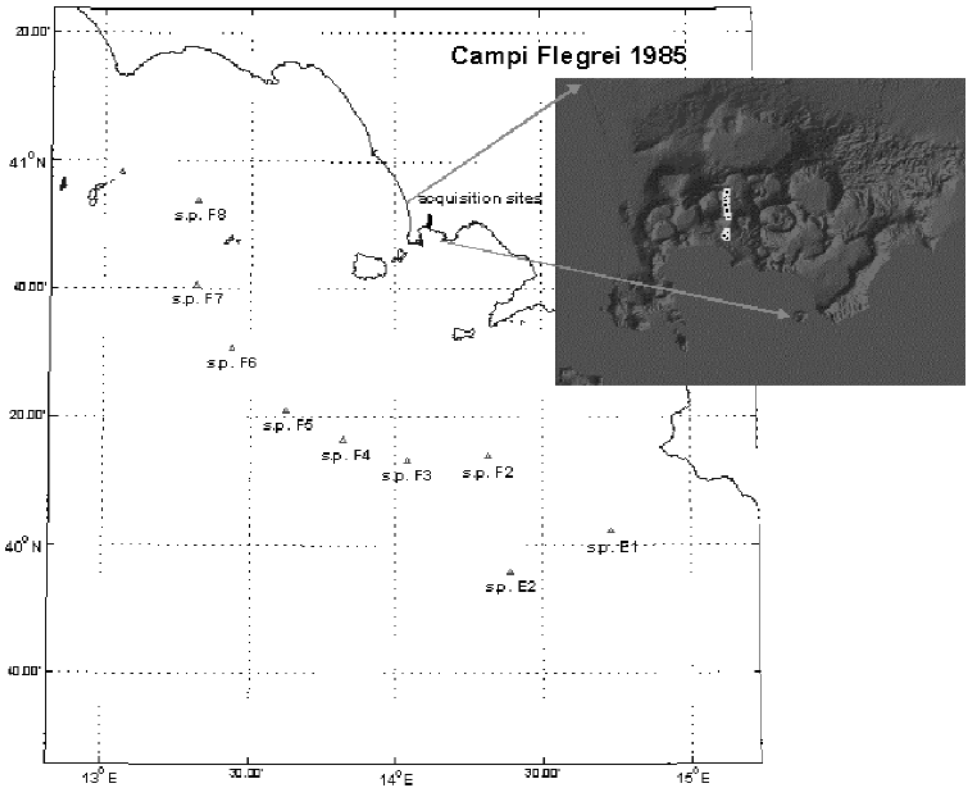

Fig. 5. Campi Flegrei 1985 DSS microarray experiment.

This data constitute a sub dataset of the 1985 experiment which were unpublished and which were never processed in previous studies (Ferrucci et al., 1989). This sub data set constitutes an useful information also in order to compare with the SERAPIS 2001 seismic experiment. Recording examples of the recovered data are shown in Figures 6a and 6b.

The activity product consists of a data compilation report. The data were transferred to the Napoli data base center and, in the future, the homogenisation and integration with the other data of the 1985 experiment will be performed.

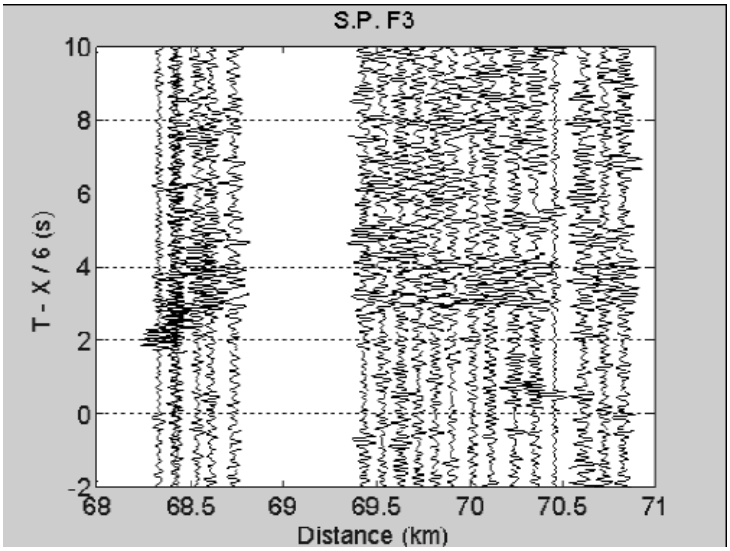

Fig. 6a. Microarray data S.P. F3, vertical Component. Filtered 2-10 Hz. Profile configuration.

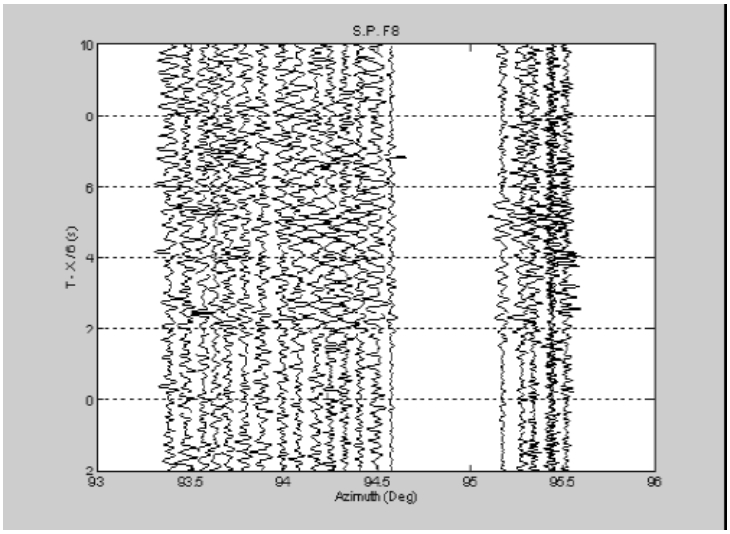

Fig. 6b. Microarray data S.P. F8, vertical Component. Filtered 2-10 hz. Fan configuration.

Conclusion

A typical acquisition lay-out of industrial surveys for oil research has been performed during SERAPIS experiment. The high quality and density of acquired seismic information suggest the experiment design can be exported to

investigate the structure of other coastal volcanoes. An advanced array of sea-bottom instruments has been installed and operated during three week, demonstrating that sub-marine seismic monitoring of volcanic activity is feasible and should be implemented in the future with permanent systems, linked to the on-shore monitoring networks.
The Serapis experiment provided a valuable P-wave arrival time data set allowing for the 3-D tomographic reconstruction of the sub-surface structure underneath the whole bays of Naples and Pozzuoli. The processed Serapis P-wave travel-time collection, extended with an already acquired data set (MareVes97 project), allowed to compute the most comprehensive 3D P-wave velocity distribution in the bay of Naples down to about 6 km depth, including a small scale, high-resolution model in the Campi Flegrei caldera.
The three-dimensional image of the top of Mesozoic carbonate basement is reconstructed underneath the bay of Naples and the Mt. Vesuvius area. Its morphology is very complex due to the occurrence of fault escarpments and depressions, whose link with the volcanic activity is still to be fully understood.

Acknowledgments

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