

2D and 3D high resolution seismic imaging of shallow Solfatara crater in Campi Flegrei (Italy): new insights on deep hydrothermal fluid circulation processes

Grazia De Landro (1), Sergio Gammaldi (1), Vincenzo Serlenga (1,5), Ortensia Amoroso (1), Guido Russo (1), Gaetano Festa (1), Luca D' Auria (2), Pier Paolo Bruno (3), Marceau Gresse (4), Jean Vandemeulebrouck (4), and Aldo Zollo (1)

(1) Università di Napoli Federico II, Dipartimento di Fisica "Ettore Pancini", Naples, Italy, (2) Instituto Volcanológico de Canarias (INVOLCAN), Tenerife, Spain, (3) Petroleum Institute, Department of Petroleum Geosciences, Abu Dhabi, United Arab Emirates, (4) ISTERre, Université Savoie Mont Blanc, Chambéry, France, (5) Now at CNR-IMAA, Tito Scalo, Potenza, Italy

Seismic tomography can be used to image the spatial variation of rock properties within complex geological media such as volcanoes. Solfatara is a volcano located within the Campi Flegrei still active caldera, characterized by periodic episodes of extended, low-rate ground subsidence and uplift called bradyseism accompanied by intense seismic and geochemical activities. In particular, Solfatara is characterized by an impressive magnitude diffuse degassing, which underlines the relevance of fluid and heat transport at the crater and prompted further research to improve the understanding of the hydrothermal system feeding the surface phenomenon.

In this line, an active seismic experiment, Repeated Induced Earthquake and Noise (RICEN) (EU Project MED-SUV), was carried out between September 2013 and November 2014 to provide time-varying high-resolution images of the structure of Solfatara. In this study we used the datasets provided by two different acquisition geometries: a) A 2D array cover an area of $90 \times 115 \text{ m}^2$ sampled by a regular grid of 240 vertical sensors deployed at the crater surface; b) two 1D orthogonal seismic arrays deployed along NE–SW and NW–SE directions crossing the 400 m crater surface. The arrays are sampled with a regular line of 240 receiver and 116 shots.

We present 2D and 3D tomographic high-resolution P-wave velocity images obtained using two different tomographic methods adopting a multiscale strategy.

The 3D image of the shallow (30-35 m) central part of Solfatara crater is performed through the iterative, linearized, tomographic inversion of the P-wave first arrival times. 2D P-wave velocity sections (60-70 m) are obtained using a non-linear travel-time tomography method based on the evaluation of a posteriori probability density with a Bayesian approach.

The 3D retrieved images integrated with resistivity section and temperature and CO_2 flux measurements, define the following characteristics: 1. A depth dependent P-wave velocity layer down to 14 m, with $V_p < 700 \text{ m/s}$ typical of poorly-consolidated tephra and affected by CO_2 degassing; 2. An intermediate layer, deepening towards the mineralized liquid-saturated area (Fangaia), interpreted as permeable deposits saturated with condensed water; 3. A deep, confined high velocity anomaly associated with a CO_2 reservoir. With the 2D profiles we can image up to around 70 m depth: the first 30 m are characterized by features and velocities comparable to those of the 3D profiles, deeper, between 40-60 m depth, were found two low velocity anomalies, that probably indicate a preferential via for fluid degassing.

These features are expression of an area located between the Fangaia, which is water saturated and replenished from deep aquifers, and the main fumaroles that are the superficial relief of deep rising CO_2 flux. So, the changes in the outgassing rate greatly affects the shallow hydrothermal system, which can be used as a near-surface “mirror” of fluid migration processes occurring at greater depths.