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Preliminary assessment of the geothermal potential of the Vulcano Island (Archipelago Aeolian, southern Italy)

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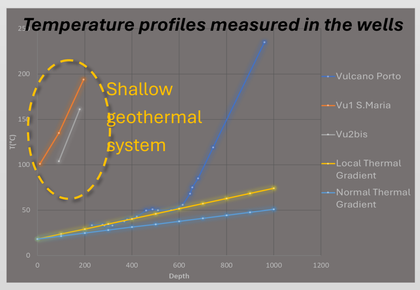
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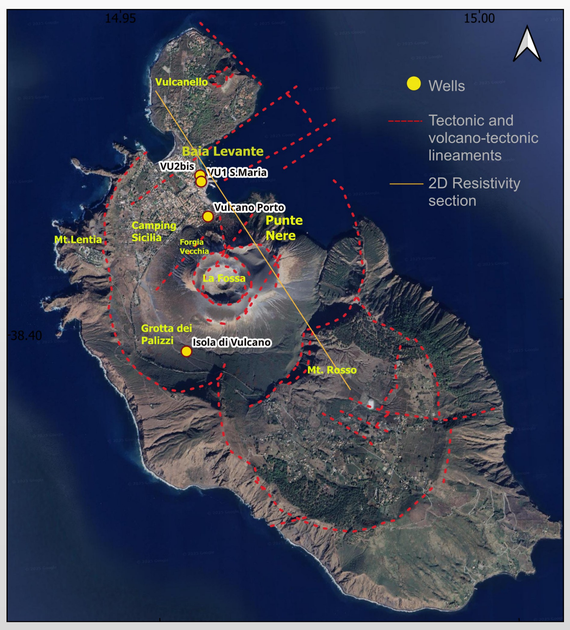
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INTRODUCTION

We present the preliminary results of the IRGIE Italian project (Inventory of Geothermal Resources of the Aeolian Islands, 2023–2026), led by the Istituto Nazionale di Geofisica e Vulcanologia (INGV), which aims to investigate the geothermal potential of the Aeolian Islands (southern Italy) to reduce their dependence on fossil fuels. Initial studies have focused on Vulcano island, where previous investigations conducted in the 1980s, identified a shallow geothermal system (100–200 m depth) in the northern sector of the island, with temperatures up to 200°C.

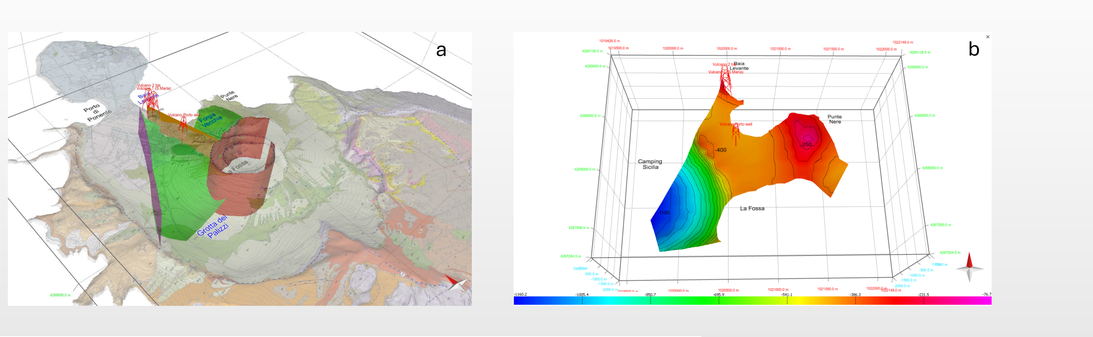






METHODOLOGY

To evaluate the feasibility of geothermal exploitation in this island, a multidisciplinary approach was adopted, combining 3D geological, geophysical and fluid-dynamic modelling. Results of geophysical surveys, including magnetotellurics (MT) and electrical resistivity tomography (ERT), were conducted to identify the geothermal reservoir at depth. A 3D numerical simulation was then carried out to reconstruct the temperature distribution within the system. Finally, a 3D qualitative geological model was built by integrating geological and geophysical data, and providing the geometrical parameters with the final aim to estimate the heat in place of the identified geothermal reservoir.



3D MAGNETOTELLURIC MODELING

An original short-period magnetotelluric survey (MT) was conducted on Vulcano Island to produce a three-dimensional resistivity model of structures up to 2.5 km deep. The MT surveys successfully identified a shallower hydrothermal system, detected as a conductive anomaly (Di Giuseppe et al., 2023).

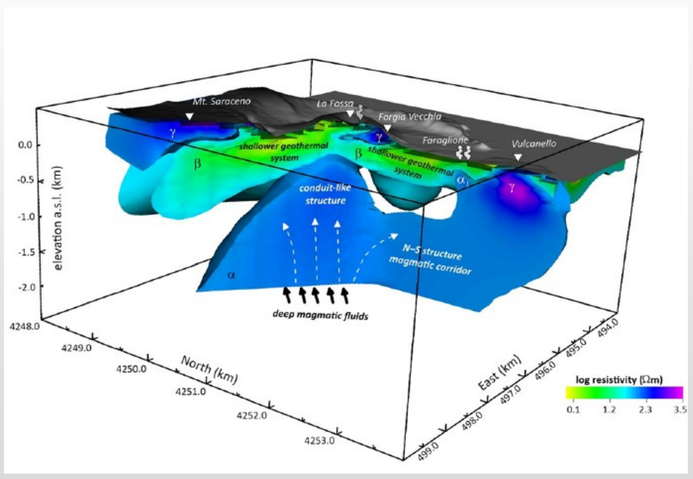


Figure 1. Sketch model of the La Fossa caldera deducted by the 3D resistivity model.

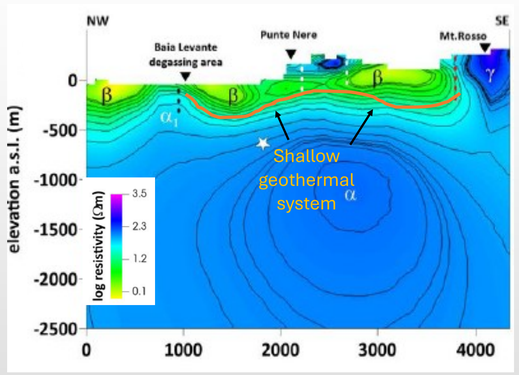


Figure 2. Resistivity section (location on the sketch map of the introduction panel) showing the conductive anomaly (β).

3D GEOLOGICAL RESERVOIR MODELING

Based on results from MT surveys integrated with different types of geological data, a 3D subsurface reconstruction of the geothermal reservoir was developed. The analysis of lateral resistivity anomalies at depth allowed for the identification of structural discontinuities that compartmentalize the reservoir. This reconstruction provides the geometrical parameters (depth and thickness) requires to assess the theoretical geothermal potential of the explored reservoir.

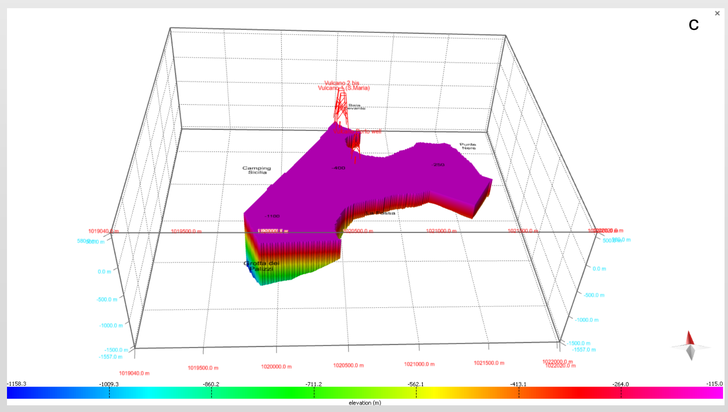
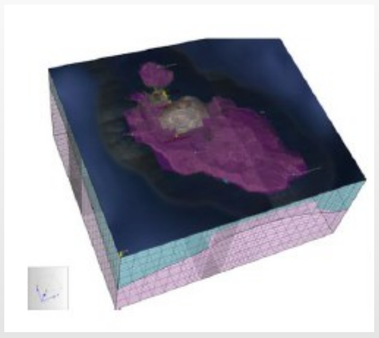


Figure 3. 3D reconstruction of the geothermal reservoir; a) bottom surface in green; b) depth of the bottom surface; c) volume of the resevoir.

NUMERICAL MODELING OF HEAT TRANSPORT

A numerical model of Vulcano Island was developed using TOUGH2 (ECO2N module) to simulate high-temperature H_2O–CO_2 fluids. The system includes three permeability zones: the fracture network (100 mD), the crater conduit (250 mD), and a 200 °C geothermal aquifer (60 mD). A deep inflow of hot water and CO_2 reproduces the elevated temperatures on the eastern side. At steady state, the 200 °C isotherm occurs at ~200 m depth, with CO_2-rich fluids rising along fractures and causing degassing near Vulcano Porto.



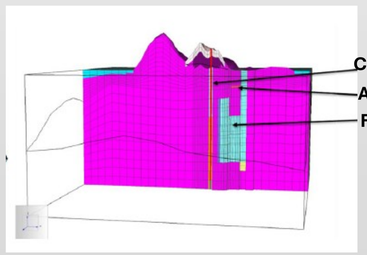


Figure 4. Numerical domain of the fluid dynamic model for the island of Vulcano.

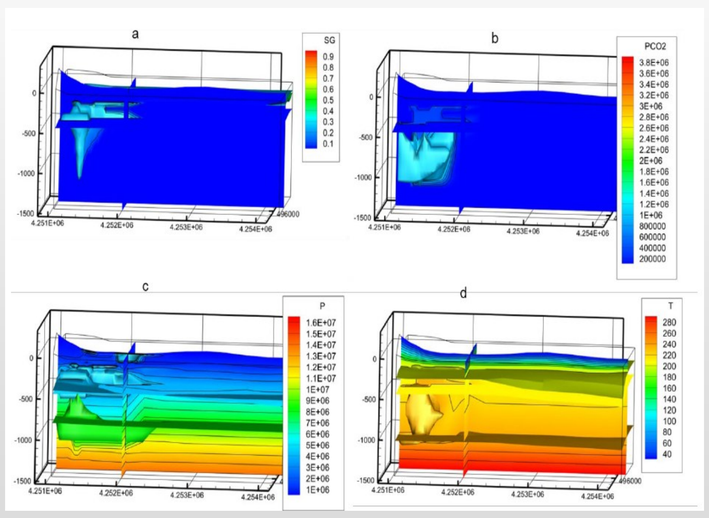


Figure 5. Results regarding gas saturation distribution (volume fraction; a), CO_2 partial pressure (Pa; b), pressure (Pa; c) and temperature (°C; d).

GEOTHERMAL POTENTIAL ASSESSMENT

A preliminary evaluation of the reservoir's geothermal potential was performed by estimating the total heat in place stored in both the rock (E_r) and the water (E_w), using the volumetric method of Muffler and Cataldi (1978), to provide an initial estimate of the accessible geothermal resource base.

Total stored heat = $E_{water} + E_{rock}$

$$E_{water} = \rho_w c_{p,w} \Phi V_{bulk} (T - T_{ref}) \qquad E_{rock} = \rho_r c_{p,r} (1-\Phi) V_{bulk} (T - T_{ref})$$

where
V : total bulk volume
ρ_r and ρ_w : density of rock and water
$C_{p,r}$ and $C_{p,w}$: specific heat capacity of rock and water
Φ: porosity
V_{bulk}: total bulk volume
T: average reservoir temperature
T_{ref}: reference temperature
(yearly average surface temperature)

The key geothermal parameters—density, porosity, and specific heat—were obtained from literature data and in situ measurements.

Preliminary results indicate that **the total estimated heat in place (HIP)** within the reservoir **is approximately 233 PJ.**

Figure 7. 3D point cloud of temperatures (from TOUGH2 simulation results) inside the reservoir showing a medium value of 200 °C

CONCLUSION AND OUTLOOK

The study provides key insights into the geothermal resources of Vulcano Island, including the amount of energy stored within the identified reservoir.

Preliminary results are encouraging and suggest promising annual power extraction, offering a solid basis for estimating the technical potential while accounting for recovery factor, plant efficiency, and system lifespan.

To reduce uncertainties in reservoir parameters, the deterministic approach will be complemented by a probabilistic analysis, yielding a distribution of potential values rather than a single estimate. This combined strategy enhances the reliability of the assessment and supports future feasibility studies and system design.

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