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Physical model of a fumarolic system inferred from a high-resolution 3-D Resistivity image of Solfatara volcano

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Solfatara crater, located inside the Phlegrean Fields caldera, is showing a significant unrest activity since 10 years with a increase of ground deformation, degassing and heating. Electrical Resistivity Imaging was performed between 2012 and 2016 with the purpose of improving our knowledge of the shallow hydrothermal system. The complete dataset includes 43,432 D-C measurements inverted using the E4D code. This 3-D inversion was compared with the mappings of surface temperature, diffuse soil CO_2 flux and self-potential in order to better constrain the interpretation of the observed resistivity structure in terms of lithological contrasts and hydrothermal signatures.

For the first time, we highlighted in 3-D the main geological units: Monte Olibano lava dome and Solfatara crypto-dome appear as two relatively resistive bodies (50-100 Ω.m). Furthermore, the resistivity model clearly revealed the contrasting geometry of the hydrothermal circulation in the Solfatara crater. A channel-like conductive structure (7 Ω.m) represents the condensate that flows from the main fumarolic area down to the liquid-dominated Fangaia mud pool. This interpretation is consistent with the negative Self-Potential anomaly and with the surface observations.

We imaged at a metric-resolution the two main fumaroles, Bocca Grande and Bocca Nuova, that have the following geochemical characteristics. Bocca Grande vent: 162°C, ∼150 t of CO_2 released per day with a mass ratio $CO_2/H_20 = 0.4$ and Bocca Nuova vent: 148°C, ∼50 t of CO_2 released per day with a mass ratio $CO_2/H_20 = 0.45$.

The differences between these geochemical characteristics could lead one to believe that they are fed by two distinct sources at depth. On the contrary, our resistivity model shows that the two fumarolic vents are directly connected to a common resistive body (30-50 Ω.m) at a depth of 50 meters. This structure likely represents a single gas reservoir feeding the two fumaroles. Its depth corresponds indeed to a steam source at a pressure of 6 bar and at a temperature of least 165 °C. The geophysical images combined with the geochemical data allowed us to build up a multiphase fluid flow model of the Bocca Grande and and Bocca Nuova fumaroles using the TOUGH 2 code. Our results show that the distinct resistivity structure, temperature, and water content of the both fumaroles are due to the particular geometry of the condensate flow that intersects and contaminates the Bocca Nuova but not the Bocca Grande fumarole.

These results indicate the necessity to combine geophysical and geochemical approaches in order to better apprehend the structure complexity and the dynamics of fumaroles and hydrothermal systems.