Geophysical Research Abstracts
Vol. 16, EGU2014-11830, 2014
EGU General Assembly 2014

Identification of shallow volcanic structures in Timanfaya National Park (Lanzarote, Canary Islands) through combined geophysical prospecting techniques

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The Timanfaya National Park is a volcanic area, which occupies a surface area of about 51 sq. km in the southwest of Lanzarote Island (Canary Archipelago, Spain). The 1730-1736 eruption gave rise to this volcanic landscape with more than 30 volcanic cones formed in different phases of basaltic type eruptions. It was one of the most important volcanic events occurred in the Canary Archipelago over the last 500 years. Several canyons ("jameos") are crossing this landscape in all directions, being created while the surface of the lava cooled off, and broke into pieces, falling down into the several tubes. Its location and identification is important to prevent hazards or to achieve a good exploitation from a visitor viewpoint in a restricted touristic area as the Timanfaya National Park. The use of prospective techniques to investigate the near subsurface structure of the park is very complicated, and only some regional study through gravity, magnetism and seismicity have been undertaken to attempt to model the deeper crustal structure of Lanzarote Island.

This work presents a new study about the location of recent lava tubes at the volcanic area of Timanfaya National Park by the analysis and joint interpretation of high-resolution gravity, ground penetrating radar (GPR), and electromagnetic induction (EMI) data obtained over areas which had not been surveyed up to date. The studied lava flows are located at the Calderas Quemadas zone.

The processed GPR radargram displays a complex pattern of reflections along the whole profile up to $\sim$9 m depth. The strongest reflections can be grouped in four different areas defined by several hyperbolic reflections. Direct visual inspections carried out in the field allow confirming the occurrence of lava tubes at two of the locations where hyperbolic reflections are defined. Then, the strong reflections observed have been interpreted as the effect of the roof and bottom interfaces of several lava tubes. A microgravity survey along the same profile defines a wide gravity low with the minimum values located at the central part. Over-imposed to this main trend, several minor relative gravity highs and lows can be observed. Using the previous information from the GPR data to construct an initial model, a final 2.5D gravity model has been obtained with four lava tubes of different geometries in good agreement with the GPR results. Besides, EMI data gathered from the same profile have been used to obtain an inverted 2D resistivity model that displays four high resistivity areas that closely matches the locations of the lava tubes derived from the previous methods. The model obtained from EMI data exhibit a vertical and horizontal resolution lower than the GPR and microgravity ones, although it reaches a deeper investigation depth ($\sim$20 m).

The comparison of the results obtained from the different techniques has revealed that joint interpretation of GPR, microgravity and EMI methods provides reliable models useful for the detection of unknown shallow lava tubes. These non-destructive geophysical techniques are of vital importance in areas of special protection such as National Parks.