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

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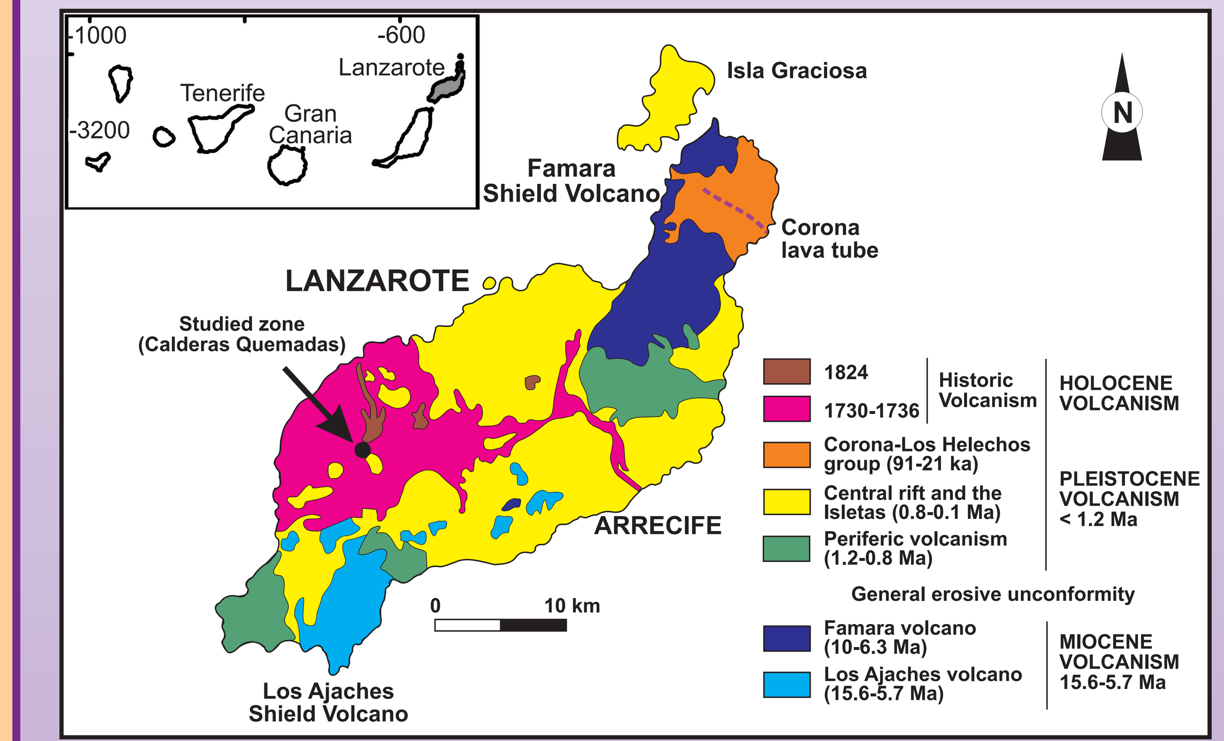
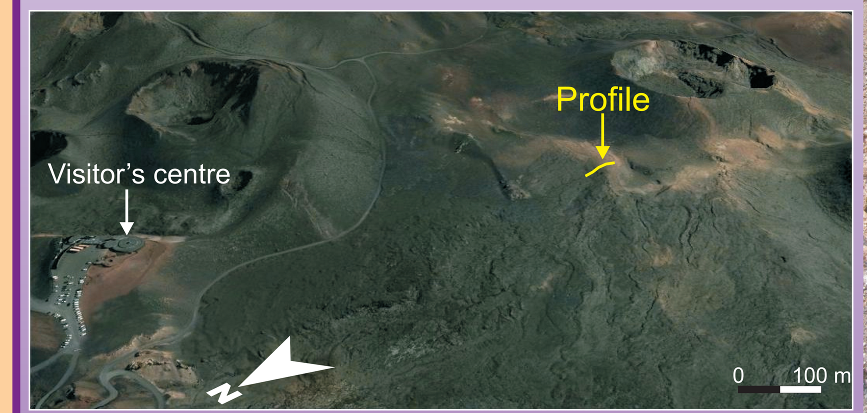
INTRODUCTION

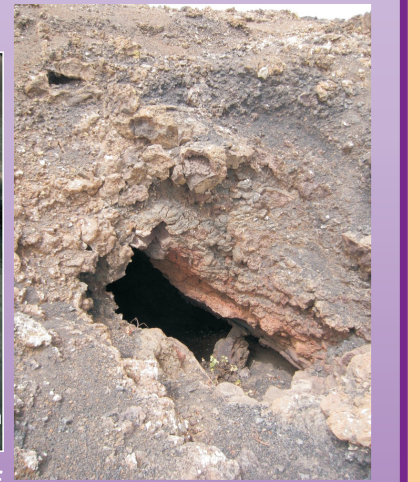
The Timanfaya National Park is a volcanic area of about 51 sq. km in the southwest of Lanzarote island (Canary Archipielago, Spain). The historical 1730-1736 eruption gave rise to this volcanic landscape with more than 30 volcanic cones formed in different phases of basaltic type eruptions. It was one of the most important volcanic events occurred in the Canary Archipielago 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, failing 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.

This work presents a study about **the location of recent lava tubes** at the 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 not surveyed up to date. The studied lava flows are located at the Calderas Quemadas zone.





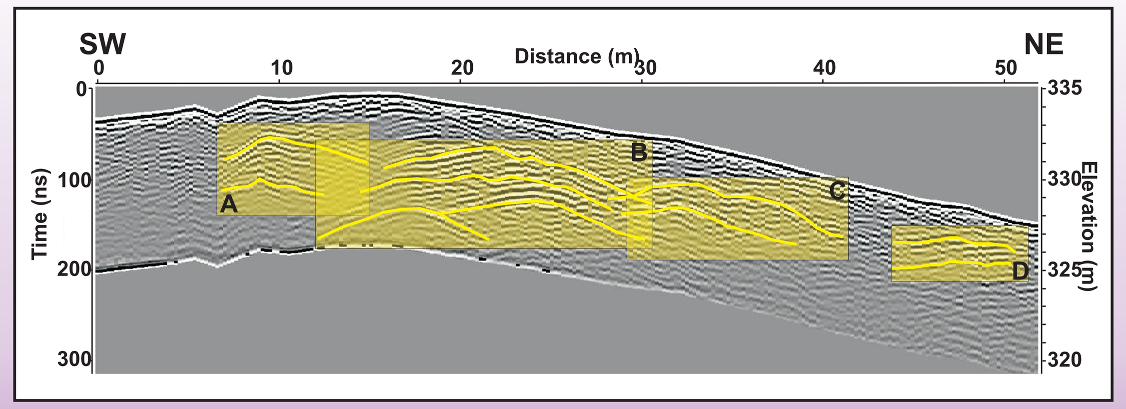
3D view of the studied area, near to the location of the Timanfaya National Park visitor's centre. The profile, with ~50 m length, has been carried out over a recent lava flow belonging to the historical 1730-36 eruption, and show evidences of, at least, two shallow air-filled lava tubes.



Partial collapse of the roof indicating the location of a major lava tube located at ~20m from the beginning of the profile.

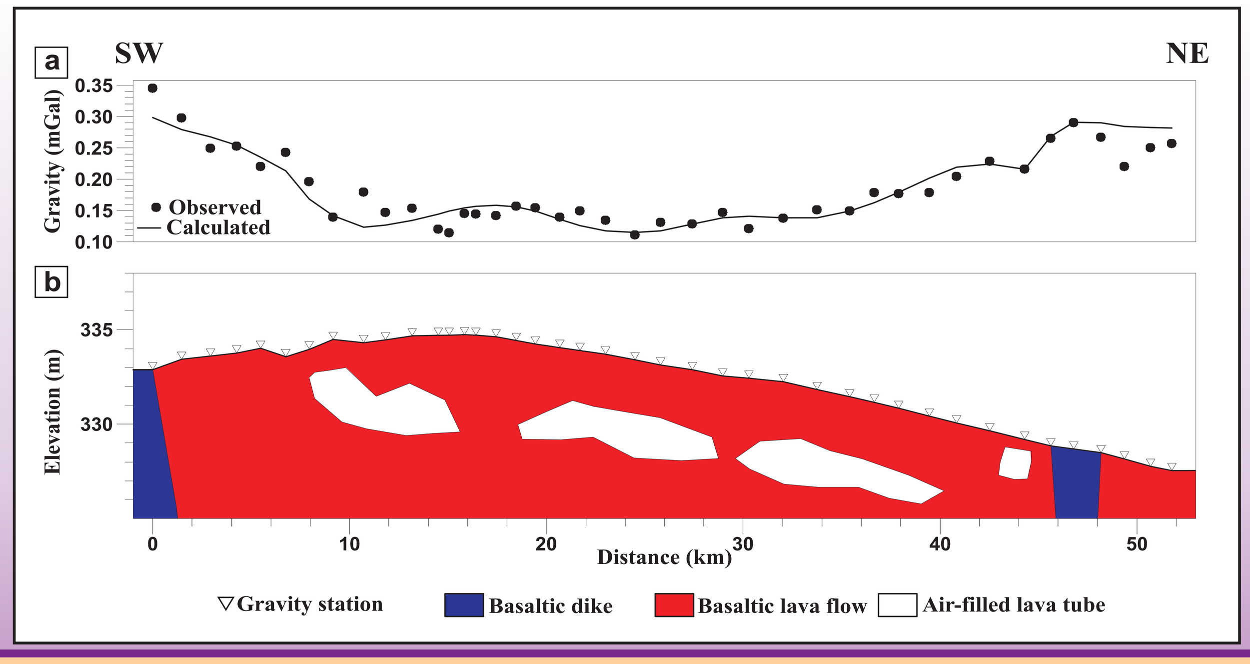
GROUND PENETRATING RADAR (GPR)

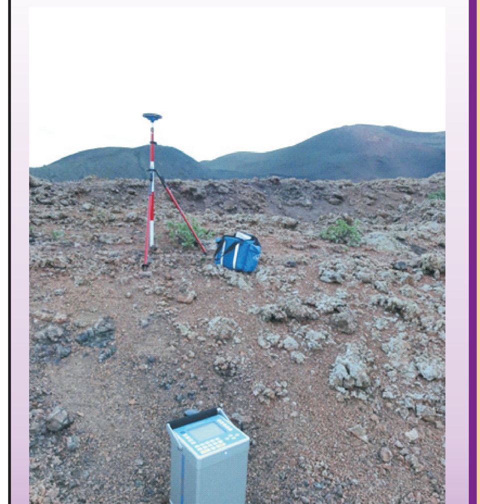
The GPR processed radargram displays a complex pattern of reflections along the whole profile up to ~9 m depth. The strongest reflections can be grouped in four different areas (A-D) defined by several hyperbolic reflections. Direct visual inspections carried out in the field allow confirming the occurrence of lava tubes at two of the locations (A and B) 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.



MICROGRAVITY

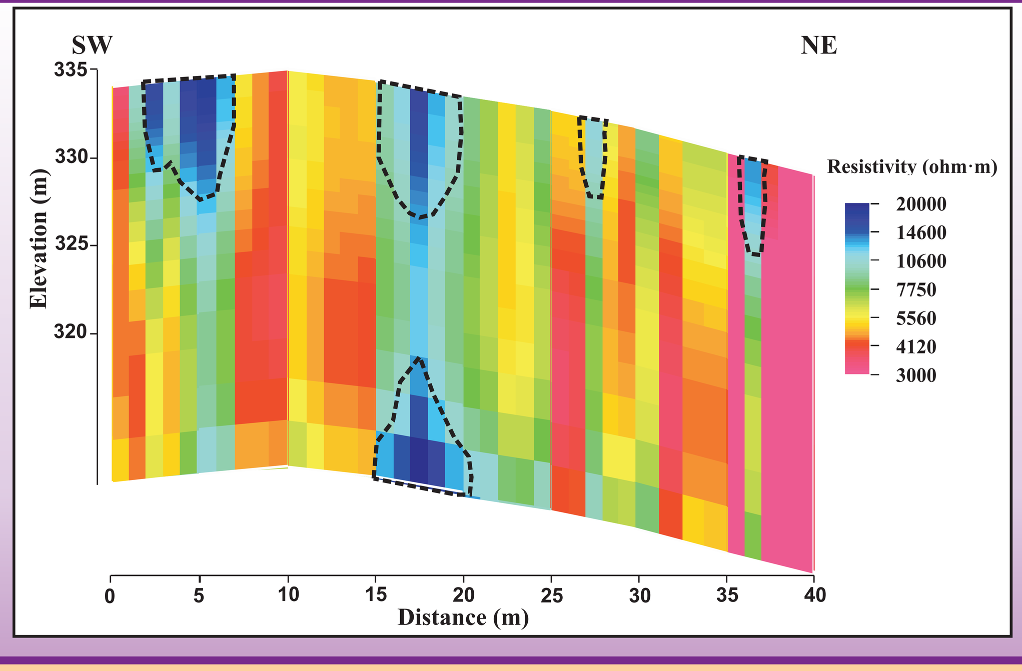
A microgravity survey (~1 m station spacing) along the GPR profile defines a wide gravity low with the minimum values located at the central part (a). Over-imposed to this main trend, several minor relative gravity highs and lows can be observed. Using the previous information from the GPR data to construct an initial model, a final 2.5D gravity model (b) has been obtained with four lava tubes of different geometries and two near-vertical basaltic dikes. The overall RMS error of the final model is ±0.022 mGal.





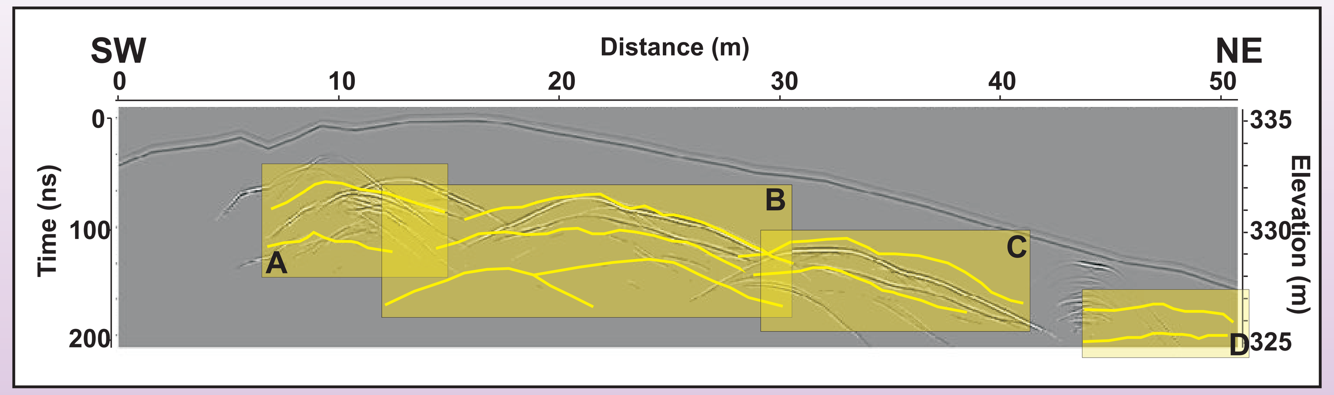
ELECTROMAGNETIC INDUCTION (EMI)

EMI data for the same profile (1 m station spacing, vertical and horizontal dipole modes, 10, 20 and 40 m loop spacings) have been used to derive an inverted 2D resistivity model. It displays four shallow high resistivity areas that closely matches to the lava tubes locations derived from the previous methods. The model obtained from EMI data exhibit a lower resolution than the GPR and microgravity ones but it reaches a deeper investigation depth (~25 m). A deep (~20 m depth) high resistivity area has also been interpreted as an air-filled lava tube. The homogeneous resistivity area located at the end of the profile (37 to 40 m) is interpreted as a vertical prismatic body, probably a vertical dike.



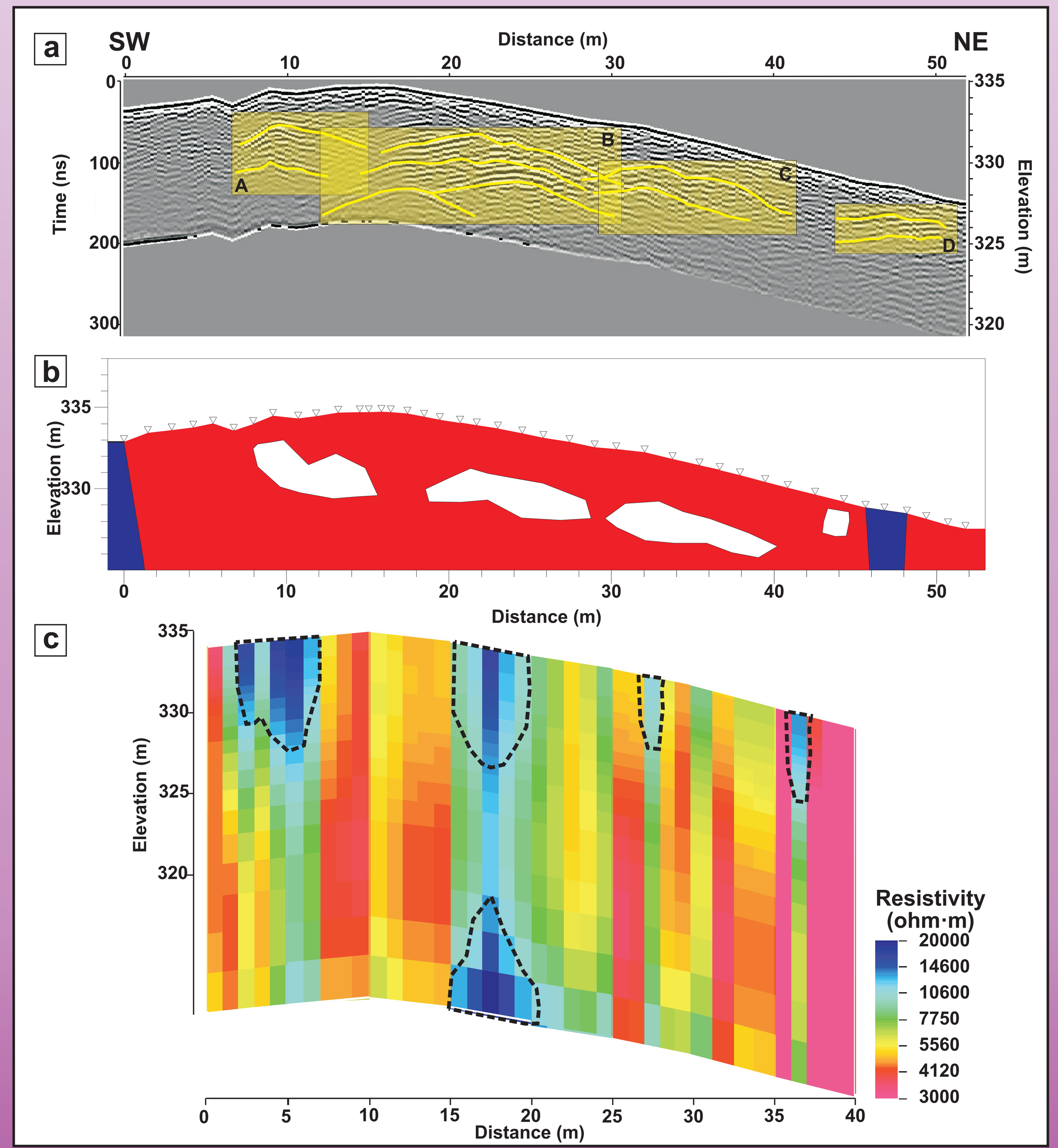
GPR MODELLING

GPR data provides useful information about the location of the roof of the lava tubes. However, the irregular geometry that characterizes the lava tubes makes the resulting radargram difficult to interpret. In order to better understand the observed reflections, a synthetic model using the results of the gravity modeling has been developed, and the resulting radargram compared to the real one. This has been carried out using a Finite Difference Time Domain (FDTD) method (GPRMax). A good agreement between the synthetic reflections and the real ones (yellow lines) is found for lava tubes A, B and C, which indicates that the location and geometry of the cavities obtained from the gravity modeling closely fits with the lava tubes causing the observed GPR reflections. Reflections from D seems to be better related to the vertical basaltic dike as they do not fit the small lava tube.



DISCUSSION AND CONCLUSIONS

GPR data (a) provides the finest resolution both in the horizontal and vertical directions. The radargram clearly identifies strong reflections associated to the lava tubes or the internal structure of the lava flow.
Gravity modelling (b) is a useful tool in order to detect gravity lows associated to air-filled cavities. However, it becomes difficult to unambiguously associate a particular size and geometry of the structures to the observed Bouguer anomaly data. A previous knowledge about the location and depth of the lava tubes from prior geological/geophysical information is needed to obtain a reliable model.
EMI resistivity model (c) defines the same location of the structures than GPR and microgravity methods, but the position of the lava tube roof is not properly imaged. We interpret this as a consequence of the lower resolution of the technique when compared to GPR and microgravity. In general, we can say that the EMI method is a useful tool to define the location of the lava tubes although its actual geometry is not as properly imaged as with GPR and microgravity.



The best way to compensate the weak points for every method is to combine the results coming from the three techniques to obtain the best possible model.
The **comparison of the results obtained from the different techniques (a-c)** 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**.

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