Geophysical and geochemical survey across El Hierro (Canary Islands) during the 2011-2012 monogenetic eruption

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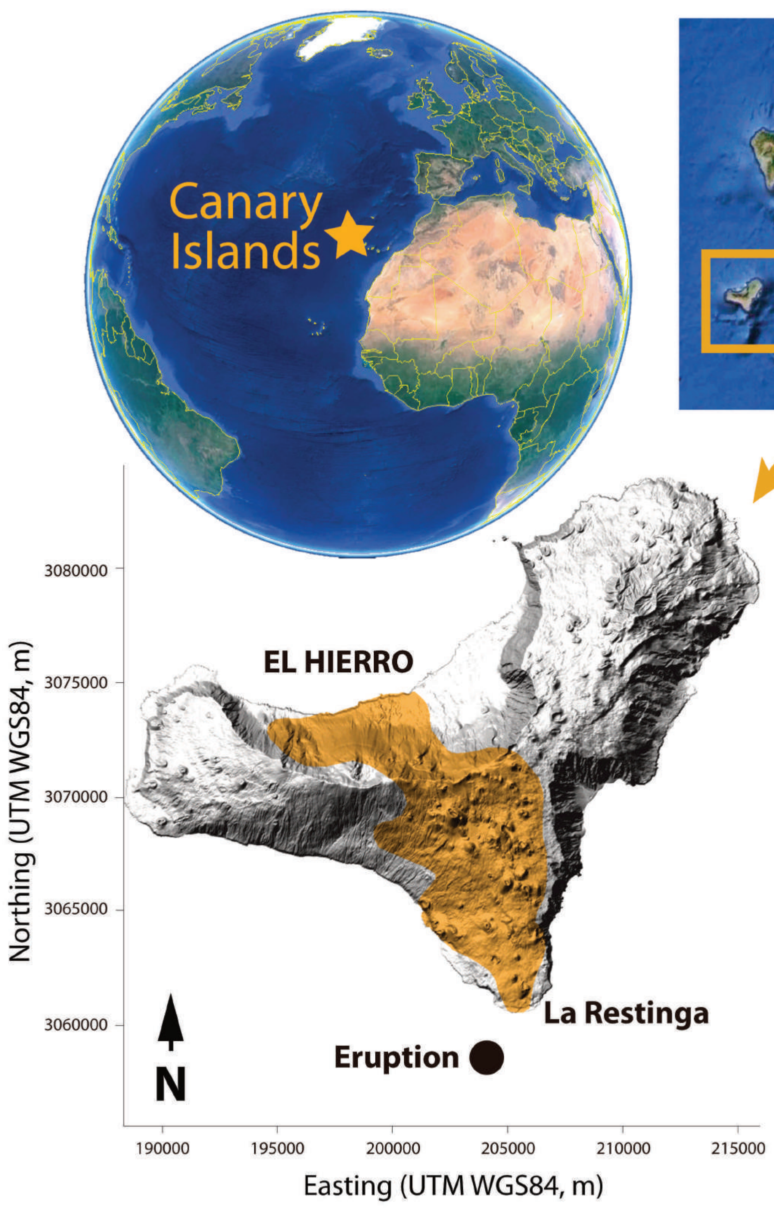


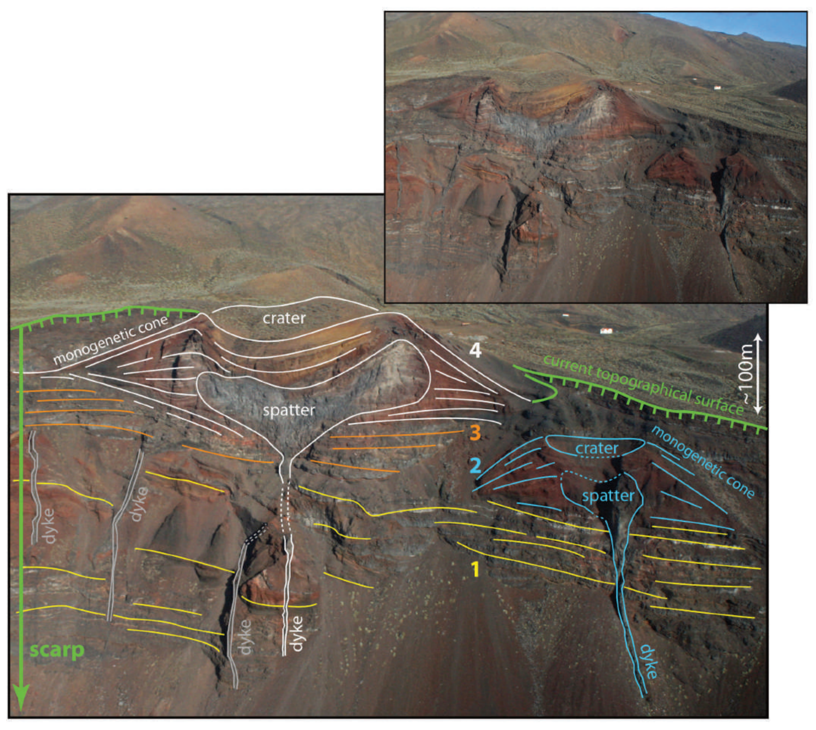


Figure 1. Localization of El Hierro island (Canary Islands). Geophysical and geochemical study area in orange colour. Right: two monogenetic cones at the western point of El Hierro. The internal structure of the edifices was exposed by the erosion of the coast line (Barde-Cabusson et al., 2013).

Method

The self-potential (SP) method consists in measuring a natural difference of electrical potential between two electrodes. We use Cu-CuSO4 nonpolarizable electrodes and a high impedance voltmeter. The dataset is composed of closed profiles, with a measurement spacing of 20 m (except in the central part of the island), and is corrected to the sea level at the North and South of the island.

The sea level sets an absolute reference of 0 mV for the SP dataset. Basically, on active volcanoes the main source of SP anomalies with respect to the reference is due to the flow of groundwater through a porous rock matrix (electrokinetic effect). The flow of pore water drags mobile positive charges from the surface of the rocks, in the flow direction. This generates relative positive SP anomalies for upward flows (e.g.: hydrothermal fluids) and negative SP anomalies for downward flows (e.g.: meteoric water infiltration).

Here additional soil CO_2 flux measurements were acquired in part of the study area.

Introduction

Monogenetic volcanic fields are characterized by a huge diversity of the eruptive dynamics where the magma can reach the surface almost anywhere in the field, depending on tectonics, local geology, etc. Knowing when the next eruption will take place is thus only part of the challenge beside understanding where and which type of eruption will arise.

In the island of El Hierro (Canary Islands, Spain), monogenetic volcanism is common and use to concentrate along the three rift zones of the island (Fig. 1). On the 10th of October 2011 a submarine monogenetic eruption started off the coast of La Restinga. Knowing where the magma would reach the surface was a major concern as the earthquakes preceding the eruption migrated from the north to the south of El Hierro, until the eruption started (Lopez et al., 2012). The second concern was the about the possibility of a hydromagmatic eruption taking place near the inhabited coast of El Hierro.

This study case sets out the necessity of a double approach to better understand monogenetic volcanic systems and their dynamics (past and present), as an essential prerequisite to improving eruption forecasting in time, space, and concerning the type of the eruptions:

- A structural approach: developing methods sensitive to fluid circulations, allowing to map rising hydrothermal fluids and infiltrating meteoric water, as well as the main structural features guiding them.
- A dynamic approach consisting in developing new monitoring methods measuring hydrothermal activity variations related to the magmatic activity.

Here we focus on the first approach, with the results of a geophysical and geochemical survey (self-potential and soil CO_2 flux) crossing the island of El Hierro, performed during the 2011-2012 seismic crisis and eruption.

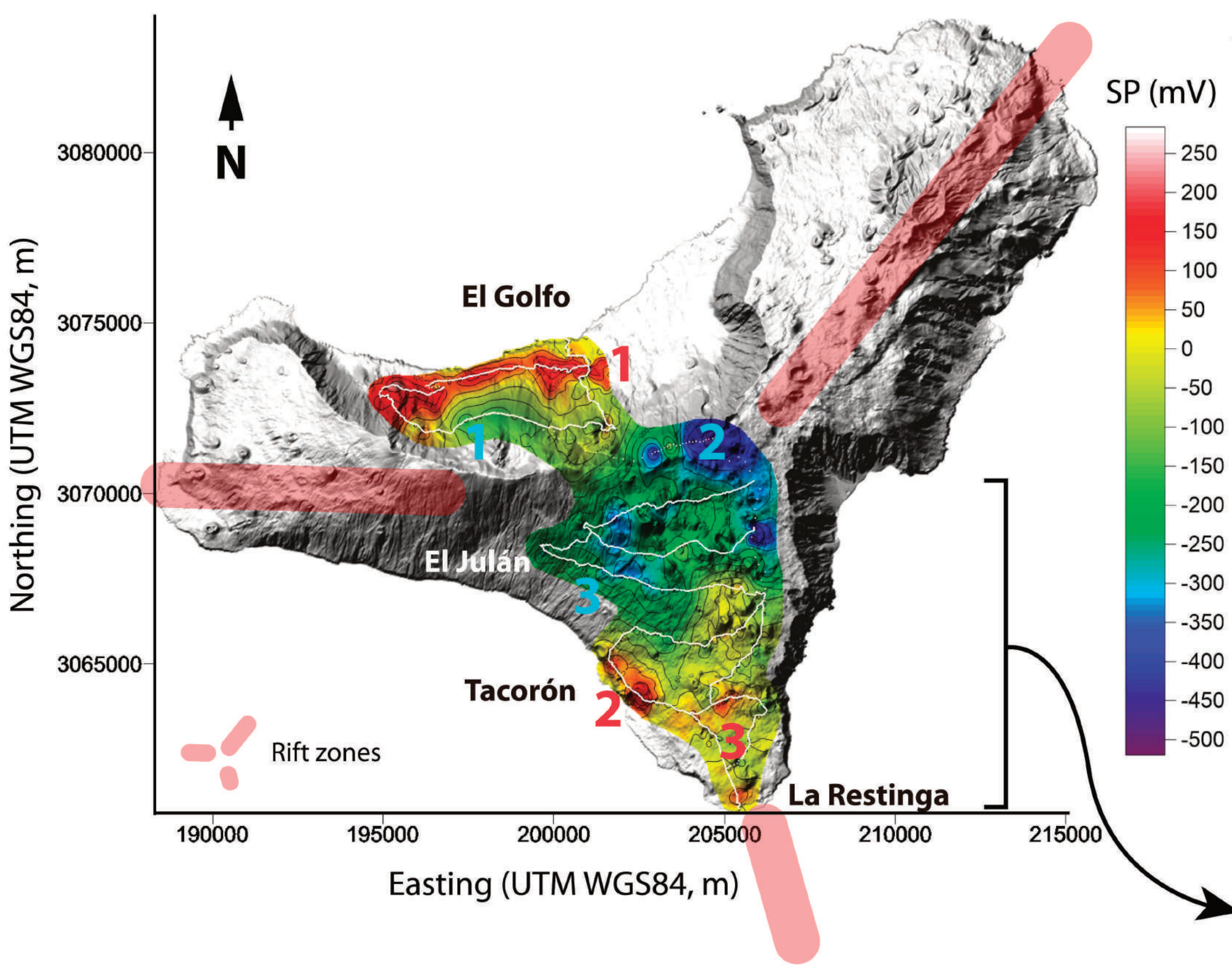
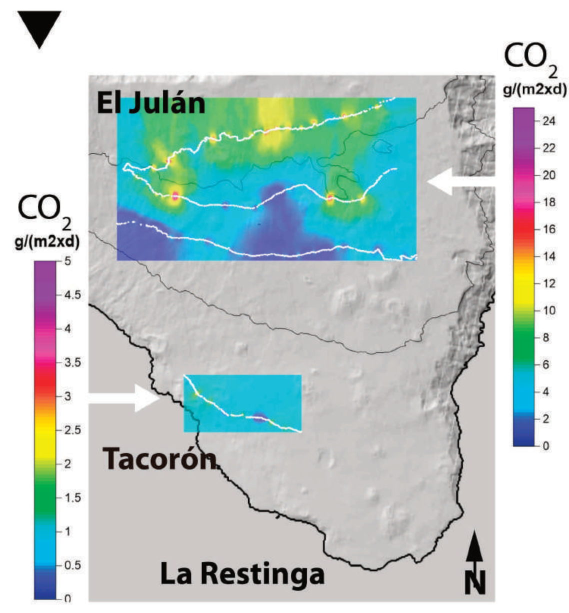
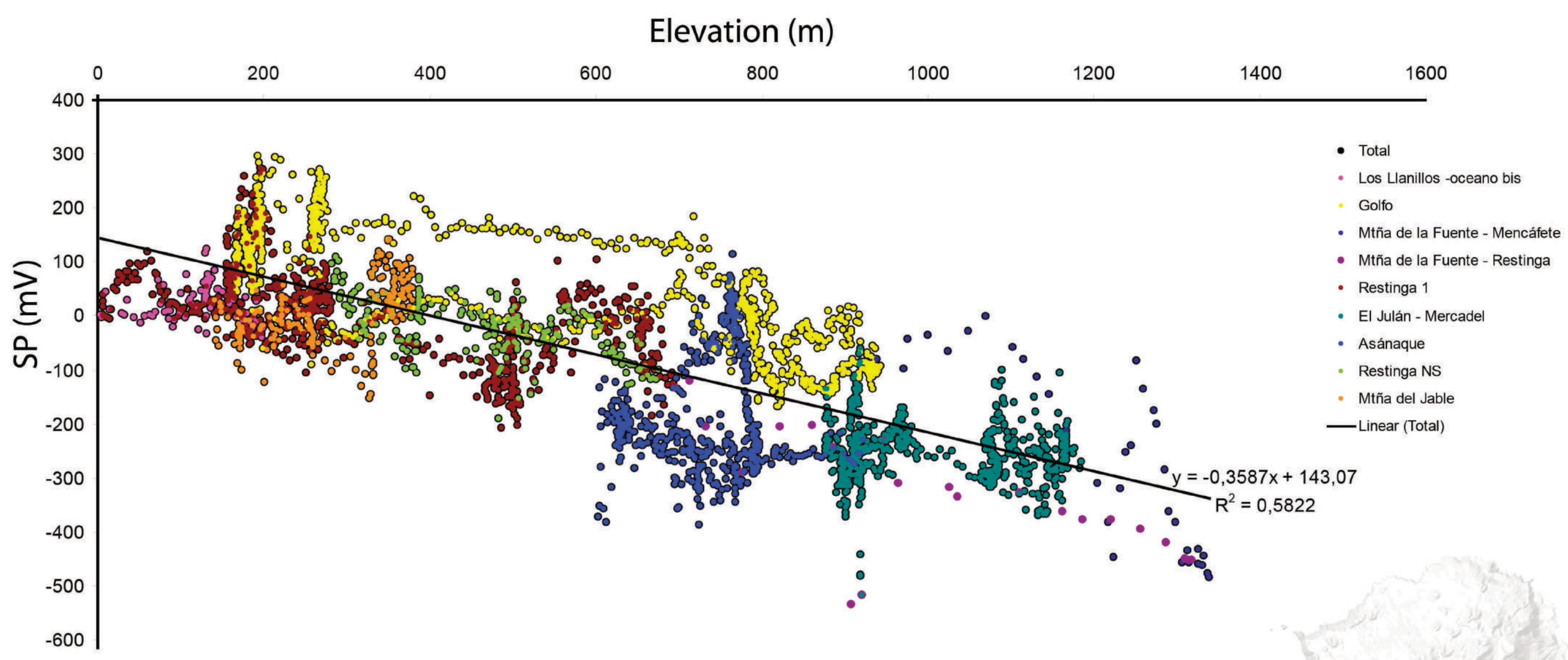


Figure 2. Self potential map across the island of El Hierro (white dots are measure points). We distinguish some SP maxima (in red colour) along the northern coast of El Golfo (number 1), in Tacorón (2), and at La Restinga, where a rift zone shapes the southern tip of the island (3).

As well, we highlight a series of SP minima (blue numbers) at Tanganasoga Volcano (number 1), on the NE rift zone (2), and in El Julián area (3).

Below: CO_2 measurements in part of the SP study area show low gas emission. Only few measurements are higher in El Julián.





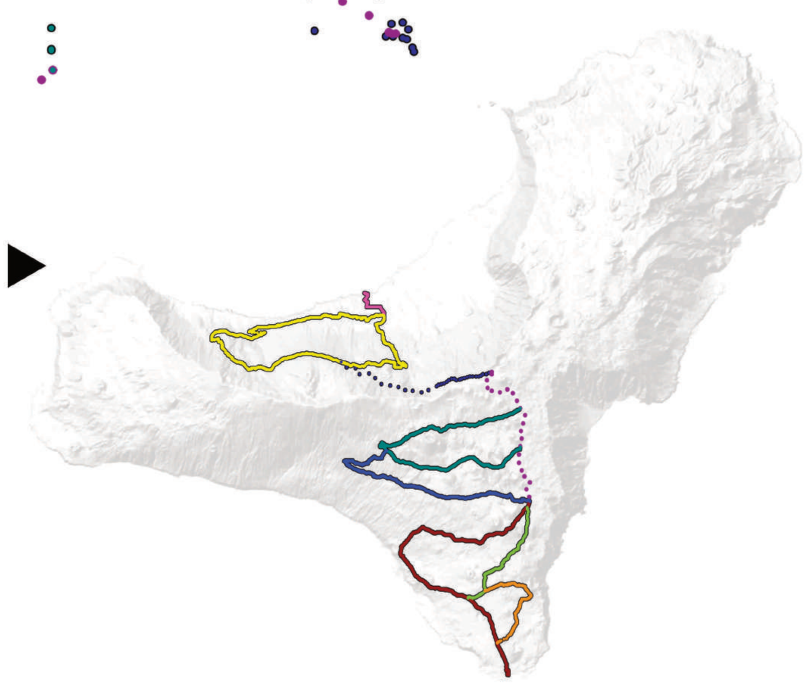


Figure 3. Up: SP vs elevation for various sections of the dataset located on the DEM of the island (on the right).

An analysis of SP vs elevation shows:

- A general "hydrogeological behaviour" of the studied area illustrated by a negative correlation between SP and elevation.
- Anomalies with respect to this general pattern corresponding to SP maxima highlighted in the SP map (Fig. 2)
- SP values are globally higher in the Golfo northern depression compared to the rest of the studied area, for similar elevations.

Conclusions

For additional conclusions concerning the link between our dataset and the volcanic activity, this preliminary presentation of the geophysical data acquired at El Hierro during the 2011-2012 eruptive crisis should be completed by a comparative dataset in a period of volcanic rest.

However, we could highlight SP anomalies compatible with hydrothermal activity in Tacorón and in the southern part of the island, along the southern rift zone, which could be related to the eruption off the coast of La Restinga.

The SP maximum in El Golfo might be related to the rise of volcanic activity: the seismic crisis beginning in the North may have enhance fracturing in this area, creating new preferential passes for hydrothermal fluids.

In the central part of the island the presence of negative SP anomalies is likely related to the dominance of the hydrogeological activity (infiltration). The deep hydrothermal activity related to magma rising at depth may have not been able to "compete" against infiltration, due to the thickness of the volcanic layers and their high permeability in the superficial part of the ground (scoria of the Tanganasoga volcano and fractures associated to the three rift zones).

References

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Highlight: geophysical tools for imaging monogenetic volcanism

What do we have till now?

2D resistivity imaging. Here an example with an ERT model (b) of the Puig d'Adri volcano, a complex monogenetic volcano built by hydromagmatic and Strombolian activity. R and C stands for resistive and conductive units respectively. c: Geological interpretation. (Barde-Cabusson et al., 2013)

What's the future?

3D resistivity imaging for

- Structural studies: understanding the weight of structural and hydrogeological parameters of the substrate in the control of the eruptions (location and type)
- Dynamic studies: adapting and developing electrical methods for the observation of parameters related to volcanic activity or slope stability.

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