

## Exploring coastal geothermal reservoirs in 3D by combining land and shallow water CSEM and MT in volcanic islands

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### SUMMARY

Magnetotellurics became an essential tool in the exploration and characterization of geothermal reservoirs in volcanic environment, through its ability to map the contrasts between a conductive clay cap and more resistive reservoir and unaltered rocks. In many cases in volcanic islands, the geothermal reservoirs are suspected to extend over the coastline, being partially immersed. Even they are often easily accessible by drilling from the coast, the offshore reservoirs are never imaged by resistivity method because of the additional costs and difficulties, and therefore never exploited. Additionally, coasts are often heavily populated and anthropized, generating noise limiting the performance of MT and can even prevent its use. Finally yet importantly, proximity to the sea/land interface, strong variations in topography and near-shore bathymetry make the 3D EM modeling and inversion extremely challenging.

We show in this work that it is possible to image those challenging reservoirs with resistivity methods, by combining in a single campaign controlled source EM (CSEM) and MT with both land and shallow water instrumentation. A suitable instrumentation for efficient deployment of both land and marine EM receivers at the same time of multiple powerful land galvanic transmitters are the key ingredients to obtain a reliable dataset. On the other hand, we show that special care of bathymetry and topography in the 3D modeling and inversion are essential, but feasible.

We applied this methodology on the Geothermal Field of Bouillante (Guadeloupe, French West Indies). With the proposed methodology, we could provide for the first time an image of the extension of the reservoir in the bay. A 3D resistivity model with a resolution inaccessible so far allows us to map some structural discontinuities of the clay cover controlling the shape of the reservoir, and possibly controlling fluid flows.

The results also clearly show that cross-shore CSEM is as able as MT to image the clay cover and identify the reservoir in the 0-2km depth range, both in land and over sea. CSEM provides improved sensitivity to the higher resistivity of the reservoir, and facilitate increasing resolution with the lighter and less demanding recording systems and the better coverage offered by the multiple source illumination. On the other hand, only MT can provide information bellow 2km. Although for regional scale mapping MT must be preferred, because common systems can be used for CSEM and MT, we highly recommend refining the model and locating exploration and production wells with joint acquisition to take the best of both approaches.

**Keywords:** Geothermal exploration, coastal reservoir, volcanic islands, MT, CSEM, marine EM

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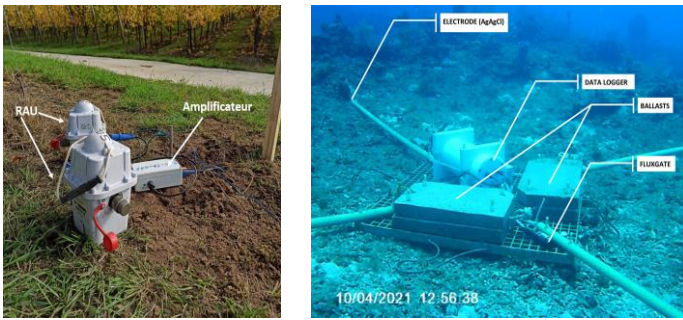


Figure 1: a) BRGM light land EM system b) MAPPEM Geophysics marine system

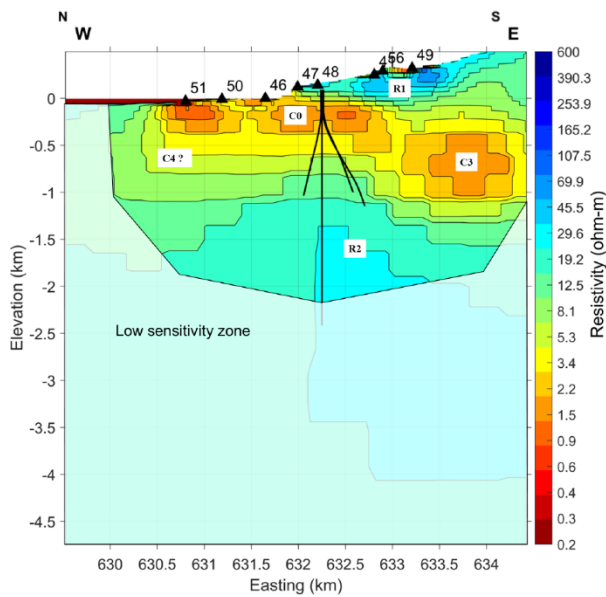


Figure 3 : Resistivity profile across the coast showing clay cover (C0, C3, C4), the reservoir R2, recent lavas (R1) and the existing production wells.

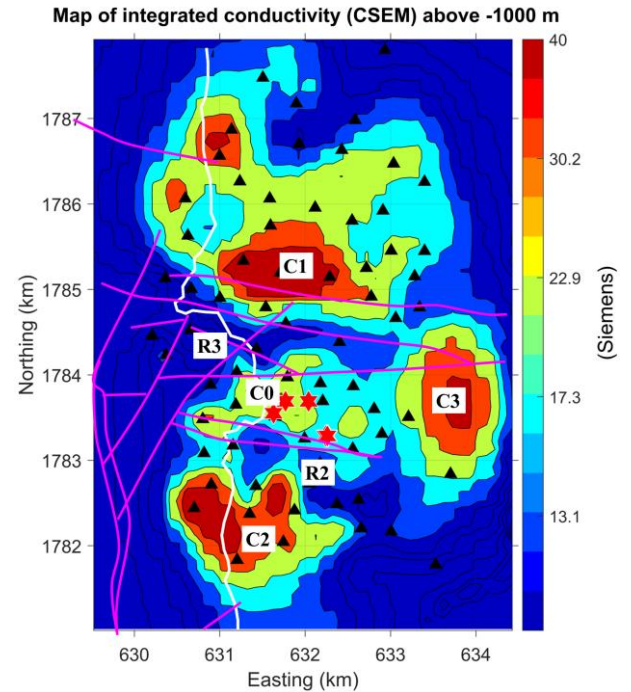


Figure 2: Map of integrated conductivity over 0-1000m (from CSEM model) highlighting the coherence between the resistivity model and the known fracture network (pink lines, from marine seismic) and suggesting a structural segmentation of the clay cover.

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