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Deep electrical structure of the Deception Island active volcano (Antarctica) by means of magnetotelluric data

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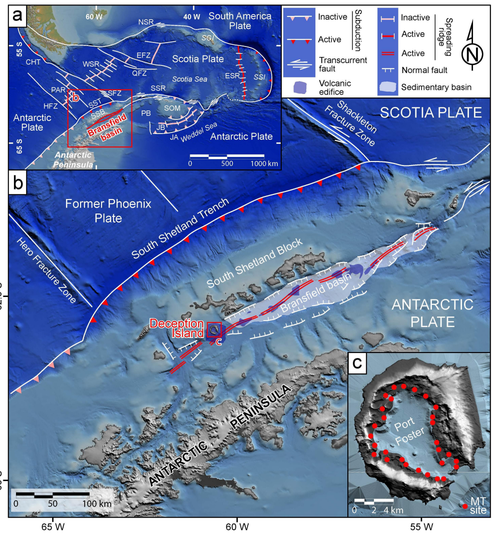
INTRODUCTION

Deception Island is an active volcano located in the South Shetland Islands (northwestern Antarctica). It has a roughly horseshoe shape encircling the Port Foster Bay, corresponding to the collapsed caldera. Its origin is related to the Quaternary vulcanism associated to the opening of the Bransfield Basin (Figure 1).

Since the Eocene - Oligocene (~35 Ma) the rupture of the continental connection of South America and Antarctica determined the opening of the Drake Passage and the widespread of continental fragments around the Scotia Arc. A conspicuous system of small oceanic basins and thinned continental blocks was formed during the opening of the Scotia Sea. Westwards, the Phoenix plate subducted below the Pacific continental margin of the Antarctic Plate driven by the spreading of the Phoenix-Antarctic Ridge (PAR). The activity of the PAR stopped 3,3 Ma ago and these plates become joined in the Antarctic plate. However, the roll-back processes along the South Shetland Trench (SST), together with the relative westward displacement of the South America and Scotia Plates in respect to the Antarctic Plate along the South Scotia Ridge (SSR), determined the rifting of a continental slice of the northwestern margin of the Antarctic Peninsula known as the South Shetland Block (SSB). Both, the slab roll-back along the SST and the southwestward trans-tensional activity of the SSR determined the opening of the NE-SW elongated Bransfield Basin with asymmetrical boundaries. The southeastward margin of this basin is shaped by low slopes and large submarine canyons and constitutes a typical passive continental margin. The northwestern margin, however, features a distinct sharpness, defined by a prominent fault separating the continental South Shetland block from the basin underlain by either oceanic or thinned continental crust (Galindo-Zaldívar et al., 2004-2006; Catalán et al., 2013; Parera-Portell et al., 2023).

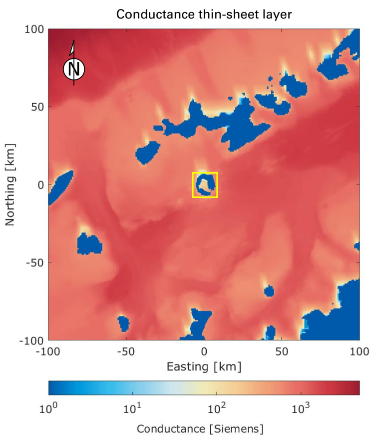
Deception Island locates close to this main fault. The surrounding area is also tectonically active and constitutes the southwestern edge of propagation of the Bransfield Strait opening. Moreover, the subducted oceanic slab of the former Phoenix plate below the South Shetland Islands is probably located in depth. Therefore, any determination of the deep structure of this Island may consider the complex geodynamics setting of the area.

Continuous seismicity together with high geothermal activity suggest the presence of a shallow magma chamber bellow Deception Island. This feature has been addressed by several geological and geophysical investigations. However, despite extensive research, there is still a knowledge gap concerning the deep electrical iso-anisotropic structure of the island. MT method constitutes a challenging tool to reveal the significance of the different processes that undergone this region. A total of **29 broad-band MT stations** were strategically installed across Deception Island's inner bay during the 2022-2023 Spanish Antarctic Research Campaign. Site spacing varied between 0.5 and 1.5 km. Measurements included the horizontal electric and magnetic fields, along with the vertical magnetic field, collected over approximately 48 hours using MT5-C (Phoenix Geophysics) and ADU07-e (Metronix) systems. Furthermore, an additional **Long Period** station continuously recorded data for over **2 months**. The data processing was performed using the FFMT software package developed by Frankfurt University using a multivariate approach, based on the eigenvalue decomposition method by Egbert (1997).

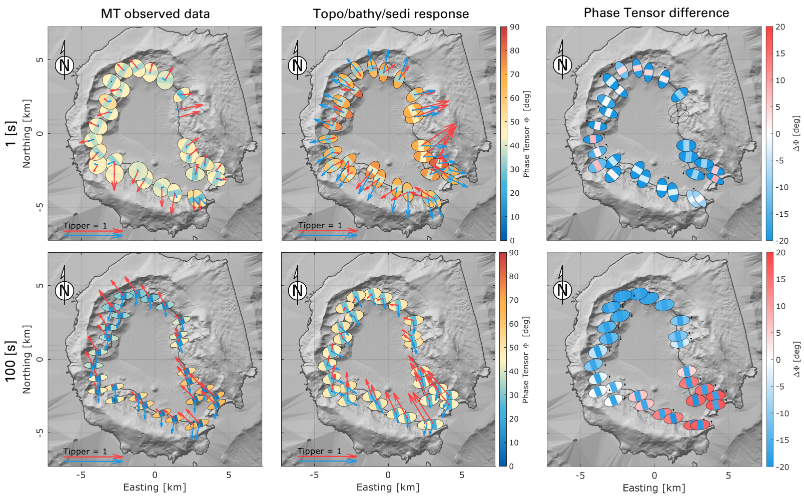


▲ **Figure 1.** Deception Island in the framework of the tectonic setting of the Scotia Arc. **a.** Tectonic setting of the Scotia arc. PAR, Phoenix-Antarctic Ridge; BB, Bransfield Basin; SSB, South Shetland Block; SSR, South Scotia Ridge; SST, South Shetland Trench; CHT, Chile Trench; HFZ, Hero Fracture Zone; JA, Jane Arc; JB, Jane Bank; PB, Powell Basin; SOM, South Orkney microcontinent; WSR, West Scotia Ridge; ESR, East Scotia Ridge; SSI, South Sandwich Islands. **b.** Tectonic setting of Bransfield Basin. **c.** Location of MT stations at Deception Island. (Modified from Galindo-Zaldivar et al., 2004 and Morales-Ocaña et al., 2023)

OCEAN EFFECT AND MT-RESPONSES

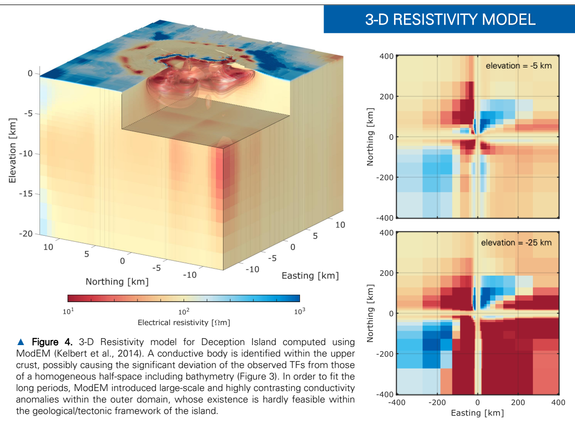


▲ **Figure 2.** Conductance thin-sheet layer used to compute the ocean effect on MT responses. Digital elevation (gmrt.org) and sediment thickness (noaa.gov) models are combined to compute the conductances for a layer of 100 m coupled to a homogeneous half-space of 100 [Ωm]. The model extents to a domain of 500 × 500 × 500 km³. Forward responses were computed using COMSOL Multiphysics. The yellow polygon corresponds with the view extents on **Figure 3**.



▲ **Figure 3.** Induction vectors (IV), Phase Tensors (PT) and comparison between the observed and ocean effect PTs responses. For 1 [s] (top), the observed and modeled PTs show a consistent orientation which respond to the coastline of the inner bay, although a clear discrepancy in the imaginary part of IVs is observed. For 100 s, the PT orientation can almost be explained by the inclusion of bathymetry. However, a systematic angle deviation between the NNW and SE regions is identified. Moreover, the modeled IVs are not able to reproduce the constant orientation of the measured responses of approximately 35°NW, indicating an increasing conductivity towards SE, presumably within the crust.

3-D RESISTIVITY MODEL



▲ **Figure 4.** 3-D Resistivity model for Deception Island computed using ModEM (Kelbert et al., 2014). A conductive body is identified within the upper crust, possibly causing the significant deviation of the observed TFs from those of a homogeneous half-space including bathymetry (Figure 3). In order to fit the long periods, ModEM introduced large-scale and highly contrasting conductivity anomalies within the outer domain, whose existence is hardly feasible within the geological/tectonic framework of the island.

OUTLOOK

Besides the ocean influence identified on MT responses for Deception Island, the PTs difference suggest that local-contrasting conductivity features are required to match measured data. Electrical resistivity models derived from standard transfer functions (TF) inversion, reveal a highly conductive anomaly at depth of approximately 0 to -2 km. Despite different inversion strategies followed, the modeling process introduces large 'symmetrical' conductivity anomalies in the outer FD domain to explain TFs, while the inner domain is barely modified from -2.5 km. This highlights the need for further modeling experiments to enhance our understanding of the volcanic system.

Advanced 3-D forward modeling (e.g., anisotropic features) has potential to provide an initial conductivity reference, guiding the inversion process towards a more plausible model. This approach enhances our understanding of key geodynamic factors influencing Deception Island inner structure.

Furthermore, while establishing permanent MT recordings is currently unfeasible, periodic measurements during Spanish Antarctic campaigns could monitor the volcano's activity. This challenge serves as motivation for future project proposals.

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