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Results of Geoelectrical Surveys in the Area of Crater 70, Deception Island, Maritime Antarctica

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SUMMARY

In February of 2013 a geophysical survey using geoelectrical methods was performed in the Crater 70 area of Deception Island in Maritime Antarctica. The area suffered volcanic eruptions in 1967, 1969, and 1970. Two electrical resistivity tomography (ERT) profiles and a vertical electrical sounding (VES) were done with the objective of detecting and evaluating permafrost depth and thickness. By direct measurement along the two ERT profiles the depth of the frozen ground varied from 40 and 70 cm. The geophysical survey indicates that the frozen ground has an average thickness ranging from 3 to 6 m. Furthermore, the electrical resistivity of the frozen ground is about 4,000 Ω .m. Since the geoelectrical surveys were done over young volcano-sedimentary deposits resulting from the recent eruptions, it is possible to conclude that permafrost is recovering in the area.

Introduction

Deception Island is horse-shoe shaped stratovolcano with 15 km diameter and a large caldera that opens towards the southeast, forming a bay about 7 km wide. The maximum altitude is at Mount Pond (539 m a.s.l.). About 57% of the island area is covered by glaciers. In geological terms Deception Island is composed of volcano-sedimentary deposits, including pyroclastic flows and deposits, strombolian scoriae and lava, volcanic and hypo-volcanic indurated ashes, and phreatomagmatic deposits. Recent eruptions took place in the interior of the island in 1967, 1969, and 1970.

Permafrost is widespread in the island but its characteristics are still poorly studied. In this study we present geoelectrical data collected in the Crater 70 area of Deception Island which was formed during the eruptions of 1970. The study area is located in the southern slope of a volcanic cone and the objective of the geoelectrical survey was to determine if there were any permafrost aggradation after the eruptive event and to assess the thickness of the frozen body. Two electrical resistivity tomography (ERT) profiles and a vertical electrical sounding (VES) were done (Fig. 1).

Geoelectrical methods are particularly well adapted to study the spatial distribution of permafrost because of its high electrical resistivities in comparison with the electrical resistivities of soil and rocks with water and above 0 °C.

Method

The two ERTs were made along the same direction (Fig. 1); however, only profile 2 can be seen in Fig. 1. For each ERT 40 electrodes were used in a Wenner configuration; adjacent electrodes were 2 m apart. The software RES2DINV (Loke and Barker, 1995, 1996) was used for inverting the apparent electrical resistivity values into two-dimensional models of electrical resistivity of the ground (Figs. 2 and 3). The models are a representation of the distribution of the electrical resistivity of the ground to depths of about 13 m along profiles 78 m long. ERT profile 1 was done on a flat area at the base of the slope of the volcano cone; most of ERT profile 2 was done along the slope of the volcanic cone with its last quarter in the lower slope section; both ERT profiles were done along the same direction. The vertical electrical sounding (Fig. 4) was done in the lower part of the slope crossing the lower section of ERT profile 2 (Figs. 1 and 3).

The apparent electrical resistivity values measured during the field work appear to be of high quality; as a matter of fact, no parasitic currents were detected during the several surveys; also, considering the resolution of the resistivimeter used for the field work, after repetition of some measurements, for apparent electrical resistivity stability control, their values did not change with time.

A Schlumberger configuration was used to perform the vertical electrical sounding. The maximum distance AB was 200 meters and the apparent resistivity values were inverted using the code RES1D; the RMS of the inversion is 4.2 %.

Both ERTs and VES were done using an ABEM SAS 300 resistivimeter. For the ERTs a control unit made in the Geophysical Centre of the University of Evora was used.

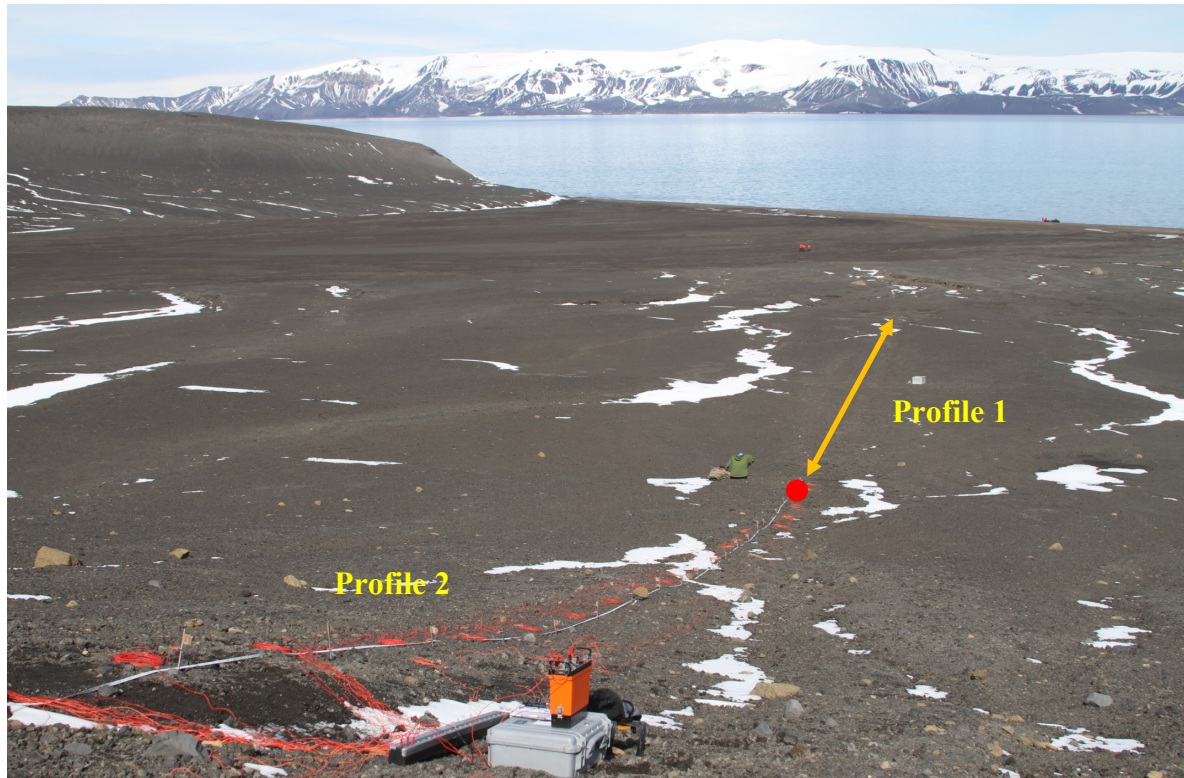


Figure 1 Layout of the ERT profile 2; the red cables indicate the location of the stainless electrodes. Profile 1 is in the continuation of profile 2 towards the beach and is represented by the orange double arrow. The red dot represents the centre of the vertical electrical sounding which was done parallel to the beach.

Results

Along the two ERT profiles thaw depth probing was also done to compare with the geoelectrical results. Along profile 1 (Fig. 2) the top of the frozen ground varied from 50 to 70 cm and the electrical resistivity of the frozen ground was about 1,300 Ω .m. Along profile 2 (Fig. 3) the top of the frozen ground varied from 40 to 70 cm and the electrical resistivity to the frozen ground was about 1,600 Ω .m. In both profiles the electrical resistivity increased with depth to values that vary from 4,000 to 7,400 Ω .m.

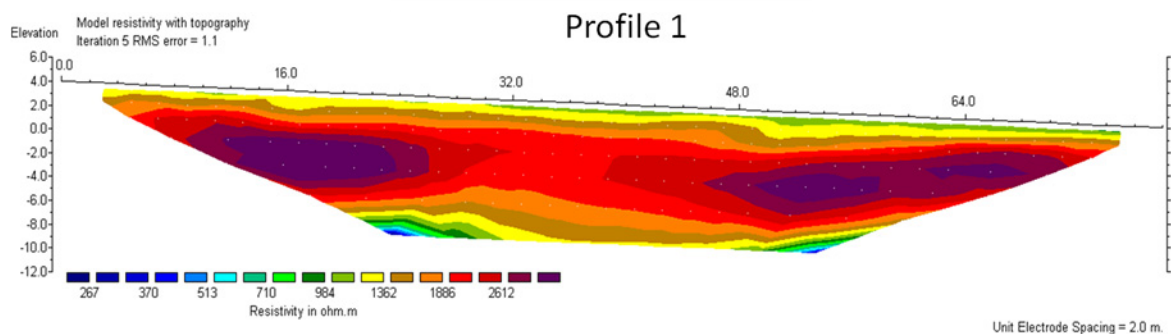


Figure 2 ERT profile 1. Reddish colours correspond to high electrical resistivities and bluish colours correspond to low electrical resistivities. Two high electrical resistivity lenses are apparent near the ends of the profile.

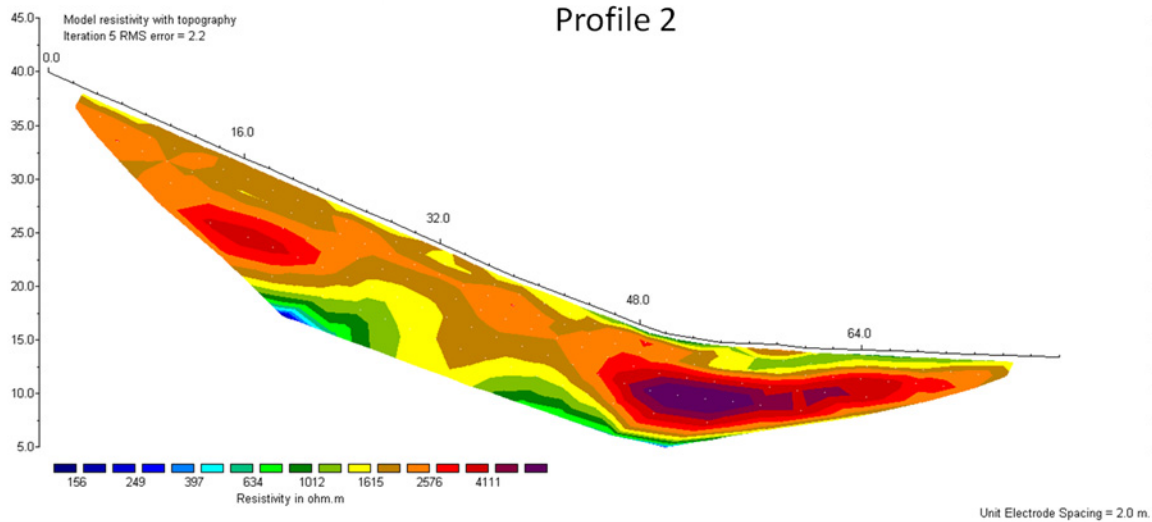


Figure 3 ERT profile 2. Reddish colours correspond to high electrical resistivities and bluish colours correspond to low electrical resistivities. A high electrical resistivity block is apparent in the right side of the profile.

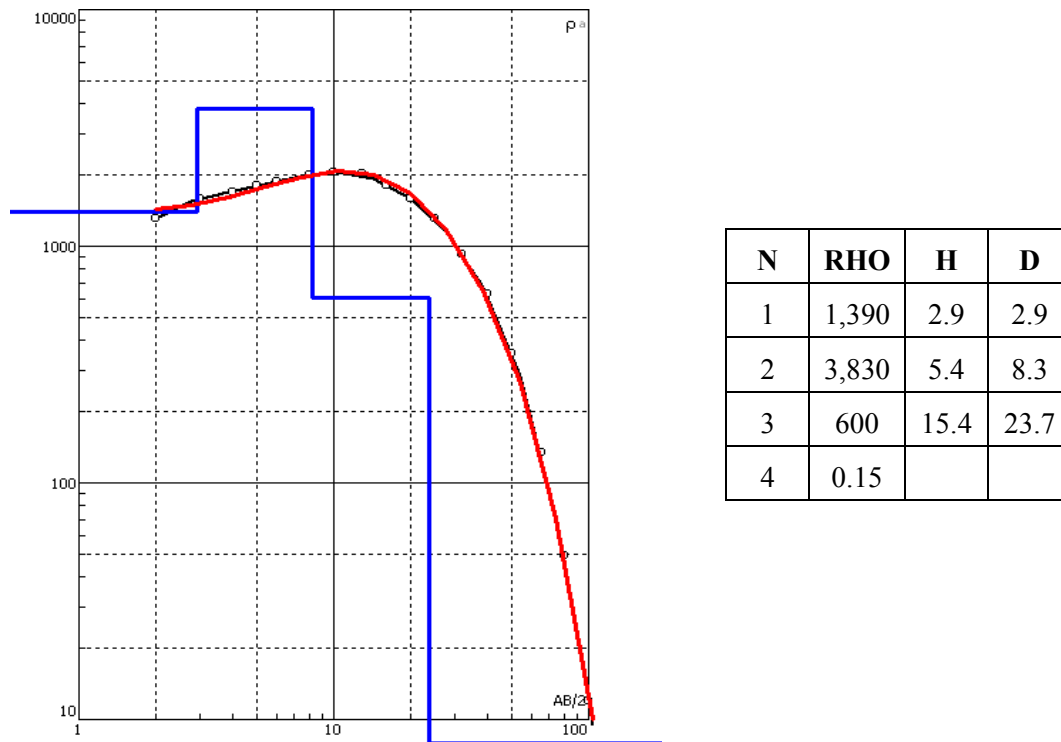


Figure 4 Vertical electrical sounding done in Crater 70. Small circles are data points; the red curve is the synthetic VES curve generated by the model (in blue). Electrical resistivities and layer thicknesses are shown in the table at the right; N is the number of layers, RHO is the electrical resistivity in $\Omega.m$, H is the thickness of the layer in m, and D is the depth in m.

Conclusions

Both ERTs indicate that the thickness of permafrost is about 10-12 m with a body of more resistive frozen material at intermediate depth; this result is also observed in the VES which indicates, though, that the frozen layer is about 6 m thick with the higher electrical resistivities located between about 3 and 8 m depth. Both electrical resistivity tomographies and the vertical electrical sounding gave similar electrical resistivity values for the frozen ground (permafrost?). Such a higher resistivity is probably related to higher ice-content as has been observed in other areas in Deception Island.



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