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# AEROMAGNETIC AND ELECTRICAL RESISTIVITY SURVEYS OF ASCENSION ISLAND

by

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## ABSTRACT

As part of an evaluation of the geothermal energy potential, the University of Utah Research Institute conducted a detailed aeromagnetic survey of Ascension Island, South Atlantic Ocean, in 1983. Interpretation of the data, supported by three-dimensional numerical modeling, indicated structural features and a low-magnetization area near the center of the island. Reconnaissance and detailed electrical resistivity surveys were completed in 1984 and these identified a zone of low apparent resistivity which corresponds to anomalous temperatures and alteration well above a high-temperature geothermal system.

## INTRODUCTION

The geothermal energy potential of Ascension Island was evaluated to determine the feasibility of a low-cost, renewable energy alternative for United States facilities at Ascension Auxiliary Airfield (Ascension AAF). Geologic mapping and interpretation for this resource was completed in a study by Nielson and Sibbett (1996). They concluded that the young age of Ascension Island volcanic activity, the presence of geologic structures to provide permeability, and the probability of fluids to transport thermal energy demonstrated a very high potential for the discovery of a geothermal resource. They recommended an exploration program of aeromagnetic and electrical resistivity surveys and thermal gradient drilling. A brief summary of the exploration program describing drilling results was presented by Nielson and Stiger (1989). This paper describes the geophysical surveys and their results.

## GEOLOGY

Ascension Island is located about 80 km west of the Mid-Atlantic Ridge and 50 km south of the Ascension fracture zone (van Andel et al.,1973). The island is the top of a volcanic mountain which rises 4 km above the sea floor to 850 m above sea level. Nielson and Sibbett (1996) describe the geology of the island in detail. A brief summary of some aspects of the geology is important to understanding the conduct and results of the geophysical surveys. Nielson and Sibbett (1996) note that basalt flows dominate the surface of the island and suggest that the youngest flows are probably several hundred years old, based on the lack of weathering and erosion. Trachyte lava flows, pyroclastic deposits, domes and intrusions dominate the central and eastern parts of the island. Prominent cinder cones occur throughout the island. An environment such as this would be expected to produce significant responses on an aeromagnetic survey. Geologic mapping documented the presence of some faults. However, young volcanic rocks were clearly obscuring the structural geology. This suggested that aeromagnetics would be an appropriate tool to aid in mapping unexposed faults.

The young age of the basalt flows precludes the development of a significant soil profile for much of the island. Without soils and fine-grained erosional deposits to retain moisture, the basalt flows and trachytes present a very high impedance near-surface environment. The introduction of current into the ground for electrical resistivity surveys was expected to be difficult. Nielson and Sibbett (1996) did map several areas of alluvial deposits, generally of limited extent, and old well casings, and these areas were important to the completion of the resistivity surveys.

## AEROMAGNETIC SURVEY

The remote location of Ascension Island, near the center of the South Atlantic Ocean, presents problems for completing any form of detailed aeromagnetic survey at reasonable cost. The presence of a British helicopter unit, the 845th Squadron Detachment, Royal Navy, on Ascension Island in 1983 provided an opportunity to conduct a cost-effective survey using a "button on" or portable aeromagnetic survey system. The British base commander agreed with the U.S. AAF base commander to provide helicopter support for the survey when flight operations schedules permitted. The authors mobilized a button-on magnetic survey system to Ascension Island in February 1983. Details of the equipment, survey, and interpretation will be presented in a forthcoming paper (Ross et al., 1996a). In summary, 29 flight lines were flown at S65°E directly into (or out of) the southeast trade winds at an average separation of 380 m, with eight tie lines flown in a north-northeast direction. The mean terrain clearance of the magnetometer sensor was approximately 200 m.

### Survey Results

The overall accuracy of the data compilation, reflecting errors in position, diurnal variation, altitude variation and leveling, was judged to be +/- 20 nT (nanoteslas). This is less than desired for high-quality surveys flown with a permanent equipment installation at a barometric elevation, but sufficient and useful for the exploration effort. A map of total magnetic intensity (less a constant value of 27,000 nT) was compiled at a scale of 1:25,000 and contoured at 20 nT.

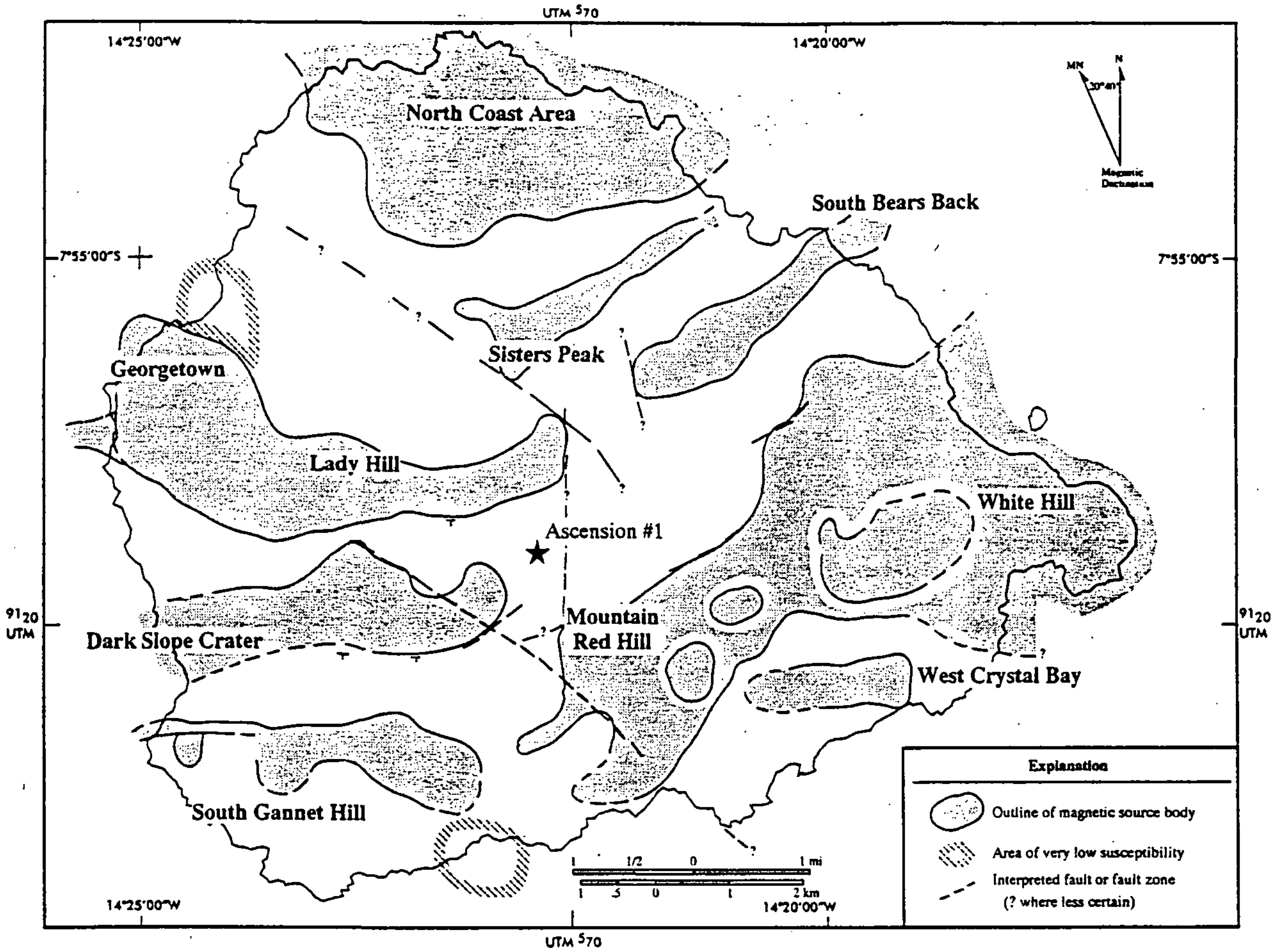


Figure 1. Generalized interpretation of aeromagnetic map, Ascension Island, showing the principal magnetic source locations and interpreted structure. The location of Ascension #1 is shown for reference.

Interpretation of the data was supported by a magnetic susceptibility survey and numerical modeling (Ross et al., 1996a). Magnetic anomalies were computed for several simple vertical prism models using the magnetic field characteristics of Ascension Island. A qualitative interpretation of the data was then completed using reference to the precomputed models, simple depth estimates, and a cross correlation between magnetic intensity, topography, and geologic maps. Detailed numerical modeling was then employed to refine the location, size, and magnetization of various magnetic bodies identified in the qualitative interpretation (Ross et al., 1996a). Figure 1 summarizes the results of the interpretation, showing the location of magnetic source bodies and probable geologic structures. Figure 1 presents a picture of east- and northeast-trending magnetic sources peripheral to the central core of the island. The magnetic sources are interpreted as zones of increased dike density and intrusives which now occupy the feeder zones for recent cinder cones and basalt flows. The central 7 $km^2$ of the island is relatively non-magnetic and is cut by northeast-, northwest- and north-trending structures. The combination of structural intersections and low magnetization suggests the possibility of rock alteration resulting in magnetite destruction, or more acidic intrusive rocks at moderate (200-1000 m) depths. A low-magnetization area north and west of Green Mountain appears to be the most likely area for the presence of a geothermal system at depth.

## ELECTRICAL RESISTIVITY SURVEYS

Electrical resistivity surveys were completed in June 1983 and September 1984 to delineate low resistivity zones which may result from conductive high-temperature fluids and associated clay alteration zones resulting from the water/rock interaction of these fluids. A reconnaissance resistivity survey (Ross et al., 1996b) was conducted using the bipole-dipole array which permits great flexibility in the deployment of the transmitter dipole (i.e. electrode sites) and the selection of receiver sites. Keller et al.(1975) describe the method in some detail. Two existing well casings, and small areas of alluvium, colluvium, and ash or soil deposits mapped by Nielson and Sibbett (1996) were used, where possible, to locate good transmitter electrodes. Other electrodes, on cinders or flows, required a substantial effort to get satisfactory current (3-5 amps) into the earth. Transmitter dipoles of 610 m length and orthogonal receiving dipoles of 152 m were used in this survey. Six transmitter (Tx) dipoles and 50 receiver (Rc) sites provided good reconnaissance resistivity coverage for the area outlined in Figure 2. The computed

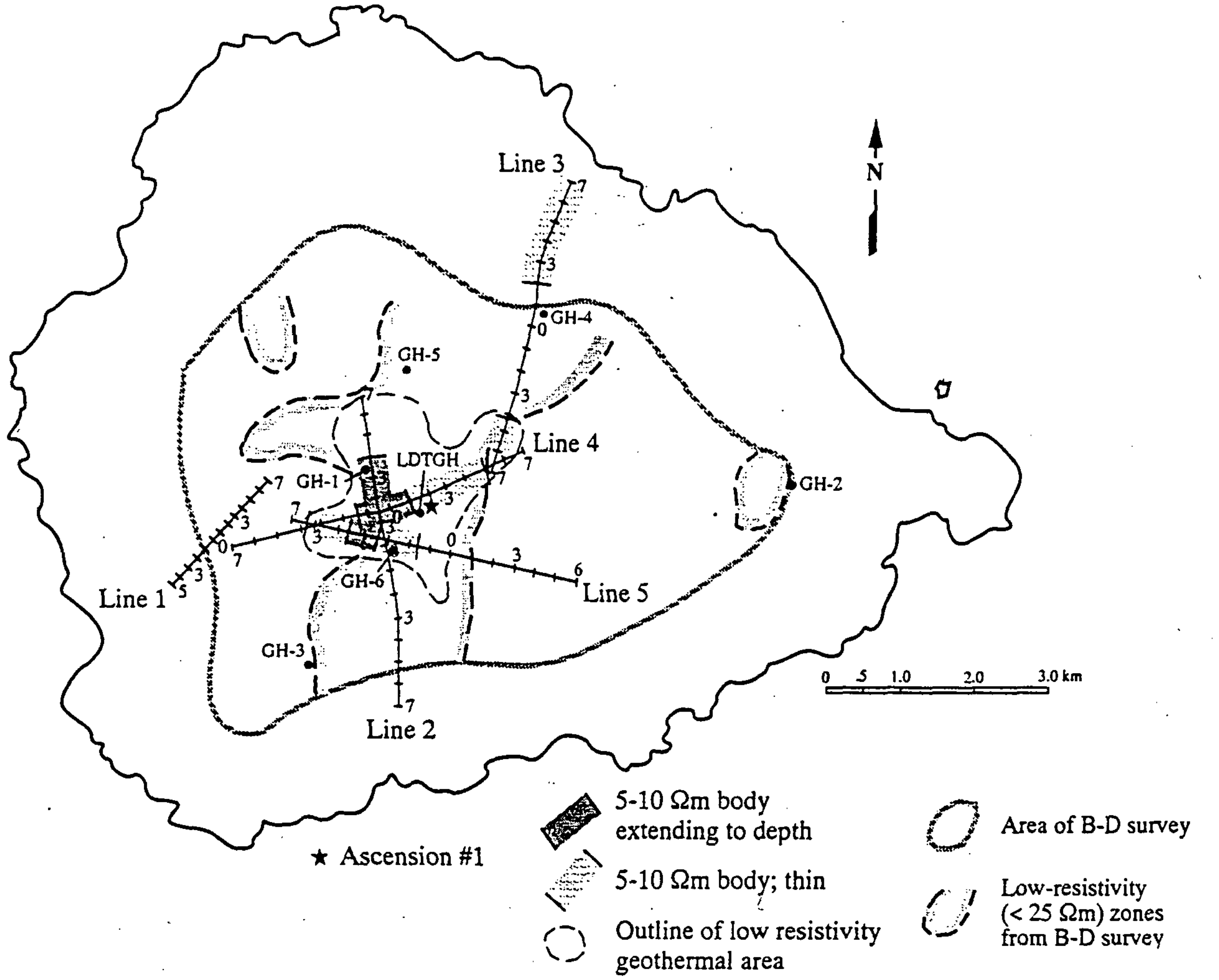


Figure 2. Electrical resistivity survey summary map, Ascension Island. The location of temperature gradient holes (GH series and LDTGH) and Ascension #1 are shown for reference.

apparent resistivity applies to the general area between and including the transmitter and receiver sites, but can be strongly biased by the resistivity of the transmitter site. The low resistivity zones, with most apparent resistivities of 5 to 25 ohm-m, identified by this reconnaissance survey are also shown on Figure 2.

Following completion of most of the reconnaissance survey, dipole-dipole lines were completed to provide better lateral resolution of low resistivity areas (Ross et al., 1996b), and to indicate the resistivity variation with depth. Figure 2 shows the location of these lines and a summary of numerical modeling results for these lines. Line 1 was a line of 152 m dipoles completed to determine the suitability of this area for a proposed fresh water well and to determine the resistivity layering for the first 300 m depth. High apparent resistivities (230-760 ohm-m) provided no encouragement for the presence of a thick fresh water lens. Lines 2, 3, 4, and 5 used 305 m dipoles to map resistivities to depths of 610 m or more. Numerical modeling was completed for all profiles using program IP2D (Killpack and Hohmann, 1979) which provides for the modeling of irregular topography. The program arrives at an estimate of true depth, geometries and intrinsic resistivities of multiple bodies in an iterative (forward modeling) procedure. Figure 3 shows the observed data for Line 4 in pseudosection form (above) and the best-fit numerical model (below).

Line 4 is centered about 300 m west of the deep exploration hole, Ascension #1, described by Nielson and Stiger (1989). The profile trends N68°E and S80°W from its center, Station 0, and crosses severe topography along the eastern part of the line. Observed apparent resistivities greater than 100 ohm-m for the near separations (n=1,2) arise from much higher near surface resistivities, as shown in the numerical model. The pervasive 15 ohm-m layer modeled near sea level depths is also present in the models for lines 2 and 5. We believe this represents the migration of sea water at depth beneath much of the island. A 5 ohm-m body (Fig. 3) extends to depth from station 1.5 W to 1 E, then thins to the northeast. This zone of lowest resistivity could readily be explained by geothermal fluids, higher rock and fluid temper-

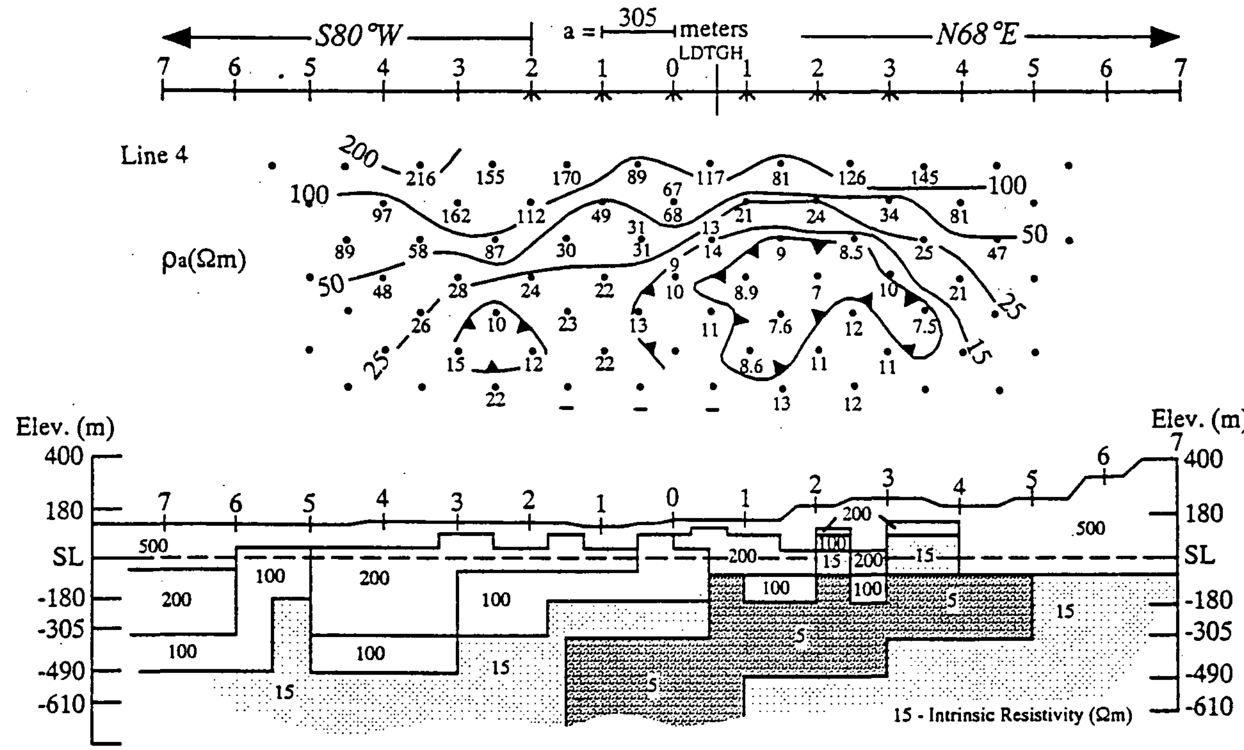


Figure 3. Dipole-dipole resistivity line 4. Observed data pseudosection (above) and best-fit numerical model interpretation (below).

atures, associated wall rock alteration, or any combination of these possibilities.

## SUMMARY

A detailed aeromagnetic survey of Ascension Island was flown in February and March 1983. Interpretation of the data yields a picture of east and northeast-trending magnetic sources peripheral to the central core of the island. The central part of the island appears to be relatively non-magnetic, and is cut by northeast-, north-, and northwest-trending structures.

A reconnaissance electrical resistivity survey was completed for approximately 35 km$^2$ within the central part of the island and this indicated a 2 to 3 km wide, north-trending zone of low apparent resistivity. Dipole-dipole resistivity lines completed as follow-up show a somewhat different outline for the low resistivity zone. A numerical model interpretation of these profiles suggests that sea water underlies much of the island, but also defines a local area of 5 to 10 ohm-m resistivity beneath higher elevations near the center of the island. Temperature gradient drilling reported by Nielson and Stiger (1989) showed elevated temperatures and gradients in this area. A deep exploration test well, Ascension #1, revealed alteration dominated by smectite and calcite from shallow depths to greater than 1300 m (Nielson and Stiger, 1989). This alteration, well above the >200°C geothermal reservoir intersected at depth, and the elevated fluid and rock temperatures, probably give rise to the low-resistivity zone.

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