ELECTRICAL RESISTIVITY SURVEYS

ASCENSION ISLAND
SOUTH ATLANTIC OCEAN

Prepared for

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1.0 EXECUTIVE SUMMARY

This report describes electrical resistivity and self-potential surveys completed in March and June of 1983 as part of the Phase II evaluation of the geothermal potential of Ascension Island. These geophysical surveys had been recommended following an earlier geologic study which concluded that geologic conditions were permissive and favorable for the occurrence of a high-temperature geothermal resource.

Reconnaissance electrical resistivity measurements were completed which covered the central 35 sq km of the island. A broad zone of low apparent resistivity was mapped which trends north-northeast from Devil's Riding School through Thistle Hill. Areas west of Spoon Crater and northeast of Thistle Hill showed the lowest apparent resistivities within this broad (2 km by 5 km) zone.

Dipole-dipole surveys were completed which have refined the location, depth and intrinsic resistivity of the low resistivity zones. The profiles show high resistivities above sea level, with some resistive masses extending to considerable depth. Low-resistivity zones at depth are thought to result from sea water incursion within a few kilometers of the coast. Geothermal brines probably contribute to low-resistivity zones further inland, i.e. from Devil's Riding School to McTurk's Culvert, and south of Thistle Hill. Resistivity survey work was difficult to complete where fresh lava flows give rise to high electrode impedance. As a result, the low resistivity zones remain incompletely defined. The low resistivity areas defined by the survey work were recommended for thermal gradient test drilling in a subsequent exploration effort. Additional resistivity work would contribute to the optimum siting of a production well.

Self-potential surveys were completed at three locations in an attempt to map electrical potentials generated by moving geothermal fluids. Several small positive anomalies were recorded which correspond to mapped geologic structures and favorable low-resistivity zones. The amplitudes of the anomalies are small compared to self-potential anomalies observed in thermal areas on Hawaii and in the western United States. The presence of the anomalies is considered favorable, but not at all definitive as to the presence of a high-temperature geothermal system.

A single dipole-dipole resistivity line was complete north of Command Hill to determine the potential for a shallow fresh water table in the area. The observed high-resistivity values were not favorable for the presence of a fresh water lens above the salt water zone. A recommendation was made that an alternate site be selected for the fresh water well.

2.0 INTRODUCTION

The geothermal energy potential of Ascension Island is being 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 evaluation was completed in a Phase I study by Nielson and Sibbett (1982). 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. Nielson and Sibbett (1982) recommended that the U.S. Air Force proceed with a Phase II program of more detailed exploration activities. The electrical resistivity surveys reported here are one part of the geophysical exploration effort.

3.0 GEOLOGY

Ascension Island is located about 100 km west of the Mid-Atlantic Ridge median valley and 50 km south of the Ascension fracture zone (van Andel et al., 1973), as shown in Figure 1. As described by Nielson and Sibbett (1982), the island is composed almost entirely of volcanic rocks, and is the top of a volcanic mountain which rises 4 km above the sea floor and is perhaps 50 km in diameter at its base.

Nielson and Sibbett (1982) present a detailed geologic map of Ascension Island, describe the units and structures in detail, and discuss the geologic history of the island. The geophysical surveys were conducted to extend the geologic data to depth and to search for physical properties indicating a geothermal system at depth. A brief review of the geology is useful as a prelude to discussing the electrical resistivity survey.

Basalt flows dominate the surface of Ascension Island, with the youngest flows emanating from the Sisters Peak and South Gannett Hill areas. Nielson and Sibbett (1982) suggest that these flows are probably several hundred years old based on the lack of weathering and erosion. These flows cap older flows which occur throughout the island. Trachyte lava flows, pyroclastic deposits, domes and intrusions dominate the central and eastern portions of the island. Age dating suggests that the Bears Back dome was emplaced approximately 610,000 years ago. The Middleton Ridge rhyolite flow, exposed at the base of the Green Mountains stratigraphic sequence, was dated at approximately 0.94 m.y. Prominent cinder cones and cinder aprons occur throughout the island.

The young age of the basalt flows precludes the development of a significant soil profile for most 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 in which injection of current

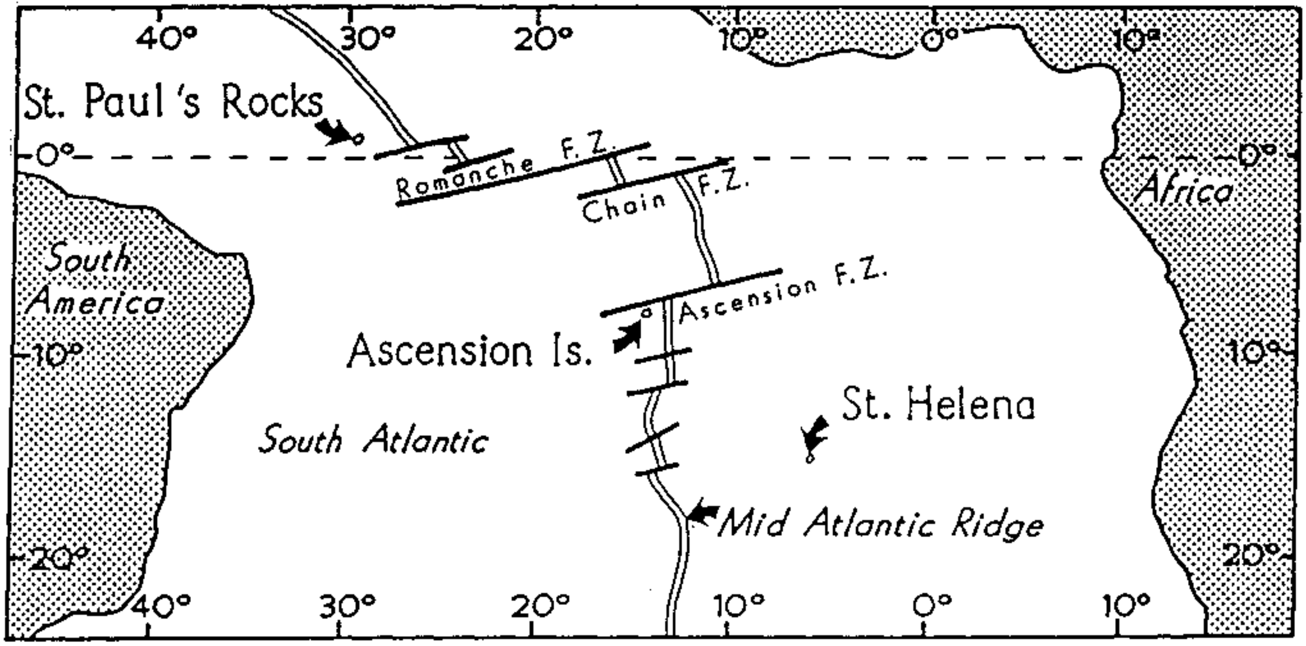

Fig. 1 Location of Ascension Island, the Mid-Atlantic Ridge and ocean fracture zones.

into the ground for electrical geophysical surveys was expected to be difficult. Nielson and Sibbett (1982) also mapped several areas of alluvial deposits, which, although generally of limited extent, were very important to the completion of the electrical resistivity surveys because current could be easily injected in these areas.

4.0 GEOPHYSICS

4.1 Orientation Survey

No significant geophysical data base has been published for Ascension Island, although Dash and Milson (1973) do comment on the gravity field of the island. Nielson and Sibbett (1982) recommended aeromagnetic and resistivity surveys and thermal gradient drilling as the Phase II geothermal exploration program. The aeromagnetic survey was completed in March 1983 and is reported separately (Ross et al., 1984).

A resistivity orientation survey was conducted in March 1983 following completion of the magnetic survey. Electrical resistivity surveys are commonly used in geothermal exploration because they often delineate low-resistivity zones which result from high-temperature fluids containing dissolved ions, and the clay alteration zones which result from the water/rock interaction of these fluids (Ward et al., 1980). An orientation survey was scheduled to evaluate the problem of high surface impedance due to the lack of soil deposits and surface moisture, and to evaluate the suspected high electrical/electromagnetic noise levels associated with BBC radio antenna fields and broadcasting, and other electronic installations. A field inspection was made of six areas tentatively selected for reconnaissance transmitter electrodes on the basis of location and the presence of alluvium, sand or soil development. Holes were dug and metal stakes emplaced to form electrode groups and these appeared to be satisfactory for 1-5 amp current inputs. Attempts to actually transmit current and measure the resultant voltages were unsuccessful due to transmitter failure.

4.2 Electrical and Electromagnetic Noise Study

A second factor which determines the feasibility of performing a successful electrical survey, in addition to having an adequate signal, is the local electrical noise level. The multitude of transmitting antennas, grounded structures and communication facilities on Ascension Island gave concern that electrical measurements would be very difficult or impossible with standard instrumentation. If noise levels were found to be acceptably low in the frequency range of interest (0.05 to 2000 Hz) then electromagnetic (EM) or time-domain electromagnetic (TDEM) sounding techniques could be considered in subsequent geophysical surveys as an alternative to the grounded-electrical resistivity method.

Noise studies were conducted at two sites: northeast of Two Boats on the Northeast Bay Road and along the ridge west of Cricket Valley. A 250-foot (76 m) length of communication wire was laid out in a line and connected to non-polarizing Cu-$CuSO_4$ porous potential electrodes at each end. Electrical noise levels at a number of frequencies were monitored with a Tektronix field oscilloscope and a Fluke digital voltmeter.

The high-power BBC shortwave radio-frequency energy was observed to attenuate much more rapidly than expected and was not believed to present an interference problem with measurements. However, at Cricket Valley, the low-frequency (about 400 kHz) radio navigation transmitter ground signal was as large as the expected survey signal and its keying appeared to influence the Fluke voltmeter. Many other noise sources were observed on the oscilloscope screen including sferics (distant lightning discharges), voltages caused by powerline return currents and random fluctuations and spikes of unknown origin but probably due to varying power line loads. Such noises are difficult to filter out but they did not appear to interfere with the measurements expect in the vicinity of Two Boats and at very low survey signal strengths.

A π filter was constructed and placed in series with the receiving dipole to reduce the radio-frequency (above 5 kHz) component of noise and was used in all subsequent self-potential and resistivity measurements. It was concluded that electrical and electromagnetic noise levels were not large enough to preclude electrical resistivity surveys, as long as transmitted current inputs in the range 1 to 5 amp could be achieved.

4.3 Reconnaissance Resistivity Survey

The electrical resistivity geophysical method is used to measure the earth's resistivity, i.e. the ease with which the ground conducts electricity. High resistivity values indicate poor conductivity whereas low resistivity values indicate good conductivity. In the earth, electricity flows in the ground water because of the movement of dissolved chemical ions (salts). Most rock-forming minerals themselves do not conduct electricity. Soil moisture is held both in pore spaces between mineral grains and within and adjacent to clay minerals; thus parameters that can cause changes in measured resistivity include:

1. Porosity and permeability of the ground
2. Amount of water in the ground (percentage of saturation)
3. Amount and type of dissolved salt
4. Amount and nature of other fluids in the ground
5. Amount and nature of clay minerals present.

Geothermal waters usually have a higher concentration of dissolved chemical constituents than normal ground water as well as high temperatures and thus cause a lower earth resistivity. Zones of clay alteration in the earth can often be detected and mapped by the low resistivity values associated with them.

Earth resistivity changes caused by thermal fluids and clays are mapped at the surface by deploying a system of four electrodes. A precisely controlled current is injected into the ground between two current electrodes, and a resulting voltage is measured between the two potential electrodes. The measured voltage is a function of the geometrical parameters of the electrode array, the magnitude of the injected current and the resistivity structure of the surrounding earth. An apparent electrical resistivity can be calculated from the formula,

$$\rho_a = \frac{\Delta V}{I} \times Q,$$

where I = current introduced, ΔV = measured voltage, and Q is the geometric array factor. This apparent resistivity would be the true value of resistivity if there were no lateral or vertical variations in actual earth resistivity. But since the actual resistivity does vary, the apparent resistivity is a kind of average of all the variations. To perform a survey, values of apparent resistivity are measured at a number of points at the surface of the earth. Computer assisted interpretation of the set of resistivity data is then undertaken to construct a picture of true resistivity variations in the subsurface. This picture of surface resistivity variation is then interpreted in terms of variations in rock type, alteration, and fluid salinity.

The reconnaissance resistivity survey was conducted using the bipole-dipole array, which permits the most flexibility in deployment of the transmitter dipole (and hence electrodes) and the selection of receiver sites. The bipole-dipole method permits a rapid mapping of the areal distribution at the expense of resolution. It has been widely used in geothermal exploration (i.e. Keller et al., 1975; Stanley et al., 1976) even though the contoured apparent resistivity patterns are complex and difficult to interpret. Keller et al. (1977) used this method very effectively in the reconnaissance exploration for geothermal resources on the East Rift Zone of Kilauea Volcano, Hawaii Island. The young basalt flows on Hawaii give rise to high electrode impedances, restricted surface access, and sea water intrusion, all problems which were expected and encountered on Ascension Island.

Figure 2a illustrates the bipole-dipole array geometry and parameters as used in this survey. A transmitter dipole length of 610 meters was chosen to provide adequate current penetration to depths of 600 to 1200 meters for receiver sites located from 600 to 3000 meters from this dipole. The resultant voltages were measured with orthogonal 152 m dipoles. An Elliot Model P-15B engine generator and Elliot Model 15 transmitter produced 3 to 5 amp of current at voltages of 200 to 3000 volts, which was transmitted as a time-domain pulse of 4 seconds on followed by 0.5 seconds of current off. Voltages across the potential electrodes were measured with a Fluke model 8050A digital multimeter. The total-field apparent resistivity was computed from the expression

$$\rho_a = [(V_1^2 + V_2^2)]^{1/2} \frac{Q}{I}$$

where V_1 and V_2 are the observed (orthogonal) voltages, I is the transmitted current, and Q is the geometric factor for the standardized dipole lengths and variable transmitter-receiver positions (Hohmann and Jiracek, 1979; Frangos and Ward, 1980). In practice, Q was interpolated from a contoured overlay chart at the scale of the topographic map (1:25,000) on which the transmitter

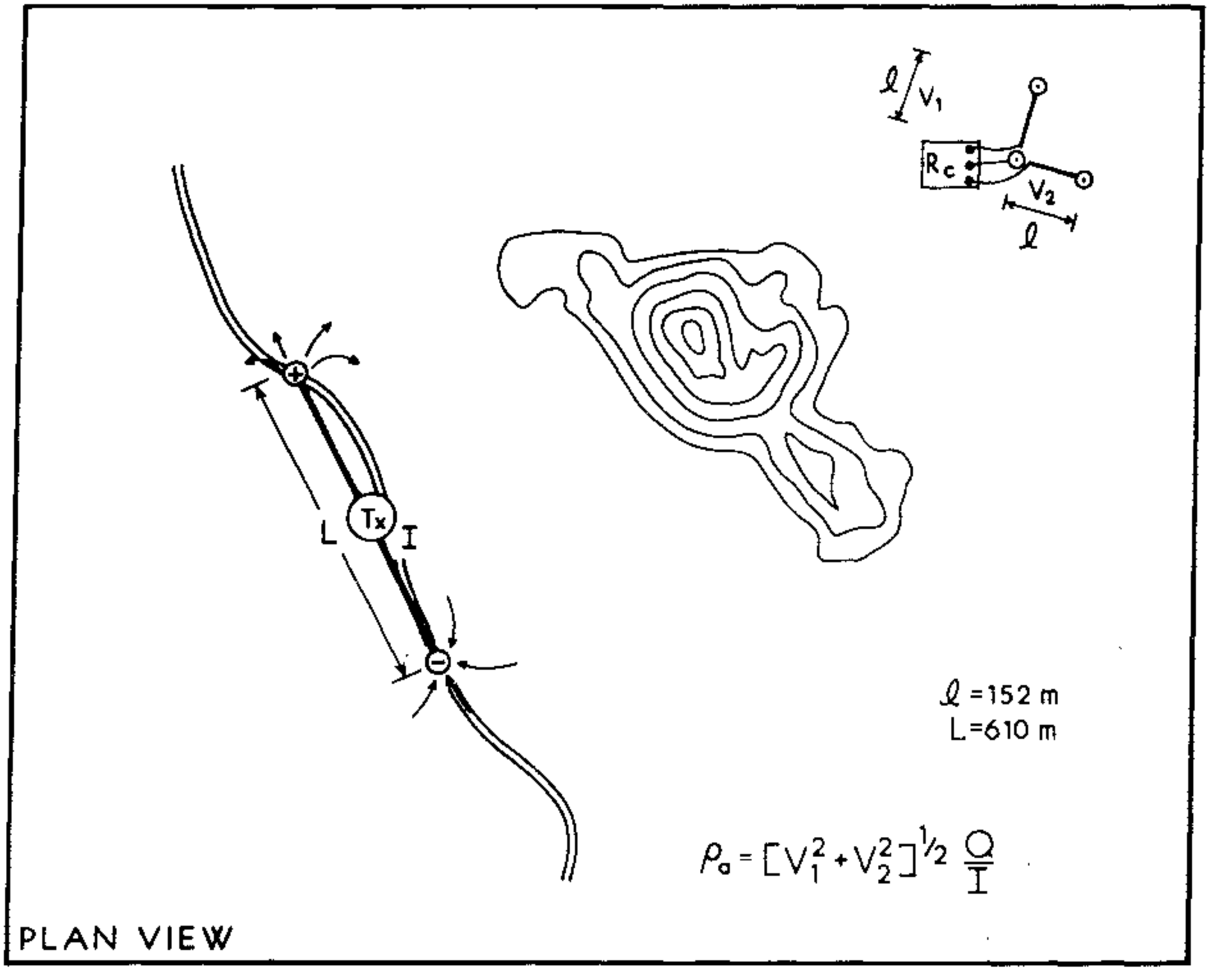

Figure 2a. Bipole-dipole array geometry as used in the reconnaissance resistivity survey.

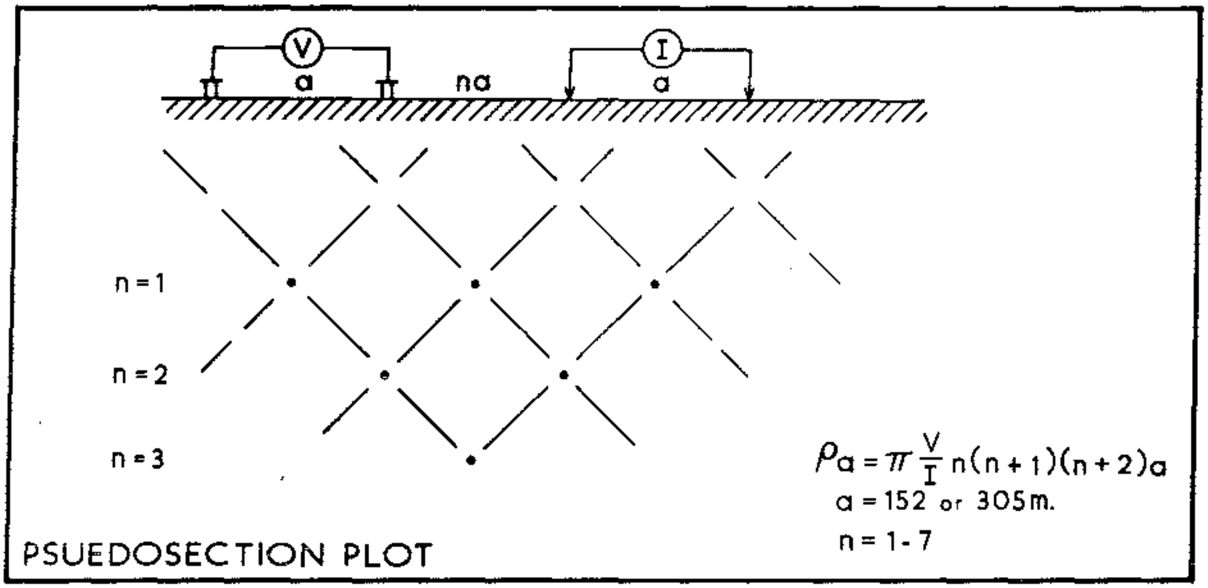

Figure 2b. Dipole-dipole array geometry used for detailed surveys.

and receiver sites had been plotted.

Transmitter sites were chosen such that electrodes could be emplaced in alluvium or weathering debris among the flows, and still result in an efficient and fairly detailed resistivity map of the island. The location of the five transmitter sites and 43 receiver sites is shown on Plate I. A substantial effort was expended in electrode preparation for each transmitter dipole. Six to twelve aluminum stakes were driven into small holes, salted and watered with 10 to 20 gallons of water at each electrode. The cable, water and other items had to be hand carried as much as 700 meters for the "far" electrode at several sites because of the rough terrain and limited access. The effort was rewarded with low electrode impedances and input currents of 3 to more than 5 amps. Some electrodes had to be modified to reduce the input current to 5 amps, while others required additional salt and frequent watering. The Elliot transmitter and Fluke receiver performed flawlessly for the entire survey. Low apparent resistivity and communications "noise" resulted in low signal/noise ratios for several stations, and a synchronous-detection, time-domain Elliot receiver would have improved the data and reduced the recording time. An upper limit to apparent resistivity was established for several stations where the signal/noise levels prevented a precise resistivity value.

The reconnaissance resistivity survey covers an area of approximately 35 sq km in the central portion of the island. Although a more complete coverage of the island would be desirable, this could not be accomplished without great cost and effort. Helicopter support could provide access to additional areas but few good transmitter sites remain, and very high surface impedances are expected on the unweathered flows, cinders, and trachytes. Any new readings west of the present survey (U.S. base north to Georgetown and the antenna fields) would be suspect because of a high density of grounding cables, wires, structures, etc. Transmitter sites within a kilometer of the coast would certainly be dominated by the 0.2-2 ohm-m current path afforded by sea water at depth and offshore, as noted by Keller et al. (1977) in their studies of the Kilauea east rift zone. Accordingly the survey was limited to the central portion of the island considered most favorable for the development of a geothermal resource. The Sisters Peak - Bears Back area is only partially covered by the survey because of poor access and high surface impedance. Transmitter-receiver separation, reduced apparent resistivity and other parameters for all stations are listed in Table 1.

Transmitter 1 was oriented N80°E and was located on older alluvium just south of Hospital Hill, quite near the center of the island. The western electrode included the drill casing of two old wells as well as several small metal stakes. An input current of 5 amp permitted good data readings as far as 2800 m from the transmitter. Apparent resistivities observed were generally low to moderate (12-39 ohm-m), even though large separations should give rise to current penetration well below sea level. Low values of 9 ohm-m were observed to the north and northeast, and 12 ohm-m values to the south-southwest.

Transmitter 2 was located on the southeast side of Dark Slope Crater and was oriented S40°W. High apparent resistivities (562 and 367 ohm-m) were observed for stations N1 and SW2 with short Tx-Rc separations. Larger separations along similar directions resulted in much lower apparent resistivities (23 and 115 ohm-m) indicating lower resistivity material at increased depths. The lowest apparent resistivities were 13 and 15 ohm-m values observed to the east, south of Devil's Riding School and Spoon Crater.

Transmitter 3 was oriented N10°E along the NASA road in Grazing Valley. Moderate resistivities (79 and 57 ohm-m) were noted to the southeast and east

TABLE I

RECONNAISSANCE RESISTIVITY DATA SUMMARY

Transmitter	Receiver	Distance (m)	I (amp)	Q	ρ_a (ohm-m)
Tx-1 (Old Well)	1-ENE	2800	5.00	900	8.8?*
	1-NNE	2060	5.00	425	9.0
	1-N	2030	4.90	530	18.6
	1-NW	1740	4.90	235	19.3
	1-WNW	2440	4.90	525	15.2
	1-W	1820	5.00	200	11.8
	1-SW-1	1820	4.90	225	15.2
	1-SW-2	1810	4.90	305	12.2
	1-S	1590	4.80	275	12.6
	1-SE	2520	4.80	750	39.1
	1-E	2630	4.72	600	31.9
Tx-2 (Dark Slope Crater)	2-SE	900	4.63	40	95.7
	2-S	810	4.58	20	562
	2-NW	1510	4.53	250	76.1
	2-NE-1	1460	4.55	95	19.4
	2-E-1	1680	4.52	180	14.8
	2-N-1	1030	4.54	50	367
	2-ESE	2240	4.50	575	$\leq$ 13.3*
	2-NE-2	1860	4.51	210	28.7
	2-N-2	2030	4.92	350	115.2
	2-SW	1740	4.80	175	23.1
Tx-3 (Grazing Valley)	3-SE	1560	4.60	160	78.9
	3-E	1780	4.61	390	57.3
	3-NW	1620	4.60	260	175.8?
	3-W	2120	4.65	620	$\leq$ 12.3*
	3-N	1750	4.57	180	12.0
	2-SE	2390	4.73	600	12.0
	3-NE	2280	4.65	400	$\leq$ 34.0#
Tx-4 (One Boat Dump)	4-N	2420	3.85	575	19.7
	4-NW	1220	4.20	125	7.2
	4-W	1340	4.13	90	82.4
	4-SW	2360	4.06	465	12.8?*
	4-SE-1	1320	3.98	165	13.1
	4-NE-2	3200	4.01	1300	$\leq$ 9.2*
	4-NE-1	2940	3.95	900	$\leq$ 5.1*
	4-NE-3	1220	3.90	60	152.0
Tx-5 (Devil's Ashpit)	5-ENE	880	3.20	20	142
	5-NE	1220	3.13	85	87.7
	5-N-1	960	3.10	55	66.3
	5-N-2	1440	3.12	185	2,435
	5-NW	1480	3.10	180	379
	5-W	1420	3.08	90	58.3
	5-SW	2240	3.08	385	130

* very low signal - ρ upper bound
\# high noise level - ρ upper bound

across Mountain Red Hill and a questionable value of 176 ohm-m was found to the northwest. The 176 ohm-m is questioned because six nearby Tx-Rc stations (Plate I) all recorded values between 12 and 15 ohm-m. An instrument reading error is suspected. Low apparent resistivities of 12 and 12.3 ohm-m were observed to the south and west, confirming the low resistivity zone observed from Tx-2. A 12.0 ohm-m value observed to the north confirms the elongation of this low resistivity zone towards transmitter site Tx-1.

Transmitter 4 was oriented N60°E in cinders and alluvium across the southeast side of the One Boat dump area. Low signal strengths permitted only an upper limit on apparent resistivity for the southwest and NE-1 and NE-2 recording sites. The large separation for the northeast side suggests deep current penetration. Thus the low apparent resistivities could indicate salt water incursion or geothermal brines at depth. The only high resistivity value from Tx-4 was an 82 ohm-m value observed 1300 m west along the Hogan's By-Pass road.

Transmitter 5 was located southwest of the NASA site on cinders of the Devil's Ashpit. Lack of access and low exploration priority dictated that no observations be taken southeast of the transmitter site, on the slope toward the ocean. Stations to the southwest, west, and northwest all showed high apparent resistivities. An extremely high value of 2,435 ohm-m, recorded at site N-2, may result from a local, very high resistivity body beneath the receiver site, or a geometric effect due to Cricket Valley. Two receiver sites within Cricket Valley recorded moderate apparent resistivities (66 and 88 ohm-m) which probably indicate a local zone of lower resistivity associated with Cricket Valley.

Although the interpretation of reconnaissance scale bipole-dipole data is rather qualitative and complex (Hohmann and Jiracek, 1979), low resistivity regions can be identifed in a cost-effective manner. This survey has identified four low resistivity zones: 1) the Lady Hill-Travelers Hill-Sisters Peak area; 2) south of Devil's Riding School; 3) Grazing Valley-Hospital Hill, and 4) Cricket Valley. Even with numerical model results of Hohmann and Jiracek (1979) and overlapping coverage from different transmiter sites, one cannot resolve ambiguities among lateral position, depth and intrinsic earth resistivity from bipole-dipole data alone. This survey has delineated four areas of low apparent resistivity and thereby identified the more promising areas for the more laborious dipole-dipole follow up.

4.4 Dipole-Dipole Surveys

Three dipole-dipole profiles were completed to obtain more detailed electrical resistivity data. The geometry and plotting scheme for this array are shown in Figure 2b. All electrodes are placed in a line, a uniform distance (separation) apart. The dipole-dipole array is widely used in geothermal, mineral and petroleum exploration because it is an efficient means of collecting a large number of data points which are influenced by the lateral position and depth characteristics of the resistivity distribution. Numerical modeling programs can be used in a forward modeling or iterative manner to determine the resistivity distribution and the intrinsic resistivity values. The locations of the three profiles are shown on Plate I.

Line 1 was oriented N45°E and centered approximately 600 m northwest of Command Hill. This line was completed to determine the suitability of this area for a proposed fresh water well, and to determine the resistivity layering of the first 300 m of depth. Five current electrodes were emplaced 152 m apart, forming a 'five-spread' with electrode separation of 152 m. The line was terminated at station 5 SW (i.e. 760 m southwest of center) because a high density of grounding cables, fence, and the U.S. base power-generating station beyond this point would give rise to meaningless data. The observed data are plotted as Figure 3. High apparent resistivities (400-800 ohm-m) were observed for most of the line. The highest resistivities were observed in the northeast among the splatter cones of Donkey Plain and immediately beneath the center of the line. Resistivity values decreased substantially between stations 4 and 5 SW. A gentle slope toward the southwest resulted in current penetration well below sea level on this end of the line, thereby reducing the apparent resistivities.

All dipole-dipole lines were modeled using a finite-element algorithm orignally developed by Rijo (1975) and programmed by Killpack and Hohmann (1979). A discussion of the modeling accuracy, assumptions and limitations is presented in an earlier geothermal resistivity study by Ross (1979).

Plate II shows the numerical model solution for line 1. The vertical scale is twice the horizontal scale. High intrinsic resistivities (> 200 ohm-m) indicate little pore space or, more likely, unsaturated pore space. Lower resistivities (100 and 50 ohm-m) at depth probably indicate increasing saturation with sea water. There does not appear to be a well-defined fresh water table in a porous aquifer. On the basis of these data it was recommended that a water well not be sited in the Command Hill-Table Crater area.

Line 2 trends roughly north and is centered just north of the NASA road east of Devil's Riding School (Plate I). This is a line of six current electrodes spaced 305 m apart (a six-spread of 305 m dipoles). This line was sited to provide additional lateral and vertical detail on the low resistivity zone indicated by reconnaissance resistivity measurements. The specific location was chosen to utilize alluvium and soil deposits, to the extent possible for suitable electrode placements. Long carrying distances and poor electrode sites in young lava flows prevented extending the line further to

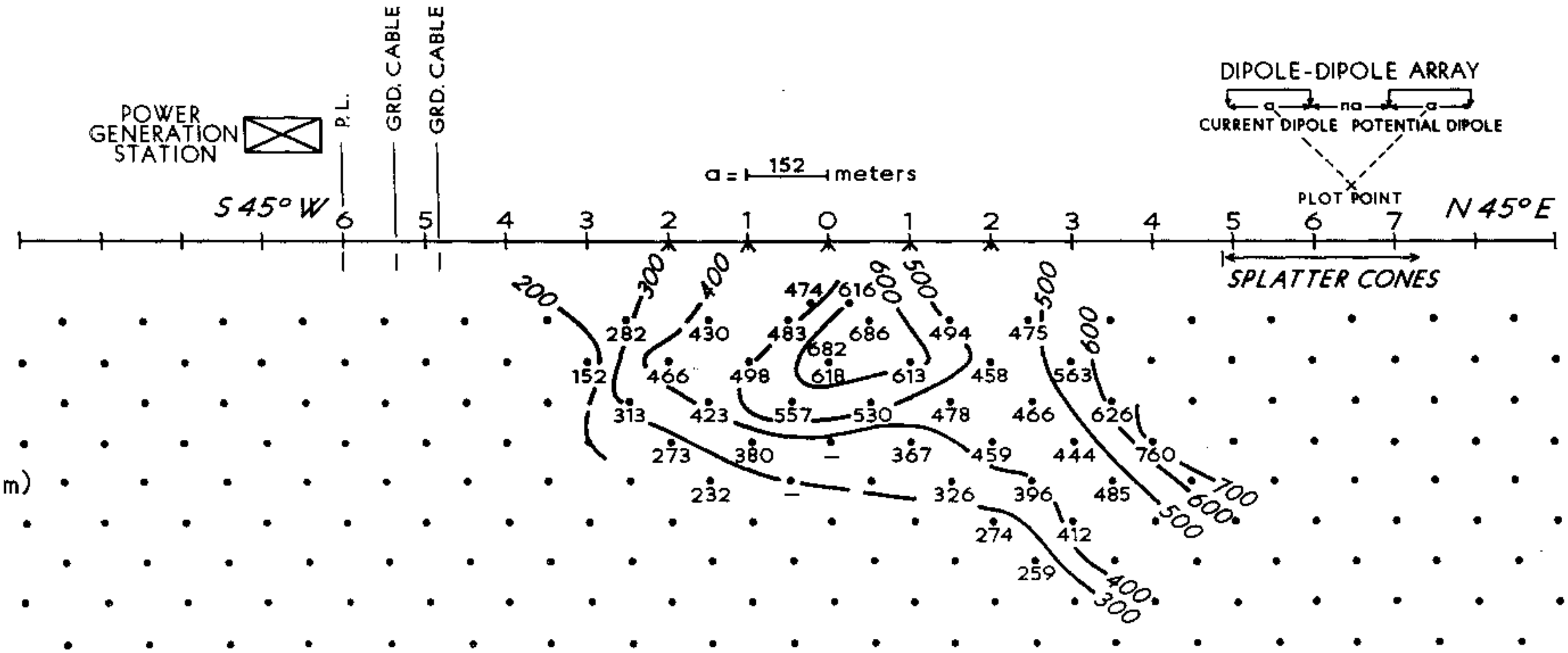

FIGURE 3

LINE 1

DIPOLE-DIPOLE ARRAY—APPARENT RESISTIVITY

TRANSMITTER: ELLIOT 15A RECEIVER: FLUKE

ASCENSION ISLAND, SOUTH ATLANTIC

DATA BY
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JUNE 16, 1983

the south. Current inputs of 3-4 amps were achieved at all dipoles and resulted in good signal strengths.

The observed data for line 2 are shown as Figure 4. Observed resistivities decrease from 100-200 ohm-m at the first separation to 10-30 ohm-m for separations 5, 6, and 7. Thus, a rough resistivity layering with depth is indicated. The lower resistivity values observed for larger separations are in excellent agreement with the reconnaissance resistivity data. The numerical model solution for these data, Plate II, shows 200 to 500 ohm-m bodies above sea level, a mix of 200 to 30 ohm-m bodies from 70-150 m below sea level and an extensive zone of 15 ohm-m below this. We believe the 30 to 200 ohm-m bodies represent a thin fresh water zone and its mixing zone with sea water, and possibly geothermal waters. A 10 ohm-m zone may exist between station 1 to 4 north, as inferred by a slightly better fit to the observed data. The most prospective geothermal area, inferred from these resistivity data, would extend between stations 0 and 4 north.

Dipole-dipole line 3 is centered north of an antenna array along the North East Bay road and trends approximately N15°E. Once again the line location utilizes the presence of alluvium and volcanic fragmental deposits for the location of electrodes. Line 3 is a five-spread with 305 m dipoles. Transmitted currents varied between 3 and 4 amps. The observed data of Figure 5 indicate high (200-450 ohm-m) near surface resistivities corresponding to the alluvium and young basalt flows. These units are either very dry or the contained waters have few dissolved ions. Resistivity decreases with increased separation (greater depth).

Plate II shows the numerical model interpretation. This is a complex resistivity distribution and probably indicates three-dimensional effects, particularly near Thistle Hill and the flows and structure between the road

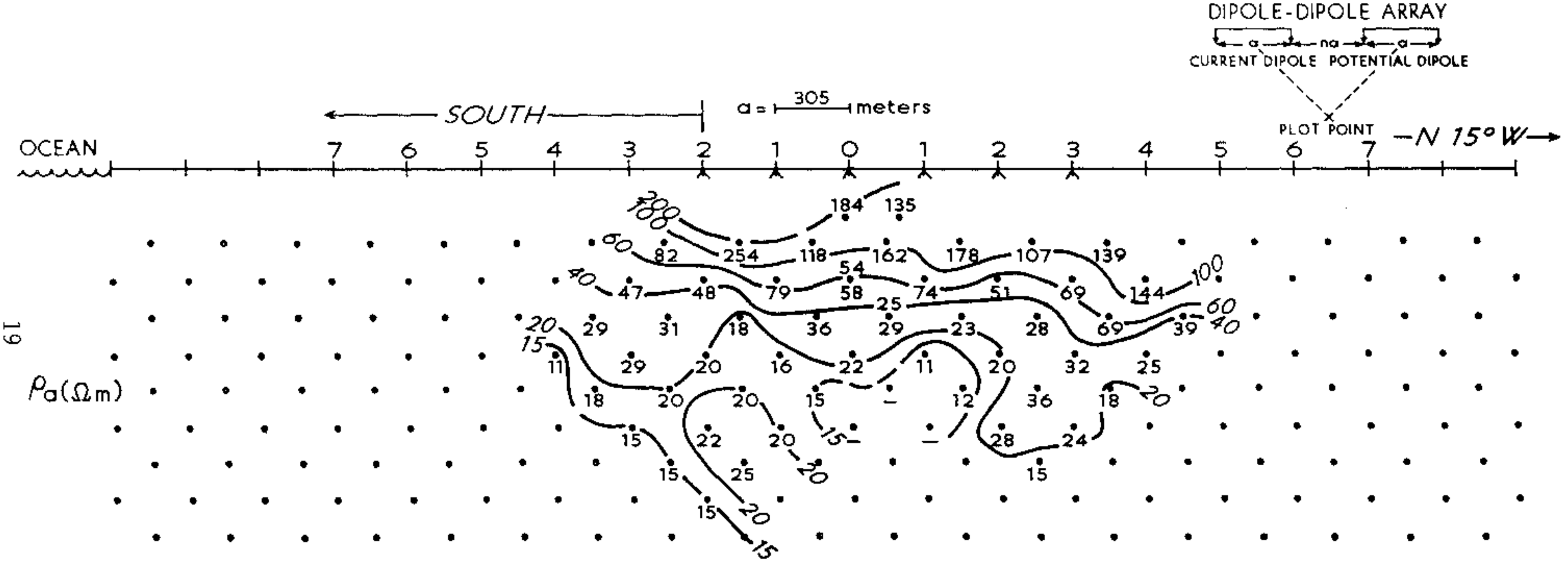

FIGURE 4

LINE 2

DIPOLE-DIPOLE ARRAY—APPARENT RESISTIVITY

TRANSMITTER: ELLIOT M15 RECEIVER: FLUKE

ASCENSION ISLAND, SOUTH ATLANTIC

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JUNE 17, 18, 1983

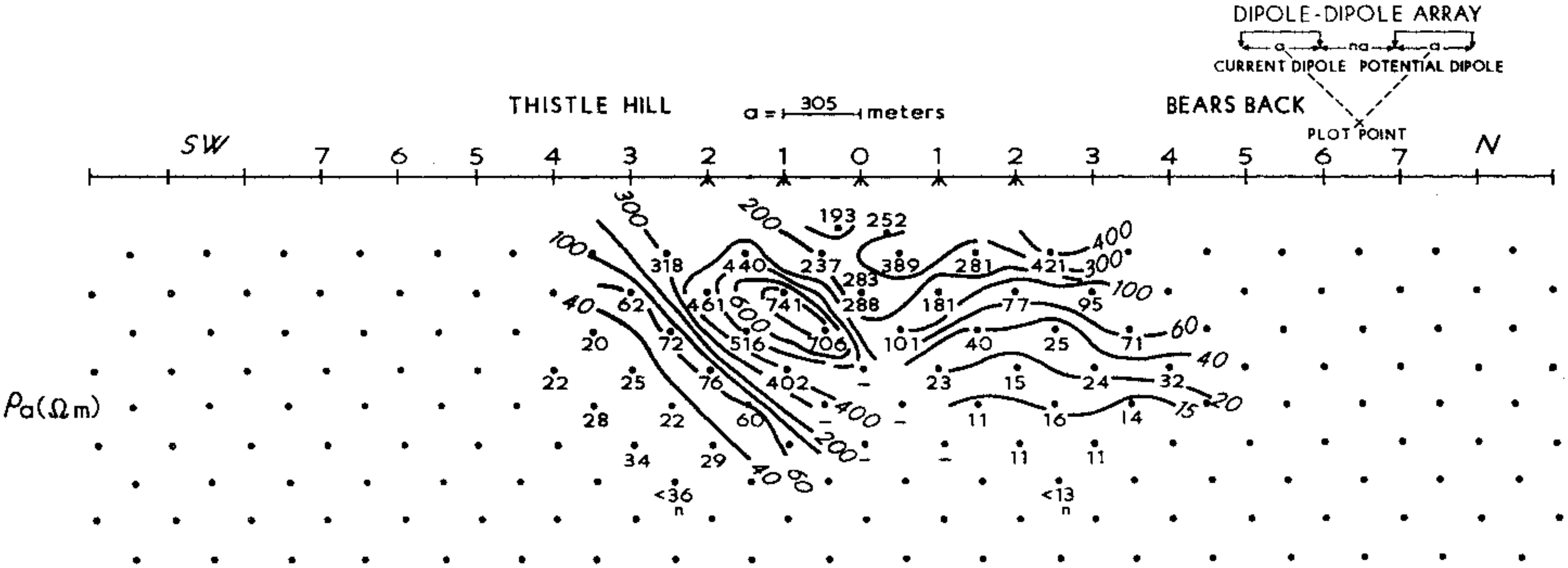

FIGURE 5

LINE 3

DIPOLE-DIPOLE ARRAY-APPARENT RESISTIVITY

TRANSMITTER: ELLIOT M15 RECEIVER: FLUKE

ASCENSION ISLAND, SOUTH ATLANTIC

DATA BY
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and Bears Back. Hence the numerical model solution is only a fair approximation to the actual resistivity structure along the line. The high resistivity bodies, which extend well below sea level (as at Thistle Hill), are most logically dense, low porosity intrusives (or low porosity flows?). The 10 ohm-m zone at depth near Bears Back is within two km of the coast and probably indicates sea water intrusion. Low resistivity bodies south of Thistle Hill indicate a higher water table and possible thermal fluids at moderate depth. The model is not well constrained beyond Station 5SW because near-surface data (near separation) were not recorded with the 5-electrode spread.

4.5 Self-Potential Profiles

The self-potential (SP) method measures an electrical voltage difference at the surface of the earth which results from natural (rather than induced) electrical currents. The method has been employed since 1830 to search for buried mineral deposits which may generate electric currents through chemical reactions occurring near the water table. Electrical currents are also generated by groundwaters moving down a hydrologic gradient or by thermal fluids moving to the surface in fracture zones. Voltage differences of more than 600 millivolts (mv) in a distance of one kilometer have been observed, and differences of 200 mv per kilometer are fairly common. Zablocki (1977) documented 600 mv positive anomalies over steaming fissures in the Kilauea East Rift Zone, Hawaii. Self potential (SP) traverses were considered lower priority than resistivity work on Ascension, and were completed when the failure of the motor-generator and transmitter during the March orientation survey made time available for this work.

Two nonpolarizing porous potential electrodes were used to determine voltage differences at the surface. Preferred survey procedure is to establish a base station outside the area of interest, establish a reference pot (porous electrode) at this point, and advance the moveable or forward pot while unreeling up to 2 km of communication wire connected to the stationary pot. Thus, a profile of potential (voltage) difference with respect to the stationary pot is determined directly. An alternate method, less precise but better suited to rough terrain and poor access, was used on Ascension Island. The forward pot was connected by a 76 m (250 m) length of communication wire to the Fluke digital multimeter which occupied the following pot location. The π filter (discussed earlier) reduced the radio-frequency noise levels without disturbing the SP voltages. After each reading, the two pots were advanced simultaneously and the rear pot occupied the same point as the forward pot of the previous measurement. In this manner, a plot of cumulative potential with respect to the initial reference station was completed.

Figure 6 shows the location of the three SP traverses completed in March 1983. The reduced data are shown in Figure 7.

The Booby Hill traverse was completed on March 6, 1983. The traverse began at the east end of the South African dump (reference potential location) and progressed along a S70°E trend for a distance of 2500 feet (762 m). The traverse was entirely in young basalt flows (bf, bg_2 of Nielson and Sibbett, 1982) and crosses the Booby Hill fracture zone. The traverse was terminated after a two-hour effort when a light mist became a heavy, salty rain which threatened the operation of the digital voltmeter. Although the accuracy of a given measurement was less than 0.5 mv the cumulative potential plot (Figure 7) is very irregular, and because the traverse is short, no real significance is attached to these data. Three peaks of 60 to 180 mv occur on the flows, and the smallest coincides with the Booby Hill structure.

The Hospital Hill SP traverse trended northeast from the center of

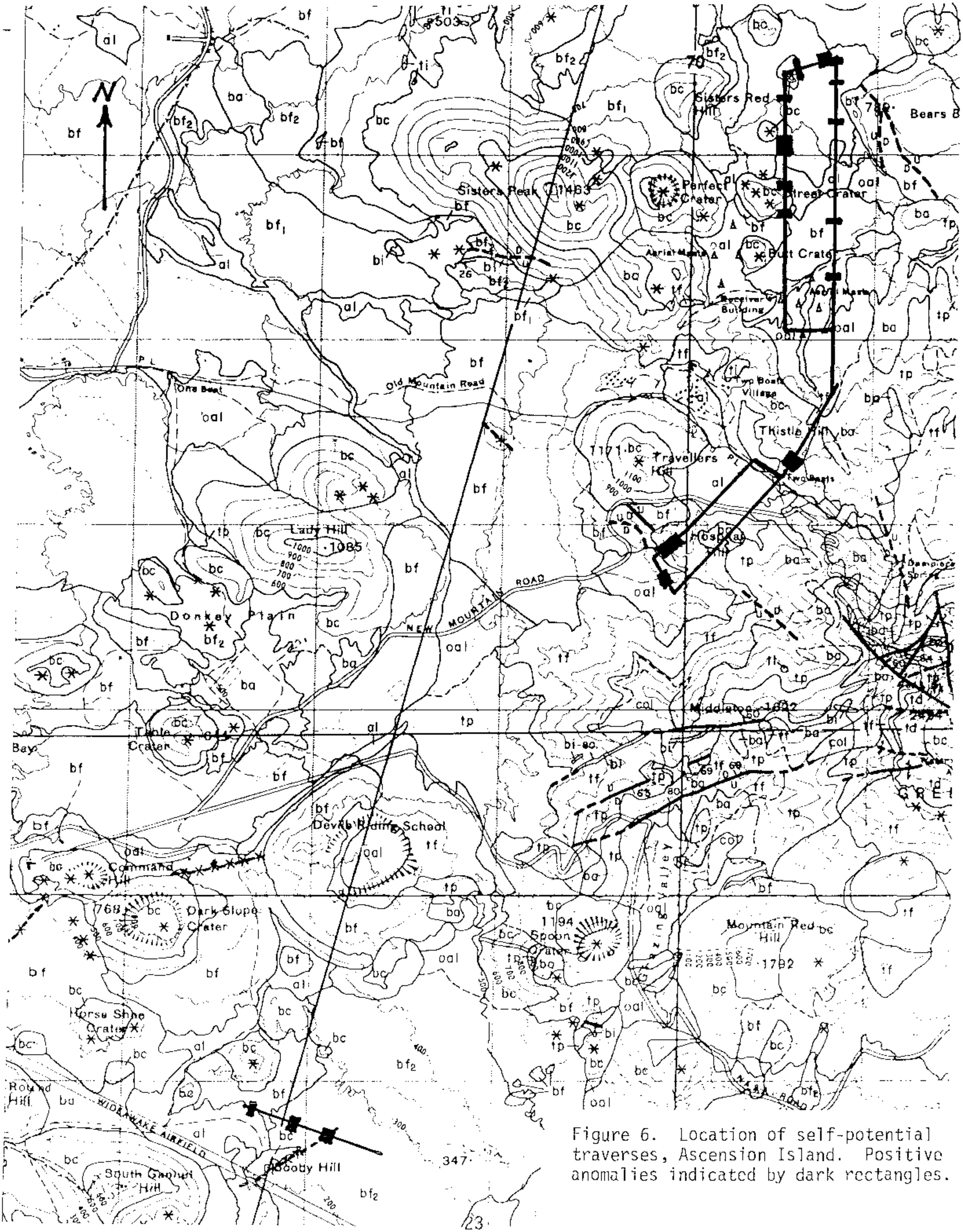
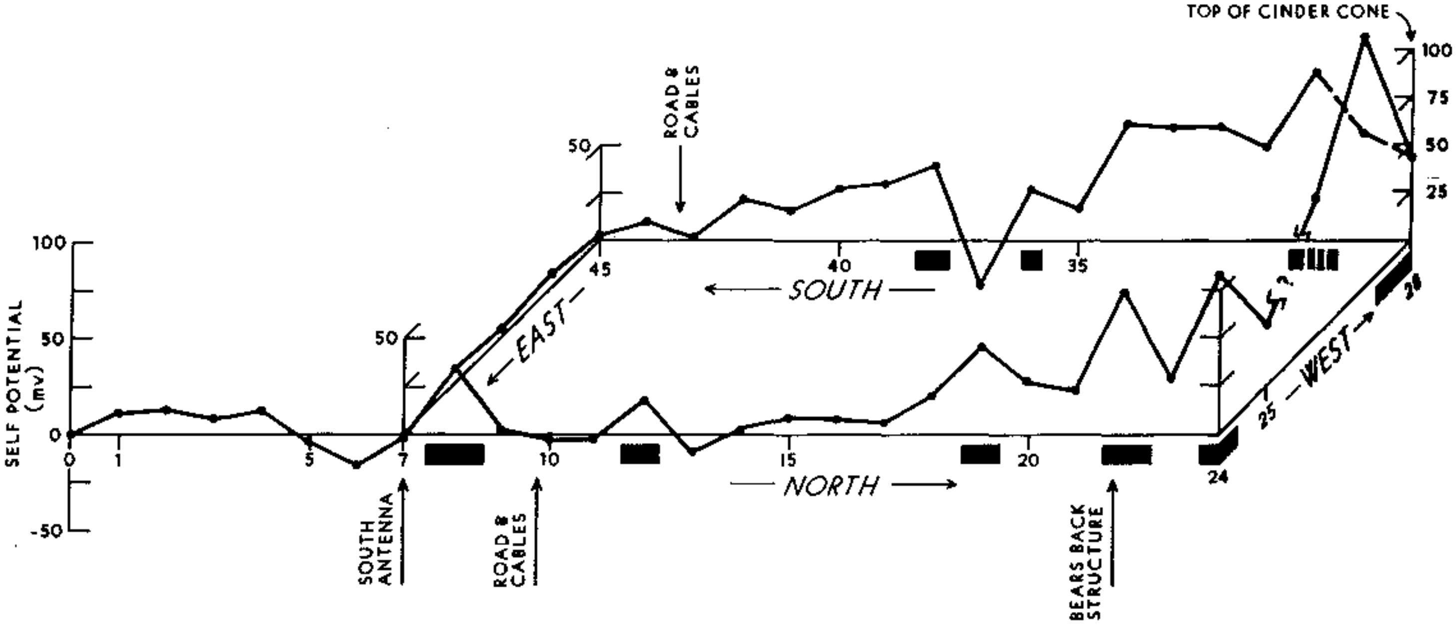
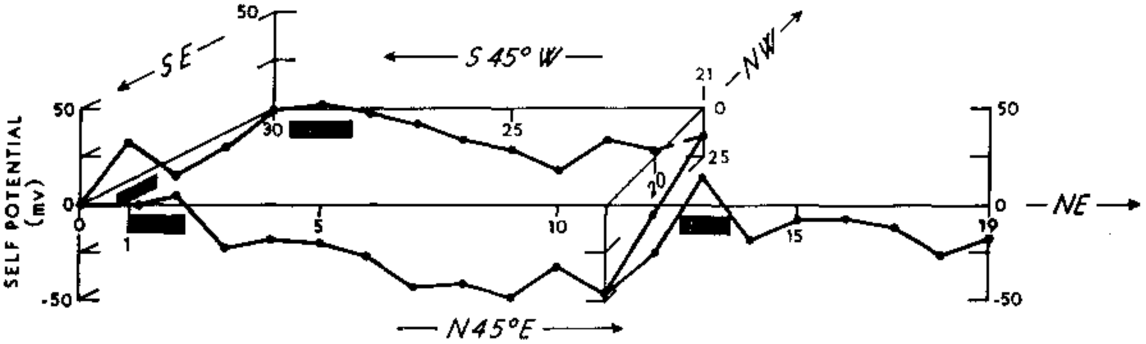


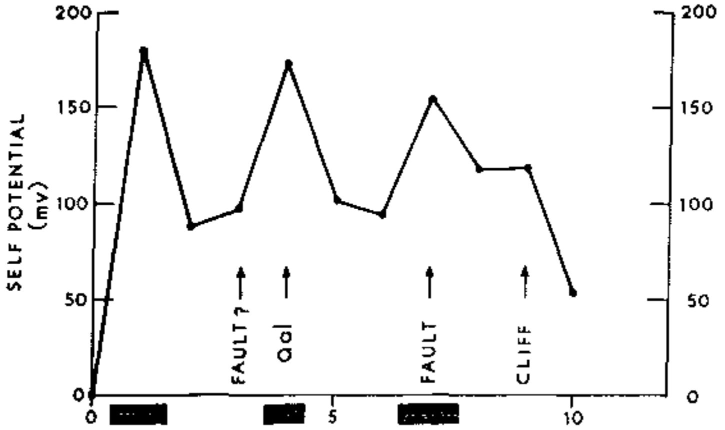
Figure 6. Location of self-potential traverses, Ascension Island. Positive anomalies indicated by dark rectangles.



a) Thistle Hill Traverse



b) Hospital Hill Traverse



c) Booby Hill Traverse

Figure 7. Self-potential traverses on Ascension Island.

resistivity transmitter dipole Tx-1, passed by Two Boats and down Thistle Hill (Figure 6). Returning to Two Boats the traverse trended northwest, then southwest and southeast to the point of beginning. The traverse sought evidence for fluid movement along northwest trending structures mapped at the north side of Green Mountain.

A well defined 60 mv SP high occurs just northeast of Two Boats just down slope from the crest of Thistle Hill. Topography may contribute to the anomaly, but this is not evident from the data. A broad 25 mV high occurs west of Hospital Hill where two structures trend northwest to Travelers Hill. This weak SP anomaly may arise from fluid movement along these structures. A minor one station 25 mv SP high also occurs on the closing leg of the traverse, quite near the resistivity transmitter dipole Tx-1. No special significance is attached to this low amplitude anomaly, which could arise from a soil difference between the measuring pot electrodes.

The longest SP traverse was the Thistle Hill traverse. This traverse began just south of alluvium, at the northern limit of the Hospital Hill traverse (Figures 6,7). Several one to three station positive anomalies were noted, with amplitudes of 20 to 100 mv. All were well defined in view of the moderate noise level (< 2 mv) in the data. The larger amplitude anomalies occur at the northern limit of the traverse, and some are repeated on the west and south trending legs of the traverse. The northern three anomalies occur along the projection of the Bears Back structure. Weak (10 to 40 mv) anomalies align along the projection of vents near Street Crater. These anomalies are readily related to geologic structures and may indicate the movement of fluids at depth along those structures. They are considered favorable for, but not definitive of, the occurrence of a geothermal system.

5.0 SUMMARY AND RECOMMENDATIONS

A feasibility study completed in February and March 1983 indicated that an electrical resistivity survey could be completed for much of the area of Ascension Island thought to have geothermal potential. Careful selection of reconnaissance transmitter dipole locations and electrode locations would be required to avoid high impedance problems, but electrical noise problems could be overcome.

The reconnaissance resistivity survey was conducted in June and utilized favorable electrode sites, such as local alluvial deposits, to obtain a spoke-like survey coverage over the central portion of the island. A broad zone of low apparent resistivity (< 20 ohm-m) trends north-northeast from Devil's Riding School through Thistle Hill. Two coherent zones of 5 to 15 ohm-m are indicated at depth within this area, west of Spoon Crater, and northeast of Thistle Hill (Plate I). Short separation readings indicated higher near surface resistivities, of the order of 20 to 400 ohm-m. Higher resistivity areas were also noted to the west of Devil's Riding School and east of Grazing Valley, across Green Mountain. Anomalous low resistivities are also associated with Cricket Valley.

Two dipole-dipole lines were sited on the basis of the reconnaissance results, where surface materials permitted good electrode conditions. A nearly continuous zone of low (15 ohm-m) resistivity is indicated at depths greater than 100-300 m below sea level on Line 2. Much of this low-resistivity material is probably brine saturated basalts resulting from sea water incursion. Somewhat higher resistivities (30 ohm-m) above these may indicate a fresh water or mixing zone above the salt water. Numerical model solutions are slightly better for a model which includes a 10 ohm-m zone near McTurk's culvert.

Line 3 revealed a more complex resistivity structure in the Thistle Hill-Bears Back area. Low resistivity zones of 10 ohm-m were delineated north of Bears Back as sea level is approached, and near Hospital Hill. The northern portion of the Bears Back low is readily explained by sea water incursion but the Hospital Hill low, beneath higher elevations in the center of the island, could well indicate alteration and brines associated with a geothermal system. A similar argument applies to low resistivity zones delineated on Line 2.

Self-potential anomalies may result from several manmade or geologic conditions, including geothermal fluid flow along structures. Thus, the presence of positive or quadripole self-potential anomalies is considered a favorable indicator, but is not definitive of geothermal potential. Several local anomalies mapped on Ascension may relate to fluid flow along structures. These include: a small anomaly along the Booby Hill structure, which trends northeast toward the resistivity low near Spoon Crater; small anomalies near the Hospital Hill resistivity low, and local anomalies near the Bears Back structure and resistivity low. The latter anomaly may indicate a geothermal contribution to the low resistivity zone otherwise readily attributed to salt water at depth.

The electrical survey results, considered together, have delineated zones of low electrical resistivity and minor self-potential anomalies along known structures, both encouraging for the presence of a geothermal system. These favorable areas have been recommended for thermal gradient drilling and observations, as the next definitive step in the exploration program. The drilling and preliminary temperature observations have been completed, but final stabilized gradients and temperatures are yet to be determined. These results will be reported in a later paper.

Additional electrical surveys, both resistivity and self-potential, may be cost effective for siting a deep production well, should the thermal gradient results be favorable. Most of the available electrode sites have already been used, and construction of the new British base has added numerous grounded structures in one area of geothermal potential. Various survey designs are being considered to determine if additional surveys will be cost effective.

One dipole-dipole resistivity line was completed near Command Hill to evaluate the depth and configuration of the fresh water table in the area. This line indicated a complex resistivity structure and high resistivity values indicating either low porosity or great depth to a saturated zone. Based on these data a recommendation was made not to site the fresh water well near Command Hill.

6.0 ACKNOWLEDGEMENTS

We would like to acknowledge the support and enthusiasm of a number of people and organizations who contributed to the completion of this project. These include George Hotchco, Lt. Col. William D. Bryden, and Lt. Col. Ed Roscoe of the U.S. Air Force as well as William Koslow of Pan American World Services and Don Coffey, PAN AM Manager, and his staff on Ascension Island.

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APPENDIX I

NUMERICAL MODEL RESULTS

Dipole-Dipole Line 1, a = 500 feet

Dipole-Dipole Line 2, a = 1000 feet

Dipole-Dipole Line 3, a = 1000 feet

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DIP-DIP RESISTIVITY ITER #8, SUBFILE #7
LINE 1
MEDIA RESISTIVITY (OHM-METERS)
        50.00     100.00     400.00     500.00     700.00
MEDIA PFE (%)
         0.00       0.00       0.00       0.00       0.00

  88  77  66  55  44  33  22  11  00  11  22  33  44  55  66  77  88      DEPTH
.........1.........2.........3.........4.........5.........6.........7
3333333333333333333333333333333344444444444333333333555555555555555555
3333333333333333333333333332233344554444444333333333555555555555555555  150 Ft.
3333333333333333333333333332333444554445555553333333333555555555555555  300 Ft.
2222222222222222222333344444444555555555555553333333333335555555555555  600 Ft.
3333333333333333333333344444444555555555555553333333333333355553333333
2222222222222222222222222222222555555555555553333333333222233333333333  1000 Ft.
2222222222222222222222222222222222222255555333333333332222222222222222
2222222222222222222222222222222222222222222222222222222222222222222222
1111111111111111111111111111111111111111111111111111111111111111111111
1111111111111111111111111111111111111111111111111111111111111111111111
1111111111111111111111111111111111111111111111111111111111111111111111
.........1.........2.........3.........4.........5.........6.........7


     S45°W          CALCULATED RESISTIVITY (OHM-METERS)          N45°E

 -5     -4     -3     -2     -1      0     +1     +2     +3     +4     +5
 :------:------:------:------:------:------:------:------:------:------:



          377.   268.   402.   490.    646.   556.   502.   398.

       287.   224.   450.   497.   513.   658.   526.   553.   424.

   252.   160.   314.   449.   486.    440.   548.   538.   554.   380.

226.   138.   218.   288.   407.   392.   334.   528.   508.   476.   309.

   123.   188.   200.   257.   313.    289.   304.   473.   418.   377.

       169.   175.   185.   194.          260.   260.   375.   322.
```

```
ASCENSION  LINE 2 A-1000 FT    ITER #10, FILE #20
LINE 2  A=1000 FT
MEDIA RESISTIVITY (OHM-METERS)
        10.00      15.00      30.00      200.00     500.00
MEDIA PFE (%)
         0.00       0.00       0.00       0.00       0.00

  88  77  66  55  44  33  22  11  00  11  22  33  44  55  66  77  88   DEPTH
.........1.........2.........3.........4.........5.........6.........7
4444444444444444444444455554455555554555555555555555555555555544444444
4444444444444444444444455554445554444554445555555555555555555544444444 300 Ft.
3333333333344444444444445554444554444454444444433335555555544444444444 600 Ft.
2222222222333444433333344443333444444443333444433334444555544443333333 1000 Ft.
3333333333333333333333333333333333333333333333333333333555533333333333
2222222222222222222222222222222222222222211111111112222333333333333333 2000 Ft.
2222222222222222222222222222222222222222211111111112222222222222222222
2222222222222222222222222222222222222222222222222222222222222222222222
2222222222222222222222222222222222222222222222222222222222222222222222
2222222222222222222222222222222222222222222222222222222222222222222222
2222222222222222222222222222222222222222222222222222222222222222222222
.........1.........2.........3.........4.........5.........6.........7


     SOUTH             APPARENT RESISTIVITY (CALCULATED)        N/10°W

   -5     -4     -3     -2     -1      0     +1     +2     +3     +4     +5
    :------:------:------:------:------:------:------:------:------:------:


            171.    95.   225.   188.    160.   176.   130.    92.

         100.    42.    51.    87.    81.     76.   46.    46.    73.

      37.    30.    32.    25.    41.     37.    24.    30.    39.    43.

   25.    12.    31.    23.    13.    34.    12.    24.    34.    23.    17

      10.    16.    26.    14.    14.     14.    15.    32.    23.    10.

          16.    14.    17.    18.           25.    20.    23.    13.
```

```
ASCENSION            ITER #20, FILE #43
LINE 3  A- 1000 FT
MEDIA RESISTIVITY (OHM-METERS)
       10.00      25.00      50.00      300.00     700.00
     1200.00
MEDIA PFE (%)
        0.00       0.00       0.00        0.00       0.00
        0.00

  88  77  66  55  44  33  22  11. 00  11  22  33  44  55  66  77  88
.........1.........2.........3.........4.........5.........6.........7  Depth
2222222222222222222333444444444444444445555555555555555555555555555555
2222222222222222222333444444444444444445555555555555555555555555555555 -300 Ft.
1111111111111122222333445554444445544445555555555444455555555444444444 -600 Ft
1111111111111111122666666665555555566636663333333222222444433333333333 -1000 Ft.
1111111111111111122666666665555555566636663222222111111111111111111111
1111111111111111122666666662222222266626662221111111111111111111111111 -2000 Ft
1111111111111111111666666662222222255222222111111111111111111111111111
1111111111111111111666666662222222222222222111111111111111111111111111
1111111111111111111555555552222222222222222111111111111111111111111111
1111111111111111111222222222222222222222222111111111111111111111111111
1111111111111111111111111111111111111111111111111111111111111111111111
.........1.........2.........3.........4.........5.........6.........7


      S15°W            APPARENT RESISTIVITY (CALCULATED)            N15°E

   -5     -4     -3     -2     -1      0     +1     +2     +3     +4     +5
    :------:------:------:------:------:------:------:------:------:------:



                 80.    344.    488.    385.    491.    289.    398.    253.

              56.    96.    382.    601.    495.    245.    93.    79.    61.

          41.    52.    88.    352.    643.    189.    70.    24.    37.    24.

       40.    35.    43.    72.    327.    219.    51.    22.    20.    25.    12.

          33.    27.    32.    62.    102.    62.    19.    22.    16.    20.

              25.    20.    27.    19.             29.    22.    19.    14.
```