BACA PROJECT

DATA AND REPORTS

GEOLOGY

No.	Transfer Date	Release Date	Title
1.	B	B	Hydrothermal Geology of the Valles Caldera, New Mexico by R.F. Dondanville - 1971.
2.	B	B	Airborne Infrared Geothermal Exploration--Valles Caldera, New Mexico Earth Resources Operations, North American Rockwell Corp.-1972.
3.	B	B	Electrical Resistivity Survey in Valles Caldera, New Mexico by Group Seven, Inc. - 1972.
4.	B	B	Additional Data--Electrical Resistivity Survey in the Valles Caldera, New Mexico by Group Seven, Inc. - 1972.
5.	B	B	Reconnaissance Resistivity Survey Baca Property, McPhar - 1973.
6.	B	B	Supplemental Report--Reconnaissance Resistivity and Schlumberger Depth Sounding Surveys Baca Property - McPhar - 1973.
7.	B	B	Quantitative Gravity Interpretation Valles Caldera Area, New Mexico by R.L. Segar - 1974.
8.	B	B	Mercury Soil Gas Survey Baca Prospect by Allied Geophysics Inc. - 1974.
9.	A	A	Mercury analysis - 1974 gradient holes.
10.	B	B	Geothermal Geology of the Redondo Creek Area Baca Location by T.R. Slodowski - 1976.
11.	B	B	Magnetotelluric--Telluric Profile Survey, Valles Caldera Prospect by Geonomics - 1976 as reprocessed by QEB Inc. - 1978.
12.	B	B	Geological Resume of the Valles Caldera by T.R. Slodowski - 1977.

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SUPPLEMENTAL REPORT ON THE RECONNAISSANCE RESISTIVITY AND SCHLUMBERGER DEPTH SOUNDING SURVEYS OF THE BACA PROPERTY VALLES CALDERA AREA SANDOVAL COUNTY, NEW MEXICO

FOR

UNION OIL COMPANY

McPHAR GEOPHYSICS

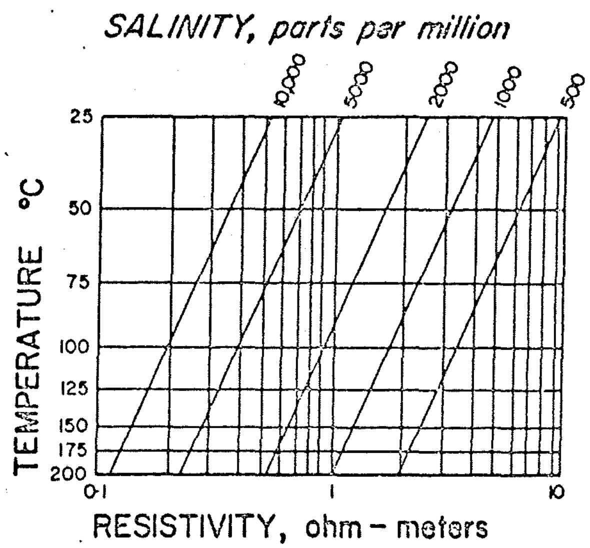
NOTES ON GEOTHERMAL EXPLORATION USING THE RESISTIVITY METHOD

Many geophysical methods have been tried in the exploration for geothermally "hot" areas in the upper regions of the earth's crust. The only method that has been consistently found to be successful has been the resistivity technique. In this geophysical method, the specific resistivity (or its reciprocal, the specific conductivity) of the earth's subsurface is measured during traverses over the surface.

The principle of the technique is based on the fact that the resistivity of solution-saturated rocks will decrease as the salinity of the solutions is increased and/or the temperature of the system is increased (see Figure 1). Therefore, volumes of the earth's crust that contain abnormally hot and saline solutions can often be detected as regions of low resistivity.

The resistivity measurements are usually made using grounded current and potential electrodes, but some useful data can sometimes be obtained using electromagnetic techniques. The field data shown on plan maps in Figure 2 are from the Broadlands Area in New Zealand; in this area there are substantial flows of hot water and steam at the surface.

The results show resistivity lows measured with a Wenner Configuration Resistivity Survey and a loop-loop electromagnetic survey. The anomalous pattern is much the same in both cases and the regions of low resistivity correlate well with the areas of increased rock temperature.

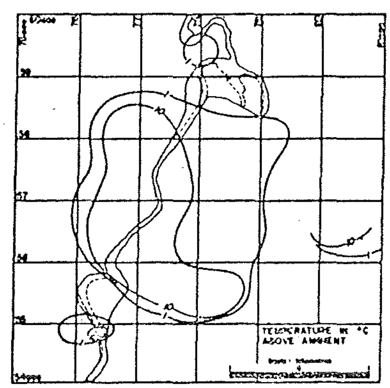


VARIATIONS OF SOLUTION RESISTIVITY
WITH TEMPERATURE AND SALINITY

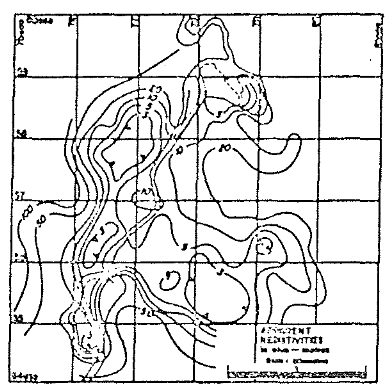
FIG. 1

GEOPHYSICAL SURVEY

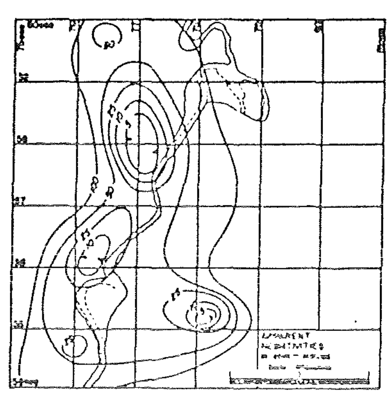
BROADLANDS AREA, NEW ZEALAND



A. TEMPERATURE AT 15m DEPTH



B. APPARENT RESISTIVITY SURVEY USING WENNER CONFIGURATION A = 180m.



C. APPARENT RESISTIVITY SURVEY USING LOOP TO LOOP ELECTROMAGNETIC METHOD

COIL SEPARATION = 68 metres FREQUENCY = 440 Hz

FIG. 2

If the rock volume saturated with hot solutions does not extend to the surface it will be necessary to use large electrode intervals to detect the resistivity lows. The resistivity data shown in "pseudo-section" form in Figure 3 is from Java. Along this line there are two deep regions of low resistivity detected for the larger electrode intervals used. Zone A is associated with surface manifestations of geothermal activity. The source of the resistivity low at Zone B is unknown.

If the abnormally hot region occurs in a sedimentary basin, the general resistivity level can be quite low, due to the high porosity in normal sediments. This is the case in the Imperial Valley of California. The resistivities shown in Figure 4 are from an area near El Centro, California. The largest electrode separation used was 12,000 feet.

The results show a two-layer geometry with the upper layer having a thickness of approximately one-half electrode interval (i.e. 1,000 feet). The resistivity in the upper layer is 3.0 ohm-meters; the resistivity of the lower layer is 1.5 ohm-meters. Due to the small resistivity contrast, additional measurements would be necessary to determine the possible geothermal importance of the lower resistivity layer at depth.

The results shown in Figure 4 are from a dipole-dipole electrode configuration survey. Our dipole-dipole data is plotted as a "pseudo-section" for several values of n; the separation between the current electrodes and potential electrodes, as well as the location of the electrodes along the survey line, determine the position of the plotting point. The two-dimensional array of

APPARENT RESISTIVITY SURVEY, DIENG PLATEAU AREA, JAVA, INDONESIA

Pseudo Section Plotting Method Along Dieng–Bator Road

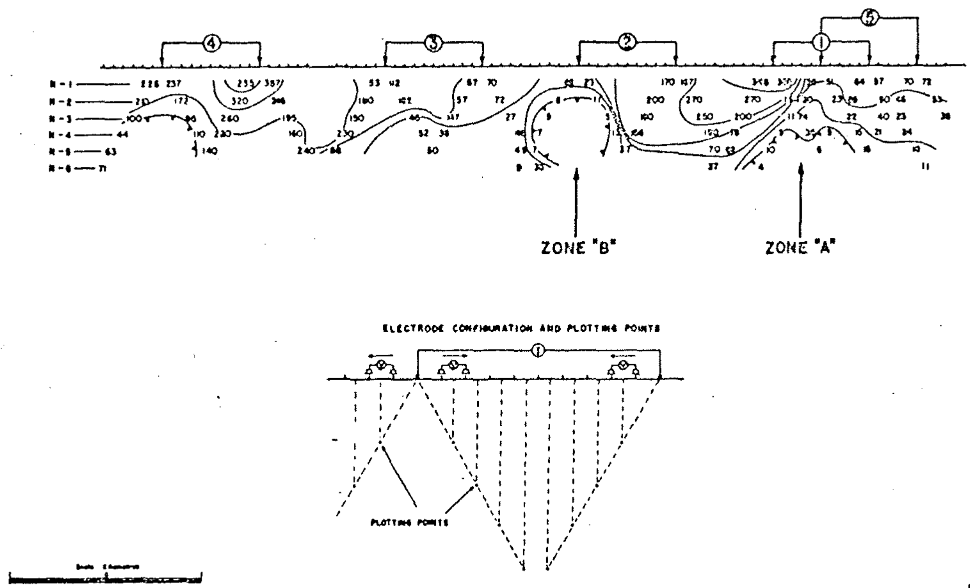


FIG. 3

RESISTIVITY SURVEY, IMPERIAL VALLEY–CALIFORNIA.

LINE-"0", FREQUENCY–0·125Hz.

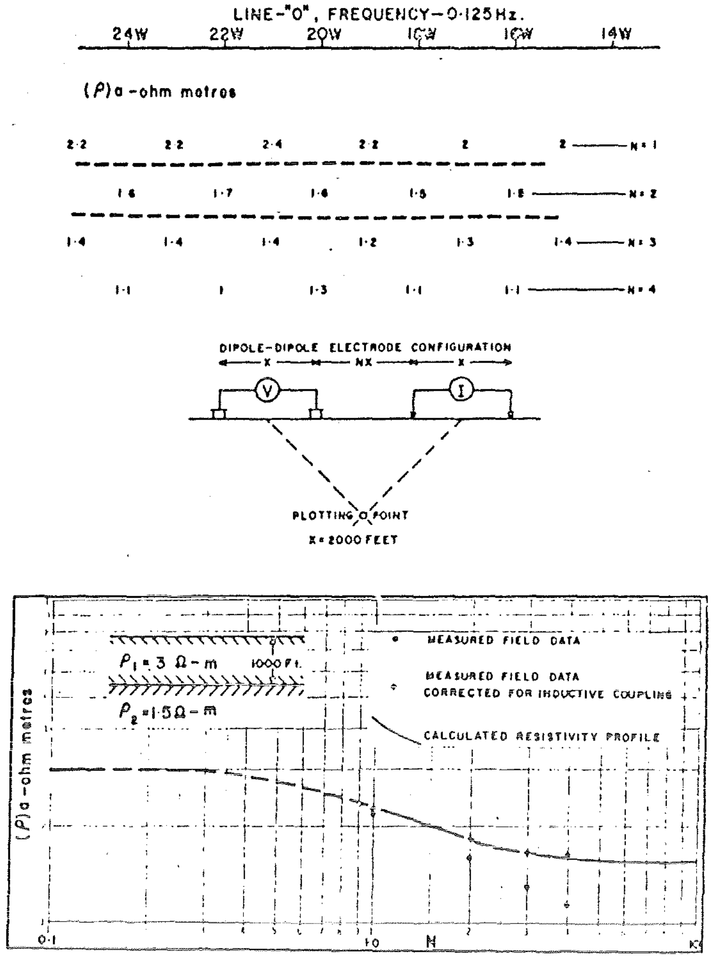
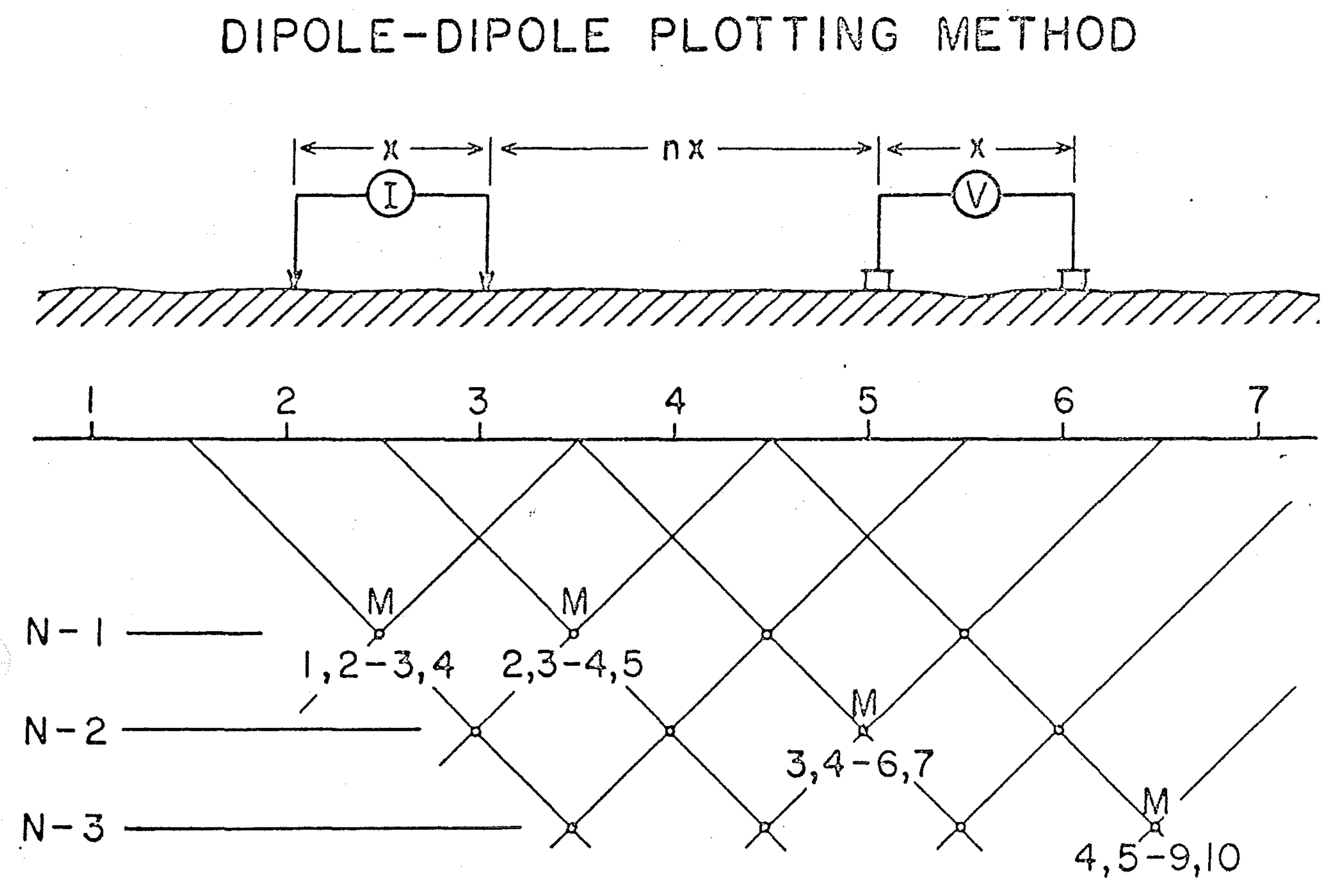


FIG. 4

data is then contoured (see below). The contour plots are not sections of the



electrical properties of the earth; they are convenient graphical representations of the measurements made. However, with experience the contour patterns can be interpreted to give some information about the source of the anomaly.

If the contour patterns indicate very simple geometries, more quantitative interpretations can often be made. For instance, if the contours are horizontal for a lateral distance of four to six electrode intervals, a horizontally layered geometry is indicated. In this situation, theoretical type-curves for dipole-dipole measurements in a layered geometry can be used in "curve fitting" techniques to give the true resistivities and depths for the earth.

McPHAR GEOPHYSICS

SUPPLEMENTAL REPORT ON THE RECONNAISSANCE RESISTIVITY AND SCHLUMBERGER DEPTH SOUNDING SURVEYS OF THE BACA PROPERTY VALLES CALDERA AREA SANDOVAL COUNTY, NEW MEXICO FOR UNION OIL COMPANY

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1. INTRODUCTION

At the request of Mr. Richard Donnanville, Consultant for Union Oil Company of California, McPhar Geophysics Inc., has continued and completed a reconnaissance resistivity and 5 Schlumberger depth sounding surveys in Valles Caldera Area, Sandoval County, New Mexico. The initial survey was terminated in July, 1973, by mutual agreement of Union Oil and McPhar. Termination was caused by excessive telluric noise resulting from intense thunderstorm activity in the area. The survey was resumed and completed following the end of the active thunderstorm period.

The geology of the area has been summarized by Bell in the initial report.

The purpose of the reconnaissance survey was to locate and delineate zones of low resistivity that might indicate areas of concentrated thermal activity. The Schlumberger depth sounding surveys were made to provide additional information on the thickness and resistivity of the geoelectric column in selected anomalous zones defined by the previous survey. In both cases, a frequency of 0.125 Hz was used in order to minimize attenuation of the electric field due to eddy current dissipation of energy and at the same time avoid telluric noise. The reconnaissance survey was made with 2000 foot dipoles along 2 reconnaissance lines. The Schlumberger depth soundings were made with the expanding Schlumberger electrode array with spacings expanding from 500 feet to as much as 15,000 feet where required by survey specifications.

The survey was conducted by Mr. Arlo Furniss, geophysicist, under the supervision of Mr. Donnanville.

2. PRESENTATION OF RESULTS

The resistivity survey results are shown on the following data plots in the manner described in the notes which accompany this report.

Line	Electrode Intervals	Dwg. No.
7	2000 feet	R 6126-1
8	2000 feet	R 6126-1
A	Schlumberger Depth Sounding	Figure 1
B	Schlumberger Depth Sounding	Figure 2
C	Schlumberger Depth Sounding	Figure 3
D	Schlumberger Depth Sounding	Figure 4
E	Schlumberger Depth Sounding	Figure 5

Also enclosed with this report is Dwg. No. RP 4909-R, at a scale of 1" = 2000'. The definite, probable and possible resistivity low anomalies are indicated by bars, in a manner shown in the legend, on this plan map as well as on the data plots. These bars represent the surface projection of the anomalous zones as interpreted from the location of the transmitter and receiver electrodes when the anomalous values were measured.

The thickness and resistivity of the various layers are illustrated graphically on each depth sounding curve and tabulated in Table I. The geoelectric section has been derived by standard curve matching techniques.

3. DISCUSSION OF RESULTS - DIPOLE-DIPOLE LINES

Anomalous resistivity responses are present on each line. The complex resistivities present on Line 1 through Line 6 do not occur in the area surveyed by Line 7 and Line 8. A discussion of the results of each survey line follows.

Line 7

Line 7 was a short traverse across a zone containing 3 geothermal wells; Baca 2, Baca 8, and Bond 1. The length of the line and dearth of data points makes interpretation quite difficult. The major feature is a sharp resistivity contrast at about 50E indicating a contact, high resistivity to the east, low resistivity to the west. The low-resistivity zone west of the contact is anomalous and coincidently contains the 3 wells mentioned earlier. The anomalous zone is open to the west; resistivities appear to decrease in that direction. The low-resistivity zone is classified definite, 0 to 20W; probable, 0 to 20E and possible 20E to 40E.

Line 8

Definite anomalies are present at 100E to 160E and 20E to 20W, open to the west. The area between both definite anomalies is a probable anomaly zone. Moderate to shallow depths are indicated for all zones. Excellent continuity with depth is indicated throughout the zone.

A contact is indicated near 180E to 200E by the complex resistivity contrast. The area west of the contact zone appears to be similar to a 2-layer case.

3.(A) DISCUSSION OF RESULTS - SCHLUMBERGER DEPTH SOUNDING

The geoelectric section was derived by curve-matching techniques using a set of curves calculated for a layered earth. As illustrated on the dipole-dipole resistivity profile, the area surveyed with the depth-sounding technique is not layered but complex, with vertical and horizontal discontinuities. Therefore, the geoelectric section is an estimate that ignores all vertical discontinuities, and errors of unknown magnitude are always present.

A discussion of each line follows, mindful of the errors inherent to the technique.

Line A

Line A explores a definite anomaly at about 75N, expanding along Line 3. The dipole-dipole data suggests a complex 2-layer case with a high surficial resistivity yielding to an anomalous low-resistivity zone, continues with depth. A strong resistivity contrast indicates a contact at or near 75N with low-resistivity material to the south and high resistivity to the north. The presence of the contact has a profound effect on the depth-sounding data.

A complex 4-layer case is indicated by the depth-sounding curves. Layer 1 is 56 feet thick with a resistivity of 40 ohm-feet, indicating soils and/or weathered bedrock. Layer 2 is 200 feet thick with a resistivity of 770 ohm-feet; probably post-caldera rhyolite. Layer 3 is definitely anomalous; the resistivity is 4.2 ohm feet and the thickness is 1400 feet. Layer 4 is very thick and resistive, indicating normal basement. Alternately, layer 4 could represent impermeable material beneath the steeply-dipping contact at 75N. The contact would account for the disparity between the continuous-with-depth anomaly indicated by the dipole-dipole survey and the limited depth derived from the soundings.

<u>Line B</u>

Line 4 investigates a definite anomaly at 100E on Line 4. On the dipole-dipole profile, a uniform earth bounded by a higher resistivity zone to the east is indicated. A weak horizontal discontinuity is indicated on n = 3.

A 4-layer geoelectric section is indicated from the depth sounding. Layer 1 is 52 feet thick with a resistivity of 10 ohm-feet, indicating conductive soils. Layer 2 is 52 feet thick with a resistivity of 100 ohm-feet, indicating a thin, weathered or altered unit, compositionally similar to Layer 2, Line A. Layer 3 is definitely anomalous, consisting of 1300 feet of low-resistivity material of 2.3 ohm-feet. Layer 4 is resistive and thick-assumed to be infinite. The horizontal discontinuity noted on the dipole-dipole profile probably represents the interface at layer 3 and layer 4. The thickness of layer 1 and layer 2, about 100 feet, would not have been apparent on the 2000 foot dipole-dipole spread.

Line C

Line C probes an unanomalous zone near 140N on Line 1. The dipole-dipole profile indicates a moderately high resistivity zone bounded on either side by sharp but poorly-defined resistivity lows. Bounding contacts are indicated at 100N and 18N. The resistivity is rather complex, continuity with depth is indicated and numerous vertical discontinuities are present.

In contrast, a complex 3-layer case is indicated from the depth-sounding curves. Layer 1 has a thickness of 70 feet with 40 ohm-feet, indicating soils and/or weathered bedrock. Layer 2 is definitely anomalous, 1800 feet thick with a resistivity of 4.2 ohm-feet. Layer 3 is thick resistive basement.

A topographic profile along Line C suggests a possible source of part of the disparity between the geoelectric section and the dipole-dipole data. The sounding point is in a small valley and there is 500 feet of vertical relief along lines to the north. The resistivity low may be in part owing to a strong topographic effect. However, the topography would not account for the entire low.

Line D

Line D investigates an unanomalous portion of Line 2 near station 80E. Resistivities along Line 2 are moderately high with a minor low at 50E to 90E. Strong resistivity contrasts indicate contacts at these points. No layering is suggested.

A complex 3-layer case is indicated by the depth-sounding curve. Layer 1 is 310 feet thick with a resistivity of 6.7 ohm-feet. The source is probably conductive alluvium; swampy areas are common in Valle Grande. Layer 2 has a thickness of 60 feet with a resistivity of 17 ohm-feet, indicating weathered bedrock. Layer 3 is thick, resistive basement. The combined thickness of layer 1 and layer 2 would not be apparent on a 2000-foot dipole-dipole survey except as a slight decrease in n = 1 values. Good correlation between the geoelectric section and the dipole-dipole data is present.

Line E

Line E was traversed across Line 2 as shown on plan map Dwg. No. RP 4909-R crossing near station 0. The area surveyed was similar to the area at Line D.

A complex 3-layer case is indicated by the sounding curve. Layer 1 has a thickness of 200 feet with a resistivity of 25 ohm-feet, indicating thick alluvium cover. Layer 2 has a thickness of 40 feet with a resistivity of 10 ohm-feet, indicating conductive beds, perhaps saline sediments. Layer 3 is thick resistive basement.

4. CONCLUSIONS AND RECOMMENDATIONS

The reconnaissance resistivity survey has further delineated an area of interest indicated by Line 3 and Line 4 of the previous survey. The definite anomaly at 100E to 160E on Line 7 is definitely of interest. As suggested by Bell in the previous report, the anomalous zone defined by Line 3, Line 4, and Line 8 appears to be a NW-trending fault zone. The fault zone may serve as the plumbing system for ascending geothermal fluids.

A definite anomaly at 20E to 20W, open to the west, is also of interest. This open anomaly may be the northern extension of a zone indicated on Line 7 and Line 4. Additional lines are necessary to fully delineate and define this possible zone.

The Schlumberger depth soundings indicate excellent shallow conductivity on Line A and Line B, further establishing this zone as a potential thermal area.

Comparison between the geoelectric section derived from the depth soundings with the dipole-dipole data at each point shows poor to good correlation. The lack of correlation in each instance is immediately apparent when the geologic complexity of the region surveyed is considered. Schlumberger depth soundings are designed to delineate the geoelectric section in a layered earth. As illustrated on the dipole-dipole profiles, the Valles Caldera is definitely not a layered earth situation.

Line D and Line E indicate the same unanomalous condition inducated by Line 2.

TABLE I

GEOELECTRIC SECTION

Line No.	Layer	Thickness (feet)	Resistivity $\rho a/2\pi$ (ohm-ft)	Interpretation
A	1	56	40	
	2	200	770	cap rock, ?, rhyolite
	3	1400	4.2	anomalous zone
	4	infinite	very high	basement
B	1	52	10	soils
	2	52	100	
	3	1300	2.3	anomalous zone
	4	infinite	very high	basement
C	1	70	40	soils
	2	1800	4.2	anomalous zone
	3	infinite	very high	basement
D	1	310	6.7	conductive soils
	2	60	17	alluvium
	3	infinite	very high	basement
E	1	200	25	soils - swamp
	2	40	10	alluvium
	3	infinite	very high	basement

Line C is quite puzzling in its response compared to the Line 1 response at the same station. Perhaps the situation can be rectified by detailed analysis of the well data from nearby Baca 5 and Baca 9, geologic and geochemical studies. Indeed, all these factors should be carefully studied and compared to the resistivity studies prior to drilling.

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Dated: January 11, 1974