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REPORT ON THE RECONNAISSANCE DIPOLE-DIPOLE RESISTIVITY SURVEY IN THE SODA LAKE AREA CHURCHILL COUNTY, NEVADA FOR CHEVRON OIL COMPANY

McPHAR GEOPHYSICS

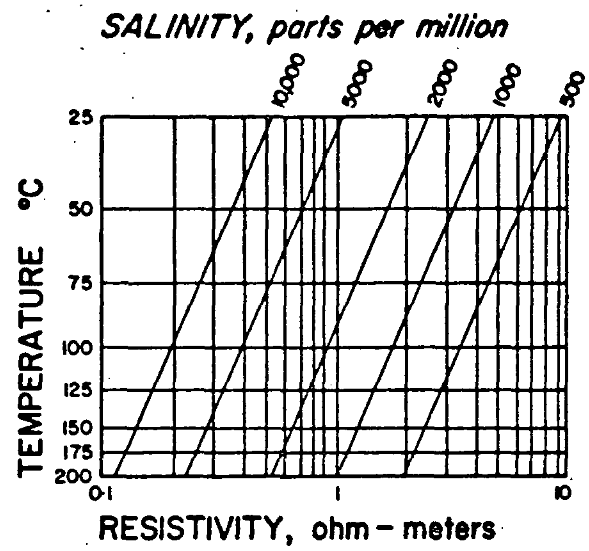
NOTES ON GEOTHERMAL EXPLORATION USING THE RESISTIVITY METHOD

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.

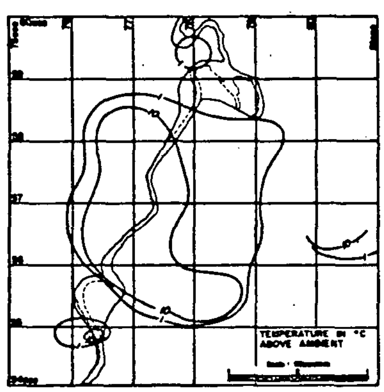


VARIATIONS OF SOLUTION RESISTIVITY
WITH TEMPERATURE AND SALINITY

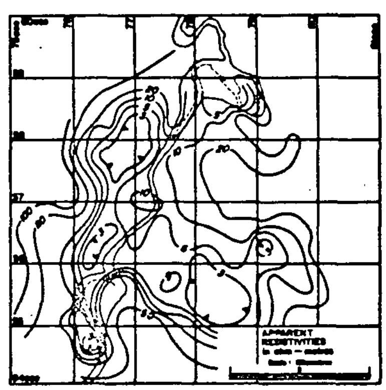
FIG. I

GEOPHYSICAL SURVEY

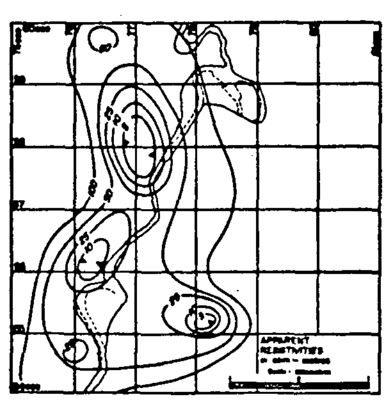
BROADLANDS AREA, NEW ZEALAND



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 • 65metres 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

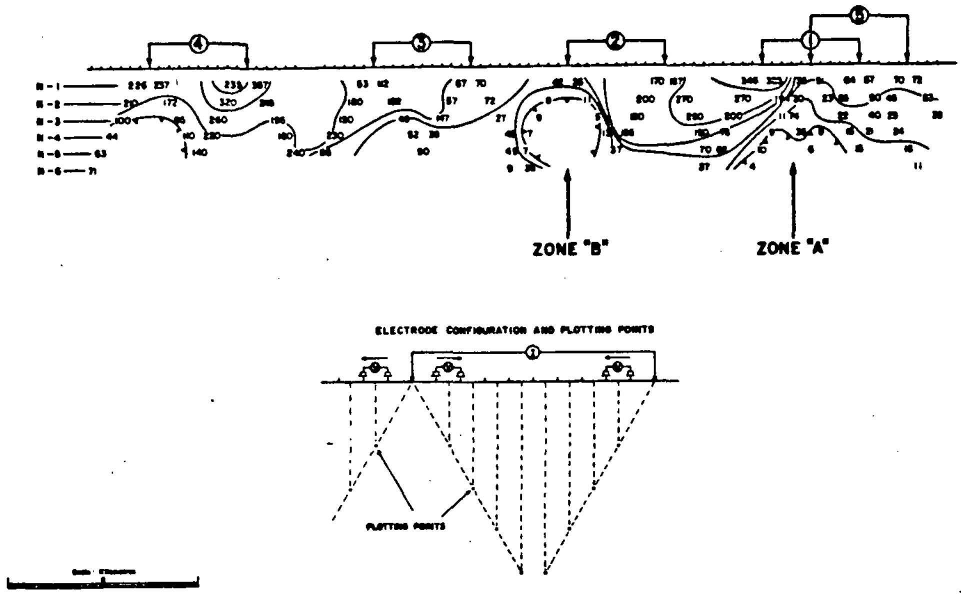


FIG. 3

RESISTIVITY SURVEY, IMPERIAL VALLEY–CALIFORNIA.

LINE–"O", FREQUENCY–0·125 Hz.

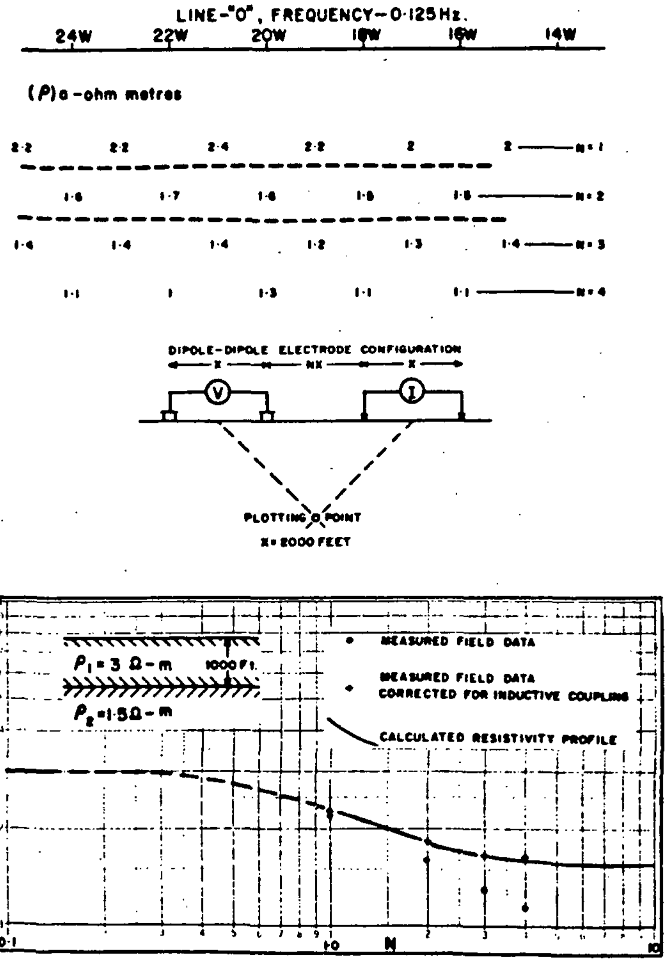
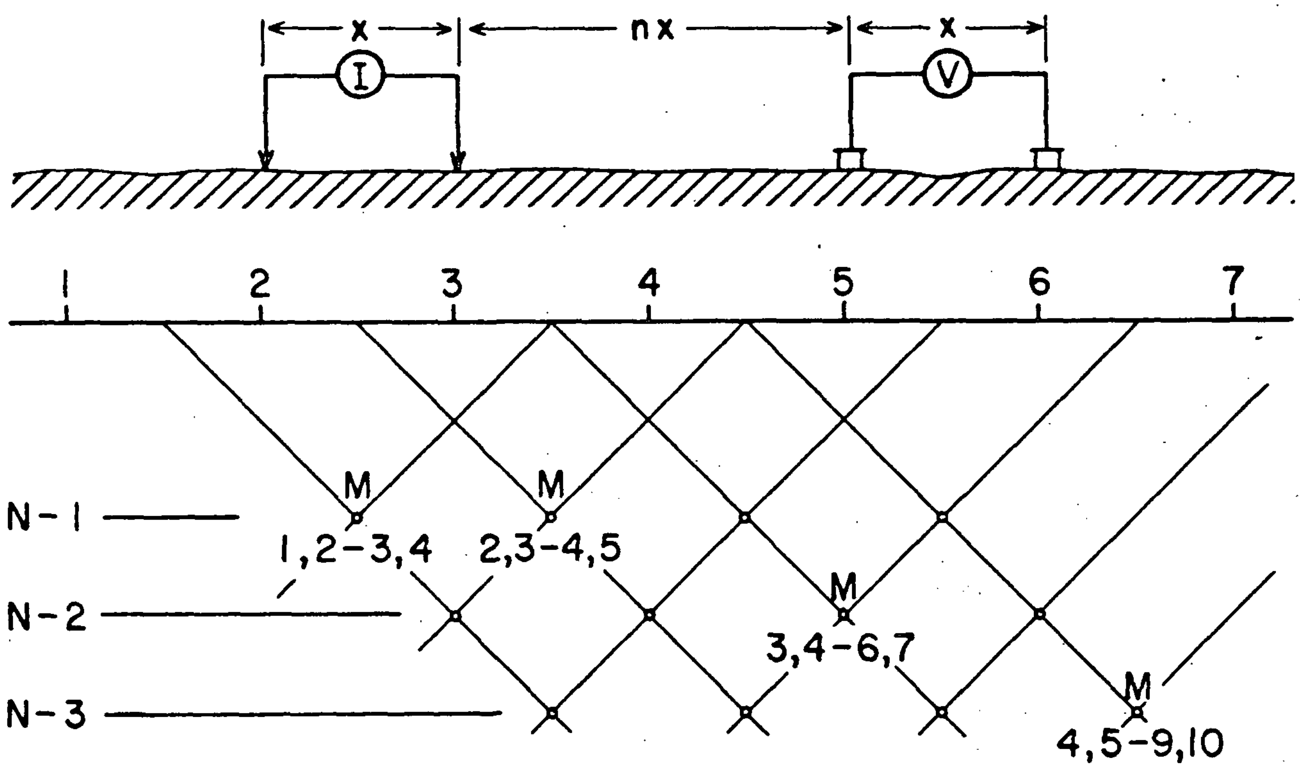


FIG. 4

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

DIPOLE-DIPOLE PLOTTING METHOD



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

REPORT ON THE

RECONNAISSANCE DIPOLE-DIPOLE

RESISTIVITY SURVEY

IN THE

SODA LAKE AREA

CHURCHILL COUNTY, NEVADA

FOR

CHEVRON OIL COMPANY

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1. INTRODUCTION

At the request of Mr. William Mero of Chevron Oil Company McPhar Geophysics has completed a Reconnaissance dipole-dipole Resistivity Survey in the Soda Lake Area, Churchill County, Nevada.

Initially, the resistivity survey of the Soda Lake, Known Geothermal Resource Area, was to consist of five north-south lines across an area of high temperature gradient. It was apparent, upon completion of Line A through Line E, that a zone of low resistivity extended beyond the area surveyed and additional lines were proposed to determine the extent of this zone. Measurements were made with 2000 foot dipoles at one-through-four dipole separations along eight reconnaissance lines spaced approximately one mile apart. 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.

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.
A	2000 feet	R 6128-1
B	2000 feet	R 6128-1
C	2000 feet	R 6128-1
D	2000 feet	R 6128-2
E	2000 feet	R 6128-2
F	2000 feet	R 6128-2
G	2000 feet	R 6128-3
Hq	2000 feet	R 6128-3
J	2000 feet	R 6128-3

Also enclosed with this report is Dwg. No. RP 4948, a plan map of the Soda Lake Area grid 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.

3. DISCUSSION OF RESULTS

The reconnaissance resistivity survey of the Soda Lake area has outlined a zone of low resistivity extending for approximately 10 miles in a northeasterly direction and averaging two miles in width, an area of approximately 13,000 acres. A description of the resistivity response along each survey line follows.

Line A

Definite anomalous responses (less than 1.5 ohm feet resistivity) occur between 50N to 130N and 150N to 220N. This definite response is interrupted between 130N and 150N by a slight increase in resistivity which is interpreted as a probable anomaly.

The resistivity response south of station 40N appears to indicate a simple layered earth with a near-surface resistive layer less than 1000 foot thick overlying a conductive subsurface. This varies from the response on the north end of the line (north of station 280N). The resistivity results of the north end of the line suggest a uniform earth, probably thick alluvial fill which does not contain any thermal fluids which produce the conductive anomalous response.

Line B

A shallow, definite anomaly occurs between 80S and 190S and extends as a possible anomaly from 190S to 260S. The definite response exhibits uniform resistivity to depth.

The possible anomaly located between 330S and 370S occurs at depth beneath a resistive overburden similar to Line A.

Line C

A broad, deep, definite anomalous response occurs between 70S and 130N with the strongest response between 40 and 60N. This response extends as a possible anomaly from 130N to 210N.

The near-horizontal contour pattern of the resistivity data between 80S and 100N suggested a simple layered earth beneath this portion of the line. Theoretical curve matching indicates a two-layer earth with the upper layer having an approximate resistivity of 40 ohm feet and a thickness of 1000 feet with the bottom layer having an approximate resistivity of 1.5 ohm feet.

The southern portion of this line was extended as Line I by Chevron Oil, but since it was an extension of Line C the data have been incorporated with this line.

Line D

The resistivity response on this line is very similar to Line A, one mile to the west. Definite anomalies occur at 20S to 20N and 50N to 160N. The interpretation of a probable anomaly between 20N and 50N is due to the increased resistivity at depth.

Line E

A broad, anomalous response of varying magnitude occurs on this line. The definite anomaly located at 20N to 30S is open on the south side due to Soda Lake. A probable anomaly extends from 20N to 70N and a possible anomaly occurs between 70N to 120N.

Line F

This line is located on the south side of Soda Lake. The definite, open-ended anomaly located on Line E does not extend far enough south to be observed on this line, but may be inferred by the possible anomaly between 10S and 10N.

The definite anomaly located between 120S and 150S is open-ended and extends as a possible anomaly from 120S to 90S.

Line G

A moderate to deep definite anomaly occurs between 60N and 50S. This line did not extend far enough south to close off the anomaly which appears to be shallowest on the south end of the line.

Theoretical curve matching of the near-parallel resistivity pattern between 0 and 100N indicates a two-layered earth. The upper layer has a thickness approximately 1000 feet and a resistivity of 20 ohm feet with the lower layer having a resistivity of 1.4 ohm feet.

Line H

The resistivity measurements along this line are slightly higher than any of the preceding lines except for the definite anomaly located at 240S to 260S.

This line is the most easterly line of the survey. The data suggest a decrease in thermal activity and may represent the eastern edge of the geothermal reservoir.

Line J

A definite anomaly occurs between 40N and 80S. The resistivity pattern for this line also exhibits horizontal contours which is indicative of horizontal layering. Theoretical curve matching indicates a two-layer earth very similar to Line G.

The possible anomaly located between 190S and 210S is open-ended to the south. The extension of this line should be considered.

4. CONCLUSIONS AND RECOMMENDATIONS

The Reconnaissance Resistivity survey of the Soda Lake area has outlined a zone of low resistivity approximately two miles wide and extending for 10 miles in a northeasterly direction. This zone appears to be ending on the east; Line H, the most easterly line surveyed, exhibits a weak anomalous response which may represent lateral effects and suggests that the potential geothermal reservoir does not extend past this line. The zone is not closed on the southwest. Additional work should be considered to determine the actual length of the anomalous zone.

Temperature gradient measurements have been obtained over part of the low-resistivity zone. Additional temperature gradient measurements may be required for complete correlation with the resistivity data which have located the strongest anomalous responses on Line C between 40N and 60N and on Line E beneath 20S.

The definite, open-ended anomaly between 120S and 140S on Line F warrants further investigation. This anomaly may represent another thermal zone which parallels the main zone. The possible anomaly on Line B between 330S and 370S may represent the north edge of the second zone and the definite anomaly on Line H between 240S and 260S may also represent this zone. Several temperature gradient measurements in this area, or the extension of Line A or Line B, would determine if this zone exists.

A complete correlation of all geological, geochemical and geophysical data is required to determine the location of a well to test the large anomalous zone.

McPHAR GEOPHYSICS INCORPORATED

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Geologist

Philip G. Hallof,
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Dated:January 11, 1974

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Re e-m coupling effects in McPhar DIDI survey at Soda Lake.

$a = 2000$ ft, $f = 1/8$ Hz throughout.

Using theoretical coupling curves for a few typical cases, we find that resistivities are <u>under</u>estimated according to following factors:

Case = n	Homog. Earth, $\rho = 2\frac{1}{2}\ \Omega$-m ($a^2f/\rho = 2\times10^5$)	Thin, resis upper layer $\rho_1 = 12\frac{1}{2}$, $\rho_2 \cong 1\frac{1}{2}$, $D_1 = A/8$	Thick, resis upper layer $\rho_1 = 12\frac{1}{2}$, $\rho_2 \cong 1\frac{1}{2}$, $D = A/2$
1	.98	.95	1.01
2	.93	.86	.91
3	.87	.74	.78
4	.79	.63	.67
5	.71	.54	.60
6	.63	.48	.55

And, for lesser contrasts, it's not so bad, viz:

n	Thick resis upper layer, $\rho_1 = 10$, $\rho_2 = 5$, $D = A/2$ ($A^2f/\rho = 2\times10^4$)	Thin resis upper layer: $\rho_1 = 10$, $\rho_2 = 5$, $D = A/8$ ($A^2f/\rho_1 \cong 2\times10^4$)
1	1.0	1.0
2	.99	.99
3	.99	↓
4	.96	↓
5	.94	↓
6	.92	.92