REPORT ON THE
RESISTIVITY SURVEY
IN THE
MEAGER CREEK SELECTED AREA,
LILLOOET RIVER REGION,
PEMBERTON, BRITISH COLUMBIA
FOR
NEVIN SADLIER-BROWN, GOODBRAND LTD.
BY
McPHAR GEOPHYSICS COMPANY

28 JAN. 1975

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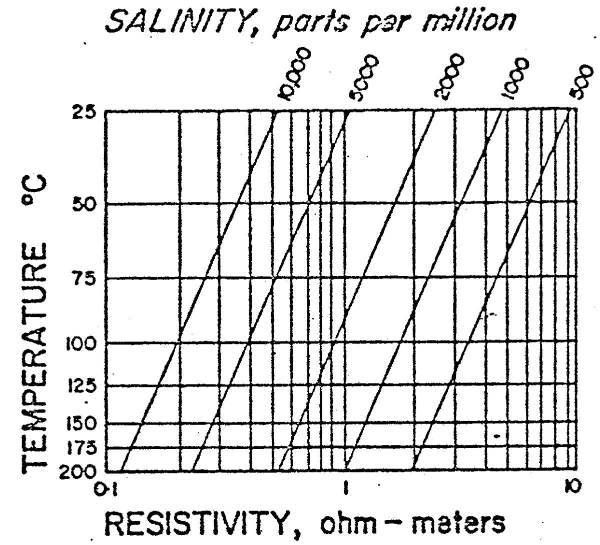
NOTES ON GEOTHERMAL EXPLORATION USING THE RESISTIVITY METHOD

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.

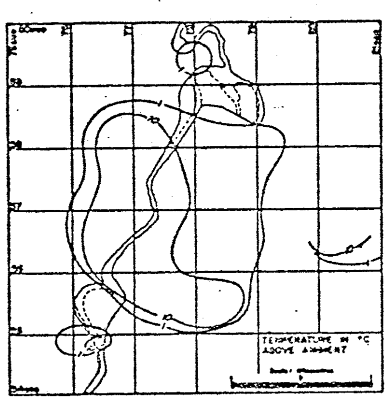


VARIATIONS OF SOLUTION RESISTIVITY
WITH TEMPERATURE AND SALINITY

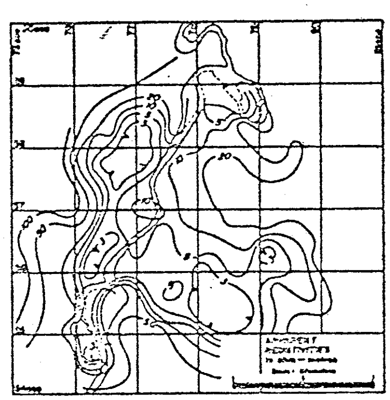
FIG. 1

GEOPHYSICAL SURVEY

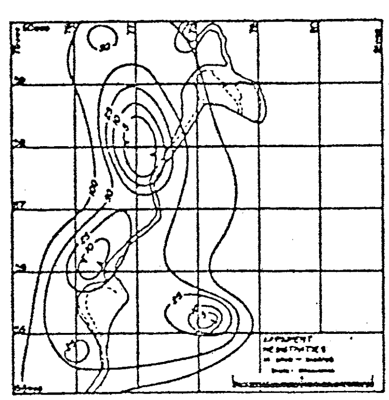
BROADLANDS AREA, NEW ZEALAND



A. TEMPERATURE AT 15m DEPTH



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



C. APPARENT RESISTIVITY SURVEY USING
LOOP TO LOOP ELECTROMAGNETIC METHOD

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–Batur Road

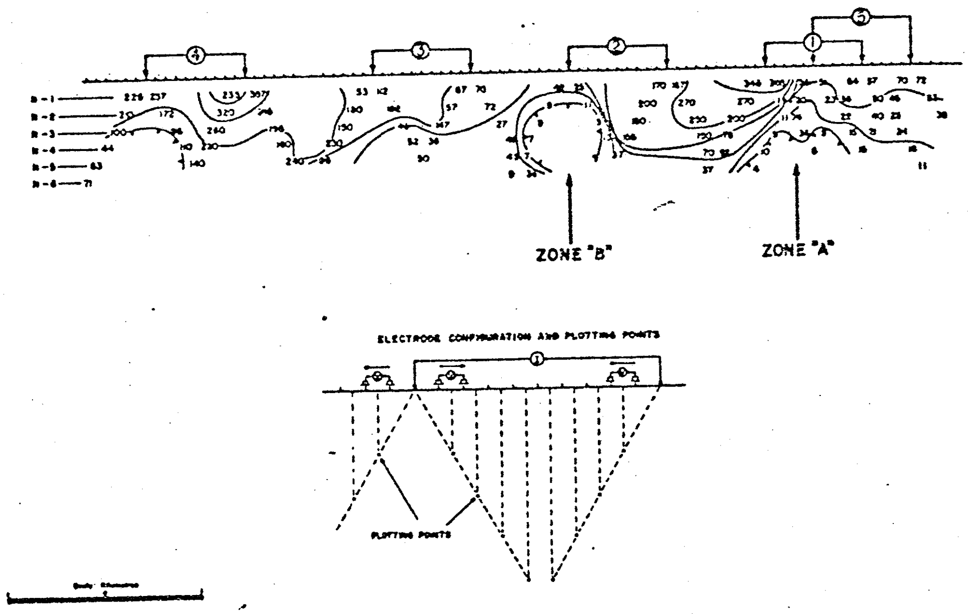
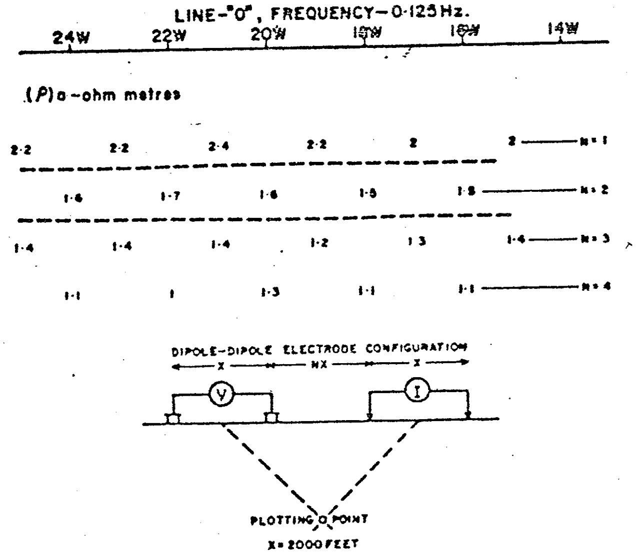


FIG. 3

RESISTIVITY SURVEY, IMPERIAL VALLEY–CALIFORNIA.

LINE–"0", FREQUENCY–0·125 Hz.



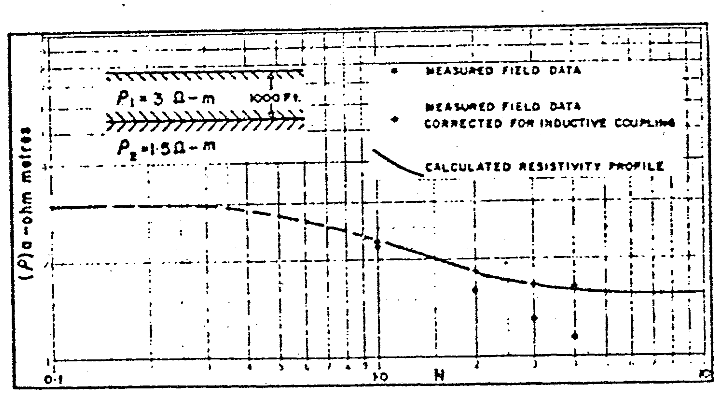
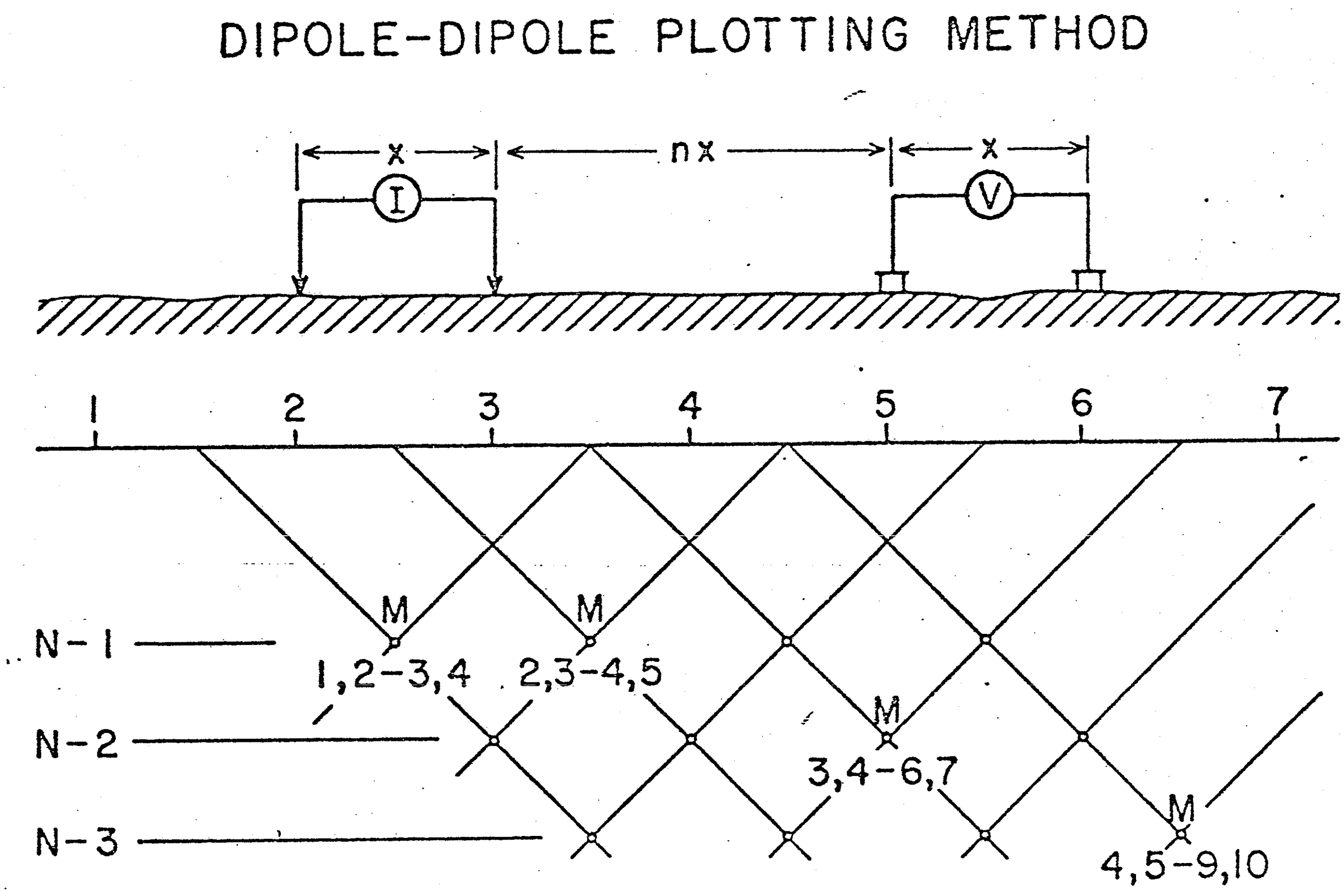


FIG. 4

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.

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1. INTRODUCTION

We have completed a Reconnaissance Resistivity survey in the Meager Creek Selected Area, on behalf of Nevin Sadlier-Brown, Goodbrand Ltd. They in turn, are acting as consultants to B.C. Hydro. The area lies approximately thirty-five miles northwest of Pemberton, B.C.; the presence of several hot springs in the vicinity suggests that the area may be of possible importance as a source of geothermal energy.

As explained in the notes preceding this report, the known geothermally active areas in the world had been found to be regions of low resistivity. The reconnaissance resistivity survey in the Meager Creek Selected Area was planned to determine the general resistivity configuration in the immediate vicinity of the hot springs and also to detect any large zones of unusually low resistivity that might be present.

2. PRESENTATION OF RESULTS

The results of the reconnaissance resistivity survey are shown on the following enclosed data plots. The results are plotted in "pseudo-section" form, so that lateral variation in resistivity can be separated from vertical variations.

Line	Electrode Intervals	Dwg. No.
A	1000 feet	R-6253-1 Top
C	1000 feet	R-6253-1 Centre
	500 feet	R-6253-1 Bottom
D	1000 feet	R-6253-2 Top
E	1000 feet	R-6253-2 Centre
F	1000 feet	R-6253-2 Bottom

Two plan maps have been prepared showing the area surveyed, the relative position of the lines and some topographic features.

Dwg. No. RP 5036-1 (Scale 1:100,000) shows all of the lines

Dwg. No. RP 5036-2 (Scale 1: 10,000) shows detail for Line C, Line D and Line E.

3. GEOLOGY

The principal rock type underlying the area is Mesozoic granodiorite, which is overlain unconformably by late Tertiary and Quaternary volcanic rocks. The volcanics are intermediate composition and form flows, fragmental rocks and plugs on the upper slopes of Meager Mountain. Most of the resistivity lines were run along valley bottoms or in topographic saddles. With the exception of Line A, all of the lines are known or presumed to be run on granodiorite. The western part of Line A is run on a dacite ignimbrite, which overlies a bed of semi-consolidated gravel, which in turn unconformably overlies granodiorite. The dacite and gravel lie in the ancestral valley of the Lillooet River.

The eastern part of Line D and adjacent parts of Line C, are on thick overburden unbroken by rock outcrop. In places the overburden near the lines consist of banks 400' high containing clay deposits of volcanic origin.

The density of fractures in the granodiorite appears to be no more nor less than any other typical Coast Range intrusive rock. Locally, however, there are faults and fractures, and in particular there is a regional set of fractures trending west northwest and dipping steeply.

Near Line A, Line C and Line D, there are three hot spring complexes. The most important of these, near station 180SW on Line C, has been thoroughly studied as to its chemical make-up. It has a temperature of nearly 60°C, and contains about 2,000 ppm. total dissolved solids. The analysis on this spring and on a few shallow drill holes nearby is available. In general the springs adjacent to Line A and Line D have similar chemical compositions and similar total dissolved solids contents, although they have a lesser rate of flow.

4. DISCUSSION OF RESULTS

The reconnaissance resistivity survey in the Meager Creek Selected

Area was carried out using 1000' electrode intervals and n = 1,2,3,4. A considerable resistivity variation was detected in the area surveyed.

Line A

This line extends NW-SE across the northern end of the area of interest. At the northwest end of the line the resistivity values show a near-surface, high resistivity layer overlying a lower resistivity second layer. This correlates with the known geology which shows a dacite overlying a semi-consolidated gravel. The apparent resistivity data in the interval from 260NW to 300NW was "computer-fit" to a layered media. The values are H = 725 feet, $\rho_1/2\pi$ = 2784, $\rho_2/2\pi$ = 448; the fit is extremely good. The depth of 725 feet is therefore, the best estimate of the thickness of the non-porous volcanic rock unit.

Some sulphide mineralization has been observed in the vicinity of the deep, distinct resistivity low at about 150NW to 160NW.

At the southeast end of the line, the last few measurements suggest a narrow zone of very low apparent resistivities centred at approximately 70NW. At this point Line A is approaching the valley of Meager Creek. The resistivity anomaly appears to be due to a narrow, porous structure (fault?) rather than to a valley filled with unconsolidated sediment. The measurements on Line A would have to be extended to the southeast to complete the anomalous pattern and permit a more definite interpretation. Closely spaced parallel lines would also have to be surveyed in order to determine the strike of the anomalous feature.

The central portion of Line A passes over the granodiorite, with neither the dacite, nor unconsolidated sediments present in significant thickness. The apparent resistivities measured are moderately high. In the interval from 140NW to 170NW the apparent resistivities at depth are appreciably lower. This suggests greater porosity (fracturing or alteration) with the rocks.

Line C

This line was surveyed along the southeast side of Meager Creek, with the vast volume of the Meager Mountain volcanic complex lying to the northwest. Within the valleys, there could be thick (several hundred feet) sections of ash and other sediments derived from volcanics. The hot springs along Meager Creek and Lillooet River issue from the Mesozoic intrusive at the base of this volcanic complex.

A major crustal facture has been identified along the valley of Lillooet River and another along the valley of Meager Creek. If this fault structure has created increased porosity, this would be a low resistivity zone approximately parallel to the line.

The apparent resistivity results from about 180SW to 90SW show that a lower resistivity zone is having an increasingly greater influence on the measurements as the survey proceeded to the southwest. To the northeast of 90SW to 80SW the apparent resistivities are high, probably reflecting the near-surface presence of the non-porous, unaltered, unfractured intrusive. The position at 90SW to 80SW is well within the valley of Meager Creek; however, the valley is much narrower to the northeast of this point and granodiorite outcrops just to the northeast of 90SW on Line C. Therefore, it is reasonable to suppose that the high resistivity rocks are much nearer to the measurement point here, than they would be to the southwest.

The apparent resistivity pattern suggests that either the overburden thickness increases to the southwest or that the line is approaching a narrow, conducting feature (fault) at a shallow angle. The apparent resistivity results in the interval from 120SW to 90SW were used to "computer interpret" a two-layer or three-layer geometry that would approximate actual earth situations.

The iterative computer program used for the inversion attempt is extremely good, and almost always gives some type of approximate answer, even in non-layered situations. In this case the program refused to give an approximate answer. It must therefore be assumed that the actual earth situation cannot be even remotely approximated by a layered medium. Certainly, it cannot be simply a gradually increasing wedge of conductive stream sediments. However, in a relatively narrow valley the conductive overburden could not be considered to be a "layered earth", in any case.

In the interval from about 270SW to 250SW the resistivity pattern changes again. To the southwest of this point the apparent resistivity level is once again moderately high, although not as high as at the northeast end of the line. In this area, the line begins to climb up the sides of the valley. At about this point the contour patterns indicate three narrow, conductive features.

There is a shallow, moderately low narrow feature centred at 295SW. There is a relatively narrow zone of low resistivities centred at

270SW to 260SW, at considerable depth. There is a very definite, narrow zone of low resistivities at 235SW. This feature seems to separate the two different resistivity environments that exist to the northeast and the southwest. This narrow, shallow feature was checked using X = 500 feet. The results show a narrow zone of low resistivities centred at 232+50SW. This anomaly has all the characteristics that one would expect from a zone of increased porosity with a narrow width and considerable vertical extent. The most obvious geologic feature would be a fault.

Line D

This east-west line extends along Meager Creek to the west of an almost 90° bend in the creek itself. At its eastern end it crosses both Line C and Line E. West of about 115W and east of about 15E, the apparent resistivities are moderately high, probably reflecting the relatively non-porous intrusive. In the interval from 115W to 15E the apparent resistivities range from low to very low.

Throughout this interval, the lowest apparent resistivity values were measured for n = 1. The values measured increase for increasing values of (n). Following the "computer interpretation" procedure used in portions of Line A and Line C, two apparently layered portions of this line were used. The apparent resistivity values in the region from 95W to 55W and from 35W to 5E were fed into the computer program. As on Line C, the result was that no layered earth could be found that would give rise to the measured values. Therefore, it cannot be assumed that the resistivity pattern measured from 105W to 15E is due simply to a thick layer of recent porous stream sediments. However, as on Line C, the topography of the valley suggests that the layering cannot extend very far to the north and south.

At the ends of this zone of low resistivities Line D still lies well within the valley of Meager Creek. Therefore, there is no reason to suppose that the overburden thicknesses would change abruptly. The ends of the resistivity low occur at topographic features (creeks, ravines, etc.) that could reflect fault structure.

It must be considered, therefore, that it is possible that the extremely low resistivities in the interval from 105NW to 15E are due to close proximity to a parallel, porous fault structure that may or may not be the conduit for geothermal solutions. The results from the brief survey reported here are not complete enough to permit a rigid interpretation.

Line E

This line was surveyed parallel to Line C, a distance of 2000 feet to the southeast. This line is entirely within the environment of moderately high apparent resistivities. There are narrow zones of somewhat lower values at 260SW to 250SW and at about 200SW. The sources of the slightly lower resistivities are indicated to be at some depth.

Line F

This line was surveyed along the top of a relatively flat hill just to the south of Meager Creek. The apparent resistivities measured are relatively uniform and moderately high.

5. CONCLUSIONS AND RECOMMENDATIONS

The first resistivity results from the Meager Creek Selected Area are of definite interest. There are distinct resistivity lows on Line C and Line D, and particularly at the intersection. The anomalous patterns of the resistivity lows appear to be due to increased thicknesses of porous, conductive stream sediments. However, attempts to do a "computer interpretation" of the results on Line C and Line D using a layered earth geometry have shown that the field data can not be approximated as being due to a layered earth. However, it must be recognized that the finite width of the valleys would limit the "infinite" behavior of the sediment layer. The possibility must be considered that the resistivity lows on Line C and Line D are due to the lines lying close to, and approximately parallel to, linear conductive features such as faults. The faults could be important as conduits for geothermal solution. The presently available data is not complete enough to permit a definite interpretation.

A drill hole has been started at about 210SW on Line C. The purpose of Hole No. 74-H-1 was to determine the nature of the sediments in the Meager Creek Valley and to determine the possible presence of a geothermal source at depth. The following drill hole log is available to date:

0 - 220 feet	coarse boulders, sand and gravel
220 - 320 feet	clay, possibly unconsolidated tuffaceous material
320 - 363 feet	boulders, sand and gravel

Several samples from the drill hole were consolidated enough to permit resistivity measurements to be made in the laboratory. These values range from 8.0 to 28 for $\rho/2\pi$ in ohm-feet. The measured resistivity values should be correlated with the geologic log for Drill Hole No. 74-H-1; it would be expected that the clay layer from 220 feet to 320 feet would have the lowest apparent resistivity value.

A better interpretation for the source of the resistivity lows measured during this reconnaissance resistivity survey could be made only if further data is available. Closely spaced parallel lines and/or perpendicular lines would have to be surveyed to determine whether the regions of lower resistivity are due to a complex layering situation within the stream sediment filled valleys or to relatively narrow, linear, conductive features (such as faults) that occur approximately parallel to the lines surveyed, in the bedrock.

The results of the first drill hole, and further resistivity data will permit a more definite interpretation.

McPHAR GEOPHYSICS COMPANY

Philip G. Hallof

Philip G. Hallof,
Geophysicist

Bruce S. Bell

Bruce S. Bell,
Geologist

(per R. C. Bell)

Dated: January 28, 1975