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R E P O R T O N T H E

MAXI-PROBE EMR-16 TEST SURVEY

AROUND

MEAGER CREEK AREA (B.C.)

FOR

GEOLOGICAL SURVEY OF CANADA

by

GEOPROBE LIMITED
32 Progress Ave.,
SCARBOROUGH, Ontario.

MARCH 1978

GEOPHYSICAL INSTRUMENTATION & SERVICES

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1. INTRODUCTION:

At the request of The Geological Survey of Canada, GEOPROBE LIMITED carried out a multi-spectral E.M. resistivity survey using the MAXI-PROBE EMR-16 system around Meager Creek Area (B.C.). The intention of the survey was to determine the thicknesses of the different electrical resistivity units of the ground at different depths by making multi-spectral E.M. measurements on the ground surface. The purpose of this test survey was to investigate if the MAXI-PROBE system was capable of determining the different layers of the ground on the basis of electrical properties of the different media. This test survey was performed for six (6) days during the month of July 1977.

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At further request from the Geological Survey of Canada, GEOPROBE LIMITED has interpreted the results of the test survey in March 1978.

The survey crew of GEOPROBE LIMITED consisted of a Geophysicist, two operators and one helper. This survey was performed under strict instructions from the scientific authority, Dr. A.K. Sinha of the Geological Survey of Canada. GEOPROBE LIMITED was involved only in making MAXI-PROBE measurements. GEOPROBE LIMITED has interpreted the results of the survey to determine the thickness and electrical resistivity of each medium.

The survey consisted of making MAXI-PROBE measurements (soundings) in nine separate areas. Each area has been designated on Plates 1 and 2 as a separate line. Test measurements were made at the initial part of the survey to select a reasonable separation (spread) between the transmitter (Tx) and receiver (Rx) units, the range of frequencies, so that the ground may be scanned with a high degree of accuracy. These data were reduced in the field with the help of a HP-67 programable calculator to obtain immediate feed-back of the results. These results formed the basis of selecting the parameters of the survey. A total of forty-five (45) measurements (soundings) were made. Prior to survey measurements, distances were chained by the crew.

2. SURVEY AREAS:

The MAXI-PROBE test survey was carried out in nine separate areas.

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Soundings were made at five (5) long lines. These are Lines 1 and 2, using a Tx-Rx spread of 300 meters, and Lines 1, 8 and 9, using a Tx-Rx spread of 500 meters. Measurements were made on shorter Lines 3, 4, 5, 6, and 7, using a Tx-Rx spread of 300 meters. Only at a few locations, soundings were made using perpendicular orientations of the Tx-Rx array. This was done to check any affects of anisotropy in electrical resistivity.

3. OBJECTIVE OF SURVEY:

This area of survey has a few hot springs. It is suspected that there probably is a source for these hot springs at a considerable depth.

The primary objective is to detail the presence of the source of these hot springs. This could be a potential geothermal resource area. The main objective of the test survey is to find out if MAXI-PROBE system is capable of determining the thickness and electrical resistivity of each medium in the ground. If successful, this MAXI-PROBE system may further be used in performing production survey to detect the geothermal zones by determining their very low electrical resistivities.

4. MAXI-PROBE EMR-16 SYSTEM:

The MAXI-PROBE EMR-16 system has been developed by GEO-PROBE LIMITED in cooperation with the Geological Survey of Canada. This system is now manufactured by GEOPROBE LIMITED.

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It operates on the principle of Geoprobe E.M. Technique invented in 1973. This equipment and the technique are patented.

The MAXI-PROBE system is a large scale multi-spectral wide-band E.M. system having a frequency range of 1 - 40,000 Hz. The principle behind this technique is that current at high frequencies penetrate only a shallow part of the ground. As the frequencies are decreased, currents penetrate deeper and deeper into the ground. Therefore, the entire depth is scanned using high to low frequencies. This system is capable of operating on 128 frequencies. However, only 15 - 30 frequencies are selected in a particular frequency range to distribute the induced currents to a range of desired depth of penetration.

This selection also depends on the electrial resistivities of the ground and the separation between the transmitter (Tx) and receiver (Rx). It is also possible to select a number of frequencies within a small frequency range to focus the induced currents to a particular depth in the ground for a detail investigation of the electrical properties at that depth.

This E.M. system has a Tx and a Rx, without any cable connecting the two. They are synchronized by very stable clocks for phase reference.

The Tx is powered by a gasoline driven generator of 2.5 Kwatts which supplies about 60 volts D.C. to the Tx.

This drives the power source to produce square waves at the transmitting loop. The transmitting loop used in this survey is a 30 foot diameter loop consisting of 10 turns of cable.

A maximum of 350 amperes of current is sent in this loop to energize the ground. This loop weighs about 20 lbs. This is an open loop. Two ends of this loop are connected at the transmitter box. This loop may be spread out on the ground in any shape; however, a circular shape obviously delivers the most dipole moment. To obtain more power at the transmitting station, two such loops were used in this survey. These loops were connected in parallel and laid on the ground in the shape of a figure eight (8) to avoid mutual coupling between these loops.

The Rx is a two channel system, measuring the inphase and quadrature components of the vertical channel and horizontal channel magnetic fields. The antenna is in the shape of a square frame which is packed by shock absorbing foam and enclosed inside a fibreglass spherical shell to protect from any vibrations that may be caused by wind. This ball sits on a ring. The levelling of this antenna system is done with the help of an air-bubble on the spherical shell.

A set of measurements at a particular receiver station is called a sounding. The Tx and Rx are kept fixed and measurements are made at high to low frequencies. The measurement point is the centre point of the Tx and Rx array.

The basic principle behind this technique is that the induction currents at each frequency penetrates a different depth in the ground. The ground is scanned from a shallow depth to a large depth using a whole range of frequencies.

Therefore, any discontinuity in the electrical resistivity of the ground is reflected in the measurements. Apparent resistivities may be calculated at each frequency so that a vertical apparent resistivity log of the ground is obtained for the whole frequency spectrum. The result of one sounding is the average result of an area approximately 20% of the separation between the Tx and Rx at the measurement point. This depends on electrical resistivities of the ground. However, if the ground is complex, more information of one sounding corresponds to the measurement point. Better accuracy is obtained in results if measurements are made at a larger number of frequencies.

Detail investigation of the ground may be done in two ways:

i) by using different separations between Tx and Rx, and
ii) by keeping the Tx fixed and moving the Rx along a line or along an arc.

It is important to mention that larger loops (50 foot - 3 loops) may be used to obtain approximately eight times more dipole moment compared to the 30-foot diameter loop.

5. SURVEY PROCEDURE:

A more or less flat ground was selected to set-up the transmitting (Tx) loop. If the Tx-loop was not horizontal, the inclination of the plane of the Tx-loop was noted.

Corrections are made to the field data for inclination of the Tx-loop.

The receiver (Tx) was set-up at a finite distance away from the Tx-station. This distance between the Tx and Rx varied in this survey. It is important to know this distance between the Tx-Rx quite accurately, because all depth estimates are evaluated in ratios of this distance.

The two transmitting loops, connected in parallel, were oriented along the line of Tx-Rx stations. The Rx-antenna (ball) was placed on a three-leg ring. The seam of the ball was oriented towards the Tx-station. This orientation is not very critical. A tolerance of $\pm 5^{\circ}$ is acceptable. The vertical direction of the antenna was oriented by levelling the air-bubble on top of the ball.

At each area, from the results of the first measurements, approximate depths of penetration are usually estimated. Then, an optimum spread between the Tx and Rx is selected to obtain a better resolution of different media at depth. However, due to the nature of the test survey and due to limited amount of time, these tests were not performed in all areas. The spread between the Tx and Rx was kept between 300 meters to 500 meters.

In this survey, a frequency range of 40Hz - 40,000 KHz was used. The number of frequencies used in this survey varied between 15 - 25. Larger number of frequencies are usually used for deeper structures.

The principle behind this technique is the fact that a particular depth is investigated using a particular frequency. Larger depths are penetrated using lower frequencies.

6. INTERPRETATION:

Measurements that were made at the Rx-station are the Inphase and Quadrature components of the Vertical (H_z) and Horizontal (H_x) magnetic fields. These four measurements were taken at each frequency of operation. For an operation of 20 frequencies, a total of 4 X 20 = 80 measurements were taken at one station.

Using the four measurements of the Inphase and Quadrature components, the interpretation parameter called the CORRELATION FACTOR was calculated at each frequency using a mini-computer. The apparent resistivity at each frequency may be calculated using these CORRELATION FACTORS by a computer. The maximum depth-penetrations were calculated using a computer. This maximum 'depth penetration' is termed here as "apparent-depth". It is possible to calculate the "apparent-resistivity" and "apparent-depth" from the measurement at each frequency. This indicates the variation of the 'apparent resistivity' with depth. This presentation is called a 'vertical apparent resistivity log' of the ground. The idea is similar to an 'electrical resistivity log' in a drill hole. However, the 'vertical apparent resistivity log' obtained by the MAXI-PROBE system is the result of measurements made on the ground surface.

(Because of the nature of the contract for the interpretation of data, a different approach was undertaken to determine the thickness and resistivity of each media. This is described later in this section).

'Apparent resistivities' at depth are by no means true indicative of actual resistivities, because the resistivities of the overlying material contribute an averaging effect. It is most important to note that the 'apparent resistivities' at depth depend on the resistivities of the overlying media. Therefore, caution must be applied not to attribute a very specific meaning to any particular value of the 'apparent resistivity'. The most important implication of 'apparent resistivity' in MAXI-PROBE technique is its variation with depth. If a material present at a particular depth is different from the one above it, the 'apparent resistivity' will show a change indicating the presence of a different medium.

The interpretation of data was done to show the resistivity and thickness of each medium. These are presented in Plates 1 and 2 in the form of DEPTH-SECTIONS. Resistivities and the thicknesses were calculated using the computer. Many media of different electrical resistivity were encountered at each sounding. At first, the minimum and maximum depth penetration were determined. Effect of each of the overlying layers was removed from the data to interpret the resistivity and thickness of an underlying layer. The resistivity of the topmost layer is the average of the resistivities including any overburden upto the bottom of the first layer indicated in the depth section. The resistivities of other layers are determined in comparison with the resistivity of the first layer.

It is not possible to detect any layer in the area of survey which is shallower than the minimum penetration obtained in the sounding.

7. RESULTS AND CONCLUSIONS:

Results of survey have been presented in the forms of "DEPTH-SECTIONS" in Plates 1 and 2. Plate 1 contains the results of soundings using a Tx-Rx spread of 300 meters and Plate 2 contains the results using a Tx-Rx spread of 500 meters. (Only sounding No. 2 in Plate 2 was performed using a Tx-Rx spread of 600 meters).

Results of each of the lines have been grouped together to represent a possible electrical resistivity section of the ground. The position and thickness of each layer is indicated in the "Apparent-Depth" axis. "Apparent-Depth" axis may be thought of as the real depth if the ground behaves like a multi-layer model. Otherwise, the real depth is not equal to apparent-depth, because rates of fall-off for E.M. responses are different for layered models compared to complex ground conditions.

The sounding number and station number have been presented on the x-axis. Where soundings have been taken using perpendicular Tx-Rx arrays, they have been represented as cross soundings.

Each probable horizon of different electrical resistivities has been presented as a dash (-). Minimum and maximum depth penetrations for each sounding have been marked as arrows facing down and arrows facing up.

Where maximum penetration has not been indicated, it should be assumed that the bottom layer continues up to the depth of investigation as outlined in the apparent-depth axis.

Estimated resistivity (in ohm-meters) of each medium has been represented as a number between two dash marks which indicates the thickness of each medium.

Numerous thin zones of quite low resistivities (less than 300 ohm-meters) have been detected. Resistivities of these zones cannot be estimated because these media are so thin. These have been represented as thin screens in depth-sections. These zones might indicate fracture zones filled with solutions. These are typical of this survey. These kinds of responses were obtained in other MAXI-PROBE surveys where interbedded clay and shale were present in a sedimentary section.

Other low resistivity zones have been detected which have considerable thicknesses. All zones that have resistivities less than 300 ohm-meters have been presented as screens for identification purposes.

Some variations of resistivities of different media have been found when Tx-Rx array is oriented perpendicular to a station. This might indicate anisotropy in electrical resistivities.

Line 1 has been surveyed using 300 meter and 500 meter spreads between the Tx-Rx.

The resistivities of the media have been found to be different for these two different Tx-Rx spreads. This effect may be explained considering a larger averaging effect in the lateral direction for a larger Tx-Rx spread compared to a smaller Tx-Rx spread.

At two soundings, No. 9 and 28, the results could not be interpreted as a layer model. This may be due to a complex ground showing any structural features. These have been identified as S.F. in the depth-section.

Considerably low resistivity zones have been identified on Lines 2 and 9 which are close to Pebble Creek and Capricorn + Meager Creeks. More detail investigation of the ground should be carried out in these areas.

The overall resistivity of the host rock is found to be in the order of thousands of ohm-meters. This fact makes it feasible for the MAXI-PROBE system to obtain penetrations up to about two kilometers (2 km) in depth, if proper Tx-Rx spread and frequency range is selected. It may be concluded that the MAXI-PROBE EMR-16 system appears to have the capability of detecting low resistivity zones, typical of geothermal targets, upto a depth of 2 Km or more in this area.

Respectfully submitted by
GEOPROBE LIMITED

REGISTERED PROFESSIONAL ENGINEER
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/jm

APPENDIX 1*

LOCATION OF SOUNDING STATIONS
FOR THE GROPROBE E.M. SURVEY
IN THE MEAGER CREEK AREA, B.C.
CONDUCTED IN JULY, 1977.

* Appendix 1 compiled by A.K. Sinha of the Geological Survey of Canada, Ottawa.

Line No.	Sounding No.	Tx-Rx SEP.(m)	Location and Remarks
1	1	300.0	Line 1 began 0.5 miles East of
1	2	600.0	North Creek at 11.4 miles position
1	3	500.0	off the North Logging Road
1	4	300.0	
1	5	300.0	
1	6	500.0	
1	7	500.0	Soundings 13 and 14 were taken
1	8	300.0	at positions of 550 and 200 m.
1	9	300.0	south of the main line 1 for
1	10	500.0	studying the Anisotropy effects
1	11	300.0	in the region.
1	12	300.0	
Across 1	13	290.0	
Across 1	14	300.0	
2	15	300.0	Line 2 was taken along E-W direction
2	16	300.0	along a cross road off the North
2	17	300.0	Logging Road at 17.5 miles position
2	18	300.0	(Branch 8)
2	19	300.0	
2	20	300.0	Readings were always taken at 100 m
2	21	300.0	interval. Station 23 was taken
2	22	288.0	N-S crossing Line 2 at 350 m
Across 2	23	300.0	position.
3	24	293.5	At 21.5 mile position
3	25	300.0	(Branch 16)
4	26	300.0	At 20.2 mile position
5	27	188.0	At 19.5 mile position
6	28	125.0	At 18.5 mile position
7	29	300.0	At 18.2 mile position
Across 7	30	280.0	

Line No.	Sounding No.	Tx-Rx SEP.(m)	Location and Remarks
8	31	500.0	Line 8 started just past 24 mile position along North Road and a side road.
8	32	500.0	
8	33	500.0	
8	34	500.0	
8	35	500.0	
8	36	500.0	
8	37	500.0	Stations 38 and 39 were taken across the main line crossing it at 1040 and 820 m positions
Across 8	38	500.0	
Across 8	39	425.0	
9	40	500.0	
9	41	500.0	Station 40 was located 400 m NE-SQ of the junction of Meager and Capricorn Creeks
9	42	500.0	
9	43	500.0	
9	44	500.0	
9	45	500.0	

* See the attached map