ELECTRICAL RESISTIVITY SURVEY AT
BEULAH PROSPECT
MALHEUR COUNTY, OREGON

Prepared for

AMAX EXPLORATION, INC.

Geothermal Group

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by

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Abstract

A reconnaissance electrical resistivity survey was conducted by Terraphysics in the Beulah area, Malheur county, Oregon.

A combination of telluric and magnetotelluric methods were used. Data were obtained at two frequencies, 8 Hz and 0.05 Hz. Some d.c. resistivity measurements were also obtained.

The data indicates a shallow low resistivity zone ($<$ 10 ohm meters) occurs around the Beulah reservoir and Beulah hot springs area. The region appears to become more resistive with depth.

A second shallow low resistivity area is indicated to the southwest of the Beulah reservoir. It may be associated with a zone of highly fractured, water saturated rocks. This area also becomes more resistive with depth.

At least two faults and a number of contacts are suggested in the area.

Additional electrical survey work is recommended in the region.

Table of Contents

List of Figures

List of Tables and Plates

Introduction

Terraphysics conducted electrical surveys in the vicinity of Beulah, Malheur county, Oregon, on behalf of the Geothermal Group of Amax Exploration, Inc. The work was performed during the intervals 6-20 October, 24,27 October and on 11 November 1975. Telluric, magnetotelluric (MT) and d.c. resistivity measurements were made.

Survey Objective

The objective of the survey was to aid in the evaluation of the geothermal energy potential in the area. Various hot springs exist in the region.

Many geophysical techniques are used to evaluate a geothermal area. Since a decrease in resistivity usually occurs where the temperature of the earth increases, an electrical resistivity survey can be a useful diagnostic technique. The resistivity change with temperature can be on the order of 2.5 %/C^{o} (Keller and Frischnecht, 1970). Consequently, resistivity decreases on the order of a factor of 5 or more may be associated with geothermal brines (Keller, 1970). Intrinsic resistivities of less than 10 ohm meters may be expected.

If a geothermal area is at a sufficiently high temperature that a vapor phase is present, higher electrical resistivities are likely. Zohdy, et. al. (1973) report intrinsic resistivities of about 75-130 ohm meters for a vapor-dominated layer in Yellowstone National Park.

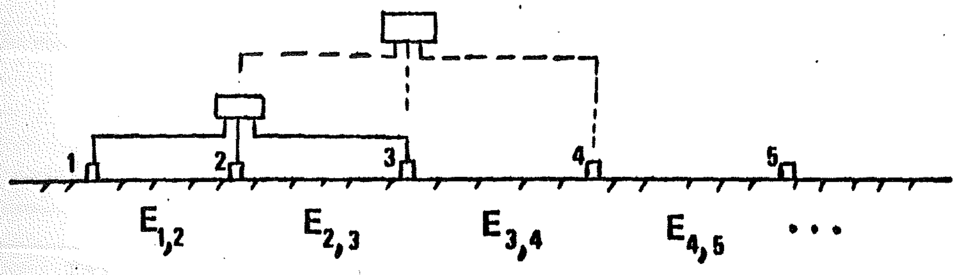
Procedure and Instrumentation

A combination of telluric and magnetotelluric methods were used as a reconnaissance technique. The collinear telluric method is illustrated in Figure 1, and has been described by Dahlberg (1945) and Boissonnas and Leonardon (1948). The technique involves measuring the ratio of the electric fields (E) between two adjacent collinear dipoles. After the readings are completed at one station, the instruments are moved to the next site and the next dipole ratio is measured.

The electric field ratio is proportional to the square root of the apparent resistivity ratio beneath the particular dipoles (see Figure 1) (Slankis and Becker, 1969; Slankis, Telford and Becker, 1972). Successive ratios are referenced back to an initial dipole so that a relative resistivity profile across the region results.

The equipment used are itemized in Table 1 and are illustrated in the schematic of Figure 1. Porous pots are used as electrodes for the telluric dipoles. Each electrode consists of a porous ceramic cup and a copper rod in a saturated copper sulphate solution. Voltages from two adjacent telluric dipoles are narrow-band filtered, amplified (2 Ithaco filters) and then displayed on a X-Y chart recorder (Simpson). The voltage ratio is easily measured as the slope of the resulting X-Y plot. An example of such data is shown in Figure 2. Measurements are usually made at 0.05 Hz and may be supplemented by data at other frequencies, such as 8 Hz. Monitoring of the higher frequency provides additional depth information. A theoretical example is described in Appendix A.

Magnetotelluric measurements are made at intervals along the telluric lines. These provide control points to calibrate the relative telluric profiles. Continuous profiles of apparent resistivity values across the area are obtained.



ELECTRIC FIELD RATIO

$$\frac{E_{i,j}}{E_{1,2}} = \frac{E_{2,3}}{E_{1,2}} \, \frac{E_{3,4}}{E_{2,3}} \cdots \frac{E_{i,j}}{E_{i-1,j-1}} = \left(\frac{\rho_{a\,i,j}}{\rho_{a\,1,2}} \right)^{\frac{1}{2}}$$

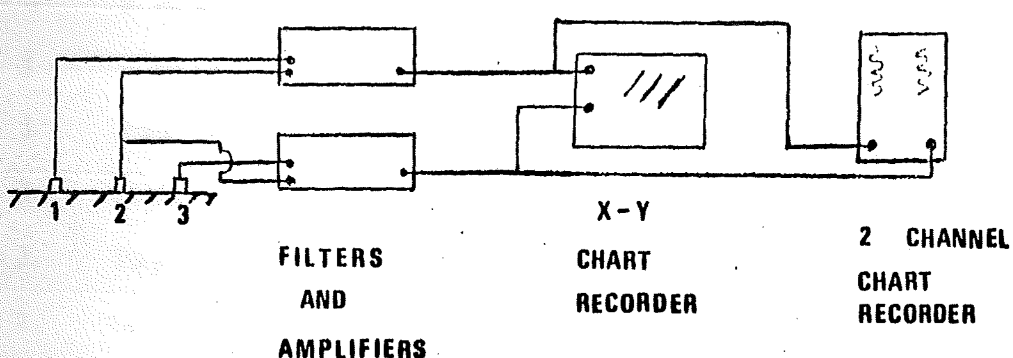
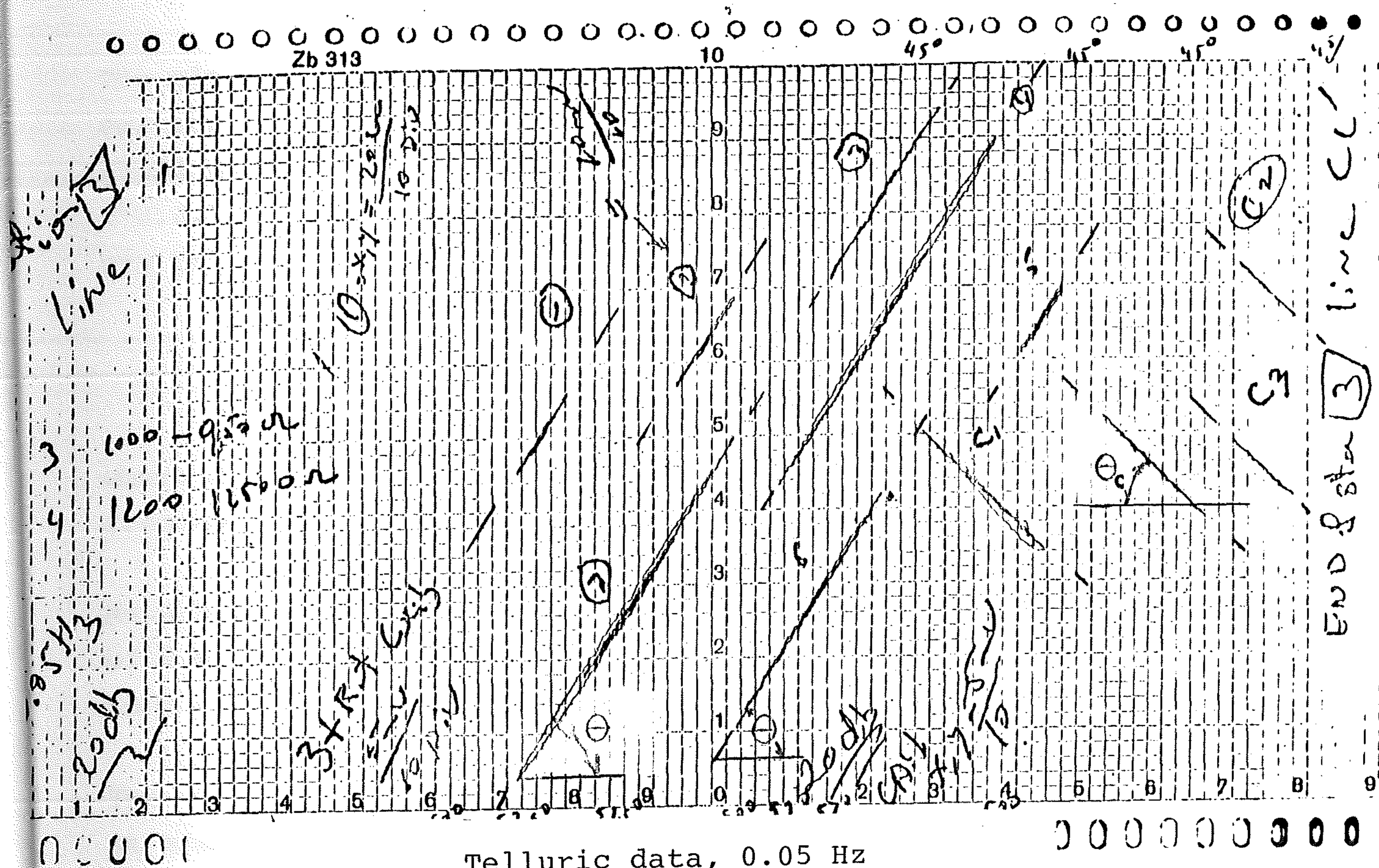


Figure 1. Collinear telluric method and instrumentation

Table 1

SURVEY EQUIPMENT

4	Ithaco model 4211 filters with amplifier options
2	Simpson X-Y model 2745 chart recorders
1	2 channel Brush 222 chart recorder
1	2 channel Gulton model TR 722J chart recorder
1	Develco 3 component superconducting Josephson Junction magnetometer
1	Tektronix 2 channel oscilloscope
2	2 channel amplifiers
1	2 channel 60 Hertz notch filter
1	Equipment trailer
5	Reels wire (30,000 feet)
1	Toyota Landcruiser 4 wheel drive
1	Chevrolet 1/2 ton pickup with instrument camper shell
1	Ford 3/4 ton pickup 4 wheel drive
1	500 watt d.c. resistivity transmitter
1	Vacuum pump (for pumping vacuum on cryogenic devices)
1	Liquid He Transfer line
1	Liquid He Level indicator
1	Simpson digital voltmeter
1	100 liter Liquid He dewar (Rental)



Telluric data, 0.05 Hz

Figure 2. The X axis represents the voltage monitored from dipole 2-3 and the Y axis represents dipole 3-4. The ratio of the voltages of these adjacent dipoles is determined from the tangent of the angle Θ from the expression

$$\frac{V_{3,4}}{V_{2,3}} = \frac{\text{TAN } \Theta}{\text{TAN } \Theta_c}$$

Calibration of the instruments is taken into consideration by the measurement of the angle Θ_c

The electric field ratio is obtained from the expression

$$\frac{E_{3,4}}{E_{2,3}} = \frac{V_{3,4}}{L_{3,4}} \cdot \frac{L_{2,3}}{V_{2,3}} = \frac{L_{2,3}}{L_{3,4}} \frac{\text{TAN } \Theta}{\text{TAN } \Theta_c}$$

Where $L_{2,3}$ and $L_{3,4}$ are the lengths of the dipoles 2-3 and 3-4 respectively.

The electric field (E_x) is measured at the same stations used for the collinear telluric data. The orthogonal magnetic field component H_y is measured using a Josephson Junction ("J.J.") magnetometer. Scalar apparent resistivities ρ_{a_x} are calculated from the expression

$$\rho_{a_x} = \frac{.2}{f}\left(\frac{E_x}{H_y}\right)^2$$

where E_x is in millivolts/km, H_y is in gammas and f is the frequency in Hertz (Hz).

Measurements normally are made at a narrow-band frequency of 0.05 Hz. Additional measurements at other frequencies such as .1, .8 and 8 Hz are sometimes obtained.

The orthogonal pair of field components E_y and H_x are measured at some stations. The resulting determination of apparent resistivity ρ_{a_y} gives an indication of the anisotropic nature of the earth.

D.C. resistivity measurements were taken in some areas. Wenner arrays with spacings up to 400 meters are sometimes used. These provide near-surface resistivity information.

Where warranted, dipole-dipole arrays are used to obtain deeper resistivity properties. Measurements are obtained with 300 to 1000 meter dipoles having separations up to 3 km. These techniques provide a check on the 8 Hz telluric and MT data.

In summary, the field procedure is as follows:

1) Telluric lines are run in a direction normal to geologic strike where feasible.
2) MT measurements are made at appropriate sites to calibrate the telluric lines.

3) D.C. resistivity measurements are taken to determine shallow resistivity properties.

4) Results of the above may warrant supplementary deeper resistivity soundings and/or electromagnetic (EM) measurements over possible geothermal target zones.

Field Operation at Beulah

In the Beulah survey, telluric dipoles ranging from 0.5 to 1.3 km in length were employed, depending on topographic conditions. Telluric measurements were made at 8 and 0.05 Hz.

Geologic strike in the area runs between north and northwest. Telluric lines were run east-west and southwest-northeast as determined by roads and access, and as specified by the client. Forty-nine (49) telluric stations were measured and a total of twelve (12) MT stations were occupied at strategic locations on the telluric lines. In addition, six (6) d.c. resistivity measurements were made.

Composition of Crew

A detailed summary of the work and personnel is documented in Appendix B. The personnel involved on the project are listed below.

A. Pessah	Party Chief	Instrumentation, survey and data analysis
J. Moroney	Field Engineer	Survey, wire crew, data analysis
W. Harvey	Field Technician	Instrumentation, equipment maintenance, wire crew
P. Guzman	Field Hand	Wire crew, equipment maintenance

Terraphysics personnel worked a total of forty-seven (47) field man days in the Beulah area of Oregon over a period of eighteen (18) days.

Operating Conditions

The weather was generally favorable and work proceeded smoothly except for one day when the instruments were effected by subfreezing temperatures and on another day when the work was stopped in the afternoon by a severe snow storm.

The personnel stayed at the Oasis Motel in Juntura, Oregon during the period of the survey work. Maximum commuting time to the farthest station was about 90 minutes.

Specific vehicles used in the project were a Toyota Landcruiser (4 wheel drive), a Ford 3/4 ton pickup (4 wheel drive), a Chevrolet 1/2 ton pickup with a camper shell and an equipment trailer (see Table 1).

DATA

The location of the telluric lines and stations are shown in Plate 1. (The Figures and Plates for the data are in the second binder.)

The telluric profiles are plotted in Figures 3 through 7. The relative electric field strength is plotted on the left side ordinate. The station locations are projected on the abscissa at the top of the plot. The E-field ratio is plotted midway between the electrode stations.

Each station represents an average of 4 to 12 measurements. In some cases, in particular when the ground becomes anisotropic, wide variations in the telluric ratio were observed. The various values are plotted.

Considerable scatter in the 8 Hz data were observed. (See item 4 on sources of error, page 17 .) The standard deviations for these values are shown as error bars in the figures.

MT readings are shown in the rectangles at their corresponding locations. The average resistivity and standard deviation are indicated. Telluric values between MT readings on a given profile were adjusted linearly to correspond to the MT readings. An apparent resistivity scale in ohm meters is shown on the right side ordinate. A summary of all the magnetotelluric data are also presented in Table 2.

Contour maps of apparent resistivities for the 8 and 0.05 Hz frequencies are depicted in Plates 2 and 3 as described from the profile data. The apparent resistivities are plotted in logarithmic contour intervals.

The contours for both the 8 Hz and 0.05 Hz data are subjected to some uncertainty due to the different telluric line directions and, consequently, possible anisotropic effects. Apparent resistivity values are presented in Table 3 for points where the telluric lines intersect. Within the statistics of the measurements, the apparent resistivity values generally agree.

Orthogonal telluric measurements were obtained at three (3) stations. Wide variations in both the phase and the amplitude ratio were observed between the orthogonal dipoles over a period of time. An average direction and a range of values are indicated in Table 4. The average direction varied between N 45° E in the southern part of the survey to N 43° W in the northern part.

The results of d.c. resistivity measurements are summarized in Table 5. These were taken at various areas along the telluric lines.

(NUMBER OF SAMPLES)

LINE & STATION	LENGTH IN METERS	DATE	0.05 Hz	8.0 Hz	0.1 Hz	0.8 Hz	COMMENTS
AA' 2-3	599	11/11	98 ∓ 42 (23)	15 ∓ 10 (24)	52 ∓ 14 (20)	28 ∓ 27 (15)	0.8 Hz data low signal, poor correlation
10-11	894	10/16	103 ∓ 56 (29)	12 ∓ 8 (37)			
B'B" 1-2	955	10/16	32 ∓ 11 (28)	10 ∓ 7 (20)			8 Hz data MT signals noisy
7-8	747	10/17	93 ∓ 38 (21)	--			8 Hz data MT signal noisy, no correlation
BB' 11-12	879	10/16	59 ∓ 28 (30)	12 ∓ 6 (11)			8 Hz data MT signal noisy, local noise?
20-21	576	10/16	61 ∓ 21 (28)	16 ∓ 7 (29)			
CC' 21-22	720	10/16	44 ∓ 23 (22)	9 ∓ 3 (11)			8 Hz data MT signal noisy
DD' 20-21	909	10/18	65 ∓ 22 (12)	--			8 Hz data MT signal noisy, no correlation

STANDARD DEVIATION
(NUMBER OF SAMPLES)

LINE & STATION	LENGTH IN METERS	DATE	0.05 Hz	8.0 Hz	0.1 Hz	0.8 Hz	COMMENTS
DD' 28-29	879	10/17	29 ∓ 12 (17)	9.2 ∓ 5.7 (25)			
EE' 2-3	734	10/19	27 ∓ 8 (15)	22 ∓ 14/(8) 5 ∓ 2/(14) 11 ∓ 12/(22) all			2 groups 8 Hz
6-7	932	11/11	84 ∓ 24 (29)	20 ∓ 7/(22) 4.7 ∓ 2.9/(28) 11 ∓ 9/(50) all	61 ∓ 31 (20)	--	0.8 Hz data, low signal level no correlation; 8 Hz data, 2 groups

Table 3

Comparison of Apparent Resistivity Values for Different Telluric Line Directions

Line	Stations	Telluric Line Direction	Apparent Resistivity Values ∓ Standard Deviation Ohm Meters		Comments
			8 Hz	0.05 Hz	
AA'	10-11	N 80° E	12 ∓ 8	103 ∓ 56	
BB'	11-12	N 43° E	12 ∓ 6	59 ∓ 28	
BB'	20-21	N 43° E	16 ∓ 7	61 ∓ 21	
CC'	21-22	E-W	9 ∓ 3	44 ∓ 23	
DD'	30-2	N 85° E	15 ∓ 9	13 ∓ 6	Values from extrapolated telluric data
BB'	2-3	N 24° E	19 ∓ 13	22 ∓ 8	
BB'	1-2	N 24° E	10 ∓ 7	32 ∓ 11	

Table 4

Orthogonal Telluric Measurements

0.05 Hz

Location Line	Location Station	Approximate Direction Electric Field
AA'	1	N 45° E (Range N 34° E to N 68° E)
CC'	22	N 40° E (Range N 10° E to N 65° E) (Phase shift between orthogonal dipoles)
EE'	4A	N 43° W (Range N 10° E to N 88° W) (Wide variation in both phase and amplitude ratio)

Table 5

D.C. Resistivity Measurements

Beulah, Oregon

Location	Type	Spacing Length Meters	Apparent Resistivity Ohm Meters
Line BB' Station 13	Wenner	"a" spacing 15	34
Line DD' Station 29	Wenner	"a" spacing 15	12
Stations 25-26 29-30	Dipole-Dipole	3110 meter separation, dipole center to center	< 10 ($\approx 6 \mp 2$)
Line EE' Station 3	Wenner	"a" spacing 15	35
Stations 3-4A	Wenner	Not equal spacings, average "a" spacing 178 meters	40
Stations 3-4A 6-7	Dipole-Dipole	2470 meter separation, dipole center to center	< 10 ($\approx 8 \mp 2$)

Sources of Error

The principal sources of error in the telluric-magnetotelluric methods are:

1) Station locations and dipole lengths are determined from topographical maps, bench marks, and actual field measurements. In general, dipole lengths are determined to within 5%. The possibility of the accumulation of small errors yielding a large uncertainty after a number of stations was reduced by taking magnetotelluric measurements at intervals along the telluric profiles. Telluric values between MT readings were adjusted linearly to correspond to the MT values.

2) Errors due to instrumentation are kept to a minimum. At each frequency reading, the instruments were calibrated. In some cases, calibrations were taken before and after the data.

3) In cases where the earth becomes highly anisotropic, a phase shift can occur between measurements of adjacent telluric dipoles. In this case, the E-field ratio depends upon the polarization of the incident field and, in general, wide variations in both amplitude and phase are observed. Then attempts are made to obtain information over as much of the area as possible with MT readings and d.c. resistivity measurements.

4) In some areas, considerable noise is observed on the higher frequency data, 8 Hz; this is probably caused by local industrial electrical activity. Attempts are made to minimize any error from these near field sources by careful inspection of each cycle of data on high speed oscillographic records. Considerable scatter in the data usually results, however, in those areas.

Discussion of Data

Geological Province

The Beulah area lies at the border between the Blue Mountains and Basin and Range Provinces in the eastern central part of the state of Oregon. This area is "characterized by north trending mountain ranges and intervening flat valleys, which are blanketed with alluvium or recent lava flows" (McKee, 1972). "The rocks consist primarily of extensive sheets of solidified lava. Much of the lava is basalt, but some widespread silicic ash flows and tuffs are present" (McKee, 1972). Nonmarine sandstone, shale and conglomerates are interbedded with the volcanic strata.

Numerous steeply dipping faults occur in the region. They generally trend in a north-south direction and many of the mountain ranges have been raised by block fault systems. Some of the faults in the region have been recently active.

Beulah Area, Oregon

The area surveyed was in the vicinity of the Beulah reservoir. A number of thermal springs occur in this region. The water at Beulah hot springs, on the northeast side of the Beulah reservoir, has a temperature of 85°C. (Waring, 1965)

A wide variety of rocks have been mapped in this area. They are predominately younger Cenozoic (Miocene and Pliocene) sedimentary and volcanic rocks and Quaternary alluvium. Two north-south trending faults have also been mapped in the area (McKee, 1972; Greene et. al., 1972).

The 8 Hz and 0.05 Hz data in Plates 2 and 3 appear to reflect the faults and some of these different rock types.

(a) 8 Hz Data

Two fairly large low resistivity areas (< 10 ohm meters) are the most prominent features of the 8 Hz data depicted in Plate 2. The largest is centered near the area of the Beulah reservoir and the Beulah hot springs, line B B' B", stations 40 to 2. The other area also occurs on line BB', stations 13 to 15. These areas are discussed further with respect to the 0.05 Hz data.

The profiles in Figure 3 indicate that in the southern part of the survey, line AA', the near surface electrical properties are fairly laterally uniform; the values range between 10 to 25 ohm meters. The profiles of the other lines indicate larger resistivity variations of peaks and troughs. These appear to reflect faults or contacts of different rock types.

On line BB', the changes at stations 12-13 and 18-19 may be associated with faults that have been mapped in the area, these are indicated as F_1 and F_2 in Figure 2. These faults are also indicated on line DD', further to the north, Figure 6. The resistivity variations possibly associated with the fault F_2 still appear prominent on line DD'. The changes associated with the mapped location of fault F_1 (line DD', stations 23-24) are not as clear, a more significant feature does appear about one kilometer further to the west, (stations 21 to 23).

On line EE', in the northernmost part of the survey, two faults or contacts are suggested at stations 3 to 4 and 6 to 7.

(b) 0.05 Hz Data

The 0.05 Hz data reflect deeper resistivity properties of the area. The contours depicted in Plate 3 and the profiles in Figures 3 through 7 generally exhibit much the same pattern as the 8 Hz data; higher apparent resistivity values are indicated for all the 0.05 Hz data for the entire area that was surveyed.

Relatively low apparent resistivity values occur in the Beulah reservoir area ($<$ 10 ohm meters at line DD', station 30). Low resistivity values also were observed at 8 Hz in this area. The geology mapped in this region consists of Quarternary alluvium and tuffaceous sedimentary rocks. The low resistivity values could be associated with hot geothermal brines, highly conductive sedimentary rocks or it may be reflecting a combination of the two cases.

Both the 8 Hz and 0.05 Hz low resistivity patterns extend to the northwest from the Beulah reservoir. They appear to be bound on the west by a projection of the fault F_2.

The closest survey measurement to the thermal springs occurs on line B'B", stations 1-2, this is about 1/2 kilometer from the springs. The two frequency data suggest that the area becomes more resistive with depth, 10 $\mp$ 7 ohm meters, skin depth 562 meters at 8 Hz vs 32 $\mp$ 11 ohm meters, skin depth 12725 meters at 0.05 Hz. The actual sensing depths are usually much less than these skin depths. Multifrequency MT measurements with a complete model solution would be required to determine the actual properties and depths.

Another relatively low apparent resistivity area ($<$ 25 ohm meters) occurs to the southwest of the Beulah reservoir, on line BB', stations 13 to 17. This is in the same general area as the resistivity low observed at 8 Hz ($<$ 4 ohm meters). The area appears to become more resistive with depth. Basalt and andesite are indicated in this region (Greene et. al., 1972). One would normally expect these to have relatively high resistivity values. A considerable number of springs occur in the area, the zone also lies between two north-south trending faults, these were discussed with respect to the 8 Hz data. These conditions suggest that the low apparent resistivity values may be reflecting a zone of highly fractured, water saturated rocks.

Since the telluric response to lateral resistivity changes is different for different frequencies, all the above depth interpretations are subject to some uncertainty. Two dimensional modelling of the area would be required to evaluate this effect.

(c) D.C. Resistivity Measurements

D.C. resistivity measurements were taken in a few areas in order to provide some comparison with the telluric magnetotelluric results. The majority of the measurements, however, appeared to be taken in areas where faults and contacts occur. Because of the large lateral apparent resistivity variations, it is not possible to make a simple comparison. For example, a value of nine (9) ohm meters with a skin depth of 533 meters is indicated at 8 Hz on line EE', stations 3-4. A value of 40 ohm meters is observed in this area at an average Wenner "a" spacing of 178 meters. The MT data at 8 Hz on line EE' is subject to some uncertainty since two groups of values were indicated, see Table 2. The telluric data, however, also suggest a fault or contact occurs in this area; between stations 3 to 5 the apparent resistivity increases sharply. Two dimensional modelling of the area and additional d.c. resistivity measurements would be required to establish whether the apparent results of the two different techniques are compatable.

Summary and Recommendations

The present resistivity survey delineates a shallow low resistivity zone in the area of the Beulah reservoir and Beulah hot springs. The area appears to become more resistive with depth. In view of the relatively high temperature of Beulah hot springs, 85^{o}C, consideration should be given that steam may exist at depth and could be reflected by higher resistivity values. Other geophysical techniques, such as measuring the thermal gradients and the water geochemistry, could help verify this hypothesis.

A second shallow low resistivity area is indicated to the southwest of the Beulah reservoir. Since a considerable number of springs occur in the area, this may be reflecting a zone of highly fractured, water saturated rocks. The data suggest at least two north-south trending faults occur in the area.

Additional survey work is recommended in the area to the east of Beulah hot springs, this would help define the boundary of the low resistivity zone. A few MT readings to the northwest of the Beulah reservoir would help verify the projected apparent resistivity contours in that area, for example, a measurement should be made about five (5) kilometers north of line DD', station 28.

Additional low frequency MT and active d.c. resistivity soundings directly over the Beulah hot springs could help define the source of the hot waters. In view of the three dimensional nature of the area, solutions for impedance tensors (Grillot, 1975) and at least two dimensional modelling probably would be required to unfold the deep intrinsic properties of the area.

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APPENDIX A

Theoretical telluric results over hypothetical models are shown in Figures A1 and A2. The difference between the two models is the inclusion of a one (1) ohm meter body in Figure A2. This could be representative of a geothermal target.

Two points are of particular note.

(1) The telluric response is characteristically dominated by resistivity variations occurring beneath the measuring stations. This is seen in both the figures.

(2) The use of multifrequencies provides some initial determination of depth information. For example, a significant difference is observed between the 0.03 Hz telluric response over the two models. The 8 Hz response is not effected. The 8 Hz E.M. wave in this case does not significantly penetrate to the depth of the one (1) ohm meter body. (The skin depth of an 8 Hz E.M. wave is 562 meters in a 10 ohm meter material. The top of the one (1) ohm meter body was 500 meters deep.) These results place a bound on the depth of the anomoly observed on the 0.03 Hz data. It must be deeper than a few hundred meters and less than a few thousand meters. A more precise depth could, of course, be determined with intermediate frequency data.

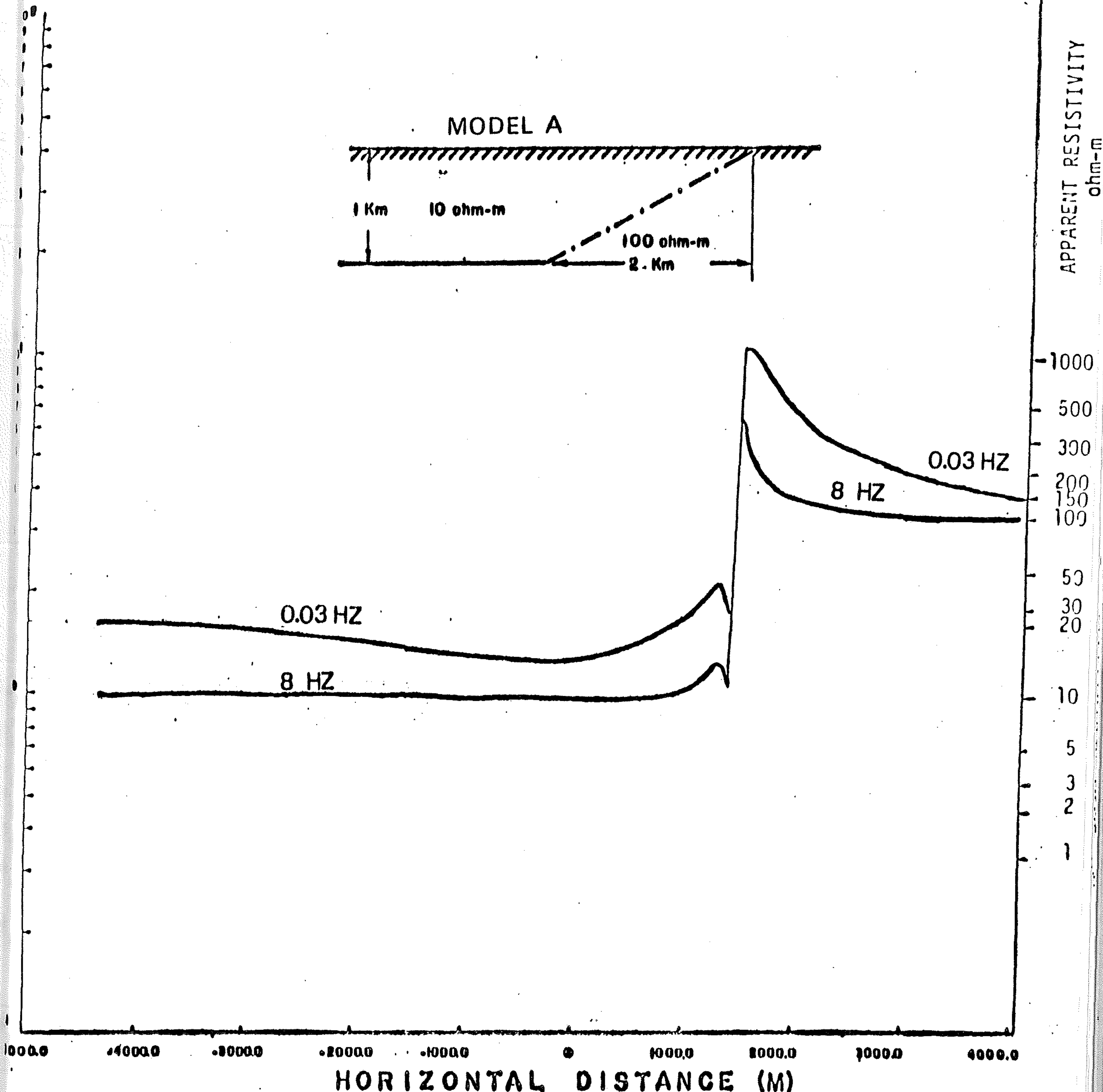

Figure A1. Telluric response at 8 Hz and at 0.03 Hz over Model A.

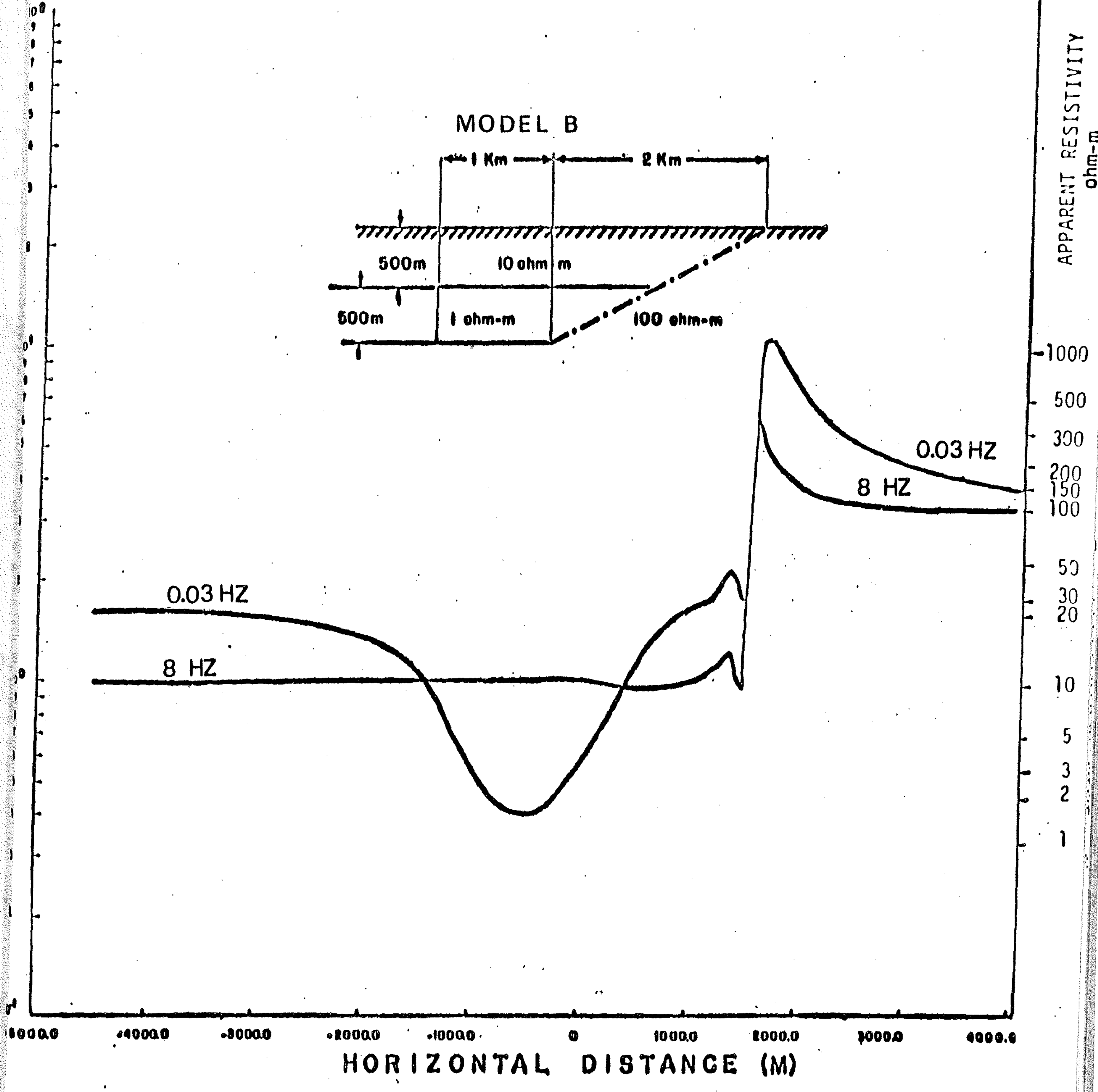

Figure A2. Telluric response at 8 Hz and at 0.03 Hz over Model B, inclusion of a one ohm meter body at 500 meters depth.

Appendix B

Personnel and Operations Summary

MONTH

October

TERRAPHYSICS

PROJECT Beulah, Oregon

DAY	DATE	TECHNIQUE	TOTAL STATIONS	LOCATIONS	FREQ.S Hz 05	01	0.8	8		PERSONNEL MAZZELLA	PESSAH	GUZMAN	HARVEY	MORONEY
Mon.	6th			Load Equipment Mobilization to Beulah, Oregon									X	X
Tue.	7th			Mobilization, arrive at Beulah, Oregon(480 miles)									X	X
				Unload equipment and charge batteries, Ship empty liquid He dewar									X	X
Wed.	8th	T	3	Line AA' ST 1A, 2, 3	X			X					X	X
		OT	1	Line AA' ST 1A (Low signal level ST 4)	X			X					X	X
Thu.	9th	T	7	Line AA' ST 4, 5, 6, 7, 8, 9, 10	X			X					X	X
Fri.	10th	T	--	Line BB' Tried ST 11, 12 (cold weather, temperature approximately freezing)									X	X
Sat.	11th	T	6	Line BB' ST 11, 12, 13, 14, 15, 16	X			X					X	X
Sun.	12th			Day off										

TECHNIQUE CODES T - TELLURICS OT - ORTHOGONAL TELLURICS MT - MAGNETOTELLURICS R - D.C. RESISTIVITY EM - ELECTROMAGNETIC (ACTIVE)

TERRAPHYSICS

MONTH

October

PROJECT Beulah, Oregon

DAY	DATE	TECHNIQUE	TOTAL STATIONS	LOCATIONS	FREQ.S Hz 05	01	08	8		PERSONNEL: MAZZELLA	PESSAH	GUZMAN	HARVEY	MORONEY
Mon.	13th		4	Line BB' ST 17, 18, 19, 20									X	X
Tue	14th	T	2	Line BB' ST 21, 40									X	X
		OT	1	Line CC' ST 22									X	X
Wed.	15th	T	4	Line CC' ST 23, 24, 25, 26	X			X			X	X	X	X
Thu.	16th	T	6	Line B'B" ST 2, 3, 4, 5, 6, 7	X			X					X	X
		MT	6	Line AA' ST (10-11)	X			X			X	X		
				Line B'B" ST (1-2), (11-12), (20-21)	X			X			X	X		
				Line CC' ST (21-22)										
Fri.	17th	T	2	Line DD' ST 23, 24	X			X					X	X
		MT	2	Line DD' ST (28-29)	X			X			X	X		
				Line B'B" ST (7-8)	X			X			X	X		
Sat.	18th	T	3	Line DD' ST 20 , 21 , 22	X			X					X	X
		MT	1	Line DD' ST (20-21)	X			X			X	X		
Sun	19th	T	7	Line EE' ST 2, 3, 4A, 5, 6, 7, 8	X			X			X	X	X	
		OT	1	Line EE' ST 4A	X			X			X	X	X	
		MT	1	Line EE' ST (2-3)	X			X			X	X	X	

TECHNIQUE CODES T - TELLURICS OT - ORTHOGONAL TELLURICS MT - MAGNETOTELLURICS

R - D.C. RESISTIVITY EM - ELECTROMAGNETIC (ACTIVE)

MONTH

October/Nov.

TERRAPHYSICS

DAY	DATE	TECHNIQUE	TOTAL STATIONS	PROJECT Beulah, Oregon LOCATIONS	FREQ.S Hz 05	01	08	8		PERSONNEL MAZZELLA	PESSAH	GUZMAN	HARVEY	MORONEY
OCTOBER		T	2	Line BB' ST 8, 9										
Mon.	20th	T	4	Line DD' ST 26, 27, 28, 29, (Poor signal level poor data ST 30)	X			X			X	X	X	X
Tue.	21st	T	1	Line DD' ST 30 (Repeat) (½ day) (Mobilization)									X	X
Fri.	24th	R	4	Line EE' Dipole-Dipole ST (3-4) to (6-7), Line EE' ST 3 50' W, ST (3-4) 600' W Line BB' ST 13 50' W							X	X		X
Sat.	25th			Day off										
Sun.	26th			Day off										
Mon.	27th	R	2	Line DD' ST 29 50' W Dipole-Dipole ST (25-26) to (29-30) (Heavy snow storm started 1500 hours)							X	X		
NOVEMBER														
Tue.	11th	MT	2	Line EE' ST (6-7)	X	X	X	X			X	X		
				Line AA' ST (2-3)	X	X	X	X			X	X		

TECHNIQUE CODES T - TELLURICS OT - ORTHOGONAL TELLURICS MT - MAGNETOTELLURICS

R - D.C. RESISTIVITY EM - ELECTROMAGNETIC (ACTIVE)

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