GL02417

TELLURIC MAGNETOTELLURIC SURVEY
AT
McCOY PROSPECT

CHURCHILL COUNTY
NEVADA

Prepared for

AMAX EXPLORATION, INC.
Geothermal Group

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TERRAPHYSICS
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Abstract

A telluric-magnetotelluric (TMT) survey was conducted on the McCoy prospect, Churchill county, Nevada.

Rotated tensor data were obtained at 14 base stations and 26 remote sites. An in-field computer processing system was implemented and 3 stations were processed in the field.

A conductive zone of less than 2 ohm meters is suggested in the area at depths of about 7 km.

Considerable changes in strike direction are suggested over the area.

High skewness values occur over a number of stations suggesting that three dimensional effects are present over a considerable portion of the survey area.

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Introduction

Terraphysics conducted a telluric-magnetotelluric (TMT) survey in the McCoy prospect, Churchill county, Nevada on behalf of Amax Exploration, Inc. The field work was conducted during the period of 4 to 26 February 1980.

Survey Objective

The objective of the survey was to aid in the evaluation of the geothermal potential of the area.

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° (Keller and Frischknecht, 1970). Consequently, resistivity decreases on the order of a factor a 5 or more may be associated with geothermal brines(Keller, 1970). Intrinsic resistivity values 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 resistivity values are likely. Zohdy, et. al. (1973) report intrinsic resistivity values of about 75-130 ohm meters for a vapor-dominated layer in Yellowstone National Park.

Telluric-Magnetotelluric Instruments and Procedure

A schematic of the equipment and field setup is illustrated in figure 1. Five component MT data is obtained at the base station (two horizonal electric field components and three magnetic field components). At each remote site two orthogonal electric field components are measured. The data is filtered, amplified, and telemetered back to the base station where it is recorded on magnetic tape at the same time as the base station data. Seasoned lead strips are used for the electrodes for the electric field measurements and the magnetic field measurements are obtained with a superconducting magnetometer.

In general, a base station with magnetic field measurements is utilized for each setup. Typical distances between the base and remote stations is one to two kilometers.

In order to solve for impedance tensors, the analog data from the magnetic tape is digitized (12 bits) and evaluated utilizing a LSI-11 DEC minicomputer. The computer system is mounted in the field instrument truck such that data may be processed in the field in real time.

The remote reference method of analysis was used,following a technique described by Gamble et.al.(1978). The remote station data are treated as tensors and evaluated using the base station magnetic fields. In this work, the electric fields were used as the references to calculate the cross powers. This method provides results without bias errors, however poor results may occur if the electric fields are linearly polarized.

The computer analysis is separated into two parts utilizing Gamble's (1979) computer programs. The first program digitizes the data (12 bits) into segments 1024 points long. The segment is tapered, Fourier transformed, and the cross powers are calculated.

TELLURIC
MAGNETOTELLURIC
SETUP

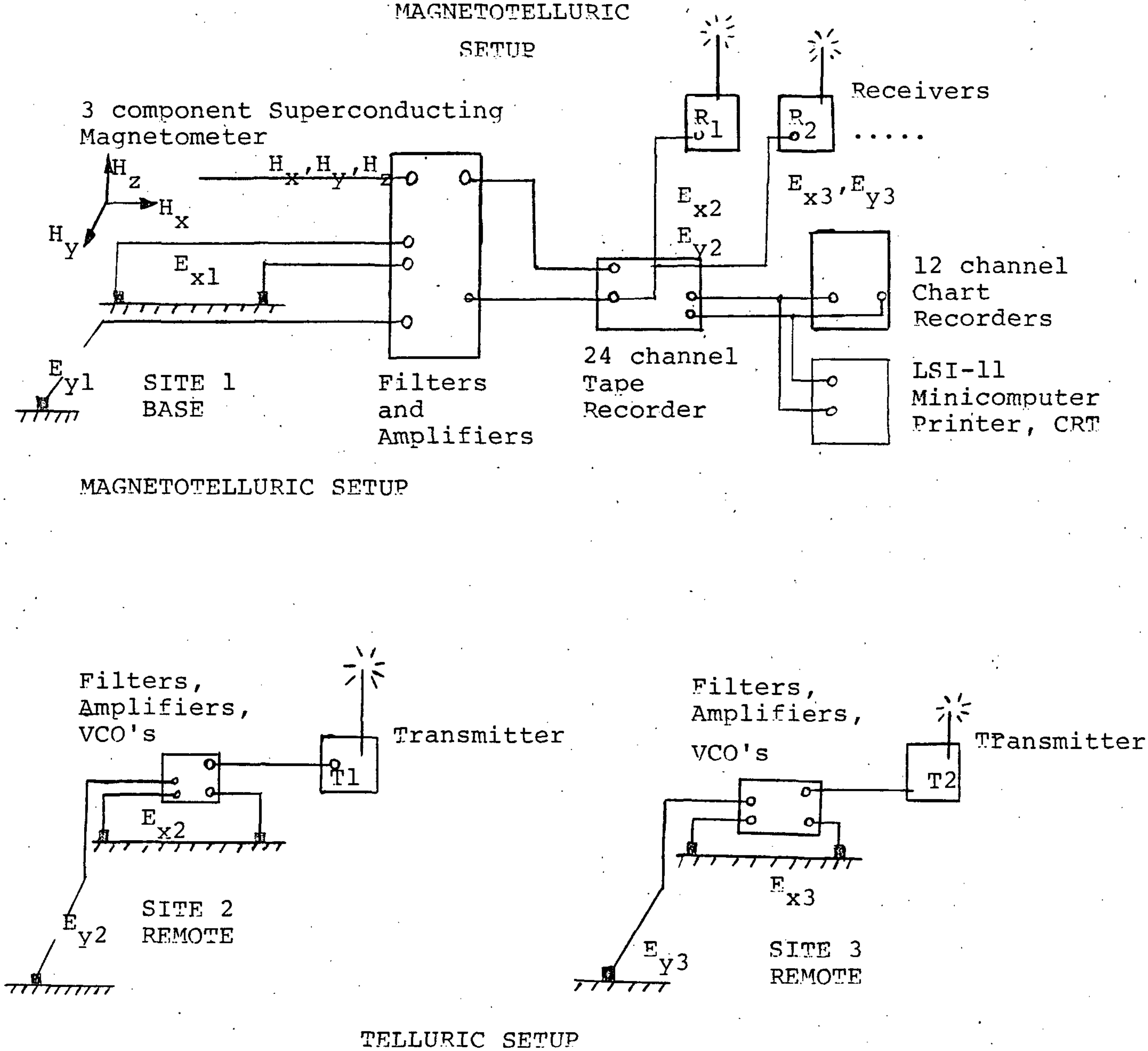

Figure 1. Magnetotelluric-Telluric Instruments

The process is repeated for subsequent data sets with the option of rejecting any segment due to noise spikes or signal level saturations. The accumulated average cross power values are stored. This process can be performed in real time. After a data run is completed the second computer program utilizes the average cross powers and calculates the impedances, principal axis directions, rotated apparent resistivity values, skewness, impedance phases, tippers, and tipper strike directions.

The principal axis direction is calculated such that the impedance tensor quantity $|Z_{xy}|^2 + |Z_{yx}|^2$ is maximized. This defines the direction for the principal impedance terms Z_{xy}' and Z_{yx}'. For a two dimensional structure, the diagonal terms Z_{xx}' and Z_{yy}' are zero at this rotation angle. An indication of the three dimensional nature of the area can be represented by the ratio of the magnitude of the rotated diagonal to off diagonal terms. This is called the skewness, S.

$$S = \frac{|Z_{xx}' + Z_{yy}'|}{|Z_{xy}' - Z_{yx}'|}$$

Principal apparent resistivity values are calculated from

$$\rho_x = 0.2\ T\ |Z_{xy}'|^2 \quad \text{and}$$

$$\rho_y = 0.2\ T\ |Z_{yx}'|^2$$

where T is the period in seconds.

The vertical magnetic field is utilized to determine the strike direction. For a normal incident plane wave over a two dimensional structure, the vertical magnetic field arises only from the TE Mode, H_x field perpendicular to strike (Vozoff, 1972).

We assume $H_z = AH_x + BH_y$ and calculate a rotation direction such that A is maximized.

For the two dimensional case $H_z = A'H_x'$ and the rotated X axis defines a direction perpendicular to strike. In the present work the strike direction is indicated in the computer printout. The magnitude of the vertical field, A', the tipper, gives some indication of any lateral resistivity variations.

Monitoring different frequency bands provides various depth information. An indication of the depth penetration is sometimes given by the apparent skin depth, δ_a. This is defines as the depth where the amplitude of the electric field has fallen to 1/e of its value at the surface and is calculated from the expression

$$\delta_a = 503 \left(\frac{\rho_a}{f}\right)^{\frac{1}{2}}$$

where ρ_a is the apparent resistivity in ohm meters, f the frequency in HZ, and the resulting skin depth is in meters. The lower the frequency, the deeper the penetration.

The actual sensing depths are usually much less than the skin depths. Complete model solutions are required to determine the intrinsic properties and depths. Two dimensional computer modelling would be required to interpret the results if significant lateral variations occur. However a preliminary interpretation can be obtained with a one dimensional model based upon the TE Mode apparent resistivity data. The rational for this approach is that for a deep sounding, the TE Mode is less affected by near surface lateral changes than the TM Mode (Patrick and Bostick, 1969). In the present work a continuous one dimensional inversion method described by Bostick, 1976, was used.

Field Operations

In the present survey, telluric dipoles of about 200 meters were used in an "L" configuration. They were orientated north-south and east-west.

The field system filters prewhitened the spectrum such that data could be obtained wide band from 0.01 to 10 Hz. From 3 to 6 hours of data were recorded for each setup. After the elimination of poor sections of data, this resulted in about 1½ hours of processed data. Two overlapping frequency bands were used, 0.01 to 1 Hz, and 0.1 to 10 Hz. A summary of the processed data is indicated in Table I.

Fourteen setups of data were obtained consisting of 14 base stations and 26 remote sites. Four of the stations were reoccupied with a different base station location, data were obtained at 36 unique sites. In field processing was only performed for stations M1,A1,B1. The remainder of the stations were processed after the entire survey was completed. This was done to take maximum advantage of a period of relatively good field weather.

High winds were encountered on 7 days. The magnetometer was buried about 18 inches and surrounded by a wind shield. The telluric dipole wires were carefully laid out on the ground and weighted down with rocks or buried every 2 meters. Because of the brush in the area this proved to very time consuming.

Rain, snow or hail were encountered on 4 days, delaying the survey about a day. The presence of cattle and sheep in the area presented a problem on 3 days when they knocked over an antenna and trampled over the telluric wires.

The personnel stayed at the Pony Canyon Motel in Austin, NV. Commuting time to the survey area varied from 50 minutes to over 2 hours each way, depending upon the muddy road condition and the location of the survey.

Specific vehicles used on the project were a Dodge Powerwagon (4 wheel drive) , a Ford 3/4 ton instrument truck (4 wheel drive) and an equipment trailer.

Composition of Crew

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

A. Mazzella	Geophysicist	Instruments, survey, data processing
J. Malloy	Field Assistant	Survey, wire crew

Data

The location of the stations are shown in Plate 1. Plots of the data and the one dimensional inversions are presented in the second binder. Data points are plotted that meet the following criteria:

(1) skewness < 0.5 (except for station B2 where values < 1.0 were plotted)

(2) phase between 0 and -90 degrees.

The rotated apparent resistivity values, rotation angle, skewness, phase, tipper and tipper strike angle are plotted for each station.

Table I

Magnetotelluric Data Processed

High frequency band sample period 0.03 seconds

Low frequency band sample period 0.30 seconds

STATIONS	# SEGMENTS HIGH BAND 10 to 0.1 HZ	# SEGMENTS LOW BAND 1 to 0.01 HZ	DATA QUALITY
M1,A1,B1	208	25	Fair
M2,A2,B2	216	28	Fair but high skewness values on B2
M3,A3,B3	163	40	Fair but high skewness values at long periods
M4,A4	218	28	Fair but high skewness values
M5,A5,B5	147	16	Fair
M6,A6,B6	155 181	23	Good
M7,A7,B7	181	43	Good
M8,A8,B8	207	32	Good but high skewness on A8 at long periods
M9,A9,B9	150	17	Good but high skewness at long periods
M10,A10,B10	125	14	Fair but high skewness at long periods

Table I (continued)

STATIONS	#SEGMENTS HIGH BAND	#SEGMENTS LOW BAND	DATA QUALITY
M11,A11	132	18	Good but high skewness at long periods
M12,A12,B12	131	14	Good
M13,A13,B13	210	24	Good but high skewness at long periods
M14,A14,B14	182	20	Good but high skewness at long periods at A14

The interpreted resistivity sections (based upon the one dimensional inversions) along lines AA'A", BB' and CC' are plotted in plates 2,3, and 4. The stations are projected upon the lines, up to 1.5 km in some cases.
The rotated axis used for the TE Mode inversion and the tipper strike direction are indicated in plate 5. In some cases there was considerable scatter in the tipper strike over the frequency range and an approximate average was used.

Discussion of Data

Considerable resistivity variations are observed in the interpretations throughout the survey area. Resistivity values from 1 to over 16,000 ohm meters are observed.

A low resistivity zone of less than 2 ohm meters is suggested in the area of stations B7 to A8 at depths of about 7 km. It does not appear to extend to the north (see line AA", ST B14) or to the east (see line CC', ST A9). At stations A6 and B7 another conductive zone (4 ohm meters) is suggested nearer the surface at depths of about 1 to 2 km.

These interpretations should be taken with caution. The resistivity data,for example,at station A9 does not appear to agree with the corresponding phase information between the periods of 1 to 10 seconds. The data may be contaminated with electrical noise from nearby farm or mining operations or from welding at the drill site. To the north of Station B7 the data from stations B14,A14 and M14 suggest a very high resistivity zone at depth and almost a 90 degree change in the strike direction (east-west). This is not understood although a considerable amount of faulting occurs in the area.
The data in plate 5 suggest a number of other changes in strike direction occur throughout the area.

Poor data were obtained over a significant portion of Line BB' in the northern part of the survey area. High skewness values, greater than 1 in some cases, indicate that the area is strongly three dimensional.

A test of the uncertainity associated with the extrapolation of the magnetic field to the remote sites was provided at a number of locations that were reoccupied with the magnetometer located at a different base site. In one case the remote and base stations were interchanged (M3=A4, and M4=B3). A comparison of the data is shown in pages 115 to 122 in the second binder. In general, there is good agreement in the resistivity trend for all the sites. There is good agreement is the rotation angle of the principal axes and in the skewness values and a fair agreement in the phases. A difference in resistivity values of about 30 to 50% is observed at the short periods. At station A1=A2 a difference of about 20% is seen at the longer periods. These differences may be attributed to variations of 10 to 25% in the magnetic fields between the different base locations.

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APPENDIX A

OPERATIONS SUMMARY

MONTH

FEBRUARY 1980

TERRAPHYSICS

PROJECT MCCOY NEVADA

CHARGE DAYS	DATE	TECHNIQUE	TOTAL STATIONS	LOCATIONS	FREQ. BAND Hz					MAZZELLA	MALLOY	LANGE		
NC	4	M		Pickup supplies, liquid HE (7hrs)						X				
½	5	M		Mobilization, pack equipment leave CA for Austin, NV. Truck breaks down in Sierra Nevada MTS						X				
½	6	M		Repair truck, continue to Austin, NV						X				
1	7	Survey area		McCoy mine area, survey-setup M1,A1 B1 dipodes high winds, bury dipole wires						X	X			
NC	8	Down day		Fill Magnetometer , "O" rings cracks- repair						X				
1	9	TMT	3	Data M1,A1,B1 ; survey layout M2,B2 dipoles low signal windy, bury dipole wires cattle knock over antenna at A1						X	X	X		
1	10	TMT		More data M1,A1,B1 ; process data in the field lots of cattle in area						X	X			
1	11	TMT	3	Data M2,A2,B2, pickup setup 2, survey M3,A3,B3						X	X			
1	12	TMT	3	setup dipoles M3,A3,B3 Data M3,A3,B3 low signals						X	X			

TOTALS
Mobilization 1
Survey 5

T - TELLURICS OT - ORTHOGONAL TELLURICS MT - MAGNETOTELLURICS

R - D.C. RESISTIVITY EM - ELECTROMAGNETIC M - MOBILIZATION

MONTH

FEBRUARY 1980

TERRAPHYSICS

PROJECT McCOY, NEVADA

CHARGE DAYS	DATE	TECHNIQUE	TOTAL STATIONS	LOCATIONS	FREQ. BAND H_Z	MAZZELLA	MALLOY
1	13	TMT	2	Data M4,A4; survey setup dipoles M5,B5		X	X
1	14	TMT	3	light rain starts 7:30A.M. in Austin Data M5,A5,B5 (when rain stops, not much here) Survey M6,A6,B6, setup A6,B6		X	X
1	15	TMT	3	Setup M6 Data M6,A6,B6 ; Survey M7,A7,B7, setup A7,B7		X	X
1	16	TMT	3	Setup M7 Data M7,A7,B7 ; survey M8, A8,B8, setup M8		X	X
1	17	TMT	3	setup B8, A8 Data M8,A8,B8 High winds, rain starts 3:00P.M. Heavy rain by 4P.M.		X	X
1/2	18	TMT	-	Pickup M8,A8,B8 ; Rain still falling fairly heavy 8:30 A.M. , road very muddy and slick		X	X
1/2		Down - Weather : Rain					

[illegible]S
Survey 5½
Standby ½
Weather

T - TELLURICS OT - ORTHOGONAL TE[illegible] MT - MAGNETOTELLURICS
R - D.C. RESISTIVITY EM - ELECTROMAGNETIC M - MOBILIZATION

MONTH

FEBRUARY 1980

TERRAPHYSICS

PROJECT McCOY, NEVADA

LOCATI...

CHARGE DAYS	DATE	TECHNIQUE	TOTAL STATIONS		FREQ. BAND Hz	MAZZELLA	MALLOY	LANGE
1	19	TMT	3	Survey, setup M9,A9,B9 Data M9,A9,B9 Very windy, lots of high frequency spikes observed on all channels Arc welder at drill site and/or from local ranches		X	X	
1	20	TMT	3	Setup M10,A10,B10 Data M10,A10,B10 survey M11', A11', B11 layout B11		X	X	X
1	21	TMT	2	Snow 2 to 6 inches over survey area above 4800ft Raining below, road very muddy and slick Can't get into M11' and A11' locate and setup new A11 and M11, rain stops about 2P.M. obtain some data M11, A11 (no B11) low signals		X	X	X
1	22	TMT		Continue data at M11, A11 ; survey M12, A12 and B12(old B11) Takes 2 3/4 hours each way from Austin to sites		X	X	
1	23	TMT	3	Roads and area very muddy and slick Setup M12, A12 Data M12, A12, B12 ; survey M13, A13, B13 setup A13		X	X	
1	24	TMT	3	Setup M13, B13 Data M13, A13, B13 ; survey M14, A14, B14 setup A14, B14		X	X	

TOTALS
Survey 6 days

T - TELLURICS OT - ORTHOGONAL TELLURICS MT - MAGNETOTELLURICS

R - D.C. RESISTIVITY EM - ELECTROMAGNETIC M - MOBILIZATION

MONTH

FEBRUARY 1980

TERRAPHYSICS

PROJECT McCOY, NEVADA

CHARGE DAYS	DATE	TECHNIQUE	TOTAL STATIONS	LOCATIONS	FREQ. BAND Hz	PERSONNEL: MA[illegible]LLA	PERSONNEL: MALLOY
1	25	TMT	3	Setup M14 Data M14, A14, B14 (move M14 250 meters off road lots of vehicles on road from drilling crews- do not appear to pick them up on magnetometer. ~~Pick up all setups, pack equipment~~		X	X
1	26	Mobilization		back to California , return He dewar		X	
	27			Unload equipment			

TOTALS
Survey 1 day
Mobilization 1 day

T - TELLURICS OT - ORTHOGONAL TELLURICS MT - MAGNETOTELLURICS

R - D.C. RESISTIVITY EM - ELECTROMAGNETIC M- MOBILIZATION