TEC-13

TELLURIC AND MAGNETOTELLURIC SURVEY
AT
GRAND VIEW WEST
OWYHEE CO., IDAHO

for

AMAX EXPLORATION, INC.

May 1978

by

Aldo Mazzella

TERRAPHYSICS
815 SOUTH TENTH STREET
RICHMOND, CALIFORNIA 94804
(415) 234-8961

Abstract

A telluric-magnetotelluric (T-MT) survey was conducted in the Grand View West prospect, Idaho.

Rotated tensor data were obtained at three base stations and 7 remote sites.

A conductive zone appears to underlie a fairly large part of the area (< 2 ohm meters, ~ 20 km deep). It appears to intrude closer to the surface (~10 km) suggesting a possible fault conduit.

A number of near surface conductive zones are suggested. These may be reflecting geothermal zones, conductive sediments or a combination of the two cases.

Table of Contents

Introduction

Terraphysics conducted a telluric-magnetotelluric (T-MT) survey in the Grand View West area, Idaho on behalf of Amax Exploration Inc. The field work was conducted during the period 13-20 May 1978.

Survey Objective

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

Telluric-Magnetotelluric Instruments and Procedure

A schematic of the instruments 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 a pair of orthogonal electric field components is measured. In some cases a "T" configuration is used where a closer density of stations is desired. 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. Porous pots or seasoned lead strips are used for electrodes for the electric field measurements, the telluric dipoles. 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 2 to 5 km.

In order to solve for impedance tensors (the remote station data are treated as tensors also) , the analog data on the magnetic tape is digitized (12 bits) in the laboratory and evaluated on a large core computer.

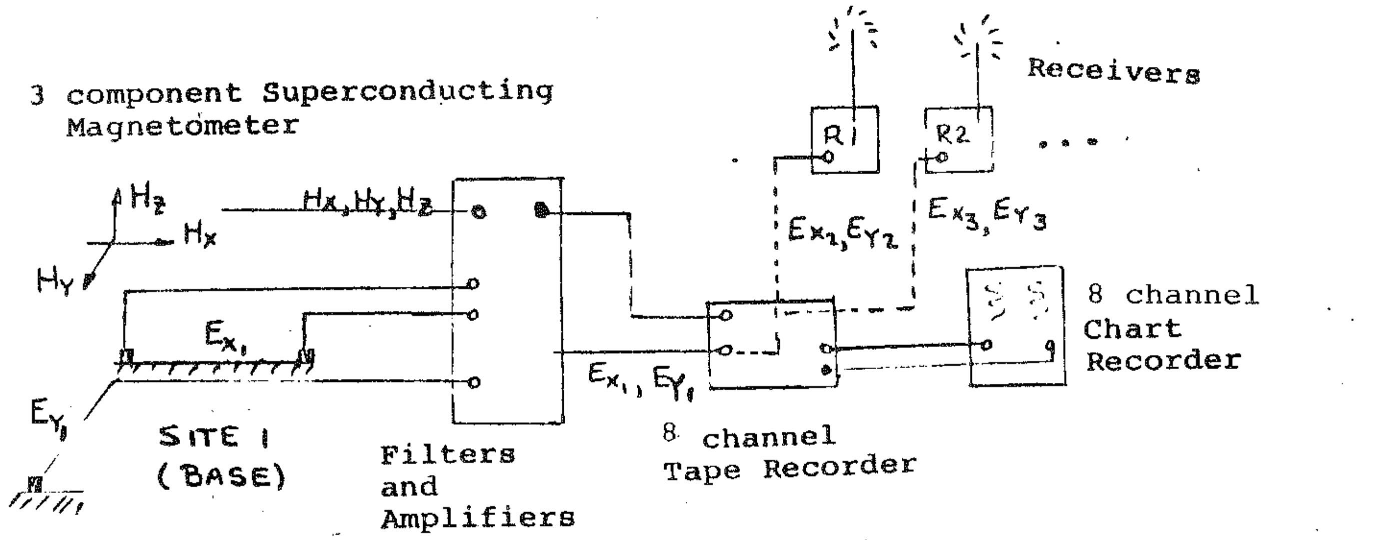
One method of analysis follows that described by Sims and Bostick (1969) and Vozoff (1972). We can write the impedance equations as

$$E_x = Z_{xx}H_x + Z_{xy}H_y$$
$$E_y = Z_{yx}H_x + Z_{yy}H_y \qquad (3)$$

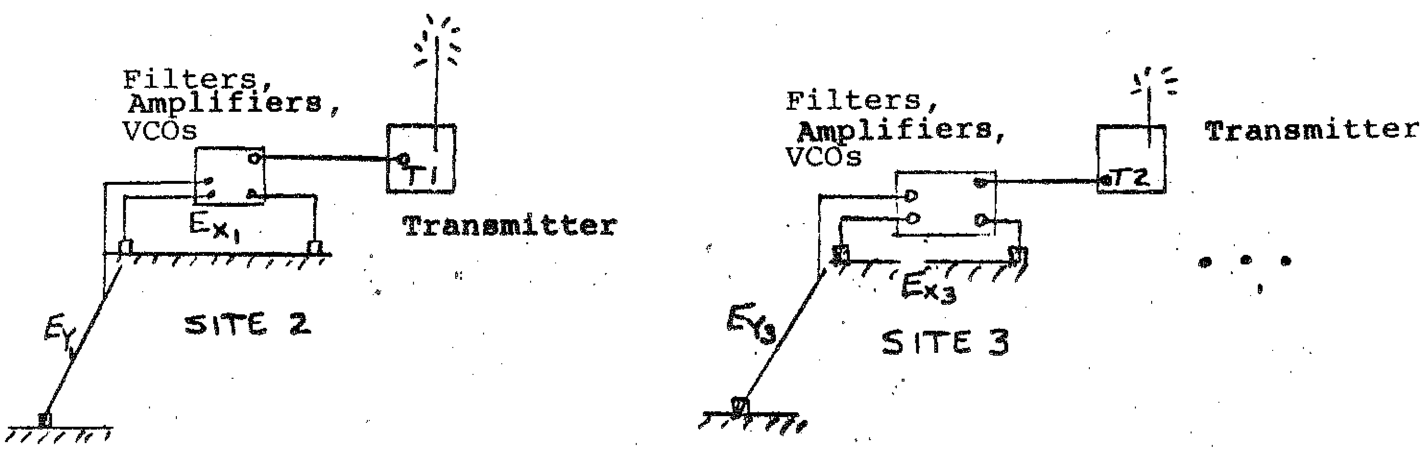
Estimates of the impedance tensor terms (Z_{xx},etc.) are obtained in a mean square sense. We define a quantity

$$\psi = \sum_{i=1}^{n} (E_{xi} - Z_{xx}H_{xi} - Z_{xy}H_{yi})(E^*_{xi} - Z^*_{xx}H^*_{xi} - Z^*_{xy}H^*_{yi}) \qquad (4)$$

where E^*_{xi} is the complex conjugate of E_{xi}, etc. and find values of Z_{xx} and Z_{xy} that minimize ψ . The resulting equations involve auto and cross power density spectra.



MAGNETOTELLURIC SETUP



TELLURIC SETUP

Figure 1. Magnetotelluric-Telluric Instrumentation

The time sequences of digital data are tapered, Fourier transformed, smoothed and constant Q estimates of the spectra densities are obtained.

Estimates of the impedance terms are calculated in the present work by four methods: the first uses equations that can bias the results downward due to noise on the magnetic fields, the secord uses equations that can bias the results upward due to noise on the electric fields, the third method uses an average of the four different possible equations with the base fields, and the fourth method calculates cross powers utilizing the remote electric fields. This last method provides results without bias errors, however poor results can occur if the electric fields are linearly polarized.

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 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.

$$S = \frac{|Z_{xx}' + Z_{yy}'|}{|Z_{xy}' - Z_{yx}'|} \qquad (6)$$

Principal apparent resistivity values are calculated from

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

$$\rho_Y = 0.2 \quad T \quad |Z_{yx}'|^2 \qquad (7)$$

where T is the period in seconds..

An indication of the quality of the impedance estimates is provided by the coherency (η) between the measured electric fields and the electric fields predicted by forming the product of the measured magnetic field and unrotated impedance tensor (see equation 3). In general the results are rated as good for $\eta \geq .90$.
Uncertainity values for the apparent resistivities are also calculated representing two standard errors, or 95% confidence levels (Reddy et al., 1976).
These quantities are only calculated for the method that utilizes the magnetic fields in the impedance tensor estimates.

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. The magnitude of the vertical field, A', the tipper, gives some indication of any lateral resistivity variations. The direction of the tipper points downward from the conductive to the resistive side of the structure.

Monitoring different frequencies provides various depth information. An indication of the depth penetration is sometimes given by the apparent skin depth, δa. This is defined 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 is 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 modeling 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 300 meters were used. They were orientated north-south and east-west.

The field system filters somewhat prewhitened the spectrum so that data was obtained wide band from 0.01 to 10 Hz. About 4 to 6 hours of data were recorded for each setup with about 1 hour of the best data processed on the computer.

Three setups of data were obtained consisting of 3 base stations and 7 remote sites.

Data at an additional remote site was discarded when local residents strung the telluric dipole wire in the air on fence posts.

Very high winds were encountered throughout the entire period of the field operations. The winds persisted sometimes throughout the night. The telluric wires were carefully laid out on the ground and weighted down with rocks or buried about every 10 feet.
Because of the brush in the area this proved to be very time consuming.
Light rain fell on one day , it did not delay the survey.

The personnel stayed at the Town Center Motel in Mountain Home, Idaho. Commuting time to the survey area was about one hour each way.

Specific vehicles used on the project were a jeep (4 wheel drive) and a Ford 3/4 ton pickup with a camper shell (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 analysis
L. Donahue	Field Technician	Survey, wire crew

Data

The location of the stations are shown in plates 1 and 2. Plots of the data and the one dimensional inversions are presented in the second binder. Data points are plotted that meet the following selection criteria:

1) skewness $<$ 1.0

2) phase between 0 and 90 degrees

The rotated apparent resistivity values, the rotation angle, the skewness and the phase are plotted for each of the remote reference method and the average method. In addition, the tipper, the tipper rotation angle, and the tipper skewness(also an indication of three dimensional properties) are also plotted for each station.

The tipper direction and the approximate strike direction at each base station for a period $T \sim 30$ secs are plotted in plate 3. The rotated axis for the TE Mode are also plotted for each site.

The interpretated resistivity sections (based upon the one dimensional inversions) along lines AA' and BB' are plotted in plates 4 and 5.

The computer printouts are presented in a separate binder.

Discussion of Data

A number of interesting features are suggested from the interpretations along lines AA' and BB' (plates 4 and 5).

A conductive zone ($<$ 2 ohm meters)appears to underlie the area from stations B2 to M6 at a depth of 10 to 20 km. In the area between M4 and A6 this conductive region intrudes closer to the surface ($<$ 10 km) suggesting a possible fault conduit for geothermal fluids.

Near the surface a low resistivity zone ($<$ 5 ohm meters) is indicated at a depth of 400 to 1000 meters. this zone extends from station A6 to the northeast about 13 km to B4. This may be reflecting geothermal fluids, a zone of conductive sediments or a combination of the two cases.

Another low resistivity near surface zone is suggested in the area of line BB' station M5 to B3 ($<$ 10 ohm meters, 400 meters deep). This may just be reflecting conductive near surface sediments.

A conductive zone ($<$ 10 ohm meters is suggested beneath station B3 at a depth of about 8 km. The data suggest that this zone might occur closer to the surface to the northeast of B3. This might then reflect the same "fault conduit" feature indicated along line AA'.

Summary and Recommendations

A conductive zone appears to underlie a fairly large region of the area (< 2 ohm meters, 20 km deep). It appears to intrude closer to the surface between stations M4 and A6 (~10 km) suggesting a possible fault conduit.

A similar feature is suggested to the northeast of station B3 on line BB'. Additional survey work is recommended in this area to define this feature.

It is recommended that other geophysical techniques such as a microearthquake survey and temperature gradient measurements be performed and might provide insight to this posulated fault conduit.

A number of near surface conductive zones are indicated. These may be reflecting geothermal brines, conductive sediments or a combination of the two cases.

MONTH

MAY, 1978

TERRAPHYSICS

APPENDIX A

PROJECT GRAND VIEW WEST, IDAHO

DAY	DATE	TECHNIQUE	TOTAL STATIONS	LOCATIONS	FREQ.S Hz 05	01	08	8		DONAHUE	WILSON	MAZZELLA	CORWIN	PEER
½M	12	M		Mobilization						X		X		
0	13			Equipment preparation						X		X		
1	14	S		Survey M4, A4, B2, lay out wire, windy						X		X		
1	15	TMT	3	Data M4, A4, B2 light rain, windy Survey setup M5,A5,B3						X		X		
1	16	TMT	3	Data M5,A5,B3 (LINE BB) very windy Setup, survey M6,A6,B5						X		X		
1	17	TMT	0	Data M6,A6,B5 Very high winds, data no good Farmers move B5 wire						X		X		
1	18	TMT	4	Data M6,A6N,S, B4 (setup B4)						X		X		
½	19	M	-	Mobilization						X		X		

Mob. 1 day, Survey-data 4 days
Bad weather 1 day

SP- SELF POTENTIAL

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

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

REFERENCES

Bostick, F.X. 1976, Paper presented on Geothermal Workshop at University of Utah,

Keller, G. V., 1970, Induction Methods in Prospecting for Hot Water, United National Symposium, Pisa, Italy.

Keller, G. V., and Frischknecht, F. C., 1970, Electrical Methods in Geophysical Prospecting, Pergamon Press, Inc.

Oakeshott, G. B., 1971, California's Changing Landscapes, McGraw-Hill Book Company, San Francisco, California.

O'Brien, D. P., and Morrison, H. F., 1967, Geophysics, Vol. XXXII, No. 4, August 1967.

Patrick, F.W. and Bostick, F.X., 1969, Magnetotelluric Modeling Techniques, Technical Report No. 59, Electronics Research Center, Univeristy of Texas, Austin, Texas.

Reddy, I.K. , Phillips, R.J., Whitcomb, J.H., Cole, D.M., and Taylor, R.A., 1976, Monitoring of Time Dependent Electrical Resistivity by Magnetotellurics, Journal of Geomagnetism and Geoelectr., 28.

Sims, W.E. and Bostick, F.X., 1969, Methods of Magnetotelluric Analysis , Technical Report No. 58, Electrical Geophysical Research Laboratory, Electronics Research Center, University of Texas, Austin , Texas.

Vozoff, K, 1972, The Magnetotelluric Method in the Exploration of Sedimentary Basins, Geophysics, Vol. 37, No. 1,.

Waring, G. A., 1965, Thermal Springs of the United States and Other Countries of the World--A Summary. Geological Survey Professional Paper 492, U. S. Printing Office, Washington, D.C.

Zohdy, A. A. R., Anderson, L. A., Muffler, L. J. P., 1973, Resistivity, Self Potential, and Induced Polarization Surveys of a Vapor-Dominated Geothermal System, Geophysics, Vol. 38, No. 6, p. 1130.