ELECTRICAL RESISTIVITY SURVEY AT ANIMAS PROSPECT HIDALGO COUNTY, NEW MEXICO

Prepared for

AMAX EXPLORATION, INC.

Geothermal Group

March, 1976

by

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Abstract

A reconnaissance electrical resistivity survey was conducted by Terraphysics in the Animas area, Hidalgo County, New Mexico.

A combination of telluric and magnetotelluric methods was used. Some d.c. resistivity measurements were also obtained.

The general structural features of a typical Basin and Range Province area are delineated. High resistivity values, reflecting volcanic rocks, are observed in the mountains and lower values are observed in the valley sediments. A considerable number of other features, contacts and faults are delineated.

The results indicate two low-resistivity areas ($<$ 6 ohm meters) to the east and west of the hot wells in Lower Animas valley. A resistivity high ridge appears directly beneath the hot wells.

The resistivity pattern at 0.05 Hz, in the vicinity of the hot wells, is similar to both the gravity and the magnetic data.

Additional survey work is recommended in the area.

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Introduction

Terraphysics conducted electrical surveys in the vicinity of Animas, Hidalgo County, New Mexico, on behalf of the Geothermal Group of Amax Exploration, Inc. The work was performed during two intervals, 17 January to 2 March and 16 June to 12 August 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 wells 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.

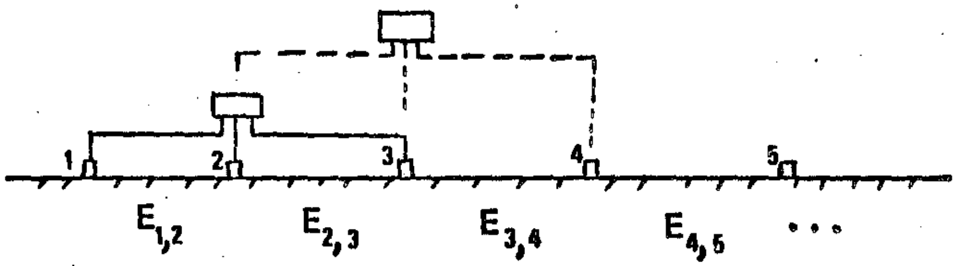
Procedure and Instrumentation

A combination of telluric and magnetotelluric methods was 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 is itemized in Table 1 and 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 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 →

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

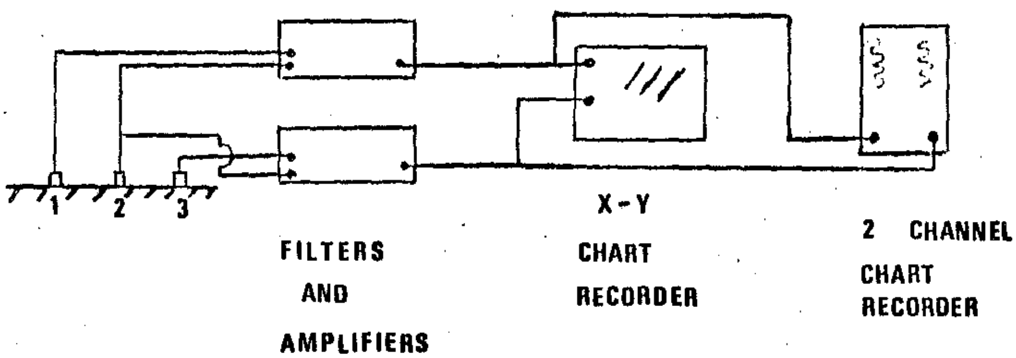
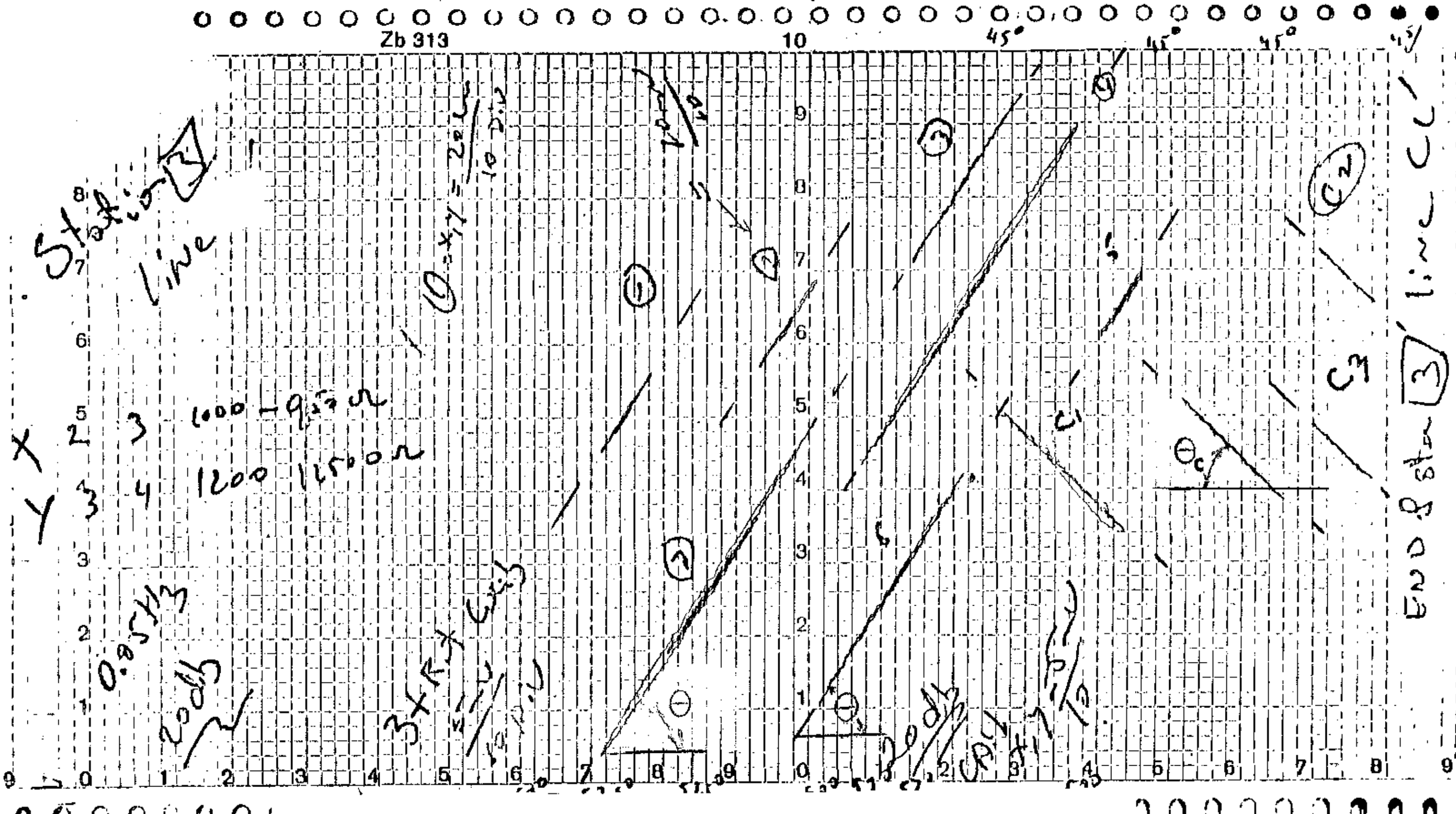


Figure 1. Collinear telluric method and instrumentation

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
1	2 channel amplifier
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	Jeep, 4 wheel drive
1	Lockheed model store 4 magnetic tape deck
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)
1	Geotronics motor generator set
1	Geotronics EM Transmitter
1	Mark I Telluric receiver
	Various rental vehicles



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

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

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

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

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 as the collinear telluric data. The orthogonal magnetic field component H_y is measured with 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 1500 meter dipoles having separations up to 5 km. These techniques provide a check on the near-surface 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 Animas

In the Animas survey, telluric dipoles ranging from 0.5 to 1.5 km in length were employed, depending on topographic conditions. Telluric measurements were made primarily at 0.05 Hz although some 8 Hz data were obtained.

Geologic strike in the area runs between north and northwest. Telluric lines were run east-west as determined by roads and access, and as specified by the client. Two hundred (200) telluric stations were measured and 42 MT stations were occupied primarily at strategic locations on the telluric lines. In addition, 36 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
L. Donahue	Field Engineer	Survey, wire crew, vehicle maintenance
W. Harvey	Field Technician	Instrumentation, equipment maintenance, wire crew
P. Guzman	Field Hand	Wire crew, equipment maintenance
K. Dohl	Field Hand	Data Analysis

Terraphysics personnel worked a total of 232 field man days in the Animas area of New Mexico over a period of 72 days. In addition, A. Mazzella spent 21 days in the field with the crew.

Operating Conditions

During the first interval from January to March, the weather was generally favorable. Some interference and delay did occur when another geophysical company moved into the area with an active d.c. resistivity system. A 50 Ampere current dipole was planted adjacent to our line. Measurements were repeated at those stations where possible interference occurred.

During the second interval, June 16th to August 10th, the work was significantly impeded by lightning storm activity. Some stations were repeated between the hours of 0400 to 1000, when lightning activity appeared to be at a minimum. On some days, however, the lightning activity seemed to occur continuously over a 24 hour interval. Data affected by lightning are not presented in the final results.

The personnel stayed at the Lordsburg Travelodge in the town of Lordsburg, New Mexico, the nearest town in which the personnel could be housed. 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 jeep (4 wheel drive), a Chevrolet 1/2 ton pickup with camper shell and an equipment trailer.

DATA

The locations 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 12. 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.

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 is presented in Table 2.

A contour map of apparent resistivities for the 0.05 Hz data is depicted in Plate 2 as described from the profile data. The apparent resistivities are plotted in logarithmic contour intervals.

A pseudosection of the telluric-MT data along line FF' is presented in Figure 13. The apparent skin depth is plotted as the ordinate, and station locations are projected on the abscissa at the top of the plot. Scalar apparent resistivities are mapped in logarithmic contour intervals.

Orthogonal telluric measurements were obtained at eight (8) stations. Variations in both the phase and the amplitude ratio were observed between the orthogonal dipoles over a period of time. Average directions are indicated in Table 3.

The directions varied between N 23^{o} W in the northern part of the survey to N 34^{o} W in the southern part, and N 16^{o} W along the east side of the Animas valley.

The results of d.c. resistivity measurements are summarized in Table 4. Apparent resistivity pseudosections for a dipole-dipole expansion along lines AA' and LL' are presented in Figures 14 and 15.

PLACE Animas, New Mexico

TABLE 2 MAGNETOTELLURIC DATA

APPARENT RESISTIVITY OHM METERS ∓ STANDARD DEVIATION
(NUMBER OF SAMPLES)

LINE & STATION	LENGTH IN METERS	DATE	0.05 Hz	8.0 Hz	0.1 Hz	0.8 Hz	COMMENTS
AA' 1-2B	835	1/23	3.9 ± 0.9 (6)	9.2 ± 2.5 (19)			
2A-2B	481	1/23	123 ± 139 (18)				
2B-3	975	1/23	9.7 ± 5.7 (19)				
7-8	610	1/23	38 ± 6 (14)	9.9 ± 1.0 (3)			
8-9	576	1/23	80 ± 22 (26)	--			no usable signals 8 Hz
9-10	716	2/28	24 ± 14 (29)				
10-11	549	2/28	36 ± 9 (11)	86 ± 48 (9)			
11-12	899	1/23 2/28	53 ± 55 (22)				

PLACE Animas, New Mexico

TABLE 2 MAGNETOTELLURIC DATA

APPARENT RESISTIVITY OHM METERS ∓ STANDARD DEVIATION
(NUMBER OF SAMPLES)

LINE & STATION	LENGTH IN METERS	DATE	0.05 Hz	8.0 Hz	0.1 Hz	0.8 Hz	COMMENTS
BB' 1-2	640	1/24	158 ± 81 (26)	291 ± 86 (11)			large 60 Hz noise on 8 Hz data
2-3	564	1/24	34 ± 19 (17)	892 ± 350 (10) ?			large 60 Hz noise on 8 Hz data
7-8	960	1/24 3/2	18 ± 20 (46)	3 ± 3 (2) ?			large 60 Hz noise on 8 8 Hz data
8-10A	1524	1/24 3/2	9.2 ± 10.5 (28)				
10A-10B	796	3/2	155 ± 182 (22)				
14B-17A	1622	1/25	5.7 ± 7.9 (22)				
20-21A	988	3/2	24 ± 24 (22)				
21A-21B	463	3/2	212 ± 127 (50)				

PLACE Animas, New Mexico

TABLE 2 MAGNETOTELLURIC DATA

APPARENT RESISTIVITY OHM METERS ∓ STANDARD DEVIATION
(NUMBER OF SAMPLES)

LINE & STATION	LENGTH IN METERS	DATE	0.05 Hz	8.0 Hz	0.1 Hz	0.8 Hz	COMMENTS
CC' 10-11	805	2/28	28 ± 14 (17)	4.2 ± 1.9 (8)			
16-17	800	2/28	306 ± 66 (18)	44 ± 16 (14)			
20-21	724	2/28	40 ± 33 (39)	37 ± 6 (6)			
C'C" 36-37	693	7/10	--	256 ± 70 (20)		161 ± 28 (8)	
38A-39A	846	7/9	118 ± 94 (12)	93 ± 25 (13)	64 ± 21 (18)	53 ± 36 (20)	
38B-39B	594	7/9	1070 ± 540 (20)	86 ± 31 (23)	849 ± 191 (18)	167 ± 71 (18)	Orthogonal MT
43-44	805	7/9	108 ± 32 (26)	41 ± 14 (21)	63 ± 21 (17)	32 ± 15 (9)	
44A-45	805	7/9	77 ± 35 (22)	--	51 ± 26 (26)	45 ± 42 (7)	8 Hz data, noisy

PLACE Animas, New Mexico

TABLE 2 MAGNETOTELLURIC DATA

APPARENT RESISTIVITY OHM METERS ∓ STANDARD DEVIATION
(NUMBER OF SAMPLES)

LINE & STATION	LENGTH IN METERS	DATE	0.05 Hz	8.0 Hz	0.1 Hz	0.8 Hz	COMMENTS
C'C" 44A-44B	297	7/9	397 ± 127 (22)	42 ± 17 (13)	320 ± 135 (16)	66 ± 30 (26)	Orthogonal MT
DD' 3-4	1090	2/26	65 ± 27 (51)	7.2 ± 2.6 (13)			
21-22	1059	2/25	182 ± 88 (26)	33 ± 13 (35)			
EE' 9A-10	853	3/1	3.2 ± 2.3 (34)				
9A-9B	805	3/1	35 ± 31 (34)				Orthogonal MT
15-16	739	3/1	60 ± 42 (51)				
FF' 4-5	579	7/8	2 groups 21 ± 9/(8) 66 ± 12/(5) 38 ± 25/(13) all	24 ± 5 (6)			
8-9	724	7/8	4.9 ± 3.8 (12)	13 ± 8 (15)	14 ± 4 (6)		

PLACE Animas, New Mexico

TABLE 2 MAGNETOTELLURIC DATA

APPARENT RESISTIVITY OHM METERS ∓ STANDARD DEVIATION
(NUMBER OF SAMPLES)

LINE & STATION	LENGTH IN METERS	DATE	0.05 Hz	8.0 Hz	0.1 Hz	0.8 Hz	COMMENTS
FF' 11B-12A	811	7/14 7/18	11 ± 5 (15)	22 ± 11 (22)			
15-16	815	7/14	75 ± 26 (16)		17 ± 9 (9)	6 (2)	
19-20	610	7/14 7/18	4.3 ± 2.9 (14)	12 ± 5 (21)	3.4 ± 1.6 (7)	4.5 ± 2.2 (11)	
HH' 2-3	719	7/14	209 ± 98 (22)	52 ± 58 (24)			
23-24	805	7/19	187 ± 142 (26)	89 ± 40 (21)			
MT 4	488	7/19	232 ± 110 (10)	52 ± 27 (21)			
XX' 7-8	805	7/3	96 ± 41 (22)	25 ± 9 (26)	69 ± 40 (16)	29 ± 10 (20)	
12-13	805	7/7	--	85 ± 10 (9)			

PLACE Animas, New Mexico

TABLE 2 MAGNETOTELLURIC DATA

APPARENT RESISTIVITY OHM METERS ∓ STANDARD DEVIATION
(NUMBER OF SAMPLES)

LINE & STATION	LENGTH IN METERS	DATE	0.05 Hz	8.0 Hz	0.1 Hz	0.8 Hz	COMMENTS
XX' 16-17	805	7/19	38 ± 13 (8)	70 ± 45 (9)			
26-27	805	7/19	68 ± 50 (22)				

Table 3

Orthogonal Telluric Measurements

0.05 Hz

Location Line	Location Station	Electric Field Direction
AA'	1A	N 24° W
BB'	10A	N 25° W
CC'	12A	N 16° W
DD'	6B	N 34° W
EE'	9A	N 23° W
FF'	10A	N 25° W
FF'	20A	N 16° W
XX'	2A	N 32° W

Table 4

D.C. Resistivity Measurements

Animas, New Mexico

Location	Type		Spacing Length Meters	Apparent Resistivity Ohm Meters
Line AA'				
Station 1	Wenner	"a" spacing	15	30
Stations 1-2B	Wenner	"a" spacing	305	9.0
Stations 1-2B 3-4	Dipole-Dipole	center to center	1725	16
1-2B 4-5	Dipole-Dipole		2414	15
1-2B 5-6	Dipole-Dipole		3155	12
1-2B 6-7	Dipole-Dipole		3764	13
Line BB'				
Station 19	Wenner	"a" spacing	15	60
Station 20	Wenner	"a" spacing	15	80
Stations 19-20	Wenner	"a" spacing	305	22

Table 4 (con't.)

D.C. Resistivity Measurements

Animas, New Mexico

Location	Type		Spacing Length Meters	Apparent Resistivity Ohm Meters
Line C'C"				
Station 36	Wenner	"a" spacing	15	48
Line DD'				
Station 1	Wenner	"a" spacing	15	28
Line EE'				
Station 9A	Wenner	"a" spacing	15	48
Stations 9A-10	Wenner	"a" spacing	305	5.7
Line LL'				
12A-C_2	Gradient		1646	24
12A-C_2 21A-2	Dipole-Dipole	center to center	2606	17
12A-C_2 20A-21A	Dipole-Dipole		3856	14

Table 4 (con't.)

D.C. Resistivity Measurements

Animas, New Mexico

Location	Type	Spacing Length Meters		Apparent Resistivity Ohm Meters
Line MM'				
Station R 1	Wenner	"a" spacing	305	55
R 2	Wenner	"a" spacing	305	38
R 3	Wenner	"a" spacing	305	32
R 4	Wenner	"a" spacing	305	39
R 5	Wenner	"a" spacing	305	45
Line NN'				
Station R 1	Wenner	"a" spacing	305	17
R 2	Wenner	"a" spacing	305	19
R 3	Wenner	"a" spacing	305	15
R 4	Wenner	"a" spacing	305	18
R 5	Wenner	"a" spacing	305	23

Table 4 (con't.)

D.C. Resistivity Measurements

Animas, New Mexico

Location	Type		Spacing Length Meters	Apparent Resistivity Ohm Meters
Line XX' Station 9	Wenner	"a" spacing	15	108
Station 17	Wenner	"a" spacing	15	73
Station 20	Wenner	"a" spacing	15	197
Station 25	Wenner	"a" spacing	15	440
Stations 7-8 9-10	Dipole-Dipole	center to center	1609	23
16-17 18-19	Dipole-Dipole		1609	65
18-19 20-21	Dipole-Dipole		1609	66
20-21 22-23	Dipole-Dipole		1609	34

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 has been reduced by taking magnetotelluric measurements at intervals along the telluric profiles. Telluric values between MT readings have been adjusted linearly to correspond to the MT values.

2) Errors due to instrumentation are kept to a minimum by calibrating the instruments at each station. In some cases, calibrations were taken both before and after each frequency reading.

3) When 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, probably caused by local industrial electrical activity. Attempts have been 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 Animas area lies in the Basin and Range Province in southwestern New Mexico. This "province is characterized by north and northwest trending mountain ranges, which alternate with intervening basins and valleys,...streams run into inland valleys and end in saline lakes and playas" (Oakeshott, 1971).

Characteristically, the ranges are uplifted blocks (horsts) bounded by faults while the valleys are sediment-filled, downdropped fault blocks (gabbens).

Animas Area

The topography of the Animas area consists of alternating mountain ranges and valleys typical of the Basin and Range Province. The elevation ranged from about 1200 to 1700 meters.

In general, high apparent resistivity values are observed in the mountainous areas, reflecting volcanic rocks, while low resistivity values are observed in the valleys, reflecting alluvium and sedimentary deposits (Dane and Bachman, 1965).

A number of hot wells, with boiling water at a 50 meters depth, are located in the middle of the survey area (line BB', station 17).

0.05 Hz Data

The resistivity data depicted in Plate 2 indicates a complicated pattern that appears to focus in the area of the hot wells. A north-south resistivity high ridge appears to run directly beneath the hot wells (line BB', stations 17-19 and line FF', stations 15-16), and two low resistivity areas ($<$6 ohm meters) are indicated to the east and west. These patterns are similar to those observed on both the magnetic and the gravity data.

The low resistivity areas could be associated with hot geothermal brines, highly conductive sedimentary deposits of clays and gravels or a combination of the two.

These features are also delineated in the pseudosection of Figure 13, which is along line FF', one kilometer to the south of the hot wells. The resistivity low zone to the west appears to extend downward to the area of line FF', stations 8-9, where a magnetic low also occurs.

The low resistivity zones in Figure 13 appear to be centered at apparent skin depths of 2 to 3 kilometers. The actual depths are usually much less than these apparent values. In view of the anisotropic nature of the area, two-dimensional modelling would probably be required to unfold an accurate representation of its intrinsic properties.

A considerable number of other features are indicated in Plate 2. Perhaps the most prominent is an east-west trending contact or fault that occurs just south of line C'C". It appears to extend westward into the valley just south of Table Top Mountain (line HH', stations 25-28).

D.C. Resistivity Data

D.C. resistivity measurements were taken in various area to check the telluric-magnetotelluric data and give some additional interpretation insight.

The d.c. resistivity data shown in Figure 14, along line AA', agree well with the telluric-MT data. For example, at stations 1-2, the Wenner value of 9.0 ohm meters at an "a" spacing of 305 meters corresponds very well with the 8 Hz value of 9.2 ohm meters, skin depth 539 meters. The dipole-dipole value of 13 ohm meters beneath stations 3-4, dipole separation 4 kilometers, corresponds fairly well with the 0.05 Hz value of 25 ohm meters, skin depth 11 kilometers. A comparison summary of other data and stations is presented in Table 5, a similar agreement is seen.

The low resistivity value (5.7 ohm meters, "a" spacing 305 meters) on line EE', stations 9A-10, is probably associated with a thick layer of conductive lake bed deposits. A low resistivity value was observed in the 0.05 Hz data in this area (see Figure 8) and probably also reflects this conductive layer.

Table 5

Comparison of D.C. Resistivity and

Telluric-Magnetotelluric Data

	D.C. Resistivity			Telluric-Magnetotelluric			
Location	Type	Spacing Meters	Apparent Resistivity Ohm Meters	Location	Frequency Hz	Apparent Skin Depth Meters	Apparent Resistivity Ohm Meters
<u>Line AA'</u>							
1-2B	W	305	9.0	AA',1-2B	8	539	9.2
1-2B 6-7	D-D	3764	13	AA',3-4	.05	11247	25
<u>Line MM'</u>							
St 4	W	305	39	HH',4-5	8	1227	47
<u>Line XX'</u>							
7-8 9-10	D-D	1609	23	XX',7-8 8-9	8 8	889 1138	25 41
16-17 18-19	D-D	1609	65	XX',17-18	8	1488	70
18-19 20-21	D-D	1609	66	XX',19-20	8	1139	41
20-21 22-23	D-D	1609	34	XX',21-22	8	1139	41

Summary and Recommendations

The resistivity data appears to delineate the basic structure of the area. In general, high resistivity values, reflecting volcanic rocks, are observed in the mountains and lower values, reflecting conductive sedimentary deposits, are observed in the valleys. A considerable number of other features, contacts and faults are indicated.

Two low resistivity areas ($<$ 6 ohm meters at 0.05 Hz) are delineated. They occur both to the east and west of the hot wells (boiling) in the Lower Animas valley. A resistivity high ridge appears to occur directly beneath the hot wells.

Additional low frequency MT and active soundings in the area of the hot wells would help define the source of the hot waters. In view of the three-dimensional nature of the area, solutions for MT impedance tensors (Grillot, 1975) and at least two-dimensional modelling 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 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 affected. The 8 Hz E.M. wave in this case does not significantly penetrate to the depth of the one 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 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.

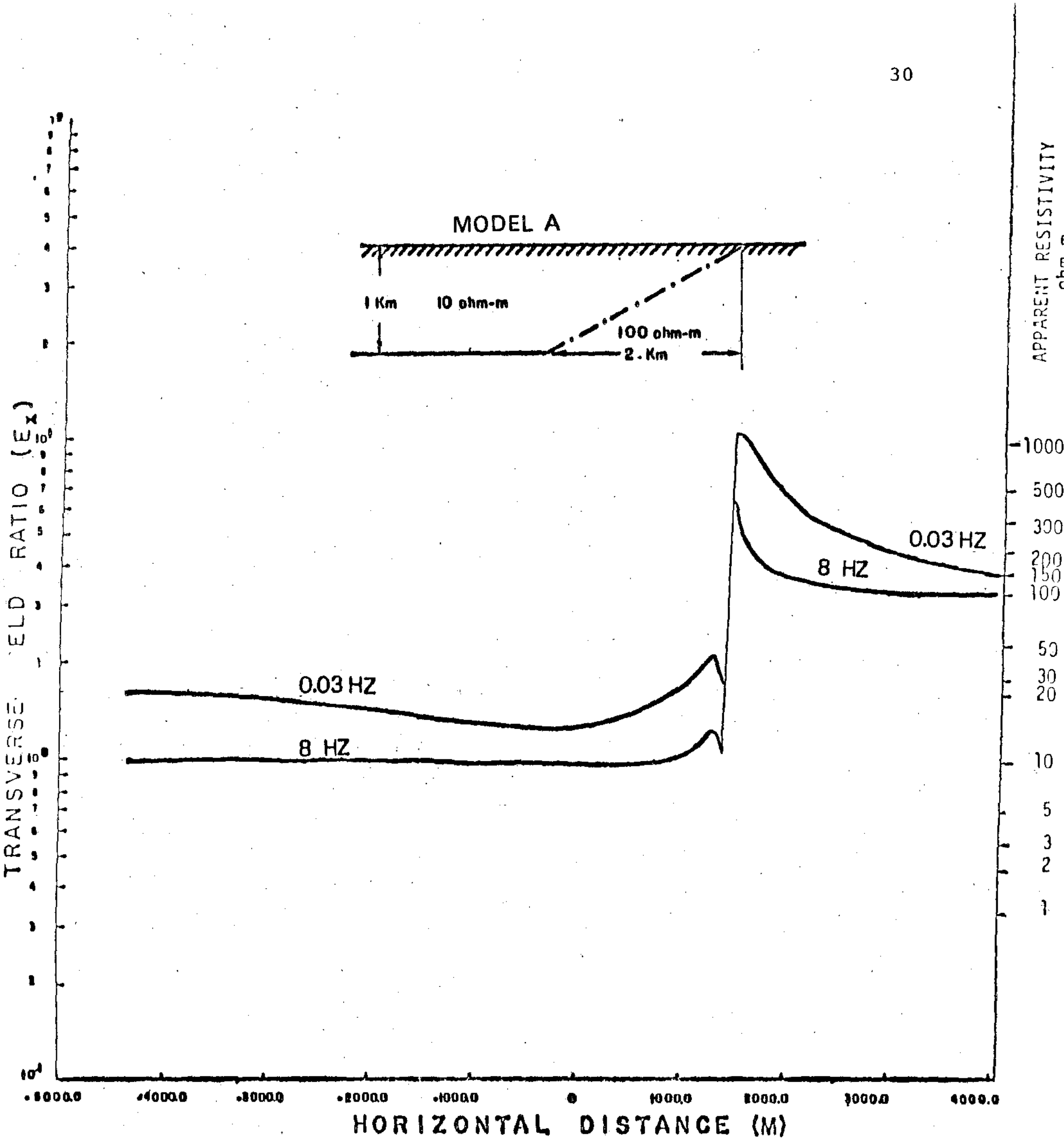

Figure A1. Telluric response at 8 Hz and at 0.03 Hz over Model A.

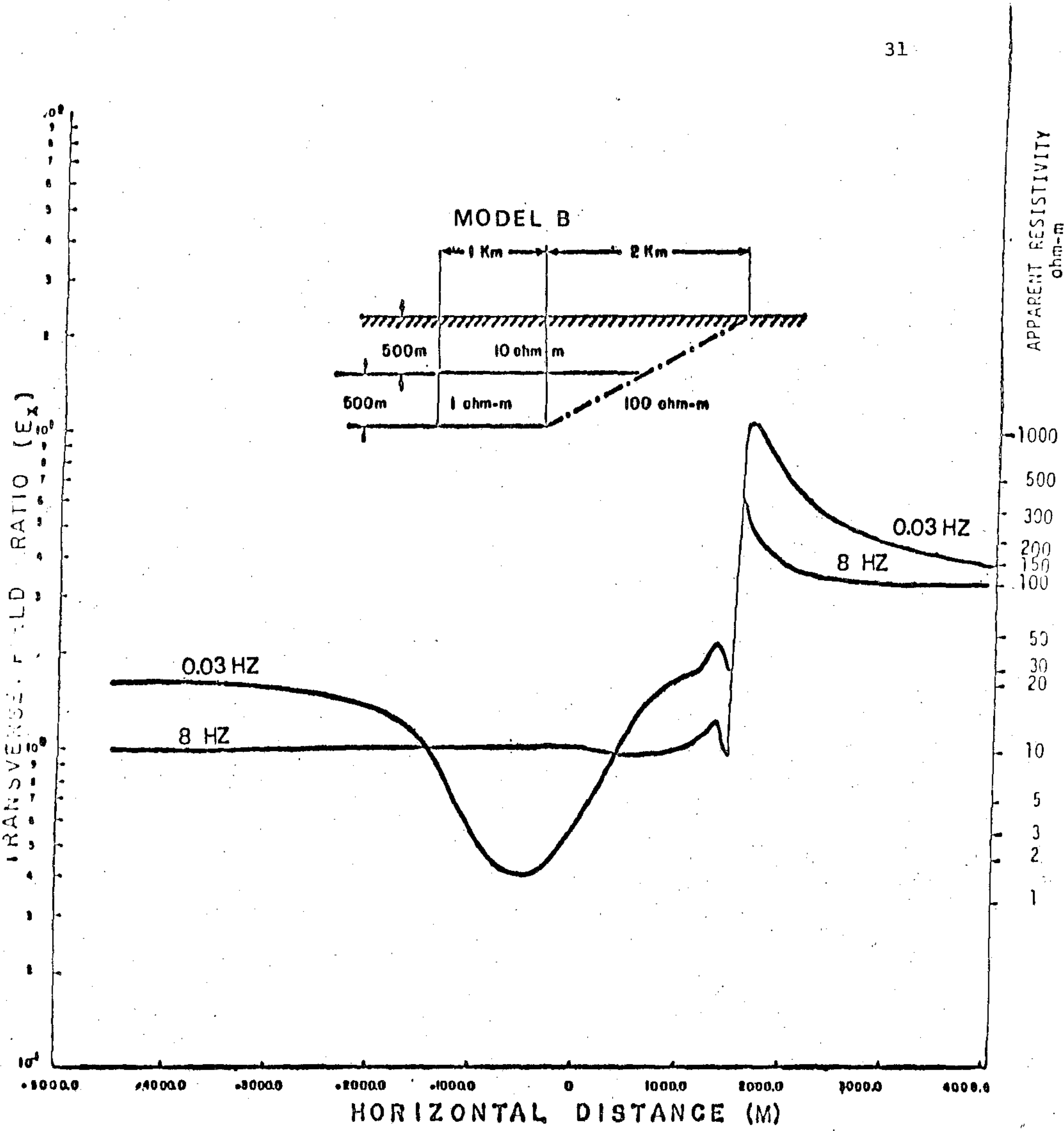

Figure A2. Telluric response at 8 Hz and at 0.03 Hz over Model B, inclusion of a one ohm meter body at 500 meters depth.

Appendix B

Personnel and Operations Summary

MONTH

January, 1975

TERRAPHYSICS

PROJECT Animas, New Mexico

DAY	DATE	TECHNIQUE	TOTAL STATIONS	LOCATIONS	FREQ.S Hz .05	.01	.08	8		MAZZELLA	PESSAH	GUZMAN	HARVEY	DONAHUE
Tue.	14th			Mobilization to Lordsburg, New Mexico							X	X		
Wed.	15th			Mobilization to Lordsburg, New Mexico							X	X		
Thu.	16th			Mobilization							X	X		X
Fri.	17th			Survey Mobilization							X	X		 X
Sat.	18th	T	10	Line AA, ST 1, 2, 3, 4, 5, 6, 7, 8, 9, 10	X						X	X		X
Sun.	19th	T OT	7 1	Line AA, ST 11, 12, 13, 14, 15, 16, 17 Line AA, ST 12	X X						X	X		X

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

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

MONTH

January, 1975

TERRAPHYSICS

PROJECT Animas, New Mexico

DAY	DATE	TECHNIQUE	TOTAL STATIONS	LOCATIONS	FREQ.S Hz .05	.01	.08	8		PERSONNEL MAZZELLA	PESSAH	GUZMAN	HARVEY	DONAHUE
Mon.	20th	T	2	Line AA', ST 1-0-18, 0-18-19A	X						X	X		X
		OT	1	Line AA', ST 1	X									
				Mobilization to Lordsburg, N.M. (New Vehicle)						X				
Tue.	21st	T	2	Line AA', ST 18-19A-20, 19A-20-21A	X					X	X	X		X
Wed.	22nd	T	3	Line BB', ST 2, 3, 4	X					X	X	X		X
Thu.	23rd	T	3	Line AA', ST 1, 2, 8 (Repeat to test effect of interference noise pick up of other geophysical company.)	X									
		MT	6	Line AA', ST 1-2, 2-3, 2A-2B, 7-8, 8-9, 11-12	X			X		X	X	X		X
Fri.	24th	T	1	Line AA', ST 1	X					X	X	X		X
		T	6	Line BB', ST 2, 3, 4, 4-5-7, 5-7-8, 7-8-10										
		MT	4	Line BB', ST 1-2, 2-3, 7-8, 8-10	X			X						
Sat.	25th	T	6	Line BB', ST 8-10-12A, 10-12B-14A, 12B-14B-17A, 14B-17A-19, 17A-19-20, 19-20-21 (Very low signals)	X					X	X	X		X
		MT	1	Line BB', ST 14B-17A	X									

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

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

MONTH

January, 1975

TERRAPHYSICS

PROJECT Animas, New Mexico

DAY	DATE	TECHNIQUE	TOTAL STATIONS	LOCATIONS	FREQ.S Hz 05	0.1	0.8	8		MAZZELLA	PESSAH	GUZMAN	HARVEY	DONAHUE
Sun.	26th			Data analysis Off						X	X	X		X
Mon.	27th	T	3	Line DD', ST 2, 3, 4	X						X	X		X
Tue.	28th	T	8	Line DD', ST 4-5-6A, 5-6A-7A, 6B-7B-8, 7B-8-9, 9, 10, 11, 12	X						X	X		X
Wed.	29th	T	3	Line DD', ST 13, 14, 15	X						X	X		X
Thu.	30th			Off										
Fri.	31st			Vehicle maintenance Survey Line EE'							X			X

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

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

MONTH

February, 1975

TERRAPHYSICS

PROJECT Animas, New Mexico

DAY	DATE	TECHNIQUE	TOTAL STATIONS	LOCATIONS	FREQ.S Hz 05	01	08	8		PERSONNEL MAZZELLA	PESSAH	GUZMAN	HARVEY	DONAHUE
Sat.	1st	T	13	Line EE', ST 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12 13, 14	X						X	X		X
Sun.	2nd	T	7	Line EE', ST 15, 16, 17, 18, 19, 20, 21	X						X	X		X
Mon.	3rd	T	2	Line BB', ST 17B-19-20, 19-20-21 (Repeat due to low signals before)						X	X	X		X
Tue.	4th	T	3	Line BB', ST 20, 21, 22	X									
		R	3	Line BB', ST 19, 20 50 Ft. Wenner; ST 19-20 1000' W						X	X	X		X
Wed.	5th	T	3	Line AA', ST 1-0-18, 0-18-19B, 18-19B-21B	X					X	X	X		X
		R	1	Line AA', ST 1, 50' Wenner										
Thu.	6th	T	4	Line BB', ST 23 Line LL', ST 2, 3, 4	X					X	X	X		X

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

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

MONTH
February, 1975

TERRAPHYSICS

Phase II

PROJECT Animas, New Mexico

DAY	DATE	TECHNIQUE	TOTAL STATIONS	LOCATIONS	FREQ.S Hz .05	.01	.08	8		MAZZELLA	PESSAH	GUZMAN	HARVEY	DONAHUE
Fri.	7th	T R R	1 1 4	Line AA', ST 4 (Repeat test of previous data, noise pick up) Line AA', ST 1-2 1000' W Line AA', dipole-dipole T- 1-2, Rec 3-4, 4-5, 5-6, 6-7	X					X	X	X		X
Sat.	8th	R	3	Line LL', dipole-dipole T- AA' 12A, Rec BB' 21B-21A, 21A-2 Gradient array betweeen 12A and C_2						X	X	X		X
Sun.	9th	T	3	Line CC', ST 9, 10, 11	X						X	X		X
Mon.	10th	T	9	Line CC', ST 12, 13, 14, 15, 16, 17, 18, 19, 20	X						X	X		X
Tue.	11th	T	5	Line CC', ST 21, 22, 23, 24, 25 (Repeat 14) poor signal	X						X	X		X
Wed.	12th			Off										

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

MONTH

February, 1975

TERRAPHYSICS

PROJECT Animas, New Mexico

DAY	DATE	TECHNIQUE	TOTAL STATIONS	LOCATIONS	FREQ.S Hz 05	01	08	8		PERSONNEL MAZZELLA	PESSAH	GUZMAN	HARVEY	DONAHUE
Thu.	13th	T	4	Line CC', ST 1, 2, 4, 8	X						X	X		X
Fri.	14th	T	4	Line CC', ST 3, 5, 6, 7	X						X	X		X
Mon.	24th	T	5	Line DD', ST 16, 17, 18, 19, 20	X					X		X		X
Tue.	25th	T	3	Line DD', ST 21, 22, 23	X					X		X		X
		MT	1	Line DD', ST 21-22	X			X						
Wed.	26th	MT	1	Line DD', ST 3-4	X			X		X		X		X
		R	1	Line DD', ST 4 50' W										
Fri.	28th	T	3	Line AA', ST 9, 10, 11 (Repeat test of noise pick up of other geophysics crew)	X					X		X		X
		MT	6	Line AA', ST 9-10, 10-11, 11-12 Line CC', ST 10-11, 16-17, 20-21	X			X						

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

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

MONTH

March, 1975

TERRAPHYSICS

Phase II

PROJECT Animas, New Mexico

DAY	DATE	TECHNIQUE	TOTAL STATIONS	LOCATIONS	FREQ.S Hz .05	.01	.08	8		PERSONNEL MAZZELLA	PESSAH	GUZMAN	HARVEY	DONAHUE
Sat.	1st	OT	1	Line EE', ST 9A-9B-10	X					X		X		X
		MT	3	Line EE', ST 9A-10, 9A-9B, 15-16	X									
				Line BB', ST 8-10A, 10A-10B										
		R	2	Line EE', ST 9A, 50' W; 9A-10, 1000' W										
Sun.	2nd	MT	2	Line BB', ST 20-21, 21-21B, 7-8	X					X		X		X
		OT		Line CC', ST 11-12A-12B	X									
		OT	2	Line DD', ST 6B-6C-7B	X									

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

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

MONTH

June, 1975

TERRAPHYSICS

Phase II

PROJECT Animas, New Mexico

DAY	DATE	TECHNIQUE	TOTAL STATIONS	LOCATIONS	FREQ.S Hz 05	01	08	8		DOHL	MAZZELLA	PESSAH	GUZMAN	HARVEY	DONAHUE
Sat.	14th			Mobilization to Lordsburg, New Mexico								X	X	X	X
Sun.	15th			Off											
Mon.	16th			Equipment and vehicle maintenance Survey line FF'											
Tue.	17th	T OT	9 1	Line FF', ST 2, 3, 4, 5, 6, 7, 8, 9, 10A Line FF', ST 10A	X X			X				X	X	X	X
Wed.	18th	T	5	Line FF', ST 11B, 12A, 13B, 14, 15	X			X				X	X	X	X
Thu.	19th	T OT	5 1	Line FF', ST 16, 17, 18, 19, 20 Line FF', ST 20	X X			X				X	X	X	X

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

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

MONTH

June, 1975

TERRAPHYSICS

Phase II

PROJECT Animas, New Mexico

DAY	DATE	TECHNIQUE	TOTAL STATIONS	LOCATIONS	FREQ.S Hz .05	.01	.08	8		DOHL	MAZZELLA	PESSAH	GUZMAN	HARVEY	DONAHUE
Wed.	25th	T OT	6 1	Line XX', ST 2A, 3, 4, 5, 6, 7 Line XX, ST 2A	X			X				X	X	X	X
Thu.	26th	T	7	Line XX', ST 8, 9, 10, 11, 12, 13, 14	X			X				X	X	X	X
Fri.	27th	T	2	Line XX', ST 15, 16	X			X				X	X	X	X
Sat.	28th	T	8	Line XX', ST 17, 18, 19, 20, 21, 22, 23, 24	X			X				X	X	X	X
Sun.	29th			Off											
Mon.	30th	T	3	Line XX', ST 25, 26, 27 (Data questionable, lightning) Survey Line C'C"	X			X				 X	X	X	X

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

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

MONTH

July, 1975

TERRAPHYSICS

Phase II

PROJECT Animas, New Mexico

DAY	DATE	TECHNIQUE	TOTAL STATIONS	LOCATIONS	FREQ.S Hz 05	01	08	8		DOHL	MAZZELLA	PESSAH	GUZMAN	HARVEY	DONAHUE
Tue.	1st	T	3	Line XX', ST 28, 29, 30 (Data questionable, lightning)	X			X				X	X	X	X
		OT	1	Line XX', ST 30											
Wed.	2nd	MT	1	Line XX', ST 28-29 (Data questionable, lightning)	X			X				X	X		
		R	1	Line XX', dipole-dipole ST 21-22 to 22-23										X	X
Thu.	3rd	R	5	Line XX', dipole-dipole ST 18-19 to 20-21, 16-17 to 18-19, 7-8 to 9-10, ST 9, 20 50' Wenner						X		X	X	X	X
Fri.	4th	T	4	Line C'C" ST 27, 28, 29, 30 (Data questionable, lightning)	X			X		X		X	X	X	X
Sat.	5th			Day off											
Sun.	6th			Day off											

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

MONTH

July, 1975

TERRAPHYSICS

Phase II

PROJECT Animas, New Mexico

DAY	DATE	TECHNIQUE	TOTAL STATIONS	LOCATIONS	FREQ.S Hz 05	01	08	8		PERSONNEL DOHL	MAZZELLA	PESSAH	GUZMAN	HARVEY	DONAHUE
Mon.	7th	T	6	Line C'C", ST 32, 33, 34, 35, 36, 37 (Some data questionable, lightning)	X			X					X	X	X
		MT	1	Line XX', ST 28-29, 28-28B	X	X	X	X		X		X			
Tue.	8th	T	6	Line C'C", ST 36, 37, 38, 39A, 40, 41 (Some data questionable, lightning)	X			X					X	X	X
		MT	2	Line FF', ST 4-5, 8-9	X	X	X	X		X		X			
Wed.	9th	T	3	Line C'C", ST 42, 43, 44 (Some data questionable, lightning)	X			X				X	X	X	X
		MT	5	Line C'C", ST 44-45, 44-44B, 38A-39A, 38B-39B, 43-44	X	X	X	X							
Thu.	10th	MT	4	Line C'C", ST 38A-39A, 38B-39B, 36-37, 31-32 (Some data questionable, lightning)	X	X	X	X					X	X	X
		R	1	Line C'C", ST 36 50'Wenner											
Fri.	11th	MT	1	Line XX', ST 24-25 (Data questionable, lightning)	X	X	X	X				X	X	X	X
		R	2	Line XX', ST 17, 24 50'Wenner											
Sat.	12th			Off											

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

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

MONTH

July, 1975

TERRAPHYSICS

Phase II

PROJECT Animas, New Mexico

DAY	DATE	TECHNIQUE	TOTAL STATIONS	LOCATIONS	FREQ.S Hz 05	01	08	8		DOHL	MAZZELLA	PESSAH	GUZMAN	HARVEY	DONAHUE
Sun.	13th	MT	1	Line XX', ST 26-27 (Data questionable, lightning)	X			X					X	X	X
Mon.	14th	T	5	Line HH', ST 2, 3, 4, 5, 6 (Some data questionable, lightning)	X			X					X	X	X
		MT		Line HH', ST 2-3 Line FF', ST 19-20, 11B-12A, 15-16	X	X	X	X		X		X			
Tue.	15th	T	4	Line HH', ST 7, 8, 9, 10 (Some data questionable lightning)	X			X					X	X	X
Wed.	16th	T	3	Line HH', ST 24, 25, 26	X			X					X	X	X
		MT	1	Line HH', ST 23-24, 24A-24B	X			X		X		X			
Fri.	18th	MT	3	Line HH', ST 2-3 Line FF', ST 11B-12A, 19-20 (Big storm, shut down 1500)	X			X			X		X	X	X
Sat.	19th	MT	4	Line HH', ST 23-24, MT 4 Line XX', ST 16-17, 26-27 (Afternoon storm shut down 1500)	X			X			X		X	X	X

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

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

MONTH

July, 1975

TERRAPHYSICS

Phase II

PROJECT Animas, New Mexico

DAY	DATE	TECHNIQUE	TOTAL STATIONS	LOCATIONS	FREQ.S Hz 05	01	08	8		PERSONNEL DOHL	MAZZELLA	PESSAH	GUZMAN	HARVEY	DONAHUE
Sun.	20th	T	3	Line XX', ST 20, 21, 22	X			X					X	X	X
Mon.	21st	T	5	Line XX', ST 23, 24, 25, 26, 27 (Afternoon lightning storm 2 stations questionable)	X			X					X	X	X
Sun.	27th	T	3	Line HH', ST 24, 25, 26	X			X					X	X	X
Mon.	28th	T	4	Line HH', ST 27, 4, 5, 10	X			X				X	X	X	X
Tue.	29th	T	2	Line HH', ST 11, 12	X			X				X	X	X	X
Wed.	30th	T	2	Line DD', ST 24, 25 (2 slopes will repeat)	X			X				X	X	X	X

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

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

MONTH

July/August

TERRAPHYSICS

Phase II

PROJECT Animas, New Mexico

DAY	DATE	TECHNIQUE	TOTAL STATIONS	LOCATIONS	FREQ.S Hz 05	01	08	8		DOHL	MAZZELLA	PESSAH	GUZMAN	HARVEY	DONAHUE
JULY Thu.	31st	T	3	Line DD', ST 24, 25, 26	X			X				X	X	X	X
AUGUST Fri.	1st	T	4	Line DD', ST 27, 28, 29, 30	X			X				X	X	X	X
Sat.	2nd	T	11	Line C'C", ST 27, 28, 29, 30, 31, 32, 33, 34 35, 36, 37 (Repeated stations due to possible lightning activity.)	X			X				X	X	X	X
Sun.	3rd	T	1	Line C'C", ST 3B Mobilization	X			X			X	X		X	X
Mon.	4th	T	3	Line C'C", ST 38, 39, 40 Mobilization	X			X			X	X		X	X
Tue.	5th	T	6	Line C'C", ST 38, 39, 40, 41B, 42, 43 Mobilization	X			X			X	X		X	X

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

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

MONTH

August, 1975

TERRAPHYSICS

Phase II

PROJECT Animas, New Mexico

DAY	DATE	TECHNIQUE	TOTAL STATIONS	LOCATIONS	FREQ.S Hz 05	01	08	8	PERSONNEL	DOHL	MAZZELLA	PESSAH	GUZMAN	HARVEY	DONAHUE
Wed.	6th	T	2	Line C'C", ST 40, 42 Lightning storm 1100	X			X						X	X
Thu.	7th	T	--	Line XX', ST 27, 28 (Poor data) Lightning storm activity appears 24 hours.	X			X						X	X
Fri.	8th	T R	-- 2	Line XX', ST 27, 28 (Poor data) Cotton City, ST 1, 2, 1000' W	X			X						X	X
Sat.	9th	T R	1 1	Line XX', ST 27, 28 (Poor data) Old Animas Road, ST 1, 1000' Wenner	X			X						X	X
Sun.	10th	T R	1 1	Line XX', ST 26, 27 Old Animas Road, ST 2, 1000' Wenner	X			X						X	X
Mon.	11th	T R	1 3	Line XX', ST 26 Old Animas Road, ST 3, 4, 5, 1000' Wenner	X			X						X	X

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

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

MONTH

August, 1975

TERRAPHYSICS

Phase II

PROJECT Animas, New Mexico

DAY	DATE	TECHNIQUE	TOTAL STATIONS	LOCATIONS	FREQ.S H_Z 05	0.1	0.8	8		PERSONNEL DOHL	MAZZELLA	PESSAH	GUZMAN	HARVEY	DONAHUE
Tue.	12th	R	3	Cotton City, ST 3, 4, 5 1000' Wenners										X	X
Wed.	13th			Packing and mobilization										X	X
Thu.	14th			Mobilization										X	X
Fri.	15th			Mobilization										X	X

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

REFERENCES

Boissonnas, E. and Leonardon, E. G., 1948, Geophysical Exploration by Telluric Currents, with Special Reference to a Survey of the Haynesville Salt Dome, Wood County, Texas, Geophysics, Vol. XIII, p. 387.

Dahlberg, R. S., 1945, An Investigation of Natural Earth Currents, Geophysics, Vol. 10, p. 494.

Dane, C. H., and Bachman, G. O., 1965, Geologic Map of New Mexico, U. S. G. S.

Grillot, L. R., 1975, Calculation of the Magnetotelluric Tensor Impedance: Analysis of Band-limited MT Signal Pairs, Geophysics, Vol. 40, No. 5, p. 790.

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

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

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

Slankis, J. A. and Becker, A., 1969, Telluric and Magneto-Telluric Measurements at 8 Hz, Society of Mining Engineers, AIME, Vol. 244, Transactions, p. 237.

Slankis, J. A., Telford, W. M., and Becker, A., 1972, 8 Hz Telluric and Magnetotelluric Prospecting, Geophysics, Vol. 37, No. 5, p. 862.

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, Vo. 38, No. 6, p. 1130.