Energy Research and Development Division
FINAL PROJECT REPORT

MT SURVEY FOR RESOURCE ASSESSMENT AND ENVIRONMENTAL MITIGATION AT THE GLASS MOUNTAIN KGRA

APPENDICES M-Q

Prepared for: California Energy Commission – Geothermal Resources Development Account
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GSY-USA, Inc.

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PREFACE

The California Legislature created the Geothermal Resources Development Account (GRDA) and the Geothermal Program in 1980. Funding comes from revenues paid to the United States government by geothermal developers for leases on federal land in California. Under the Geothermal Program, the California Energy Commission has assisted numerous eligible private entities and local jurisdictions in geothermal research, development, demonstration, commercialization, planning, mitigations, and environmental enhancement projects related to geothermal energy. The purpose of the program is to enhance and promote geothermal development in California. For more information on the Geothermal Program, please visit the California Energy Commission's Web site at. http://www.energy.ca.gov/geothermal/index.html

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MT Survey for Resource Assessment and Environmental Mitigation in the Glass Mountain KGRA is the final report for the Geothermal Reserouces Development Account contract number GEO-02-007 conducted by GSY-USA, Inc. The information from this project contributes to Energy Research and Development Division's Renewable Program.

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ABSTRACT

The objectives of this project were to use non-invasive methods to indirectly image the permeable geothermal reservoir geometry and mitigate the drilling costs and environmental impact of future geothermal development at Glass Mountain Known Geothermal Resource Area. This was done by more efficiently focusing exploration wells on the most promising target zones. Significant advances were achieved in three dimensional magnetotelluric imaging, allowing three dimensional imaging to be given greater weight than two dimensional imaging in interpreting the data. Magnetotellurics is a geophysical investigation technique that images the earth's subsurface by measuring natural variations of electric and magnetic fields at the surface. Magnetotelluric resistivity patterns were correlated with detailed data on subsurface temperatures, downhole resistivity logging, patterns of rock alteration zones and water entry zones from wells along geologic cross-sections. This confirmed that reservoir interpretation based on correlating magnetotelluric resistivity with temperature sensitive clay alteration was feasible. The magnetotelluric resistivity maps and cross-sections extended these correlations to undrilled areas, revealing the likely geometry of the geothermal system.

Conceptual models based on the resistivity images indicated that major northeast trending structures and the Medicine Lake Volcano rim structure form permeable zones and reservoir boundaries in the Glass Mountain Known Geothermal Resource Area. Several areas that appear to host a relatively shallow permeable reservoir were identified. The magnetotelluric interpretation also indicated that a significant part of the Medicine Lake Volcano was unlikely to host a developable geothermal resource. Depending on the resource development strategy and supporting studies, follow-up magnetotelluric surveys could be justified. The conceptual resource model derived from this study's integrated interpretation illustrates well-targeting strategies that can be reviewed with respect to engineering and environmental issues. By more efficiently directing well targeting, magnetotelluric resistivity imaging can reduce dry hole costs, as well as focus planning efforts and mitigate the environmental impacts of resource development.

Keywords: electromagnetic survey, geothermal exploration, geophysics resistivity, magnetotellurics, petrography, Medicine Lake, Glass Mountain Known Geothermal Resource Area

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APPENDIX M:
TEM central induction sounding, Medicine Lake Area, California; Report #850503 Prepared for Santa Fe Geothermal, Inc.

Attachment XII

CEC-500-2007-XXX-ATXII

TEM central induction sounding, Medicine Lake Area, California; Report #850503 Prepared for Santa Fe Geothermal, Inc.

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GM 38.06

TEM CENTRAL INDUCTION SOUNDINGS
MEDICINE LAKE AREA
CALIFORNIA

Report # 850503

Prepared for:

Santa Fe Geothermal, Inc.

Bakersfield, California

25 September 1985

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Plate 1. Location Map: Measurement Sites Insert

SUMMARY

A transient electromagnetic survey was carried out by ElectroMagnetic Surveys, Inc. for Santa Fe Geothermal Company, in the Medicine Lake area of California during the period from 22 July to 18 August 1985. The objective of the survey was to locate deep conductors attributable to geothermal sources. The transmitter was a square loop of wire 1000 feet on a side, and the EMS multi-mode technique was used to obtain decay curve data over the broadest range possible.

A total of 37 stations were occupied as described in the location map of Plate 1. The transmitter loops are drawn to approximate scale.

Two-, three-, four- and five-layer computer inversions of the data were performed to obtain the best fit to the field data, generally with an RMS error of less than 9%. The results of the inversion effort and preliminary worksheets are presented as graphs and tables in Appendix II.

INTRODUCTION

A transient electromagnetic (TEM) survey was carried out by Electromagnetic Surveys, Inc. (EMSurveys) for Santa Fe Geothermal, Inc. near Medicine Lake, CA, during the summer of 1985. The objective of the survey was to locate deep conductors attributable to geothermal sources. The in-loop configuration was used to provide a relatively focused electromagnetic sounding to a depth of several kilometers.

The survey was carried out between 22 July and 18 August 1985. Road access was available to 23 station locations while 14 stations required hand carrying the equipment to the site. As presented in Appendix II, off-road stations are designated by the prefix 'OR' while stations with road access have the prefix 'R'. Station R18 was not measured due to U.S.D.A. Forest Service fire hazard restrictions. An equipment malfunction caused a 1-week delay while the system was returned to Toronto for servicing. A total of 37 stations were occupied.

The EMSurveys field crew consisted of H. A. Patsch (Crew Chief), Dimitri Bevc (Geophysicist), Paul Rio, Patrick Carr (Field Operators), Terry Amos and Kevin Amos. Client representatives Michael Woodruff and George Stewart were present at various times during the survey.

EQUIPMENT AND FIELD PROCEDURES

A Geonics EM-37 system was used for the survey. Detailed specifications of this system can be found in Appendix I.

The transmitter loops were 1000 x 1000 feet square with at least one corner located on a road, where possible. Loop orientation was determined by logistical considerations unless a specific orientation was requested by the client. Synchronization of the receiver (Rx) and the transmitter (Tx) was achieved by use of a reference cable link.

The 3-phase measurement procedures developed by EMSurveys' for deep sounding were used for this program. The vertical component of the secondary magnetic field was measured at each sounding location using three combinations of frequency, Tx current, and Rx moment. Initial measurements were made at a Tx repetition rate of 30 Hz with a voltage setting of 110 V. The Tx current was in the range of 26 to 28 amps and the turnoff ramp time was in the range of 255 to 265 μs.

The measurement procedure was then repeated with a voltage setting of 20 V. This reduced the turnoff ramp time to the range of 75 to 85 μs and reduced the current to the range of 5.5 to 6.5 amps which enabled more accurate readings to be made at early times.

Measurements were then taken at a repetition rate of 3 Hz, the high current voltage setting of 110 V and larger-moment sensor loop for further definition of the decay curve at later times. The sensor loop Rx, measuring somewhat less than 6 meters on a side and

containing 48 turns of wire, was used for gathering the 3 Hz data. Use of this large loop increased the Rx moment by a factor of up to 17 which enhanced detection of low amplitude-late time signals. Tx current and turnoff ramp time were within the ranges of variability seen during the 30 Hz high voltage measurements.

Several sets of readings were taken at each station to improve data statistics. Operator inspection of these data sets assured that noisy readings due to sferics or other spurious sources would be excluded from the summed and averaged data.

DATA PROCESSING AND PRESENTATION

Acquisition and Field Processing

Field data were gathered and stored by a proprietary EMSurveys data acquisition system designed and built for use with the Geonics EM-37 system. Initial processing of data was completed in the field, and decisions on survey planning were made on a daily basis. Voltages were normalized for transmitter current and receiver moment, and are given in units of nV/Am^2. Adjustments for the variable moment of the larger loop receiver, which was caused by actual variations in the loop area due to kinking and local obstacles, were made by establishing an adjustment factor based on the ratio of responses in the overlap portion of the response. After manual smoothing the transient decay voltages were inverted using a non-linear least squares algorithm developed by Dennis et al(1979) and adapted by Anderson (1982) for use in interpreting one dimensional

TEM sounding data. The smoothed decay curves are presented together with the final data plots in Appendix II.

Description of Inversion

All data points were weighted in the inversion process with a factor set equal to $1/(\text{standard deviation})^2$. The standard deviation was set equal to ten percent of the measured voltage. This weighting scheme places more importance on the later sample times which carry information from greater depths and are of primary interest in geothermal exploration.

The inversion results are presented in Appendix II. Each data set includes a summary computer output; a plot of voltage and apparent resistivity versus time for both observed and calculated data and a schematic diagram of the interpreted layered model.

The computer output includes a description of the layered model, parameter statistics, and a table containing values of the smoothed, normalized field voltages, the normalized voltages calculated from the layered model, the residual (or difference between the field and calculated values), and the percent residual error (the residual/voltage *100) for each sample time. The root mean square of the percent residual error (%RMSERR) has been calculated and is used as a measure of the "goodness of fit".

The statistics are given in table form using a parameter number and not the parameter name. The inversion routine assigns numbers to the parameters for an N layered model as follows: 1 through N indicates the layer conductivity, N+1 to 2N-1 indicates the layer

thickness and parameter number 2N indicates the shift factor. The shift factor is equal to the reciprocal of the loop radius cubed ($1/a^3$) and is used within the inversion routine for normalizing the calculated voltages. The shift factor was fixed at a value of 207 for this field survey. In several cases the covariance matrix was not positive definite and thus the statistics could not be calculated (see Anderson, 1982).

An absolute value of .9 or larger between any two parameters in the correlation matrix indicates that these parameters are highly correlated i.e., their combination is well defined, but the individual parameters are not. A common example is a thin conductive layer where the conductivity - thickness product is well defined but the individual parameters cannot be resolved.

An estimate of the standard error and percent error are included in the parameter statistics. These parameters are not the same as those used in other error analyses. A percent error of 200 does not mean that this parameter can be varied by 200 percent and not change the calculated voltages within given error bounds. This error tends to be overestimated and will increase with increased correlation between parameters. These values should be used only in a relative manner to compare parameters within a given inversion.

EM sounding methods are more sensitive to conductive layers than to resistive layers, and in general, conductive layers will have a smaller percent error and will have the parameters of conductivity and thickness better defined than resistive units.

RESULTS

The field data and the inversion results are presented in Appendix II together with work sheets to document the processing procedures.

The inversions indicate that significant variations are present in the geoelectric section in the geothermal prospect area. The data were inverted to a two-, three-, four-, or five-layer section which, in general, fit the data with less than 9 % RMS error. A few of the stations may not have been layered, causing difficulty in getting a good fit of the model to the data.

REFERENCES

Anderson, W. L., 1982, " Nonlinear Least Squares Inversion of Transient Soundings for a Central Induction Loop System ", USGS open File Report. 82-1129

Dennis, J.E., Gay, D.M., and Welsch R.E., 1979," An adaptive nonlinear least-squares algorithm ", Univ. of Wisconsin MRC Tech. Sum. Rept. 2010
(also avaliable as NTIS Rept. AD-A079-716), 40 p.

APPENDIX I. GEONICS EM-37 SPECIFICATIONS

GEONICS LIMITED

EM37 Ground Transient Electromagnetic System
Technical Specifications

Transmitter

Current Waveform	-	See Fig. 1
Repetition rate	-	3Hz or 30Hz in countries using 60Hz power line frequency; 2.5Hz or 25Hz in countries using 50Hz power line frequency; all four base frequencies are switch selectable.
Turn-off time (Δt)	-	fast linear turn-off of maximum 300 μsec. at 20 amps into 300x600m loop. Decreases proportionally with current and (loop area)$^{\frac{1}{2}}$ to minimum of 20 μsec. Actual value of Δt read on front panel meter.
Transmitter loop	-	any dimensions from 40x40m to 300x600m maximum at 20 amps. Larger dimensions at reduced current. Transmitter output voltage switch adjustable for smaller loops. Value of loop resistance read from front panel meter; resistance must be greater than 1 ohm on lowest voltage setting to prevent overload.
Transmitter protection	-	circuit breaker protection against input overvoltage; instantaneous solid state protection against output short circuit; automatically resets on removal of short circuit. Input voltage, output voltage and current indicated on front panel meter.
Transmitter output voltage	-	150 volts (zero to peak) maximum; 20 volts (zero to peak) minimum
Transmitter output power	-	2.8 kw maximum
Transmitter wire supplied	-	1800m. #10 copper wire PVC insulated with nylon jacket; transmitter wire contained on 6 reels (supplied); 2 reel winders supplied.
Transmitter motor generator	-	5 HP Honda gasoline engine coupled to 120 volt, 3 phase, 400Hz alternator. Approximately 8 hours continuous operation from full (built-in) fuel tank.

Receiver

Measured quantity	-	time rate of decay of magnetic flux along 3 axes.
Sensor	-	air-cored coil of bandwidth 40 kHz; 100cm dia. by 7x5cm cross-section. Coil holder supplied to facilitate measurement along 3 axes.
Time channels	-	20 time channels with locations and widths as shown in Fig. 2. Successive operation at 30Hz, then 3Hz, effectively gives 30 channels covering range from 80 μsec. to 80 msec.
Output display	-	4 digit plus sign LED display; display also shows channel number and gain.
Integration time	-	2^n cycles at 30Hz; n=4,6,8,10,12,14 (switch selectable); similar integration times at other base frequencies.
Receiver output noise referred to input	-	typically 1.5×10^{-10} volt/m^2 at last gate at 30Hz with integration time of 34 seconds. Noise will be higher during intense local spherics activity.
Output connector	-	all 20 channels in analogue format and house-keeping functions in digital format available from output connector.
Synchronization to Tx	-	any of the following (switch selectable) (1) reference cable (2) primary pulse (3) 27 MHz radio link (40 channels) (4) high stability (oven controlled) quartz crystals.
Noise rejection circuitry	-	Selective clipping of atmospheric noise pulses at all times. Audio output of Rx coil (transmitter pulse blanked out) is available on built-in loud speaker for ready identification of interference.
Receiver batteries	-	12 volt rechargeable Gel-cell; 9 hours continuous operating time at 17°C. Two batteries and a battery charger supplied to permit charging of second battery from transmitter motor-generator during survey.

Component Dimensions

Transmitter console	25x42x36 cm
GPU	35x74x48 cm
Wirewinder	42x38x35 cm each (2 off)
Wire reels (20 amp)	33x31(dia.)cm each (6 off)
Receiver console	38x37x27 cm
Receiver coil	100 cm dia. 7x5 cm cross-section

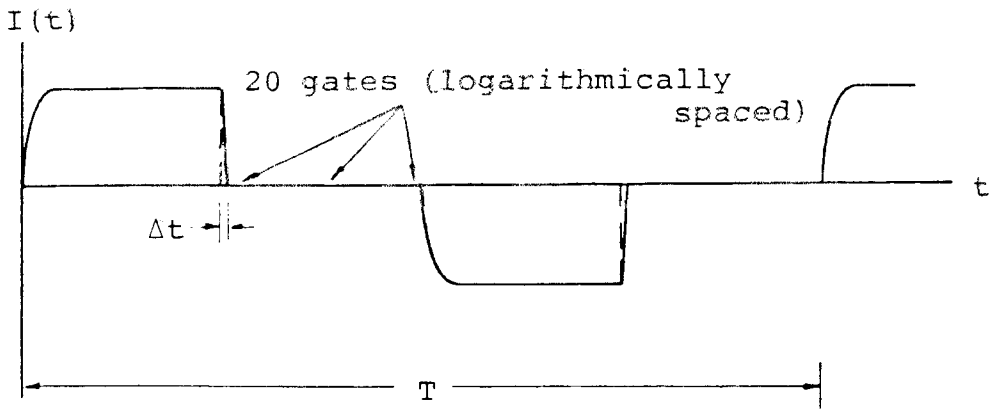
Component Weights

Transmitter console	20 kg
GPU	60 kg
Wirewinders and loaded reels (20 amp)	120 kg (total)
Receiver console (incl.20 amp-hour battery)	21.8 kg
Receiver coil	8.0 kg

Shipping Information

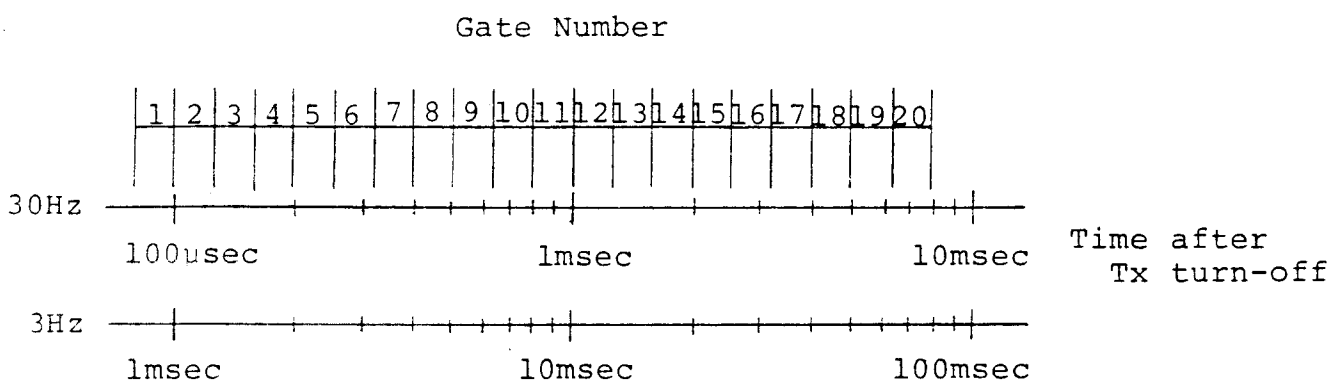
Shipment consists of 5 boxes

Two wire boxes	116x62x48 cm @ 186 kg (total)
GPU box	96x61x73 cm @ 90 kg
Receiver/transmitter box	96x75x73 cm @ 86 kg
Receiver coil/coil-holder box	110x110x20 cm @ 34 kg
Total shipping volume	1.90 cubic metres
Total shipping weight	390 kg



Transmitter Current Waveform

FIG. 1

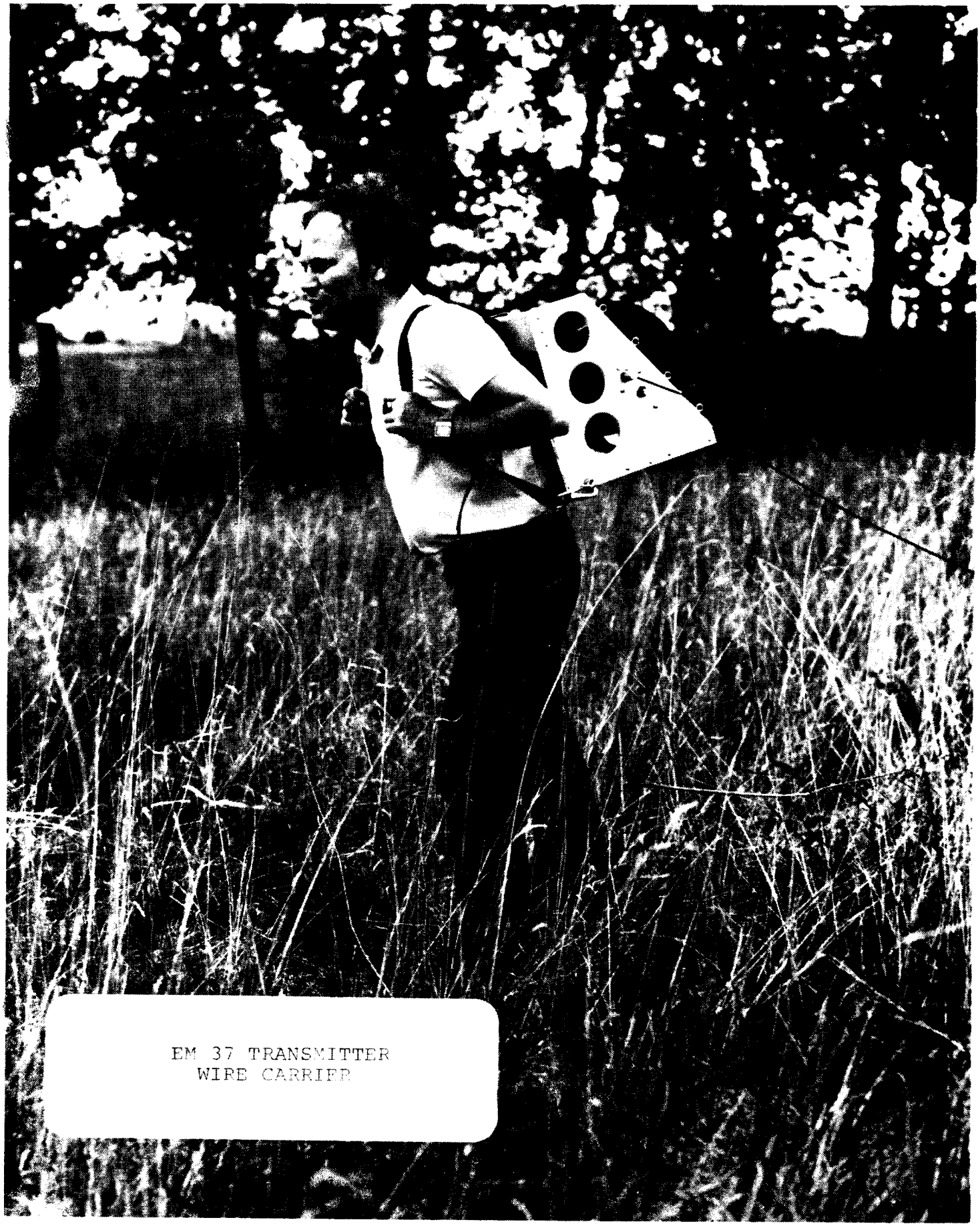


Gate Location and Widths (30 and 3Hz)

FIG. 2

FM 37 RECEIVER

EM 37 TRANSMITTER

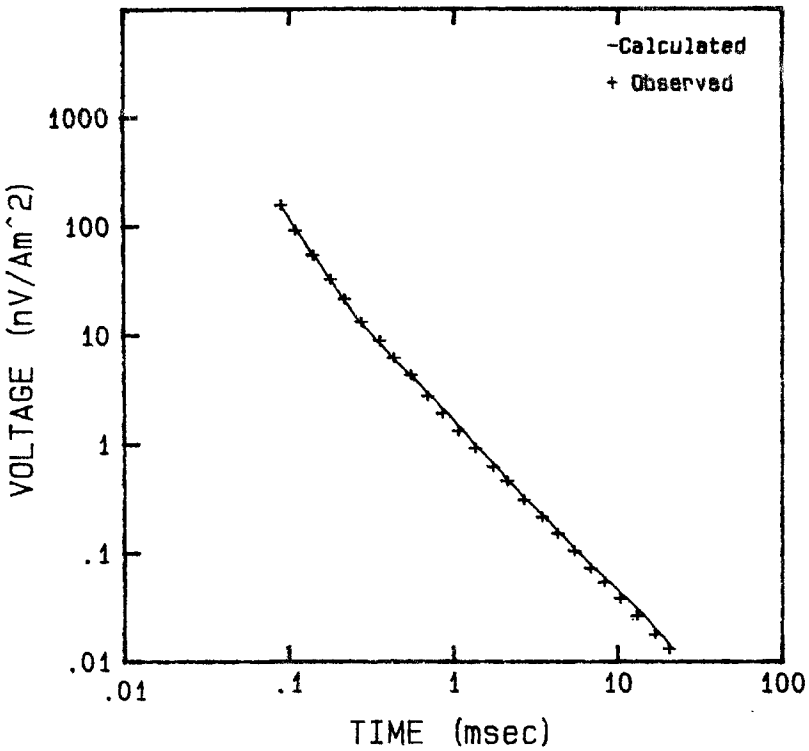


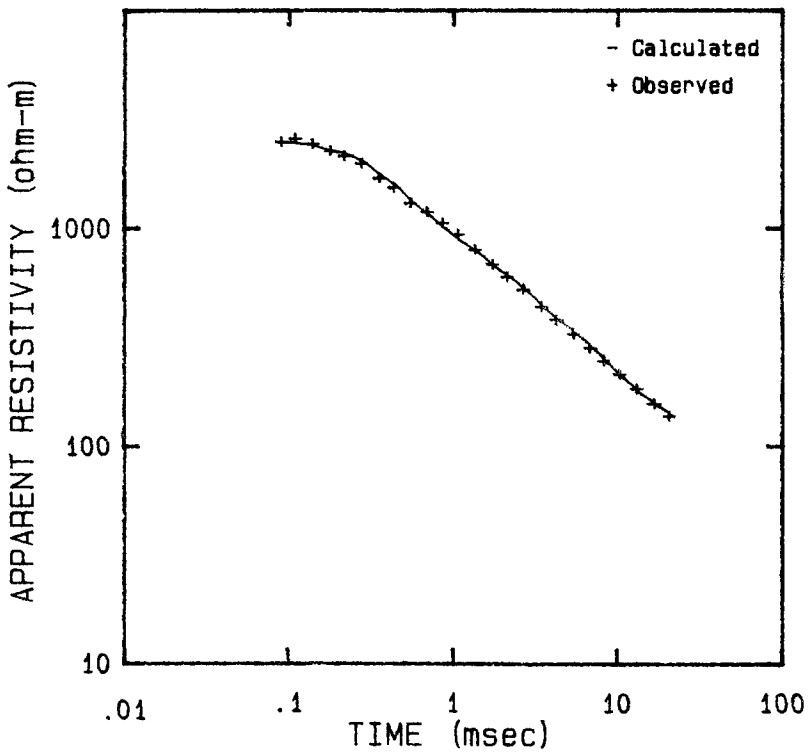
EM 37 TRANSMITTER
WIRE CARRIER

APPENDIX II. TEM SOUNDING DATA AND INVERSION RESULTS

EMSURVEYS TEM INVERSION

MEDICINE LAKE
STATION: R1





MODEL

RESISTIVITY (ohm-m)	THICKNESS (meters)
4224	212
1083	406
117	399
39	

ELECTROMAG IC SURVEYS INC.

MEDICINE LAKE R1

I	TIME (sec)	VOLTAGE (nV/Am^2)	CALC.VOLT	RESIDUAL	%RES.ERR
1	.8900E-04	.1550E+03	.1540E+03	.1030E+01	.6689E+00
2	.1100E-03	.8950E+02	.9511E+02	-.5607E+01	-.5895E+01
3	.1400E-03	.5320E+02	.5404E+02	-.8361E+00	-.1547E+01
4	.1770E-03	.3170E+02	.3183E+02	-.1275E+00	-.4005E+00
	.2200E-03	.2090E+02	.1989E+02	.1007E+01	.5060E+01
	.2800E-03	.1290E+02	.1227E+02	.6332E+00	.5162E+01
	.3550E-03	.8680E+01	.8165E+01	.5150E+00	.6307E+01
8	.4430E-03	.6090E+01	.5779E+01	.3114E+00	.5390E+01
9	.5540E-03	.4260E+01	.4123E+01	.1370E+00	.3323E+01
10	.7130E-03	.2710E+01	.2830E+01	-.1203E+00	-.4251E+01
11	.8810E-03	.1890E+01	.2030E+01	-.1405E+00	-.6919E+01
2	.1090E-02	.1300E+01	.1420E+01	-.1201E+00	-.8460E+01
.3	.1410E-02	.9060E+00	.9246E+00	-.1862E-01	-.2014E+01
14	.1790E-02	.6130E+00	.6298E+00	-.1675E-01	-.2660E+01
5	.2220E-02	.4530E+00	.4450E+00	.8010E-02	.1800E+01
6	.2850E-02	.3030E+00	.3019E+00	.1069E-02	.3539E+00
17	.3600E-02	.2120E+00	.2110E+00	.9873E-03	.4679E+00
18	.4490E-02	.1490E+00	.1487E+00	.2898E-03	.1949E+00
	.5700E-02	.1030E+00	.1014E+00	.1557E-02	.1535E+01
20	.7190E-02	.7200E-01	.7148E-01	.5200E-03	.7275E+00
21	.8800E-02	.5300E-01	.5421E-01	-.1212E-02	-.2236E+01
2	.1110E-01	.3800E-01	.3972E-01	-.1720E-02	-.4331E+01
3	.1400E-01	.2600E-01	.2793E-01	-.1928E-02	-.6902E+01
24	.1800E-01	.1800E-01	.1810E-01	-.1046E-03	-.5775E+00
5	.2200E-01	.1300E-01	.1286E-01	.1432E-03	.1114E+01

* RMSERR= 3.99

RELATION MATRIX

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	-.1072E-01	-.3029E+00	-.3656E+00	.1000E+01			
5	.5643E+00	.2939E-01	.6882E-01	-.8757E-01	.1000E+01		
	-.2663E+00	-.5364E-01	-.5741E-01	.1465E+00	-.5489E-01	.1000E+01	
	-.8419E-01	-.4869E-01	-.3197E+00	.1296E+00	-.3314E+00	-.2508E+00	.1000E

**PARM_SOL.	STD_ERROR	REL_ERROR	% ERROR **
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.9235E-03	.1949E-03	.2110E+00	.2110E+02
3 .8559E-02	.4676E-03	.5463E-01	.5463E+01
.2564E-01	.1422E-02	.5545E-01	.5545E+01
.2116E+03	.8989E-03	.4249E-05	.4249E-03
6 .4069E+03	.6871E-03	.1689E-05	.1689E-03
7 .3982E+03	.3383E-02	.8495E-05	.8495E-03

PARAMETER NAME		FINAL SOLUTION	RESISTIVITY	LAYER DEPTH
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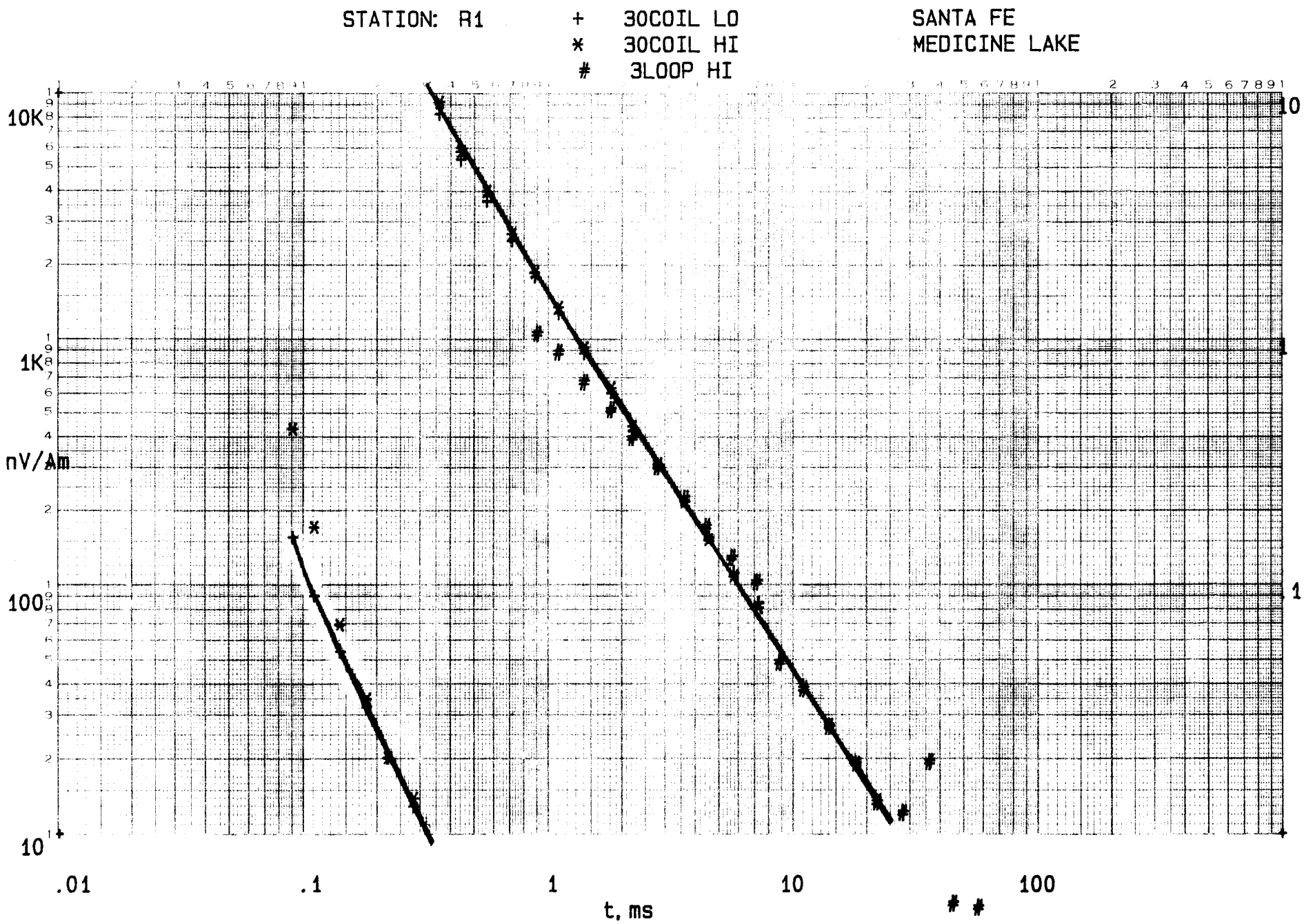
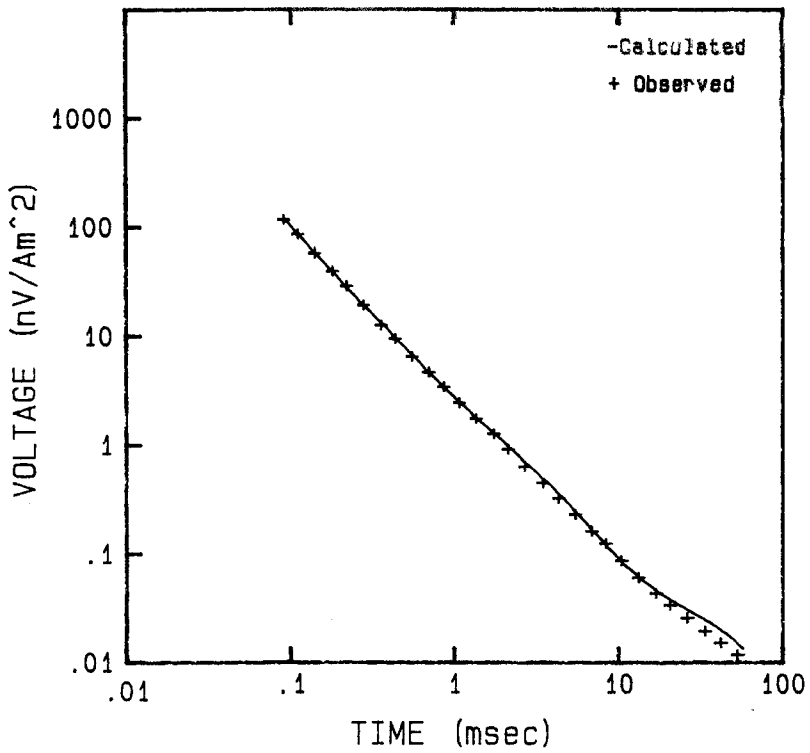
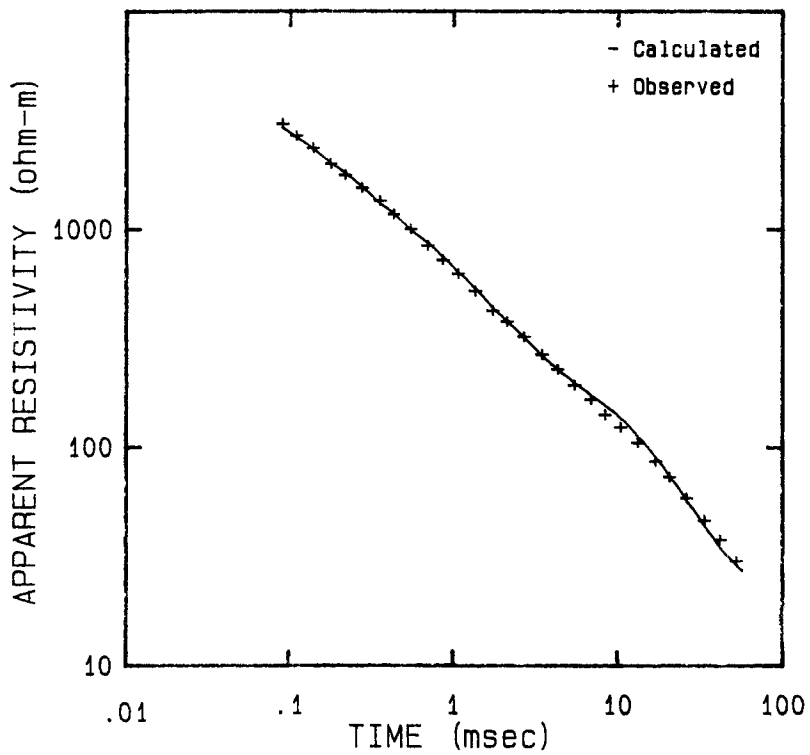
2	SIGMA(2) =	.92354E-03	.10828E+04	
3	SIGMA(3) =	.85592E-02	.11683E+03	
4	SIGMA(4) =	.25644E-01	.38996E+02	
5	THICK(1) =	.21156E+03		.21156E+03
6	THICK(2) =	.40687E+03		.61843E+03
7	THICK(3) =	.39819E+03		.10166E+04
8	SHIFT =	.20700E+03		


STATION: R1
+ 30COIL LO
* 30COIL HI
# 3LOOP HI
SANTA FE
MEDICINE LAKE
10K
1K
100
10
nV/Am
10
1
1
.01
.1
1
10
100
t, ms

EMSURVEYS TEM INVERSION

MEDICINE LAKE
STATION: R2





MODEL

RESISTIVITY (ohm-m)	THICKNESS (meters)
5882	311
333	196
71.4	160
25	393
3	

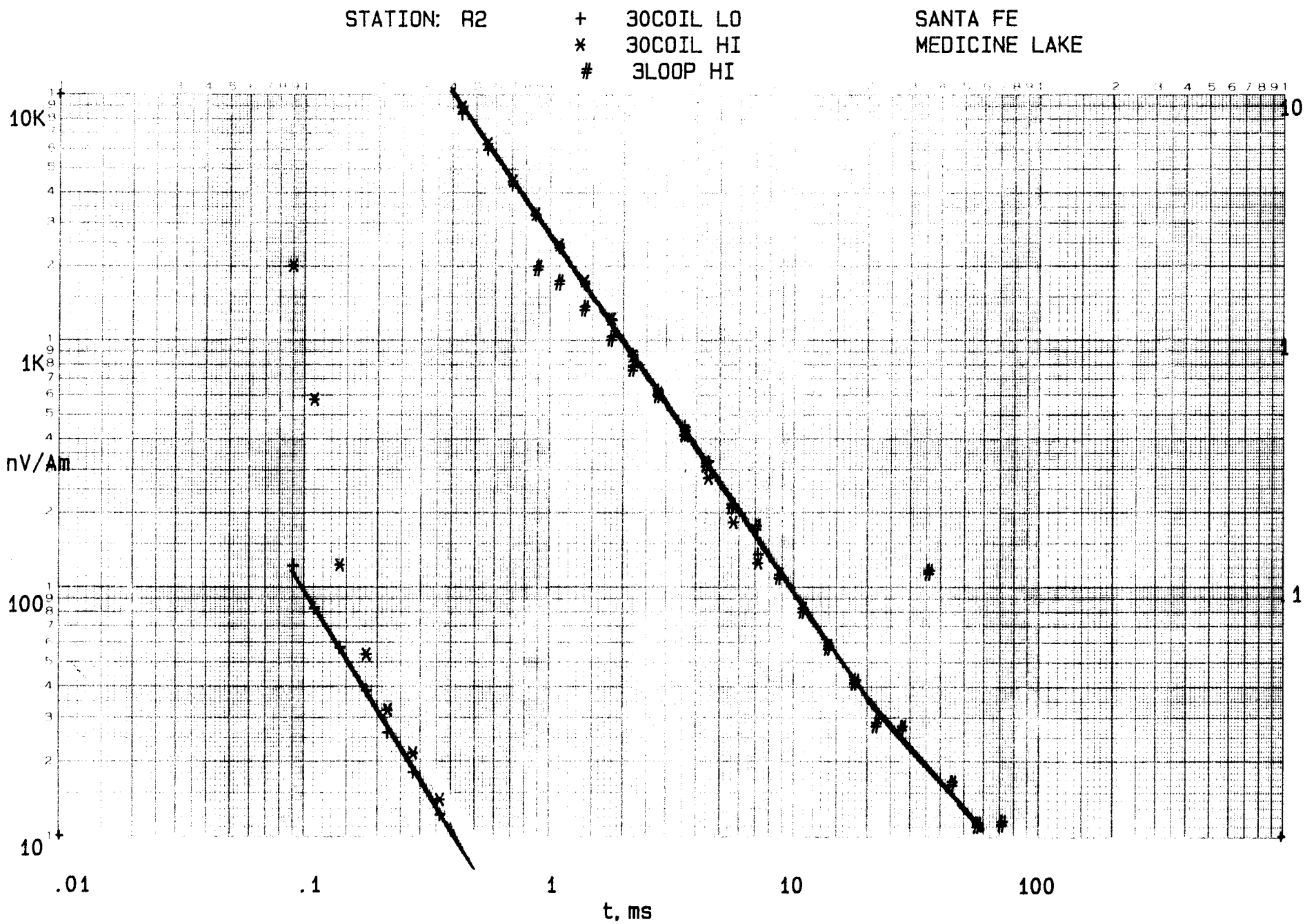
ELECTROMAGNETIC SURVEYS INC.

MEDICINE LAKE R2

I	TIME (sec)	VOLTAGE (nV/Am^2)	CALC.VOLT	RESIDUAL	%RES.ERR
1	.8900E-04	.1150E+03	.1212E+03	-.6245E+01	-.5150E+01
2	.1100E-03	.8440E+02	.8597E+02	-.1572E+01	-.1829E+01
3	.1400E-03	.5600E+02	.5671E+02	-.7124E+00	-.1256E+01
4	.1770E-03	.3850E+02	.3809E+02	.4116E+00	.1081E+01
5	.2200E-03	.2790E+02	.2691E+02	.9910E+00	.3683E+01
6	.2800E-03	.1870E+02	.1851E+02	.1932E+00	.1044E+01
7	.3550E-03	.1220E+02	.1283E+02	-.6251E+00	-.4874E+01
8	.4430E-03	.9160E+01	.9157E+01	.2966E-02	.3239E-01
9	.5540E-03	.6321E+01	.6514E+01	-.1926E+00	-.2957E+01
10	.7130E-03	.4530E+01	.4414E+01	.1162E+00	.2633E+01
11	.8810E-03	.3330E+01	.3213E+01	.1174E+00	.3654E+01
12	.1090E-02	.2380E+01	.2375E+01	.5053E-02	.2128E+00
13	.1410E-02	.1710E+01	.1679E+01	.3100E-01	.1846E+01
14	.1790E-02	.1240E+01	.1224E+01	.1550E-01	.1266E+01
15	.2220E-02	.8900E+00	.9192E+00	-.2917E-01	-.3174E+01
16	.2850E-02	.6180E+00	.6534E+00	-.3542E-01	-.5420E+01
17	.3600E-02	.4370E+00	.4653E+00	-.2831E-01	-.6083E+01
18	.4490E-02	.3170E+00	.3307E+00	-.1368E-01	-.4137E+01
19	.5700E-02	.2250E+00	.2248E+00	.1933E-03	.8599E-01
20	.7190E-02	.1570E+00	.1530E+00	.4015E-02	.2624E+01
21	.8800E-02	.1210E+00	.1095E+00	.1149E-01	.1049E+02
22	.1110E-01	.8400E-01	.7700E-01	.7003E-02	.9095E+01
23	.1400E-01	.5900E-01	.5678E-01	.2223E-02	.3915E+01
24	.1800E-01	.4200E-01	.4276E-01	-.7624E-03	-.1783E+01
25	.2200E-01	.3300E-01	.3554E-01	-.2540E-02	-.7147E+01
26	.2800E-01	.2500E-01	.2877E-01	-.3768E-02	-.1310E+02
27	.3600E-01	.1900E-01	.2309E-01	-.4088E-02	-.1771E+02
28	.4500E-01	.1500E-01	.1837E-01	-.3372E-02	-.1835E+02
29	.5700E-01	.1100E-01	.1335E-01	-.2349E-02	-.1760E+02

RMSERR= 7.43

ARAMETER	NAME		FINAL SOLUTION	RESISTIVITY	LAYER DEPTH
1	SIGMA(1)	=	.17000E-03	.58824E+04	
2	SIGMA(2)	=	.30000E-02	.33333E+03	
3	SIGMA(3)	=	.14000E-01	.71429E+02	
4	SIGMA(4)	=	.40000E-01	.25000E+02	
5	SIGMA(5)	=	.33000E+00	.30303E+01	
6	THICK(1)	=	.31100E+03		.31100E+03
7	THICK(2)	=	.19600E+03		.50700E+03
8	THICK(3)	=	.16000E+03		.66700E+03
9	THICK(4)	=	.39300E+03		.10600E+04
10	SHIFT	=	.20700E+03		


STATION: R2
+ 30COIL LO
* 30COIL HI
# 3LOOP HI
SANTA FE
MEDICINE LAKE
10K
1K
100
10
nV/Am
10
1
1
.01
.1
1
10
100
t, ms

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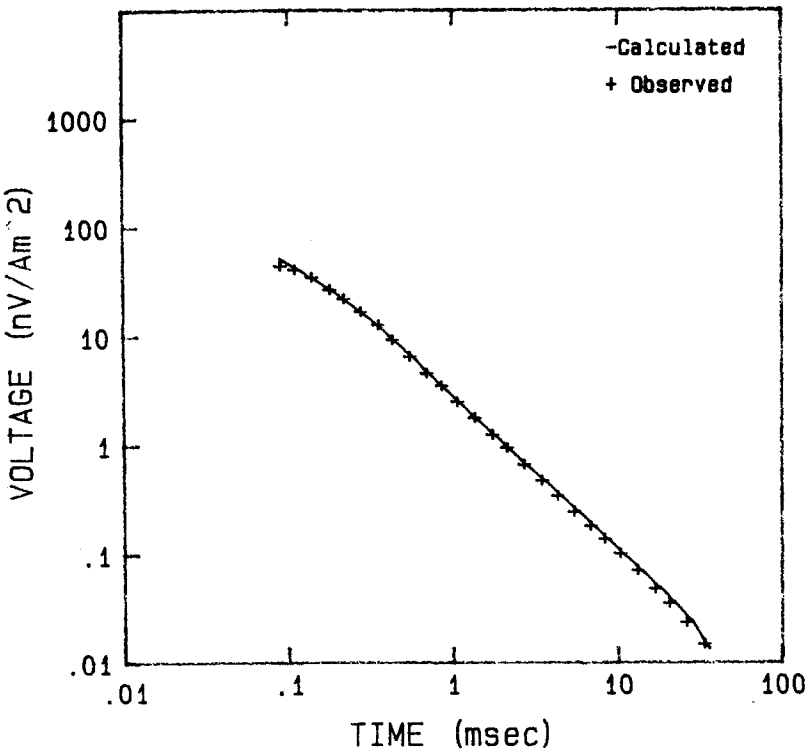
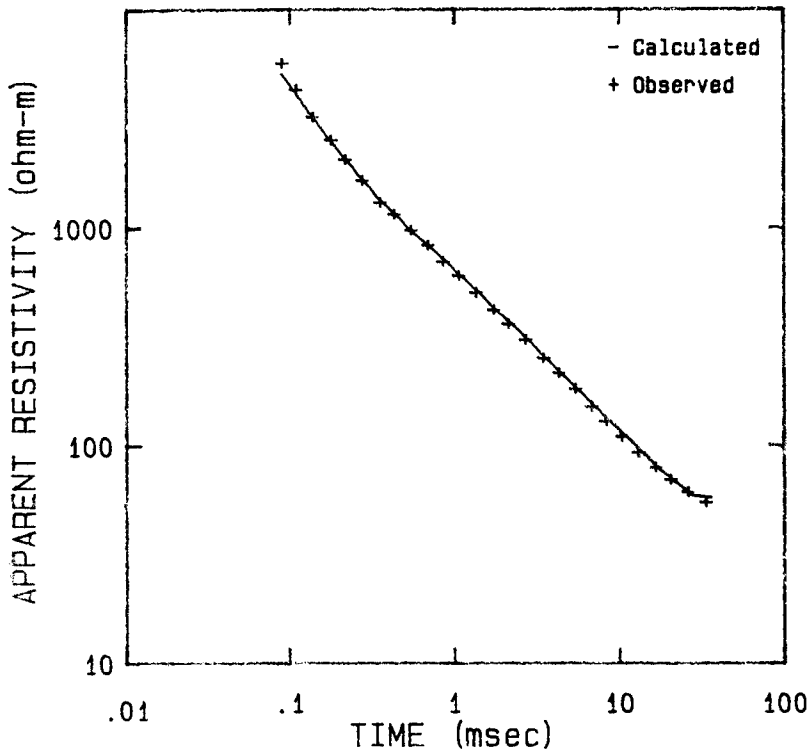
MEDICINE LAKE
STATION: R3





MODEL

RESISTIVITY (ohm-m)	THICKNESS (meters)
10249	428
89	253
29	

ELECTROMA(ETIC SURVEYS INC.

MEDICINE LAKE R3

I	TIME (sec)	VOLTAGE (nV/Am^2)	CALC.VOLT	RESIDUAL	%RES.ERR
1	.8900E-04	.4480E+02	.5259E+02	-.7791E+01	-.1481E+02
2	.1100E-03	.4110E+02	.4361E+02	-.2509E+01	-.5752E+01
3	.1400E-03	.3480E+02	.3468E+02	.1204E+00	.3471E+00
4	.1770E-03	.2670E+02	.2745E+02	-.7504E+00	-.2734E+01
5	.2200E-03	.2210E+02	.2187E+02	.2304E+00	.1053E+01
6	.2800E-03	.1690E+02	.1664E+02	.2553E+00	.1534E+01
7	.3550E-03	.1270E+02	.1244E+02	.2585E+00	.2078E+01
8	.4430E-03	.9290E+01	.9265E+01	.2516E-01	.2716E+00
9	.5540E-03	.6540E+01	.6762E+01	-.2217E+00	-.3279E+01
10	.7130E-03	.4570E+01	.4669E+01	-.9861E-01	-.2112E+01
11	.8810E-03	.3490E+01	.3404E+01	.8592E-01	.2524E+01
2	.1090E-02	.2490E+01	.2498E+01	-.7915E-02	-.3169E+00
,3	.1410E-02	.1780E+01	.1742E+01	.3832E-01	.2200E+01
14	.1790E-02	.1250E+01	.1251E+01	-.1116E-02	-.8923E-01
5	.2220E-02	.9500E+00	.9289E+00	.2109E-01	.2270E+01
6	.2850E-02	.6670E+00	.6592E+00	.7764E-02	.1178E+01
17	.3600E-02	.4750E+00	.4769E+00	-.1867E-02	-.3915E+00
[illegible]	.4490E-02	.3440E+00	.3501E+00	-.6112E-02	-.1746E+01
	.5700E-02	.2450E+00	.2511E+00	-.6143E-02	-.2446E+01
	.7190E-02	.1820E+00	.1818E+00	.2342E-03	.1288E+00
[illegible]	.8800E-02	.1390E+00	.1371E+00	.1920E-02	.1401E+01
2	.1110E-01	.1020E+00	.9879E-01	.3206E-02	.3245E+01
_3	.1400E-01	.7200E-01	.7094E-01	.1060E-02	.1494E+01
24	.1800E-01	.4800E-01	.4973E-01	-.1729E-02	-.3476E+01
5	.2200E-01	.3600E-01	.3671E-01	-.7083E-03	-.1930E+01
6	.2800E-01	.2400E-01	.2478E-01	-.7753E-03	-.3129E+01
27	.3600E-01	.1500E-01	.1372E-01	.1278E-02	.9310E+01

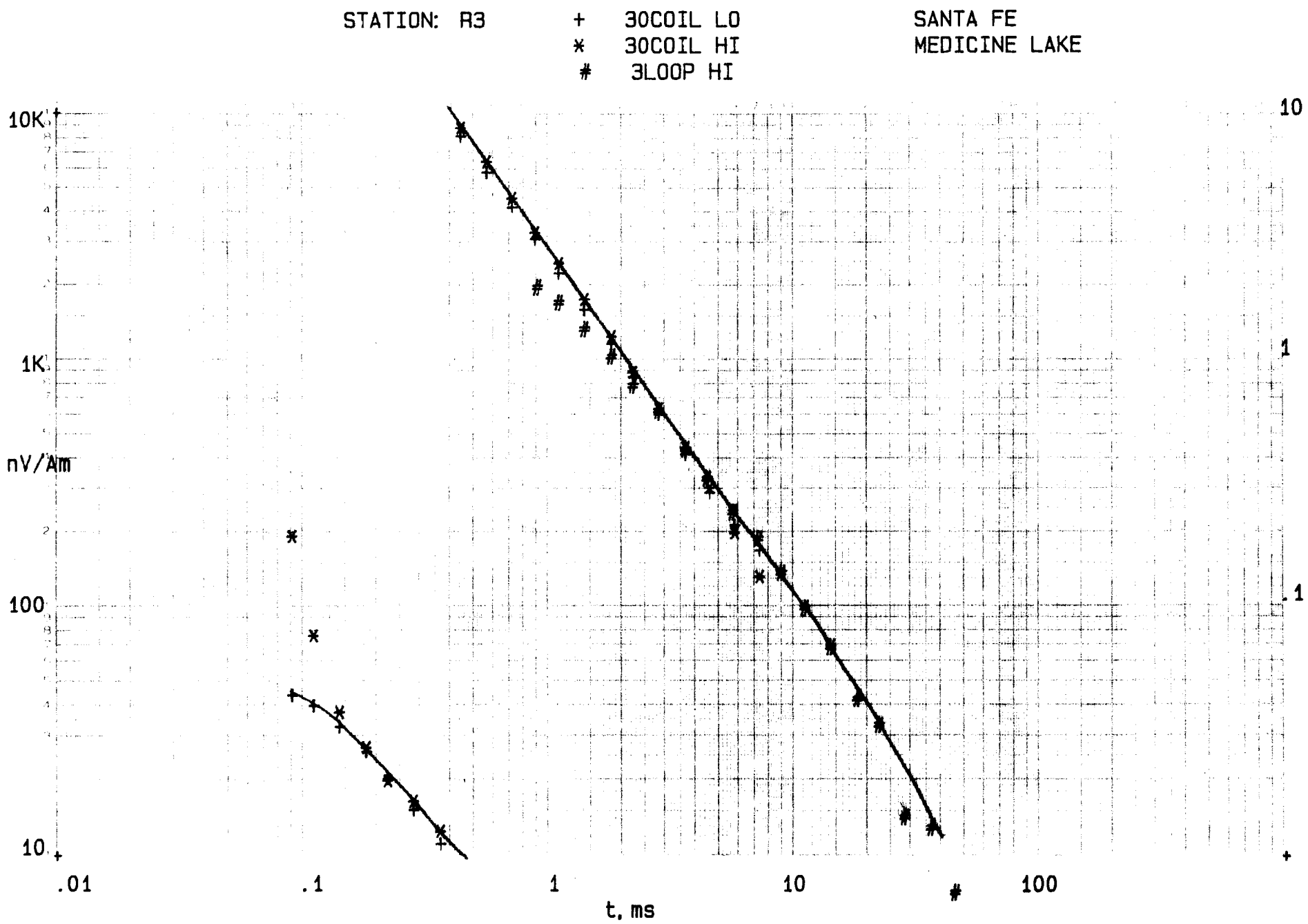
RMSERR= 4.02

ORRELATION MATRIX

	.1000E+01				
	-.1161E+00	.1000E+01			
3	-.8500E-01	-.2310E+00	.1000E+01		
4	-.8053E+00	.2119E+00	-.1519E+00	.1000E+01	
	-.4282E+00	-.4118E+00	.3608E+00	.2335E+00	.1000E+01

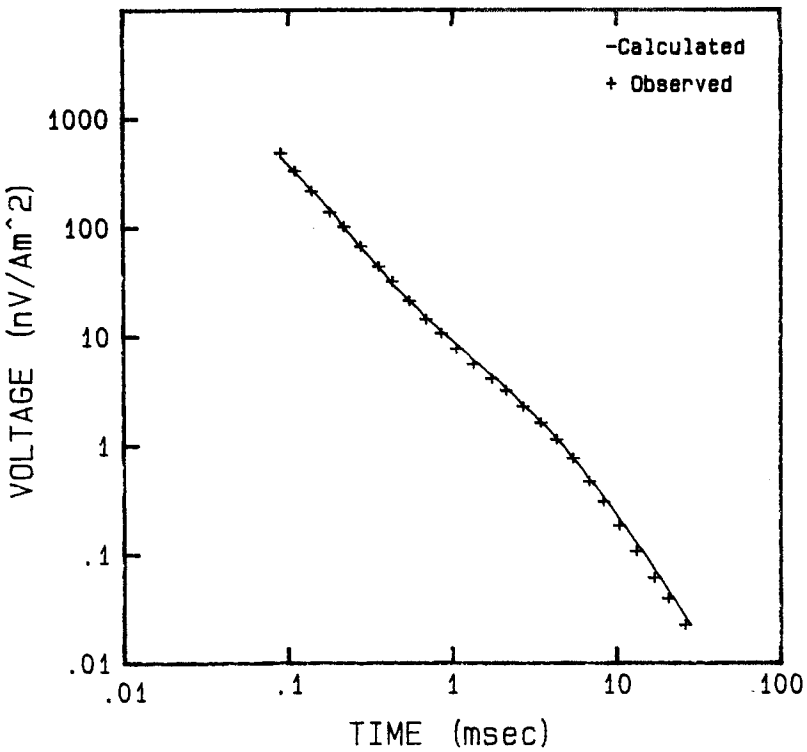
**PARM_SOL.	STD_ERROR	REL_ERROR	% ERROR **
.9757E-04	.5678E-05	.5819E-01	.5819E+01
.1126E-01	.6827E-03	.6062E-01	.6062E+01
3 .3407E-01	.1221E-02	.3585E-01	.3585E+01
.4283E+03	.3701E-03	.8642E-06	.8642E-04
.2523E+03	.3224E-02	.1278E-04	.1278E-02

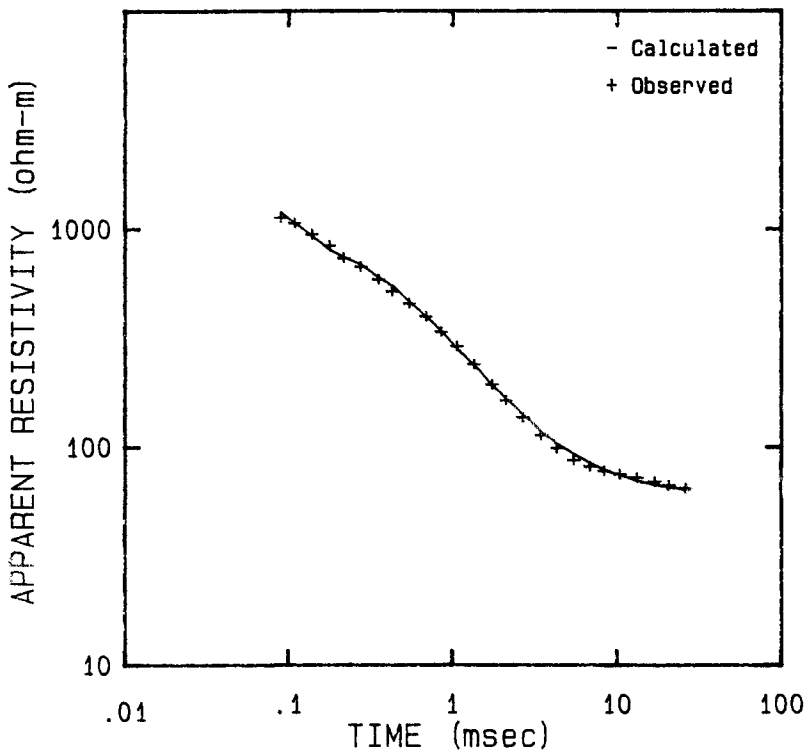
	RAMETER NAME	FINAL SOLUTION	RESISTIVITY	LAYER DEPTH
1	SIGMA(1) =	.97574E-04	.10249E+05	
2	SIGMA(2) =	.11262E-01	.88794E+02	
3	SIGMA(3) =	.34065E-01	.29356E+02	
4	THICK(1) =	.42826E+03		.42826E+03
5	THICK(2) =	.25234E+03		.68059E+03
6	SHIFT =	.20700E+03		


STATION: R3
+ 30COIL LO
* 30COIL HI
# 3LOOP HI
SANTA FE
MEDICINE LAKE
10K
1K
nV/Am
100
10
.01
.1
1
10
100
t, ms
10
1
.1

EMSURVEYS TEM INVERSION

MEDICINE LAKE
STATION: R4





MODEL

RESISTIVITY (ohm-m)	THICKNESS (meters)
2511	205
139	182
24.8	229
62	

ELECTROMAGNETIC SURVEYS INC.

MEDICINE LAKE R4

I	TIME (sec)	VOLTAGE (nV/Am^2)	CALC.VOLT	RESIDUAL	%RES.ERR
1	.8900E-04	.4770E+03	.4389E+03	.3814E+02	.8690E+01
2	.1100E-03	.3230E+03	.3186E+03	.4398E+01	.1380E+01
3	.1400E-03	.2110E+03	.2168E+03	-.5820E+01	-.2684E+01
4	.1770E-03	.1350E+03	.1445E+03	-.9539E+01	-.6600E+01
5	.2200E-03	.9930E+02	.9757E+02	.1734E+01	.1778E+01
6	.2800E-03	.6560E+02	.6334E+02	.2257E+01	.3562E+01
7	.3550E-03	.4280E+02	.4171E+02	.1090E+01	.2613E+01
8	.4430E-03	.3130E+02	.2879E+02	.2506E+01	.8703E+01
9	.5540E-03	.2070E+02	.2046E+02	.2440E+00	.1193E+01
10	.7130E-03	.1400E+02	.1428E+02	-.2807E+00	-.1966E+01
11	.8810E-03	.1050E+02	.1065E+02	-.1533E+00	-.1439E+01
2	.1090E-02	.7550E+01	.8051E+01	-.5010E+00	-.6223E+01
13	.1410E-02	.5500E+01	.5762E+01	-.2622E+00	-.4551E+01
14	.1790E-02	.4040E+01	.4211E+01	-.1712E+00	-.4066E+01
5	.2220E-02	.3140E+01	.3147E+01	-.7392E-02	-.2349E+00
6	.2850E-02	.2240E+01	.2206E+01	.3443E-01	.1561E+01
17	.3600E-02	.1590E+01	.1539E+01	.5066E-01	.3291E+01
[illegible]	.4490E-02	.1120E+01	.1068E+01	.5209E-01	.4878E+01
	.5700E-02	.7510E+00	.6950E+00	.5603E-01	.8062E+01
20	.7190E-02	.4610E+00	.4463E+00	.1472E-01	.3298E+01
21	.8800E-02	.3010E+00	.2998E+00	.1217E-02	.4059E+00
2	.1110E-01	.1820E+00	.1855E+00	-.3519E-02	-.1897E+01
23	.1400E-01	.1050E+00	.1116E+00	-.6559E-02	-.5879E+01
24	.1800E-01	.6000E-01	.6306E-01	-.3061E-02	-.4854E+01
5	.2200E-01	.3900E-01	.3963E-01	-.6265E-03	-.1581E+01
6	.2800E-01	.2200E-01	.2261E-01	-.6063E-03	-.2682E+01

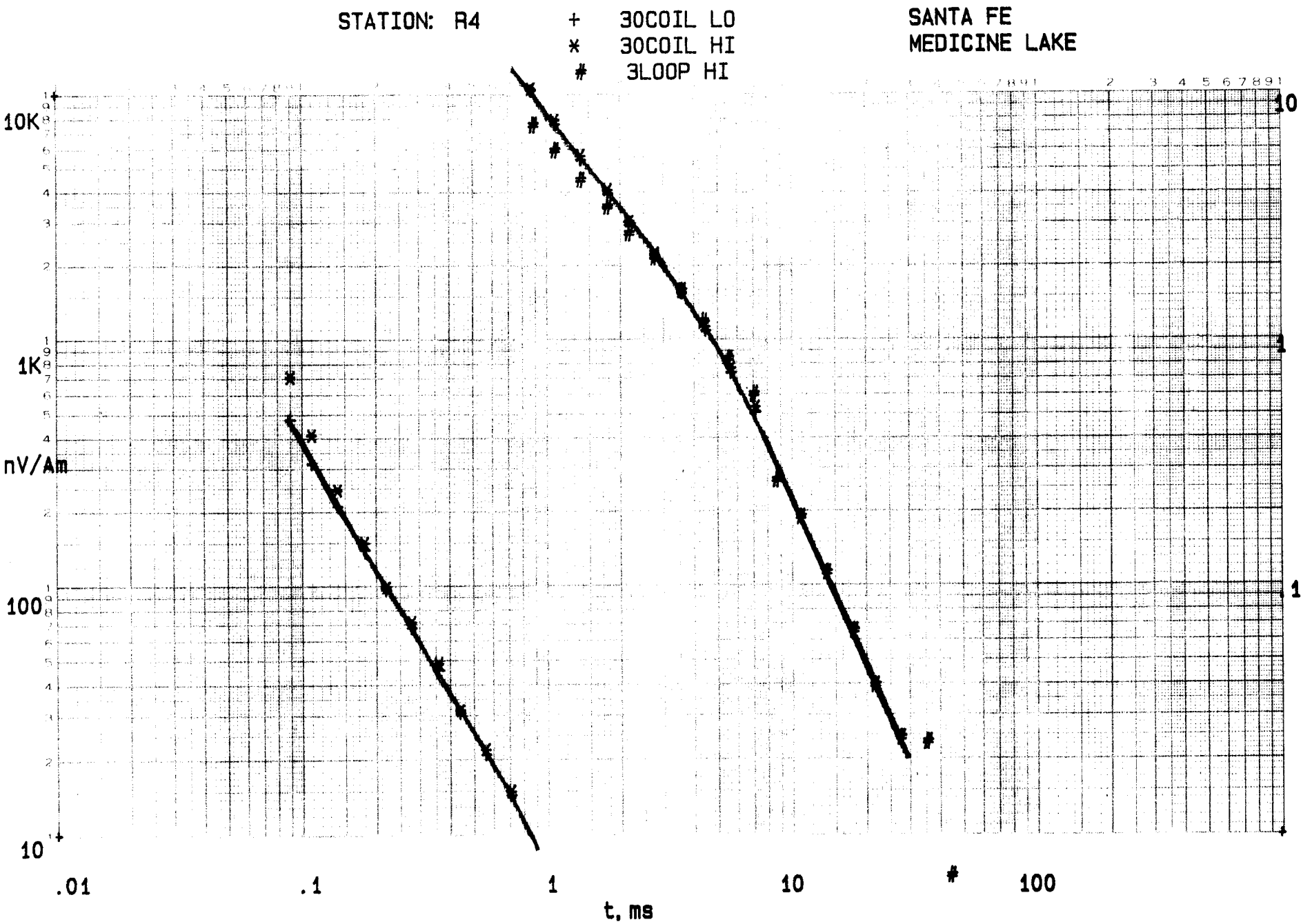
* RMSERR= 4.36

RELATION MATRIX

1	.1000E+01						
	-.4953E+00	.1000E+01					
	-.6963E+00	.1384E+00	.1000E+01				
4	-.1807E+00	-.2779E+00	.1749E+00	.1000E+01			
[illegible]	-.3667E+00	.6039E+00	.1523E+00	-.2223E+00	.1000E+01		
	.4396E+00	-.6439E+00	-.2384E+00	.1317E+00	-.6642E+00	.1000E+01	
7	-.5733E+00	.4234E-01	.4046E+00	.6692E+00	.1179E-01	-.9902E-01	.1000E

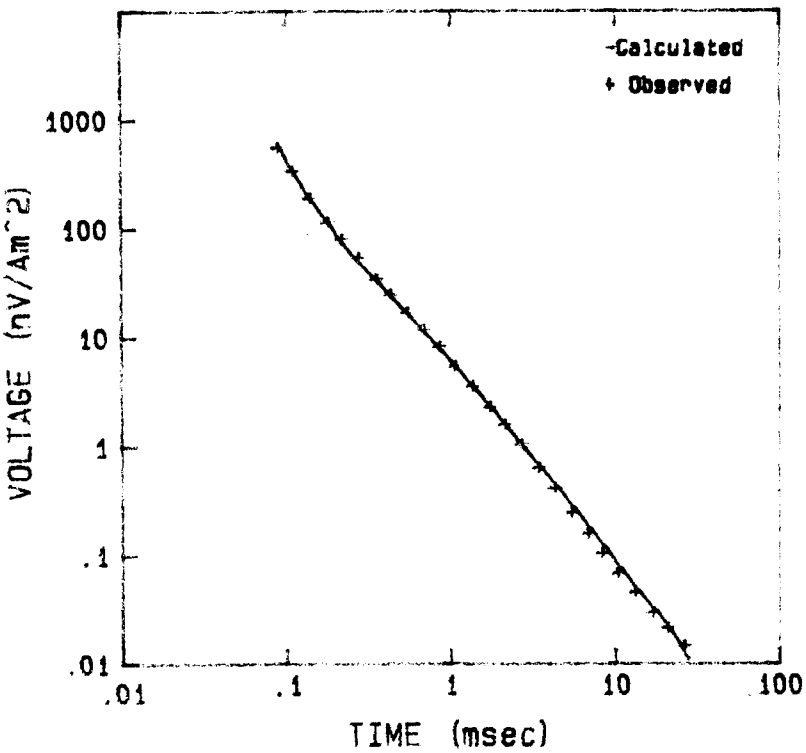
**PARM_SOL.	STD_ERROR	REL_ERROR	% ERROR **
. .3982E-03	.4105E-04	.1031E+00	.1031E+02
2 .7199E-02	.8669E-03	.1204E+00	.1204E+02
.4037E-01	.2381E-02	.5897E-01	.5897E+01
.1613E-01	.3212E-02	.1991E+00	.1991E+02
5 .2053E+03	.1406E-02	.6849E-05	.6849E-03
[illegible] .1821E+03	.2046E-02	.1124E-04	.1124E-02
.2286E+03	.5027E-03	.2199E-05	.2199E-03

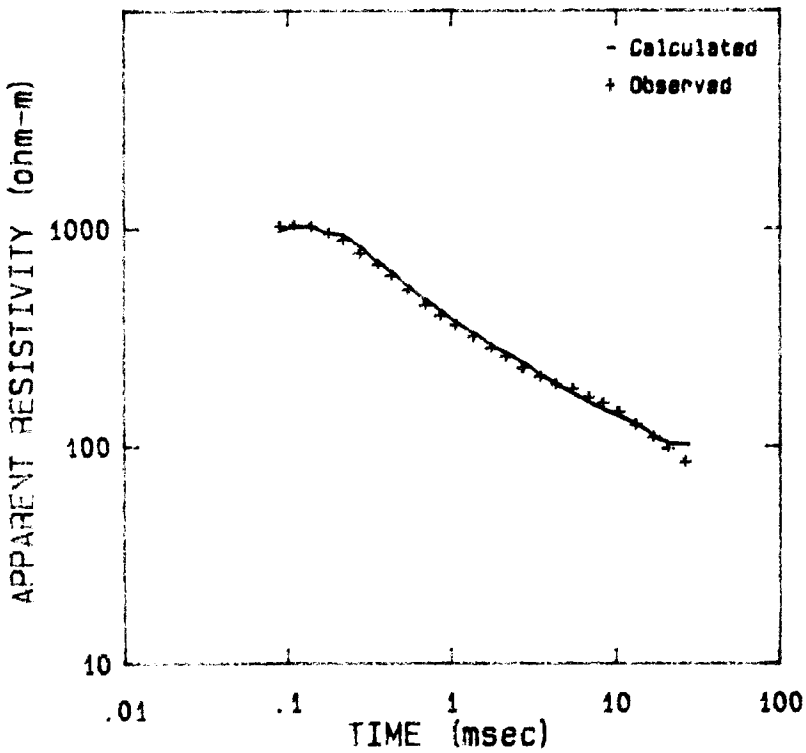
RAMETER NAME	FINAL SOLUTION	RESISTIVITY	LAYER DEPTH
1 SIGMA(1) =	.39819E-03	.25113E+04	
2 SIGMA(2) =	.71990E-02	.13891E+03	
3 SIGMA(3) =	.40374E-01	.24769E+02	
4 SIGMA(4) =	.16129E-01	.61998E+02	
5 THICK(1) =	.20527E+03		.20527E+03
6 THICK(2) =	.18206E+03		.38733E+03
7 THICK(3) =	.22859E+03		.61591E+03


STATION: R4
+ 30COIL LO
* 30COIL HI
# 3LOOP HI
SANTA FE
MEDICINE LAKE
10K
1K
100
10
nV/Am
10
1
1
.01
.1
1
10
100
t, ms

EMSURVEYS TEM INVERSION

MEDICINE LAKE
STATION: R5





MODEL

RESISTIVITY (ohm-m)	THICKNESS (meters)
523	11
906	341
88	327
59	

ELECTROMAG TIC SURVEYS INC.

MEDICINE LAKE R5

I	TIME (sec)	VOLTAGE (nV/Am^2)	CALC.VOLT	RESIDUAL	%RES.ERR
1	.8900E-04	.5520E+03	.5862E+03	-.3417E+02	-.5830E+01
2	.1100E-03	.3340E+03	.3400E+03	-.6006E+01	-.1767E+01
3	.1400E-03	.1880E+03	.1865E+03	.1548E+01	.8300E+00
4	.1770E-03	.1130E+03	.1118E+03	.1231E+01	.1102E+01
	.2200E-03	.7870E+02	.7295E+02	.5748E+01	.7879E+01
6	.2800E-03	.5310E+02	.4746E+02	.5642E+01	.1189E+02
7	.3550E-03	.3400E+02	.3257E+02	.1435E+01	.4406E+01
8	.4430E-03	.2450E+02	.2307E+02	.1430E+01	.6198E+01
9	.5540E-03	.1680E+02	.1607E+02	.7302E+00	.4544E+01
10	.7130E-03	.1170E+02	.1082E+02	.8769E+00	.8103E+01
11	.8810E-03	.8120E+01	.7583E+01	.5375E+00	.7089E+01
2	.1090E-02	.5400E+01	.5273E+01	.1268E+00	.2405E+01
.3	.1410E-02	.3550E+01	.3388E+01	.1619E+00	.4779E+01
14	.1790E-02	.2280E+01	.2217E+01	.6348E-01	.2864E+01
5	.2220E-02	.1570E+01	.1510E+01	.6019E-01	.3987E+01
6	.2850E-02	.1030E+01	.9639E+00	.6608E-01	.6855E+01
	.3600E-02	.6300E+00	.6290E+00	.1035E-02	.1646E+00
	.4490E-02	.4070E+00	.4173E+00	-.1029E-01	-.2465E+01
	.5700E-02	.2430E+00	.2671E+00	-.2414E-01	-.9036E+01
20	.7190E-02	.1550E+00	.1715E+00	-.1654E-01	-.9644E+01
21	.8800E-02	.1030E+00	.1163E+00	-.1332E-01	-.1145E+02
2	.1110E-01	.6700E-01	.7373E-01	-.6728E-02	-.9125E+01
.3	.1400E-01	.4500E-01	.4633E-01	-.1330E-02	-.2871E+01
24	.1800E-01	.2900E-01	.2804E-01	.9577E-03	.3415E+01
5	.2200E-01	.2100E-01	.1883E-01	.2165E-02	.1150E+02
6	.2800E-01	.1400E-01	.1173E-01	.2275E-02	.1940E+02

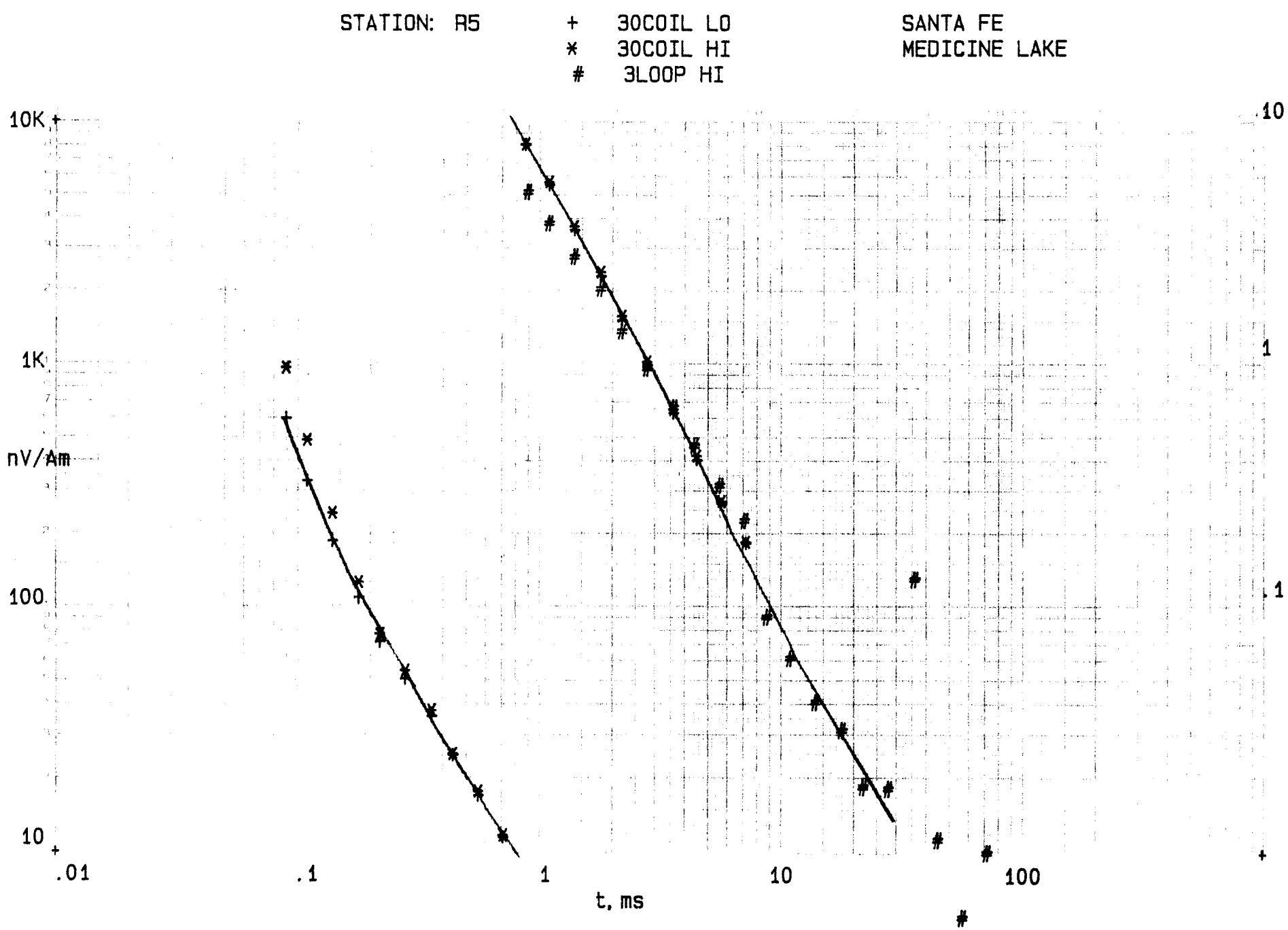
* RMSERR= 7.49

RRELATION MATRIX

1	.1000E+01						
	-.2131E+00	.1000E+01					
	.9567E-01	-.2551E+00	.1000E+01				
4	.6012E+00	-.2083E+00	-.1148E+00	.1000E+01			
5	-.1841E+00	.2079E+00	-.3297E+00	-.6264E+00	.1000E+01		
	-.9441E+00	.1368E+00	.1047E+00	-.6576E+00	.7343E-01	.1000E+01	
7	-.2406E+00	-.1424E+00	-.4582E+00	.1753E+00	.1978E+00	-.1925E-01	.1000E

**PARM_SOL.	STD_ERROR	REL_ERROR	% ERROR **
.1911E-02	.5885E-04	.3080E-01	.3080E+01
2 .1103E-02	.3608E-03	.3270E+00	.3270E+02
.1138E-01	.1072E-02	.9415E-01	.9415E+01
.1705E-01	.5734E-02	.3362E+00	.3362E+02
5 .1134E+02	.2681E-03	.2363E-04	.2363E-02
6 .3405E+03	.8429E-03	.2476E-05	.2476E-03
.3275E+03	.1083E-01	.3307E-04	.3307E-02

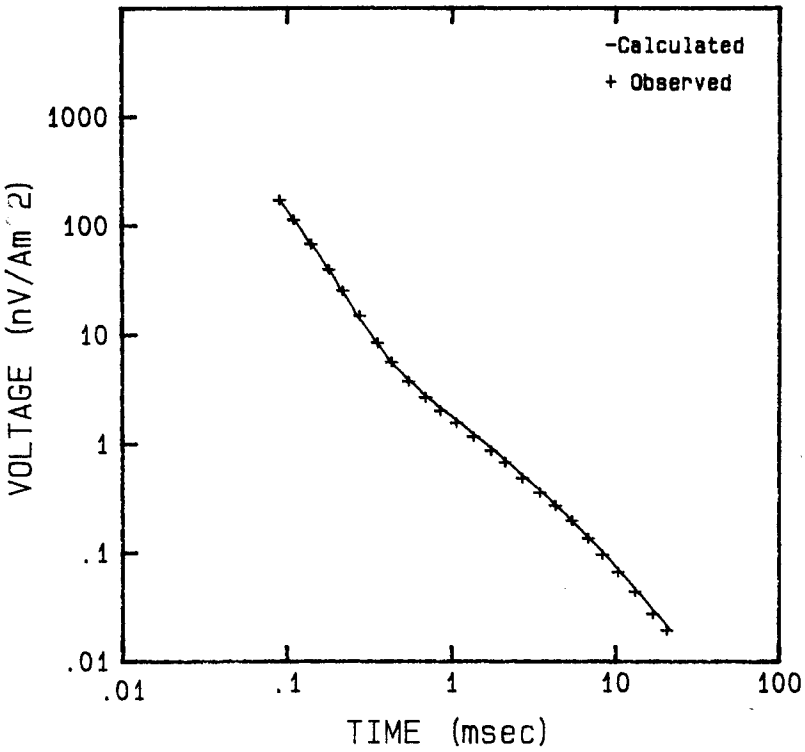
	RAMETER NAME	FINAL SOLUTION	RESISTIVITY	LAYER DEPTH
1	SIGMA(1) =	.19106E-02	.52340E+03	
2	SIGMA(2) =	.11033E-02	.90633E+03	
3	SIGMA(3) =	.11383E-01	.87853E+02	
4	SIGMA(4) =	.17053E-01	.58639E+02	
5	THICK(1) =	.11343E+02		.11343E+02
6	THICK(2) =	.34048E+03		.35183E+03
7	THICK(3) =	.32750E+03		.67933E+03
8	SHIFT =	[illegible]		

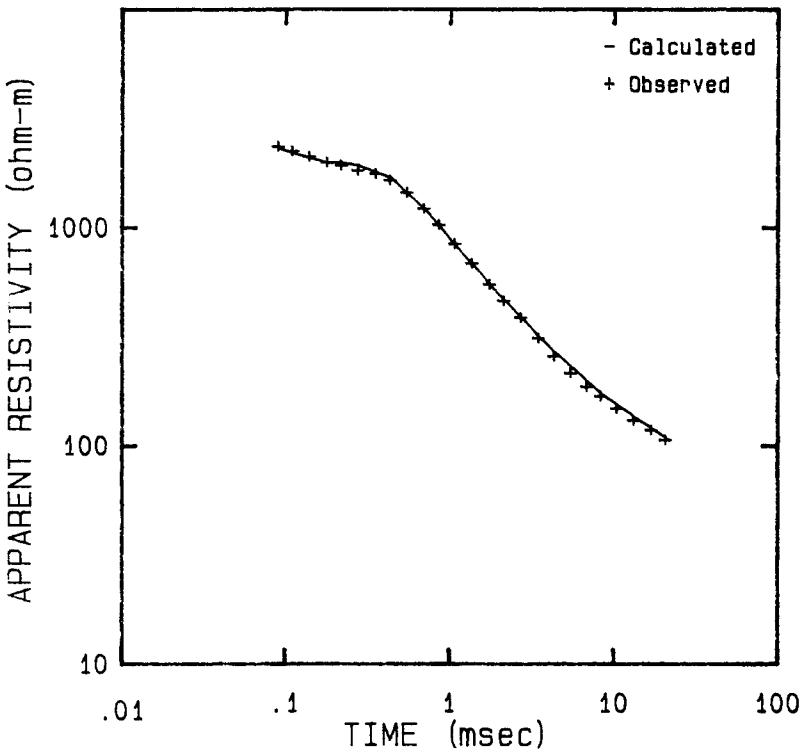

STATION: R5
+ 30COIL LO
* 30COIL HI
# 3LOOP HI
SANTA FE
MEDICINE LAKE
10K
1K
nV/Am
100
10
.01
.1
1
10
100
t, ms
10
1
.1

EMSURVEYS

TEM INVERSION

MEDICINE LAKE
STATION: R6





MODEL

RESISTIVITY (ohm-m)	THICKNESS (meters)
3051	280
672	371
39.6	

ELECTROMAGNETIC SURVEYS INC.

MEDICINE LAKE R6

I	TIME (sec)	VOLTAGE (nV/Am^2)	CALC.VOLT	RESIDUAL	%RES.ERR
1	.8900E-04	.1700E+03	.1728E+03	-.2814E+01	-.1628E+01
2	.1100E-03	.1100E+03	.1132E+03	-.3238E+01	-.2860E+01
3	.1400E-03	.6610E+02	.6716E+02	-.1061E+01	-.1580E+01
4	.1770E-03	.3880E+02	.3887E+02	-.6989E-01	-.1798E+00
[illegible]	.2200E-03	.2460E+02	.2354E+02	.1062E+01	.4512E+01
[illegible]	.2800E-03	.1460E+02	.1345E+02	.1145E+01	.8513E+01
7	.3550E-03	.8200E+01	.8018E+01	.1818E+00	.2267E+01
8	.4430E-03	.5490E+01	.5294E+01	.1959E+00	.3700E+01
9	.5540E-03	.3650E+01	.3743E+01	-.9290E-01	-.2482E+01
10	.7130E-03	.2600E+01	.2637E+01	-.3727E-01	-.1413E+01
11	.8810E-03	.1960E+01	.2042E+01	-.8238E-01	-.4034E+01
12	.1090E-02	.1520E+01	.1592E+01	-.7247E-01	-.4551E+01
13	.1410E-02	.1140E+01	.1168E+01	-.2834E-01	-.2426E+01
14	.1790E-02	.8440E+00	.8729E+00	-.2885E-01	-.3305E+01
15	.2220E-02	.6630E+00	.6714E+00	-.8402E-02	-.1251E+01
16	.2850E-02	.4740E+00	.4856E+00	-.1158E-01	-.2385E+01
17	.3600E-02	.3500E+00	.3523E+00	-.2298E-02	-.6522E+00
18	.4490E-02	.2660E+00	.2560E+00	.1004E-01	.3921E+01
19	.5700E-02	.1930E+00	.1797E+00	.1332E-01	.7416E+01
20	.7190E-02	.1340E+00	.1272E+00	.6827E-02	.5368E+01
21	.8800E-02	.9400E-01	.9310E-01	.8970E-03	.9634E+00
22	.1110E-01	.6500E-01	.6335E-01	.1648E-02	.2601E+01
23	.1400E-01	.4300E-01	.4210E-01	.8962E-03	.2128E+01
24	.1800E-01	.2700E-01	.2691E-01	.8931E-04	.3319E+00
25	.2200E-01	.1900E-01	.1904E-01	-.4029E-04	-.2116E+00

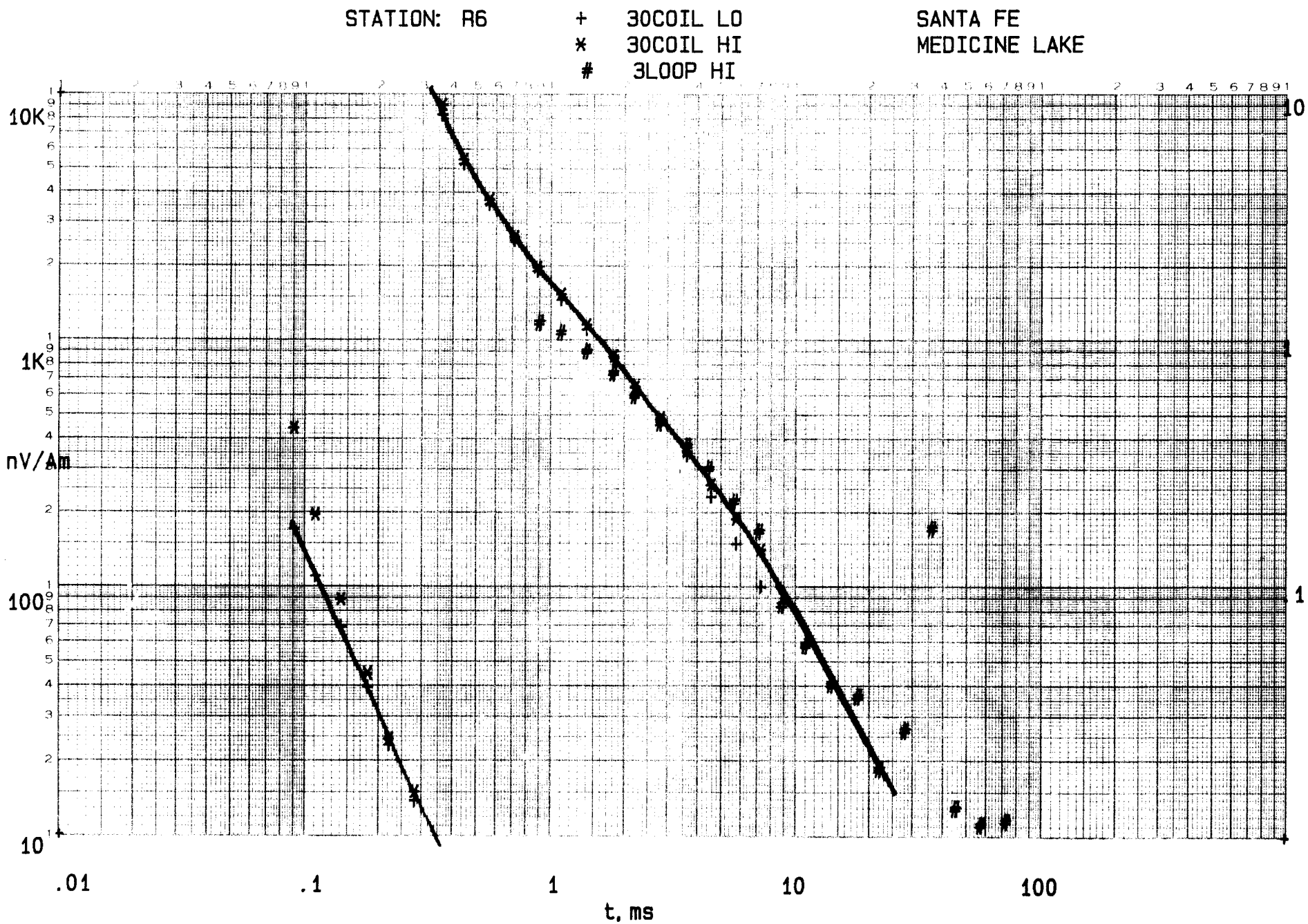
* RMSERR= 3.50

RRELATION MATRIX

	.1000E+01			
	.3087E+00	.1000E+01		
	.9416E-01	-.1905E+00	.1000E+01	
	.3888E+00	.3788E+00	-.3081E+00	.1000E+01
5	-.3831E+00	-.4573E+00	-.8492E-01	-.3767E+00	.1000E+01

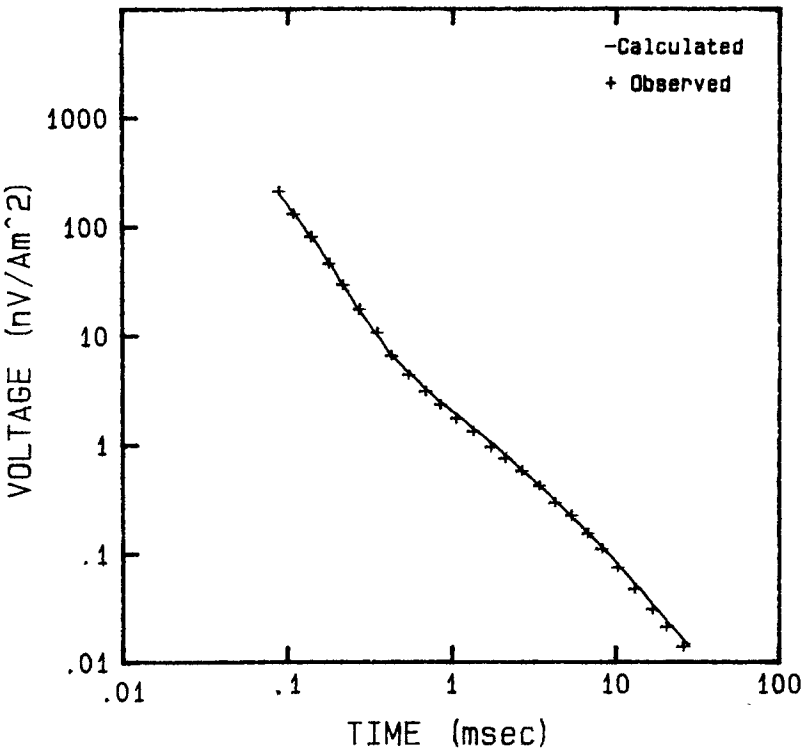
**PARM_SOL.	STD_ERROR	REL_ERROR	% ERROR **
[illegible] .3278E-03	.4794E-05	.1463E-01	.1463E+01
2 .1487E-02	.2179E-03	.1465E+00	.1465E+02
[illegible] .2522E-01	.8313E-03	.3296E-01	.3296E+01
.2796E+03	.1097E-02	.3922E-05	.3922E-03
5 .3716E+03	.6943E-04	.1868E-06	.1868E-04

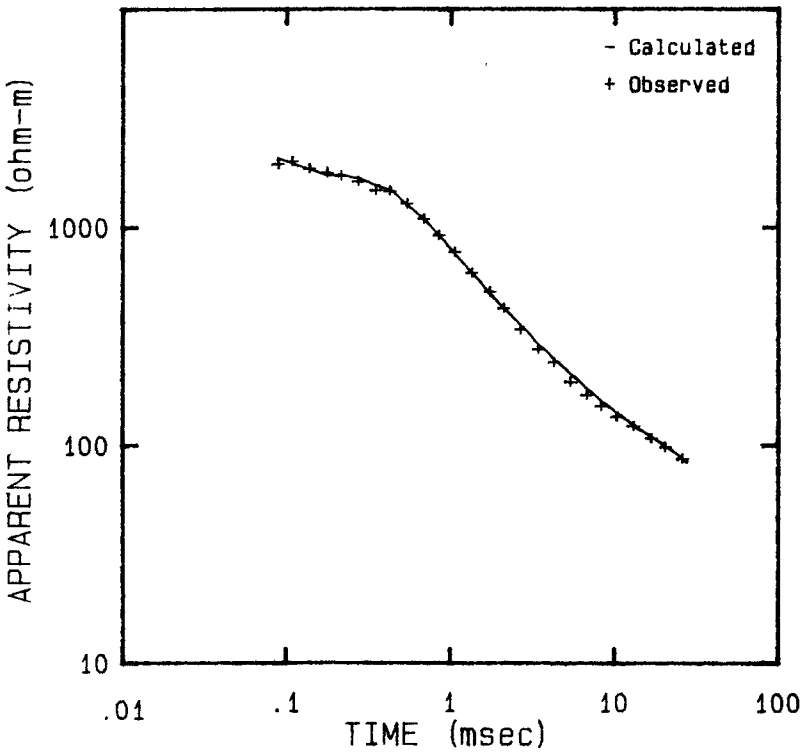
ARAMETER NAME	FINAL SOLUTION	RESISTIVITY	LAYER DEPTH
SIGMA(1) =	.32777E-03	.30509E+04	
2 SIGMA(2) =	.14873E-02	.67235E+03	
3 SIGMA(3) =	.25221E-01	.39649E+02	
4 THICK(1) =	.27961E+03		.27961E+03
5 THICK(2) =	.37162E+03		.65123E+03
6 SHIFT =	.20700E+03		


STATION: R6
+ 30COIL LO
* 30COIL HI
# 3LOOP HI
SANTA FE
MEDICINE LAKE
10K
1K
100
10
nV/Am
10
1
1
.01
.1
1
10
100
t, ms

EMSURVEYS TEM INVERSION

MEDICINE LAKE
STATION: R7





MODEL

RESISTIVITY (ohm-m)	THICKNESS (meters)
4904	222
625	400
38.4	

ELECTROMAGNETIC SURVEYS INC.

MEDICINE LAKE R7

I	TIME (sec)	VOLTAGE (nV/Am^2)	CALC.VOLT	RESIDUAL	%RES.ERR
1	.8900E-04	.2100E+03	.2021E+03	.7910E+01	.3914E+01
2	.1100E-03	.1290E+03	.1335E+03	-.4472E+01	-.3350E+01
3	.1400E-03	.7965E+02	.8053E+02	-.8843E+00	-.1098E+01
4	.1770E-03	.4530E+02	.4739E+02	-.2089E+01	-.4409E+01
5	.2200E-03	.2880E+02	.2851E+02	.2864E+00	.1005E+01
6	.2800E-03	.1720E+02	.1642E+02	.7753E+00	.4721E+01
7	.3550E-03	.1056E+02	.9819E+01	.7413E+00	.7550E+01
	.4430E-03	.6480E+01	.6387E+01	.9292E-01	.1455E+01
	.5540E-03	.4320E+01	.4483E+01	-.1629E+00	-.3634E+01
10	.7130E-03	.3040E+01	.3136E+01	-.9620E-01	-.3068E+01
11	.8810E-03	.2300E+01	.2379E+01	-.7925E-01	-.3331E+01
2	.1090E-02	.1720E+01	.1842E+01	-.1219E+00	-.6619E+01
3	.1410E-02	.1313E+01	.1356E+01	-.4338E-01	-.3198E+01
14	.1790E-02	.9410E+00	.1009E+01	-.6845E-01	-.6781E+01
5	.2220E-02	.7420E+00	.7695E+00	-.2747E-01	-.3570E+01
6	.2850E-02	.5700E+00	.5517E+00	.1830E-01	.3316E+01
17	.3600E-02	.4150E+00	.3974E+00	.1763E-01	.4436E+01
18	.4490E-02	.2910E+00	.2887E+00	.2308E-02	.7996E+00
9	.5700E-02	.2220E+00	.2023E+00	.1975E-01	.9763E+01
0	.7190E-02	.1520E+00	.1428E+00	.9152E-02	.6407E+01
21	.8800E-02	.1090E+00	.1051E+00	.3930E-02	.3741E+01
2	.1110E-01	.7400E-01	.7238E-01	.1619E-02	.2236E+01
3	.1400E-01	.4700E-01	.4848E-01	-.1476E-02	-.3045E+01
24	.1800E-01	.3100E-01	.3093E-01	.6958E-04	.2249E+00
5	.2200E-01	.2100E-01	.2174E-01	-.7412E-03	-.3409E+01
6	.2800E-01	.1400E-01	.1466E-01	-.6574E-03	-.4485E+01

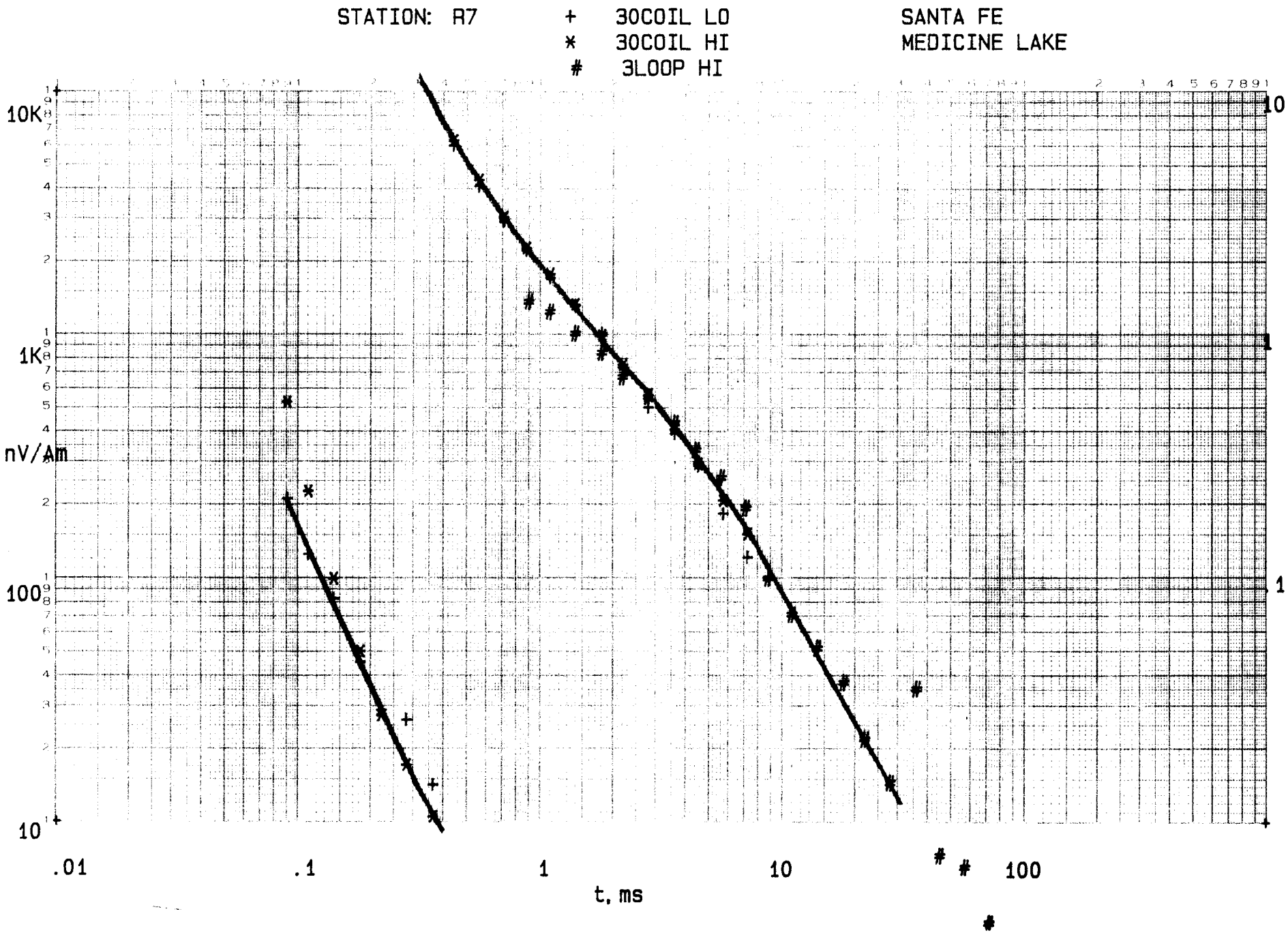
* RMSERR= 4.40

RRELATION MATRIX

	.1000E+01			
	-.1613E+00	.1000E+01		
	-.1745E+00	-.2973E+00	.1000E+01	
4	-.1142E+00	.2230E+00	-.3060E+00	.1000E+01
5	-.4260E+00	.5116E-01	-.9215E-01	-.3147E-01 .1000E+01

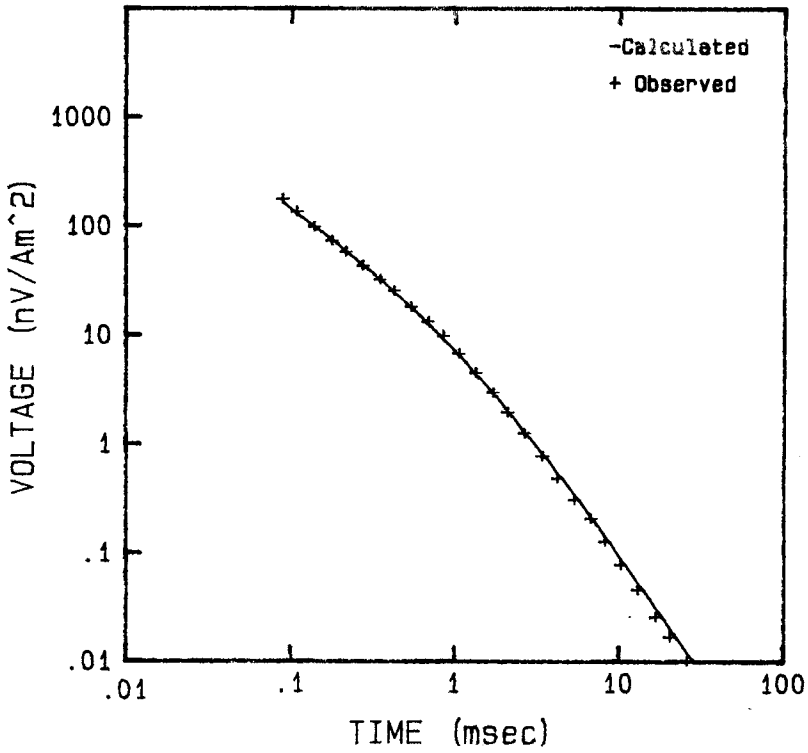
**PARM_SOL.	STD_ERROR	REL_ERROR	% ERROR **
1 .2039E-03	.7906E-05	.3877E-01	.3877E+01
.1601E-02	.1411E-03	.8812E-01	.8812E+01
.2606E-01	.5129E-03	.1968E-01	.1968E+01
4 .2216E+03	.1251E-02	.5646E-05	.5646E-03
.4002E+03	.4759E-03	.1189E-05	.1189E-03

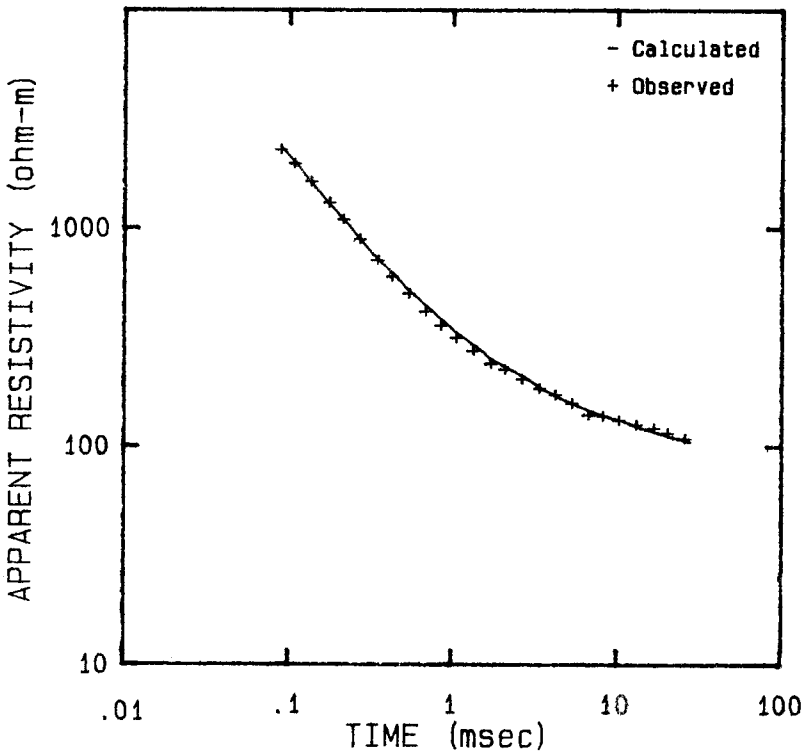
RAMETER NAME	FINAL SOLUTION	RESISTIVITY	LAYER DEPTH
SIGMA(1) =	.20391E-03	.49042E+04	
2 SIGMA(2) =	.16007E-02	.62472E+03	
3 SIGMA(3) =	.26061E-01	.38371E+02	
4 THICK(1) =	.22158E+03		.22158E+03
5 THICK(2) =	.40018E+03		.62176E+03
6 SHIFT =	.20700E+03		


STATION: R7
+ 30COIL LO
* 30COIL HI
# 3LOOP HI
SANTA FE
MEDICINE LAKE
10K
1K
100
10
nV/Am
10
1
1
.01
.1
1
10
100
t, ms

EMSURVEYS TEM INVERSION

MEDICINE LAKE
STATION: R8





MODEL

RESISTIVITY (ohm-m)	THICKNESS (meters)
2561	314
73.9	

ELECTROMAGNETIC SURVEYS INC.

MEDICINE LAKE R8

I	TIME (sec)	VOLTAGE (nV/Am^2)	CALC.VOLT	RESIDUAL	%RES.ERR
1	.8900E-04	.1759E+03	.1662E+03	.9729E+01	.5855E+01
2	.1100E-03	.1336E+03	.1286E+03	.4952E+01	.3849E+01
3	.1400E-03	.9715E+02	.9816E+02	-.1007E+01	-.1026E+01
4	.1770E-03	.7220E+02	.7427E+02	-.2070E+01	-.2787E+01
5	.2200E-03	.5720E+02	.5724E+02	-.4127E-01	-.7210E-01
6	.2800E-03	.4270E+02	.4290E+02	-.2020E+00	-.4709E+00
7	.3550E-03	.3170E+02	.3160E+02	.9881E-01	.3127E+00
8	.4430E-03	.2510E+02	.2364E+02	.1458E+01	.6167E+01
9	.5540E-03	.1790E+02	.1736E+02	.5387E+00	.3103E+01
10	.7130E-03	.1310E+02	.1206E+02	.1045E+01	.8667E+01
11	.8810E-03	.9610E+01	.8759E+01	.8514E+00	.9720E+01
2	.1090E-02	.6660E+01	.6268E+01	.3917E+00	.6248E+01
3	.1410E-02	.4460E+01	.4122E+01	.3383E+00	.8208E+01
14	.1790E-02	.2920E+01	.2754E+01	.1663E+00	.6039E+01
5	.2220E-02	.1940E+01	.1885E+01	.5465E-01	.2899E+01
6	.2850E-02	.1240E+01	.1195E+01	.4513E-01	.3777E+01
17	.3600E-02	.7680E+00	.7687E+00	-.6908E-03	-.8987E-01
8	.4490E-02	.4830E+00	.5005E+00	-.1751E-01	-.3498E+01
9	.5700E-02	.3050E+00	.3119E+00	-.6854E-02	-.2198E+01
20	.7190E-02	.2060E+00	.1942E+00	.1180E-01	.6075E+01
21	.8800E-02	.1260E+00	.1274E+00	-.1381E-02	-.1084E+01
2	.1110E-01	.7700E-01	.7814E-01	-.1144E-02	-.1464E+01
3	.1400E-01	.4600E-01	.4738E-01	-.1380E-02	-.2913E+01
24	.1800E-01	.2600E-01	.2750E-01	-.1501E-02	-.5457E+01
5	.2200E-01	.1700E-01	.1777E-01	-.7714E-03	-.4341E+01
6	.2800E-01	.1000E-01	.1052E-01	-.5202E-03	-.4944E+01

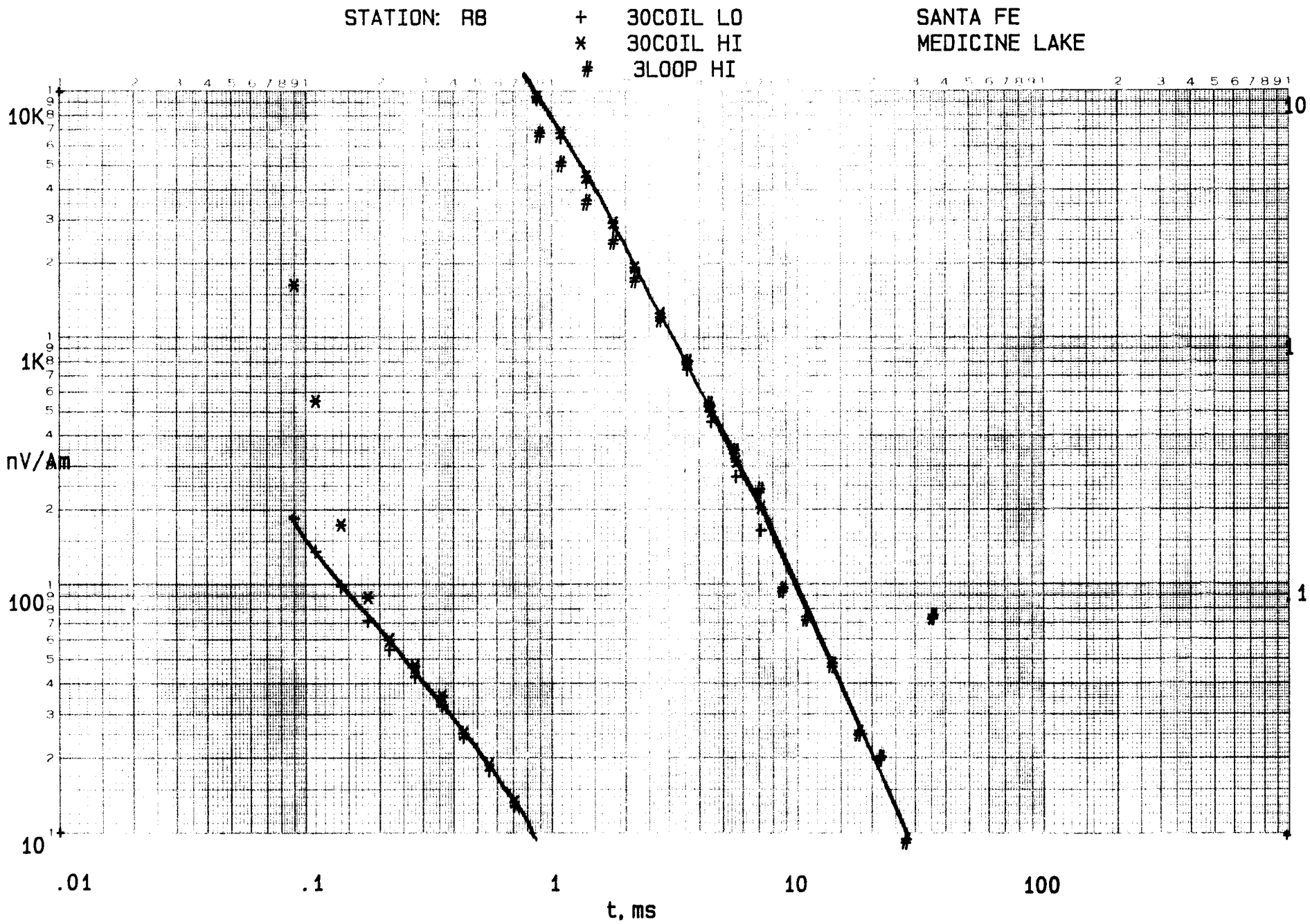
* RMSERR= 4.72

RELATION MATRIX

1 .1000E+01		
-.8252E+00	.1000E+01	
-.9601E+00	.7190E+00	.1000E+01

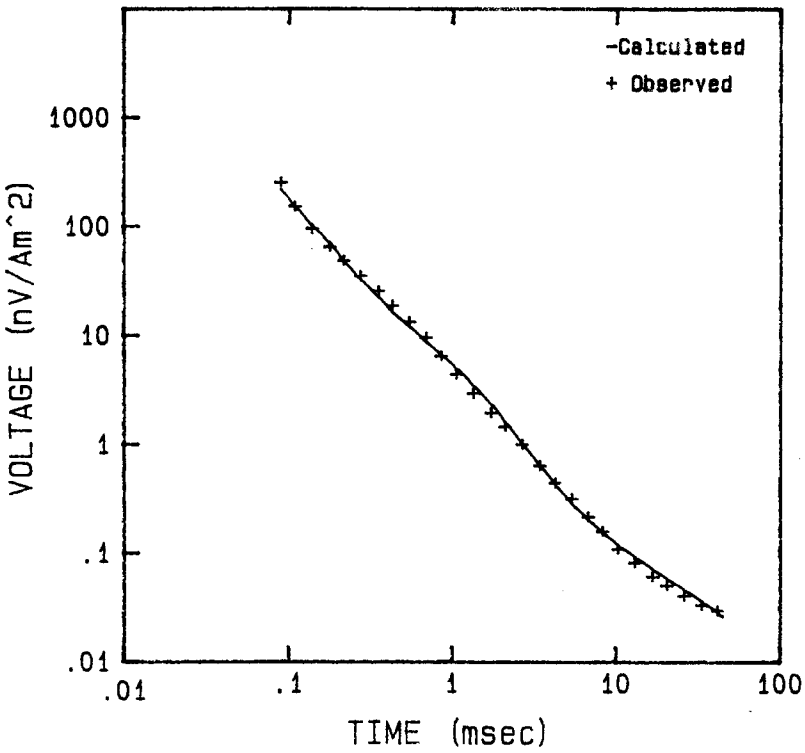
**PARM_SOL.	STD_ERROR	REL_ERROR	% ERROR **
.3905E-03	.2107E-04	.5395E-01	.5395E+01
2 .1353E-01	.5998E-03	.4433E-01	.4433E+01
3 .3140E+03	.1659E-03	.5282E-06	.5282E-04

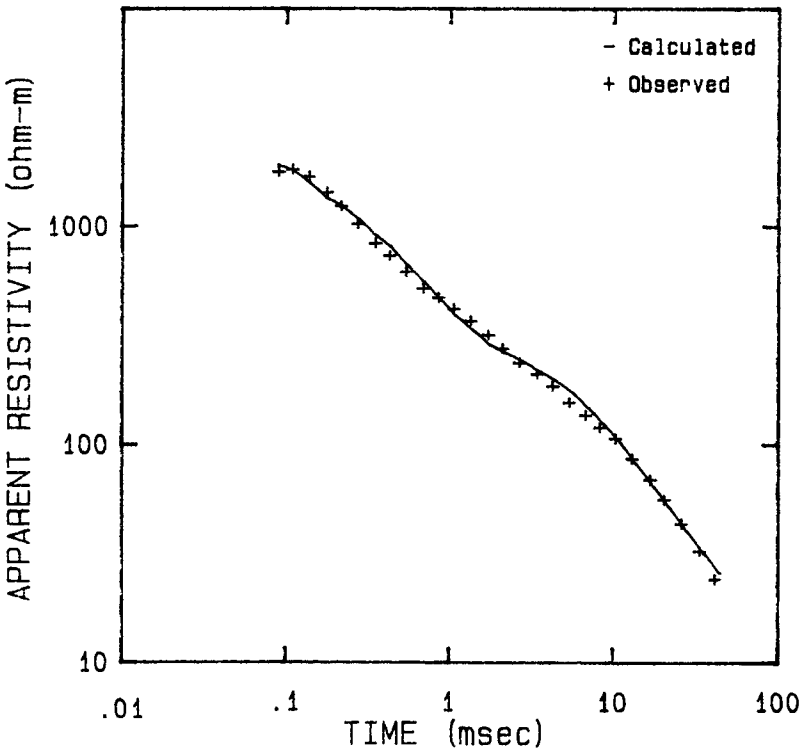
	ARAMETER NAME	FINAL SOLUTION	RESISTIVITY	LAYER DEPTH
1	SIGMA(1) =	.39050E-03	.25608E+04	
2	SIGMA(2) =	.13529E-01	.73915E+02	
3	THICK(1) =	.31399E+03		.31399E+03
4	SHIFT =	.20700E+03		


STATION: R8
+ 30COIL LO
* 30COIL HI
# 3LOOP HI
SANTA FE
MEDICINE LAKE
10K
1K
100
10
nV/Am
10
1
1
.01
.1
1
10
100
t, ms

EMSURVEYS TEM INVERSION

MEDICINE LAKE
STATION: R9





MODEL

RESISTIVITY (ohm-m)	THICKNESS (meters)
704	16.7
2208	295.3
122	144
26.7	263
1.74	

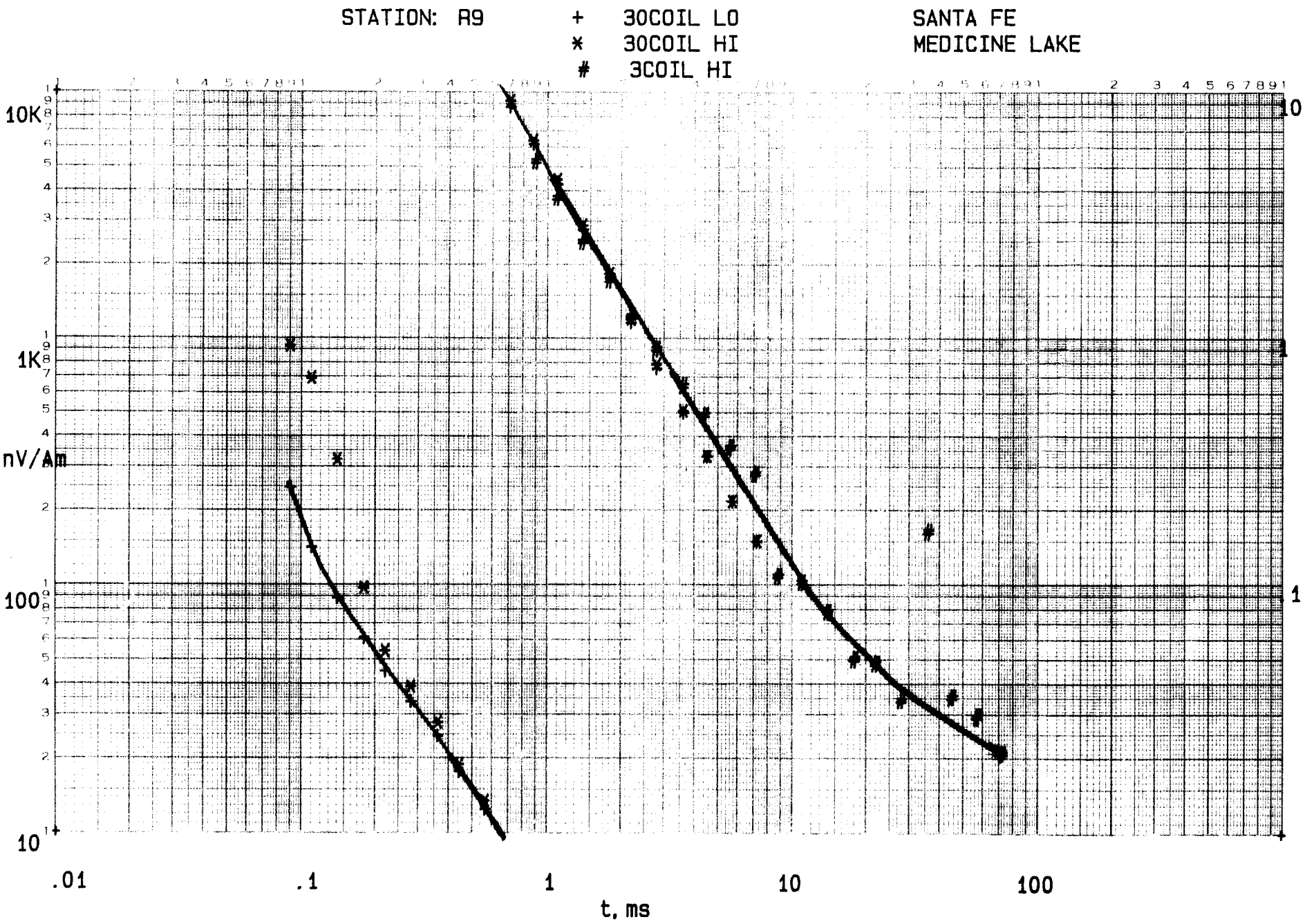
ELECTRO GNETIC SURVEYS INC.

MEDICINE LAKE R9

I	TIME (sec)	VOLTAGE (nV/Am^2)	CALC.VOLT	RESIDUAL	%RES.ERR
1	.8900E-04	.2500E+03	.2188E+03	.3119E+02	.1425E+02
2	.1100E-03	.1496E+03	.1516E+03	-.2037E+01	-.1343E+01
3	.1400E-03	.9250E+02	.1008E+03	-.8323E+01	-.8255E+01
4	.1770E-03	.6319E+02	.6902E+02	-.5832E+01	-.8450E+01
5	.2200E-03	.4753E+02	.4684E+02	.6922E+00	.1478E+01
6	.2800E-03	.3446E+02	.3176E+02	.2702E+01	.8507E+01
7	.3550E-03	.2502E+02	.2201E+02	.3003E+01	.1364E+02
8	.4430E-03	.1845E+02	.1581E+02	.2642E+01	.1671E+02
9	.5540E-03	.1304E+02	.1167E+02	.1369E+01	.1173E+02
10	.7130E-03	.9370E+01	.8400E+01	.9698E+00	.1154E+02
11	.8810E-03	.6340E+01	.6375E+01	-.3514E-01	-.5512E+00
2	.1090E-02	.4310E+01	.4781E+01	-.4705E+00	-.9843E+01
3	.1410E-02	.2870E+01	.3286E+01	-.4158E+00	-.1265E+02
14	.1790E-02	.1910E+01	.2224E+01	-.3140E+00	-.1412E+02
5	.2220E-02	.1430E+01	.1510E+01	-.8033E-01	-.5319E+01
6	.2850E-02	.9840E+00	.9422E+00	.4178E-01	.4435E+01
17	.3600E-02	.6270E+00	.5978E+00	.2922E-01	.4889E+01
18	.4490E-02	.4350E+00	.3932E+00	.4183E-01	.1064E+02
9	.5700E-02	.3120E+00	.2639E+00	.4808E-01	.1822E+02
20	.7190E-02	.2130E+00	.1896E+00	.2341E-01	.1234E+02
21	.8800E-02	.1560E+00	.1454E+00	.1059E-01	.7282E+01
2	.1110E-01	.1070E+00	.1107E+00	-.3687E-02	-.3331E+01
3	.1400E-01	.8000E-01	.8662E-01	-.6620E-02	-.7643E+01
24	.1800E-01	.6000E-01	.6673E-01	-.6734E-02	-.1009E+02
5	.2200E-01	.5000E-01	.5467E-01	-.4671E-02	-.8544E+01
6	.2800E-01	.4000E-01	.4329E-01	-.3288E-02	-.7595E+01
27	.3600E-01	.3300E-01	.3360E-01	-.6016E-03	-.1790E+01
28	.4500E-01	.2900E-01	.2617E-01	.2828E-02	.1080E+02

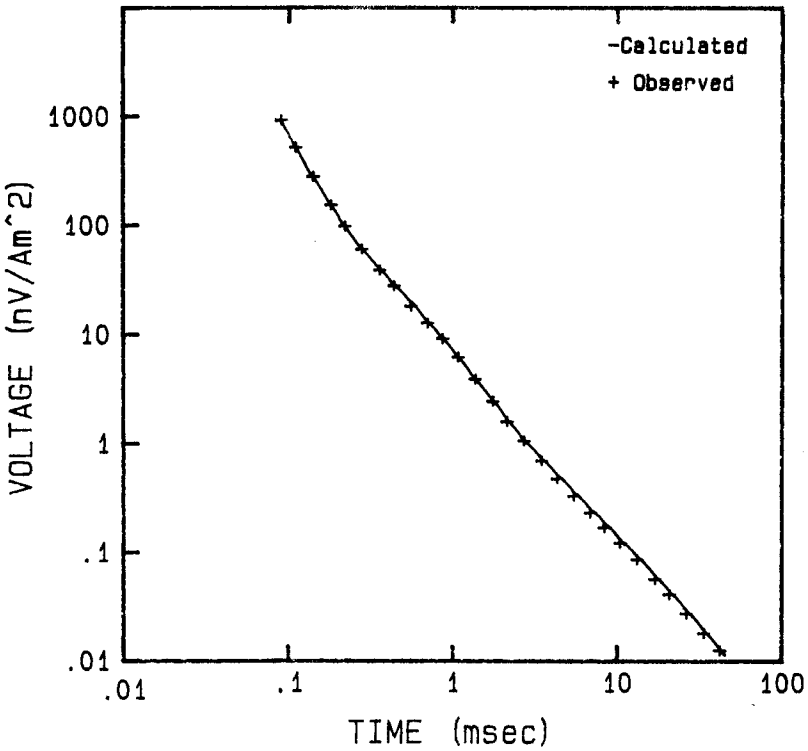
RMSERR= 9.92

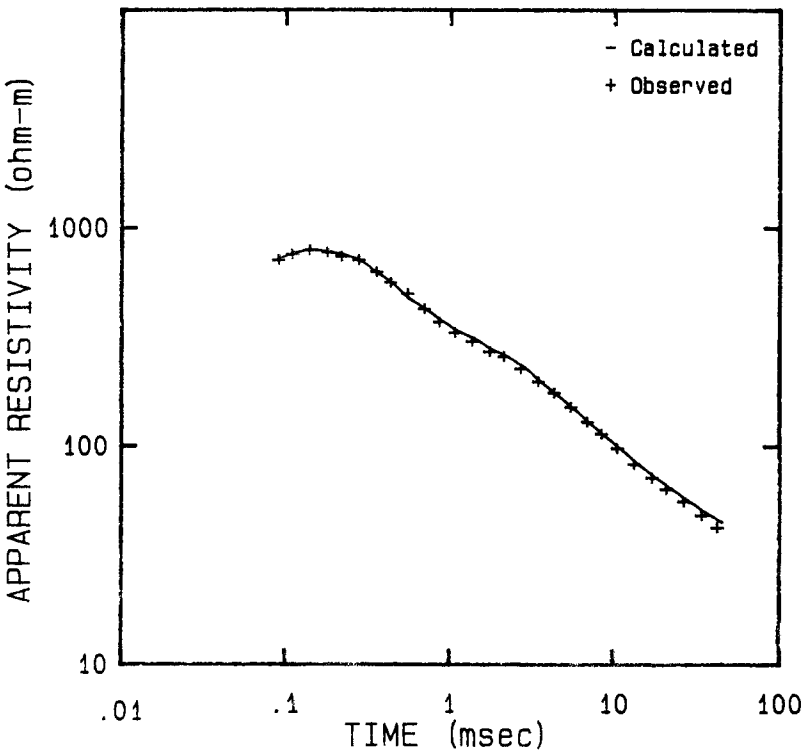
RAMETER	NAME	FINAL SOLUTION	RESISTIVITY	LAYER DEPTH
1	SIGMA(1) =	.14205E-02	.70399E+03	
2	SIGMA(2) =	.45301E-03	.22075E+04	
3	SIGMA(3) =	.81714E-02	.12238E+03	
4	SIGMA(4) =	.37486E-01	.26677E+02	
5	SIGMA(5) =	.57367E+00	.17432E+01	
6	THICK(1) =	.16681E+02		.16681E+02
7	THICK(2) =	.29508E+03		.31176E+03
8	THICK(3) =	.14410E+03		.45586E+03
9	THICK(4) =	.26320E+03		.71906E+03
10	SHIFT =	.20700E+03		


STATION: R9
+ 30COIL LO
* 30COIL HI
# 3COIL HI
SANTA FE
MEDICINE LAKE
10K
1K
nV/Am
100
10
.01
.1
1
10
100
t, ms

EMSURVEYS TEM INVERSION

MEDICINE LAKE
STATION: R10





MODEL

RESISTIVITY (ohm-m)	THICKNESS (meters)
445	48.6
850	289.4
72.5	334
16.5	

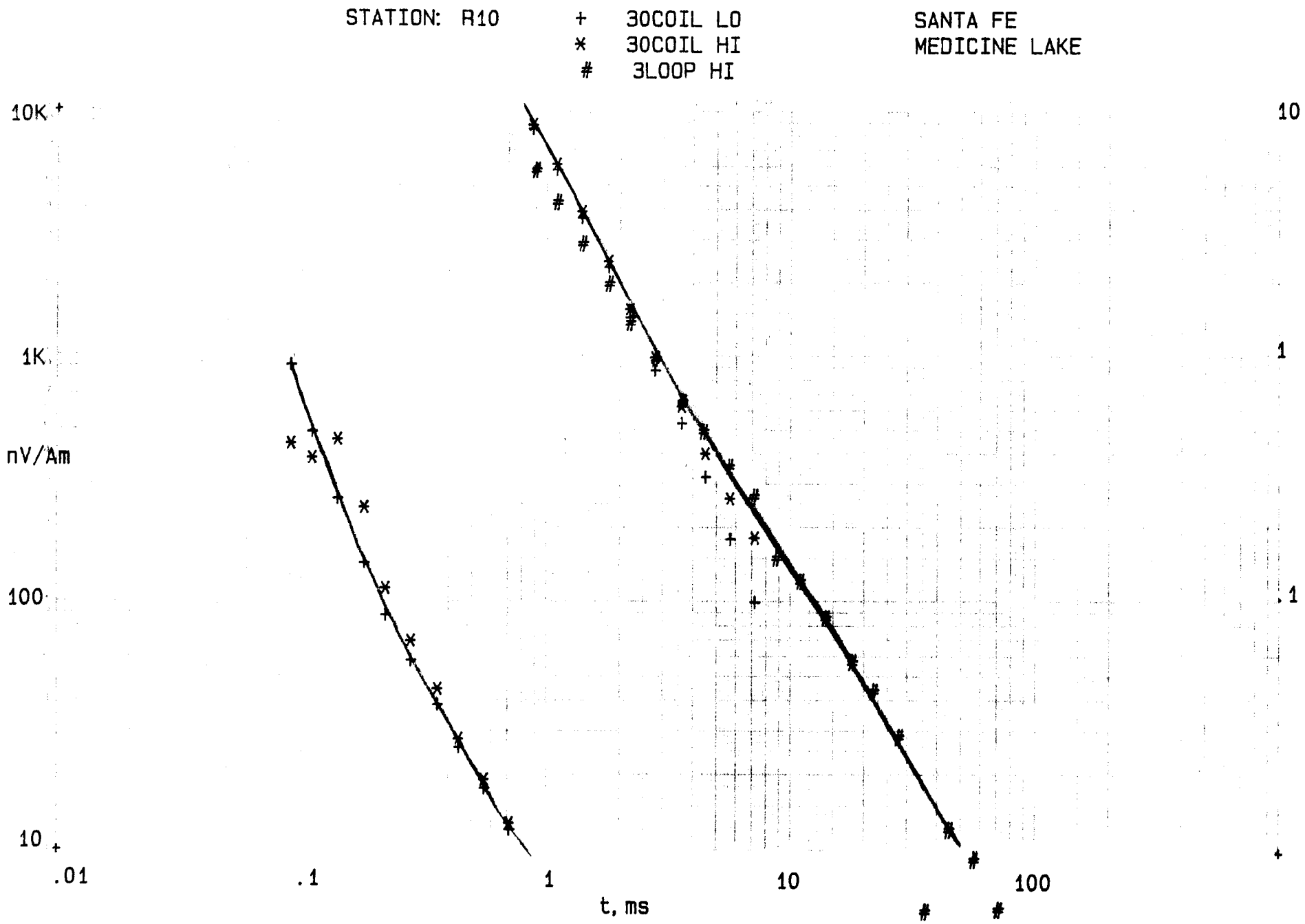
ELECTROMAGNETIC SURVEYS INC.

MEDICINE LAKE R10

I	TIME (sec)	VOLTAGE (nV/Am^2)	CALC.VOLT	RESIDUAL	%RES.ERR
	.8900E-04	.9170E+03	.9065E+03	.1046E+02	.1154E+01
2	.1100E-03	.5130E+03	.5159E+03	-.2937E+01	-.5693E+00
3	.1400E-03	.2740E+03	.2679E+03	.6143E+01	.2294E+01
4	.1770E-03	.1510E+03	.1500E+03	.1048E+01	.6990E+00
5	.2200E-03	.9650E+02	.9375E+02	.2754E+01	.2937E+01
6	.2800E-03	.5930E+02	.5902E+02	.2756E+00	.4670E+00
7	.3550E-03	.3820E+02	.3881E+02	-.6104E+00	-.1573E+01
8	.4430E-03	.2740E+02	.2754E+02	-.1420E+00	-.5155E+00
9	.5540E-03	.1790E+02	.1924E+02	-.1338E+01	-.6955E+01
10	.7130E-03	.1250E+02	.1260E+02	-.1047E+00	-.8303E+00
11	.8810E-03	.9030E+01	.8823E+01	.2065E+00	.2340E+01
2	.1090E-02	.6140E+01	.5928E+01	.2116E+00	.3570E+01
13	.1410E-02	.3850E+01	.3668E+01	.1819E+00	.4958E+01
14	.1790E-02	.2410E+01	.2337E+01	.7313E-01	.3129E+01
5	.2220E-02	.1570E+01	.1562E+01	.7764E-02	.4970E+00
6	.2850E-02	.1050E+01	.1010E+01	.4016E-01	.3977E+01
17	.3600E-02	.6860E+00	.6907E+00	-.4724E-02	-.6839E+00
18	.4490E-02	.4680E+00	.4846E+00	-.1656E-01	-.3417E+01
9	.5700E-02	.3250E+00	.3348E+00	-.9759E-02	-.2915E+01
[illegible]	.7190E-02	.2290E+00	.2361E+00	-.7080E-02	-.2999E+01
	.8800E-02	.1670E+00	.1739E+00	-.6860E-02	-.3946E+01
2	.1110E-01	.1210E+00	.1219E+00	-.9360E-03	-.7676E+00
23	.1400E-01	.8500E-01	.8462E-01	.3753E-03	.4435E+00
24	.1800E-01	.5600E-01	.5611E-01	-.1097E-03	-.1955E+00
5	.2200E-01	.4100E-01	.4008E-01	.9178E-03	.2290E+01
6	.2800E-01	.2700E-01	.2667E-01	.3279E-03	.1229E+01
27	.3600E-01	.1800E-01	.1717E-01	.8301E-03	.4835E+01
28	.4500E-01	.1200E-01	.1140E-01	.6038E-03	.5299E+01

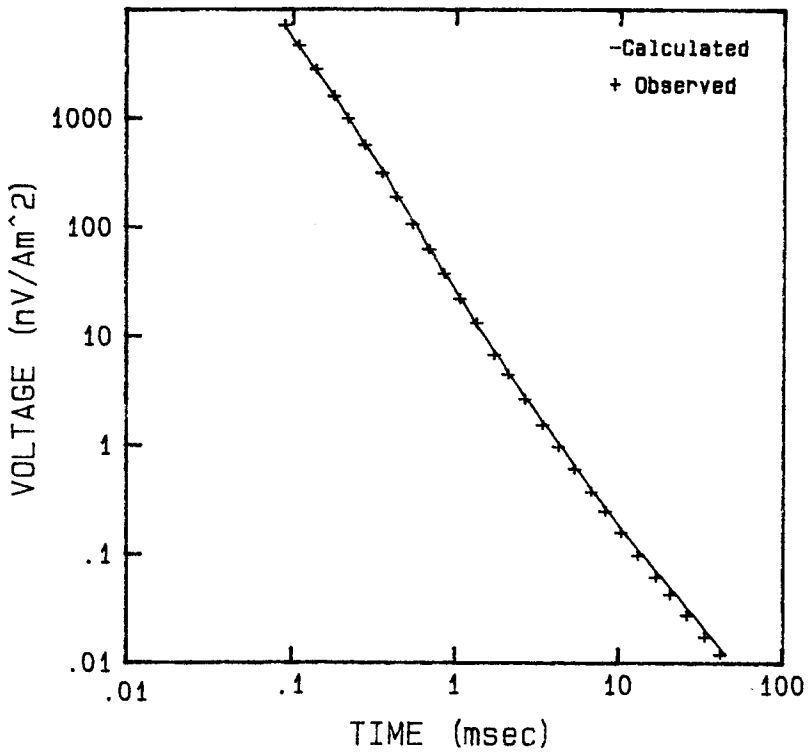
RMSERR= 2.93

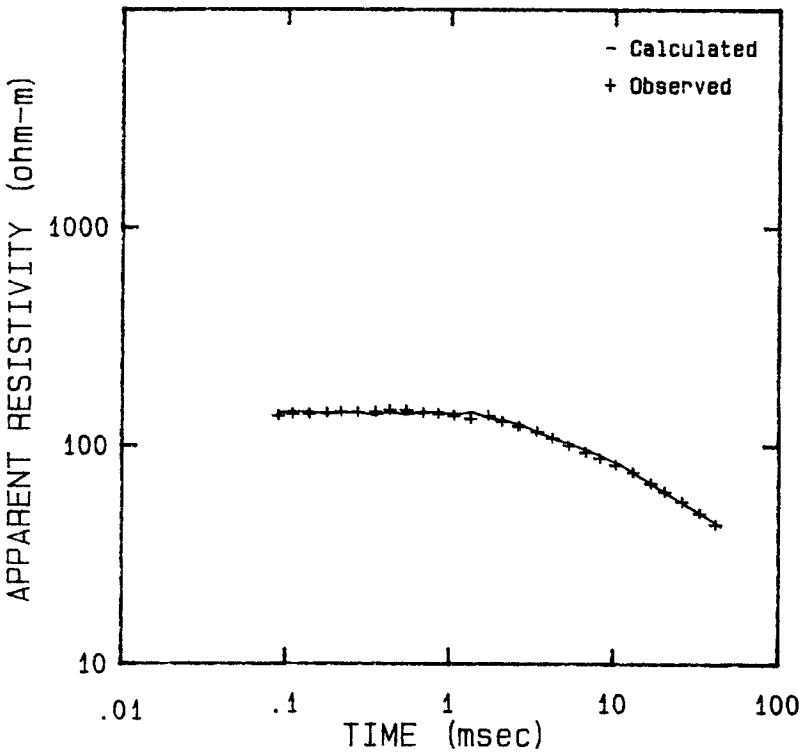
RAMETER	NAME	FINAL SOLUTION	RESISTIVITY	LAYER DEPTH
1	SIGMA(1) =	.22468E-02	.44509E+03	
2	SIGMA(2) =	.11770E-02	.84964E+03	
3	SIGMA(3) =	.13791E-01	.72509E+02	
4	SIGMA(4) =	.60699E-01	.16475E+02	
5	THICK(1) =	.48554E+02		.48554E+02
6	THICK(2) =	.28966E+03		.33821E+03
7	THICK(3) =	.33395E+03		.67216E+03
8	SHIFT =	.20700E+03		


STATION: R10
+ 30COIL LO
* 30COIL HI
# 3LOOP HI
SANTA FE
MEDICINE LAKE
10K
1K
nV/Am
100
10
.01
.1
1
10
100
t, ms
10
1
.1

EMSURVEYS TEM INVERSION

MEDICINE LAKE
STATION: R11





MODEL

RESISTIVITY (ohm-m)	THICKNESS (meters)
77.3	15.2
220	51.9
123.5	345.9
40.3	398
13.7	

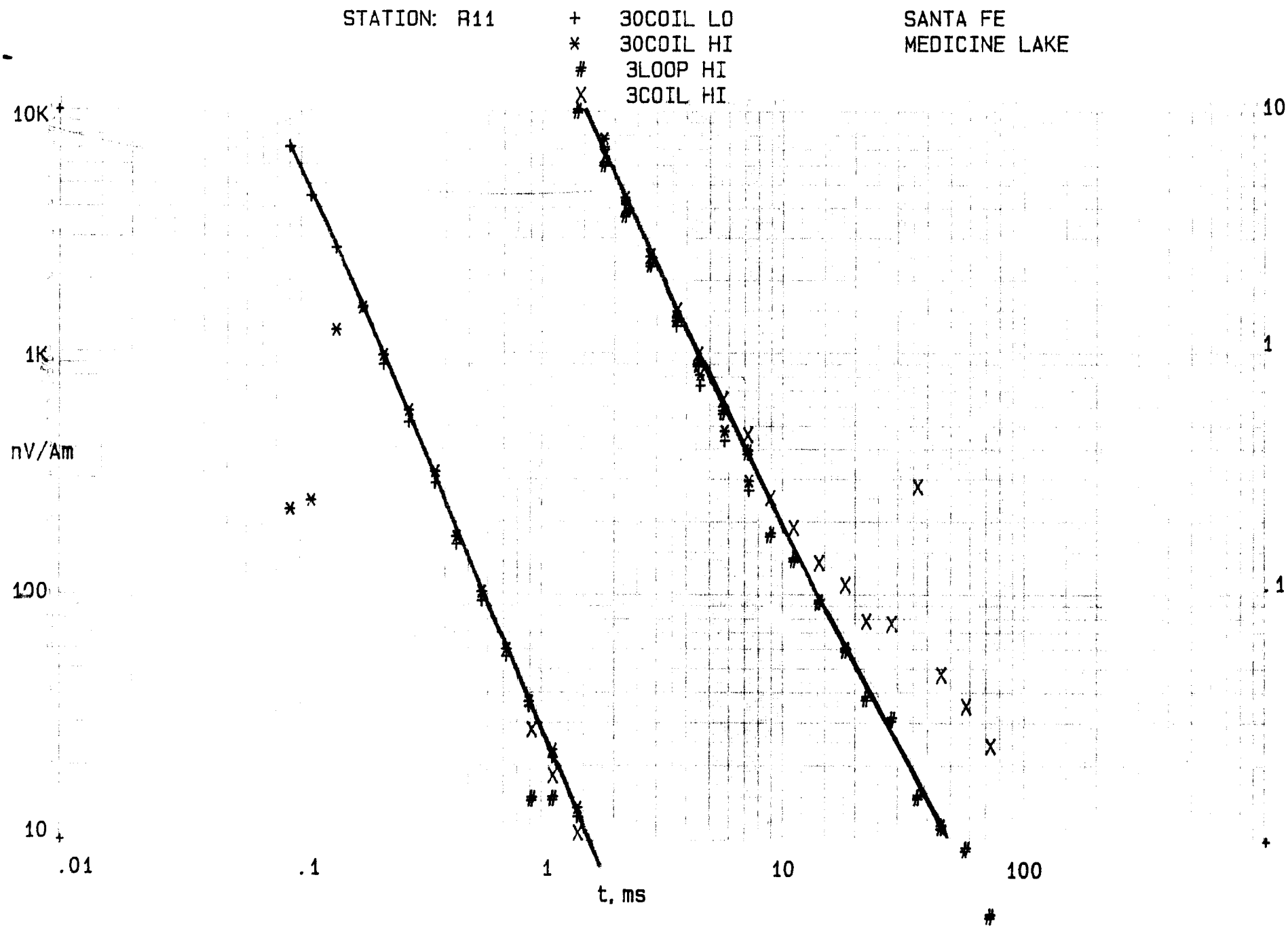
ELECTROMAGNETIC SURVEYS INC.

MEDICINE LAKE R11

I	TIME (sec)	VOLTAGE (nV/Am^2)	CALC.VOLT	RESIDUAL	%RES.ERR
1	.8900E-04	.7114E+04	.6944E+04	.1700E+03	.2448E+01
2	.1100E-03	.4620E+04	.4492E+04	.1281E+03	.2852E+01
3	.1400E-03	.2758E+04	.2658E+04	.9962E+02	.3747E+01
4	.1770E-03	.1567E+04	.1589E+04	-.2154E+02	-.1356E+01
5	.2200E-03	.9786E+03	.9842E+03	-.5625E+01	-.5715E+00
6	.2800E-03	.5630E+03	.5633E+03	-.2785E+00	-.4944E-01
7	.3550E-03	.3090E+03	.3263E+03	-.1727E+02	-.5292E+01
8	.4430E-03	.1870E+03	.1924E+03	-.5374E+01	-.2793E+01
9	.5540E-03	.1050E+03	.1117E+03	-.6735E+01	-.6028E+01
10	.7130E-03	.6210E+02	.6021E+02	.1887E+01	.3134E+01
11	.8810E-03	.3710E+02	.3589E+02	.1212E+01	.3377E+01
12	.1090E-02	.2180E+02	.2148E+02	.3178E+00	.1479E+01
13	.1410E-02	.1310E+02	.1178E+02	.1319E+01	.1120E+02
14	.1790E-02	.6670E+01	.6907E+01	-.2367E+00	-.3427E+01
15	.2220E-02	.4430E+01	.4339E+01	.9072E-01	.2091E+01
16	.2850E-02	.2620E+01	.2557E+01	.6270E-01	.2452E+01
17	.3600E-02	.1520E+01	.1547E+01	-.2687E-01	-.1737E+01
18	.4490E-02	.9640E+00	.9745E+00	-.1050E-01	-.1077E+01
19	.5700E-02	.5980E+00	.5884E+00	.9607E-02	.1633E+01
20	.7190E-02	.3710E+00	.3603E+00	.1067E-01	.2962E+01
21	.8800E-02	.2470E+00	.2419E+00	.5088E-02	.2103E+01
22	.1110E-01	.1570E+00	.1545E+00	.2507E-02	.1622E+01
23	.1400E-01	.9700E-01	.1005E+00	-.3531E-02	-.3512E+01
24	.1800E-01	.6200E-01	.6403E-01	-.2033E-02	-.3175E+01
25	.2200E-01	.4300E-01	.4473E-01	-.1734E-02	-.3876E+01
26	.2800E-01	.2700E-01	.2886E-01	-.1863E-02	-.6455E+01
27	.3600E-01	.1700E-01	.1814E-01	-.1142E-02	-.6293E+01
28	.4500E-01	.1200E-01	.1216E-01	-.1629E-03	-.1340E+01

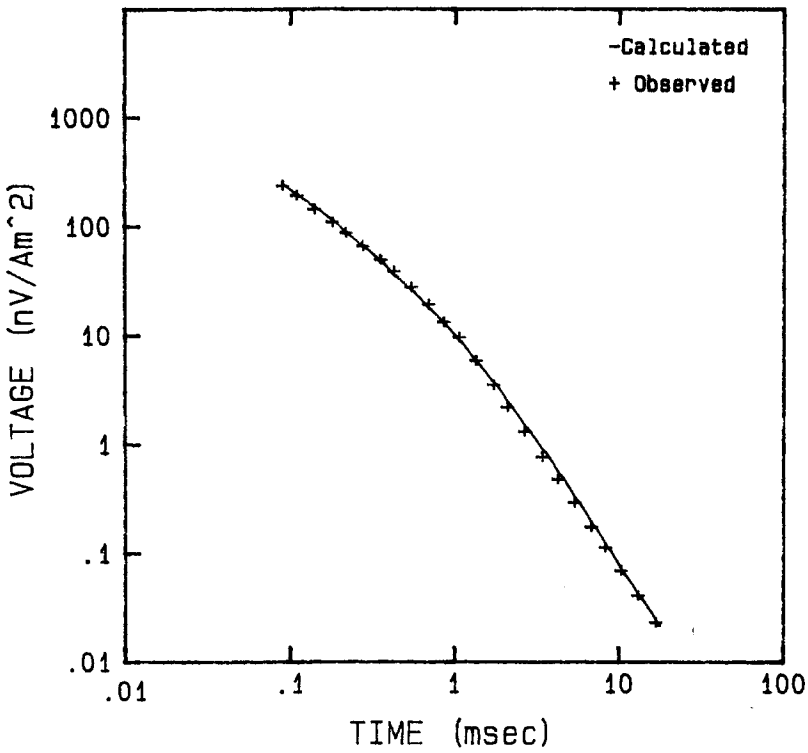
MSERR= 3.86

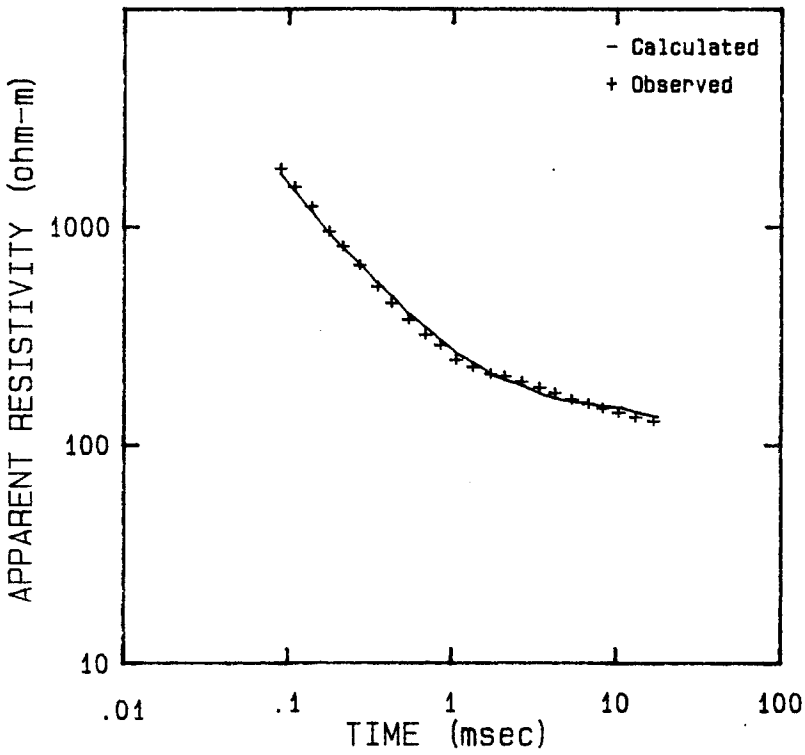
RAMETER	NAME	FINAL SOLUTION	RESISTIVITY	LAYER DEPTH
1	SIGMA(1) =	.12936E-01	.77304E+02	
2	SIGMA(2) =	.45417E-02	.22018E+03	
3	SIGMA(3) =	.80969E-02	.12350E+03	
4	SIGMA(4) =	.24806E-01	.40313E+02	
5	SIGMA(5) =	.73134E-01	.13673E+02	
6	THICK(1) =	.15166E+02		.15166E+02
7	THICK(2) =	.51928E+02		.67094E+02
8	THICK(3) =	.34542E+03		.41252E+03
9	THICK(4) =	.39879E+03		.81130E+03
10	SHIFT =	.20700E+03		


STATION: R11
+ 30COIL LO
* 30COIL HI
# 3LOOP HI
X 3COIL HI
SANTA FE
MEDICINE LAKE
10K
1K
nV/Am
100
10
.01
.1
1
10
100
t, ms
10
1
.1

EMSURVEYS TEM INVERSION

MEDICINE LAKE
STATION: R12





MODEL

RESISTIVITY (ohm-m)	THICKNESS (meters)
5667	236
247	26
77	280
135	

ELECTROMAGNETIC SURVEYS INC.

MEDICINE LAKE R12

I	TIME (sec)	VOLTAGE (nV/Am^2)	CALC.VOLT	RESIDUAL	%RES.ERR
	.8900E-04	.2360E+03	.2478E+03	-.1184E+02	-.4778E+01
2	.1100E-03	.1910E+03	.1979E+03	-.6896E+01	-.3485E+01
3	.1400E-03	.1430E+03	.1510E+03	-.8042E+01	-.5324E+01
4	.1770E-03	.1090E+03	.1148E+03	-.5824E+01	-.5072E+01
5	.2200E-03	.8670E+02	.8814E+02	-.1436E+01	-.1630E+01
6	.2800E-03	.6560E+02	.6481E+02	.7916E+00	.1221E+01
7	.3550E-03	.4930E+02	.4736E+02	.1942E+01	.4100E+01
8	.4430E-03	.3840E+02	.3489E+02	.3505E+01	.1005E+02
9	.5540E-03	.2740E+02	.2532E+02	.2083E+01	.8229E+01
10	.7130E-03	.1920E+02	.1735E+02	.1854E+01	.1069E+02
11	.8810E-03	.1320E+02	.1242E+02	.7788E+00	.6270E+01
2	.1090E-02	.9520E+01	.8723E+01	.7967E+00	.9133E+01
3	.1410E-02	.5840E+01	.5544E+01	.2956E+00	.5331E+01
14	.1790E-02	.3490E+01	.3555E+01	-.6494E-01	-.1827E+01
15	.2220E-02	.2180E+01	.2338E+01	-.1582E+00	-.6764E+01
6	.2850E-02	.1300E+01	.1404E+01	-.1045E+00	-.7439E+01
17	.3600E-02	.7620E+00	.8515E+00	-.8947E-01	-.1051E+02
18	.4490E-02	.4760E+00	.5231E+00	-.4713E-01	-.9009E+01
9	.5700E-02	.2920E+00	.3032E+00	-.1119E-01	-.3690E+01
0	.7190E-02	.1740E+00	.1762E+00	-.2195E-02	-.1246E+01
	.8800E-02	.1130E+00	.1107E+00	.2309E-02	.2086E+01
	.1110E-01	.6900E-01	.6465E-01	.4350E-02	.6729E+01
3	.1400E-01	.4100E-01	.3838E-01	.2619E-02	.6823E+01
24	.1800E-01	.2300E-01	.2181E-01	.1191E-02	.5463E+01

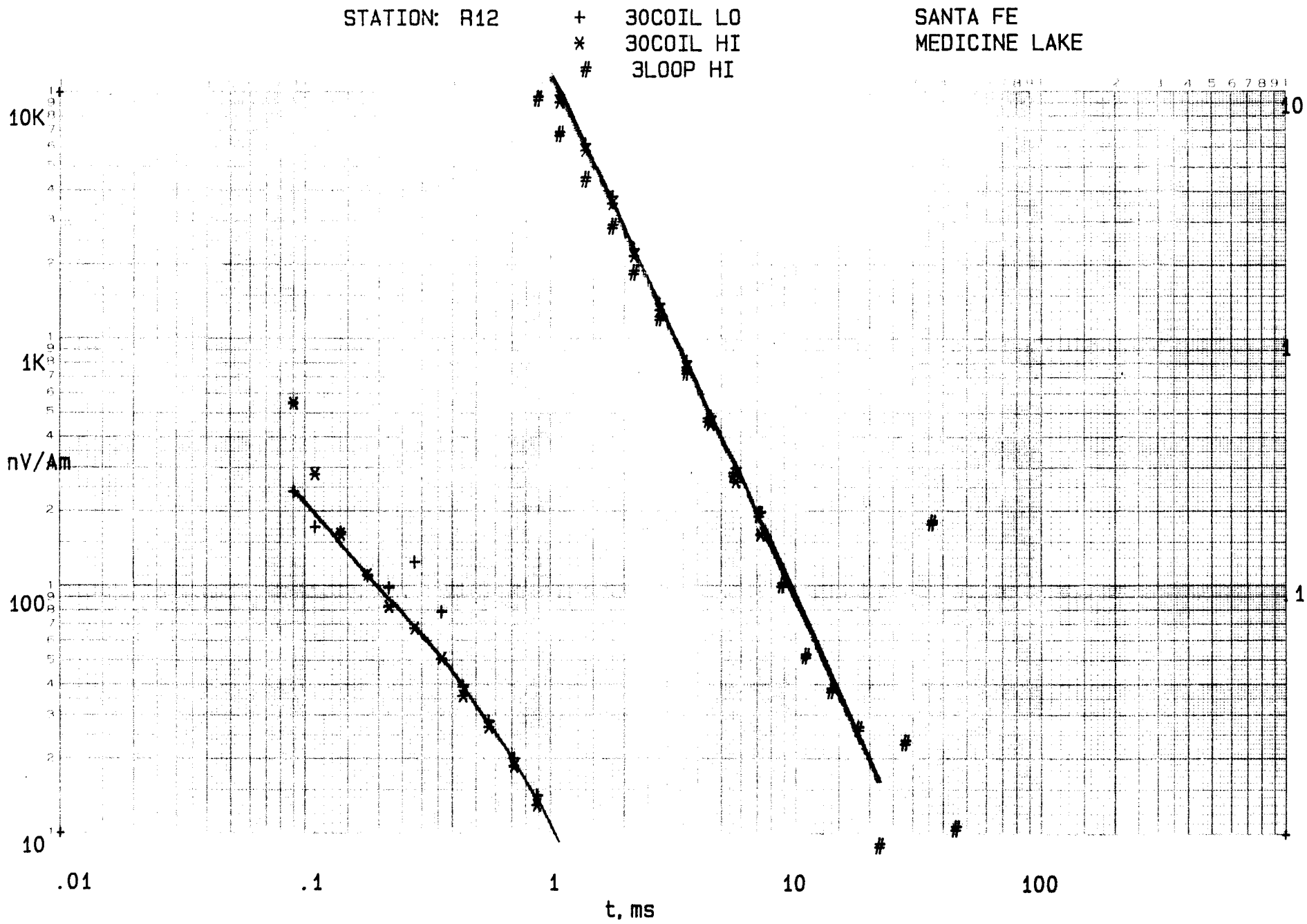
RMSERR= 6.39

ORRELATION MATRIX

	.1000E+01					
	-.5153E+00	.1000E+01				
3	.3882E+00	-.4906E+00	.1000E+01			
	.4066E-01	-.4135E+00	-.3387E-01	.1000E+01		
	.1175E+00	-.1207E+00	.3530E+00	.1634E+00	.1000E+01	
6	.6054E-01	-.4294E+00	-.1958E+00	-.5407E-01	-.5649E+00	.1000E+01
7	-.4212E+00	.2217E+00	.1657E+00	-.5360E+00	.1239E+00	-.3069E+00 .1000E

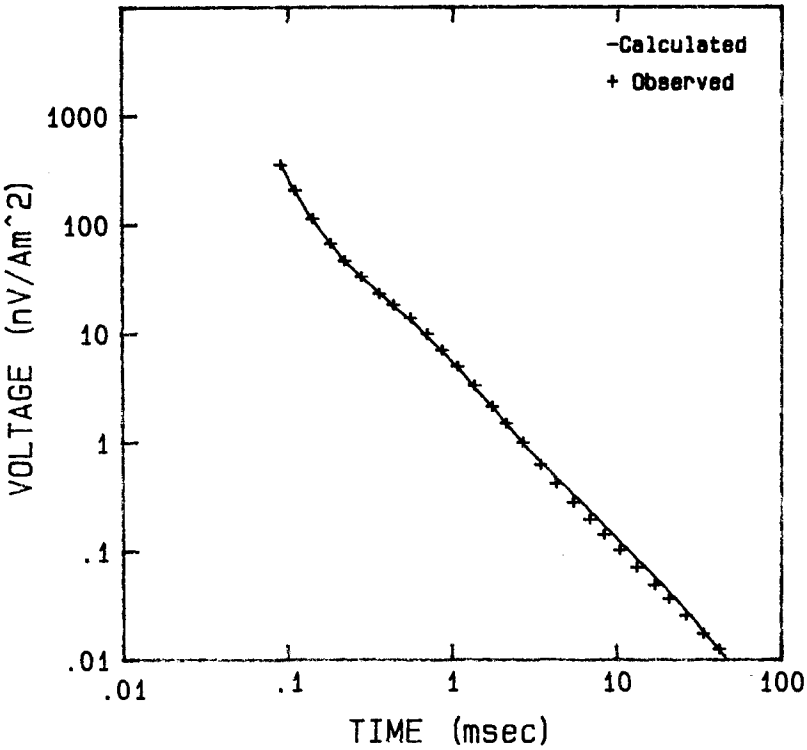
**PARM_SOL.	STD_ERROR	REL_ERROR	% ERROR **
.1764E-03	.3841E-04	.2177E+00	.2177E+02
.4041E-02	.1889E-02	.4675E+00	.4675E+02
.1296E-01	.1312E-02	.1012E+00	.1012E+02
4 .7382E-02	.2434E-02	.3297E+00	.3297E+02
.2365E+03	.1734E-02	.7332E-05	.7332E-03
.2599E+02	.1416E-02	.5447E-04	.5447E-02
.2799E+03	.1040E-02	.3716E-05	.3716E-03

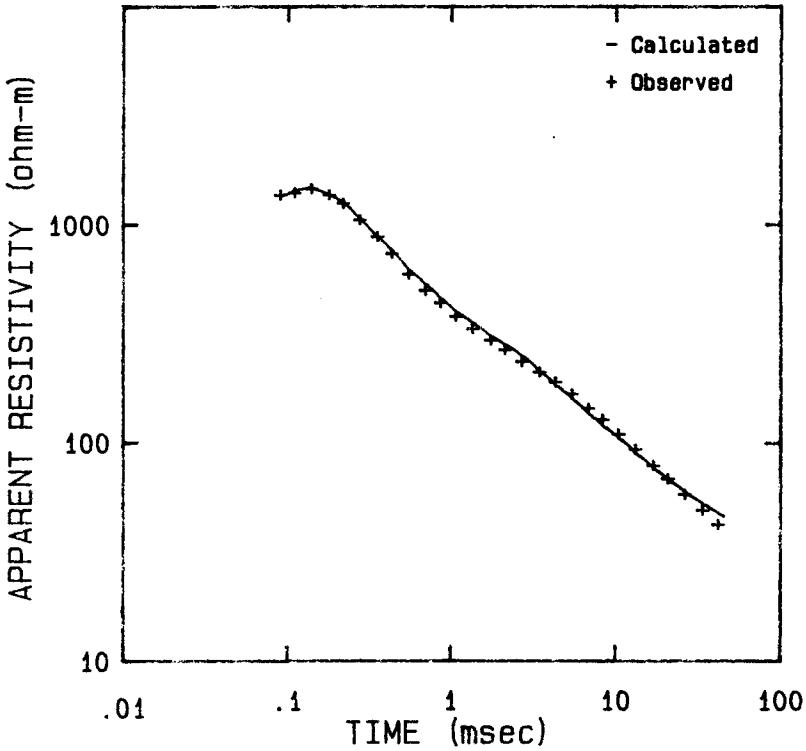
RAMETER NAME	FINAL SOLUTION	RESISTIVITY	LAYER DEPTH
1 SIGMA(1) =	.17645E-03	.56674E+04	
2 SIGMA(2) =	.40406E-02	.24749E+03	
3 SIGMA(3) =	.12964E-01	.77138E+02	
4 SIGMA(4) =	.73825E-02	.13546E+03	
5 THICK(1) =	.23648E+03		.23648E+03
6 THICK(2) =	.25990E+02		.26247E+03
7 THICK(3) =	.27992E+03		.54239E+03
8 SHIFT =	.20700E+03		


STATION: R12
+ 30COIL LO
* 30COIL HI
# 3LOOP HI
SANTA FE
MEDICINE LAKE
10K
1K
nV/Am
100
10
.01
.1
1
10
100
t, ms
10
1
1

EMSURVEYS TEM INVERSION

MEDICINE LAKE
STATION: R13





MODEL

RESISTIVITY (ohm-m)	THICKNESS (meters)
734	85
2026	296
60	321
17	

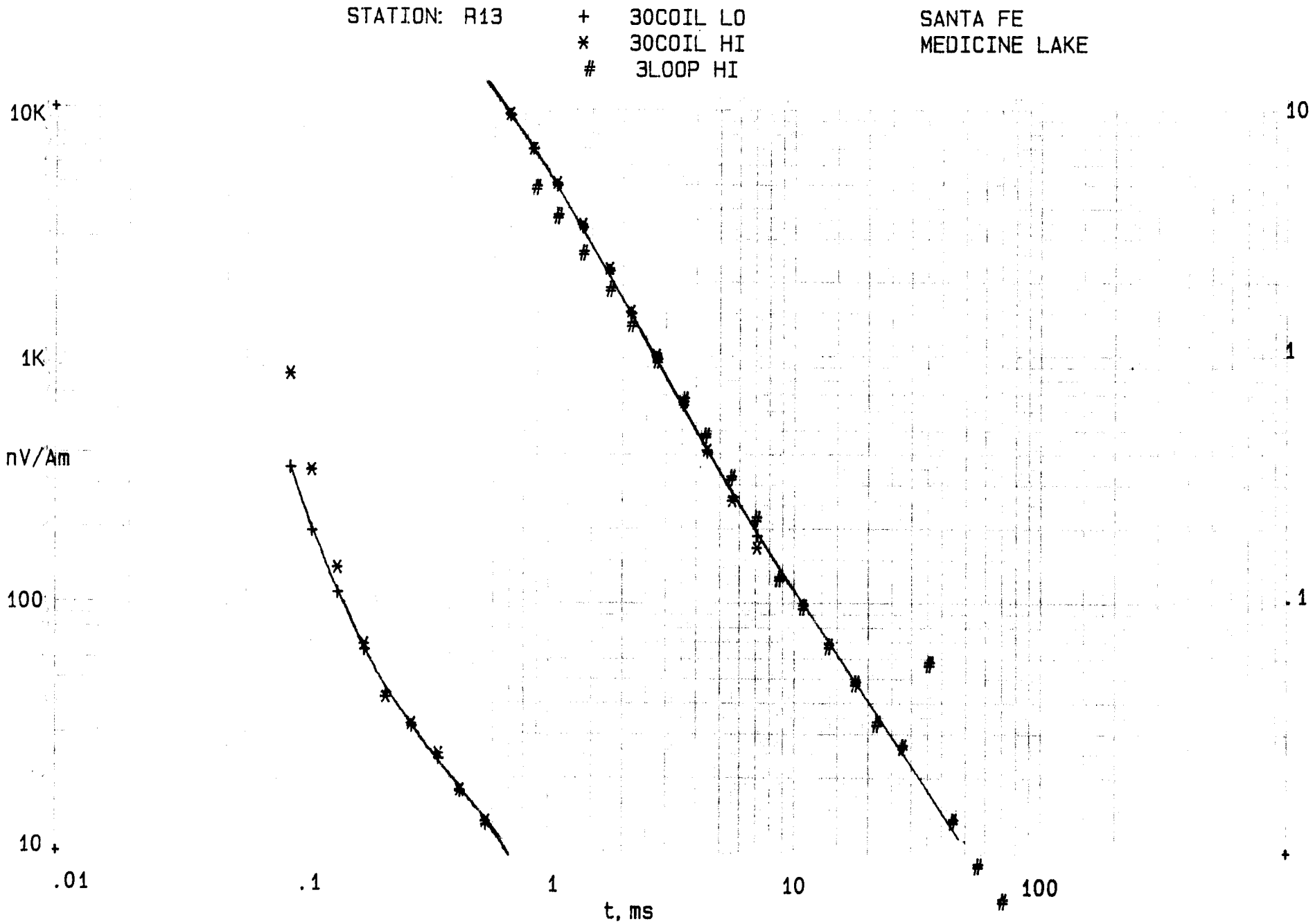
ELE OMAGNETIC SURVEYS INC.

MEDICINE LAKE R13

I	TIME (sec)	VOLTAGE (nV/Am^2)	CALC.VOLT	RESIDUAL	%RES.ERR
	.8900E-04	.3550E+03	.3667E+03	-.1167E+02	-.3182E+01
	.1100E-03	.2070E+03	.2022E+03	.4784E+01	.2366E+01
3	.1400E-03	.1130E+03	.1099E+03	.3107E+01	.2828E+01
4	.1770E-03	.6670E+02	.6627E+02	.4319E+00	.6518E+00
5	.2200E-03	.4620E+02	.4514E+02	.1063E+01	.2354E+01
6	.2800E-03	.3299E+02	.3244E+02	.5534E+00	.1706E+01
7	.3550E-03	.2300E+02	.2319E+02	-.1928E+00	-.8315E+00
8	.4430E-03	.1820E+02	.1733E+02	.8717E+00	.5031E+01
9	.5540E-03	.1380E+02	.1299E+02	.8062E+00	.6204E+01
0	.7130E-03	.9850E+01	.8969E+01	.8815E+00	.9829E+01
	.8810E-03	.6980E+01	.6564E+01	.4160E+00	.6338E+01
2	.1090E-02	.4970E+01	.4669E+01	.3011E+00	.6448E+01
3	.1410E-02	.3320E+01	.3033E+01	.2869E+00	.9458E+01
14	.1790E-02	.2120E+01	.2016E+01	.1036E+00	.5139E+01
15	.2220E-02	.1500E+01	.1390E+01	.1104E+00	.7946E+01
6	.2850E-02	.9890E+00	.9142E+00	.7478E-01	.8179E+01
17	.3600E-02	.6210E+00	.6313E+00	-.1033E-01	-.1637E+01
18	.4490E-02	.4160E+00	.4476E+00	-.3156E-01	-.7052E+01
9	.5700E-02	.2780E+00	.3104E+00	-.3241E-01	-.1044E+02
0	.7190E-02	.1940E+00	.2188E+00	-.2481E-01	-.1134E+02
	.8800E-02	.1410E+00	.1604E+00	-.1943E-01	-.1211E+02
	.1110E-01	.1010E+00	.1119E+00	-.1091E-01	-.9752E+01
3	.1400E-01	.7100E-01	.7814E-01	-.7140E-02	-.9137E+01
24	.1800E-01	.4900E-01	.5293E-01	-.3926E-02	-.7419E+01
25	.2200E-01	.3600E-01	.3831E-01	-.2309E-02	-.6027E+01
6	.2800E-01	.2500E-01	.2550E-01	-.4974E-03	-.1951E+01
27	.3600E-01	.1700E-01	.1628E-01	.7154E-03	.4393E+01
28	.4500E-01	.1300E-01	.1087E-01	.2128E-02	.1957E+02

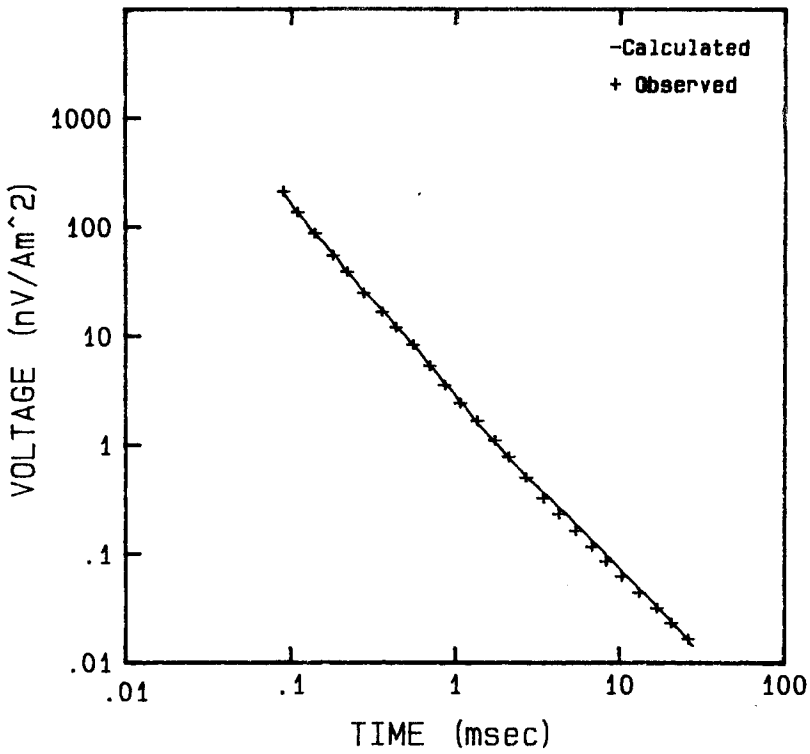
RMSERR= 7.64

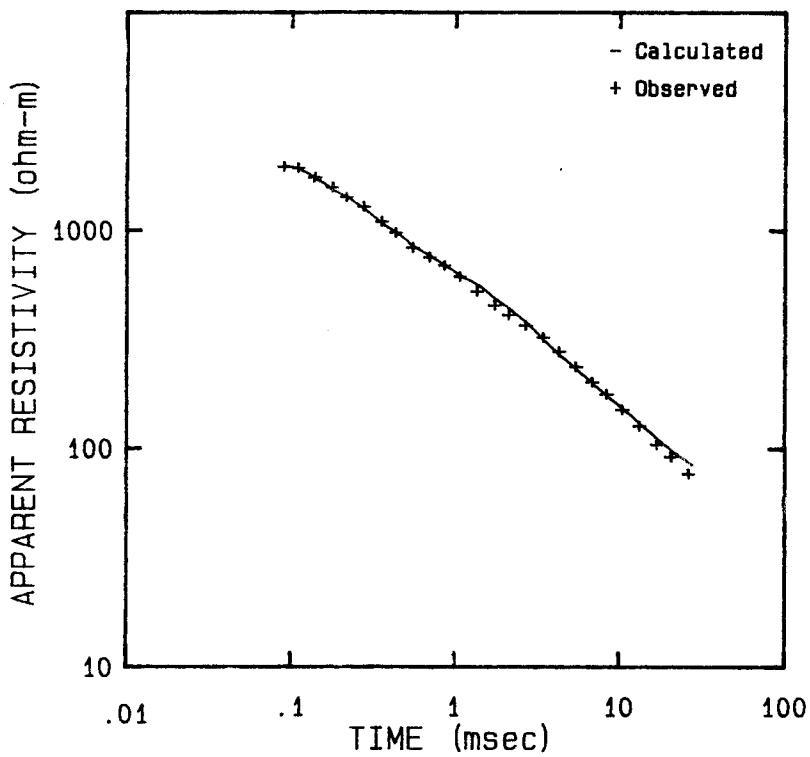
RAMETER	NAME	FINAL SOLUTION	RESISTIVITY	LAYER DEPTH
1	SIGMA(1) =	.13620E-02	.73420E+03	
2	SIGMA(2) =	.49352E-03	.20262E+04	
3	SIGMA(3) =	.16767E-01	.59640E+02	
4	SIGMA(4) =	.59517E-01	.16802E+02	
5	THICK(1) =	.84888E+02		.84888E+02
6	THICK(2) =	.29604E+03		.38093E+03
7	THICK(3) =	.32127E+03		.70220E+03
8	SHIFT =	.20700E+03		


STATION: R13
+ 30COIL LO
* 30COIL HI
# 3LOOP HI
SANTA FE
MEDICINE LAKE
10K
1K
100
10
nV/Am
10
1
.1
.01
.1
1
10
100
t, ms

EMSURVEYS TEM INVERSION

MEDICINE LAKE
STATION: R14





MODEL

RESISTIVITY (ohm-m)	THICKNESS (meters)
2343	293
386	194
122	298
29.9	

ELECTROMAGNETIC SURVEYS INC.

MEDICINE LAKE R14

I	TIME (sec)	VOLTAGE (nV/Am^2)	CALC.VOLT	RESIDUAL	%RES.ERR
1	.8900E-04	.2120E+03	.2054E+03	.6551E+01	.3189E+01
2	.1100E-03	.1360E+03	.1365E+03	-.4561E+00	-.3343E+00
3	.1400E-03	.8690E+02	.8626E+02	.6376E+00	.7391E+00
4	.1770E-03	.5430E+02	.5640E+02	-.2102E+01	-.3726E+01
5	.2200E-03	.3850E+02	.3795E+02	.5539E+00	.1460E+01
6	.2800E-03	.2450E+02	.2526E+02	-.7590E+00	-.3005E+01
7	.3550E-03	.1650E+02	.1709E+02	-.5908E+00	-.3457E+01
8	.4430E-03	.1190E+02	.1186E+02	.3837E-01	.3234E+00
9	.5540E-03	.8240E+01	.8106E+01	.1337E+00	.1649E+01
10	.7130E-03	.5310E+01	.5204E+01	.1055E+00	.2028E+01
1	.8810E-03	.3530E+01	.3558E+01	-.2792E-01	-.7846E+00
2	.1090E-02	.2420E+01	.2407E+01	.1288E-01	.5352E+00
3	.1410E-02	.1670E+01	.1515E+01	.1550E+00	.1023E+02
14	.1790E-02	.1110E+01	.1014E+01	.9553E-01	.9417E+01
5	.2220E-02	.7790E+00	.7208E+00	.5816E-01	.8068E+01
6	.2850E-02	.5020E+00	.4912E+00	.1084E-01	.2206E+01
17	.3600E-02	.3250E+00	.3486E+00	-.2364E-01	-.6782E+01
18	.4490E-02	.2330E+00	.2521E+00	-.1906E-01	-.7560E+01
9	.5700E-02	.1640E+00	.1762E+00	-.1218E-01	-.6915E+01
0	.7190E-02	.1170E+00	.1239E+00	-.6887E-02	-.5559E+01
1	.8800E-02	.8600E-01	.9116E-01	-.5163E-02	-.5663E+01
2	.1110E-01	.6300E-01	.6373E-01	-.7282E-03	-.1143E+01
3	.1400E-01	.4400E-01	.4463E-01	-.6256E-03	-.1402E+01
24	.1800E-01	.3200E-01	.3027E-01	.1730E-02	.5714E+01
5	.2200E-01	.2300E-01	.2192E-01	.1085E-02	.4949E+01
6	.2800E-01	.1700E-01	.1438E-01	.2619E-02	.1821E+02

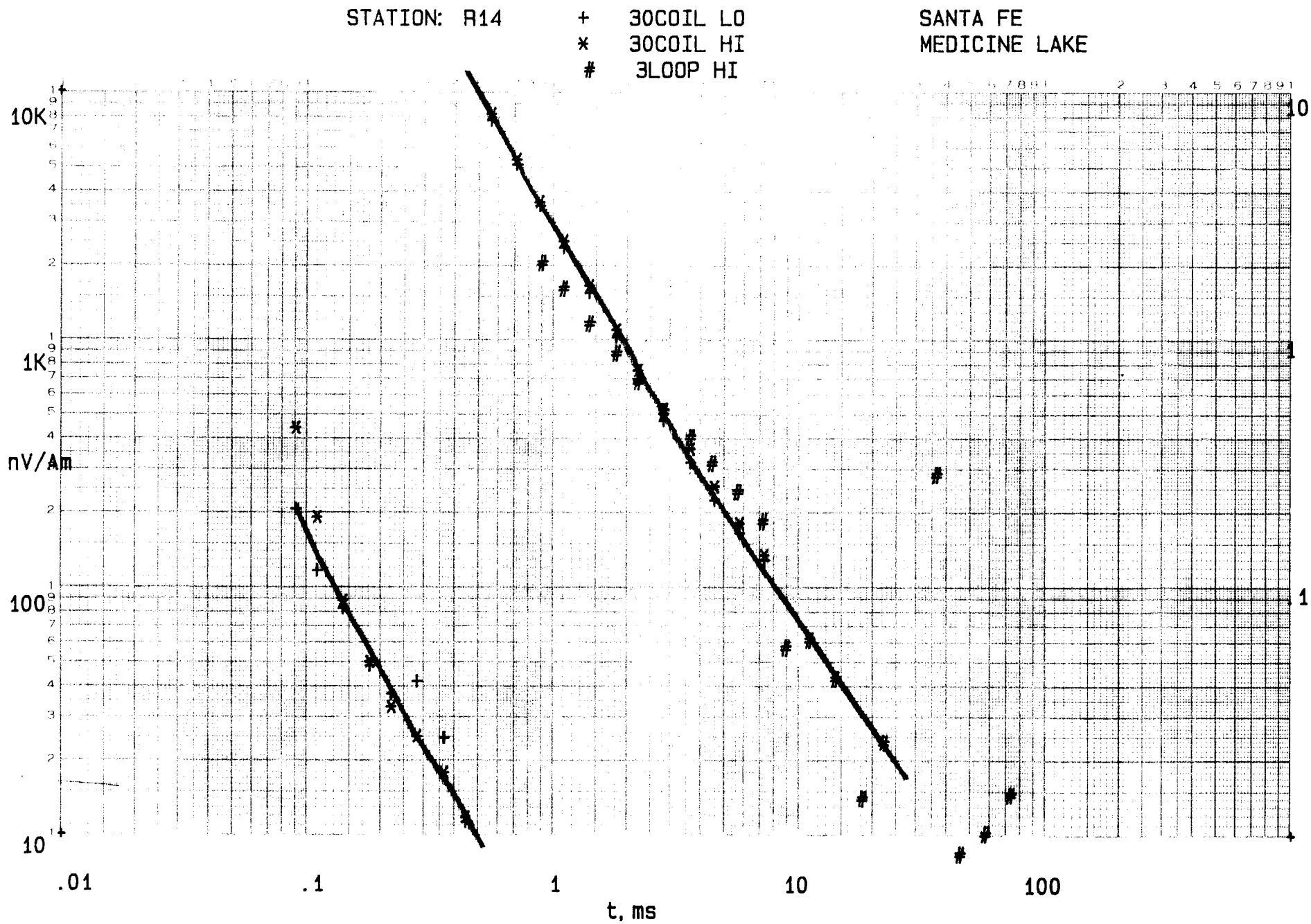
* RMSERR= 5.96

RELATION MATRIX

.1000E+01						
.3392E+00	.1000E+01					
-.4580E+00	-.6001E+00	.1000E+01				
-.6002E+00	-.1070E+00	-.6956E-01	.1000E+01			
.3267E+00	.5107E+00	-.4023E+00	-.1522E+00	.1000E+01		
-.1120E+00	-.6318E+00	.4369E+00	-.3643E+00	-.6204E+00	.1000E+01	
-.2044E+00	.1901E+00	.8069E-01	.1242E+00	.2911E+00	-.4192E+00	.1000E

**PARM_SOL.	STD_ERROR	REL_ERROR	% ERROR **
.4268E-03	.1661E-04	.3891E-01	.3891E+01
.2592E-02	.5593E-03	.2158E+00	.2158E+02
.8211E-02	.9809E-03	.1195E+00	.1195E+02
.3340E-01	.1931E-02	.5781E-01	.5781E+01
.2932E+03	.1896E-02	.6469E-05	.6469E-03
.1937E+03	.3013E-02	.1555E-04	.1555E-02
.2977E+03	.2190E-03	.7358E-06	.7358E-04

RAMETER	NAME	FINAL SOLUTION	RESISTIVITY	LAYER DEPTH
1	SIGMA(1) =	.42675E-03	.23433E+04	
2	SIGMA(2) =	.25916E-02	.38586E+03	
3	SIGMA(3) =	.82114E-02	.12178E+03	
4	SIGMA(4) =	.33396E-01	.29944E+02	
5	THICK(1) =	.29316E+03		.29316E+03
6	THICK(2) =	.19374E+03		.48690E+03
7	THICK(3) =	.29766E+03		.78456E+03


STATION: R14
+ 30COIL LO
* 30COIL HI
# 3LOOP HI
SANTA FE
MEDICINE LAKE
10K
1K
100
10
nV/Am
10
1
1
.01
.1
1
10
100
t, ms

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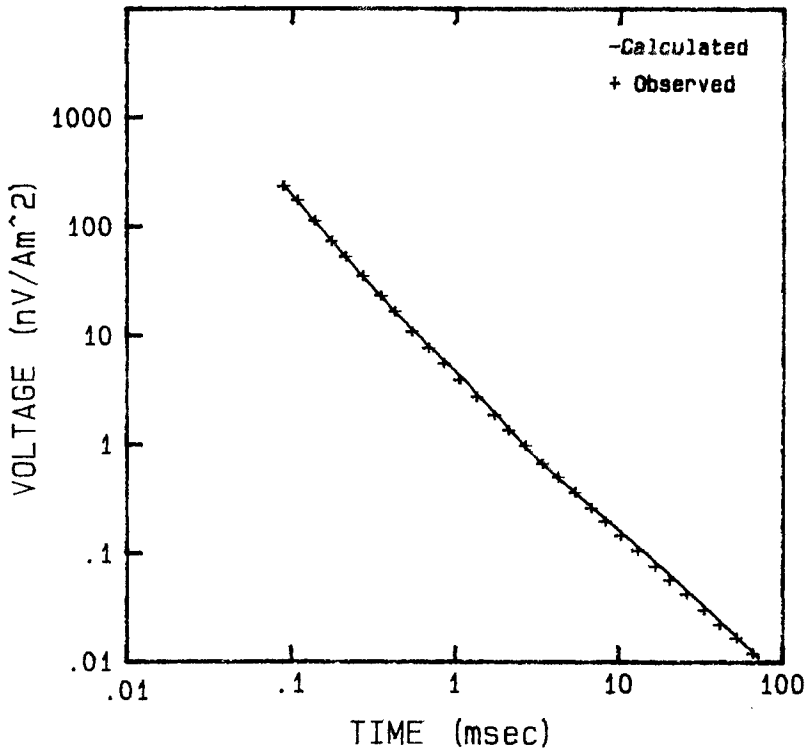
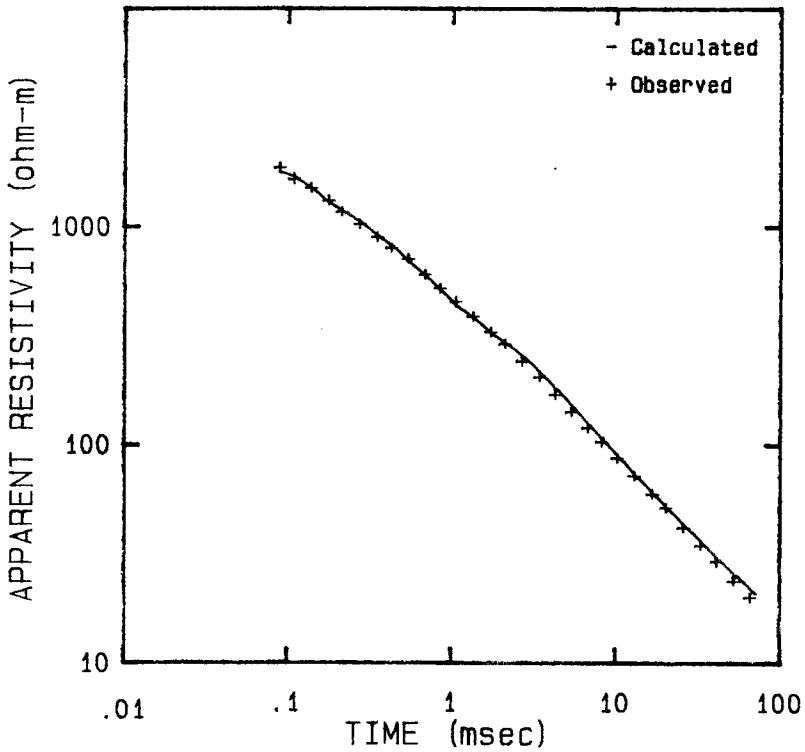
MEDICINE LAKE
STATION: R15





MODEL

RESISTIVITY (ohm-m)	THICKNESS (meters)
1678	317
134	165
29.5	200
6.5	

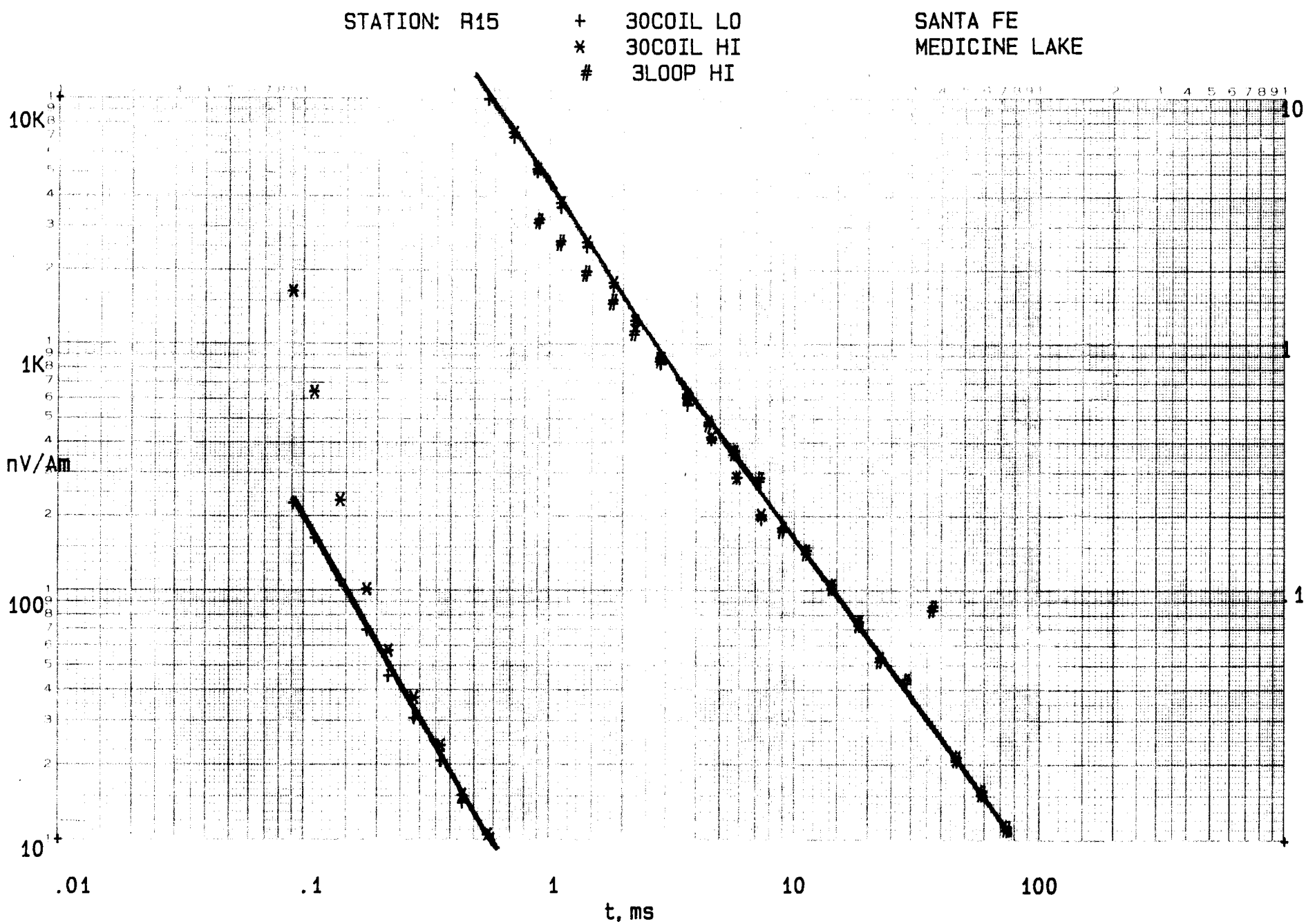
ELECTROMAGNETIC SURVEYS INC.

MEDICINE LAKE R15

I	TIME (sec)	VOLTAGE (nV/Am^2)	CALC.VOLT	RESIDUAL	%RES.ERR
1	.8900E-04	.2310E+03	.2410E+03	-.1004E+02	-.4167E+01
2	.1100E-03	.1710E+03	.1667E+03	.4262E+01	.2556E+01
7	.1400E-03	.1098E+03	.1092E+03	.6174E+00	.5655E+00
	.1770E-03	.7147E+02	.7308E+02	-.1613E+01	-.2207E+01
	.2200E-03	.5168E+02	.5078E+02	.9022E+00	.1777E+01
6	.2800E-03	.3428E+02	.3297E+02	.1310E+01	.3973E+01
7	.3550E-03	.2249E+02	.2208E+02	.4095E+00	.1855E+01
8	.4430E-03	.1616E+02	.1564E+02	.5192E+00	.3320E+01
9	.5540E-03	.1051E+02	.1111E+02	-.6013E+00	-.5411E+01
10	.7130E-03	.7460E+01	.7686E+01	-.2262E+00	-.2942E+01
11	.8810E-03	.5420E+01	.5661E+01	-.2414E+00	-.4264E+01
2	.1090E-02	.3820E+01	.4125E+01	-.3047E+00	-.7387E+01
.3	.1410E-02	.2650E+01	.2748E+01	-.9789E-01	-.3562E+01
14	.1790E-02	.1810E+01	.1865E+01	-.5530E-01	-.2965E+01
5	.2220E-02	.1320E+01	.1318E+01	.2364E-02	.1794E+00
6	.2850E-02	.9510E+00	.8859E+00	.6510E-01	.7348E+01
17	.3600E-02	.6540E+00	.6231E+00	.3086E-01	.4952E+01
18	.4490E-02	.4930E+00	.4587E+00	.3428E-01	.7472E+01
9	.5700E-02	.3580E+00	.3363E+00	.2165E-01	.6438E+01
	.7190E-02	.2570E+00	.2508E+00	.6222E-02	.2481E+01
	.8800E-02	.1940E+00	.1951E+00	-.1130E-02	-.5789E+00
2	.1110E-01	.1440E+00	.1455E+00	-.1483E-02	-.1020E+01
3	.1400E-01	.1040E+00	.1071E+00	-.3144E-02	-.2935E+01
24	.1800E-01	.7400E-01	.7650E-01	-.2504E-02	-.3272E+01
5	.2200E-01	.5600E-01	.5850E-01	-.2495E-02	-.4266E+01
6	.2800E-01	.4200E-01	.4207E-01	-.6853E-04	-.1629E+00
27	.3600E-01	.3000E-01	.2967E-01	.3308E-03	.1115E+01
28	.4500E-01	.2200E-01	.2163E-01	.3705E-03	.1713E+01
9	.5700E-01	.1600E-01	.1544E-01	.5620E-03	.3640E+01
	.7200E-01	.1200E-01	.1108E-01	.9209E-03	.8312E+01

RMSERR= 4.09

RAMETER	NAME	FINAL SOLUTION	RESISTIVITY	LAYER DEPTH
1	SIGMA(1) =	.59592E-03	.16781E+04	
2	SIGMA(2) =	.74713E-02	.13385E+03	
	SIGMA(3) =	.33949E-01	.29456E+02	
	SIGMA(4) =	.15476E+00	.64618E+01	
	THICK(1) =	.31656E+03		.31656E+03
6	THICK(2) =	.16516E+03		.48173E+03
7	THICK(3) =	.20059E+03		.68232E+03
8	SHIFT =	.20700E+03		


STATION: R15
+ 30COIL LO
* 30COIL HI
# 3LOOP HI
SANTA FE
MEDICINE LAKE
10K
1K
100
10
nV/Am
10
1
1
.01
.1
1
10
100
t, ms

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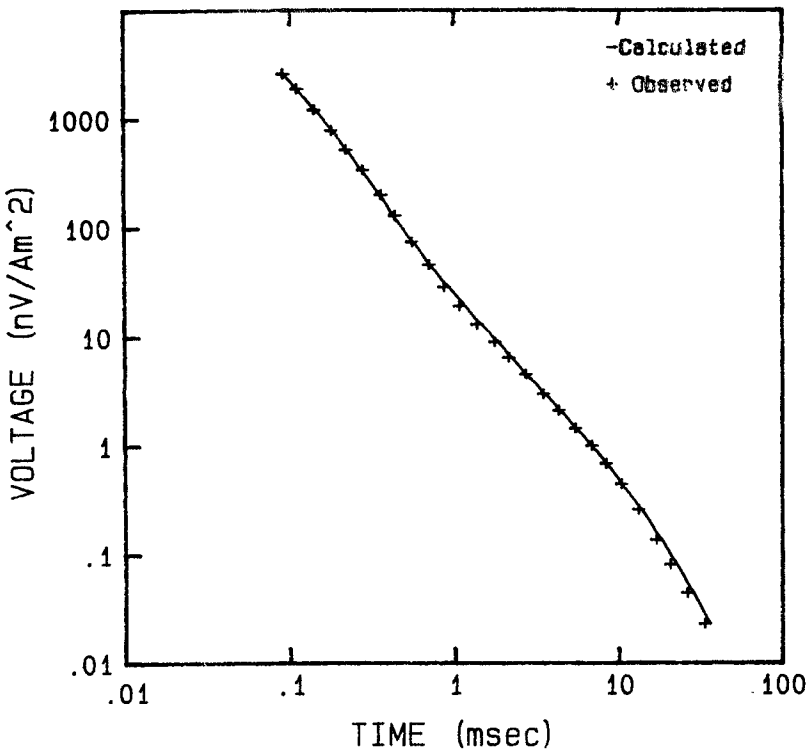
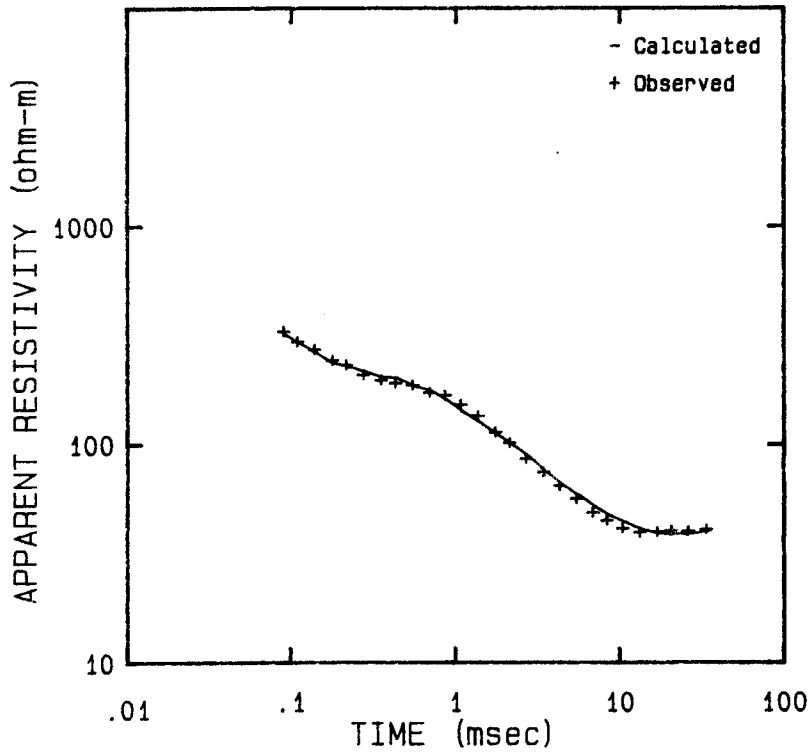
MEDICINE LAKE
STATION: R16





MODEL

RESISTIVITY (ohm-m)	THICKNESS (meters)
971	77
103	224
19.9	458
1765	

ELECTROMAGNETIC SURVEYS INC.

MEDICINE LAKE R16

I	TIME (sec)	VOLTAGE (nV/Am^2)	CALC.VOLT	RESIDUAL	%RES.ERR
1	.8900E-04	.2582E+04	.2641E+04	-.5940E+02	-.2249E+01
2	.1100E-03	.1879E+04	.1875E+04	.3615E+01	.1927E+00
3	.1400E-03	.1202E+04	.1238E+04	-.3562E+02	-.2878E+01
4	.1770E-03	.7780E+03	.8028E+03	-.2484E+02	-.3095E+01
5	.2200E-03	.5190E+03	.5237E+03	-.4750E+01	-.9068E+00
6	.2800E-03	.3370E+03	.3174E+03	.1958E+02	.6170E+01
	.3550E-03	.1990E+03	.1904E+03	.8597E+01	.4515E+01
	.4430E-03	.1280E+03	.1184E+03	.9631E+01	.8136E+01
9	.5540E-03	.7370E+02	.7397E+02	-.2707E+00	-.3659E+00
10	.7130E-03	.4530E+02	.4452E+02	.7840E+00	.1761E+01
11	.8810E-03	.2840E+02	.3031E+02	-.1914E+01	-.6313E+01
2	.1090E-02	.1890E+02	.2089E+02	-.1992E+01	-.9536E+01
3	.1410E-02	.1280E+02	.1352E+02	-.7154E+00	-.5293E+01
14	.1790E-02	.8880E+01	.9184E+01	-.3036E+00	-.3306E+01
5	.2220E-02	.6380E+01	.6458E+01	-.7794E-01	-.1207E+01
6	.2850E-02	.4470E+01	.4267E+01	.2033E+00	.4765E+01
17	.3600E-02	.2950E+01	.2913E+01	.3724E-01	.1279E+01
18	.4490E-02	.2090E+01	.2025E+01	.6529E-01	.3225E+01
9	.5700E-02	.1430E+01	.1353E+01	.7654E-01	.5655E+01
	.7190E-02	.9890E+00	.9049E+00	.8407E-01	.9290E+01
	.8800E-02	.6780E+00	.6264E+00	.5159E-01	.8235E+01
2	.1110E-01	.4410E+00	.3999E+00	.4112E-01	.1028E+02
3	.1400E-01	.2570E+00	.2460E+00	.1097E-01	.4460E+01
24	.1800E-01	.1360E+00	.1391E+00	-.3143E-02	-.2259E+01
5	.2200E-01	.8100E-01	.8569E-01	-.4689E-02	-.5472E+01
6	.2800E-01	.4400E-01	.4615E-01	-.2152E-02	-.4662E+01
27	.3600E-01	.2300E-01	.2325E-01	-.2520E-03	-.1084E+01

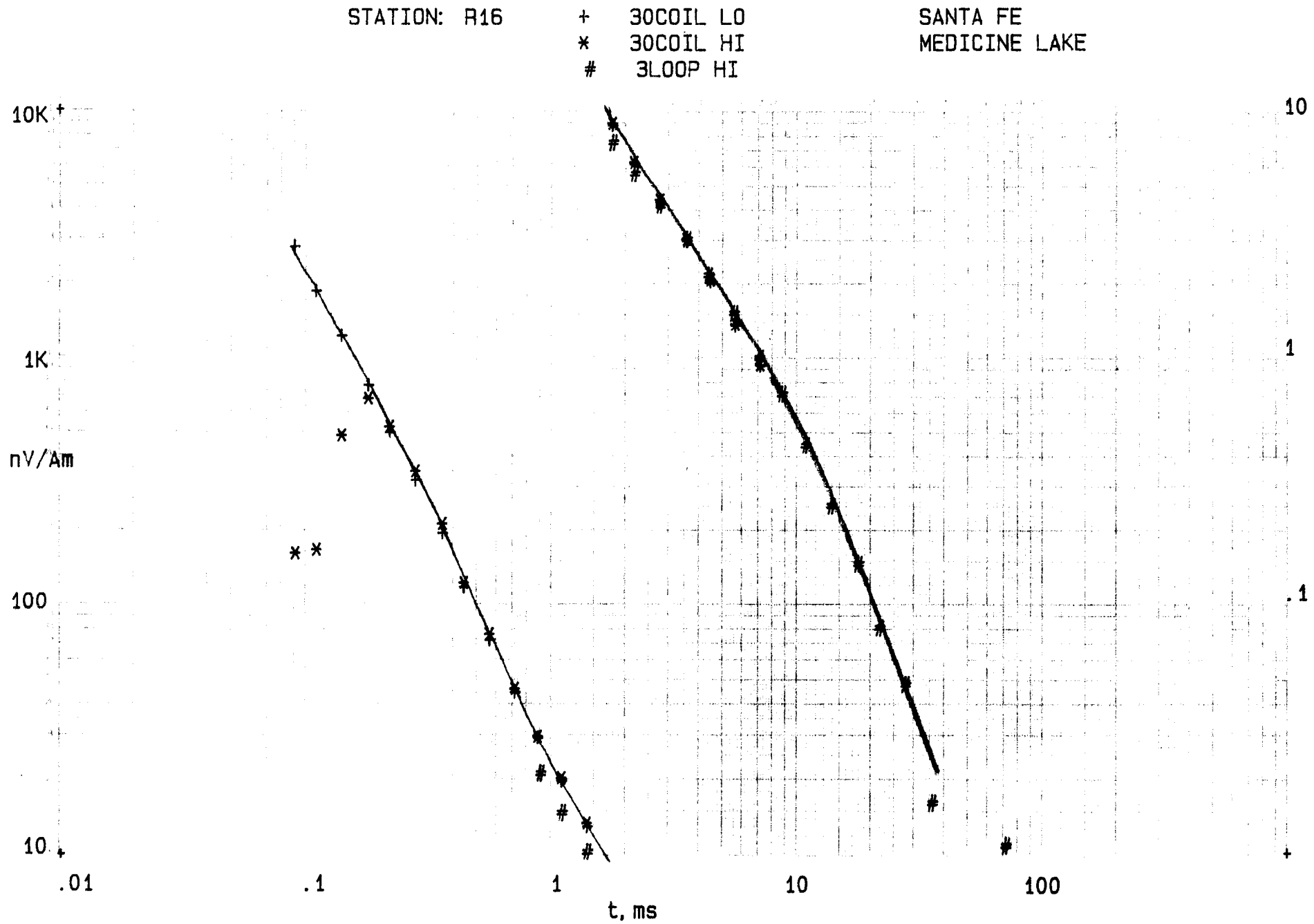
RMSERR= 5.19

ELATION MATRIX

	.1000E+01						
	-.1176E+00	.1000E+01					
3	-.8453E+00	-.1889E+00	.1000E+01				
4	-.7411E+00	-.1806E+00	.6765E+00	.1000E+01			
	-.1235E-01	.8677E+00	-.2380E+00	-.2513E+00	.1000E+01		
6	-.3904E+00	-.1779E+00	.4217E+00	.3088E+00	-.3446E+00	.1000E+01	
7	-.7652E+00	.2560E+00	.6867E+00	.2813E+00	.1770E+00	.2272E+00	.1000E

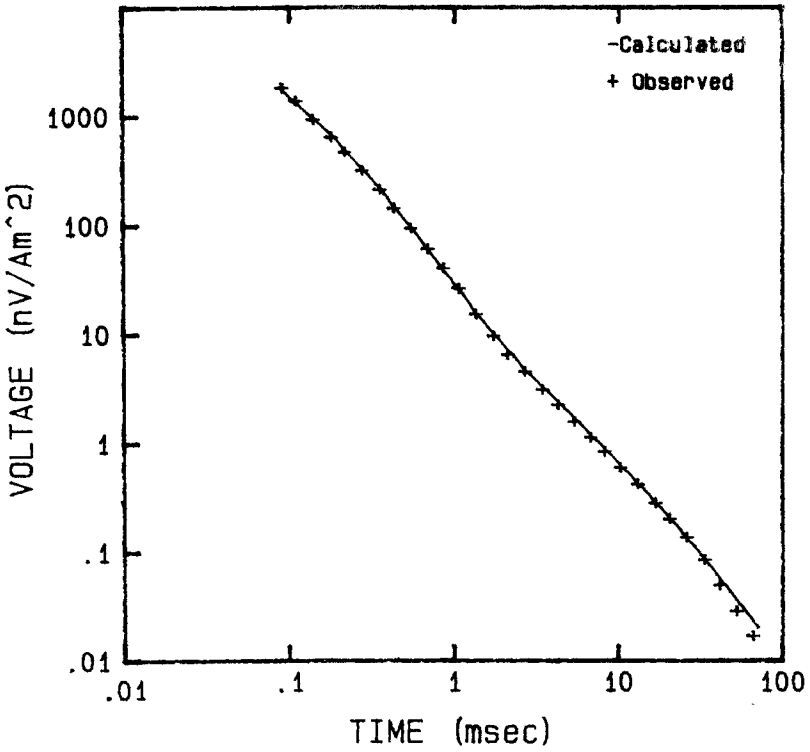
**PARM_SOL.	STD_ERROR	REL_ERROR	% ERROR **
.1030E-02	.1506E-03	.1463E+00	.1463E+02
.9745E-02	.1826E-02	.1873E+00	.1873E+02
.5023E-01	.3809E-02	.7582E-01	.7582E+01
4 .5667E-03	.6712E-03	.1184E+01	.1184E+03
5 .7740E+02	.3427E-02	.4427E-04	.4427E-02
.2236E+03	.2982E-02	.1334E-04	.1334E-02
.4578E+03	.8601E-03	.1879E-05	.1879E-03

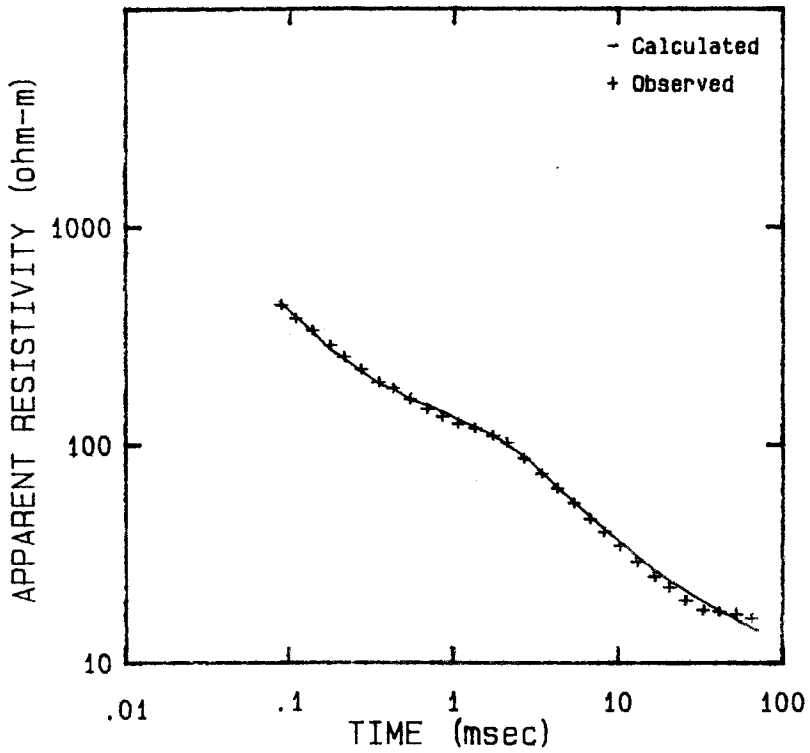
RAMETER NAME	FINAL SOLUTION	RESISTIVITY	LAYER DEPTH
1 SIGMA(1) =	.10297E-02	.97115E+03	
2 SIGMA(2) =	.97454E-02	.10261E+03	
3 SIGMA(3) =	.50233E-01	.19907E+02	
4 SIGMA(4) =	.56666E-03	.17647E+04	
5 THICK(1) =	.77404E+02		.77404E+02
6 THICK(2) =	.22358E+03		.30098E+03
7 THICK(3) =	.5783E+03		[illegible]


STATION: R16
+ 30COIL LO
* 30COIL HI
# 3LOOP HI
SANTA FE
MEDICINE LAKE
10K
1K
100
10
nV/Am
10
1
.1
.01
.1
1
10
100
t, ms

EMSURVEYS TEM INVERSION

MEDICINE LAKE
STATION: R17





MODEL

RESISTIVITY (ohm-m)	THICKNESS (meters)
676	123
55	180
20.3	80
6.8	

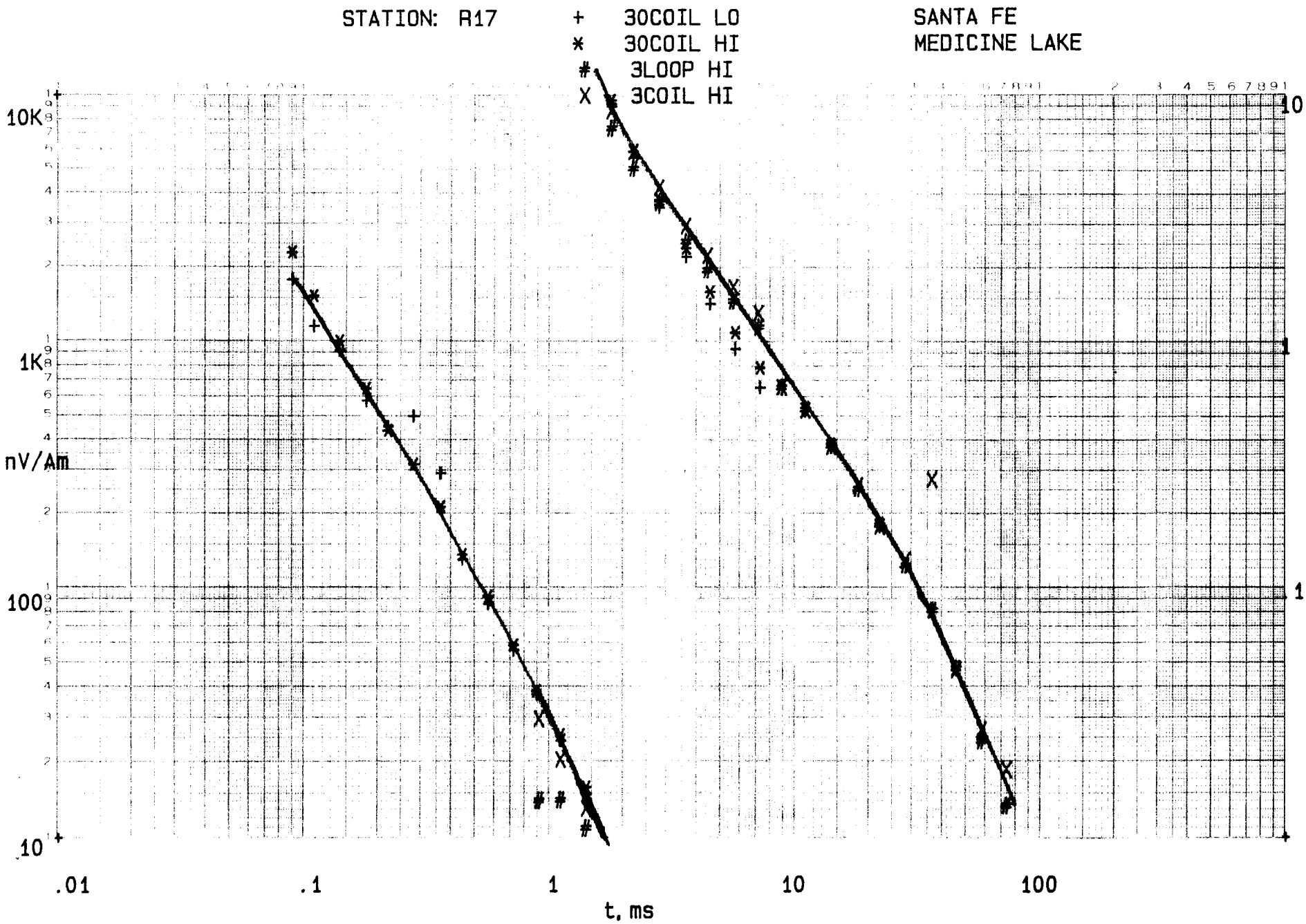
ELECTROMA ETIC SURVEYS INC.

MEDICINE LAKE R17

I	TIME (sec)	VOLTAGE (nV/Am^2)	CALC.VOLT	RESIDUAL	%RES.ERR
1	.8900E-04	.1785E+04	.1742E+04	.4280E+02	.2457E+01
2	.1100E-03	.1357E+04	.1310E+04	.4719E+02	.3603E+01
3	.1400E-03	.9105E+03	.9328E+03	-.2231E+02	-.2392E+01
4	.1770E-03	.6253E+03	.6656E+03	-.4025E+02	-.6048E+01
5	.2200E-03	.4580E+03	.4747E+03	-.1667E+02	-.3512E+01
6	.2800E-03	.3090E+03	.3201E+03	-.1107E+02	-.3460E+01
7	.3550E-03	.2060E+03	.2118E+03	-.5795E+01	-.2736E+01
8	.4430E-03	.1390E+03	.1408E+03	-.1782E+01	-.1266E+01
9	.5540E-03	.9114E+02	.9202E+02	-.8835E+00	-.9601E+00
[illegible]	.7130E-03	.5904E+02	.5611E+02	.2927E+01	.5216E+01
[illegible]	.8810E-03	.3915E+02	.3673E+02	.2425E+01	.6603E+01
12	.1090E-02	.2536E+02	.2407E+02	.1292E+01	.5366E+01
13	.1410E-02	.1487E+02	.1468E+02	.1944E+00	.1325E+01
14	.1790E-02	.9360E+01	.9450E+01	-.9022E-01	-.9547E+00
15	.2190E-02	.6330E+01	.6713E+01	-.3826E+00	-.5699E+01
16	.2850E-02	.4440E+01	.4402E+01	.3832E-01	.8706E+00
17	.3600E-02	.3004E+01	.3084E+01	-.8045E-01	-.2608E+01
18	.4490E-02	.2190E+01	.2231E+01	-.4057E-01	-.1819E+01
19	.5700E-02	.1530E+01	.1570E+01	-.3975E-01	-.2532E+01
20	.7190E-02	.1090E+01	.1107E+01	-.1722E-01	-.1555E+01
[illegible]	.8800E-02	.8170E+00	.8147E+00	.2326E-02	.2855E+00
[illegible]	.1110E-01	.5840E+00	.5670E+00	.1696E-01	.2991E+01
23	.1400E-01	.4100E+00	.3898E+00	.2025E-01	.5195E+01
24	.1800E-01	.2750E+00	.2577E+00	.1727E-01	.6700E+01
25	.2200E-01	.1970E+00	.1830E+00	.1402E-01	.7662E+01
26	.2800E-01	.1330E+00	.1195E+00	.1349E-01	.1129E+02
27	.3600E-01	.8300E-01	.7538E-01	.7618E-02	.1011E+02
28	.4500E-01	.4900E-01	.4952E-01	-.5159E-03	-.1042E+01
29	.5700E-01	.2800E-01	.3149E-01	-.3486E-02	-.1107E+02
[illegible]	.7200E-01	.1700E-01	.2007E-01	-.3066E-02	-.1528E+02

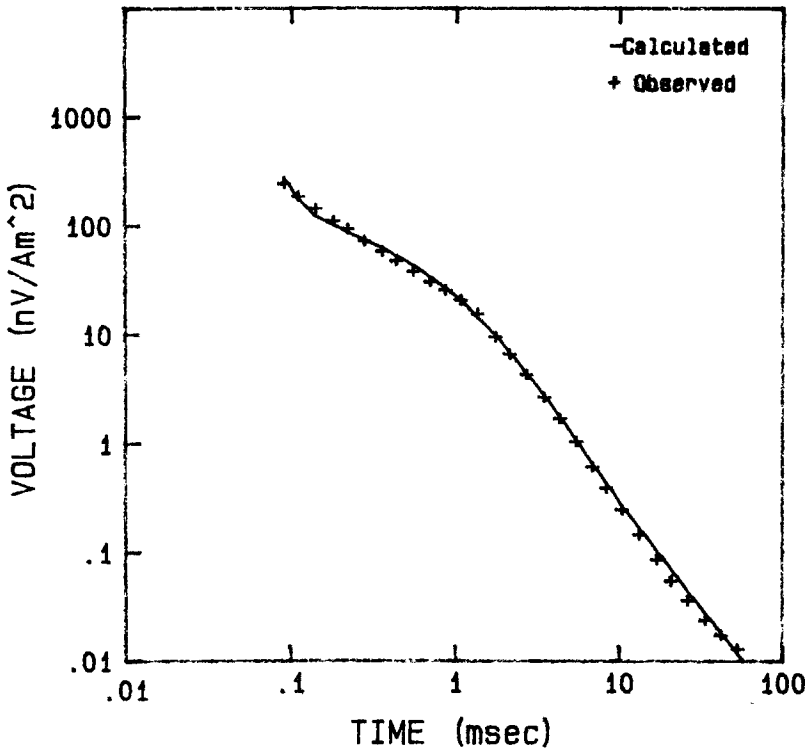
RMSERR= 5.71

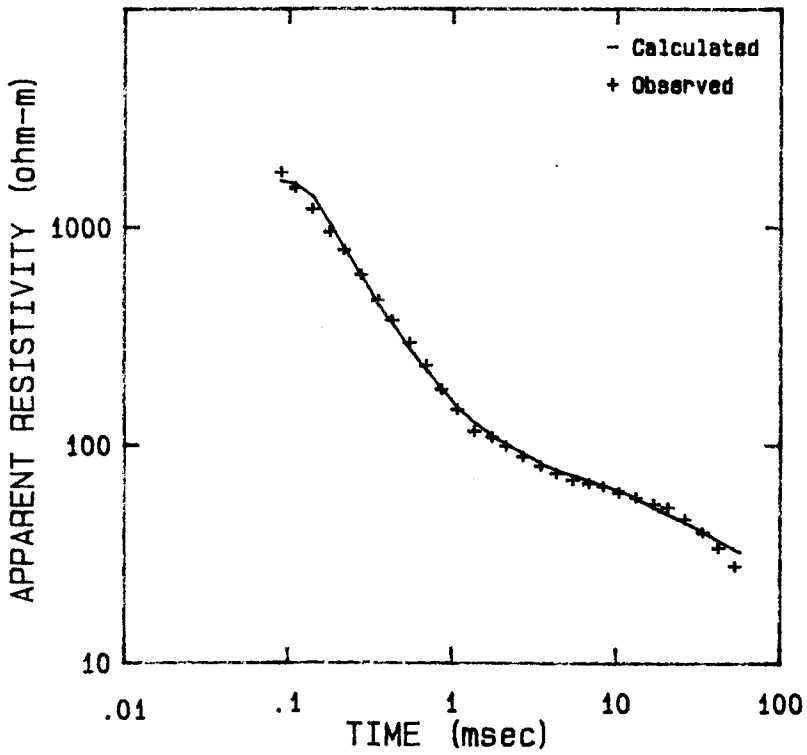
ARAMETER	NAME	FINAL SOLUTION	RESISTIVITY	LAYER DEPTH
1	SIGMA(1) =	.14797E-02	.67580E+03	
2	SIGMA(2) =	.18195E-01	.54959E+02	
3	SIGMA(3) =	.49353E-01	.20262E+02	
4	SIGMA(4) =	.14708E+00	.67990E+01	
5	THICK(1) =	.12292E+03		.12292E+03
6	THICK(2) =	.17958E+03		.30250E+03
7	THICK(3) =	.80840E+02		.38334E+03
8	SHIFT =	.20700E+03		


STATION: R17
+ 30COIL LO
* 30COIL HI
# 3LOOP HI
X 3COIL HI
SANTA FE
MEDICINE LAKE
10K
1K
nV/Am
100
10
.01
.1
1
10
100
t, ms

EMSURVEYS TEM INVERSION

MEDICINE LAKE
STATION: R19





MODEL

RESISTIVITY (ohm-m)	THICKNESS (meters)
997	276
8	33
44	382
15	

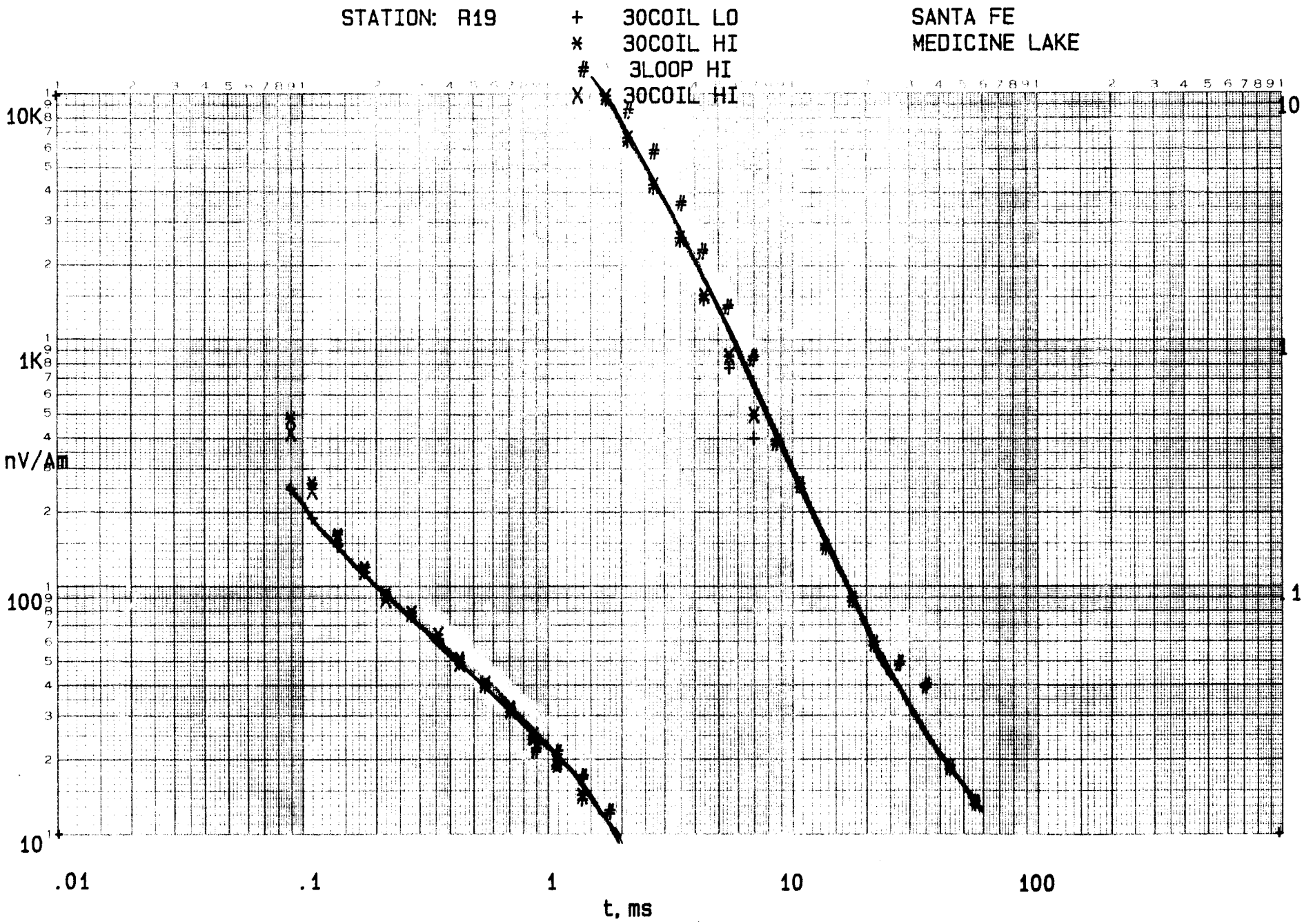
ELECTR GNETIC SURVEYS INC.

MEDICINE LAKE R19

I	TIME (sec)	VOLTAGE (nV/Am^2)	CALC.VOLT	RESIDUAL	%RES.ERR
1	.8900E-04	.2420E+03	.2768E+03	-.3482E+02	-.1258E+02
2	.1100E-03	.1850E+03	.1757E+03	.9335E+01	.5314E+01
3	.1400E-03	.1420E+03	.1225E+03	.1953E+02	.1594E+02
4	.1770E-03	.1090E+03	.1010E+03	.8028E+01	.7951E+01
5	.2200E-03	.9210E+02	.8681E+02	.5295E+01	.6100E+01
6	.2800E-03	.7170E+02	.7323E+02	-.1528E+01	-.2087E+01
7	.3550E-03	.5740E+02	.6230E+02	-.4901E+01	-.7866E+01
8	.4430E-03	.4700E+02	.5215E+02	-.5147E+01	-.9871E+01
9	.5540E-03	.3750E+02	.4250E+02	-.5001E+01	-.1177E+02
10	.7130E-03	.3020E+02	.3302E+02	-.2823E+01	-.8549E+01
11	.8810E-03	.2530E+02	.2589E+02	-.5886E+00	-.2274E+01
12	.1090E-02	.2050E+02	.1980E+02	.7023E+00	.3548E+01
13	.1410E-02	.1540E+02	.1375E+02	.1653E+01	.1202E+02
14	.1790E-02	.9430E+01	.9447E+01	-.1715E-01	-.1815E+00
15	.2220E-02	.6590E+01	.6541E+01	.4878E-01	.7457E+00
16	.2850E-02	.4250E+01	.4106E+01	.1439E+00	.3504E+01
17	.3600E-02	.2630E+01	.2583E+01	.4694E-01	.1817E+01
18	.4490E-02	.1690E+01	.1635E+01	.5546E-01	.3393E+01
19	.5700E-02	.1040E+01	.9796E+00	.6039E-01	.6165E+01
[illegible]	.7190E-02	.6130E+00	.5957E+00	.1728E-01	.2901E+01
[illegible]	.8800E-02	.3890E+00	.3923E+00	-.3339E-02	-.8511E+00
22	.1110E-01	.2470E+00	.2425E+00	.4542E-02	.1873E+01
23	.1400E-01	.1460E+00	.1528E+00	-.6753E-02	-.4421E+01
24	.1800E-01	.8600E-01	.9389E-01	-.7895E-02	-.8408E+01
25	.2200E-01	.5500E-01	.6308E-01	-.8085E-02	-.1282E+02
26	.2800E-01	.3600E-01	.3936E-01	-.3365E-02	-.8547E+01
27	.3600E-01	.2400E-01	.2450E-01	-.5022E-03	-.2050E+01
28	.4500E-01	.1700E-01	.1619E-01	.8090E-03	.4997E+01
29	.5700E-01	.1300E-01	.1031E-01	.2689E-02	.2608E+02

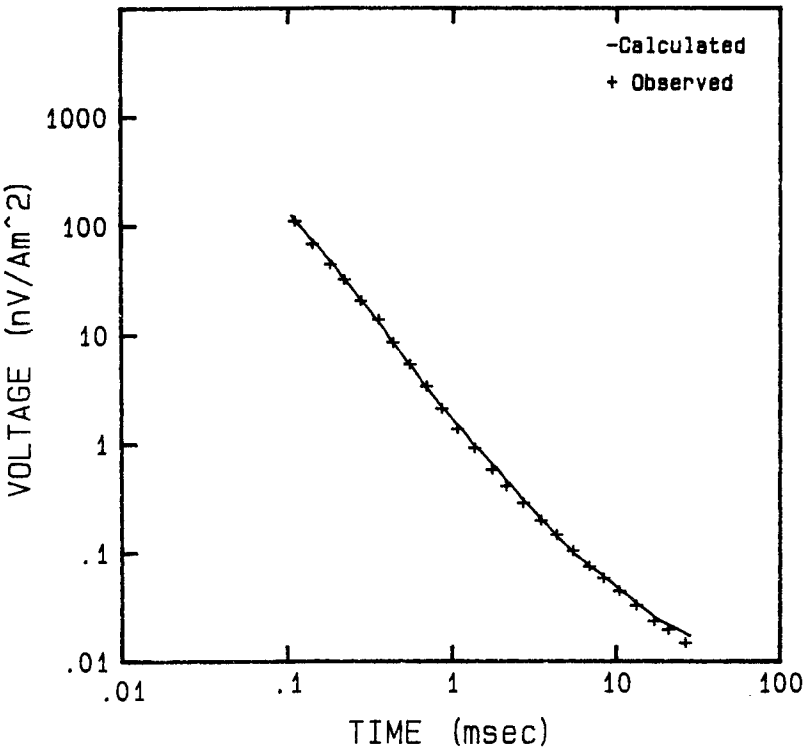
* RMSERR= 8.70

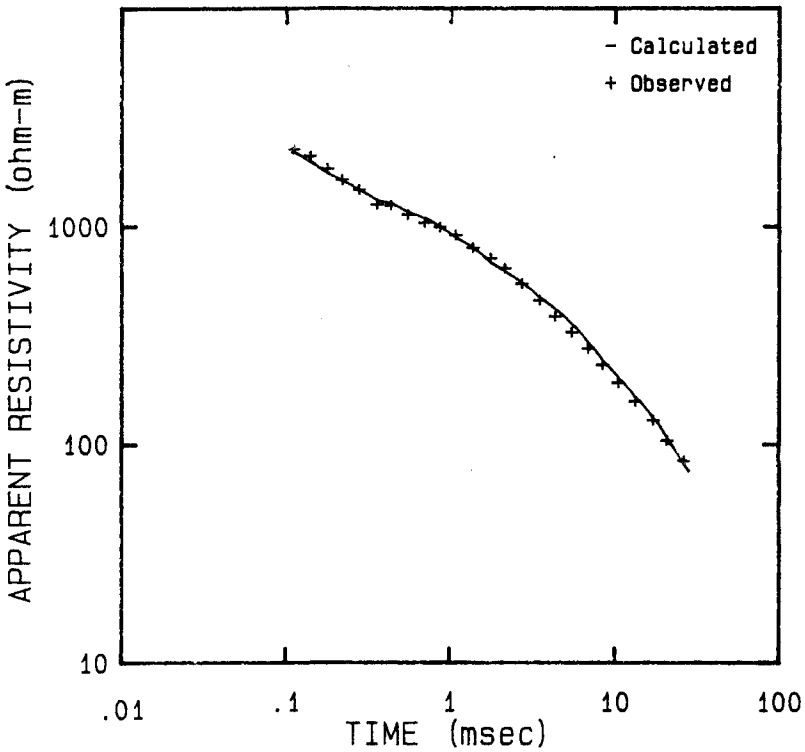
ARAMETER	NAME	FINAL SOLUTION	RESISTIVITY	LAYER DEPTH
1	SIGMA(1) =	.10029E-02	.99714E+03	
2	SIGMA(2) =	.12829E+00	.77946E+01	
3	SIGMA(3) =	.22466E-01	.44512E+02	
4	SIGMA(4) =	.66406E-01	.15059E+02	
	THICK(1) =	.27636E+03		.27636E+03
6	THICK(2) =	.32746E+02		.30911E+03
7	THICK(3) =	.38153E+03		.69063E+03
8	SHIFT =	.20700E+03		


STATION: R19
+ 30COIL LO
* 30COIL HI
# 3LOOP HI
X 30COIL HI
SANTA FE
MEDICINE LAKE
10K
1K
100
10
nV/Am
10
1
1
.01
.1
1
10
100
t, ms

EMSURVEYS TEM INVERSION

MEDICINE LAKE
STATION: R20





MODEL

RESISTIVITY (ohm-m)	THICKNESS (meters)
3043	309
471	240
231	244
37	269
5.5	

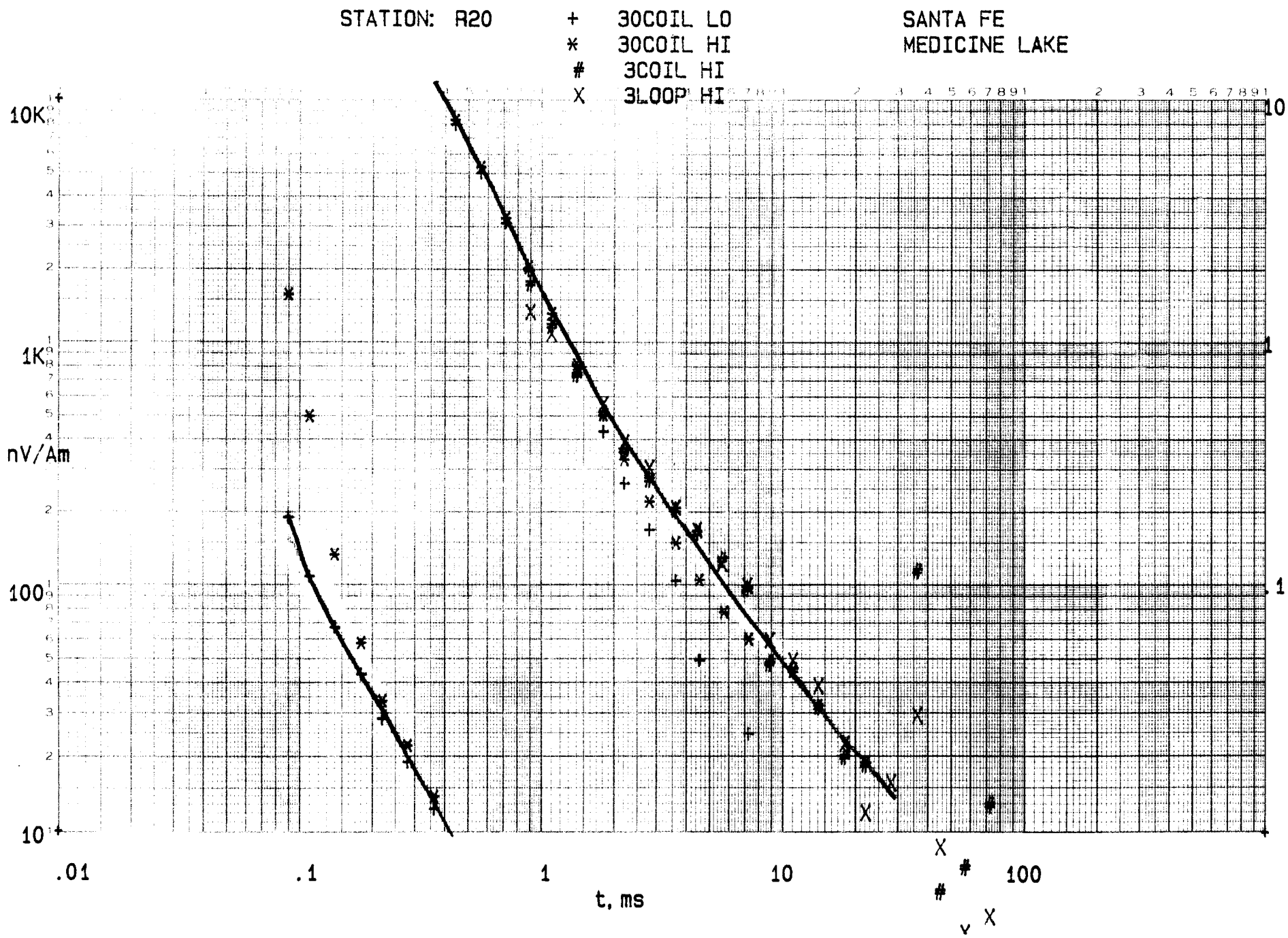
ELECTROMAGNETIC SURVEYS INC.

MEDICINE LAKE R20

I	TIME (sec)	VOLTAGE (nV/Am^2)	CALC.VOLT	RESIDUAL	%RES.ERR
1	.1100E-03	.1080E+03	.1116E+03	-.3583E+01	-.3211E+01
2	.1400E-03	.6650E+02	.7248E+02	-.5983E+01	-.8254E+01
3	.1770E-03	.4330E+02	.4675E+02	-.3454E+01	-.7388E+01
4	.2200E-03	.3140E+02	.3161E+02	-.2057E+00	-.6509E+00
5	.2800E-03	.2010E+02	.2010E+02	.4681E-02	.2329E-01
6	.3550E-03	.1360E+02	.1266E+02	.9416E+00	.7439E+01
7	.4430E-03	.8330E+01	.8060E+01	.2701E+00	.3351E+01
8	.5540E-03	.5270E+01	.5086E+01	.1835E+00	.3608E+01
9	.7130E-03	.3310E+01	.3088E+01	.2222E+00	.7195E+01
[illegible]	.8810E-03	.2070E+01	.2081E+01	-.1147E-01	-.5511E+00
11	.1090E-02	.1340E+01	.1420E+01	-.7961E-01	-.5608E+01
12	.1410E-02	.9000E+00	.9141E+00	-.1409E-01	-.1541E+01
13	.1790E-02	.5680E+00	.6194E+00	-.5143E-01	-.8302E+01
14	.2220E-02	.4020E+00	.4330E+00	-.3096E-01	-.7151E+01
15	.2850E-02	.2810E+00	.2837E+00	-.2697E-02	-.9505E+00
16	.3600E-02	.1940E+00	.1908E+00	.3212E-02	.1683E+01
17	.4490E-02	.1440E+00	.1322E+00	.1180E-01	.8924E+01
18	.5700E-02	.1020E+00	.9318E-01	.8819E-02	.9465E+01
19	.7190E-02	.7400E-01	.7102E-01	.2975E-02	.4189E+01
[illegible]	.8800E-02	.5800E-01	.5719E-01	.8107E-03	.1418E+01
[illegible]	.1110E-01	.4400E-01	.4331E-01	.6919E-03	.1598E+01
22	.1400E-01	.3200E-01	.3210E-01	-.1000E-03	-.3116E+00
23	.1800E-01	.2300E-01	.2447E-01	-.1471E-02	-.6013E+01
24	.2200E-01	.1900E-01	.2068E-01	-.1676E-02	-.8108E+01
25	.2800E-01	.1500E-01	.1709E-01	-.2094E-02	-.1225E+02

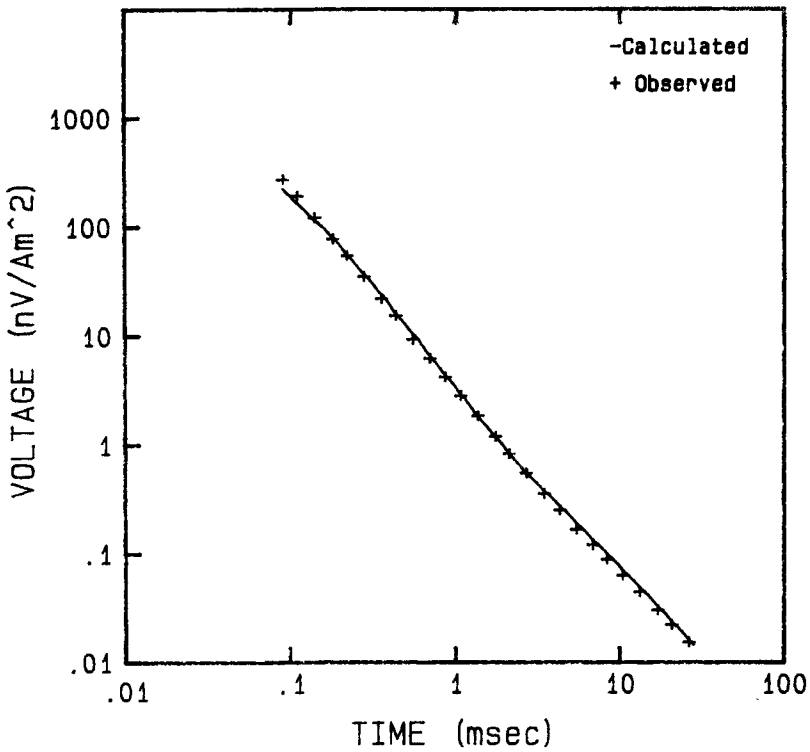
* RMSERR= 5.89

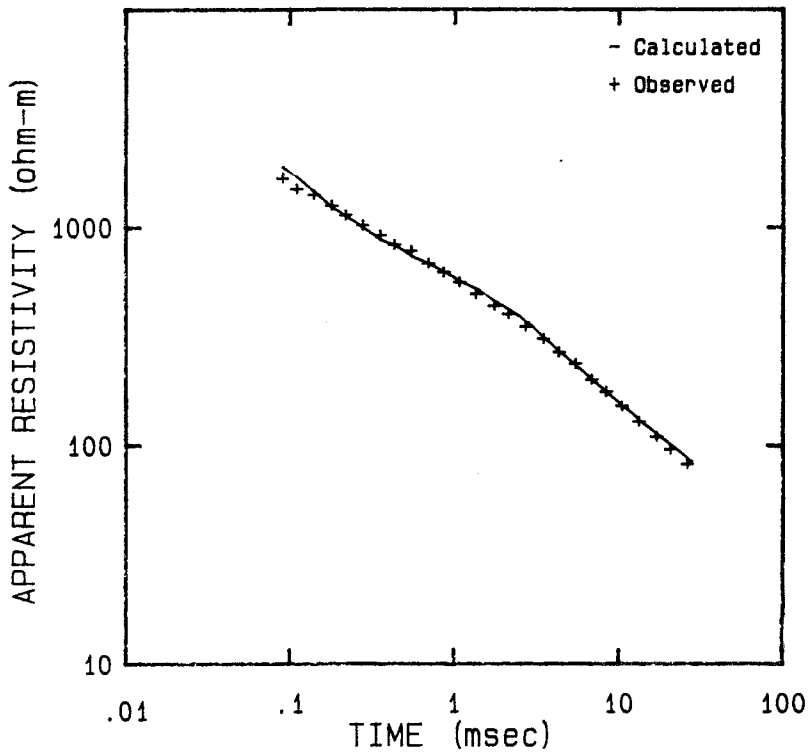
RAMETER	NAME	FINAL SOLUTION	RESISTIVITY	LAYER DEPTH
[illegible]	SIGMA(1) =	.32858E-03	.30434E+04	
2	SIGMA(2) =	.21220E-02	.47124E+03	
3	SIGMA(3) =	.43268E-02	.23112E+03	
4	SIGMA(4) =	.26899E-01	.37176E+02	
5	SIGMA(5) =	.18063E+00	.55362E+01	
6	THICK(1) =	.30934E+03		.30934E+03
7	THICK(2) =	.24004E+03		.54937E+03
8	THICK(3) =	.24381E+03		.79319E+03
9	THICK(4) =	.26910E+03		.10623E+04
10	SHIFT =	.20700E+03		


STATION: R20
+ 30COIL LO
* 30COIL HI
# 3COIL HI
X 3LOOP HI
SANTA FE
MEDICINE LAKE
10K
1K
nV/Am
100
10
.01
.1
1
10
100
t, ms
10
1
1

EMSURVEYS TEM INVERSION

MEDICINE LAKE
STATION: R21





MODEL

RESISTIVITY (ohm-m)	THICKNESS (meters)
3630	267
247	327
92.6	222
30.2	

ELECTROMAGNETIC SURVEYS INC.

MEDICINE LAKE R21

I	TIME (sec)	VOLTAGE (nV/Am^2)	CALC.VOLT	RESIDUAL	%RES.ERR
1	.8900E-04	.2700E+03	.2217E+03	.4833E+02	.2180E+02
2	.1100E-03	.1890E+03	.1645E+03	.2448E+02	.1488E+02
3	.1400E-03	.1200E+03	.1136E+03	.6399E+01	.5633E+01
4	.1770E-03	.7600E+02	.7855E+02	-.2546E+01	-.3241E+01
5	.2200E-03	.5360E+02	.5455E+02	-.9532E+00	-.1747E+01
6	.2800E-03	.3440E+02	.3574E+02	-.1335E+01	-.3736E+01
7	.3550E-03	.2160E+02	.2324E+02	-.1642E+01	-.7066E+01
8	.4430E-03	.1510E+02	.1536E+02	-.2615E+00	-.1702E+01
9	.5540E-03	.9150E+01	.1005E+02	-.8998E+00	-.8953E+01
	.7130E-03	.6160E+01	.6238E+01	-.7757E-01	-.1244E+01
1	.8810E-03	.4140E+01	.4164E+01	-.2424E-01	-.5822E+00
2	.1090E-02	.2780E+01	.2766E+01	.1381E-01	.4994E+00
.3	.1410E-02	.1830E+01	.1711E+01	.1188E+00	.6941E+01
14	.1790E-02	.1180E+01	.1110E+01	.6964E-01	.6271E+01
5	.2220E-02	.8130E+00	.7680E+00	.4502E-01	.5862E+01
6	.2850E-02	.5430E+00	.5113E+00	.3173E-01	.6206E+01
17	.3600E-02	.3510E+00	.3552E+00	-.4213E-02	-.1186E+01
18	.4490E-02	.2490E+00	.2543E+00	-.5330E-02	-.2096E+01
9	.5700E-02	.1650E+00	.1774E+00	-.1242E-01	-.7002E+01
0	.7190E-02	.1190E+00	.1244E+00	-.5370E-02	-.4318E+01
1	.8800E-02	.8700E-01	.9157E-01	-.4567E-02	-.4988E+01
2	.1110E-01	.6300E-01	.6426E-01	-.1256E-02	-.1954E+01
3	.1400E-01	.4400E-01	.4464E-01	-.6405E-03	-.1435E+01
24	.1800E-01	.3000E-01	.2979E-01	.2126E-03	.7138E+00
25	.2200E-01	.2200E-01	.2144E-01	.5550E-03	.2588E+01
6	.2800E-01	.1500E-01	.1457E-01	.4283E-03	.2939E+01

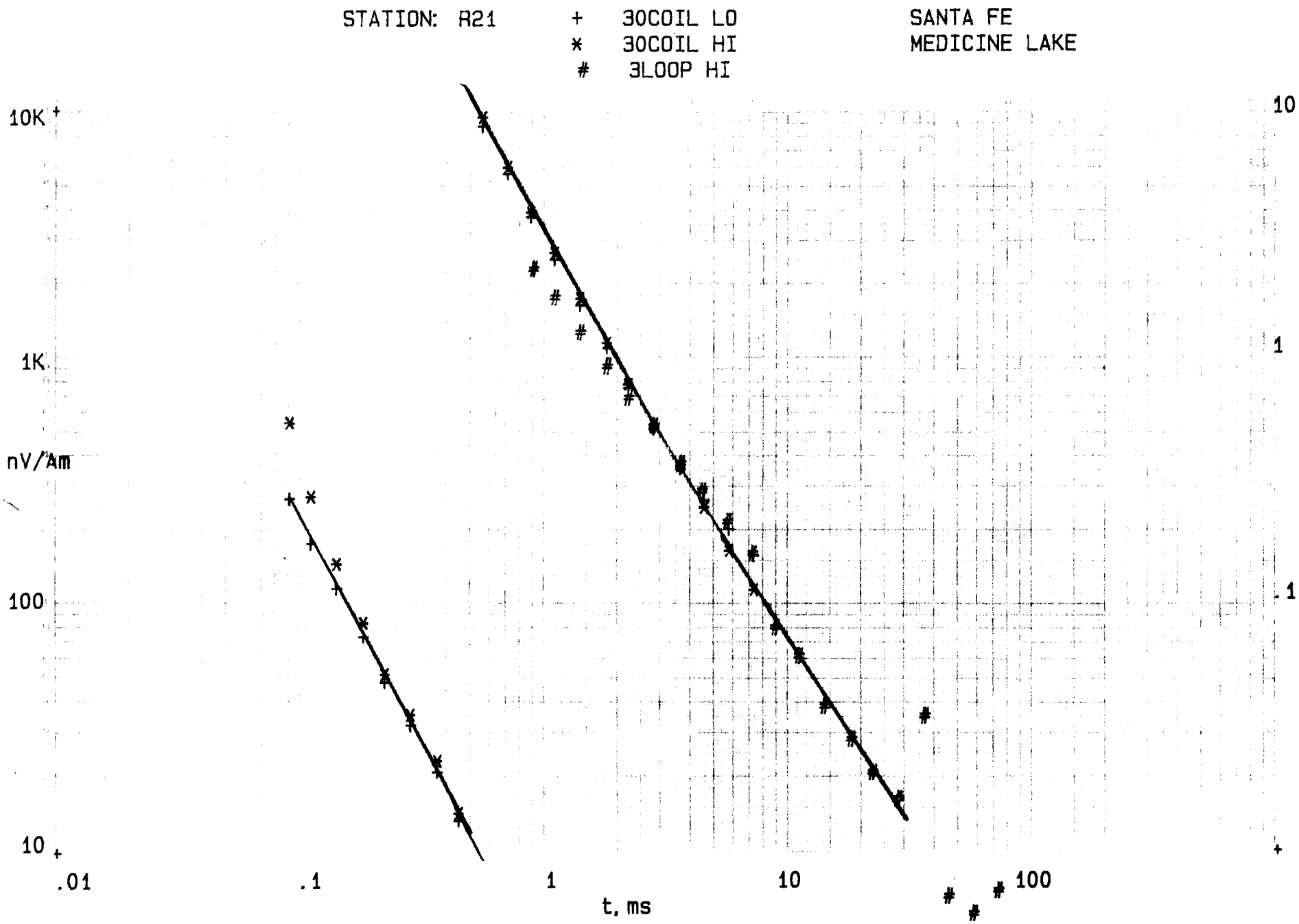
* RMSERR= 6.71

RELATION MATRIX

	.1000E+01						
	.1623E-01	.1000E+01					
	-.3088E+00	-.7366E+00	.1000E+01				
4	-.5011E+00	-.1369E+00	.8978E-01	.1000E+01			
5	-.2006E+00	.5634E+00	-.4506E+00	-.1191E+00	.1000E+01		
	-.1407E-01	-.1572E+00	-.1818E-02	-.8447E-01	-.6946E-01	.1000E+01	
7	.6562E-01	-.5778E+00	.2900E+00	.1458E+00	-.6209E+00	.4172E+00	.1000E

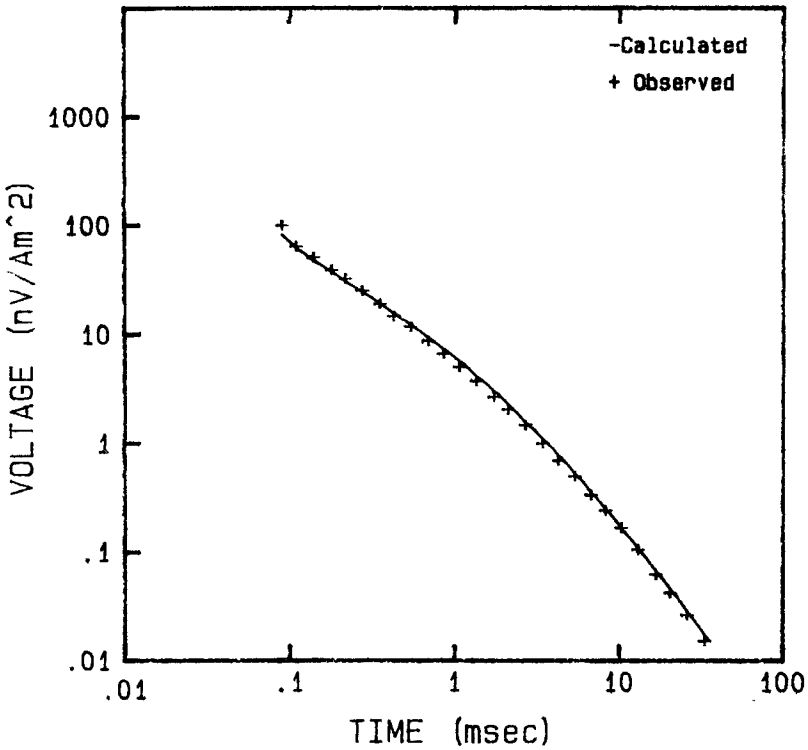
**PARM_SOL.	STD_ERROR	REL_ERROR	% ERROR **
.2755E-03	.1159E-04	.4207E-01	.4207E+01
2 .4049E-02	.6933E-03	.1713E+00	.1713E+02
- .1080E-01	.1383E-02	.1280E+00	.1280E+02
.3309E-01	.1822E-02	.5504E-01	.5504E+01
5 .2672E+03	.2199E-02	.8231E-05	.8231E-03
6 .3268E+03	.3698E-03	.1131E-05	.1131E-03
.2222E+03	.3771E-02	.1697E-04	.1697E-02

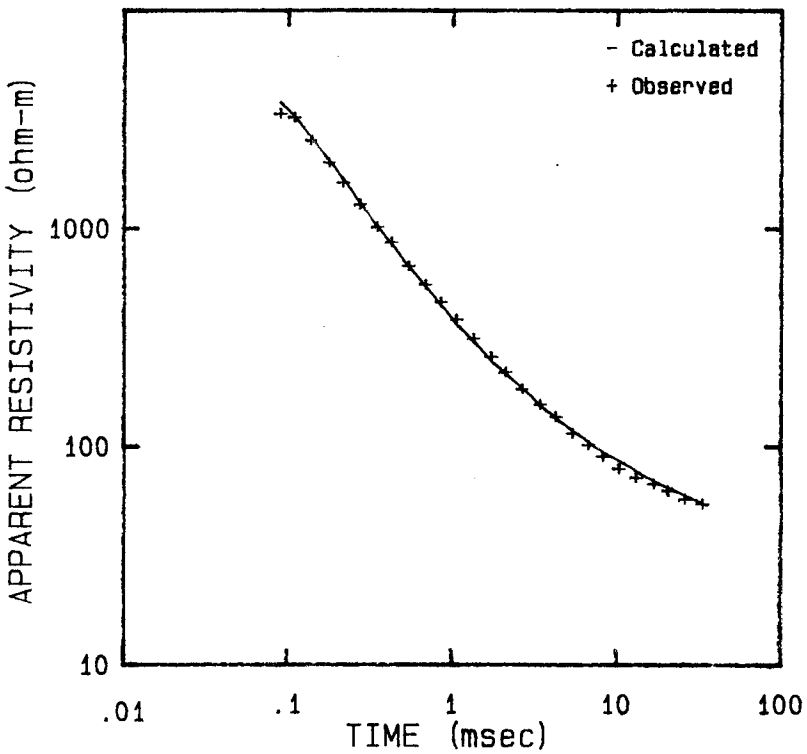
RAMETER NAME	FINAL SOLUTION	RESISTIVITY	LAYER DEPTH
1 SIGMA(1) =	.27550E-03	.36298E+04	
2 SIGMA(2) =	.40485E-02	.24700E+03	
3 SIGMA(3) =	.10801E-01	.92583E+02	
4 SIGMA(4) =	.33093E-01	.30218E+02	
5 THICK(1) =	.26720E+03		.26720E+03
6 THICK(2) =	.32685E+03		.59405E+03
7 THICK(3) =	.22224E+03		.81629E+03


STATION: R21
+ 30COIL LO
* 30COIL HI
# 3LOOP HI
SANTA FE
MEDICINE LAKE
10K
1K
nV/Am
100
10
.01
.1
1
10
100
t, ms
10
1
.1

EMSURVEYS TEM INVERSION

MEDICINE LAKE
STATION: R22





MODEL

RESISTIVITY (ohm-m)	THICKNESS (meters)
2714	387
31.6	

ELECTROMAGNETIC SURVEYS INC.

MEDICINE LAKE R22

I	TIME (sec)	VOLTAGE (nV/Am^2)	CALC.VOLT	RESIDUAL	%RES.ERR
1	.8900E-04	.9860E+02	.8197E+02	.1663E+02	.2028E+02
2	.1100E-03	.6330E+02	.6205E+02	.1247E+01	.2010E+01
3	.1400E-03	.5002E+02	.4731E+02	.2708E+01	.5725E+01
4	.1770E-03	.3820E+02	.3695E+02	.1252E+01	.3389E+01
5	.2200E-03	.3160E+02	.3020E+02	.1400E+01	.4635E+01
6	.2800E-03	.2440E+02	.2403E+02	.3691E+00	.1536E+01
7	.3550E-03	.1860E+02	.1884E+02	-.2424E+00	-.1287E+01
8	.4430E-03	.1430E+02	.1509E+02	-.7868E+00	-.5215E+01
9	.5540E-03	.1150E+02	.1186E+02	-.3644E+00	-.3071E+01
10	.7130E-03	.8490E+01	.9001E+01	-.5105E+00	-.5672E+01
11	.8810E-03	.6540E+01	.7077E+01	-.5370E+00	-.7589E+01
2	.1090E-02	.4940E+01	.5489E+01	-.5487E+00	-.9997E+01
3	.1410E-02	.3650E+01	.3963E+01	-.3130E+00	-.7897E+01
14	.1790E-02	.2600E+01	.2876E+01	-.2758E+00	-.9591E+01
5	.2220E-02	.2010E+01	.2128E+01	-.1179E+00	-.5539E+01
6	.2850E-02	.1440E+01	.1476E+01	-.3578E-01	-.2425E+01
17	.3600E-02	.9810E+00	.1031E+01	-.4994E-01	-.4844E+01
18	.4490E-02	.6820E+00	.7250E+00	-.4300E-01	-.5931E+01
9	.5700E-02	.4920E+00	.4878E+00	.4203E-02	.8616E+00
	.7190E-02	.3310E+00	.3270E+00	.3958E-02	.1210E+01
	.8800E-02	.2390E+00	.2287E+00	.1034E-01	.4521E+01
2	.1110E-01	.1660E+00	.1499E+00	.1610E-01	.1074E+02
3	.1400E-01	.1050E+00	.9716E-01	.7844E-02	.8073E+01
24	.1800E-01	.6200E-01	.6024E-01	.1762E-02	.2926E+01
25	.2200E-01	.4200E-01	.4070E-01	.1304E-02	.3203E+01
26	.2800E-01	.2600E-01	.2519E-01	.8102E-03	.3216E+01
27	.3600E-01	.1500E-01	.1525E-01	-.2517E-03	-.1650E+01

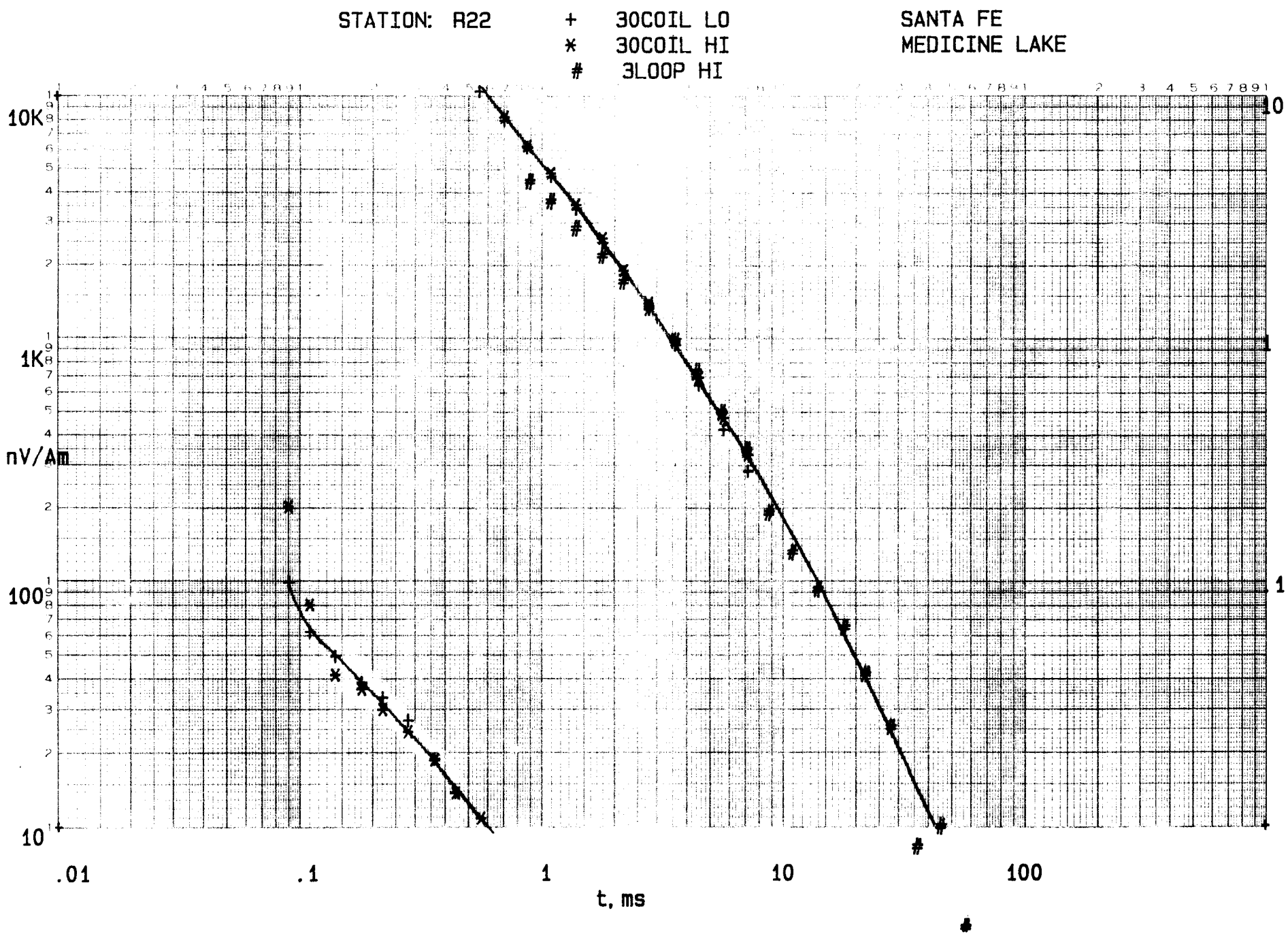
RMSERR= 6.66

ORRELATION MATRIX

	.1000E+01		
	.4810E+00	.1000E+01	
3	-.5606E+00	-.2934E+00	.1000E+01

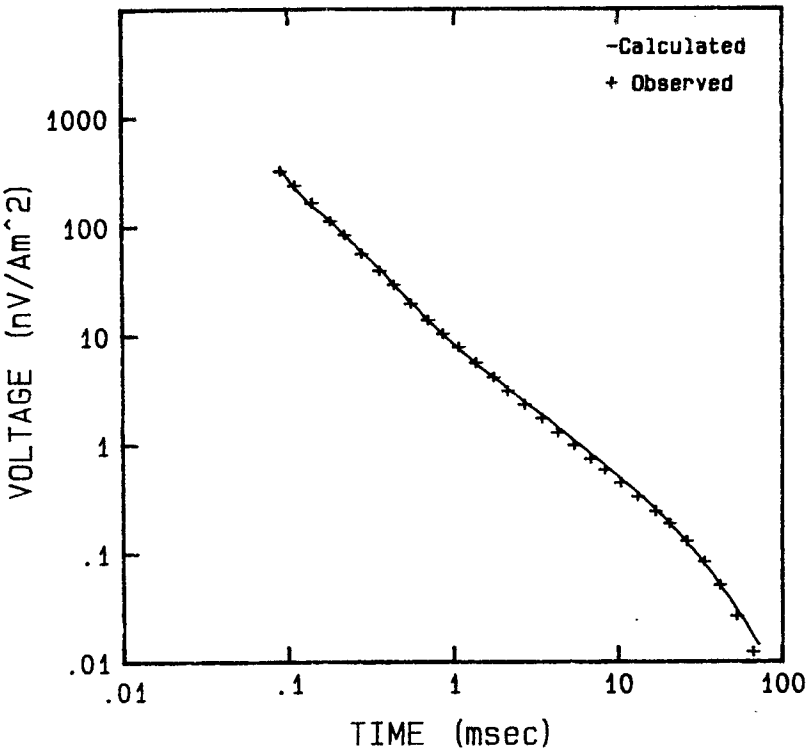
**PARM_SOL.	STD_ERROR	REL_ERROR	% ERROR **
1 .3684E-03	.2238E-04	.6076E-01	.6076E+01
2 .3160E-01	.1284E-02	.4065E-01	.4065E+01
.3866E+03	.6923E-03	.1791E-05	.1791E-03

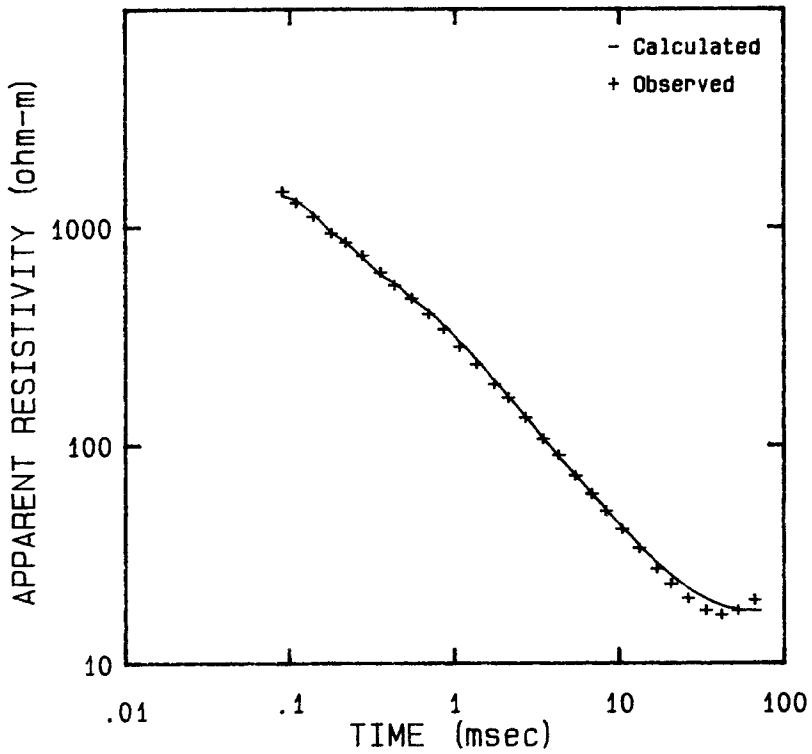
RAMETER NAME	FINAL SOLUTION	RESISTIVITY	LAYER DEPTH
1 SIGMA(1) =	.36842E-03	.27143E+04	
2 SIGMA(2) =	.31600E-01	.31646E+02	
3 THICK(1) =	.38659E+03		.38659E+03
4 SHIFT =	.20700E+03		


STATION: R22
+ 30COIL LO
* 30COIL HI
# 3LOOP HI
SANTA FE
MEDICINE LAKE
10K
1K
100
10
nV/Am
.01
.1
1
10
100
t, ms

EMSURVEYS TEM INVERSION

MEDICINE LAKE
STATION: R23





MODEL

RESISTIVITY (ohm-m)	THICKNESS (meters)
1088	285
38.9	126
6.3	371
10451	

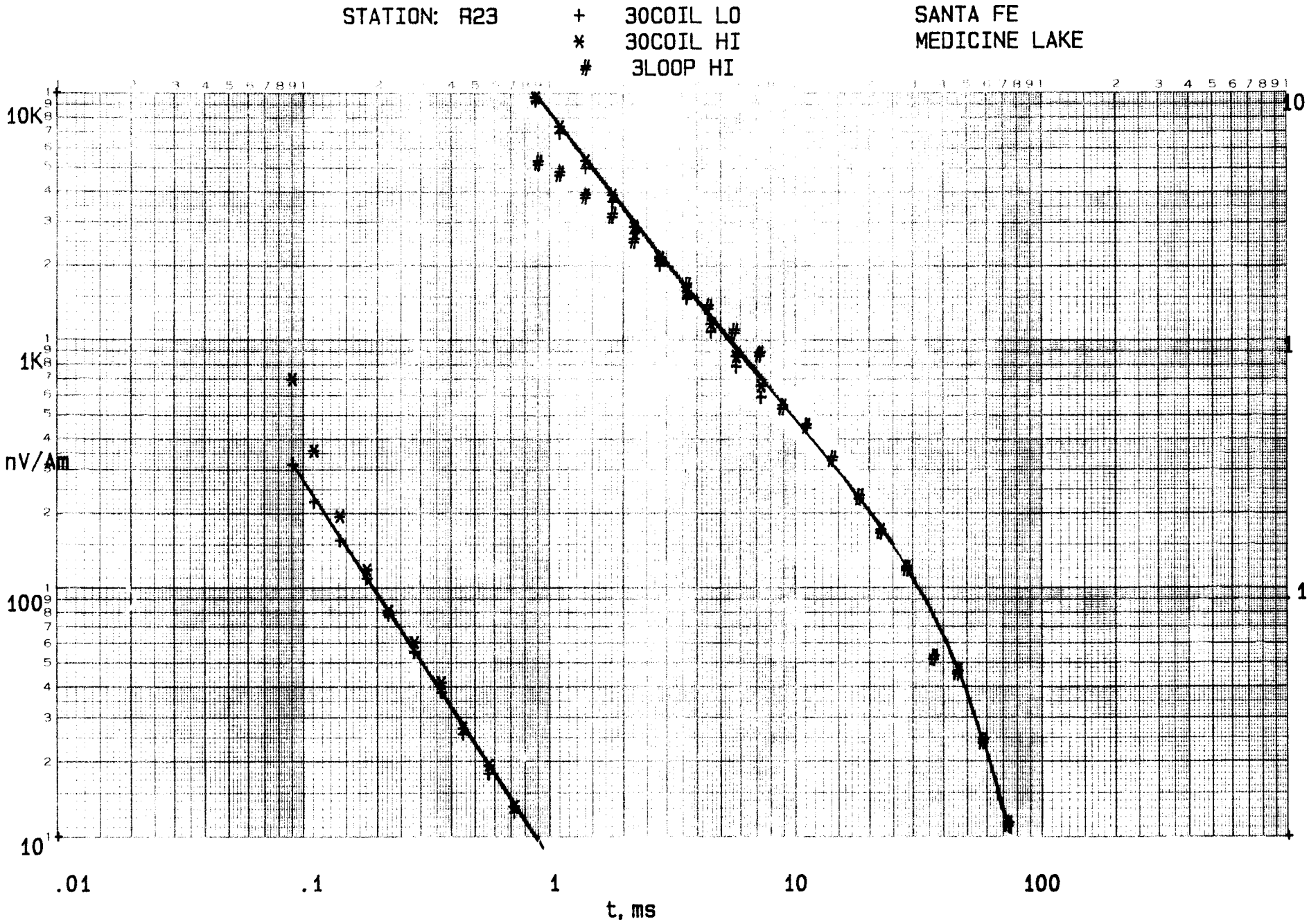
ELECTROMA[illegible]TIC SURVEYS INC.

MEDICINE LAKE R23

I	TIME (sec)	VOLTAGE (nV/Am^2)	CALC.VOLT	RESIDUAL	%RES.ERR
[illegible]	.8900E-04	.3230E+03	.3468E+03	-.2383E+02	-.6871E+01
2	.1100E-03	.2370E+03	.2276E+03	.9379E+01	.4120E+01
3	.1400E-03	.1640E+03	.1539E+03	.1006E+02	.6535E+01
4	.1770E-03	.1110E+03	.1116E+03	-.6383E+00	-.5718E+00
5	.2200E-03	.8280E+02	.8225E+02	.5506E+00	.6694E+00
6	.2800E-03	.5570E+02	.5807E+02	-.2369E+01	-.4080E+01
7	.3550E-03	.3897E+02	.4080E+02	-.1830E+01	-.4486E+01
8	.4430E-03	.2899E+02	.2826E+02	.7285E+00	.2578E+01
9	.5540E-03	.1950E+02	.1973E+02	-.2319E+00	-.1175E+01
0	.7130E-03	.1380E+02	.1340E+02	.4019E+00	.2999E+01
1	.8810E-03	.1030E+02	.9788E+01	.5117E+00	.5228E+01
2	.1090E-02	.7730E+01	.7317E+01	.4134E+00	.5650E+01
3	.1410E-02	.5590E+01	.5316E+01	.2743E+00	.5161E+01
4	.1790E-02	.4100E+01	.4011E+01	.8884E-01	.2215E+01
5	.2220E-02	.3070E+01	.3134E+01	-.6351E-01	-.2027E+01
6	.2850E-02	.2296E+01	.2357E+01	-.6065E-01	-.2573E+01
7	.3600E-02	.1725E+01	.1788E+01	-.6344E-01	-.3547E+01
8	.4490E-02	.1270E+01	.1368E+01	-.9833E-01	-.7186E+01
9	.5700E-02	.9770E+00	.1024E+01	-.4656E-01	-.4549E+01
	.7190E-02	.7270E+00	.7696E+00	-.4255E-01	-.5529E+01
	.8800E-02	.5770E+00	.5993E+00	-.2235E-01	-.3728E+01
[illegible]	.1110E-01	.4380E+00	.4491E+00	-.1110E-01	-.2471E+01
3	.1400E-01	.3270E+00	.3318E+00	-.4849E-02	-.1461E+01
24	.1800E-01	.2400E+00	.2320E+00	.7962E-02	.3431E+01
5	.2200E-01	.1850E+00	.1693E+00	.1570E-01	.9270E+01
6	.2800E-01	.1270E+00	.1122E+00	.1480E-01	.1319E+02
27	.3600E-01	.8200E-01	.7017E-01	.1183E-01	.1686E+02
28	.4500E-01	.5100E-01	.4419E-01	.6813E-02	.1542E+02
9	.5700E-01	.2600E-01	.2581E-01	.1922E-03	.7448E+00
.0	.7200E-01	.1200E-01	.1452E-01	-.2521E-02	-.1736E+02

RMSERR= 7.06

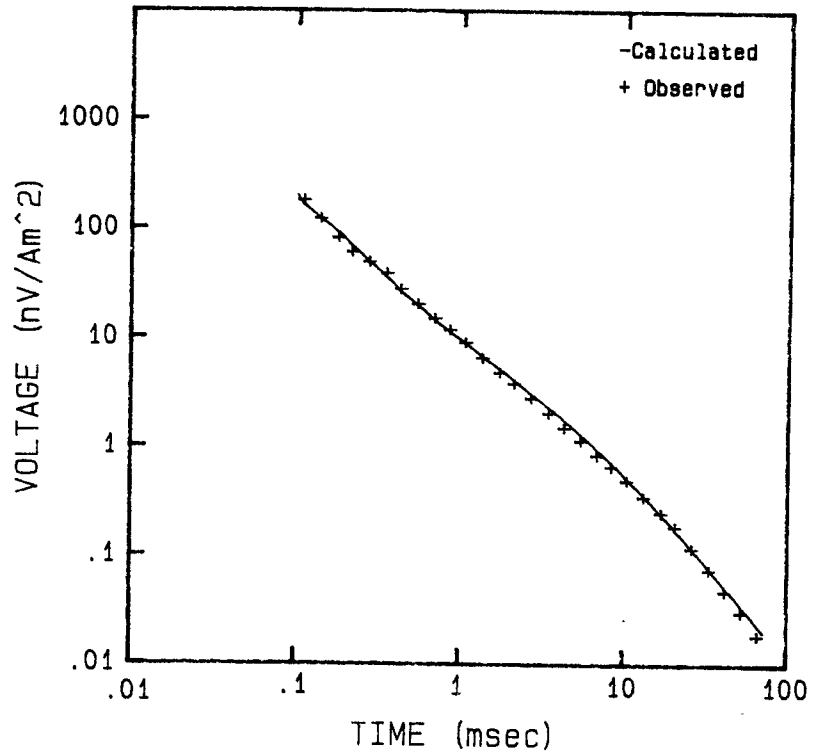
RAMETER	NAME		FINAL SOLUTION	RESISTIVITY	LAYER DEPTH
1	SIGMA(1)	=	.91885E-03	.10883E+04	
2	SIGMA(2)	=	.25730E-01	.38866E+02	
[illegible]	SIGMA(3)	=	.15789E+00	.63337E+01	
[illegible]	SIGMA(4)	=	.95685E-04	.10451E+05	
5	THICK(1)	=	.28499E+03		.28499E+03
6	THICK(2)	=	.12650E+03		.41149E+03
7	THICK(3)	=	.37045E+03		.78194E+03
8	SHIFT	=	.20700E+03		

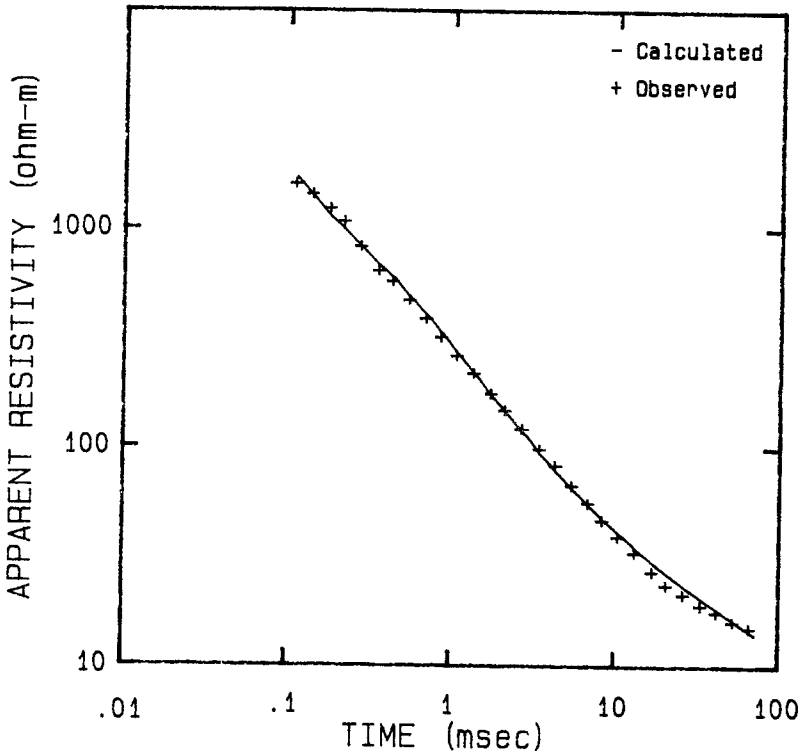

STATION: R23
+ 30COIL LO
* 30COIL HI
# 3LOOP HI
SANTA FE
MEDICINE LAKE
10K
1K
100
10
nV/Am
10
1
1
.01
.1
1
10
100
t, ms

EMSURVEYS

TEM INVERSION

MEDICINE LAKE
STATION: R24





MODEL

RESISTIVITY (ohm-m)	THICKNESS (meters)
2175	260
105	32
33.6	83
7.5	

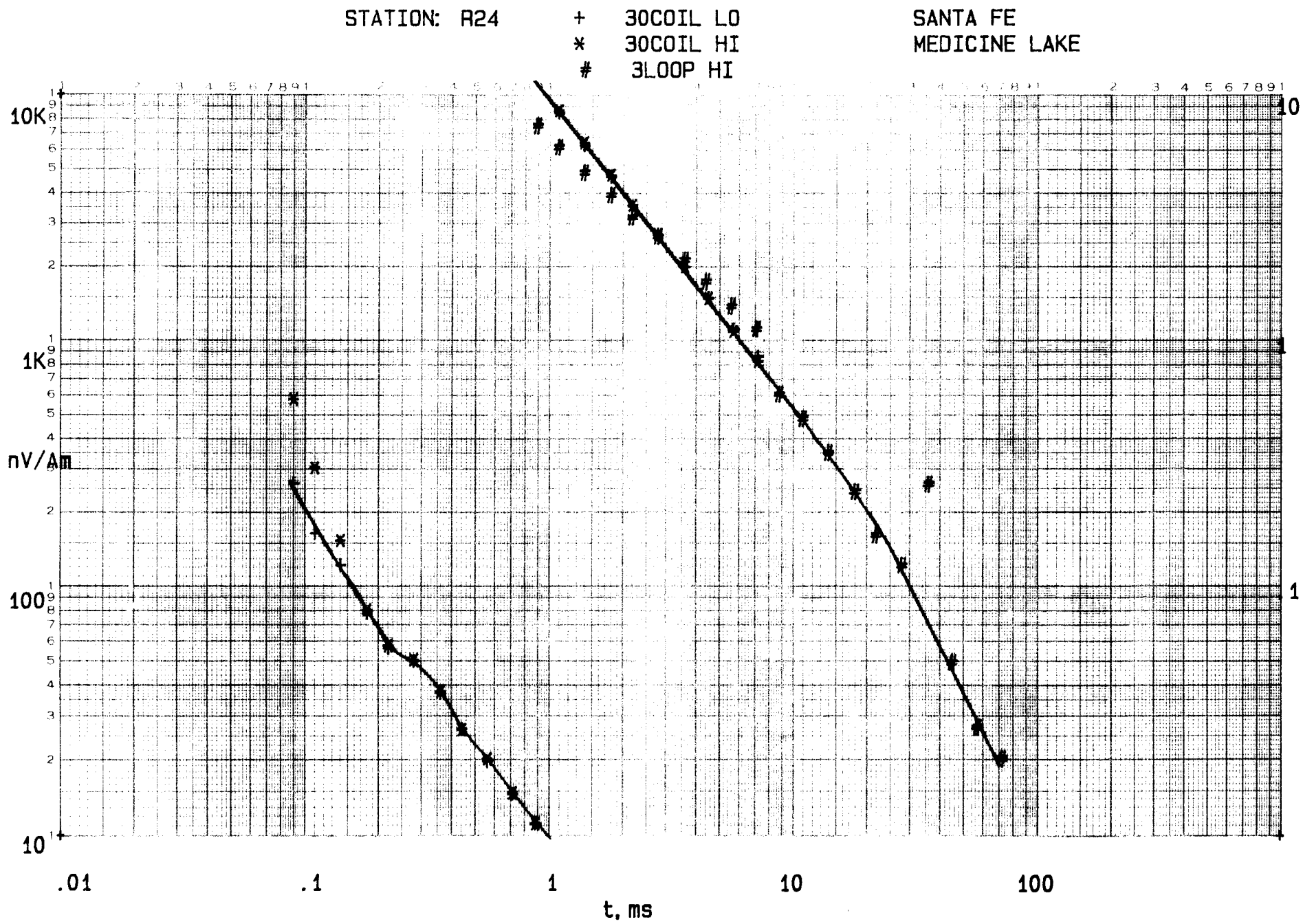
ELECTROMAGNETIC SURVEYS INC.

MEDICINE LAKE R24

I	TIME (sec)	VOLTAGE (nV/Am^2)	CALC.VOLT	RESIDUAL	%RES.ERR
1	.1100E-03	.1760E+03	.1602E+03	.1578E+02	.9848E+01
2	.1400E-03	.1190E+03	.1195E+03	-.4743E+00	-.3970E+00
3	.1770E-03	.7930E+02	.8952E+02	-.1022E+02	-.1142E+02
4	.2200E-03	.5890E+02	.6645E+02	-.7551E+01	-.1136E+02
5	.2800E-03	.4780E+02	.4773E+02	.6955E-01	.1457E+00
6	.3550E-03	.3760E+02	.3424E+02	.3358E+01	.9807E+01
7	.4430E-03	.2680E+02	.2513E+02	.1666E+01	.6627E+01
8	.5540E-03	.1970E+02	.1879E+02	.9092E+00	.4839E+01
9	.7130E-03	.1460E+02	.1379E+02	.8094E+00	.5869E+01
0	.8810E-03	.1140E+02	.1077E+02	.6274E+00	.5824E+01
11	.1090E-02	.8760E+01	.8488E+01	.2719E+00	.3203E+01
2	.1410E-02	.6350E+01	.6400E+01	-.5024E-01	-.7850E+00
3	.1790E-02	.4680E+01	.4900E+01	-.2202E+00	-.4494E+01
14	.2220E-02	.3680E+01	.3837E+01	-.1565E+00	-.4079E+01
5	.2850E-02	.2700E+01	.2873E+01	-.1733E+00	-.6032E+01
6	.3600E-02	.1980E+01	.2169E+01	-.1894E+00	-.8730E+01
17	.4490E-02	.1460E+01	.1644E+01	-.1843E+00	-.1121E+02
18	.5700E-02	.1100E+01	.1203E+01	-.1026E+00	-.8528E+01
9	.7190E-02	.8180E+00	.8733E+00	-.5525E-01	-.6327E+01
	.8800E-02	.6470E+00	.6556E+00	-.8639E-02	-.1318E+01
	.1110E-01	.4810E+00	.4658E+00	.1522E-01	.3267E+01
2	.1400E-01	.3400E+00	.3260E+00	.1400E-01	.4295E+01
3	.1800E-01	.2430E+00	.2181E+00	.2486E-01	.1140E+02
24	.2200E-01	.1820E+00	.1565E+00	.2553E-01	.1631E+02
25	.2800E-01	.1150E+00	.1042E+00	.1082E-01	.1038E+02
6	.3600E-01	.7300E-01	.6771E-01	.5286E-02	.7807E+01
27	.4500E-01	.4700E-01	.4601E-01	.9866E-03	.2144E+01
28	.5700E-01	.3000E-01	.3047E-01	-.4679E-03	-.1536E+01
9	.7200E-01	.1800E-01	.2030E-01	-.2298E-02	-.1132E+02

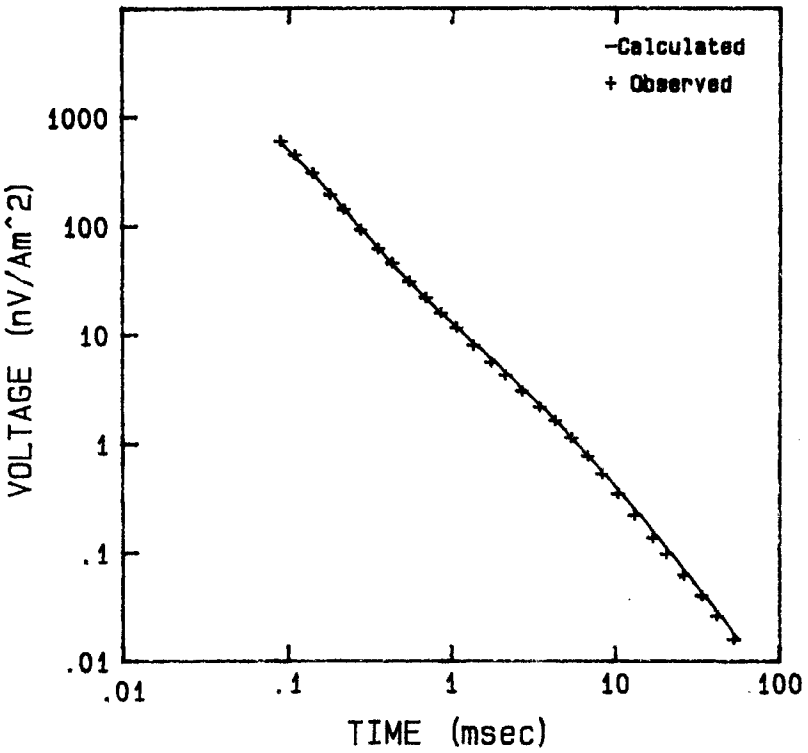
* RMSERR= 7.70

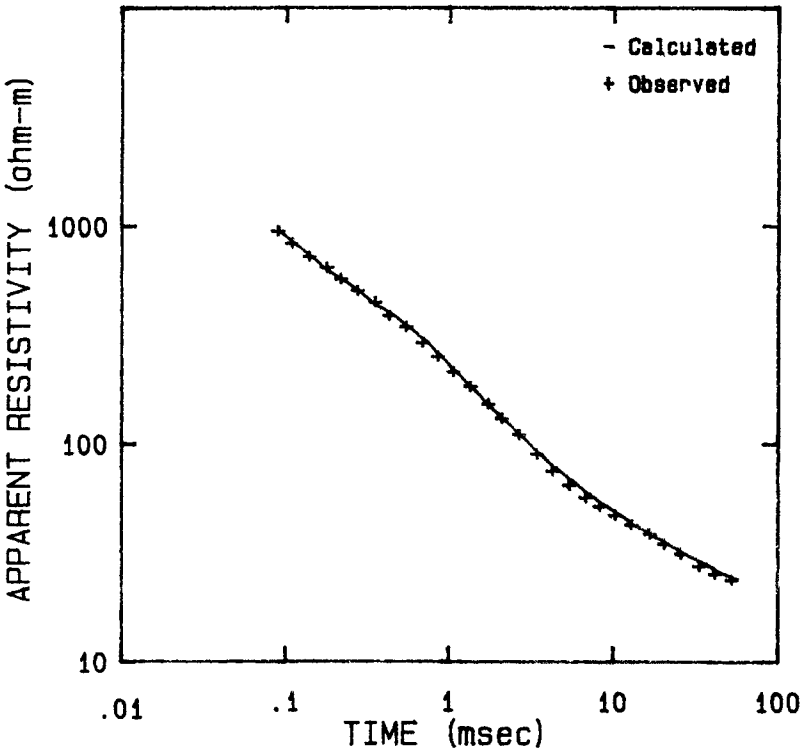
RAMETER	NAME	FINAL SOLUTION	RESISTIVITY	LAYER DEPTH
1	SIGMA(1) =	.45979E-03	.21749E+04	
2	SIGMA(2) =	.95010E-02	.10525E+03	
3	SIGMA(3) =	.29731E-01	.33635E+02	
4	SIGMA(4) =	.13397E+00	.74641E+01	
	THICK(1) =	.26036E+03		.26036E+03
	THICK(2) =	.31895E+02		.29225E+03
7	THICK(3) =	.83169E+02		.37542E+03
8	SHIFT =	.20700E+03		


STATION: R24
+ 30COIL LO
* 30COIL HI
# 3LOOP HI
SANTA FE
MEDICINE LAKE
10K
1K
100
10
nV/Am
10
1
1
.01
.1
1
10
100
t, ms

EMSURVEYS TEM INVERSION

MEDICINE LAKE
STATION: OR1





MODEL

RESISTIVITY (ohm-m)	THICKNESS (meters)
2474	154
182	87
68	111
15	

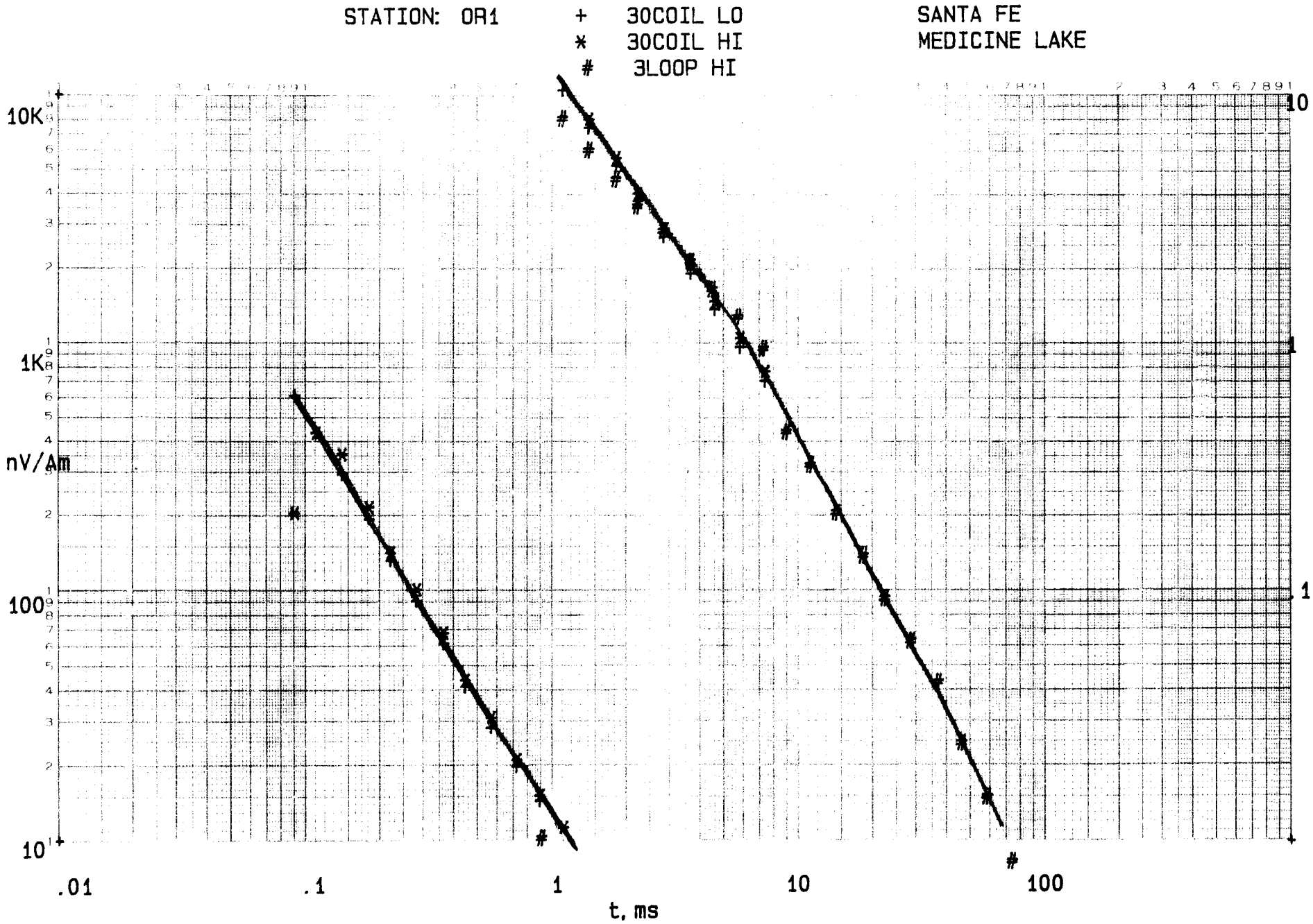
ELECTROMAGNETIC SURVEYS INC.

MEDICINE LAKE OR1

I	TIME (sec)	VOLTAGE (nV/Am^2)	CALC.VOLT	RESIDUAL	%RES.ERR
1	.8900E-04	.6030E+03	.5950E+03	.7968E+01	.1339E+01
2	.1100E-03	.4480E+03	.4322E+03	.1578E+02	.3651E+01
3	.1400E-03	.3030E+03	.2973E+03	.5713E+01	.1922E+01
4	.1770E-03	.1930E+03	.2041E+03	-.1108E+02	-.5430E+01
5	.2200E-03	.1420E+03	.1422E+03	-.2453E+00	-.1724E+00
6	.2800E-03	.9180E+02	.9407E+02	-.2274E+01	-.2418E+01
7	.3550E-03	.6140E+02	.6231E+02	-.9061E+00	-.1454E+01
8	.4430E-03	.4550E+02	.4299E+02	.2515E+01	.5850E+01
9	.5540E-03	.3070E+02	.3025E+02	.4487E+00	.1483E+01
10	.7130E-03	.2180E+02	.2080E+02	.1004E+01	.4829E+01
11	.8810E-03	.1580E+02	.1540E+02	.4017E+00	.2609E+01
2	.1090E-02	.1160E+02	.1155E+02	.4691E-01	.4060E+00
3	.1410E-02	.8020E+01	.8184E+01	-.1645E+00	-.2010E+01
14	.1790E-02	.5610E+01	.5923E+01	-.3125E+00	-.5277E+01
5	.2220E-02	.4290E+01	.4405E+01	-.1149E+00	-.2608E+01
6	.2850E-02	.3040E+01	.3092E+01	-.5219E-01	-.1688E+01
17	.3600E-02	.2190E+01	.2190E+01	.9775E-05	.4464E-03
18	.4490E-02	.1640E+01	.1566E+01	.7375E-01	.4708E+01
9	.5700E-02	.1140E+01	.1075E+01	.6484E-01	.6031E+01
	.7190E-02	.7750E+00	.7354E+00	.3962E-01	.5388E+01
1	.8800E-02	.5370E+00	.5234E+00	.1357E-01	.2593E+01
2	.1110E-01	.3520E+00	.3493E+00	.2675E-02	.7659E+00
3	.1400E-01	.2250E+00	.2299E+00	-.4856E-02	-.2112E+01
24	.1800E-01	.1380E+00	.1444E+00	-.6408E-02	-.4437E+01
5	.2200E-01	.9900E-01	.9929E-01	-.2907E-03	-.2928E+00
6	.2800E-01	.6300E-01	.6336E-01	-.3613E-03	-.5702E+00
27	.3600E-01	.4100E-01	.3979E-01	.1214E-02	.3051E+01
28	.4500E-01	.2700E-01	.2587E-01	.1129E-02	.4363E+01
9	.5700E-01	.1600E-01	.1628E-01	-.2814E-03	-.1728E+01

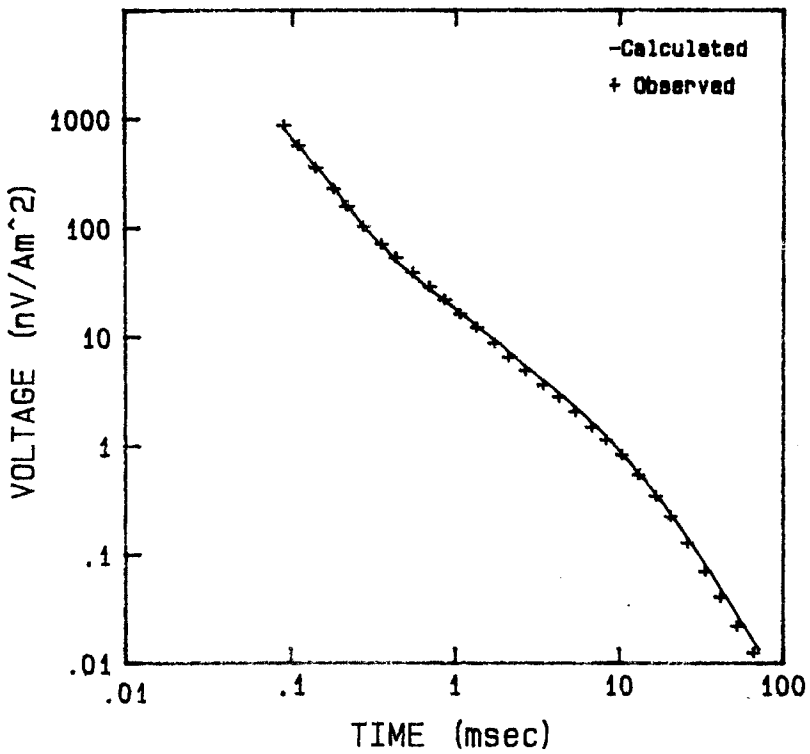
* RMSERR= 3.30

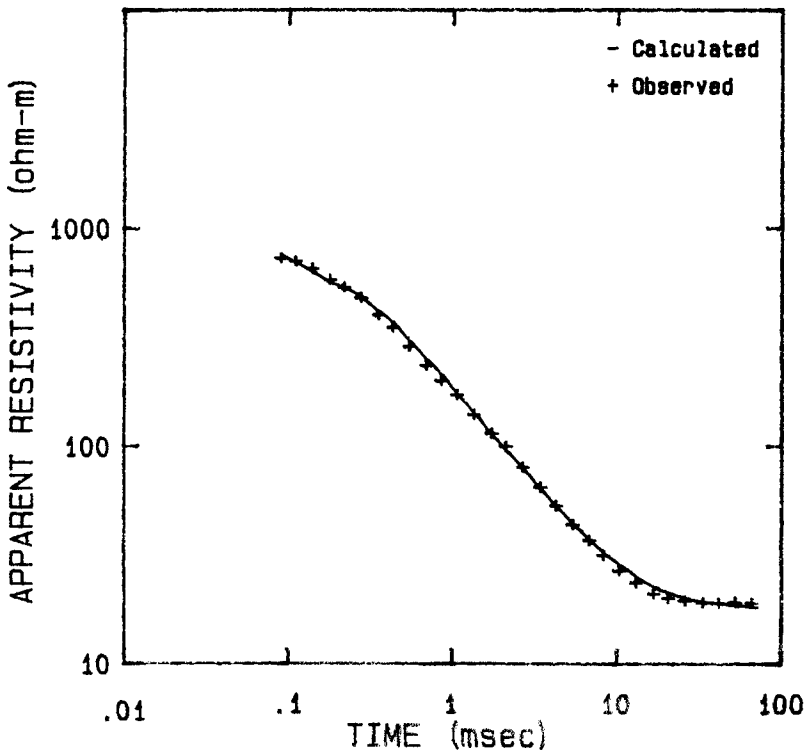
PARAMETER NAME		FINAL SOLUTION	RESISTIVITY	LAYER DEPTH
1	SIGMA(1) =	.40423E-03	.24739E+04	
2	SIGMA(2) =	.54920E-02	.18208E+03	
3	SIGMA(3) =	.14675E-01	.68145E+02	
4	SIGMA(4) =	.65743E-01	.15211E+02	
	THICK(1) =	.15392E+03		.15392E+03
6	THICK(2) =	.86919E+02		.24084E+03
7	THICK(3) =	.11154E+03		.35238E+03
8	SHIFT =	.20700E+03		


STATION: OR1
+ 30COIL LO
* 30COIL HI
# 3LOOP HI
SANTA FE
MEDICINE LAKE
10K
1K
100
10
nV/Am
.01
.1
1
10
100
t, ms

EMSURVEYS TEM INVERSION

MEDICINE LAKE
STATION: OR2





MODEL

RESISTIVITY (ohm-m)	THICKNESS (meters)
2343	139
124	106
44	48
8	269
46	

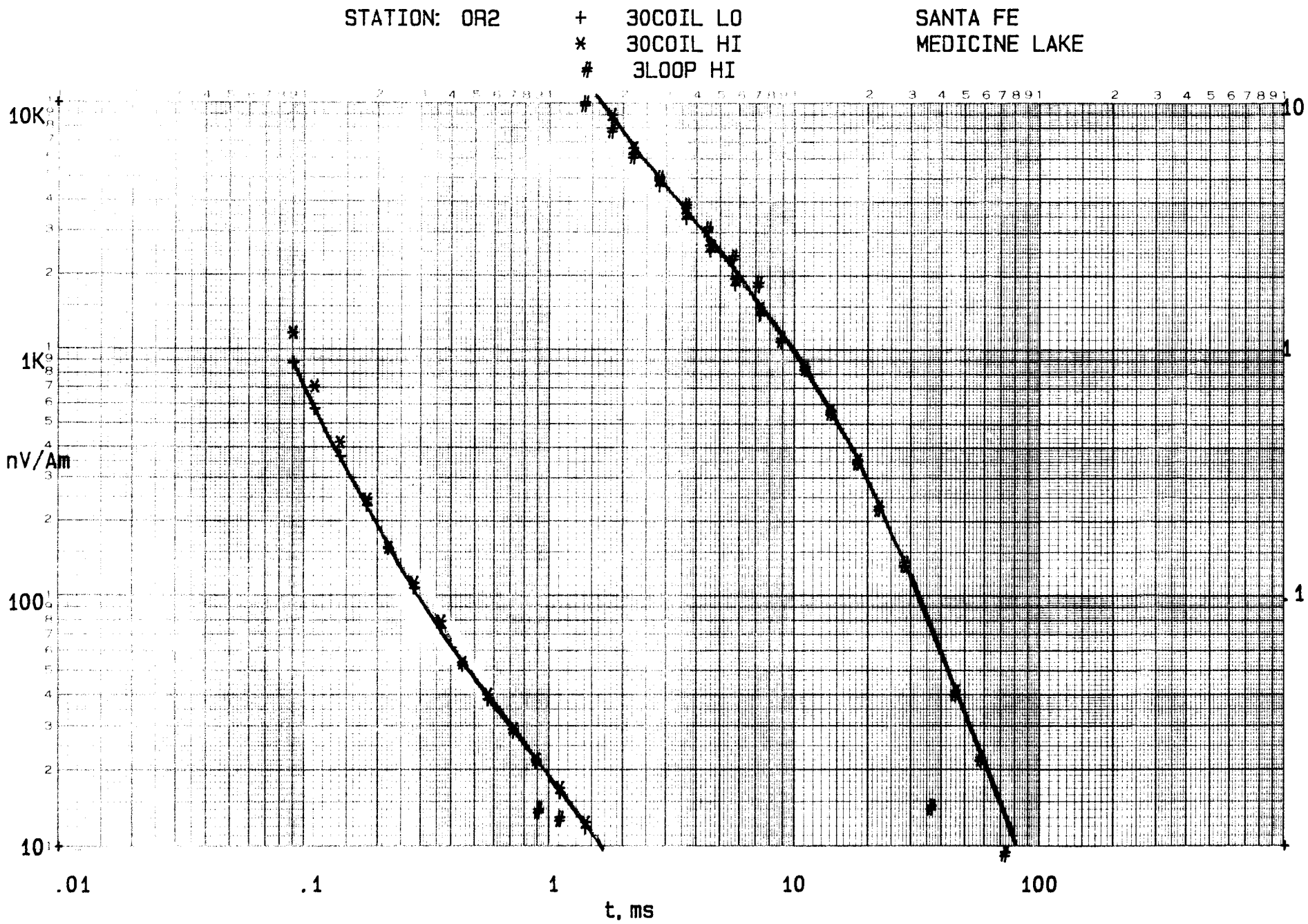
ELECTROMAGNETIC SURVEYS INC.

MEDICINE LAKE OR2

I	TIME (sec)	VOLTAGE (nV/Am^2)	CALC.VOLT	RESIDUAL	%RES.ERR
1	.8900E-04	.8800E+03	.8297E+03	.5031E+02	.6064E+01
2	.1100E-03	.5690E+03	.5761E+03	-.7090E+01	-.1231E+01
3	.1400E-03	.3540E+03	.3706E+03	-.1660E+02	-.4479E+01
4	.1770E-03	.2270E+03	.2380E+03	-.1098E+02	-.4613E+01
5	.2200E-03	.1570E+03	.1569E+03	.9160E-01	.5838E-01
6	.2800E-03	.1030E+03	.1008E+03	.2250E+01	.2233E+01
7	.3550E-03	.7070E+02	.6800E+02	.2702E+01	.3974E+01
8	.4430E-03	.5350E+02	.4874E+02	.4763E+01	.9772E+01
9	.5540E-03	.3890E+02	.3609E+02	.2809E+01	.7783E+01
10	.7130E-03	.2890E+02	.2671E+02	.2189E+01	.8196E+01
11	.8810E-03	.2190E+02	.2086E+02	.1036E+01	.4965E+01
12	.1090E-02	.1620E+02	.1632E+02	-.1233E+00	-.7553E+00
13	.1410E-02	.1210E+02	.1215E+02	-.5104E-01	-.4200E+00
14	.1790E-02	.8730E+01	.9179E+01	-.4495E+00	-.4896E+01
15	.2220E-02	.6520E+01	.7068E+01	-.5479E+00	-.7751E+01
16	.2850E-02	.4920E+01	.5197E+01	-.2772E+00	-.5334E+01
17	.3600E-02	.3630E+01	.3864E+01	-.2342E+00	-.6062E+01
18	.4490E-02	.2780E+01	.2912E+01	-.1315E+00	-.4517E+01
[illegible]	.5700E-02	.2070E+01	.2128E+01	-.5764E-01	-.2709E+01
[illegible]	.7190E-02	.1480E+01	.1539E+01	-.5915E-01	-.3843E+01
[illegible]	.8800E-02	.1140E+01	.1137E+01	.3334E-02	.2933E+00
22	.1110E-01	.8320E+00	.7792E+00	.5276E-01	.6771E+01
23	.1400E-01	.5490E+00	.5184E+00	.3059E-01	.5900E+01
24	.1800E-01	.3490E+00	.3208E+00	.2822E-01	.8797E+01
25	.2200E-01	.2280E+00	.2121E+00	.1590E-01	.7494E+01
26	.2800E-01	.1300E+00	.1256E+00	.4401E-02	.3504E+01
27	.3600E-01	.7100E-01	.7098E-01	.2129E-04	.2999E-01
28	.4500E-01	.4100E-01	.4170E-01	-.7004E-03	-.1680E+01
29	.5700E-01	.2200E-01	.2365E-01	-.1649E-02	-.6972E+01
30	.7200E-01	.1300E-01	.1365E-01	-.6525E-03	-.4779E+01

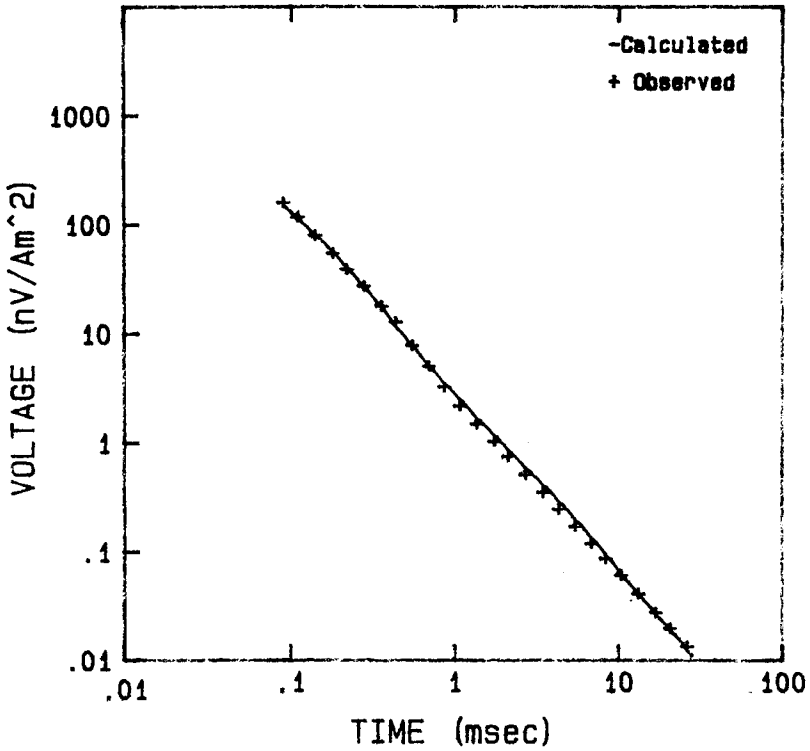
RMSERR= 5.30

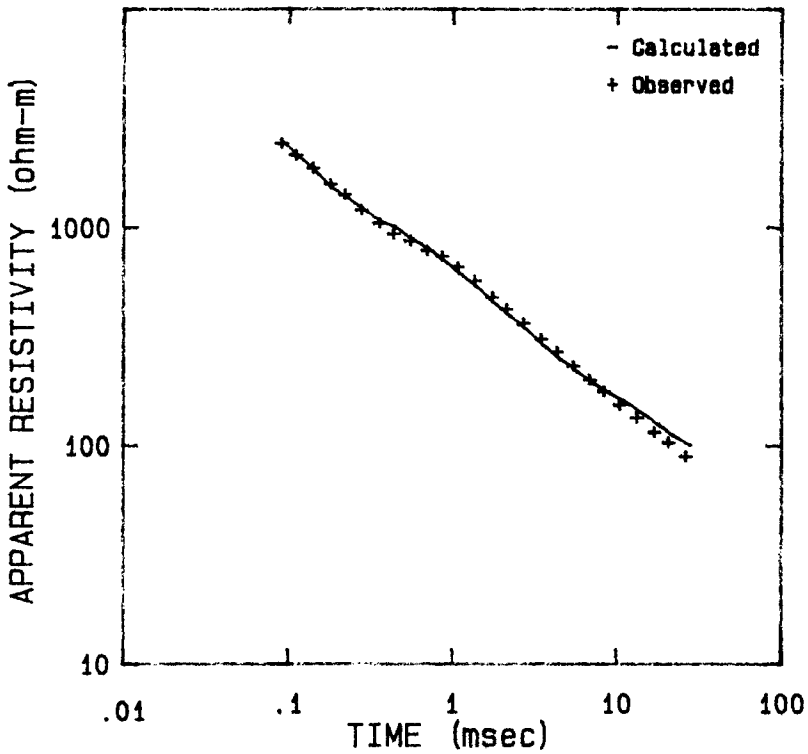
PARAMETER	NAME	FINAL SOLUTION	RESISTIVITY	LAYER DEPTH
1	SIGMA(1) =	.42675E-03	.23433E+04	
2	SIGMA(2) =	.80510E-02	.12421E+03	
3	SIGMA(3) =	.22763E-01	.43931E+02	
	SIGMA(4) =	.13014E+00	.76840E+01	
[illegible]	SIGMA(5) =	.21581E-01	.46337E+02	
6	THICK(1) =	.13862E+03		.13862E+03
7	THICK(2) =	.10644E+03		.24506E+03
8	THICK(3) =	.47905E+02		.29296E+03
9	THICK(4) =	.26932E+03		.56228E+03
0	SHIFT =	.20700E+03		


STATION: OR2
+ 30COIL LO
* 30COIL HI
# 3LOOP HI
SANTA FE
MEDICINE LAKE
10K
1K
nV/Am
100
10
.01
.1
1
10
100
t, ms
10
1
1

EMSURVEYS TEM INVERSION

MEDICINE LAKE
STATION: OR3





MODEL

RESISTIVITY (ohm-m)	THICKNESS (meters)
3741	320
235	326
55	

ELECTROMA ETIC SURVEYS INC.

MEDICINE LAKE OR3

I	TIME (sec)	VOLTAGE (nV/Am^2)	CALC.VOLT	RESIDUAL	%RES.ERR
1	.8900E-04	.1599E+03	.1524E+03	.7478E+01	.4906E+01
2	.1100E-03	.1170E+03	.1141E+03	.2905E+01	.2546E+01
3	.1400E-03	.7890E+02	.7995E+02	-.1050E+01	-.1313E+01
4	.1770E-03	.5420E+02	.5654E+02	-.2337E+01	-.4133E+01
5	.2200E-03	.3870E+02	.3975E+02	-.1051E+01	-.2644E+01
6	.2800E-03	.2705E+02	.2629E+02	.7605E+00	.2893E+01
7	.3550E-03	.1780E+02	.1710E+02	.7046E+00	.4121E+01
8	.4430E-03	.1270E+02	.1129E+02	.1411E+01	.1250E+02
9	.5540E-03	.7790E+01	.7527E+01	.2631E+00	.3495E+01
[illegible]	.7130E-03	.5025E+01	.4872E+01	.1529E+00	.3139E+01
	.8810E-03	.3210E+01	.3408E+01	-.1985E+00	-.5823E+01
[illegible]	.1090E-02	.2170E+01	.2406E+01	-.2361E+00	-.9813E+01
3	.1410E-02	.1480E+01	.1617E+01	-.1374E+00	-.8495E+01
14	.1790E-02	.1025E+01	.1125E+01	-.9994E-01	-.8884E+01
15	.2220E-02	.7480E+00	.8153E+00	-.6731E-01	-.8256E+01
6	.2850E-02	.5120E+00	.5599E+00	-.4792E-01	-.8558E+01
17	.3600E-02	.3510E+00	.3899E+00	-.3892E-01	-.9981E+01
18	.4490E-02	.2460E+00	.2740E+00	-.2805E-01	-.1023E+02
9	.5700E-02	.1710E+00	.1853E+00	-.1435E-01	-.7741E+01
[illegible]	.7190E-02	.1190E+00	.1244E+00	-.5401E-02	-.4342E+01
	.8800E-02	.8600E-01	.8664E-01	-.6352E-03	-.7332E+00
2	.1110E-01	.6100E-01	.5668E-01	.4317E-02	.7616E+01
3	.1400E-01	.4100E-01	.3716E-01	.3845E-02	.1035E+02
24	.1800E-01	.2800E-01	.2426E-01	.3742E-02	.1543E+02
25	.2200E-01	.2000E-01	.1742E-01	.2581E-02	.1482E+02
6	.2800E-01	.1300E-01	.1125E-01	.1754E-02	.1560E+02

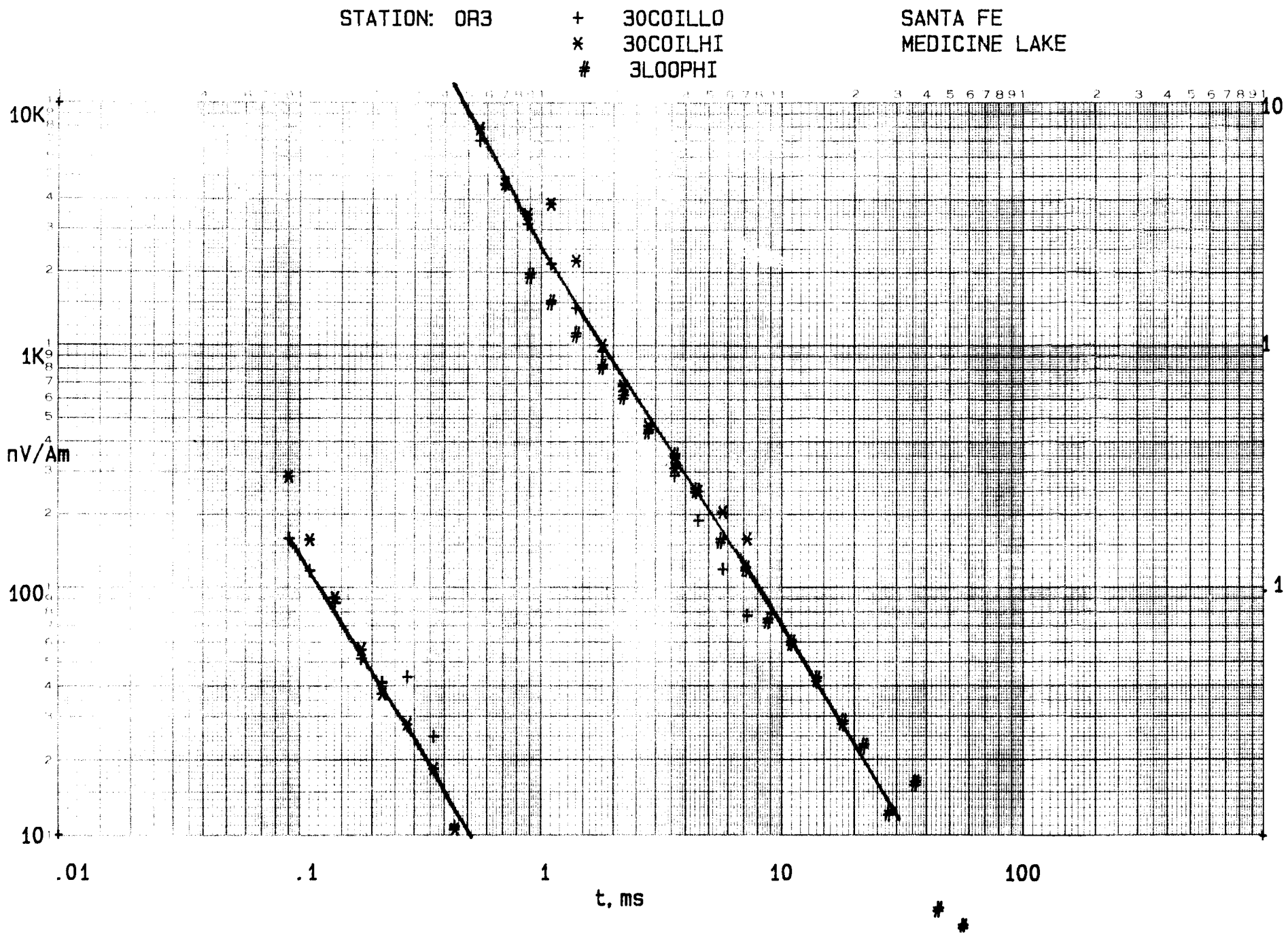
* RMSERR= 8.39

PRELATION MATRIX

.1000E+01				
-.1443E+00	.1000E+01			
.2442E+00	-.7199E-01	.1000E+01		
.1517E+00	.4366E+00	.5615E-01	.1000E+01	
-.7491E+00	.4800E+00	.2018E+00	.1387E+00	.1000E+01

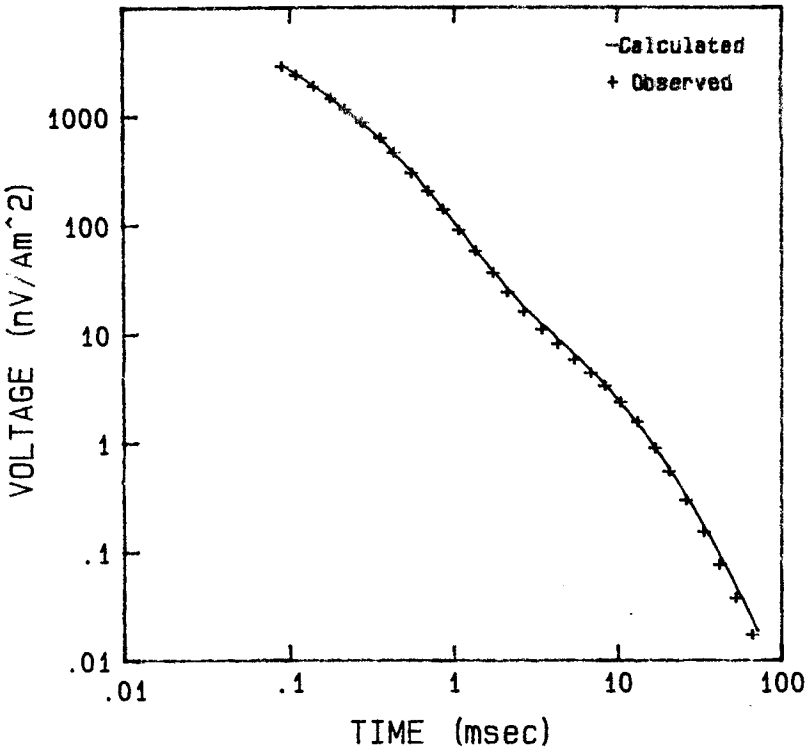
**PARM_SOL.	STD_ERROR	REL_ERROR	% ERROR **
.2673E-03	.1131E-04	.4230E-01	.4230E+01
.4254E-02	.7353E-03	.1729E+00	.1729E+02
.1830E-01	.2117E-02	.1157E+00	.1157E+02
.3205E+03	.1895E-02	.5911E-05	.5911E-03
.3258E+03	.2738E-03	.8405E-06	.8405E-04

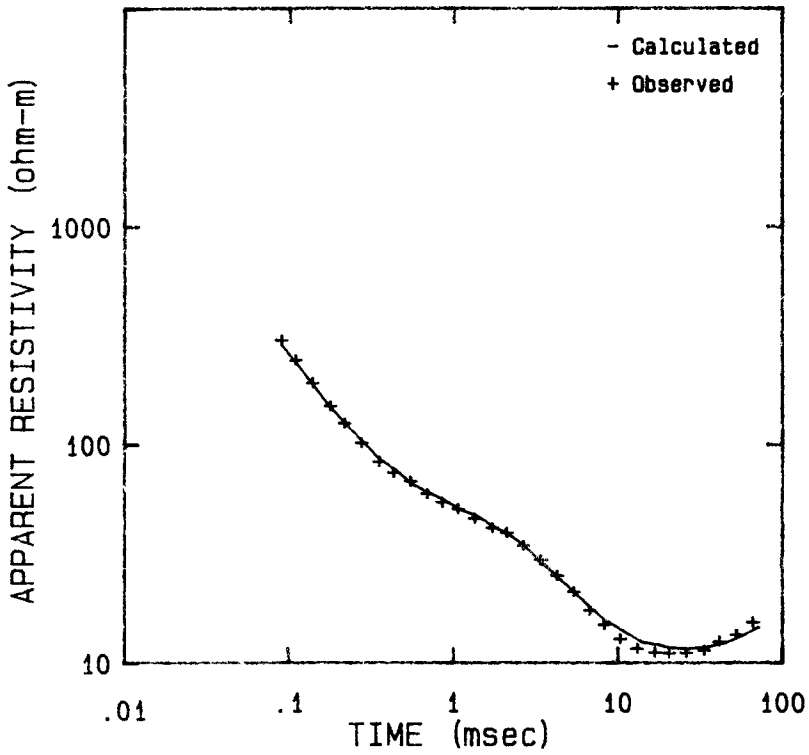
ARAMETER NAME		FINAL SOLUTION	RESISTIVITY	LAYER DEPTH
1 SIGMA(1)	=	.26730E-03	.37412E+04	
2 SIGMA(2)	=	.42538E-02	.23508E+03	
3 SIGMA(3)	=	.18297E-01	.54653E+02	
4 THICK(1)	=	.32051E+03		.32051E+03
5 THICK(2)	=	.32576E+03		.64628E+03
6 SHIFT	=	.20700E+03		


STATION: OR3
+ 30COILLO
* 30COILHI
# 3LOOPHI
SANTA FE
MEDICINE LAKE
10K
1K
100
10
nV/Am
.01
.1
1
10
100
t, ms
10
1
1

EMSURVEYS TEM INVERSION

MEDICINE LAKE
STATION: OR4





MODEL

RESISTIVITY (ohm-m)	THICKNESS (meters)
573	84
18	148
4	168
518	

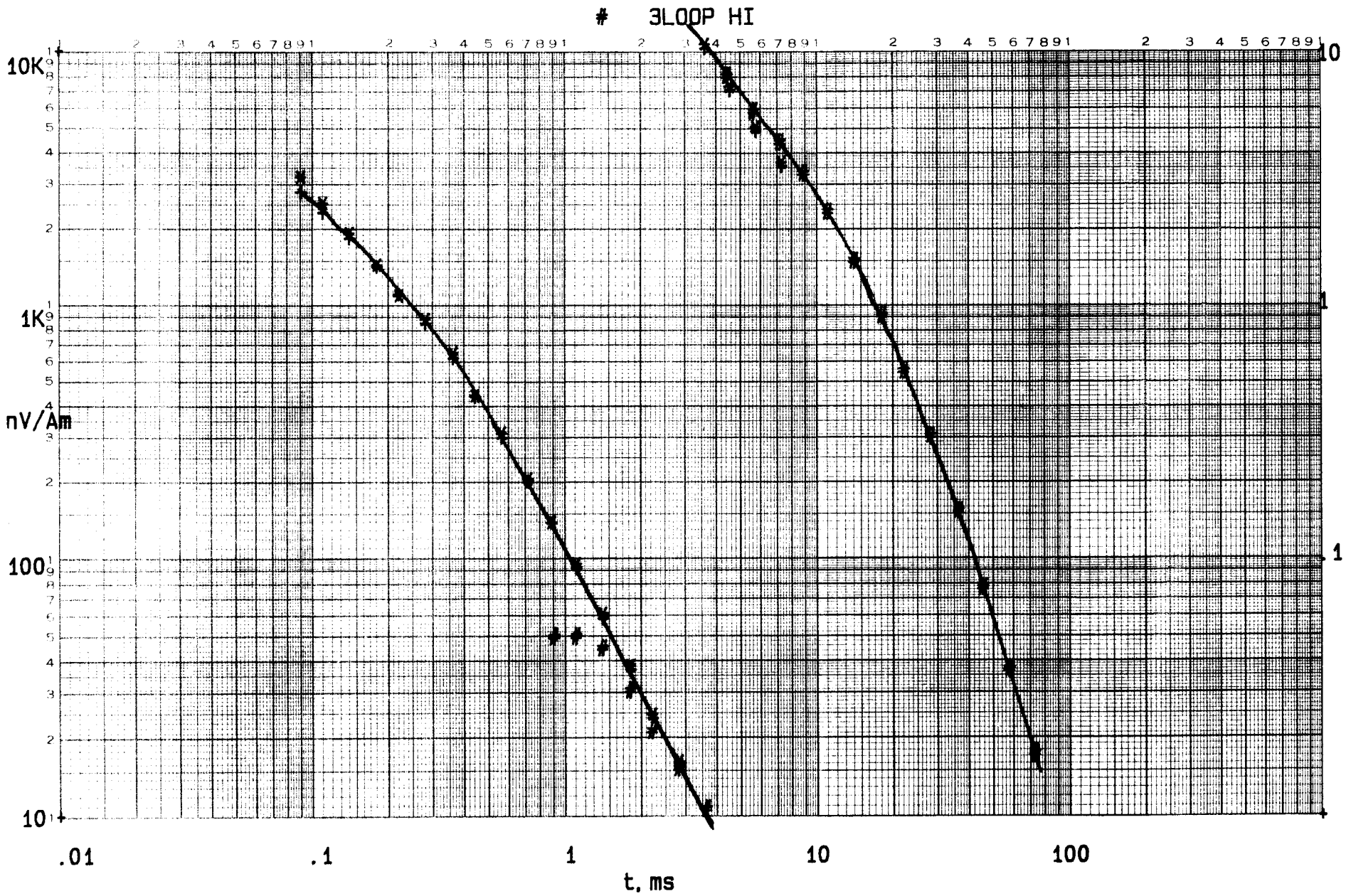
ELECTROM[illegible]TIC SURVEYS INC.

MEDICINE LAKE OR4

I	TIME (sec)	VOLTAGE (nV/Am^2)	CALC.VOLT	RESIDUAL	%RES.ERR
1	.8900E-04	.2878E+04	.3030E+04	-.1516E+03	-.5004E+01
2	.1100E-03	.2385E+04	.2459E+04	-.7445E+02	-.3027E+01
3	.1400E-03	.1880E+04	.1912E+04	-.3239E+02	-.1694E+01
4	.1770E-03	.1447E+04	.1477E+04	-.3019E+02	-.2044E+01
5	.2200E-03	.1153E+04	.1147E+04	.5868E+01	.5116E+00
6	.2800E-03	.8690E+03	.8472E+03	.2176E+02	.2568E+01
7	.3550E-03	.6300E+03	.6142E+03	.1584E+02	.2579E+01
8	.4430E-03	.4620E+03	.4423E+03	.1966E+02	.4444E+01
9	.5540E-03	.2970E+03	.3090E+03	-.1200E+02	-.3882E+01
10	.7130E-03	.2040E+03	.1995E+03	.4534E+01	.2273E+01
[illegible]	.8810E-03	.1390E+03	.1350E+03	.4031E+01	.2986E+01
12	.1090E-02	.8990E+02	.9053E+02	-.6317E+00	-.6978E+00
13	.1410E-02	.5810E+02	.5608E+02	.2019E+01	.3600E+01
14	.1790E-02	.3660E+02	.3625E+02	.3515E+00	.9698E+00
15	.2220E-02	.2420E+02	.2497E+02	-.7689E+00	-.3079E+01
16	.2850E-02	.1610E+02	.1680E+02	-.6989E+00	-.4160E+01
17	.3600E-02	.1097E+02	.1181E+02	-.8393E+00	-.7108E+01
18	.4490E-02	.8090E+01	.8622E+01	-.5318E+00	-.6168E+01
19	.5700E-02	.5836E+01	.6151E+01	-.3150E+00	-.5121E+01
[illegible]	.7190E-02	.4407E+01	.4358E+01	.4884E-01	.1121E+01
[illegible]	.8800E-02	.3330E+01	.3166E+01	.1643E+00	.5190E+01
22	.1110E-01	.2360E+01	.2125E+01	.2351E+00	.1106E+02
23	.1400E-01	.1560E+01	.1360E+01	.1997E+00	.1468E+02
24	.1800E-01	.8970E+00	.8023E+00	.9473E-01	.1181E+02
25	.2200E-01	.5510E+00	.5116E+00	.3940E-01	.7701E+01
26	.2800E-01	.2990E+00	.2836E+00	.1536E-01	.5416E+01
27	.3600E-01	.1530E+00	.1463E+00	.6669E-02	.4557E+01
28	.4500E-01	.7600E-01	.7928E-01	-.3276E-02	-.4132E+01
29	.5700E-01	.3800E-01	.3971E-01	-.1705E-02	-.4295E+01
30	.7200E-01	.1700E-01	.1926E-01	-.2257E-02	-.1172E+02

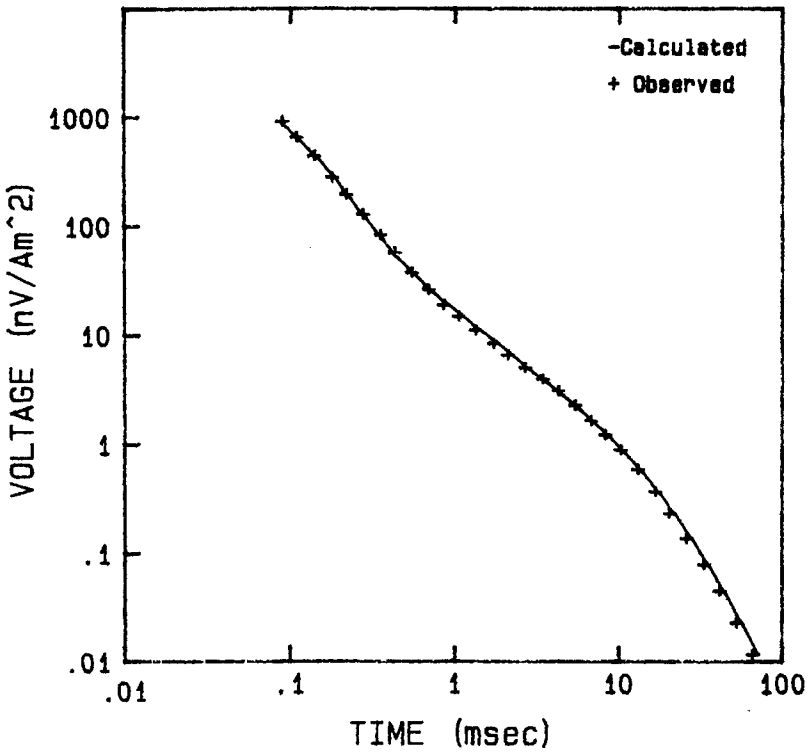
RMSERR= 5.91

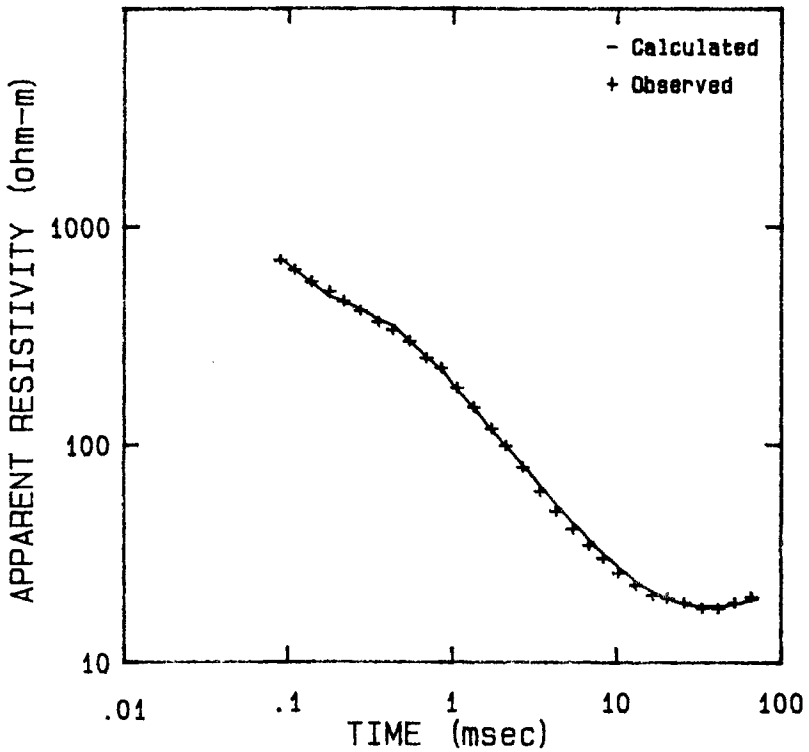
ARAMETER	NAME	FINAL SOLUTION	RESISTIVITY	LAYER DEPTH
1	SIGMA(1) =	.17460E-02	.57275E+03	
2	SIGMA(2) =	.56278E-01	.17769E+02	
3	SIGMA(3) =	.23509E+00	.42537E+01	
4	SIGMA(4) =	.19297E-02	.51822E+03	
5	THICK(1) =	.84517E+02		.84517E+02
6	THICK(2) =	.14731E+03		.23183E+03
7	THICK(3) =	.16811E+03		.39994E+03
8	SHIFT =	.20700E+03		


STATION: OR4
+ 30COIL LO
* 30COIL HI
# 3LOOP HI
SANTA FE
MEDICINE LAKE
10K
1K
100
10
nV/Am
10
1
1
.01
.1
1
10
100
t, ms

EMSURVEYS TEM INVERSION

MEDICINE LAKE
STATION: OR5





MODEL

RESISTIVITY (ohm-m)	THICKNESS (meters)
1478	156
76	143
7	277
254	

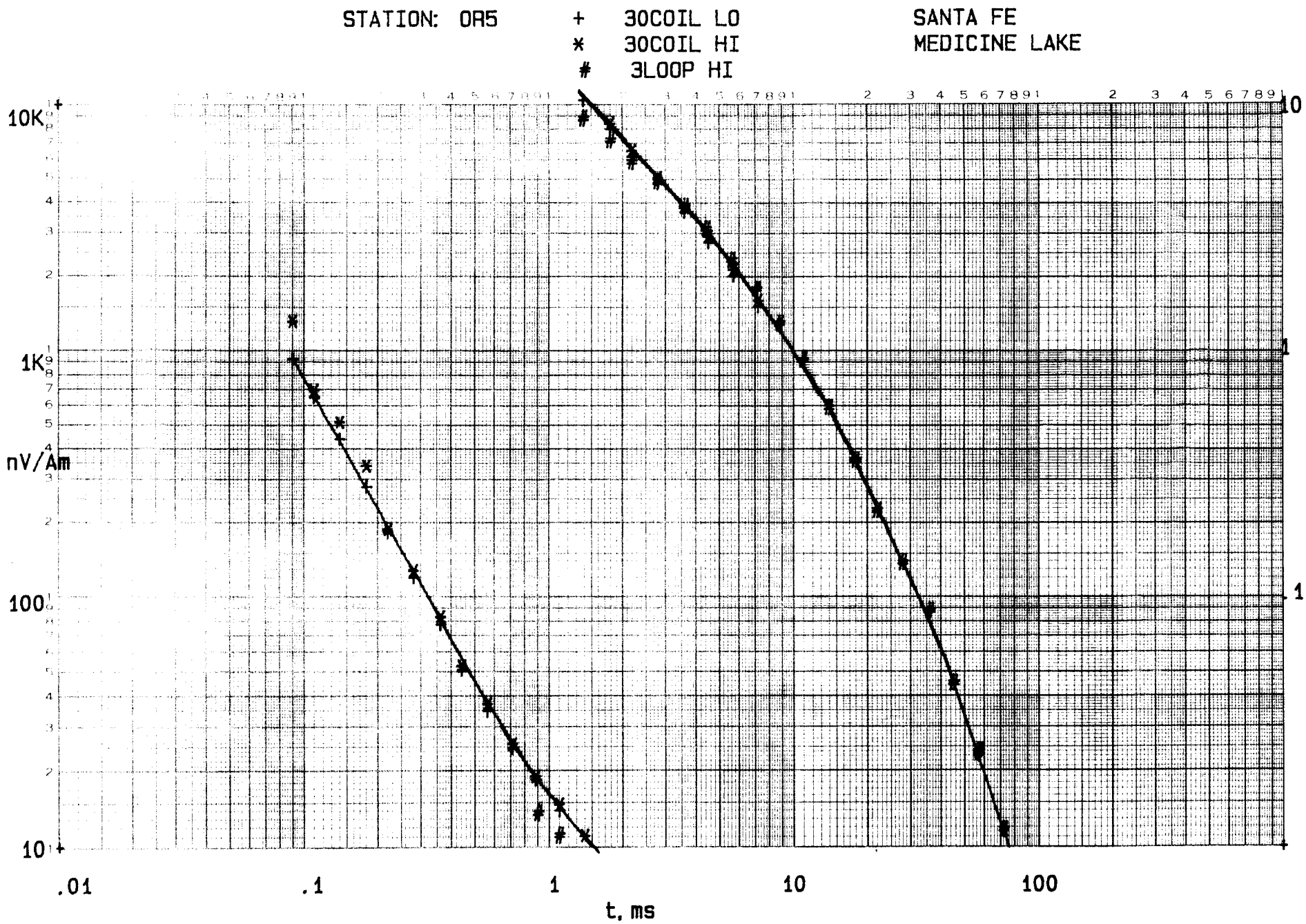
ELECTROMAGNETIC SURVEYS INC.

MEDICINE LAKE OR5

I	TIME (sec)	VOLTAGE (nV/Am^2)	CALC.VOLT	RESIDUAL	%RES.ERR
1	.8900E-04	.9230E+03	.8955E+03	.2751E+02	.3072E+01
2	.1100E-03	.6590E+03	.6582E+03	.7701E+00	.1170E+00
3	.1400E-03	.4430E+03	.4509E+03	-.7942E+01	-.1761E+01
4	.1770E-03	.2780E+03	.2981E+03	-.2009E+02	-.6740E+01
5	.2200E-03	.1940E+03	.1983E+03	-.4273E+01	-.2155E+01
6	.2800E-03	.1280E+03	.1245E+03	.3502E+01	.2813E+01
7	.3550E-03	.8280E+02	.7851E+02	.4293E+01	.5469E+01
8	.4430E-03	.5720E+02	.5283E+02	.4373E+01	.8279E+01
9	.5540E-03	.3720E+02	.3731E+02	-.1148E+00	-.3076E+00
10	.7130E-03	.2620E+02	.2625E+02	-.4547E-01	-.1732E+00
11	.8810E-03	.1890E+02	.2006E+02	-.1161E+01	-.5785E+01
2	.1090E-02	.1480E+02	.1568E+02	-.8847E+00	-.5641E+01
.3	.1410E-02	.1100E+02	.1165E+02	-.6465E+00	-.5551E+01
14	.1790E-02	.8290E+01	.8803E+01	-.5130E+00	-.5827E+01
5	.2220E-02	.6560E+01	.6821E+01	-.2606E+00	-.3821E+01
6	.2850E-02	.5020E+01	.5037E+01	-.1713E-01	-.3400E+00
17	.3600E-02	.3940E+01	.3777E+01	.1627E+00	.4308E+01
18	.4490E-02	.3080E+01	.2885E+01	.1948E+00	.6751E+01
[illegible]	.5700E-02	.2260E+01	.2141E+01	.1194E+00	.5580E+01
	.7190E-02	.1630E+01	.1580E+01	.5011E-01	.3172E+01
	.8800E-02	.1220E+01	.1192E+01	.2799E-01	.2348E+01
2	.1110E-01	.8780E+00	.8394E+00	.3859E-01	.4598E+01
3	.1400E-01	.5860E+00	.5695E+00	.1654E-01	.2905E+01
24	.1800E-01	.3660E+00	.3560E+00	.1003E-01	.2819E+01
5	.2200E-01	.2310E+00	.2372E+00	-.6205E-02	-.2616E+01
6	.2800E-01	.1360E+00	.1407E+00	-.4750E-02	-.3375E+01
27	.3600E-01	.7900E-01	.7751E-01	.1493E-02	.1926E+01
28	.4500E-01	.4500E-01	.4388E-01	.1119E-02	.2550E+01
9	.5700E-01	.2300E-01	.2344E-01	-.4442E-03	-.1895E+01
0	.7200E-01	.1200E-01	.1223E-01	-.2292E-03	-.1874E+01

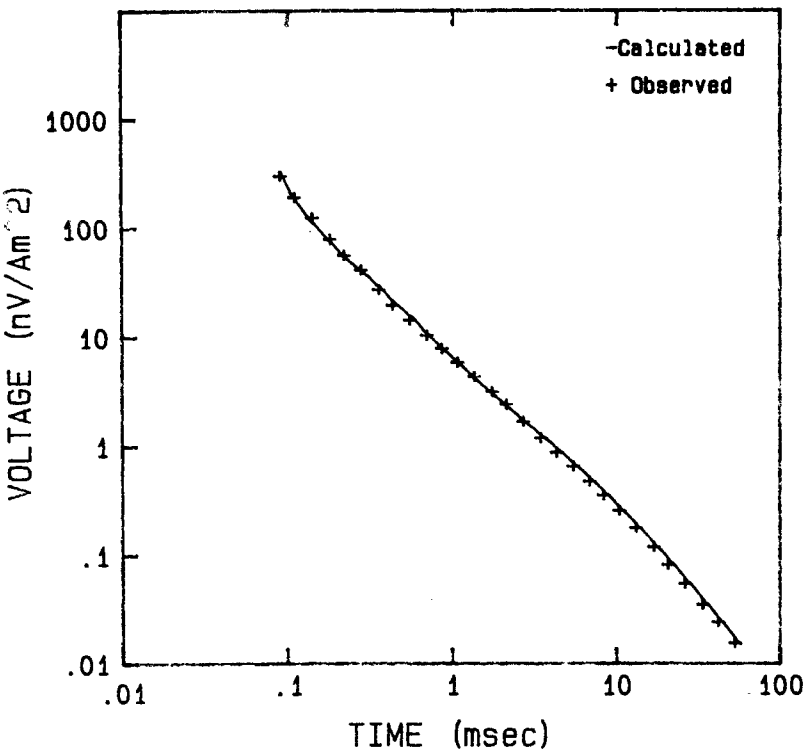
RMSERR= 4.07

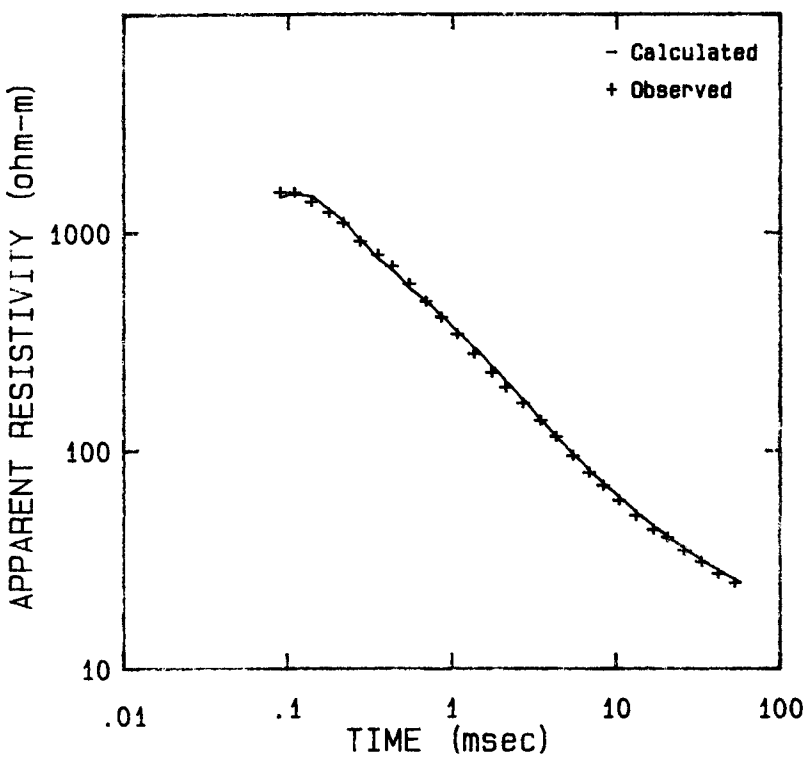
ARAMETER	NAME	FINAL SOLUTION	RESISTIVITY	LAYER DEPTH
1	SIGMA(1) =	.67666E-03	.14779E+04	
2	SIGMA(2) =	.13068E-01	.76525E+02	
3	SIGMA(3) =	.15046E+00	.66463E+01	
4	SIGMA(4) =	.39343E-02	.25417E+03	
5	THICK(1) =	.15643E+03		.15643E+03
6	THICK(2) =	.14228E+03		.29871E+03
7	THICK(3) =	.27730E+03		.57601E+03
8	SHIFT =	.20700E+03		


STATION: OR5
+ 30COIL LO
* 30COIL HI
# 3LOOP HI
SANTA FE
MEDICINE LAKE
10K
1K
nV/Am
100
10
.01
.1
1
10
100
t, ms

EMSURVEYS TEM INVERSION

MEDICINE LAKE
STATION: OR6





MODEL

RESISTIVITY (ohm-m)	THICKNESS (meters)
711	87
2640	249
40	148
11	

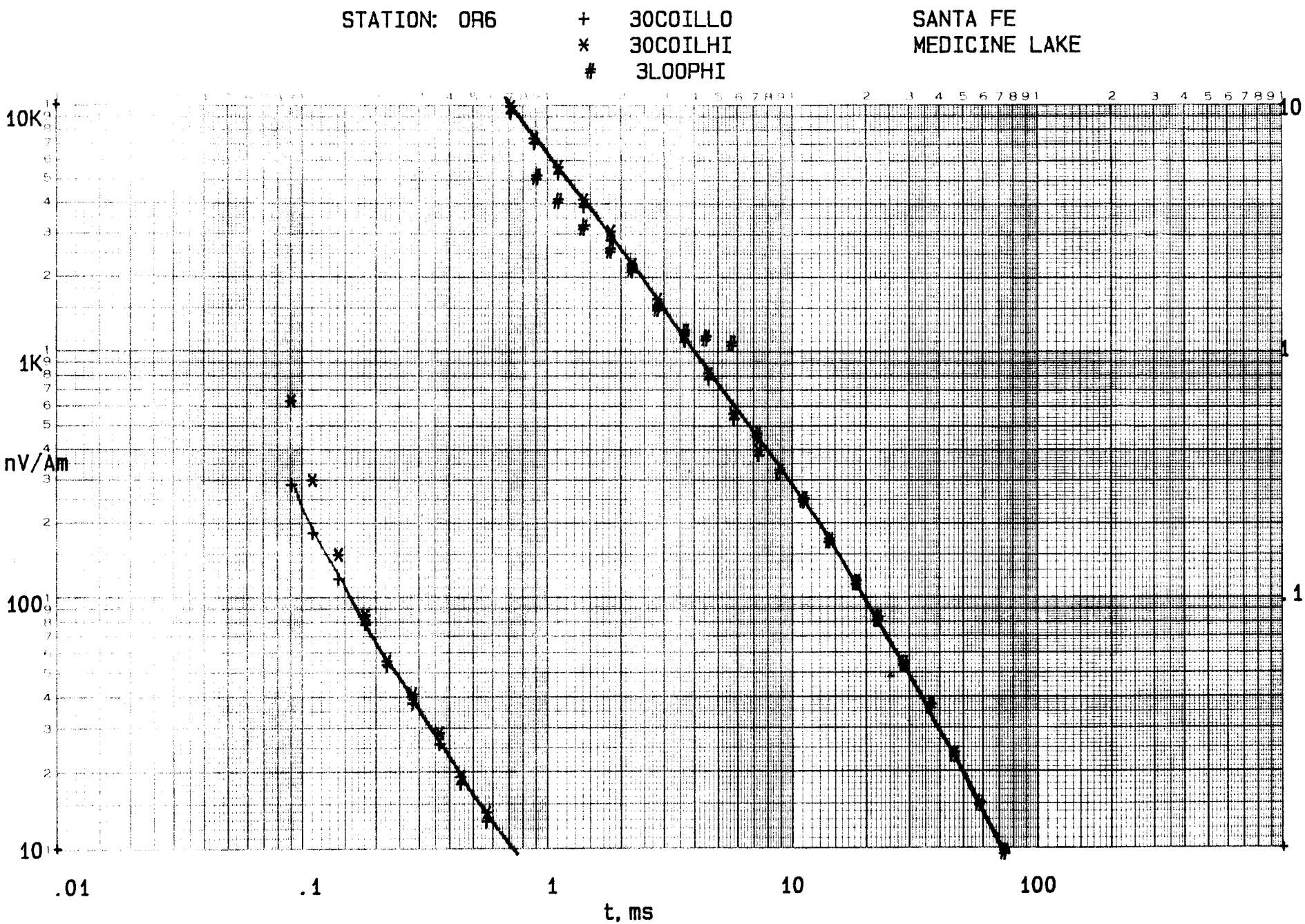
ELECTROMA TIC SURVEYS INC.

MEDICINE LAKE OR6

I	TIME (sec)	VOLTAGE (nV/Am^2)	CALC.VOLT	RESIDUAL	%RES.ERR
1	.8900E-04	.3010E+03	.3288E+03	-.2778E+02	-.8449E+01
2	.1100E-03	.1910E+03	.1867E+03	.4334E+01	.2322E+01
3	.1400E-03	.1240E+03	.1121E+03	.1189E+02	.1061E+02
4	.1770E-03	.7830E+02	.7473E+02	.3574E+01	.4783E+01
5	.2200E-03	.5570E+02	.5378E+02	.1920E+01	.3570E+01
6	.2800E-03	.4087E+02	.3999E+02	.8813E+00	.2204E+01
7	.3550E-03	.2690E+02	.2885E+02	-.1950E+01	-.6760E+01
8	.4430E-03	.1950E+02	.2095E+02	-.1446E+01	-.6904E+01
[illegible]	.5540E-03	.1410E+02	.1539E+02	-.1292E+01	-.8395E+01
[illegible]	.7130E-03	.1030E+02	.1046E+02	-.1618E+00	-.1547E+01
[illegible]	.8810E-03	.7750E+01	.7700E+01	.5018E-01	.6517E+00
2	.1090E-02	.5800E+01	.5708E+01	.9209E-01	.1613E+01
3	.1410E-02	.4310E+01	.4016E+01	.2939E+00	.7318E+01
14	.1790E-02	.3110E+01	.2946E+01	.1643E+00	.5579E+01
15	.2220E-02	.2390E+01	.2248E+01	.1419E+00	.6311E+01
6	.2850E-02	.1670E+01	.1636E+01	.3358E-01	.2052E+01
17	.3600E-02	.1170E+01	.1212E+01	-.4153E-01	-.3428E+01
18	.4490E-02	.8680E+00	.9086E+00	-.4063E-01	-.4472E+01
9	.5700E-02	.6510E+00	.6608E+00	-.9788E-02	-.1481E+01
0	.7190E-02	.4720E+00	.4791E+00	-.7136E-02	-.1489E+01
21	.8800E-02	.3520E+00	.3588E+00	-.6803E-02	-.1896E+01
2	.1110E-01	.2540E+00	.2537E+00	.3353E-03	.1322E+00
3	.1400E-01	.1770E+00	.1767E+00	.3335E-03	.1888E+00
24	.1800E-01	.1180E+00	.1175E+00	.4613E-03	.3924E+00
25	.2200E-01	.8100E-01	.8377E-01	-.2766E-02	-.3302E+01
6	.2800E-01	.5400E-01	.5519E-01	-.1188E-02	-.2152E+01
27	.3600E-01	.3500E-01	.3534E-01	-.3378E-03	-.9560E+00
28	.4500E-01	.2400E-01	.2356E-01	.4426E-03	.1879E+01
[illegible]	.5700E-01	.1500E-01	.1518E-01	-.1830E-03	-.1205E+01

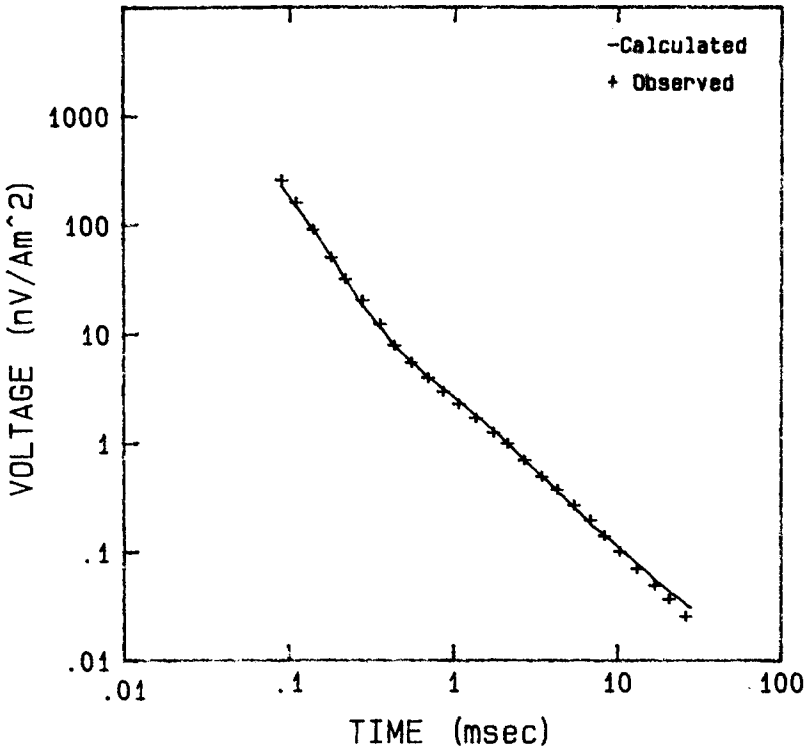
RMSERR= 4.51

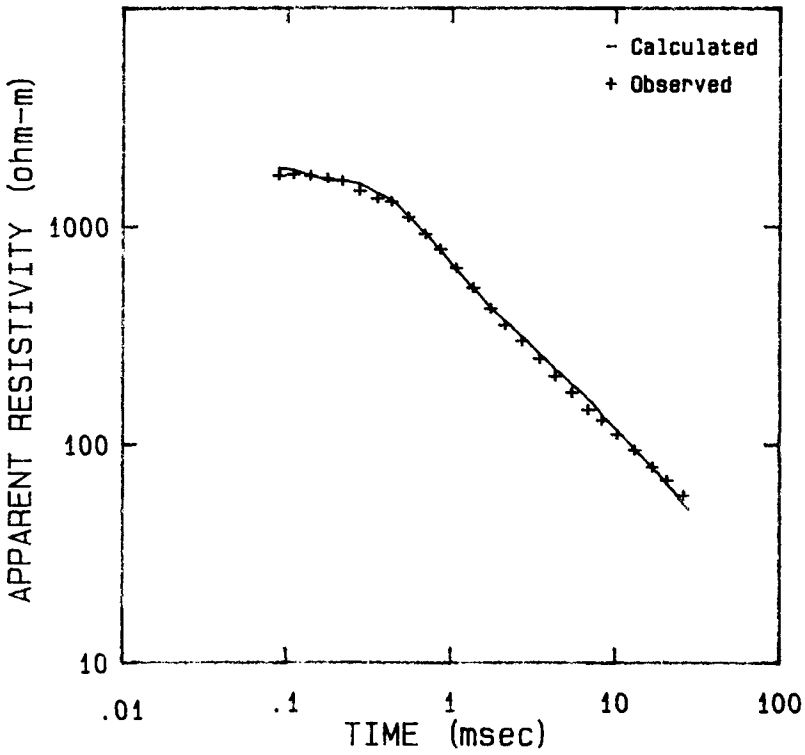
RAMETER	NAME	FINAL SOLUTION	RESISTIVITY	LAYER DEPTH
1	SIGMA(1) =	.14060E-02	.71121E+03	
2	SIGMA(2) =	.37875E-03	.26403E+04	
3	SIGMA(3) =	.25179E-01	.39715E+02	
4	SIGMA(4) =	.93063E-01	.10745E+02	
[illegible]	THICK(1) =	.87466E+02		.87466E+02
6	THICK(2) =	.24826E+03		.33573E+03
7	THICK(3) =	.14875E+03		.48447E+03
8	SHIFT =	.20700E+03		


STATION: OR6
+ 30COILLO
* 30COILHI
# 3LOOPHI
SANTA FE
MEDICINE LAKE
10K
1K
100
10
nV/Am
10
1
1
.01
.1
1
10
100
t, ms

EMSURVEYS TEM INVERSION

MEDICINE LAKE
STATION: OR7





MODEL

RESISTIVITY (ohm-m)	THICKNESS (meters)
4624	52
2116	210
493	302
28	297
10	

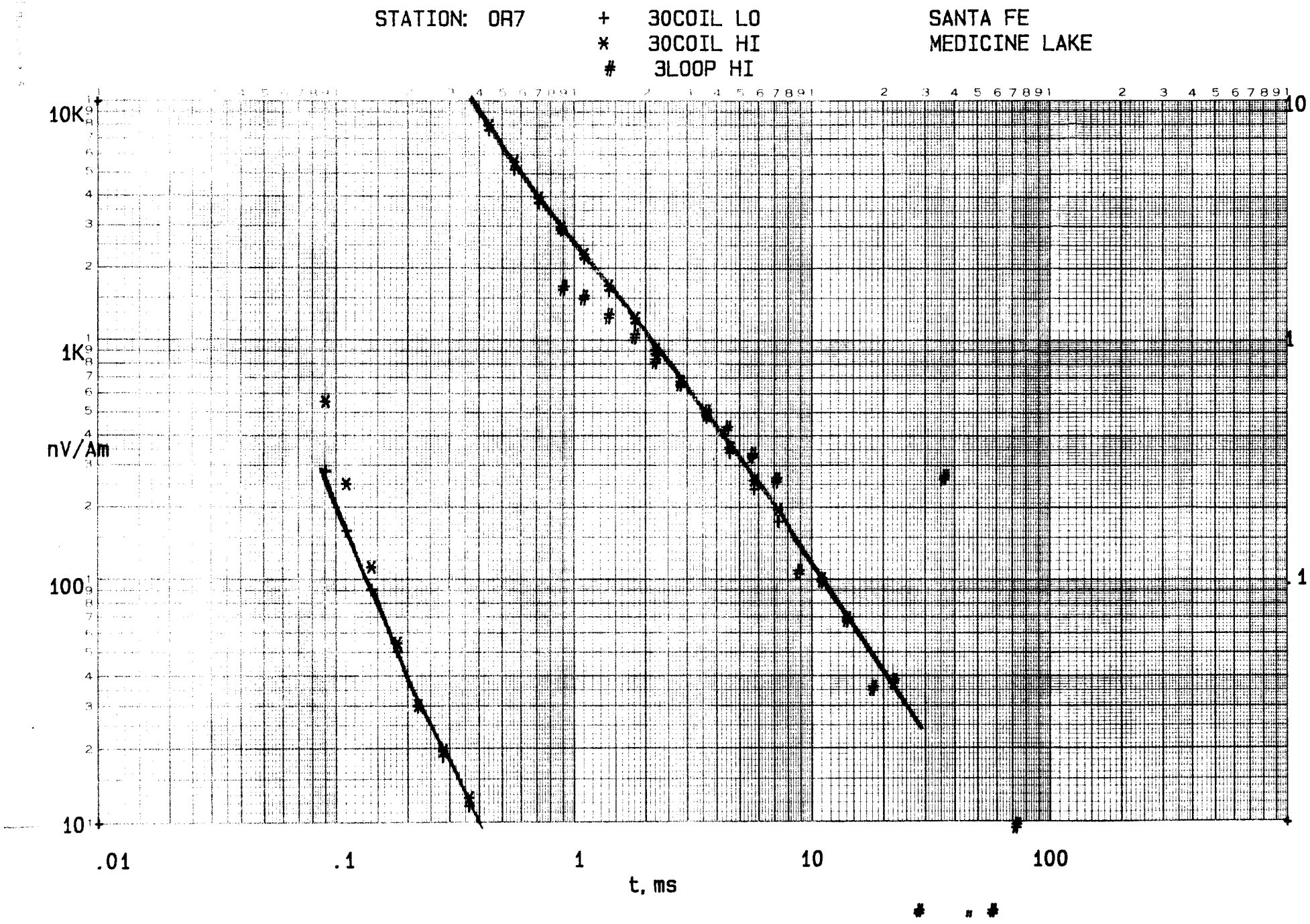
ELECTROMA TIC SURVEYS INC.

MEDICINE LAKE OR7

I	TIME (sec)	VOLTAGE (nV/Am^2)	CALC.VOLT	RESIDUAL	%RES.ERR
1	.8900E-04	.2578E+03	.2283E+03	.2953E+02	.1294E+02
2	.1100E-03	.1602E+03	.1489E+03	.1130E+02	.7586E+01
3	.1400E-03	.9005E+02	.8910E+02	.9529E+00	.1069E+01
4	.1770E-03	.4995E+02	.5185E+02	-.1900E+01	-.3665E+01
5	.2200E-03	.3149E+02	.3103E+02	.4581E+00	.1476E+01
	.2800E-03	.2026E+02	.1820E+02	.2058E+01	.1131E+02
	.3550E-03	.1221E+02	.1123E+02	.9761E+00	.8689E+01
	.4430E-03	.7750E+01	.7554E+01	.1959E+00	.2593E+01
9	.5540E-03	.5430E+01	.5434E+01	-.3931E-02	-.7233E-01
10	.7130E-03	.3920E+01	.3952E+01	-.3241E-01	-.8199E+00
11	.8810E-03	.2915E+01	.3052E+01	-.1371E+00	-.4492E+01
2	.1090E-02	.2257E+01	.2372E+01	-.1154E+00	-.4864E+01
3	.1410E-02	.1690E+01	.1734E+01	-.4375E-01	-.2523E+01
14	.1790E-02	.1250E+01	.1267E+01	-.1741E-01	-.1374E+01
5	.2220E-02	.9820E+00	.9435E+00	.3851E-01	.4082E+01
6	.2850E-02	.6920E+00	.6623E+00	.2973E-01	.4489E+01
17	.3600E-02	.4890E+00	.4690E+00	.2003E-01	.4272E+01
8	.4490E-02	.3700E+00	.3395E+00	.3051E-01	.8989E+01
	.5700E-02	.2660E+00	.2411E+00	.2486E-01	.1031E+02
	.7190E-02	.1950E+00	.1753E+00	.1973E-01	.1126E+02
21	.8800E-02	.1400E+00	.1346E+00	.5413E-02	.4022E+01
2	.1110E-01	.1000E+00	.9962E-01	.3781E-03	.3796E+00
3	.1400E-01	.7000E-01	.7300E-01	-.2995E-02	-.4103E+01
24	.1800E-01	.4900E-01	.5232E-01	-.3320E-02	-.6346E+01
5	.2200E-01	.3600E-01	.4069E-01	-.4692E-02	-.1153E+02
6	.2800E-01	.2500E-01	.3090E-01	-.5896E-02	-.1908E+02

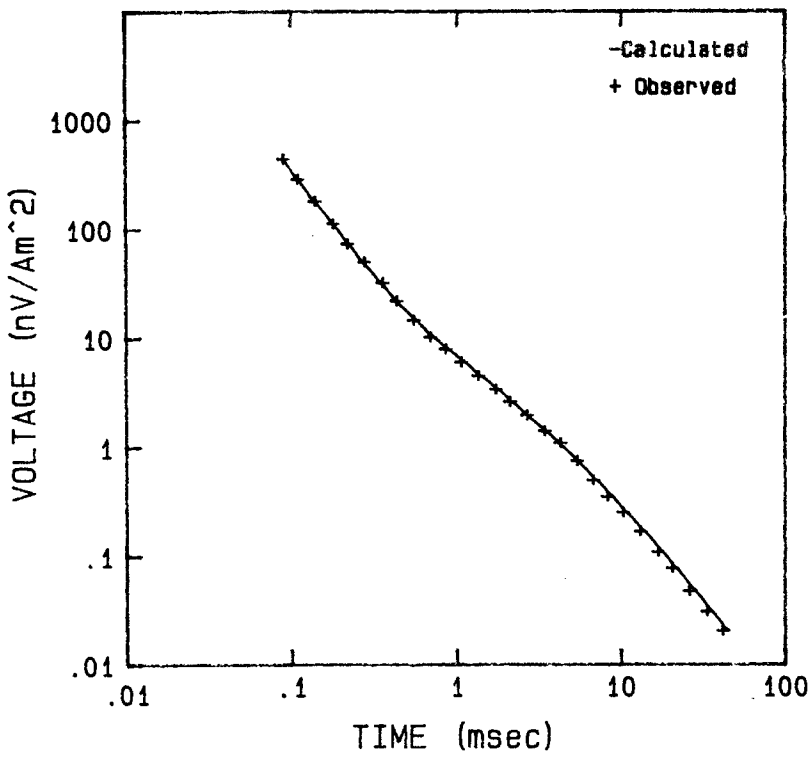
* RMSERR= 7.45

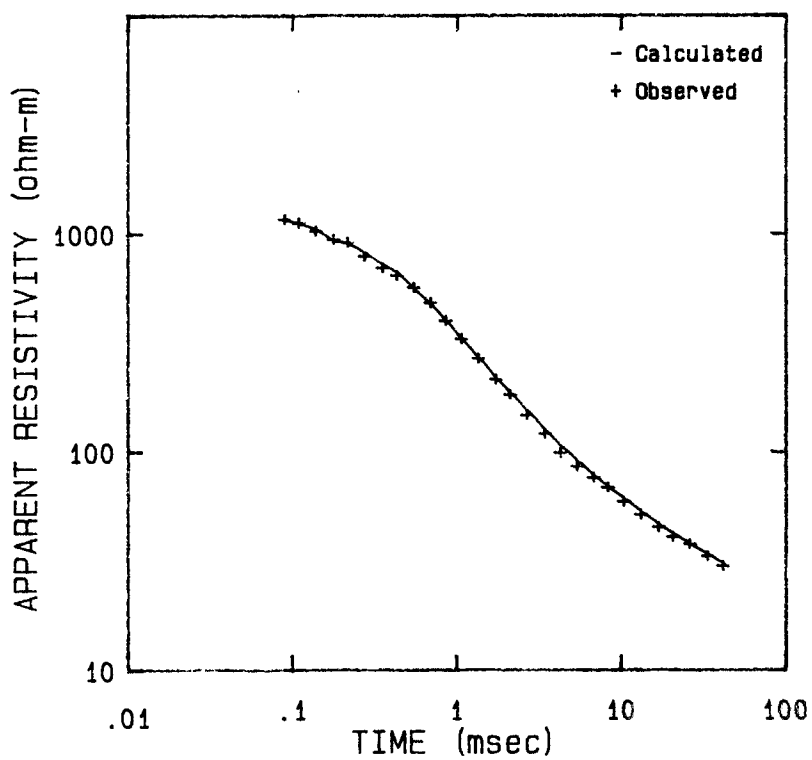
ARAMETER	NAME	FINAL SOLUTION	RESISTIVITY	LAYER DEPTH
1	SIGMA(1) =	.21628E-03	.46236E+04	
2	SIGMA(2) =	.47260E-03	.21160E+04	
3	SIGMA(3) =	.20302E-02	.49256E+03	
4	SIGMA(4) =	.35900E-01	.27855E+02	
5	SIGMA(5) =	.10370E+00	.96428E+01	
6	THICK(1) =	.51839E+02		.51839E+02
7	THICK(2) =	.21055E+03		.26239E+03
	THICK(3) =	.30174E+03		.56413E+03
	THICK(4) =	.29727E+03		.86140E+03
10	SHIFT =	.20700E+03		


STATION: OR7
+ 30COIL LO
* 30COIL HI
# 3LOOP HI
SANTA FE
MEDICINE LAKE
10K
1K
nV/Am
100
10
.01
.1
1
10
100
t, ms

EMSURVEYS TEM INVERSION

MEDICINE LAKE
STATION: OR8





MODEL

RESISTIVITY (ohm-m)	THICKNESS (meters)
2497	82
664	218
89	122
15	

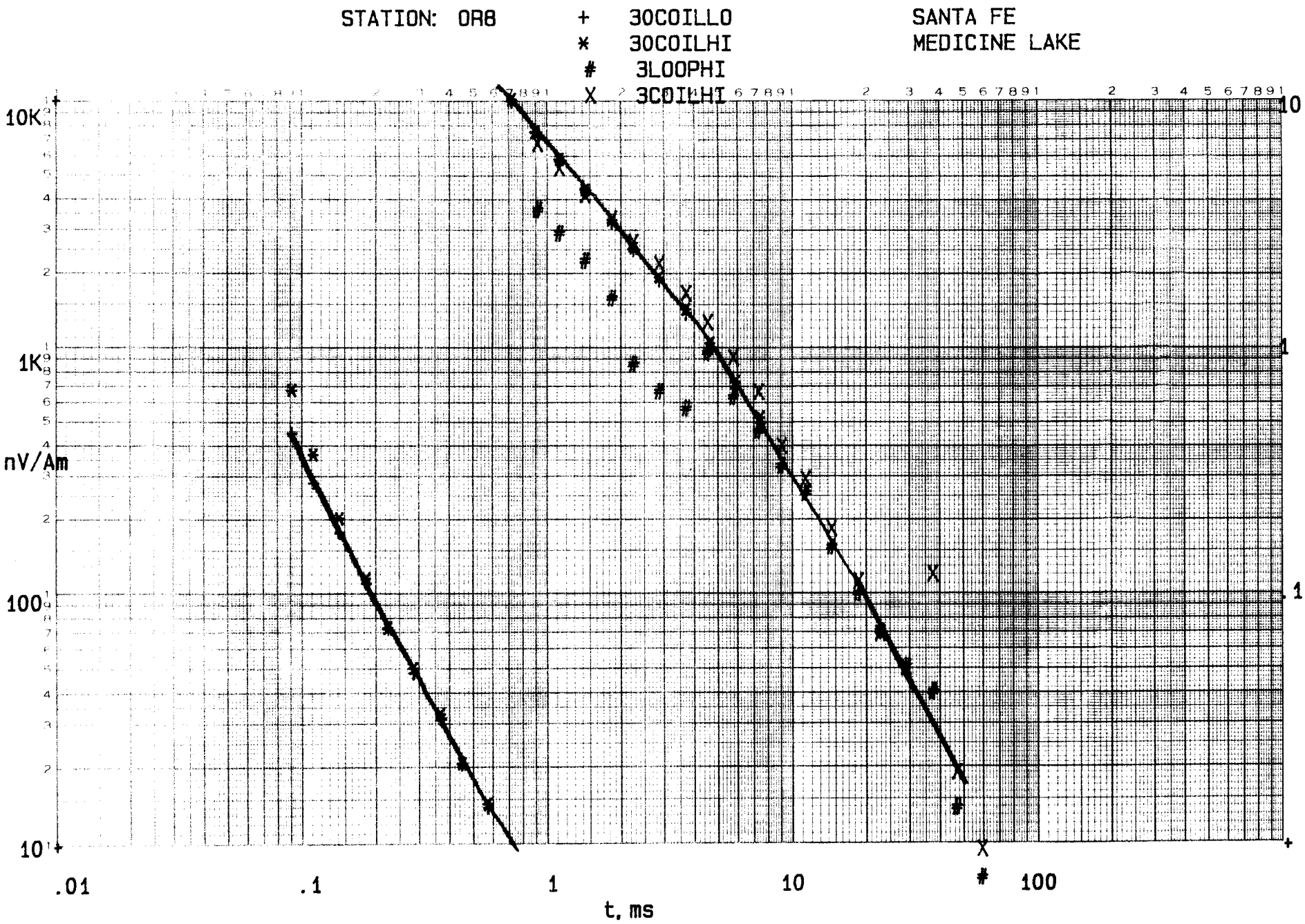
ELECTROMA TIC SURVEYS INC.

MEDICINE LAKE OR8

I	TIME (sec)	VOLTAGE (nV/Am^2)	CALC.VOLT	RESIDUAL	%RES.ERR
1	.8900E-04	.4480E+03	.4506E+03	-.2612E+01	-.5797E+00
2	.1100E-03	.2890E+03	.2922E+03	-.3243E+01	-.1110E+01
3	.1400E-03	.1810E+03	.1782E+03	.2754E+01	.1545E+01
4	.1770E-03	.1127E+03	.1126E+03	.8842E-01	.7852E-01
5	.2200E-03	.7356E+02	.7478E+02	-.1222E+01	-.1634E+01
6	.2800E-03	.5029E+02	.4741E+02	.2880E+01	.6075E+01
[illegible]	.3550E-03	.3231E+02	.3060E+02	.1705E+01	.5572E+01
8	.4430E-03	.2209E+02	.2115E+02	.9363E+00	.4426E+01
9	.5540E-03	.1463E+02	.1512E+02	-.4920E+00	-.3253E+01
10	.7130E-03	.1025E+02	.1066E+02	-.4108E+00	-.3853E+01
11	.8810E-03	.7970E+01	.8125E+01	-.1548E+00	-.1905E+01
2	.1090E-02	.6080E+01	.6255E+01	-.1748E+00	-.2795E+01
.3	.1410E-02	.4530E+01	.4586E+01	-.5622E-01	-.1226E+01
14	.1790E-02	.3380E+01	.3421E+01	-.4059E-01	-.1187E+01
5	.2220E-02	.2610E+01	.2611E+01	-.9420E-03	-.3608E-01
6	.2850E-02	.1970E+01	.1889E+01	.8066E-01	.4269E+01
17	.3600E-02	.1410E+01	.1376E+01	.3388E-01	.2462E+01
[illegible]	.4490E-02	.1100E+01	.1011E+01	.8879E-01	.8781E+01
	.5700E-02	.7510E+00	.7142E+00	.3680E-01	.5153E+01
	.7190E-02	.4980E+00	.5020E+00	-.4046E-02	-.8060E+00
21	.8800E-02	.3530E+00	.3654E+00	-.1238E-01	-.3388E+01
2	.1110E-01	.2540E+00	.2505E+00	.3500E-02	.1397E+01
3	.1400E-01	.1700E+00	.1700E+00	.2176E-04	.1280E-01
24	.1800E-01	.1100E+00	.1104E+00	-.4456E-03	-.4035E+00
5	.2200E-01	.7800E-01	.7733E-01	.6697E-03	.8660E+00
6	.2800E-01	.4800E-01	.4968E-01	-.1678E-02	-.3378E+01
27	.3600E-01	.3100E-01	.3130E-01	-.2991E-03	-.9557E+00
28	.4500E-01	.2100E-01	.2095E-01	.4770E-04	.2277E+00

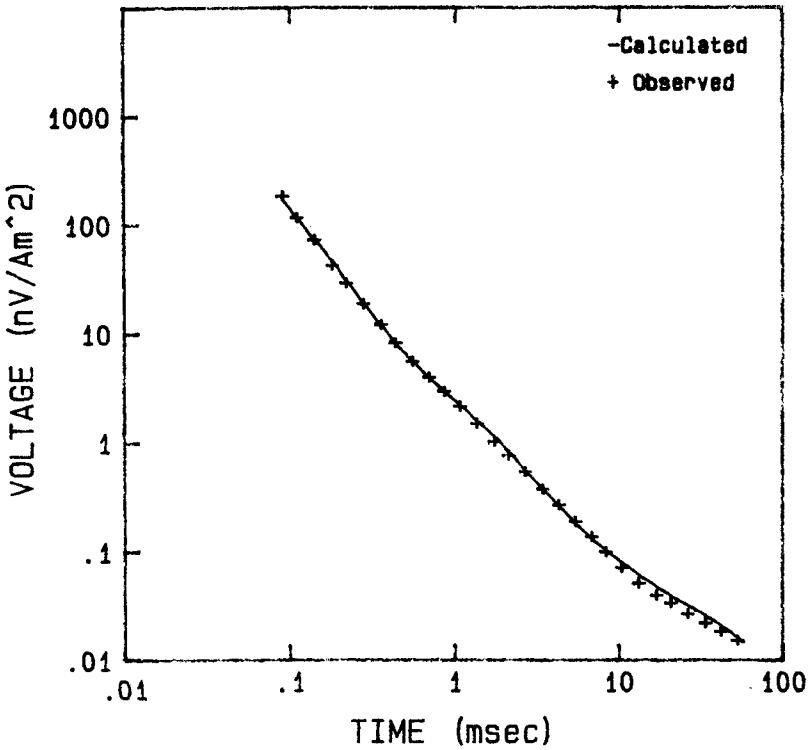
RMSERR= 3.21

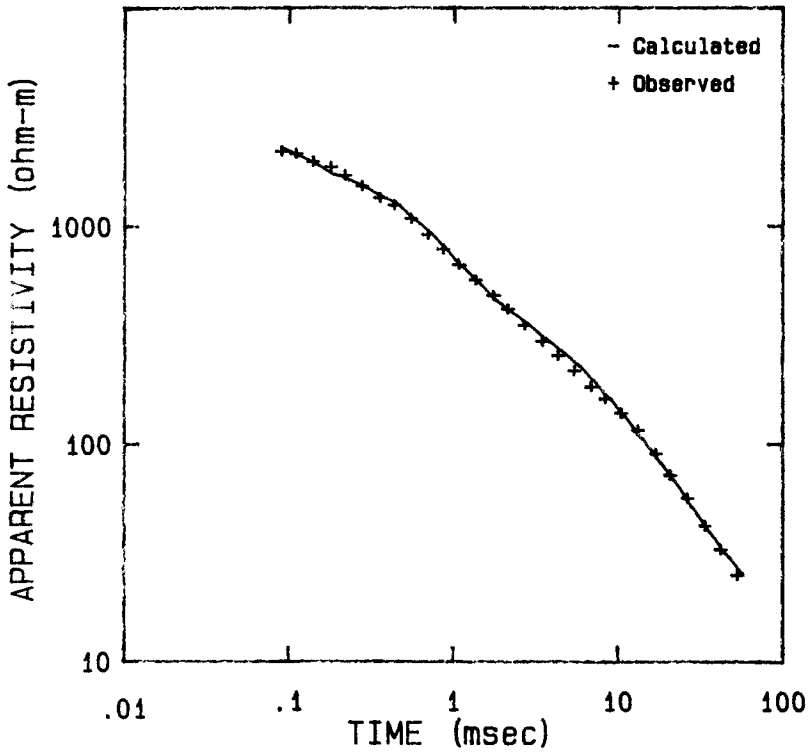
RAMETER	NAME	FINAL SOLUTION	RESISTIVITY	LAYER DEPTH
1	SIGMA(1) =	.40050E-03	.24969E+04	
2	SIGMA(2) =	.15049E-02	.66450E+03	
3	SIGMA(3) =	.11174E-01	.89497E+02	
4	SIGMA(4) =	.65254E-01	.15325E+02	
[illegible]	THICK(1) =	.81616E+02		.81616E+02
	THICK(2) =	.21892E+03		.30053E+03
[illegible]	THICK(3) =	.12147E+03		.42201E+03
8	SHIFT =	.20700E+03		


STATION: OR8
+ 30COILLO
* 30COILHI
# 3LOOPHI
X 3COILHI
SANTA FE
MEDICINE LAKE
10K
1K
100
10
nV/Am
.01
.1
1
10
100
t, ms
10
1
.1

EMSURVEYS TEM INVERSION

MEDICINE LAKE
STATION: OR9





MODEL

RESISTIVITY (ohm-m)	THICKNESS (meters)
4818	128
1351	254
263	224
33	315
5	

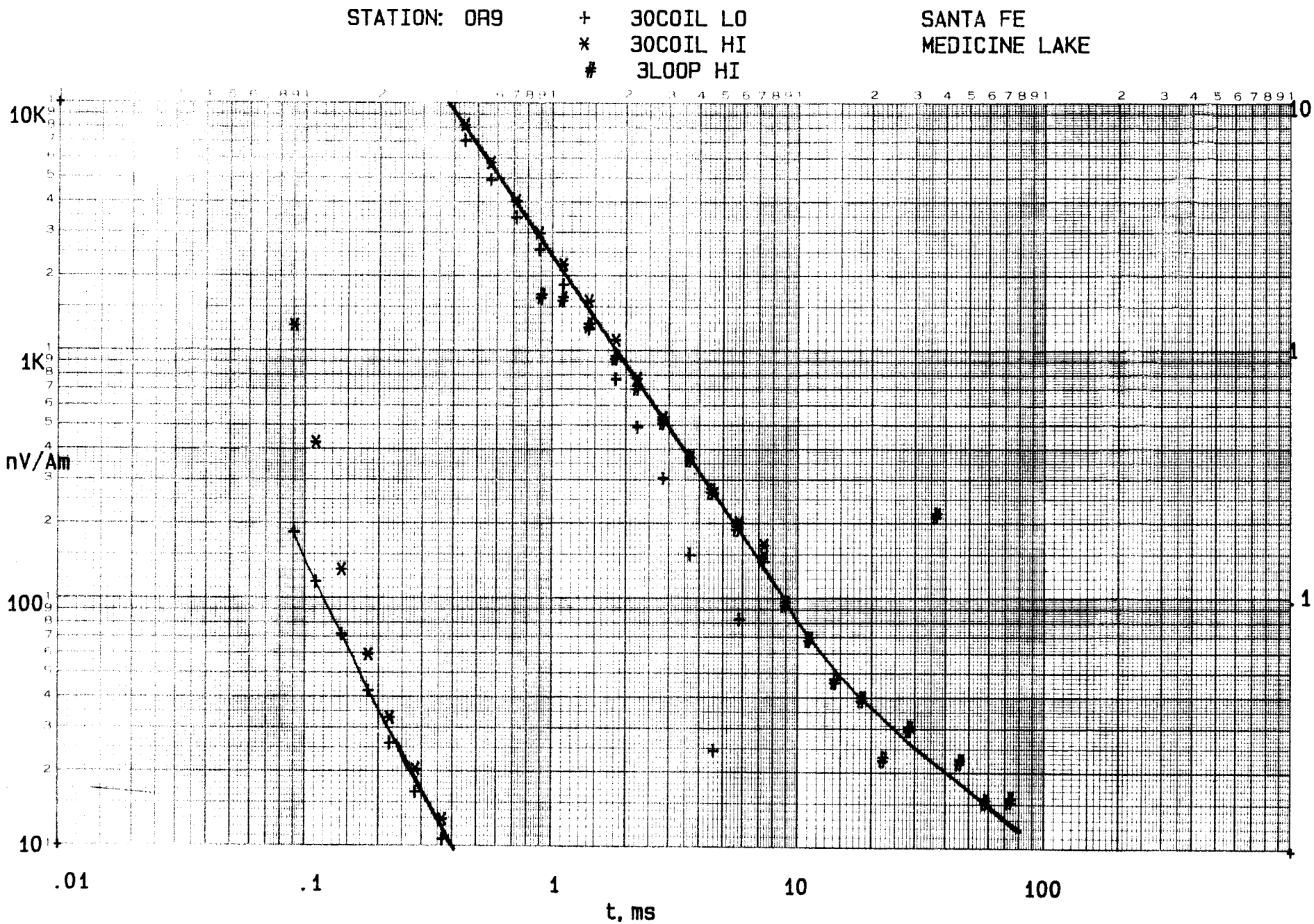
ELECTROMAGNETIC SURVEYS INC.

MEDICINE LAKE OR9

I	TIME (sec)	VOLTAGE (nV/Am^2)	CALC.VOLT	RESIDUAL	%RES.ERR
	.8900E-04	.1840E+03	.1728E+03	.1122E+02	.6493E+01
2	.1100E-03	.1160E+03	.1166E+03	-.6273E+00	-.5379E+00
3	.1400E-03	.7230E+02	.7313E+02	-.8282E+00	-.1132E+01
4	.1770E-03	.4200E+02	.4644E+02	-.4441E+01	-.9563E+01
5	.2200E-03	.2910E+02	.3035E+02	-.1250E+01	-.4117E+01
6	.2800E-03	.1880E+02	.1874E+02	.6043E-01	.3225E+00
7	.3550E-03	.1210E+02	.1171E+02	.3943E+00	.3368E+01
8	.4430E-03	.8200E+01	.7880E+01	.3196E+00	.4056E+01
9	.5540E-03	.5570E+01	.5490E+01	.8044E-01	.1465E+01
0	.7130E-03	.3970E+01	.3787E+01	.1833E+00	.4841E+01
1	.8810E-03	.2920E+01	.2845E+01	.7537E-01	.2650E+01
2	.1090E-02	.2140E+01	.2160E+01	-.1975E-01	-.9143E+00
3	.1410E-02	.1490E+01	.1529E+01	-.3863E-01	-.2527E+01
4	.1790E-02	.1010E+01	.1088E+01	-.7781E-01	-.7153E+01
5	.2220E-02	.7620E+00	.7856E+00	-.2361E-01	-.3005E+01
6	.2850E-02	.5400E+00	.5238E+00	.1618E-01	.3089E+01
7	.3600E-02	.3730E+00	.3535E+00	.1951E-01	.5520E+01
8	.4490E-02	.2680E+00	.2460E+00	.2199E-01	.8939E+01
	.5700E-02	.1890E+00	.1700E+00	.1897E-01	.1116E+02
	.7190E-02	.1360E+00	.1233E+00	.1266E-01	.1026E+02
1	.8800E-02	.9900E-01	.9697E-01	.2034E-02	.2097E+01
2	.1110E-01	.7100E-01	.7502E-01	-.4017E-02	-.5355E+01
3	.1400E-01	.5100E-01	.5811E-01	-.7112E-02	-.1224E+02
4	.1800E-01	.4000E-01	.4514E-01	-.5136E-02	-.1138E+02
5	.2200E-01	.3400E-01	.3743E-01	-.3431E-02	-.9167E+01
6	.2800E-01	.2700E-01	.3050E-01	-.3497E-02	-.1147E+02
7	.3600E-01	.2200E-01	.2431E-01	-.2311E-02	-.9507E+01
8	.4500E-01	.1800E-01	.1953E-01	-.1530E-02	-.7835E+01
9	.5700E-01	.1500E-01	.1478E-01	.2223E-03	.1504E+01

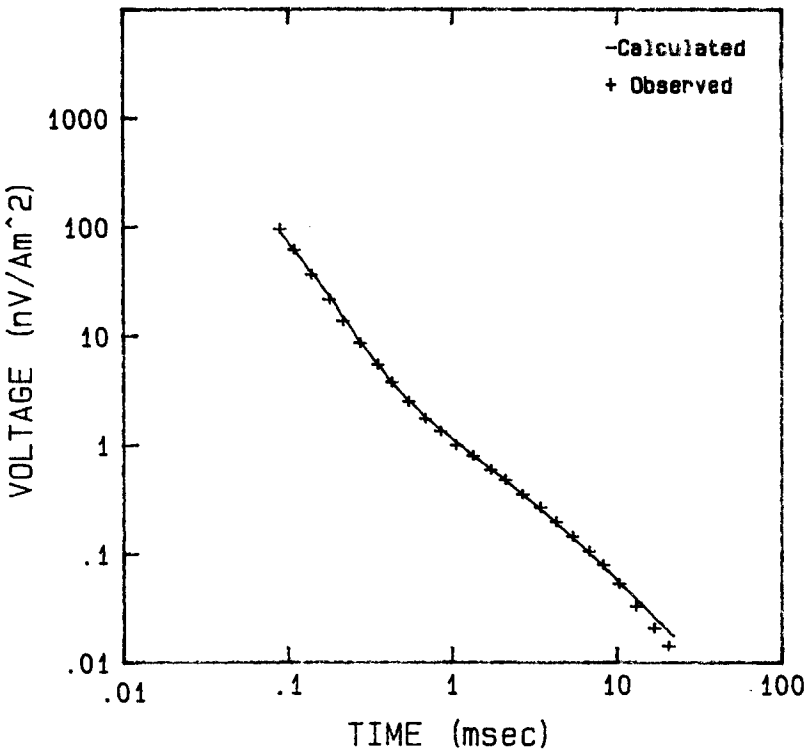
RMSERR= 6.73

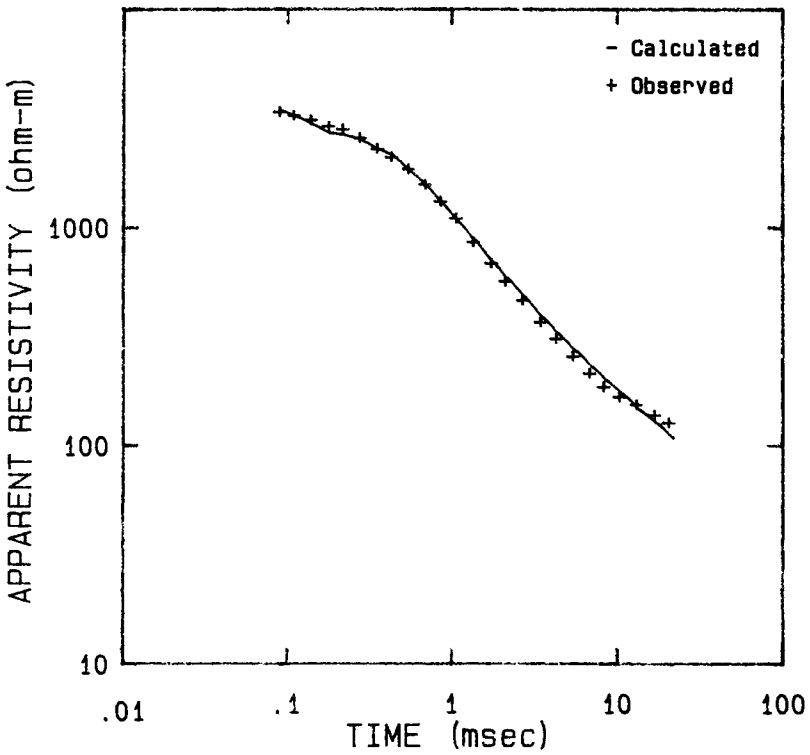
RAMETER	NAME	FINAL SOLUTION	RESISTIVITY	LAYER DEPTH
1	SIGMA(1) =	.20757E-03	.48178E+04	
2	SIGMA(2) =	.74024E-03	.13509E+04	
	SIGMA(3) =	.37982E-02	.26329E+03	
	SIGMA(4) =	.29944E-01	.33396E+02	
	SIGMA(5) =	.20783E+00	.48116E+01	
6	THICK(1) =	.12777E+03		.12777E+03
7	THICK(2) =	.25448E+03		.38226E+03
8	THICK(3) =	.22325E+03		.60551E+03
9	THICK(4) =	.31535E+03		.92086E+03
0	SHIFT =	.20700E+03		


STATION: OR9
+ 30COIL LO
* 30COIL HI
# 3LOOP HI
SANTA FE
MEDICINE LAKE
10K
1K
100
10
nV/Am
10
1
1
.01
.1
1
10
100
t, ms

EMSURVEYS TEM INVERSION

MEDICINE LAKE
STATION: OR10





MODEL

RESISTIVITY (ohm-m)	THICKNESS (meters)
6447	168
2226	288
512	304
42	

ELECTROMA(TIC SURVEYS INC.

MEDICINE LAKE OR10

I	TIME (sec)	VOLTAGE (nV/Am^2)	CALC.VOLT	RESIDUAL	%RES.ERR
1	.8900E-04	.9670E+02	.9267E+02	.4027E+01	.4345E+01
2	.1100E-03	.6220E+02	.6152E+02	.6839E+00	.1112E+01
3	.1400E-03	.3650E+02	.3828E+02	-.1784E+01	-.4659E+01
4	.1770E-03	.2160E+02	.2372E+02	-.2119E+01	-.8935E+01
5	.2200E-03	.1370E+02	.1476E+02	-.1057E+01	-.7162E+01
6	.2800E-03	.8610E+01	.8730E+01	-.1200E+00	-.1375E+01
7	.3550E-03	.5460E+01	.5439E+01	.2115E-01	.3889E+00
8	.4430E-03	.3770E+01	.3616E+01	.1535E+00	.4245E+01
9	.5540E-03	.2490E+01	.2512E+01	-.2208E-01	-.8791E+00
10	.7130E-03	.1750E+01	.1771E+01	-.2064E-01	-.1165E+01
11	.8810E-03	.1340E+01	.1357E+01	-.1666E-01	-.1228E+01
2	.1090E-02	.1000E+01	.1043E+01	-.4295E-01	-.4118E+01
13	.1410E-02	.7970E+00	.7691E+00	.2790E-01	.3628E+01
14	.1790E-02	.5950E+00	.5854E+00	.9620E-02	.1643E+01
5	.2220E-02	.4810E+00	.4553E+00	.2569E-01	.5642E+01
6	.2850E-02	.3540E+00	.3347E+00	.1930E-01	.5767E+01
17	.3600E-02	.2670E+00	.2470E+00	.1996E-01	.8080E+01
18	.4490E-02	.1990E+00	.1833E+00	.1572E-01	.8579E+01
	.5700E-02	.1460E+00	.1328E+00	.1320E-01	.9938E+01
	.7190E-02	.1070E+00	.9626E-01	.1074E-01	.1116E+02
21	.8800E-02	.8000E-01	.7202E-01	.7976E-02	.1107E+02
2	.1110E-01	.5400E-01	.5088E-01	.3119E-02	.6129E+01
3	.1400E-01	.3300E-01	.3560E-01	-.2605E-02	-.7315E+01
24	.1800E-01	.2100E-01	.2407E-01	-.3070E-02	-.1275E+02
5	.2200E-01	.1400E-01	.1759E-01	-.3586E-02	-.2039E+02

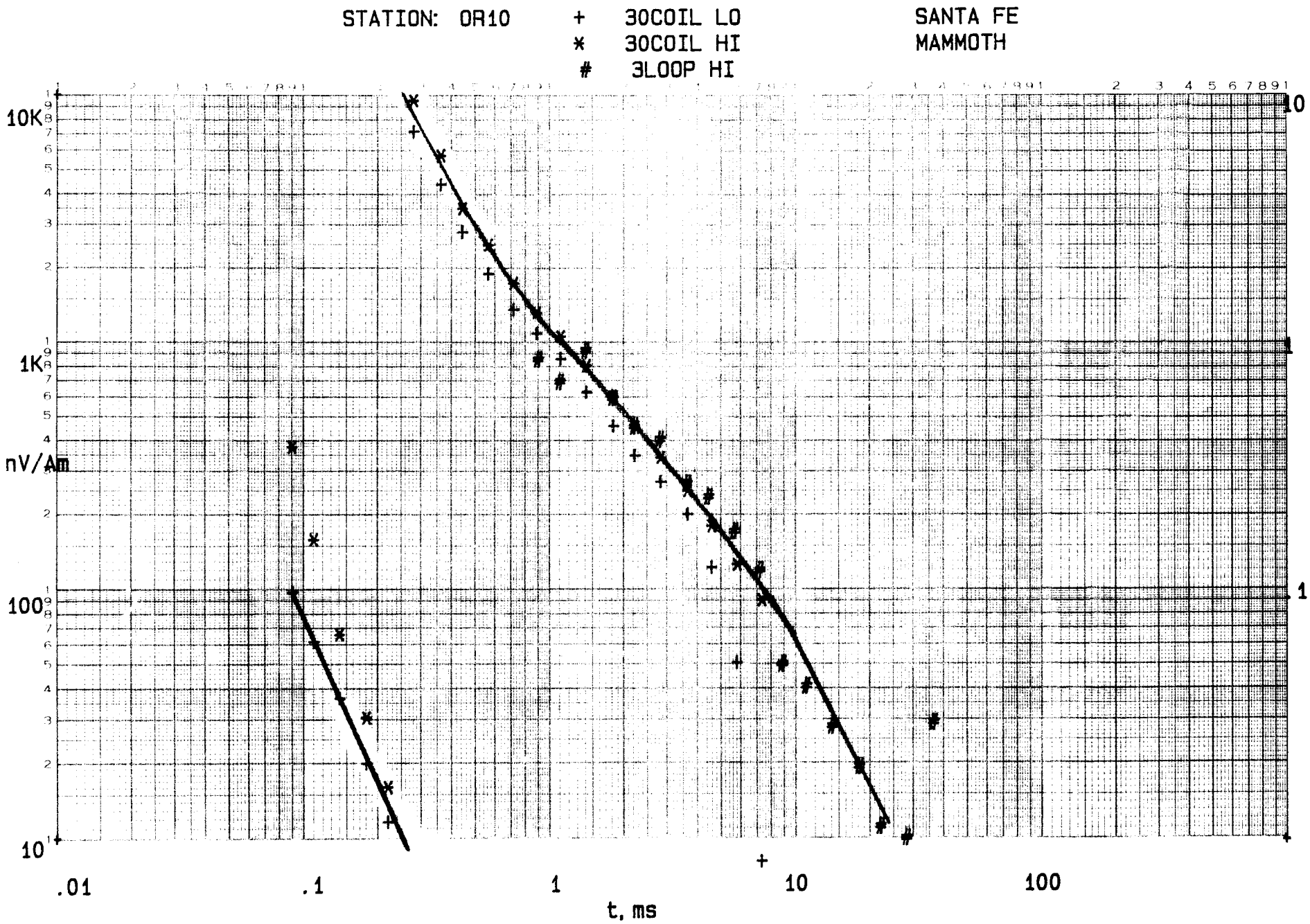
* RMSERR= 7.61

RRELATION MATRIX

.1000E+01						
.1330E+00	.1000E+01					
-.1810E+00	-.1316E+00	.1000E+01				
-.3496E+00	.4937E-01	-.1588E+00	.1000E+01			
5 .7365E+00	.9279E-01	-.2441E+00	-.2665E+00	.1000E+01		
-.6084E+00	-.2475E+00	.1891E+00	.2863E+00	-.6548E+00	.1000E+01	
-.2054E+00	-.2014E+00	.2265E+00	.1130E+00	.3113E-01	.1801E+00	.1000E

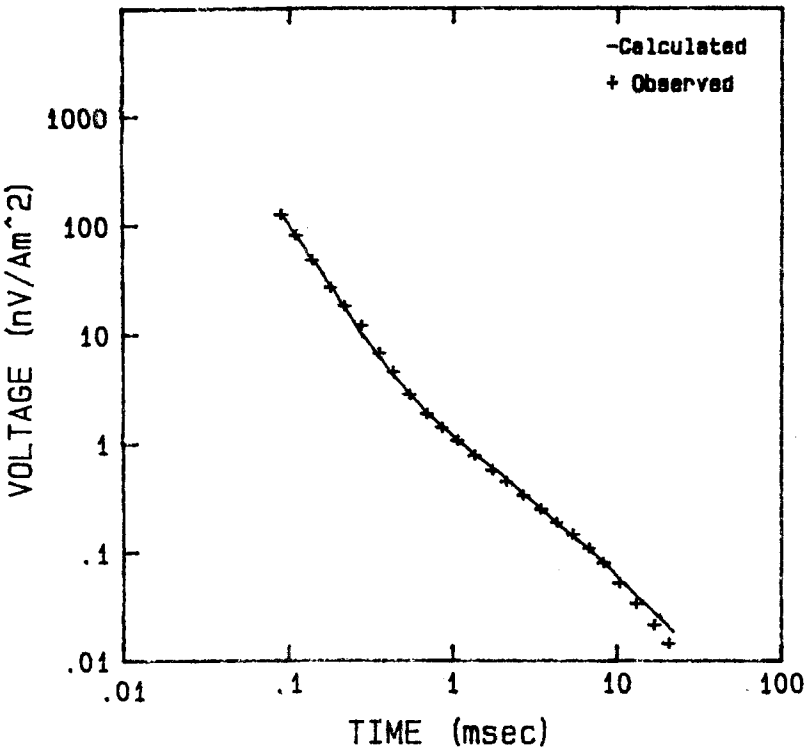
**PARM_SOL.	STD_ERROR	REL_ERROR	% ERROR **
.1551E-03	.8279E-05	.5338E-01	.5338E+01
.4491E-03	.2594E-03	.5775E+00	.5775E+02
.1953E-02	.6353E-03	.3252E+00	.3252E+02
.2378E-01	.2018E-02	.8485E-01	.8485E+01
.1676E+03	.1982E-02	.1183E-04	.1183E-02
6 .2886E+03	.3780E-02	.1310E-04	.1310E-02
7 .3035E+03	.1987E-03	.6547E-06	.6547E-04

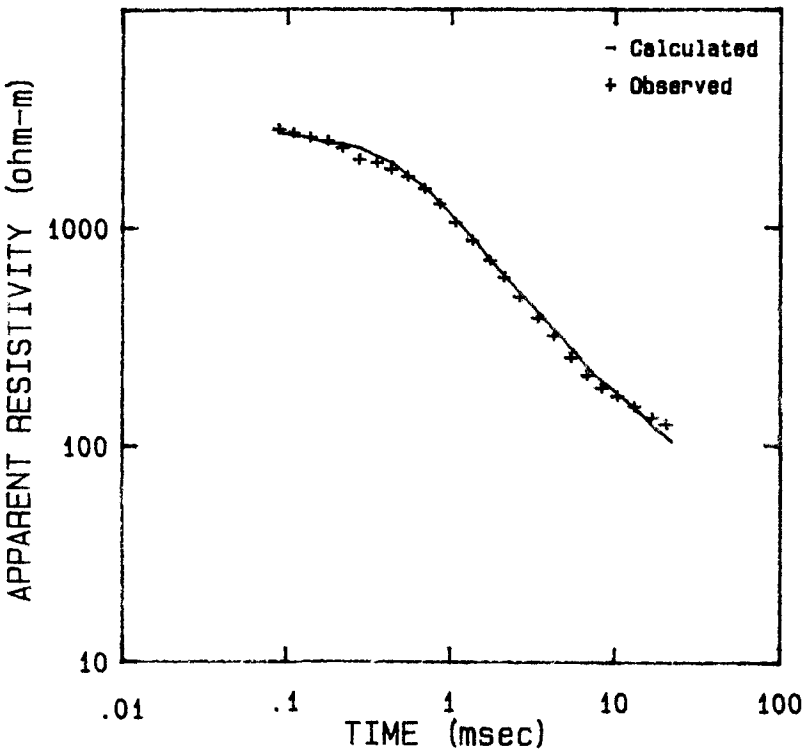
ARAMETER NAME	FINAL SOLUTION	RESISTIVITY	LAYER DEPTH
1 SIGMA(1) =	.15510E-03	.64474E+04	
2 SIGMA(2) =	.44915E-03	.22264E+04	
3 SIGMA(3) =	.19533E-02	.51197E+03	
4 SIGMA(4) =	.23783E-01	.42046E+02	
5 THICK(1) =	.16758E+03		.16758E+03
6 THICK(2) =	.28861E+03		.45620E+03
7 THICK(3) =	.30353E+03		.75973E+03
8 SHIFT =	.20700E+03		


STATION: OR10
+ 30COIL LO
* 30COIL HI
# 3LOOP HI
SANTA FE
MAMMOTH
10K
1K
100
10
nV/Am
10
1
1
.01
.1
1
10
100
t, ms

EMSURVEYS TEM INVERSION

MEDICINE LAKE
STATION: OR11





MODEL

RESISTIVITY (ohm-m)	THICKNESS (meters)
6843	220
1056	461
94	141
35	

ELECTROM ETIC SURVEYS INC.

MEDICINE LAKE OR11

I	TIME (sec)	VOLTAGE (nV/Am^2)	CALC.VOLT	RESIDUAL	%RES.ERR
	.8900E-04	.1270E+03	.1330E+03	-.5990E+01	-.4504E+01
2	.1100E-03	.8150E+02	.8437E+02	-.2869E+01	-.3400E+01
3	.1400E-03	.4790E+02	.4858E+02	-.6830E+00	-.1406E+01
4	.1770E-03	.2700E+02	.2823E+02	-.1234E+01	-.4369E+01
5	.2200E-03	.1830E+02	.1719E+02	.1107E+01	.6436E+01
6	.2800E-03	.1210E+02	.1001E+02	.2087E+01	.2085E+02
7	.3550E-03	.6760E+01	.6140E+01	.6204E+00	.1010E+02
8	.4430E-03	.4560E+01	.4091E+01	.4689E+00	.1146E+02
9	.5540E-03	.2800E+01	.2766E+01	.3373E-01	.1219E+01
0	.7130E-03	.1870E+01	.1866E+01	.3532E-02	.1892E+00
	.8810E-03	.1390E+01	.1387E+01	.2677E-02	.1930E+00
2	.1090E-02	.1070E+01	.1051E+01	.1905E-01	.1813E+01
3	.1410E-02	.7780E+00	.7696E+00	.8430E-02	.1095E+01
14	.1790E-02	.5690E+00	.5876E+00	-.1864E-01	-.3171E+01
5	.2220E-02	.4500E+00	.4555E+00	-.5548E-02	-.1218E+01
6	.2850E-02	.3360E+00	.3298E+00	.6178E-02	.1873E+01
17	.3600E-02	.2500E+00	.2386E+00	.1144E-01	.4797E+01
18	.4490E-02	.1900E+00	.1779E+00	.1212E-01	.6816E+01
9	.5700E-02	.1480E+00	.1338E+00	.1418E-01	.1060E+02
0	.7190E-02	.1100E+00	.1005E+00	.9466E-02	.9416E+01
21	.8800E-02	.8100E-01	.7611E-01	.4892E-02	.6427E+01
2	.1110E-01	.5300E-01	.5335E-01	-.3478E-03	-.6519E+00
3	.1400E-01	.3400E-01	.3709E-01	-.3094E-02	-.8340E+01
24	.1800E-01	.2200E-01	.2557E-01	-.3566E-02	-.1395E+02
5	.2200E-01	.1500E-01	.1917E-01	-.4167E-02	-.2174E+02

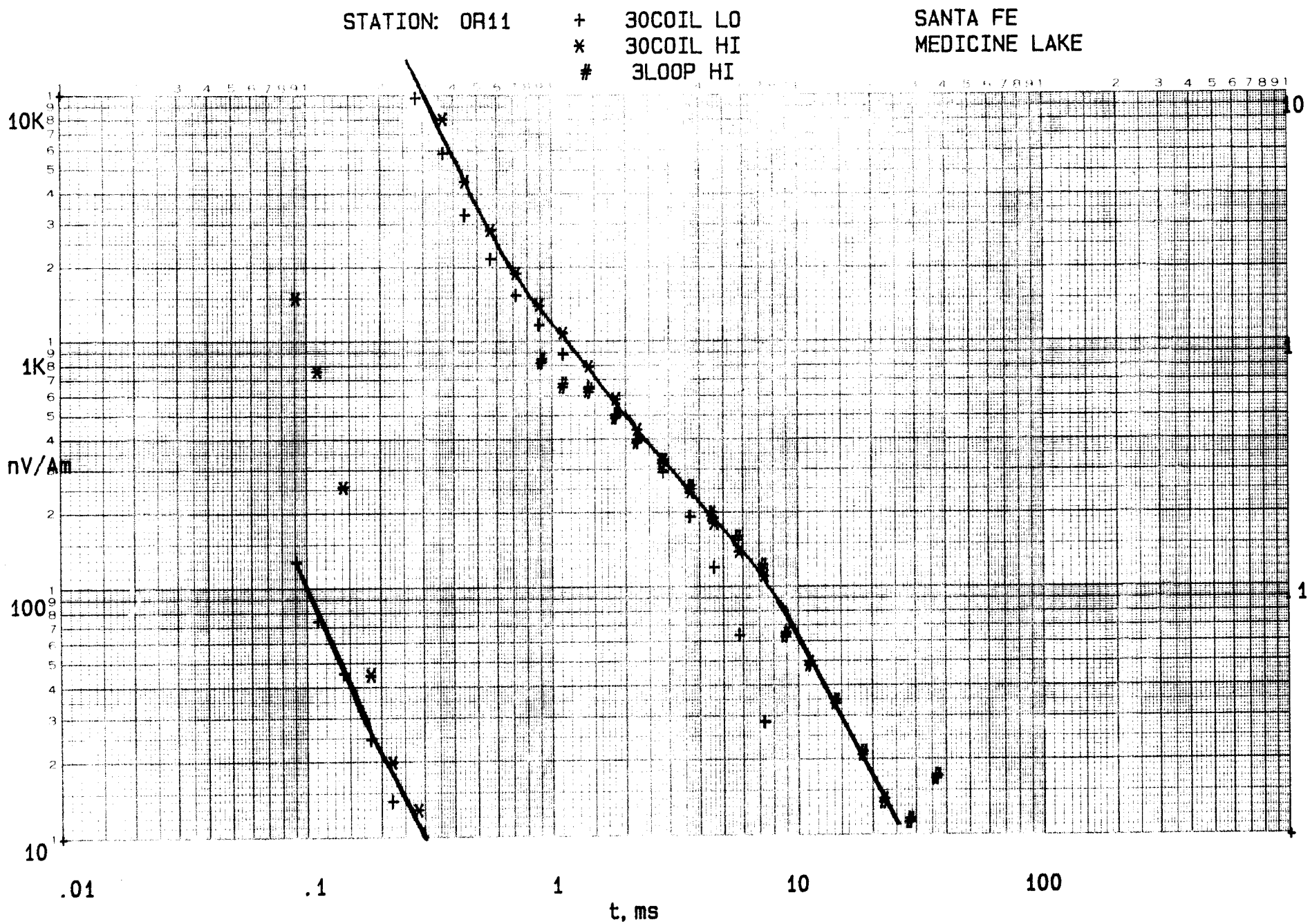
* RMSERR= 8.56

RRELATION MATRIX

	1000E+01						
	.2092E+00	.1000E+01					
	.1462E+00	-.8153E-01	.1000E+01				
	-.3804E+00	-.3314E+00	-.7805E+00	.1000E+01			
5	.1903E-01	.6449E+00	.6069E-01	-.3130E+00	.1000E+01		
6	-.4888E+00	-.7096E+00	-.1709E+00	.3665E+00	-.6770E+00	.1000E+01	
	-.5660E+00	-.1430E+00	-.5233E+00	.5021E+00	-.2253E+00	.5247E+00	.1000E

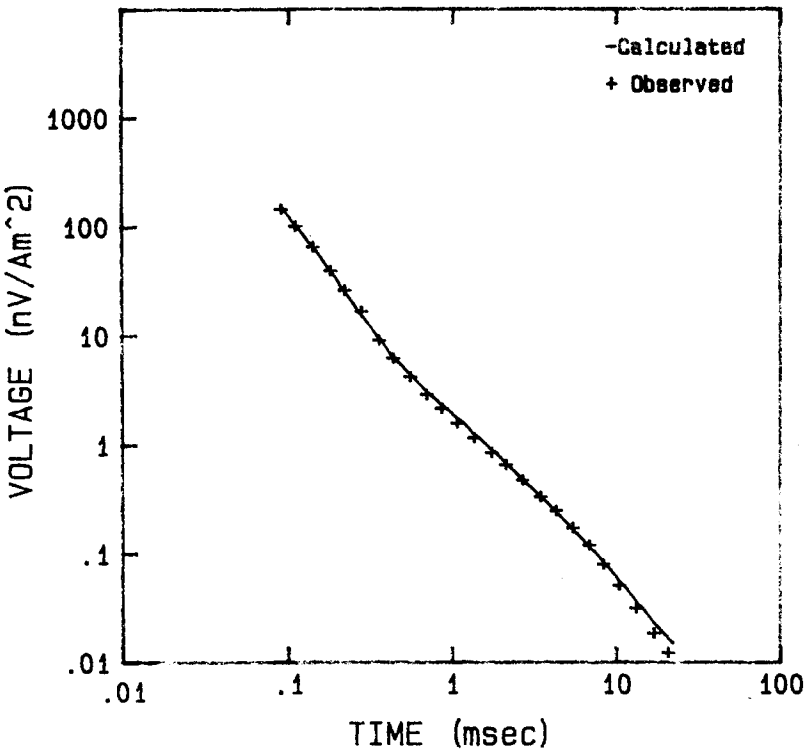
**PARM_SOL.	STD_ERROR	REL_ERROR	% ERROR **
.1461E-03	.6241E-05	.4271E-01	.4271E+01
.9466E-03	.4103E-03	.4334E+00	.4334E+02
3 .1066E-01	.2270E-02	.2130E+00	.2130E+02
.2822E-01	.5018E-02	.1778E+00	.1778E+02
.2202E+03	.3850E-02	.1749E-04	.1749E-02
6 .4606E+03	.2287E-03	.4966E-06	.4966E-04
7 .1414E+03	.3955E-02	.2798E-04	.2798E-02

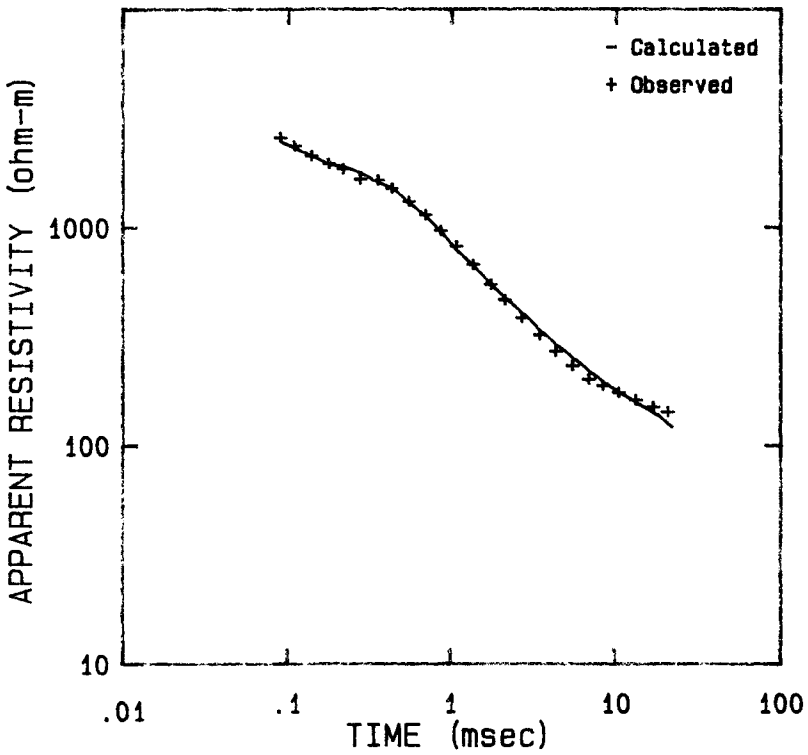
RAMETER NAME	FINAL SOLUTION	RESISTIVITY	LAYER DEPTH
1 SIGMA(1) =	.14612E-03	.68435E+04	
2 SIGMA(2) =	.94664E-03	.10564E+04	
3 SIGMA(3) =	.10655E-01	.93849E+02	
4 SIGMA(4) =	.28215E-01	.35442E+02	
5 THICK(1) =	.22019E+03		.22019E+03
6 THICK(2) =	.46055E+03		.68074E+03
7 THICK(3) =	.14137E+03		.82211E+03
8 SHIFT =	.00700E+03		


STATION: OR11
+ 30COIL LO
* 30COIL HI
# 3LOOP HI
SANTA FE
MEDICINE LAKE
10K
1K
nV/Am
100
10
.01
.1
1
10
100
t, ms

EMSURVEYS TEM INVERSION

MEDICINE LAKE
STATION: OR12





MODEL

RESISTIVITY (ohm-m)	THICKNESS (meters)
4999	255
4028	15
593	364
75	53.4
59	

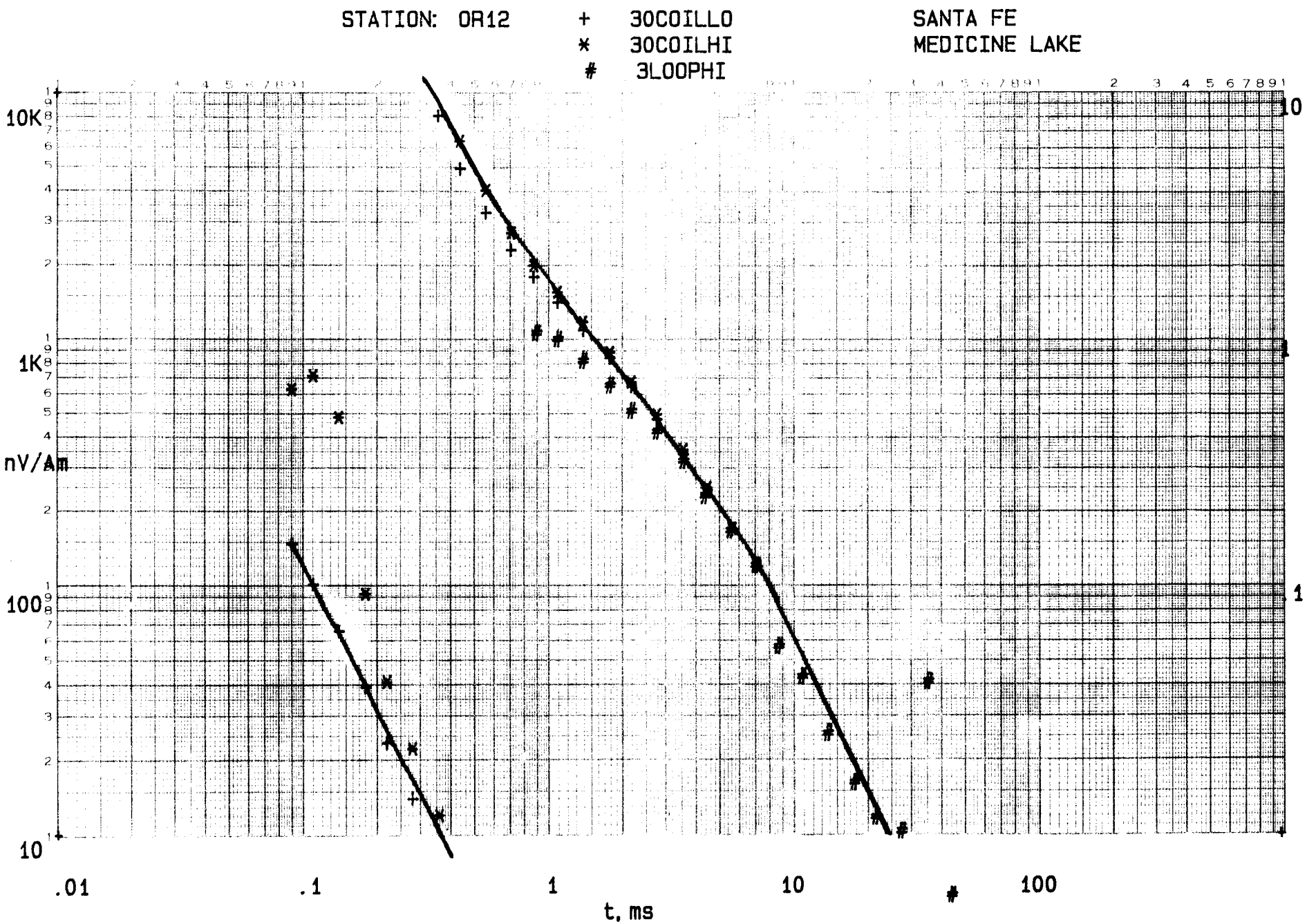
ELECTROMAG TIC SURVEYS INC.

MEDICINE LAKE OR12

I	TIME (sec)	VOLTAGE (nV/Am^2)	CALC.VOLT	RESIDUAL	%RES.ERR
1	.8900E-04	.1450E+03	.1542E+03	-.9249E+01	-.5996E+01
2	.1100E-03	.1010E+03	.1039E+03	-.2936E+01	-.2825E+01
3	.1400E-03	.6490E+02	.6475E+02	.1450E+00	.2240E+00
4	.1770E-03	.3920E+02	.3944E+02	-.2370E+00	-.6010E+00
5	.2200E-03	.2580E+02	.2479E+02	.1008E+01	.4067E+01
6	.2800E-03	.1660E+02	.1502E+02	.1576E+01	.1049E+02
	.3550E-03	.9000E+01	.9337E+01	-.3366E+00	-.3605E+01
8	.4430E-03	.6200E+01	.6186E+01	.1446E-01	.2338E+00
9	.5540E-03	.4180E+01	.4317E+01	-.1366E+00	-.3164E+01
10	.7130E-03	.2850E+01	.2985E+01	-.1350E+00	-.4524E+01
11	.8810E-03	.2140E+01	.2250E+01	-.1095E+00	-.4869E+01
12	.1090E-02	.1570E+01	.1709E+01	-.1393E+00	-.8148E+01
13	.1410E-02	.1150E+01	.1211E+01	-.6123E-01	-.5055E+01
14	.1790E-02	.8430E+00	.8704E+00	-.2736E-01	-.3143E+01
15	.2220E-02	.6520E+00	.6458E+00	.6247E-02	.9673E+00
16	.2850E-02	.4730E+00	.4512E+00	.2176E-01	.4823E+01
17	.3600E-02	.3320E+00	.3180E+00	.1395E-01	.4388E+01
	.4490E-02	.2470E+00	.2263E+00	.2075E-01	.9171E+01
	.5700E-02	.1720E+00	.1552E+00	.1684E-01	.1085E+02
	.7190E-02	.1190E+00	.1073E+00	.1169E-01	.1089E+02
21	.8800E-02	.8000E-01	.7730E-01	.2699E-02	.3491E+01
22	.1110E-01	.5100E-01	.5158E-01	-.5773E-03	-.1119E+01
23	.1400E-01	.3100E-01	.3333E-01	-.2334E-02	-.7003E+01
24	.1800E-01	.1900E-01	.2094E-01	-.1937E-02	-.9253E+01
25	.2200E-01	.1200E-01	.1525E-01	-.3252E-02	-.2132E+02

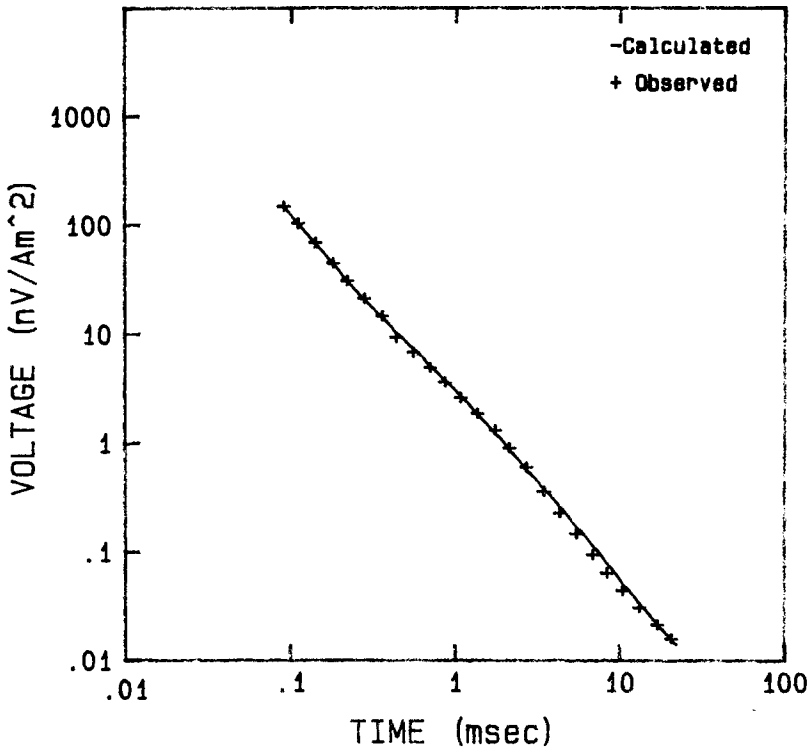
* RMSERR= 7.23

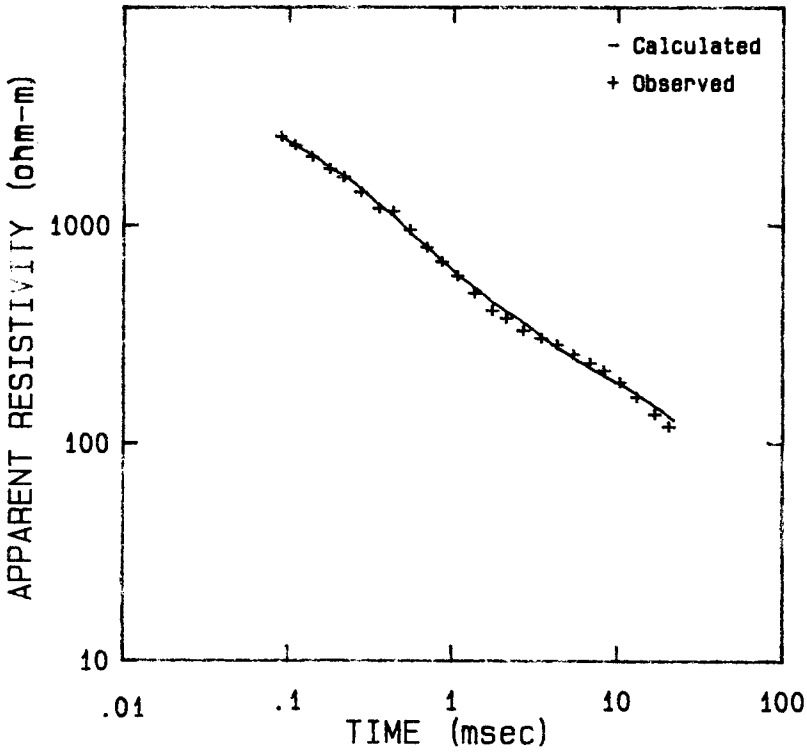
PARAMETER	NAME		FINAL SOLUTION	RESISTIVITY	LAYER DEPTH
1	SIGMA(1)	=	.20003E-03	.49993E+04	
2	SIGMA(2)	=	.24823E-03	.40285E+04	
3	SIGMA(3)	=	.16859E-02	.59317E+03	
4	SIGMA(4)	=	.13294E-01	.75223E+02	
5	SIGMA(5)	=	.17025E-01	.58737E+02	
6	THICK(1)	=	.25540E+03		.25540E+03
7	THICK(2)	=	.15064E+02		.27046E+03
	THICK(3)	=	.36406E+03		.63452E+03
	THICK(4)	=	.53437E+02		.68795E+03
	SHIFT	=	.20700E+03		


STATION: OR12
+ 30COILLO
* 30COILHI
# 3LOOPHI
SANTA FE
MEDICINE LAKE
10K
1K
100
10
nV/Am
10
1
1
.01
.1
1
10
100
t, ms

EMSURVEYS TEM INVERSION

MEDICINE LAKE
STATION: OR13





MODEL

RESISTIVITY (ohm-m)	THICKNESS (meters)
5796	277
427	239
97	395
71	

ELECTROMA TIC SURVEYS INC.

MEDICINE LAKE OR13

I	TIME (sec)	VOLTAGE (nV/Am^2)	CALC.VOLT	RESIDUAL	%RES.ERR
1	.8900E-04	.1482E+03	.1479E+03	.3007E+00	.2033E+00
2	.1100E-03	.1032E+03	.1027E+03	.4917E+00	.4787E+00
3	.1400E-03	.6836E+02	.6630E+02	.2055E+01	.3100E+01
4	.1770E-03	.4419E+02	.4337E+02	.8213E+00	.1894E+01
5	.2200E-03	.3047E+02	.2985E+02	.6222E+00	.2085E+01
6	.2800E-03	.2109E+02	.2014E+02	.9527E+00	.4731E+01
7	.3550E-03	.1457E+02	.1386E+02	.7096E+00	.5119E+01
8	.4430E-03	.9530E+01	.9973E+01	-.4432E+00	-.4444E+01
9	.5540E-03	.6780E+01	.7213E+01	-.4329E+00	-.6002E+01
0	.7130E-03	.4920E+01	.4976E+01	-.5591E-01	-.1124E+01
1	.8810E-03	.3610E+01	.3630E+01	-.1998E-01	-.5505E+00
2	.1090E-02	.2590E+01	.2620E+01	-.2999E-01	-.1145E+01
3	.1410E-02	.1870E+01	.1736E+01	.1339E+00	.7710E+01
4	.1790E-02	.1310E+01	.1175E+01	.1352E+00	.1151E+02
5	.2220E-02	.9000E+00	.8225E+00	.7751E-01	.9424E+01
6	.2850E-02	.6000E+00	.5384E+00	.6157E-01	.1144E+02
7	.3600E-02	.3600E+00	.3597E+00	.2868E-03	.7974E-01
8	.4490E-02	.2280E+00	.2444E+00	-.1644E-01	-.6724E+01
9	.5700E-02	.1470E+00	.1597E+00	-.1275E-01	-.7980E+01
[illegible]	.7190E-02	.9400E-01	.1048E+00	-.1084E-01	-.1034E+02
1	.8800E-02	.6400E-01	.7231E-01	-.8314E-02	-.1150E+02
2	.1110E-01	.4400E-01	.4685E-01	-.2854E-02	-.6091E+01
3	.1400E-01	.3100E-01	.3047E-01	.5287E-03	.1735E+01
4	.1800E-01	.2200E-01	.1962E-01	.2384E-02	.1215E+02
5	.2200E-01	.1600E-01	.1412E-01	.1880E-02	.1331E+02

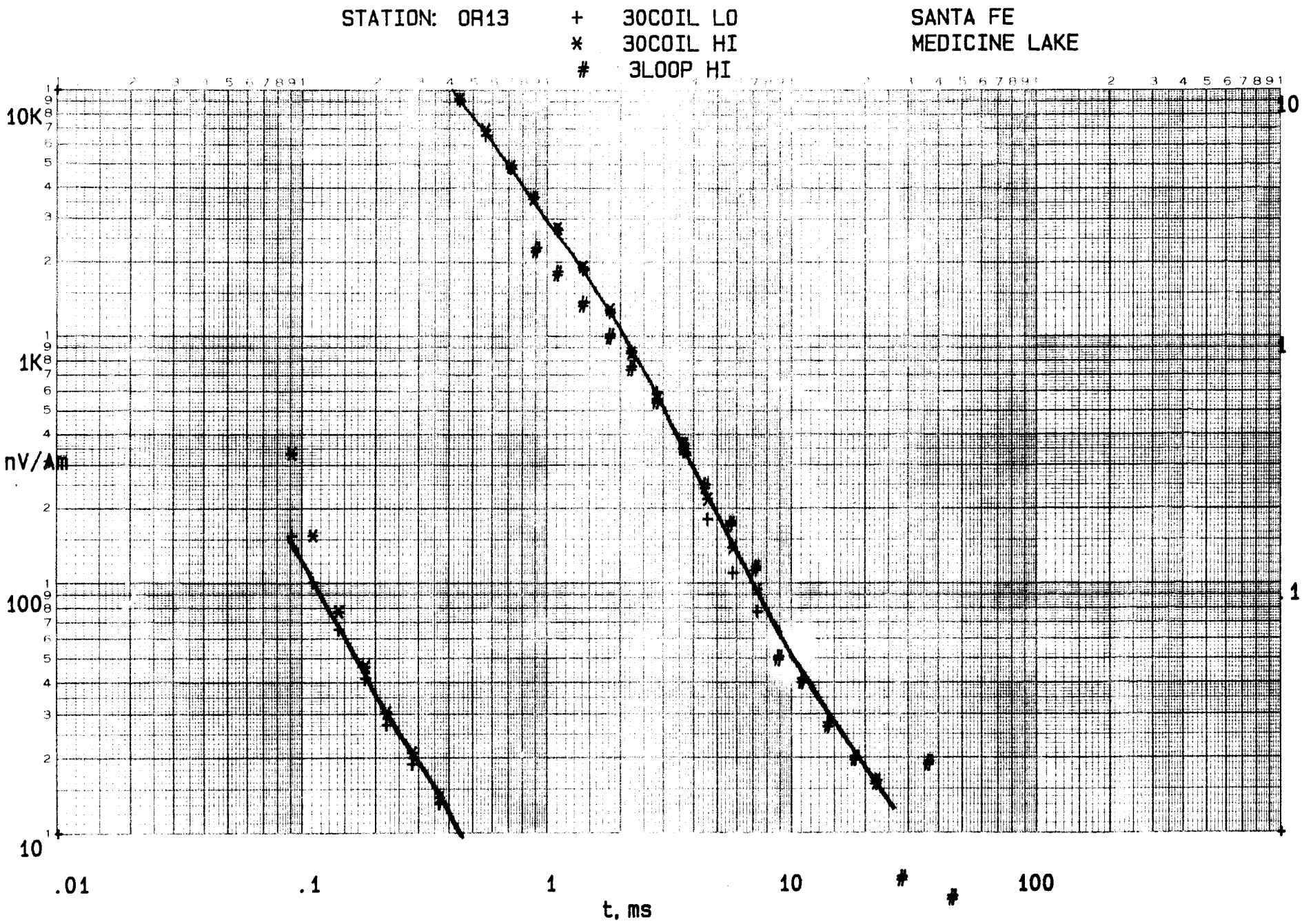
RMSERR= 7.07

RELATION MATRIX

.1000E+01						
.8275E-01	.1000E+01					
.4874E+00	-.3060E+00	.1000E+01				
.8424E+00	-.1368E+00	.5075E+00	.1000E+01			
-.3432E+00	.3220E+00	-.5886E+00	-.5567E+00	.1000E+01		
.1622E+00	-.5952E+00	.7954E-01	.3944E+00	-.4795E+00	.1000E+01	
-.2887E+00	-.2953E+00	-.5307E-01	-.2777E+00	-.1845E+00	.4318E+00	.1000E

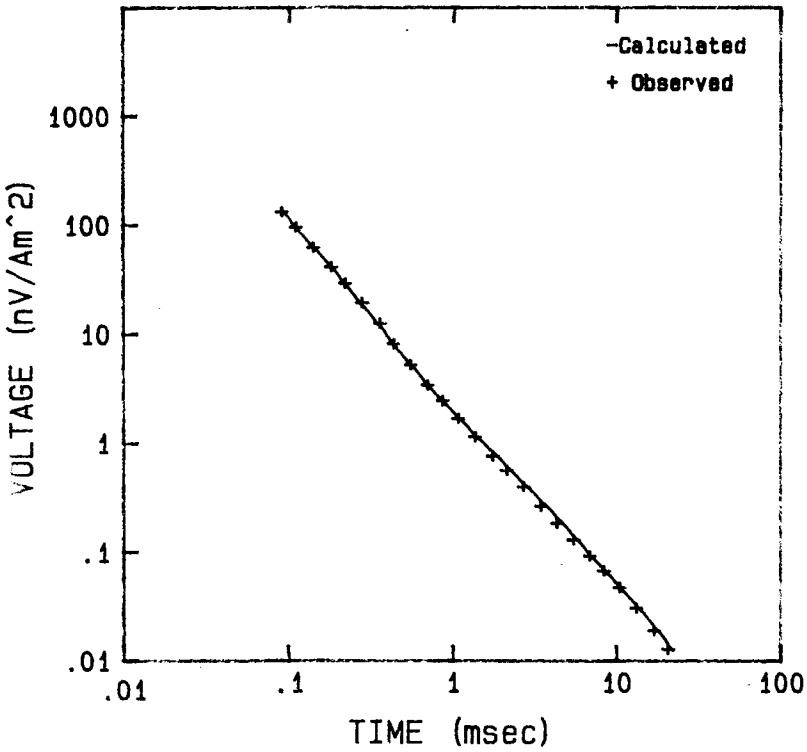
**PARM_SOL.	STD_ERROR	REL_ERROR	% ERROR **
.1725E-03	.5734E-05	.3323E-01	.3323E+01
.2339E-02	.5023E-03	.2147E+00	.2147E+02
.1034E-01	.1133E-02	.1096E+00	.1096E+02
.1416E-01	.3515E-02	.2482E+00	.2482E+02
.2772E+03	.2162E-02	.7799E-05	.7799E-03
.2390E+03	.3349E-02	.1401E-04	.1401E-02
.3949E+03	.3552E-03	.8994E-06	.8994E-04

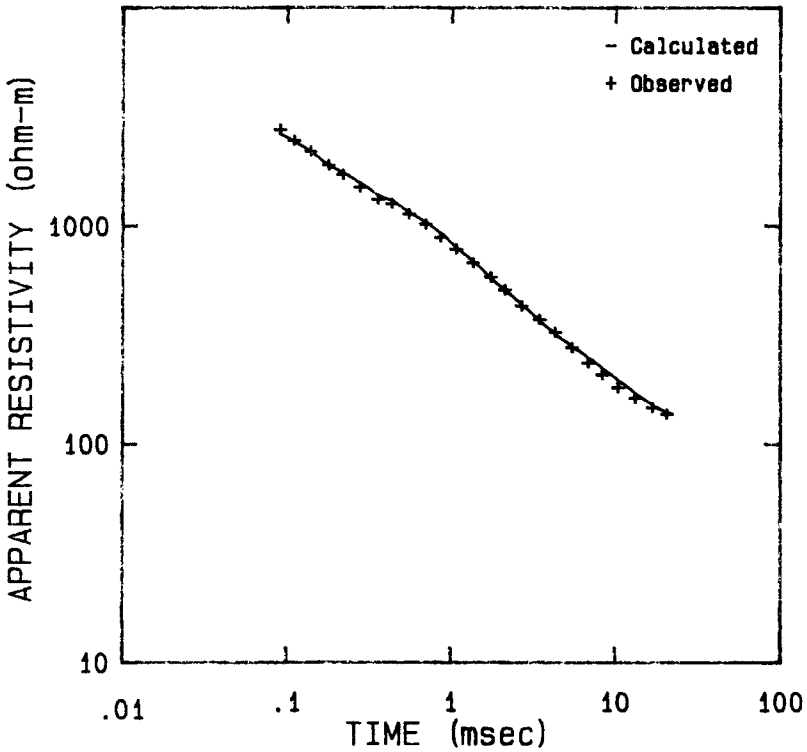
RAMETER NAME		FINAL SOLUTION	RESISTIVITY	LAYER DEPTH
1 SIGMA(1)	=	.17254E-03	.57958E+04	
2 SIGMA(2)	=	.23393E-02	.42749E+03	
3 SIGMA(3)	=	.10341E-01	.96706E+02	
4 SIGMA(4)	=	.14161E-01	.70618E+02	
5 THICK(1)	=	.27716E+03		.27716E+03
6 THICK(2)	=	.23900E+03		.51616E+03
7 THICK(3)	=	.39494E+03		.91110E+03
8 SHIFT	=	.20700E+03		


STATION: OR13
+ 30COIL LO
* 30COIL HI
# 3LOOP HI
SANTA FE
MEDICINE LAKE
10K
1K
100
10
nV/Am
10
1
.1
.01
.1
1
10
100
t, ms

EMSURVEYS TEM INVERSION

MEDICINE LAKE
STATION: OR14





MODEL

RESISTIVITY (ohm-m)	THICKNESS (meters)
4149	288
589	200
250	240
65	

ELECTROMA TIC SURVEYS INC.

MEDICINE LAKE OR14

I	TIME (sec)	VOLTAGE (nV/Am^2)	CALC.VOLT	RESIDUAL	%RES.ERR
	.8900E-04	.1320E+03	.1400E+03	-.7972E+01	-.5696E+01
2	.1100E-03	.9500E+02	.9598E+02	-.9762E+00	-.1017E+01
3	.1400E-03	.6200E+02	.6221E+02	-.2116E+00	-.3401E+00
4	.1770E-03	.4100E+02	.4138E+02	-.3832E+00	-.9261E+00
5	.2200E-03	.2890E+02	.2809E+02	.8109E+00	.2887E+01
6	.2800E-03	.1930E+02	.1814E+02	.1163E+01	.6414E+01
7	.3550E-03	.1250E+02	.1167E+02	.8286E+00	.7099E+01
8	.4430E-03	.8070E+01	.7735E+01	.3352E+00	.4333E+01
9	.5540E-03	.5190E+01	.5142E+01	.4798E-01	.9331E+00
0	.7130E-03	.3370E+01	.3304E+01	.6623E-01	.2005E+01
1	.8810E-03	.2430E+01	.2328E+01	.1018E+00	.4374E+01
2	.1090E-02	.1670E+01	.1677E+01	-.7260E-02	-.4328E+00
3	.1410E-02	.1140E+01	.1142E+01	-.2369E-02	-.2074E+00
4	.1790E-02	.7600E+00	.8017E+00	-.4166E-01	-.5196E+01
5	.2220E-02	.5630E+00	.5846E+00	-.2163E-01	-.3700E+01
6	.2850E-02	.3980E+00	.4036E+00	-.5637E-02	-.1396E+01
7	.3600E-02	.2630E+00	.2812E+00	-.1822E-01	-.6479E+01
8	.4490E-02	.1840E+00	.1967E+00	-.1267E-01	-.6444E+01
	.5700E-02	.1300E+00	.1316E+00	-.1576E-02	-.1198E+01
	.7190E-02	.9200E-01	.8863E-01	.3374E-02	.3807E+01
21	.8800E-02	.6800E-01	.6385E-01	.4149E-02	.6497E+01
2	.1110E-01	.4800E-01	.4403E-01	.3965E-02	.9005E+01
3	.1400E-01	.3100E-01	.2967E-01	.1331E-02	.4485E+01
24	.1800E-01	.1900E-01	.1860E-01	.3955E-03	.2126E+01
5	.2200E-01	.1300E-01	.1271E-01	.2916E-03	.2294E+01

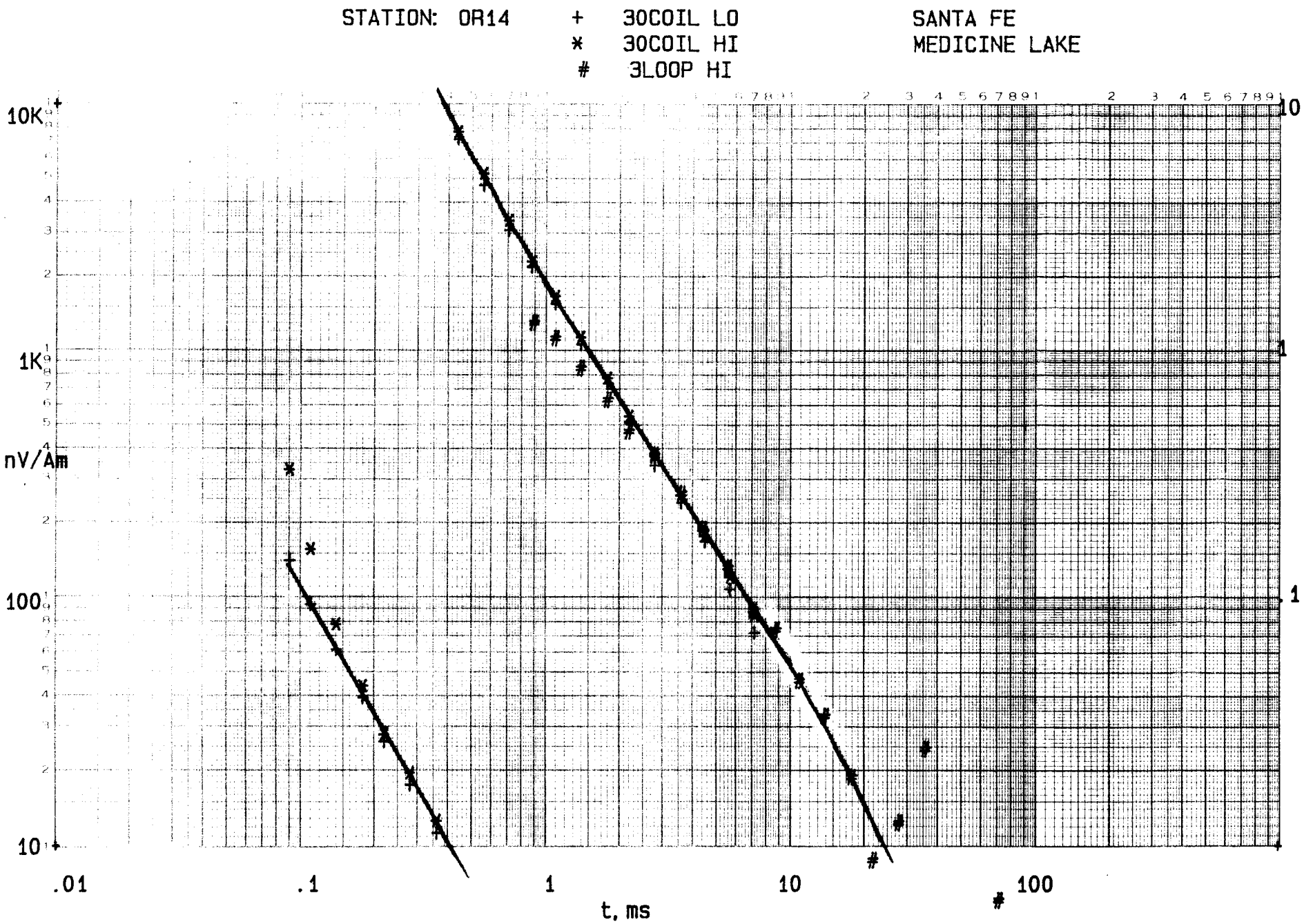
RMSERR= 4.35

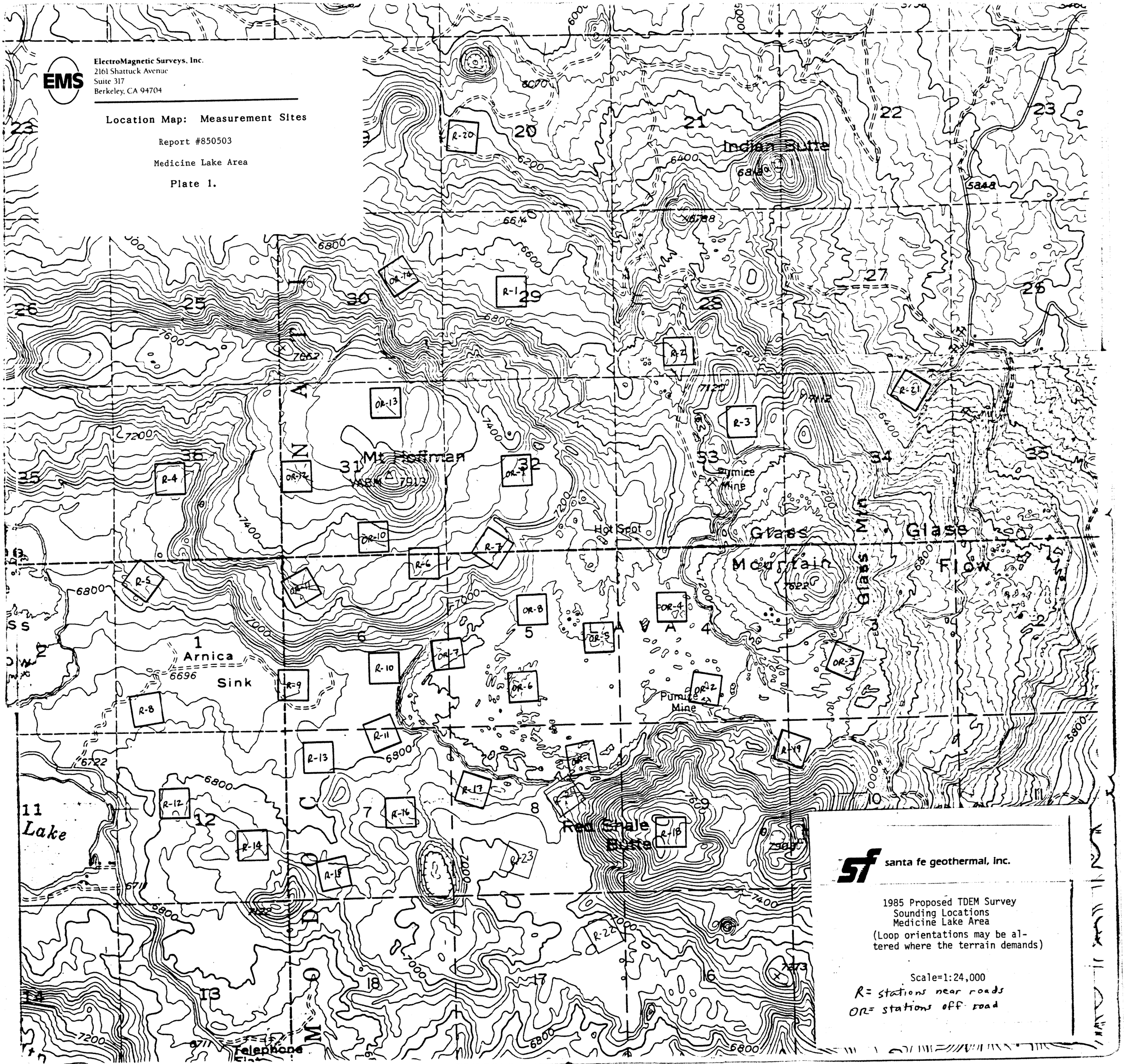
RELATION MATRIX

.1000E+01						
-.2864E-01	.1000E+01					
.4442E+00	-.3154E+00	.1000E+01				
-.1120E-01	-.5935E+00	.7010E-01	.1000E+01			
.4679E-01	.3349E-01	.4008E+00	-.1363E+00	.1000E+01		
-.2827E+00	-.1587E+00	-.6240E-01	.3029E+00	-.3870E+00	.1000E+01	
.3752E+00	.8787E-01	.4301E-01	-.3719E+00	.5330E+00	-.2857E+00	.1000E

**PARM_SOL.	STD_ERROR	REL_ERROR	% ERROR **
.2410E-03	.3246E-05	.1347E-01	.1347E+01
.1698E-02	.3221E-03	.1897E+00	.1897E+02
.4000E-02	.3514E-03	.8785E-01	.8785E+01
.1548E-01	.6928E-03	.4475E-01	.4475E+01
.2879E+03	.1984E-03	.6891E-06	.6891E-04
.2003E+03	.3172E-02	.1584E-04	.1584E-02
.2401E+03	.2209E-02	.9202E-05	.9202E-03

	RAMETER NAME	FINAL SOLUTION	RESISTIVITY	LAYER DEPTH
1	SIGMA(1) =	.24099E-03	.41495E+04	
2	SIGMA(2) =	.16985E-02	.58876E+03	
3	SIGMA(3) =	.40005E-02	.24997E+03	
4	SIGMA(4) =	.15483E-01	.64588E+02	
5	THICK(1) =	.28787E+03		.28787E+03
6	THICK(2) =	.20029E+03		.48816E+03
7	THICK(3) =	.24006E+03		.72822E+03
8	SHIFT =	.700E+03		


STATION: OR14
+ 30COIL LO
* 30COIL HI
# 3LOOP HI
SANTA FE
MEDICINE LAKE
10K
1K
100
10
nV/Am
.01
.1
1
10
100
t, ms
10
1
1


EMS
ElectroMagnetic Surveys, Inc.
2161 Shattuck Avenue
Suite 317
Berkeley, CA 94704
Location Map: Measurement Sites
Report #850503
Medicine Lake Area
Plate 1.
Indian Butte
Mt. Hoffman
Pumice Mine
Hot Spot
Glass Mountain
Glass Flow
Arnica Sink
Lake
Red Shale Butte
Telephone Flat
santa fe geothermal, inc.
1985 Proposed TDEM Survey
Sounding Locations
Medicine Lake Area
(Loop orientations may be altered where the terrain demands)
Scale=1:24,000
R= stations near roads
OR= stations off road

Attachment XIII

CEC-500-2007-XXX-ATXIII

Report No. 1 Magnetotelluric Survey Glass Mountain, California.

This document is an attachment to a report funded by the California Energy Commission's Geothermal Resource Development Account (GRDA) Program. The GRDA Program did not fund this document, but the authors of the GRDA funded report have attached it as a supporting document.

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APPENDIX N:
Report No. 1 Magnetotelluric Survey Glass Mountain, California

Attachment XIII

CEC-500-2007-XXX-ATXIII

Report No. 1 Magnetotelluric Survey Glass Mountain, California.

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California, Glass Mtn, Siskiyou Co. (MT)
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REPORT NO.1

MAGNETOTELLURIC SURVEY

GLASS MOUNTAIN, CALIFORNIA

1975

for

THE UNION OIL COMPANY

by

Alan V. Lattanner

and

Tsvi Meidav

Project No. 75.60

GEONOMICS, INC.
3165 Adeline Street
Berkeley, California 94703

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I	Magnetotelluric Survey

INTRODUCTION

This report describes the results of a magnetotelluric survey of the Medicine Lake Highland and adjacent Modoc Plateau lava beds. The location of this survey is shown in Plate 1. The magnetotelluric survey was conducted during October and November, 1975 by Geonomics, Inc. of Berkeley, California under contract to Union Oil Company, Geothermal Division, Los Angeles, California.

The Medicine Lake Highland is located in Siskiyou and Modoc Counties, California, east of Mt. Shasta. The highland is a lobe extending eastward of the southern Cascade Physiographic Province. The area has been volcanically active since the late Miocene with several mafic and silicic flows occurring in Recent and historic time. Hot springs exist within 20 miles of the Highland, but only one fumarole, the Hot Spot, was within the boundaries of the survey area.

The magnetotelluric (MT) method is used to determine the resistivity of the ground for various frequencies of oscillation of the earth's natural magnetic field. The MT method uses the fact that frequency, resistivity and depth of wave penetration are mathematically related to formulate resistivity vs. frequency graphs and to model various geological situations. The method yields information of a general nature on lithology and structure and specific information on resistivity and model dimensions. The method has been used extensively for petroleum exploration in the USSR and Europe, and to a small extent in North America for both petroleum and geothermal exploration. The basic theory was presented by Cagniard (1953) and exploration case histories have been published by Vozoff, Hasegawa and Ellis (1963) and Dowling (1970).

LOCATION AND METHOD

The magnetotelluric survey was conducted over an area of 324 sq. mi. which comprised of nine townships (T42N, T43N, T44N, R2E, R3E, R4E). Survey points were taken at the corners of a 3 mile by 3 mile grid overlying the area. Data is presented for thirty-eight of these stations that were eventually occupied during the thirty-eight day contract period.

The station numbering code presents the line number first followed by the station number for that line (i.e., stn 47≡line 4, station 7). Seven South-to-North lines, spaced 3 miles apart, each have seven stations also spaced three miles apart. Station 11 is at the SW corner of T42N, R2E (Plate I).

MAGNETOTELLURIC RESISTIVITY METHOD

Rock resistivity may be measured by monitoring the electric currents induced in the rock by the fluctuations in the earth's magnetic field. A simple relationship may be shown to exist between the amplitude of magnetic field changes, the voltage gradients induced in the earth and the earth resistivity. Furthermore, since the depth to which an electromagnetic wave penetrates depends both on the frequency and resistivity of the conductor, resistivity may be computed as a function of depth within the earth if the amplitudes of the magnetic field changes can be measured at several frequencies. Thus for a magnetic field amplitude $/\bar{H}/$ and a normal electric field amplitude $/\bar{E}/$ the resistivity (ρ_a) at a period T is:

$$\rho_a = 0.2T \left|\frac{E}{H}\right|^2 \qquad (1)$$

For a homogeneous earth, the depth of penetration (δ) of an electromagnetic wave is:

$$\delta = 0.5\sqrt{\rho_a T} \qquad (2)$$

It has been noted that the magnetotelluric method has several important advantages over the galvanic methods. Since measurements are made with currents induced in the earth, no problem is encountered in determining the resistivity beneath a highly resistant bed, such as exists when the measurement is attempted with a galvanic method. A second advantage is that resistivities may be studied to great depths within the earth.

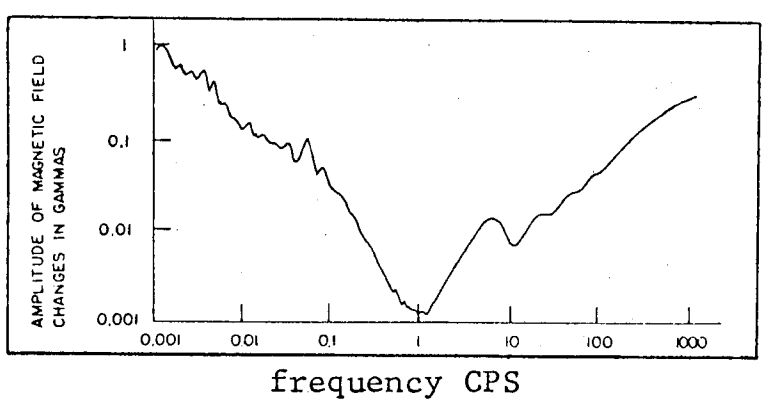

Figure 1. A Characteristic Distribution of Magnetic Field Changes Vs. Frequency.

Figure 1 shows the power distribution of the magnetic field as a function of frequency. The normal spectrum of measurement by Geonomics, Inc. is between 0.01 CPS and 10 CPS since time efficiency is usually important to our clients. However, the frequency response of our equipment is from DC to >300 CPS allowing for investigations covering the 100 meter to >1000 km depth range.

The power spectral distribution in Figure 1 places a limit on the efficiency of data acquisition at those frequencies with low natural amplitudes. It is usually more difficult to get a good data-point distribution in low amplitude ranges since the low signals are on the order of the measurement system noise level.

Data Analysis and Quality

The points plotted on Figures 3-40 are the statistical mean value of 2 to 15 individual resistivity calculations determined according to the formula

$$\bar{\rho}_a = \frac{\Sigma \rho_a}{n} \qquad (3)$$

where ρ_a is the mean apparent resistivity and n is the number of resistivities in the sample. The error bars associated with each point represent δ, the sample standard deviation, determined by the formula

$$\delta = \sqrt{\frac{\Sigma \rho_a^2 - \frac{\Sigma \rho_a^2}{n}}{n-1}} \qquad (4)$$

The apparent resistivities measured at Glass Mountain and vicinity showed a very strongly anisotropic conductivity structure. This accounts for the divergence and separation of the resulting curves where resistivity may differ by two or three orders of magnitude between the orthogonal axes of measurement. The quantitative interpretation of this data requires the use of a new set of master curves for anisotropic layered media which do not exist at present. Geonomics, Inc. is currently preparing such a master curve set which should have wide applicability in the future to magnetotelluric surveys in anisotropic volcanic terrain such as at Glass Mountain.

GEOLOGY

Geology of the Medicine Lake Highland

The Medicine Lake Highland is located on the southern margin of the High Cascades Volcanic Province, 30 miles east of Mt. Shasta in Siskiyou County, California. The Pliocene and Pleistocene lava flows of the Highland are believed to be a shield volcano centered on the Medicine Lake Basin.

The oldest rocks in the area are fragments of basalts and andesites that have been correlated with the Cedarville series of the Warner Mountains (Powers, 1932). Overlying this is the Warner Basalt which covers a vast area east of the highland. The lavas of the Medicine Lake Highland shield volcano accumulated on this basement to a height of probably 2,500 ft (MacDonald, 1966). The central portion of the volcano eventually collapsed, forming a caldera approximately 6 miles by 4 miles across with its rim 500 feet below the previous summit. Subsequent volcanic eruptions around the rim formed eight separate cones whose lava flowed into the basin and down the flanks of the Shield volcano covering the original caldera rim. The present Medicine Lake Basin is the depression left between these cones.

Post Caldera lavas were at first olivine-free andesites similar to the last of the pre-caldera lavas. These gave way to flows of olivine andesitic composition that formed Red Shale Peak, Lyons Peak and the silicic flows that formed Mt. Hoffman (Anderson, 1941) in Late Pleistocene and Recent time.

Three recent basaltic flows are known as the Callahan flow on the northern Highland slope, the Paint Pot Crater flow west of Medicine Lake and the Burnt Lava Flow which covers 14 sq. mi. on the southeastern slope. Finally, within the past millenium came a series of silicic eruptions including the Glass Mountain flow, Medicine Lake glass flow, Little Glass Mountain flow and other smaller silicic eruptions all generally within the perimeter formed by the basalt flows discussed above.

The regional volcanic province including the Highland is broken by northwest and north-trending normal faults that divide the volcanic surface into blocks, with intervening sediment filled basins in the lowlands.

Glacial deposits occur at high elevations in the Medicine Lake Highland, but their extent has not been mapped and the earlier deposits are thought to have been buried by succeeding lava flows.

Geothermal Geology of the Highland

The large volume and areal extent of Pleistocene and Recent volcanism in the Highland make the area attractive for geothermal exploration. In particular, there exist four major rhyolitic flows in the central shield area that may overlie shallow, hot rhyolite magma chambers. The most recent is Glass Mountain, extruded in historic times (Eschelberger, 1975) as a single flow with a volume of 1.0 km^3. The Hot Spot, the only active fumarole in the area, is located 1 mile west of the Glass Mountain summit. Very high heat flow at the Hot Spot is indicated by temperatures exceeding 80°C at 0.5 m depth over a 1 acre area. This is the only temperature data available in the area. Other hot springs are located to the east in Modoc County and northwest in Siskiyou County.

The groundwater potential of the area is essentially unknown and untapped. Although there are no known sedimentary deposits on the Highland other than surface glacial deposits, potentially there are buried moraines, extensive lava tube networks and porous lava flows that may act as reservoirs for ground water.

PREVIOUS WORK

Previous investigations of the area include a Bouguer gravity map of the Alturas region, a U.S.G.S. geothermal assessment of Modoc County, California, and the Alturas sheet of the geologic map of California. In particular, the gravity data over the Medicine Lake Highland should give an insight into the rocks underlying the extensive lava flows of the region.

The Bouguer Gravity Map (Chapman and Bishop, 1968)shows a positive Bouguer anomaly of 15 mgal centered 2 miles ENE of Medicine Lake. The anomaly is calculated in contrast to Mesozoic sedimentary and metamorphic rocks exposed in the nearby Klamath Mountains. Using density data published by La Fehr (1965) for the southern Cascades and MacDonald's (1966) estimate of a 2,500 ft thickness for the volcanics we calculate that the volcanic cover should produce a 6.4 mgal negative anomaly. This is in accord with numerous published examples of negative anomalies associated with volcanic areas in the Cascade province. Therefore, there is very probably a high density mass underlying the Highland. Smith and Shaw (1975) estimate that a magma chamber underlies this region, having a volume range of 160 km^3 to 640 km^3. Using 400 km^3 as the average volume figure with a vertical cylinder model (Dobrin, 1960), we calculate a density of 2.99 g/cm^3 for the body corresponding to a basic igneous magma of gabbroic composition. Since the bulk of the Medicine Lake shield volcano is composed of basalt, basaltic andesite flows and tuff sheets with the rhyolite-dacite suite of considerably less volume and confined to the central part of the shield, this model of a large basic magma chamber seems plausible.

A study of the geothermal potential of Modoc County, California by Duffield and Fournier (1974) lists nine geothermal wells drilled in the Modoc lava beds east of the Medicine Lake Highland. Although the known geothermal resources of Modoc County are 30-60 miles from the area of interest here, the authors note that "all of Modoc County is a potentially attractive target for the exploration of geothermal resources, because virtually the entire county is underlain by Miocene or younger volcanic rocks...areas of shallow elevated temperature that are not expressed at the surface by hot springs, geysers and fumaroles could be present." They have correlated several wells with major faults and crustal lineaments, some of which may extend across the area of interest here.

QUALITATIVE INTERPRETATION OF MT SURVEY RESULTS

Four zones of anomalously low resistivity were outlined during the survey. These are presented on Plate I.

The main anomaly trends northeast and southwest from the Medicine Lake Caldera, and appears to be structurally related to the Caldera itself. This anomaly is presented in vertical section in Figure 2. From the figure it may be seen that the northeast anomaly (<10 ohm-meters) dips steeply toward the caldera rim from the area of the recent Glass Mountain volcanic event. The area underlying the caldera itself shows high resistivities to great depth. To the southwest of the caldera a vertical anomaly shows rapidly decreasing resistivity with depth, from surface values of 25 ohm-meters to a deep value of 3 ohm-meters. These anomalies suggest that rocks at elevated temperatures occupy the intersection of a northeast fracture trend with the caldera rim fracture. Other interpretations regarding the cause of the resistivity lows that are not related to the occurrence of an active geothermal system are possible. These include: fossil geothermal systems that may have caused alteration of rocks to clays and zeolites; or the occurrence of high vesicular basalt at depth. The absence of anomalies to the immediate northwest and southeast of the caldera indicates the absence of a similar structural weakness in those areas.[1]

The 10 ohm-meter anomaly at Stations 13 and 14 is due to the presence of a thick relatively conductive layer beneath a thin surface resistive layer, as interpreted from the shape of the curve for Station 14. The deeper layer is probably a near horizontal conductor corresponding to a water saturated zone and should remain an area of interest

---

[1]Hot dry-rock anomalies are not easily distinguishable by resistivity methods if the dry rocks are at temperatures much below melting (less than 600-700°C). Similarly, young vapor-dominated systems may be characterized by high resistivity (mature systems would have established alteration zones with low-resistivity manifestations). Recognition of such systems may be possible at times through combination of data (gravity-electrical, geochemical-electrical and others).

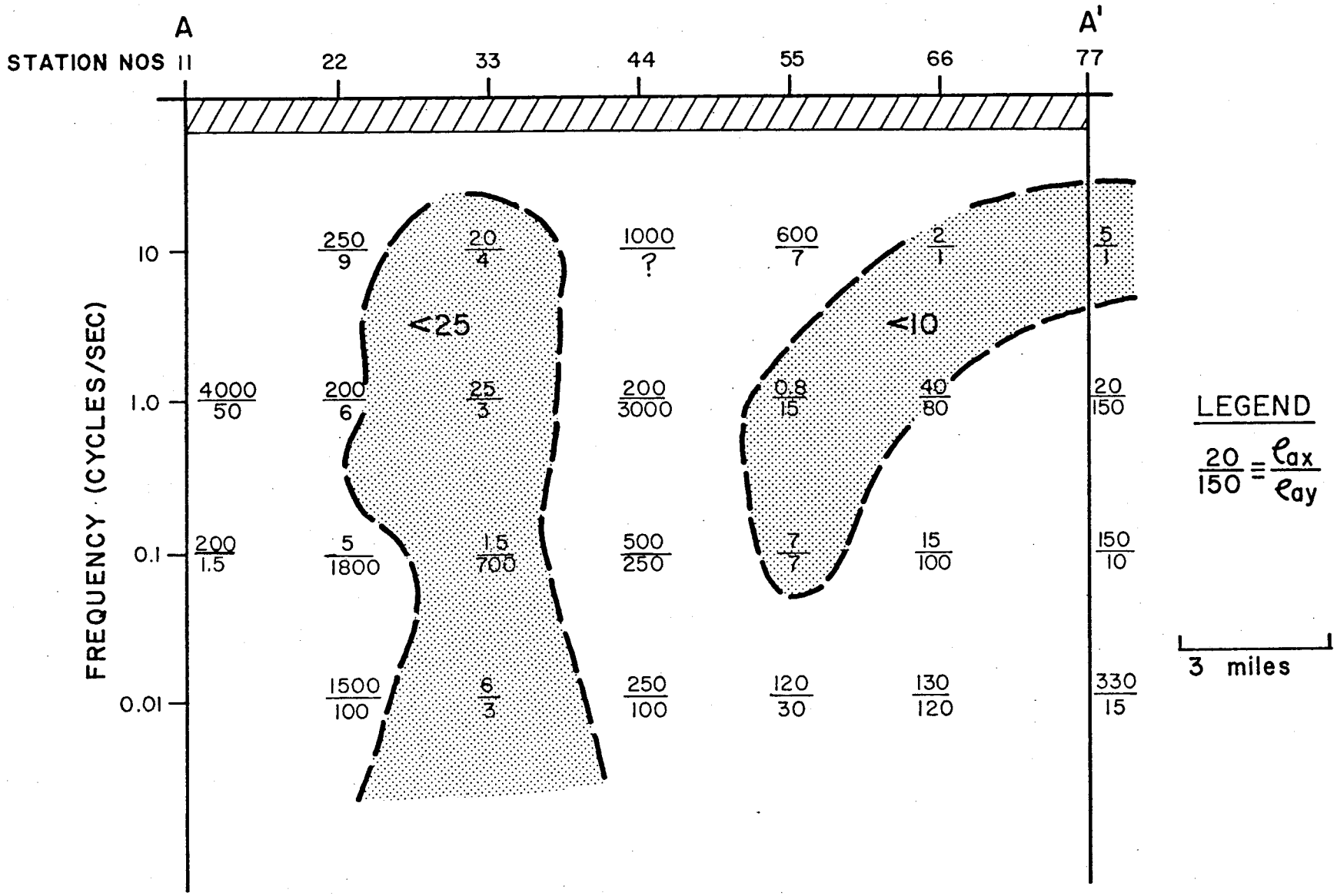

Figure 2. Glass Mountain MT Survey Vertical Section AA'
This vertical section extends diagonally across the Glass Mountains Prospect (Plate I). Apparent resistivity is plotted as a function of frequency, showing the relative depths of the various anomalous zones. Maximum depth at 0.01 Hz is approximately 10 km, minimum 2 km.

since water supply will be a problem for geothermal development in the Glass Mountain-Medicine Lake Highland area.

The most conductive anomaly located trends northeast across the recent basalt flows near stations 52 and 63. Resistivities of less than 2 ohm-meters were encountered here at intermediate depths (approximately 1 km-3 km). The anomaly parallels the caldera anomaly, but the existence of a structural relation to the caldera is still unclear. It is expected that the quantitative interpretation that will accompany the final report will shed some light on this problem.

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MT SOUNDING CURVE LEGEND

HxEy Measurement Axis

HyEx Measurement Axis

Standard Deviation Error Bars

GLASS MOUNTAIN MAGNETOTELLURIC SURVEY

Station 11

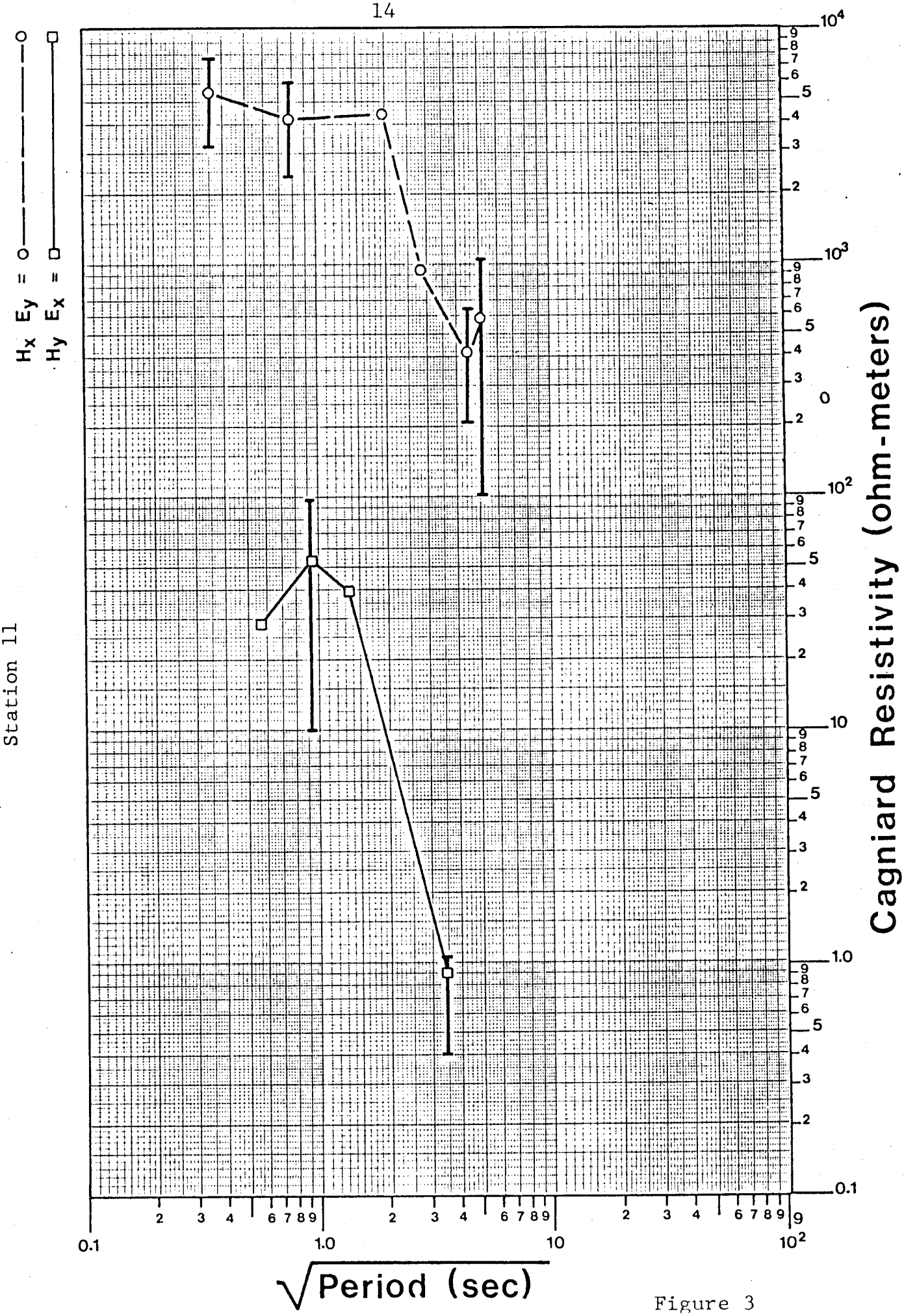


Figure 3

GLASS MOUNTAIN MAGNETOTELLURIC SURVEY

Station 12

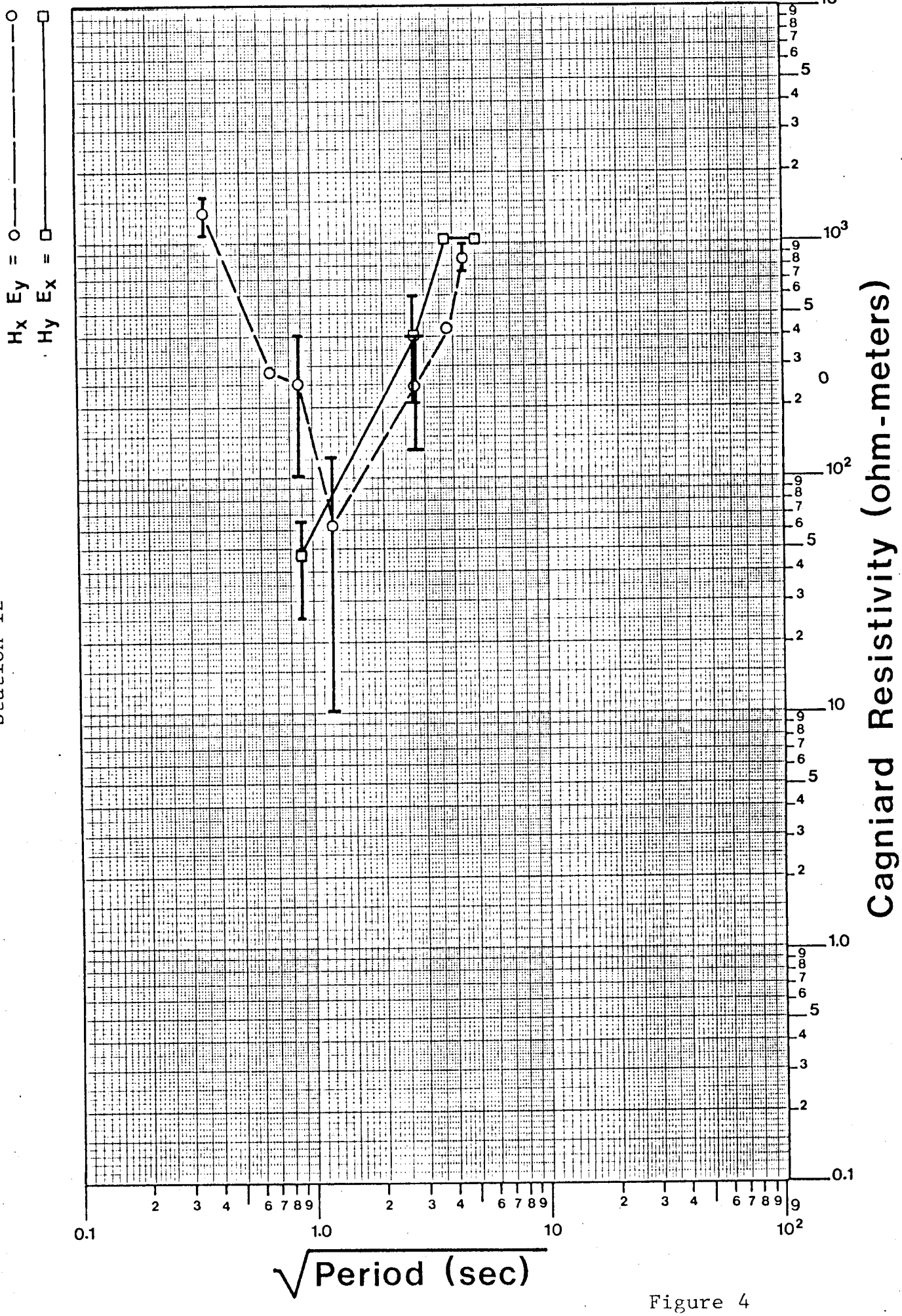


Figure 4

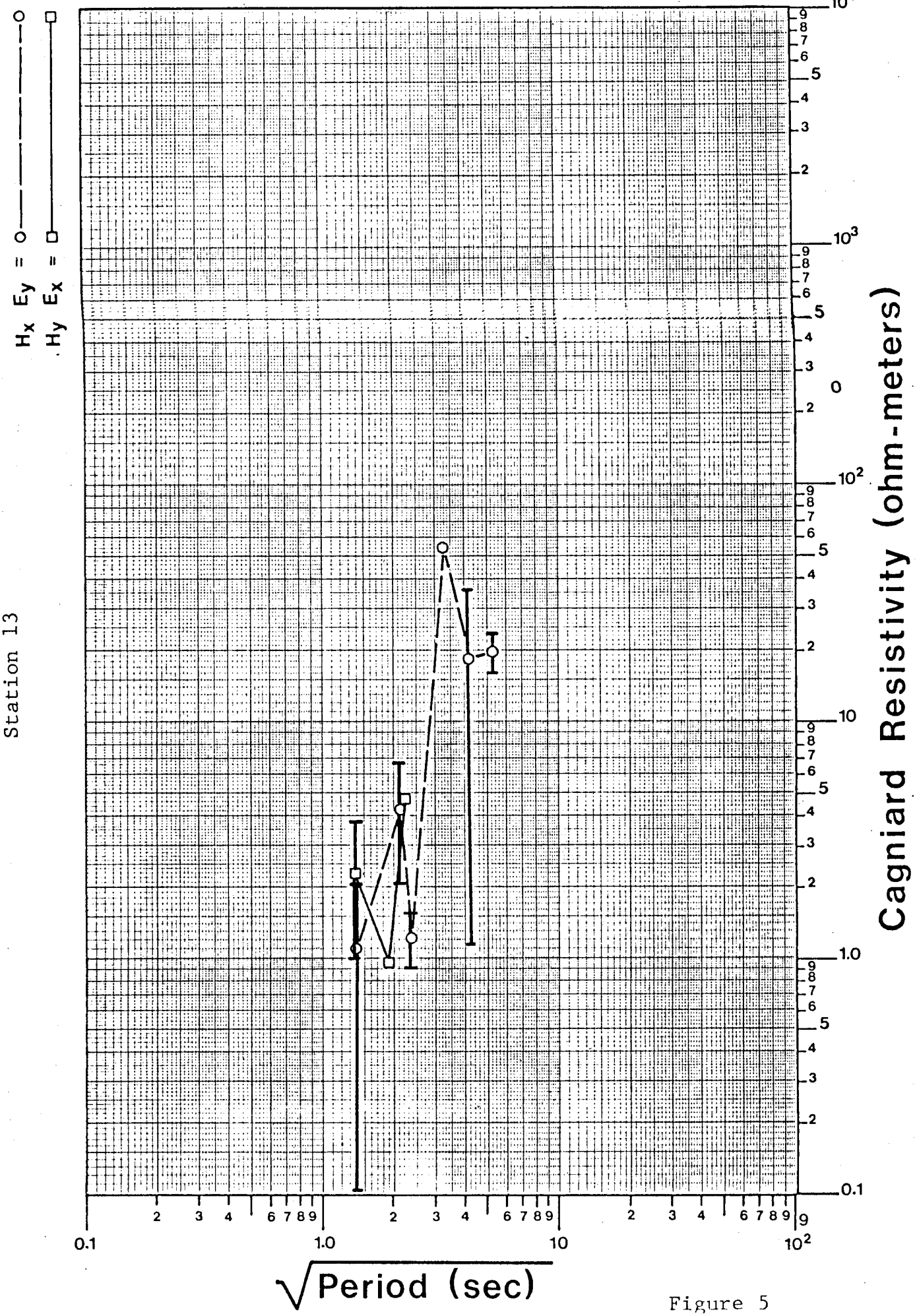

GLASS MOUNTAIN MAGNETOTELLURIC SURVEY
Station 13
H_x E_y = o
H_y E_x = □
Cagniard Resistivity (ohm-meters)
$\sqrt{\text{Period (sec)}}$
0.1
1.0
10
10^2
10^3
10^4

Figure 5

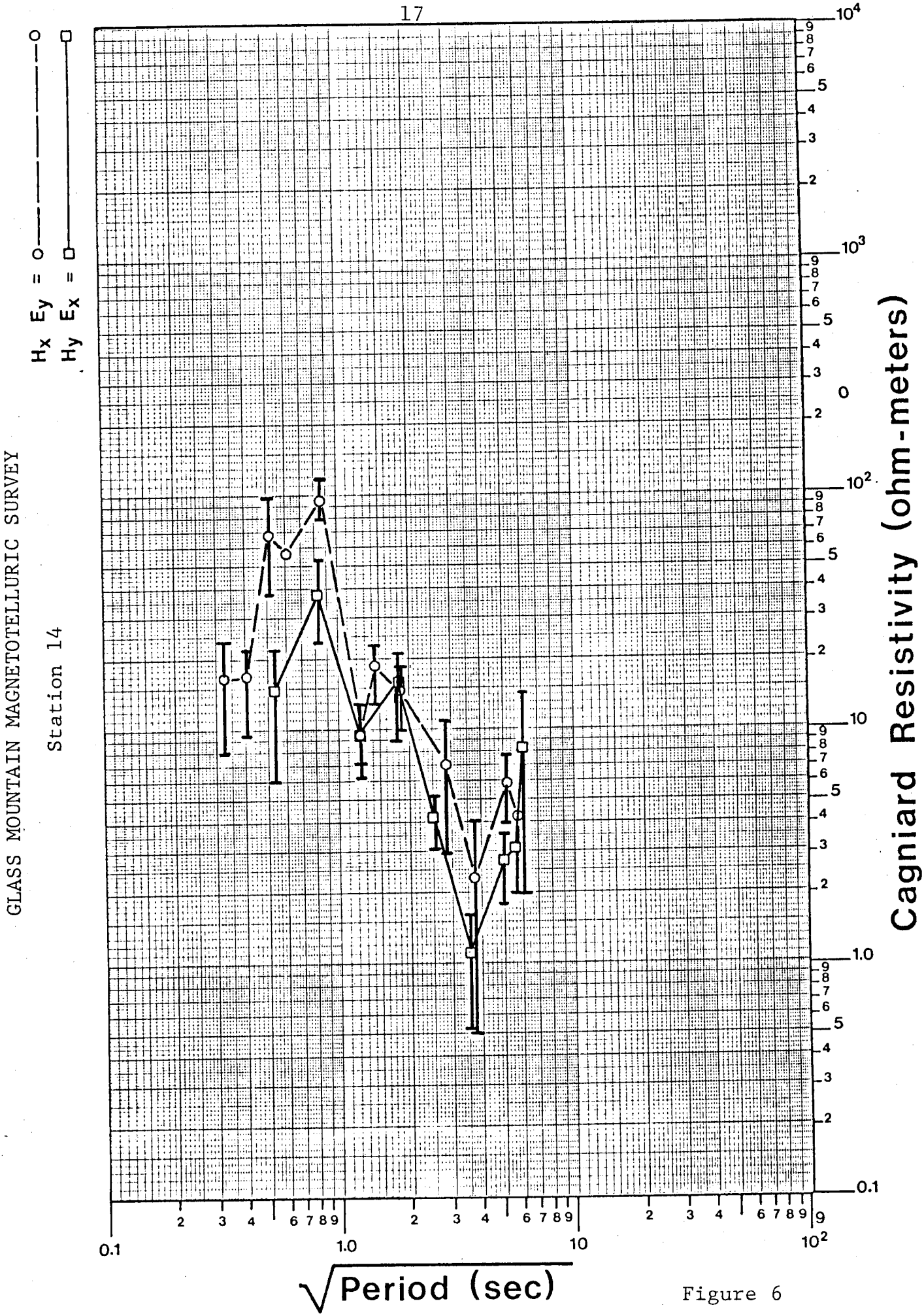

GLASS MOUNTAIN MAGNETOTELLURIC SURVEY
Station 14
Hx Ey = o
Hy Ex = □
Cagniard Resistivity (ohm-meters)
√Period (sec)
0.1
1.0
10
10²
10³
10⁴

Figure 6

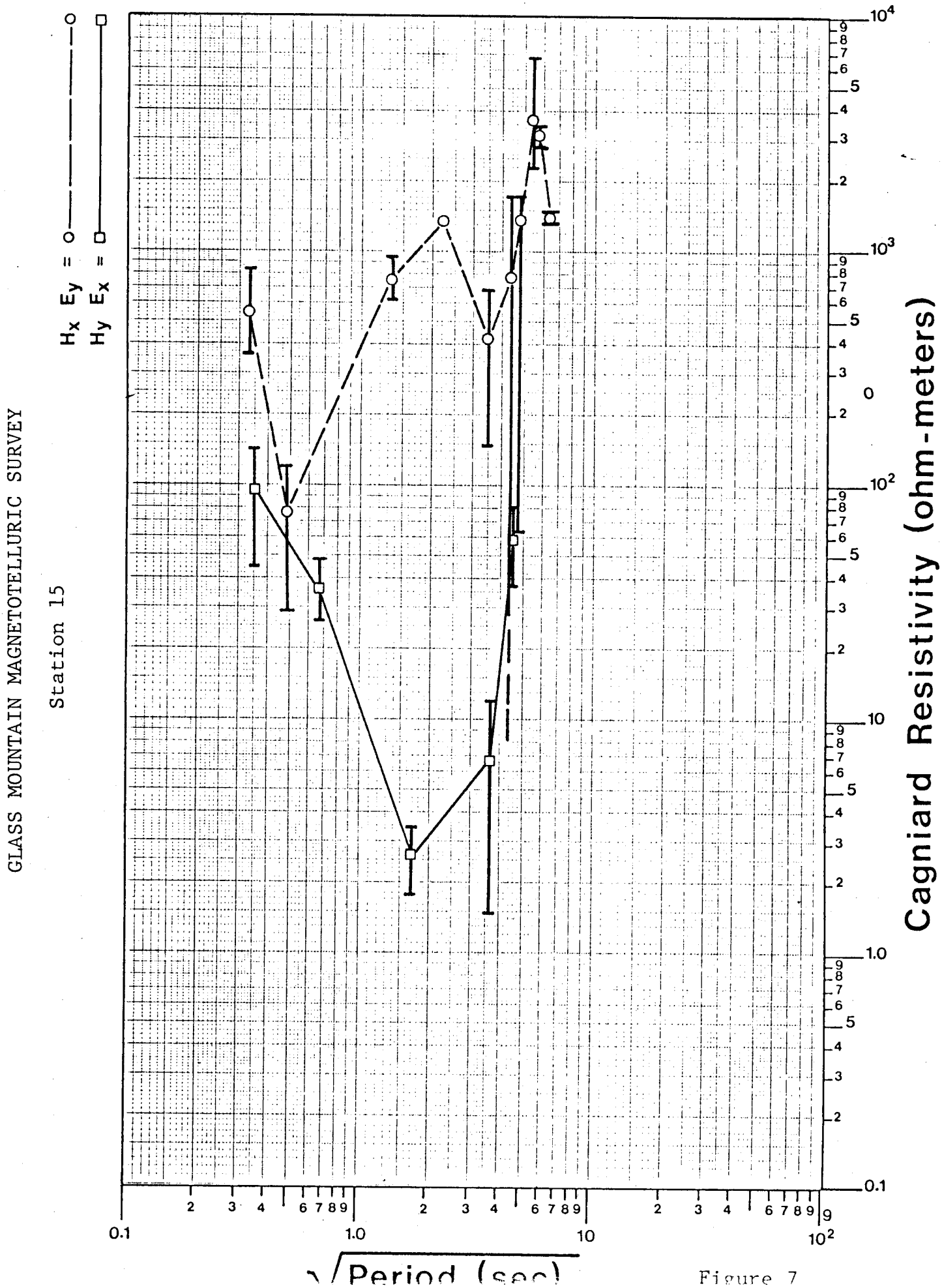

GLASS MOUNTAIN MAGNETOTELLURIC SURVEY
Station 15
Hx Ey = o
Hy Ex = □
Cagniard Resistivity (ohm-meters)
√Period (sec)
0.1
1.0
10
10²
10³
10⁴

Figure 7

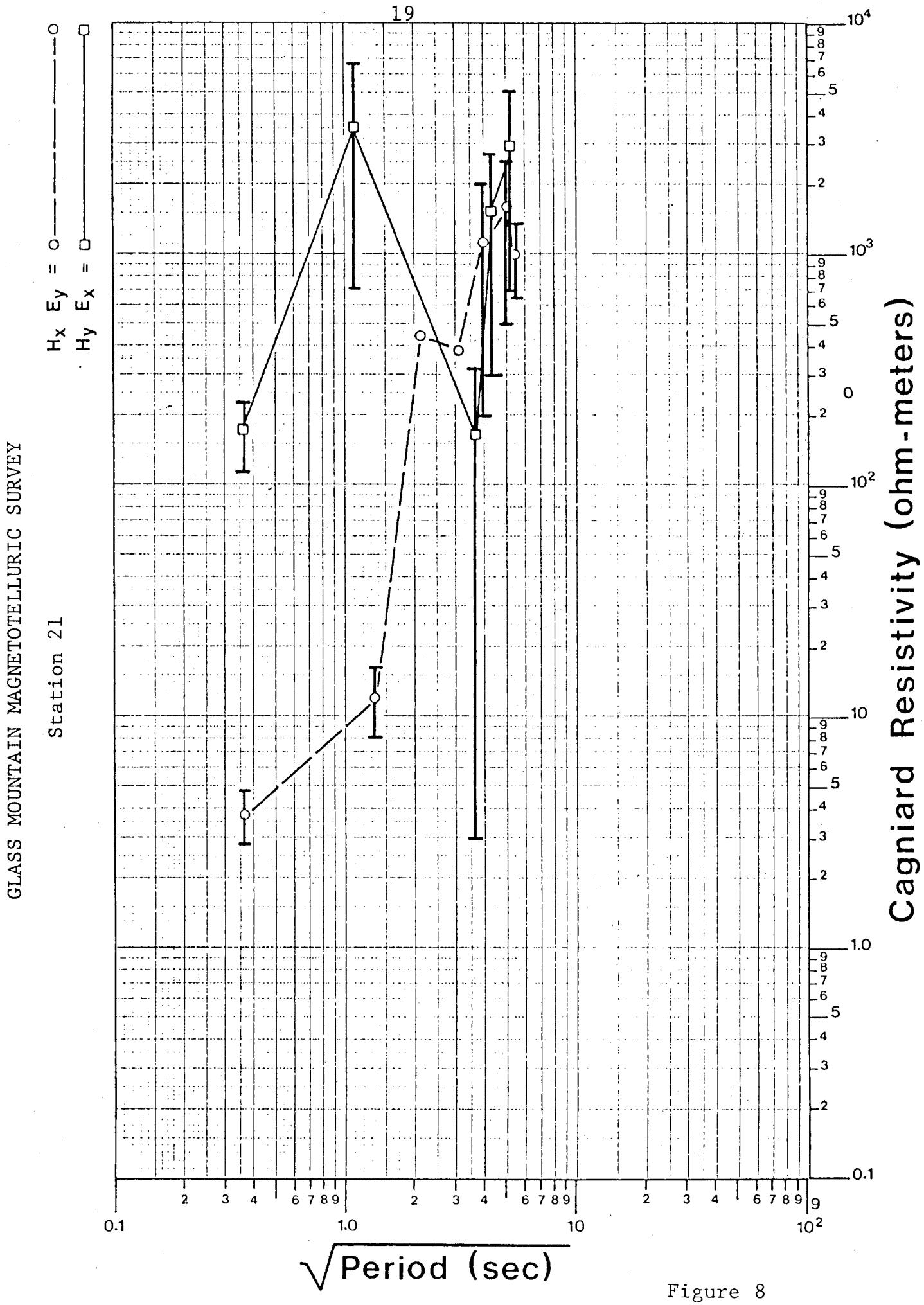

GLASS MOUNTAIN MAGNETOTELLURIC SURVEY
Station 21
Hx Ey = o
Hy Ex = □
Cagniard Resistivity (ohm-meters)
√Period (sec)
0.1
1.0
10
10²
10³
10⁴

Figure 8

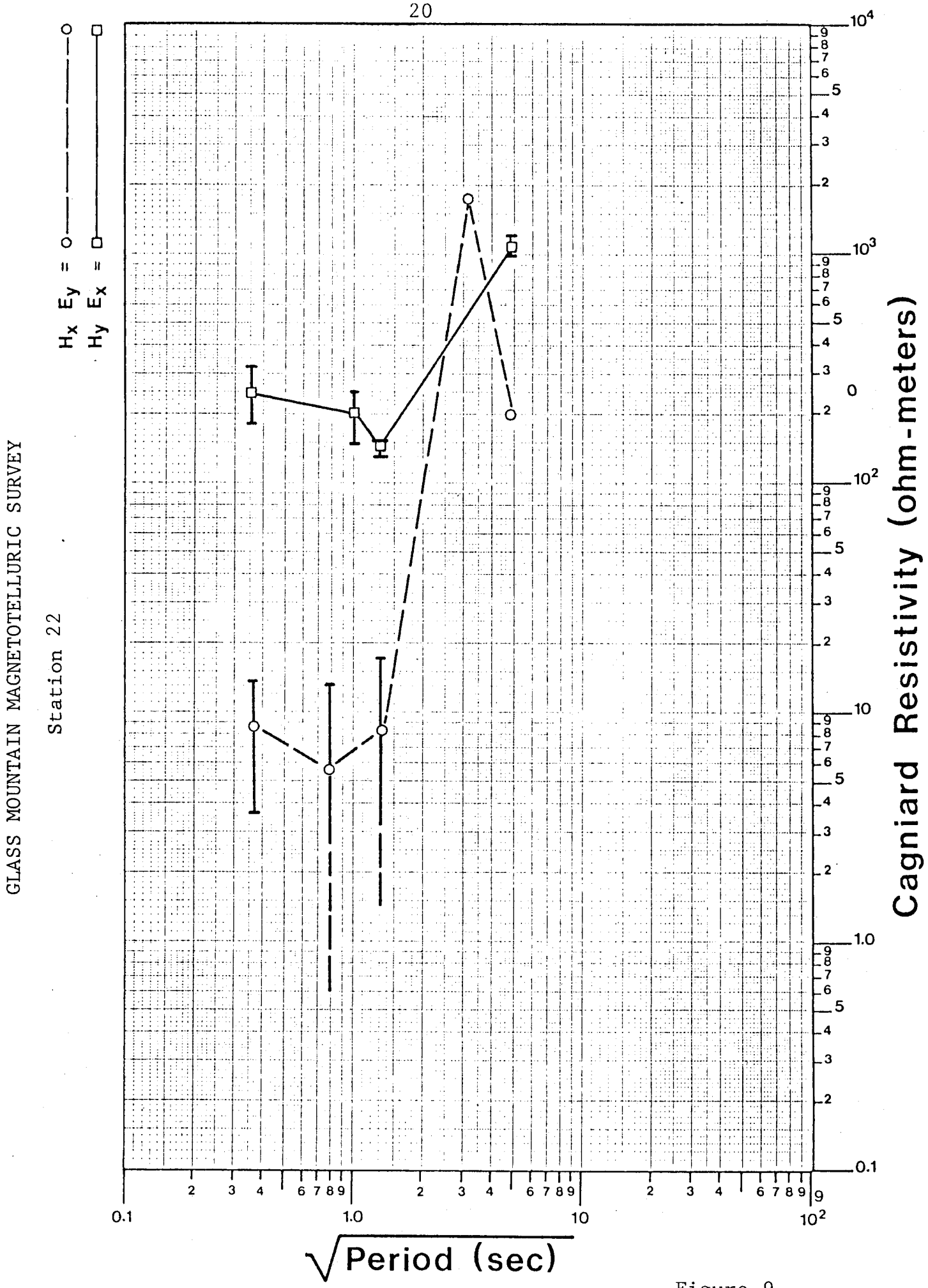

GLASS MOUNTAIN MAGNETOTELLURIC SURVEY
Station 22
H_x E_y = ○
H_y E_x = □
Cagniard Resistivity (ohm-meters)
$\sqrt{\text{Period (sec)}}$
0.1
1.0
10
10^2
10^3
10^4

Figure 9

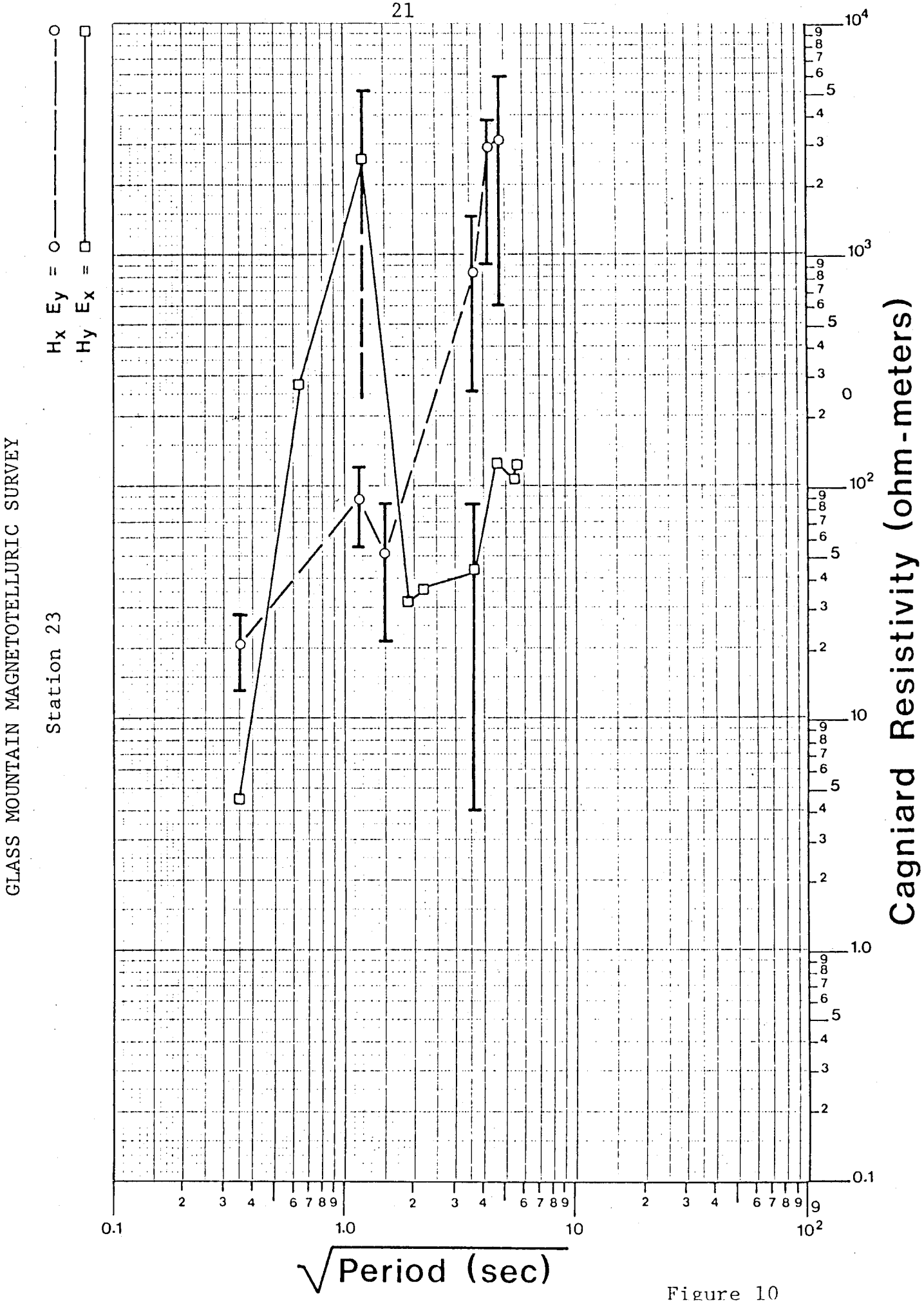

GLASS MOUNTAIN MAGNETOTELLURIC SURVEY
Station 23
H_x E_y = ○
H_y E_x = □
Cagniard Resistivity (ohm-meters)
$\sqrt{\text{Period (sec)}}$
0.1
1.0
10
10^2
10^3
10^4

Figure 10

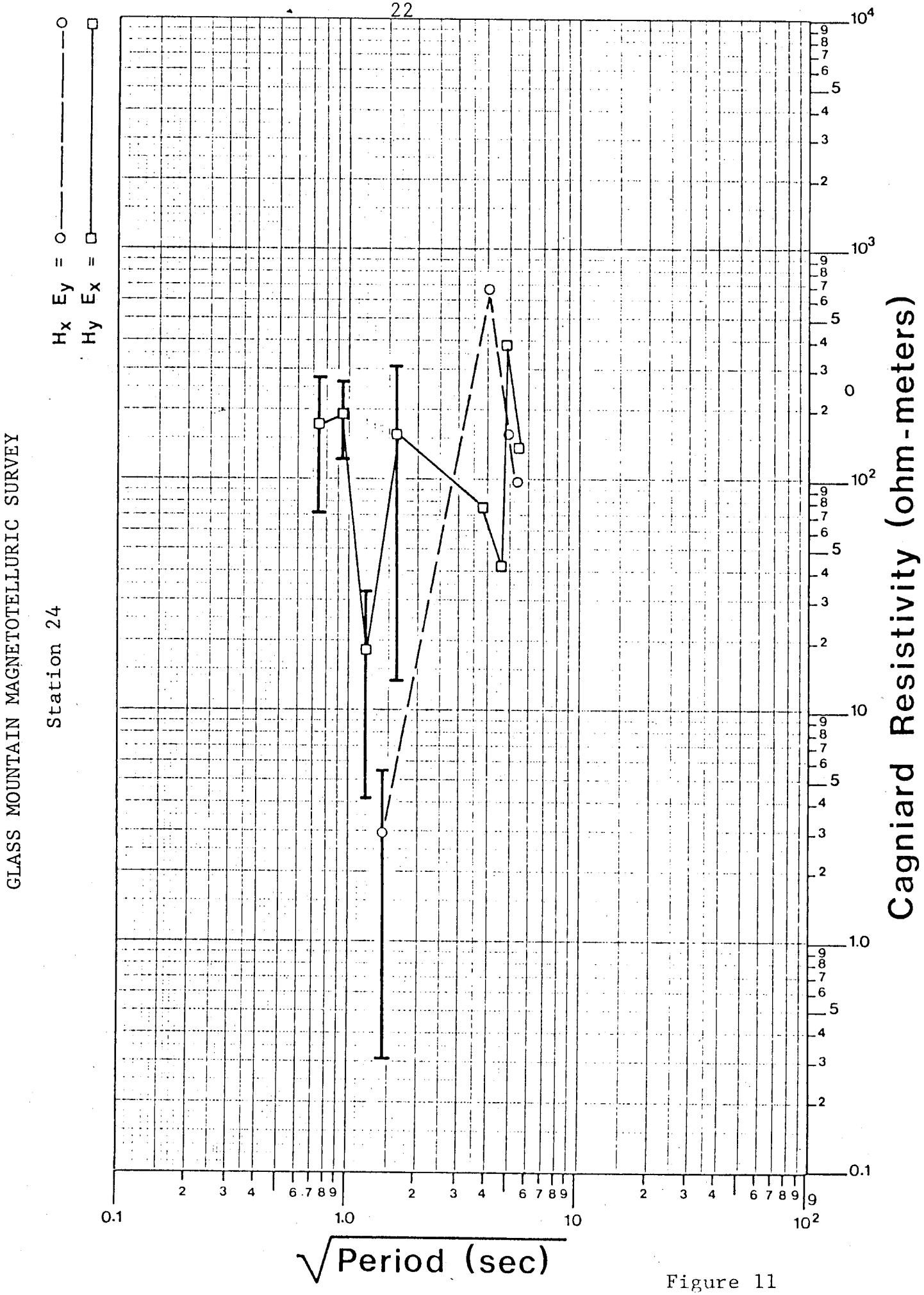

GLASS MOUNTAIN MAGNETOTELLURIC SURVEY
Station 24
H_x E_y = ○——○
H_y E_x = □——□
Cagniard Resistivity (ohm-meters)
$\sqrt{\text{Period (sec)}}$
0.1
1.0
10
10^2
10^3
10^4

Figure 11

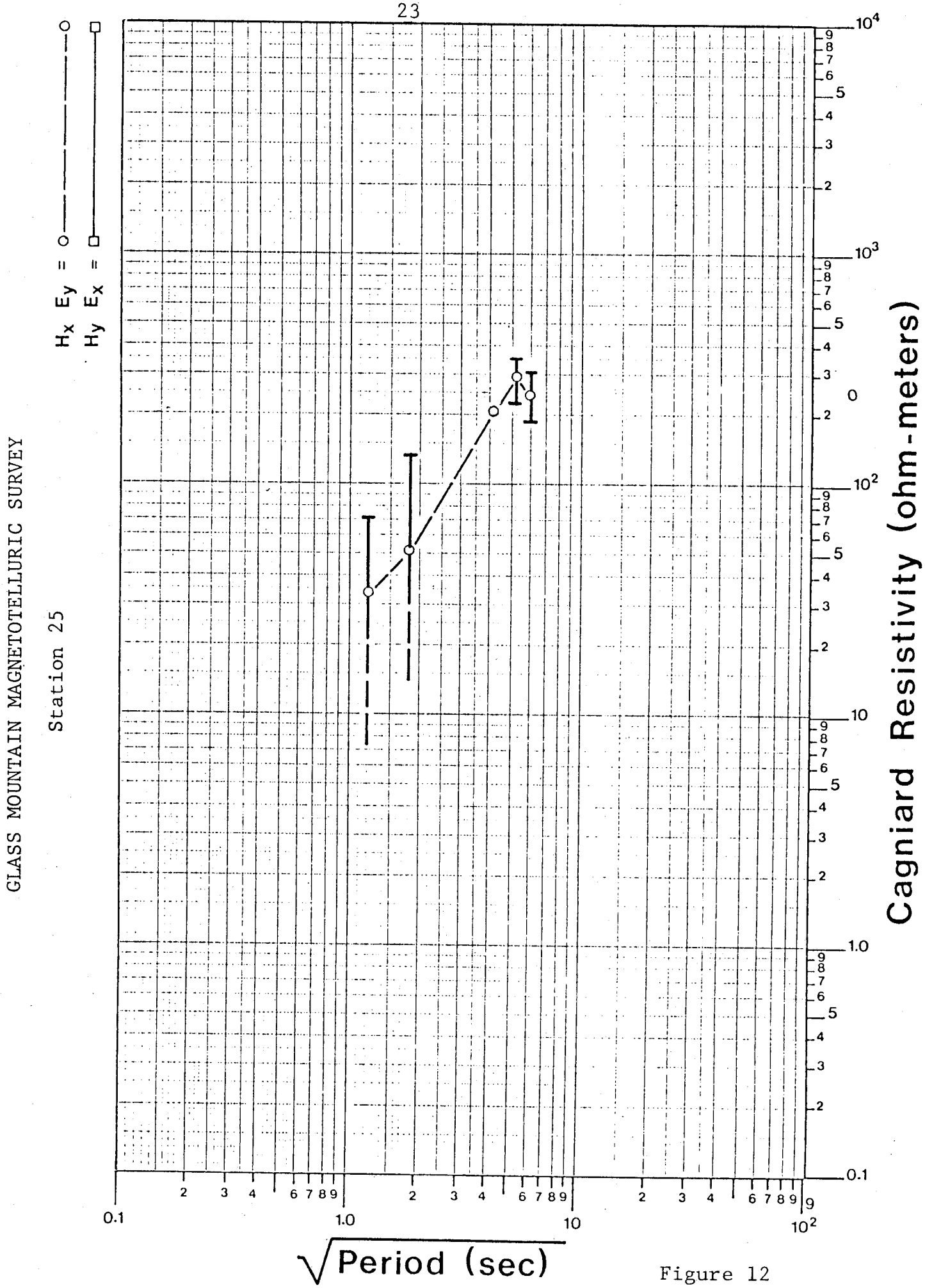

GLASS MOUNTAIN MAGNETOTELLURIC SURVEY
Station 25
Hx Ey = ○
Hy Ex = □
Cagniard Resistivity (ohm-meters)
√Period (sec)
0.1
1.0
10
10²
10³
10⁴

Figure 12

GLASS MOUNTAIN MAGNETOTELLURIC SURVEY

Station 26

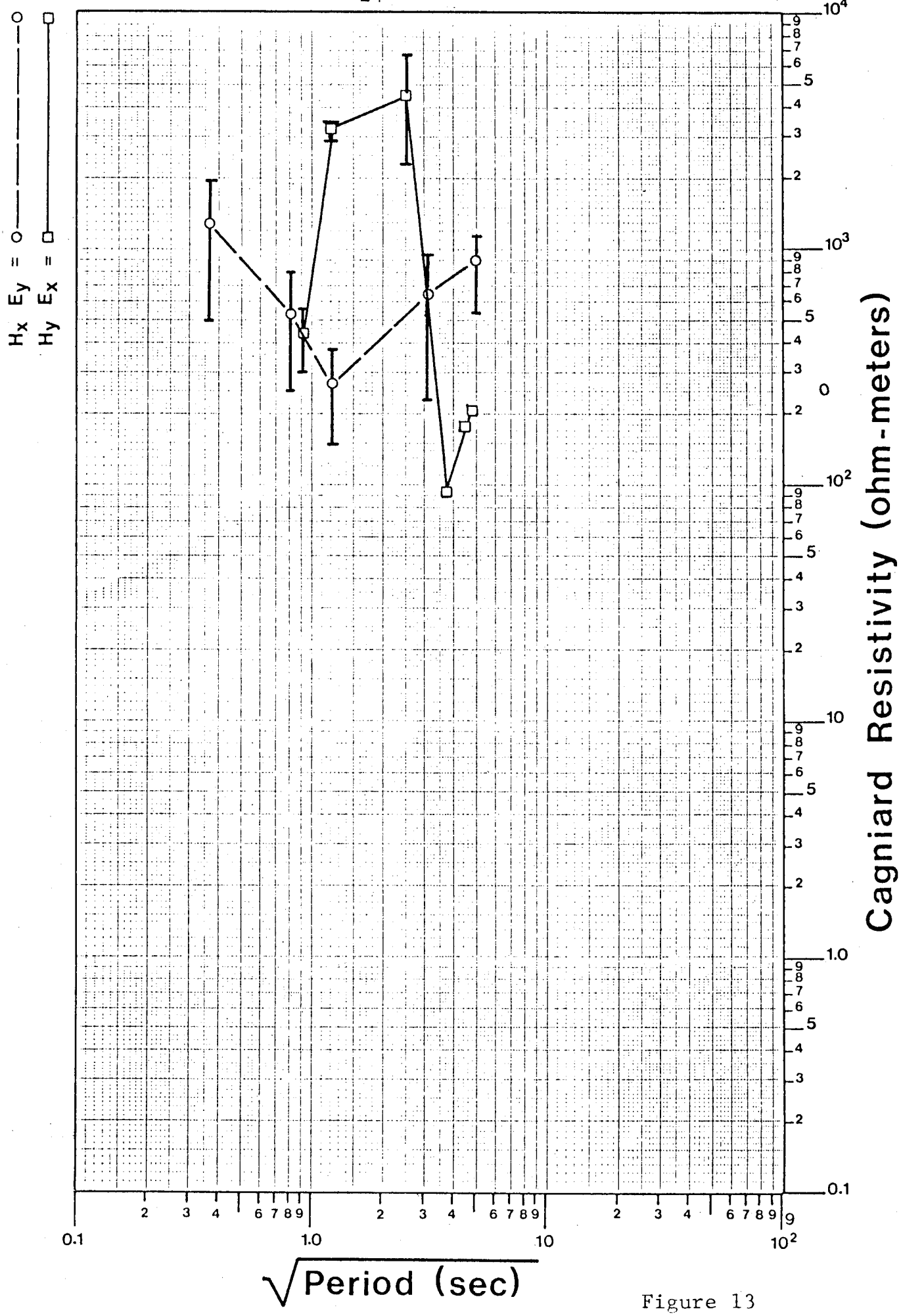


Figure 13

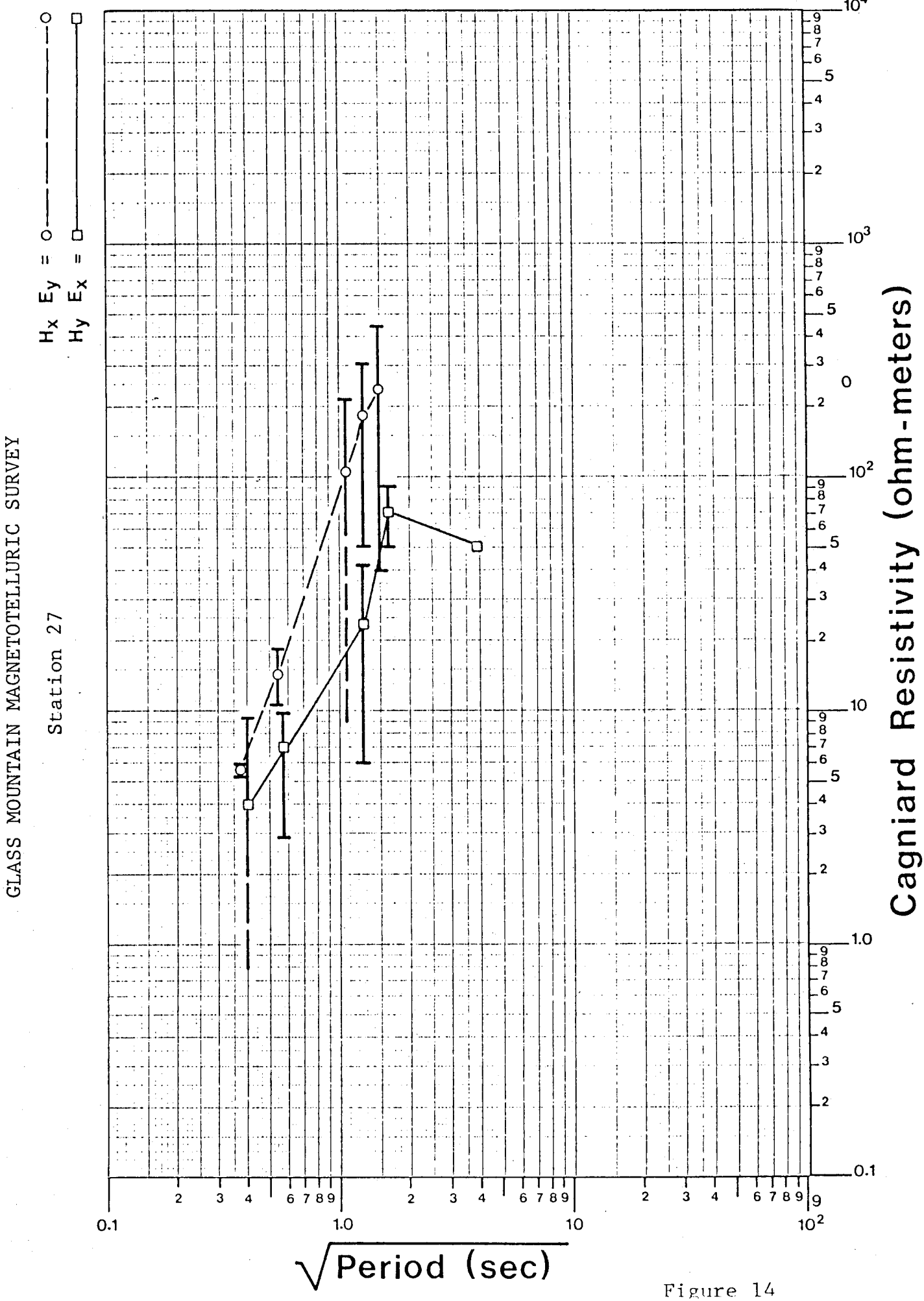

GLASS MOUNTAIN MAGNETOTELLURIC SURVEY
Station 27
H_x E_y = O
H_y E_x = □
Cagniard Resistivity (ohm-meters)
$\sqrt{\text{Period (sec)}}$
0.1
1.0
10
10^2
10^3
10^4

Figure 14

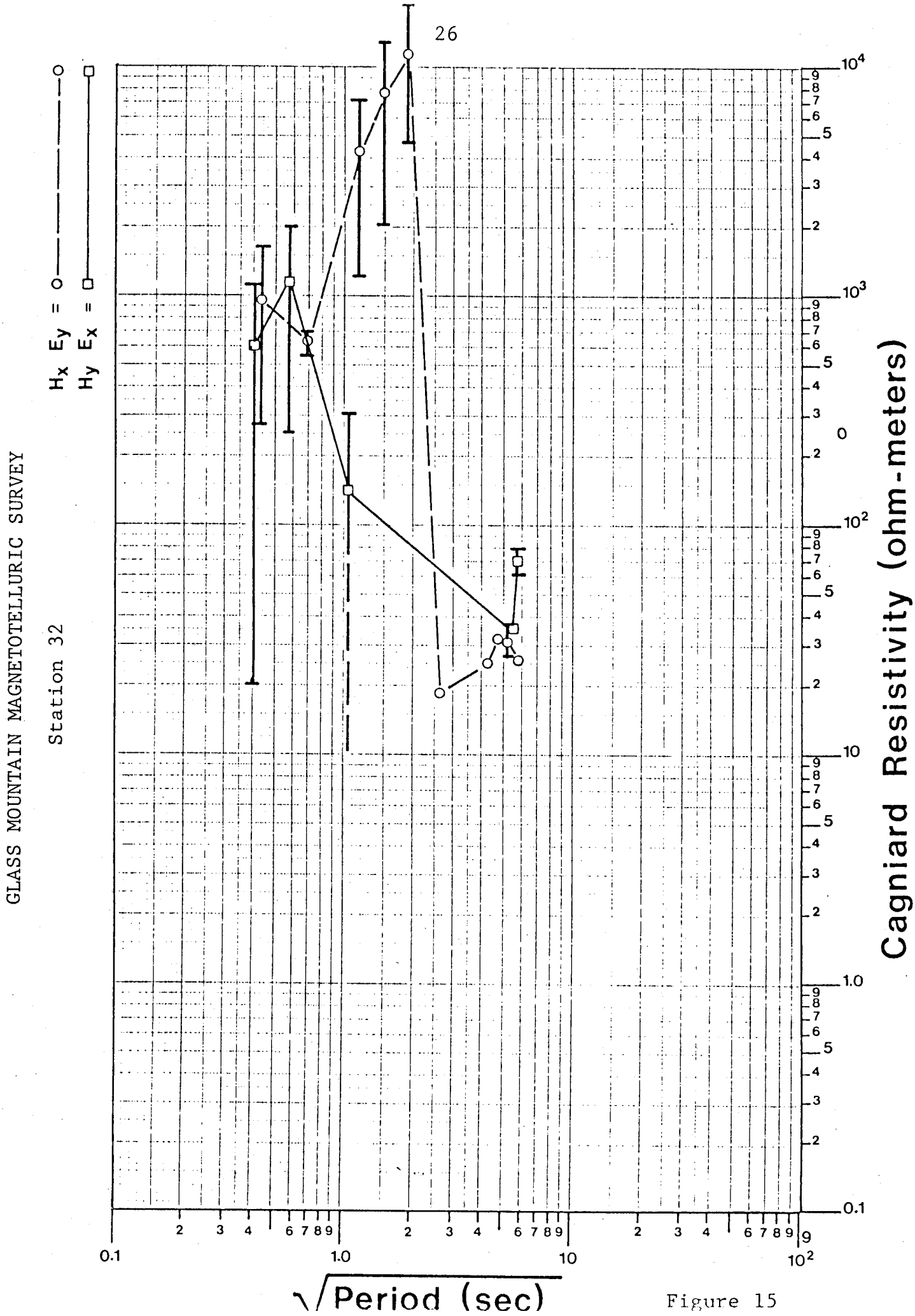

GLASS MOUNTAIN MAGNETOTELLURIC SURVEY
Station 32
H_x E_y = o
H_y E_x = □
Cagniard Resistivity (ohm-meters)
$\sqrt{\text{Period (sec)}}$
0.1
1.0
10
10^2
10^3
10^4

Figure 15

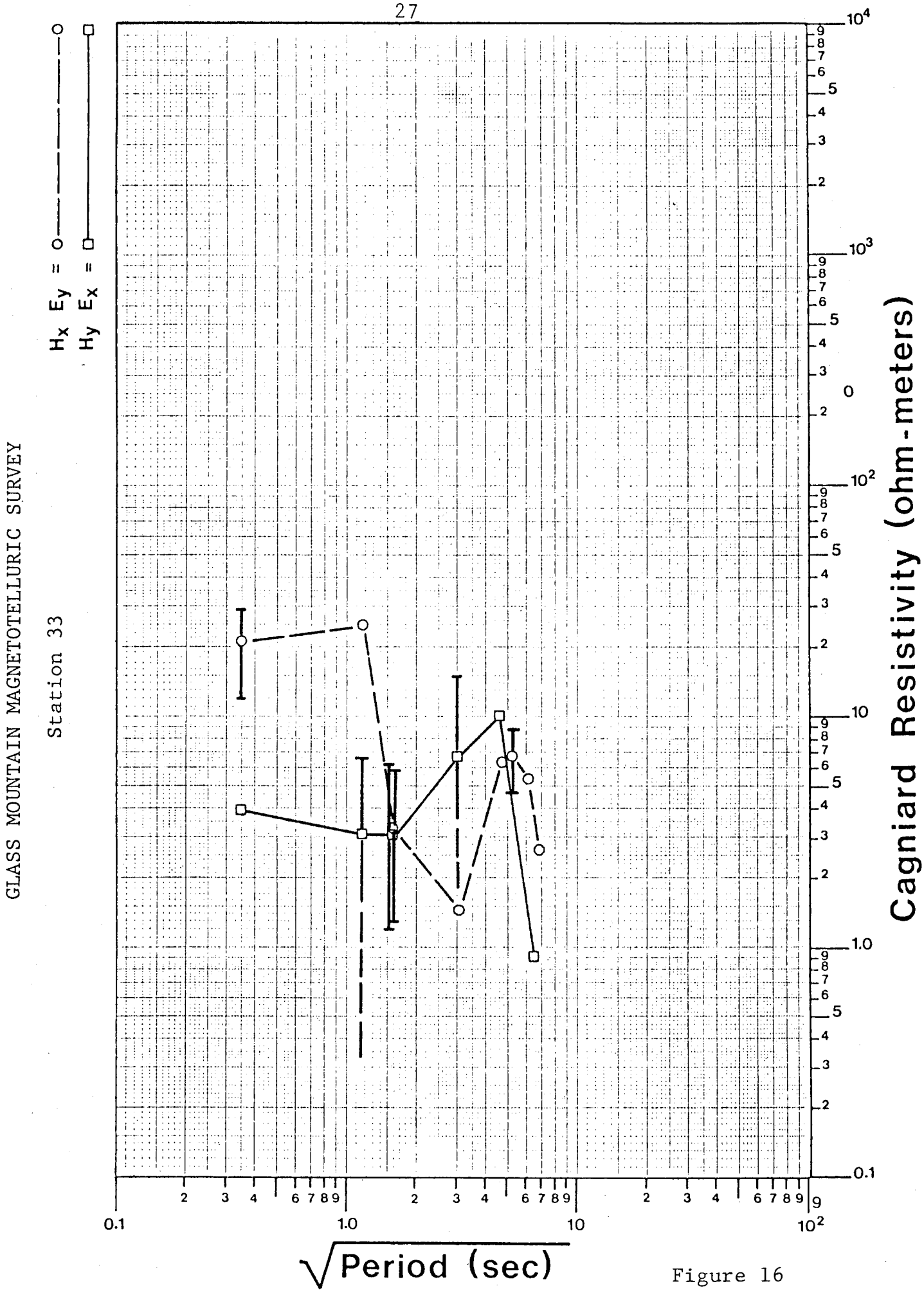

GLASS MOUNTAIN MAGNETOTELLURIC SURVEY
Station 33
H_x E_y = o
H_y E_x = □
Cagniard Resistivity (ohm-meters)
$\sqrt{\text{Period (sec)}}$
0.1
1.0
10
10^2
10^3
10^4

Figure 16

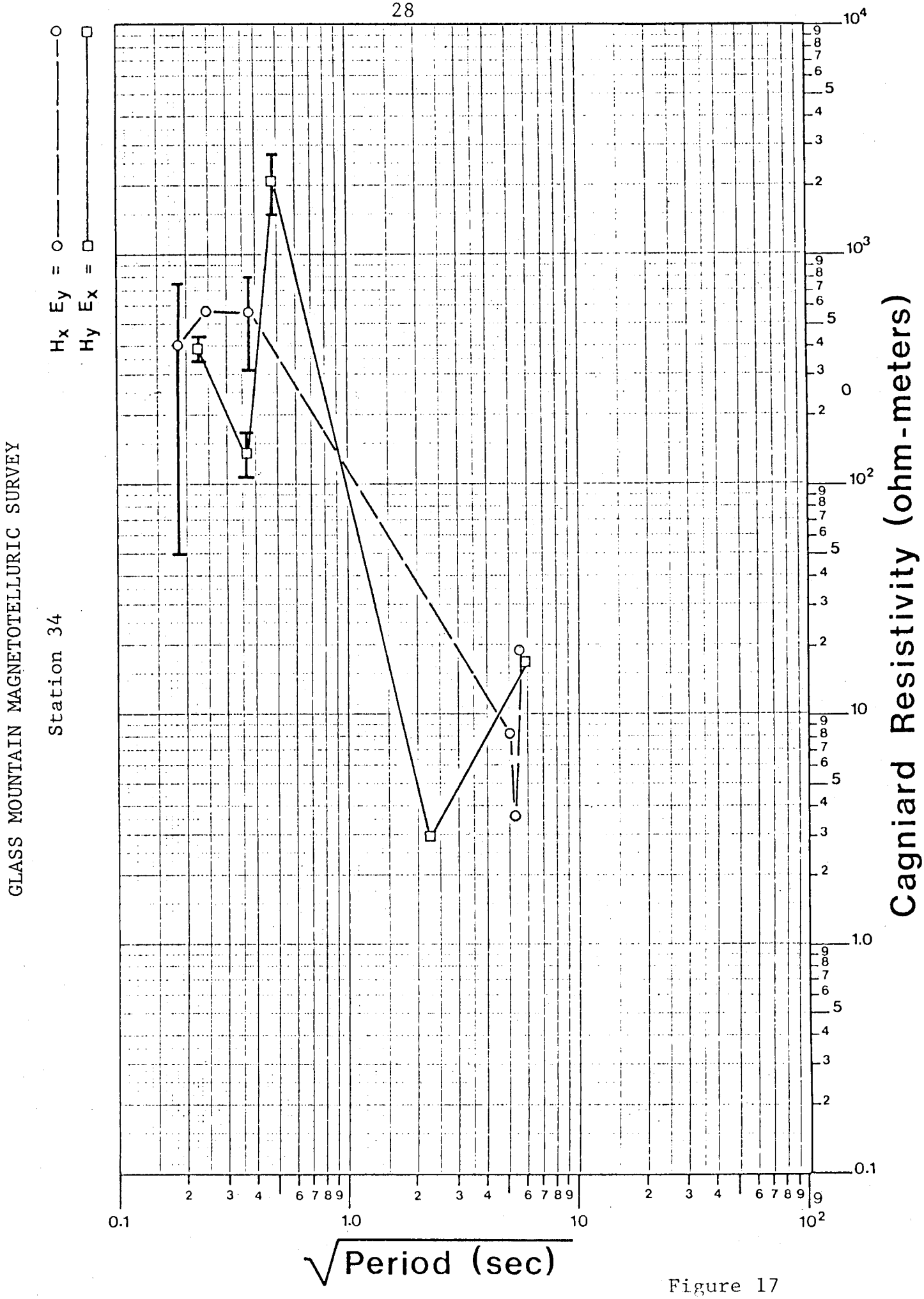

GLASS MOUNTAIN MAGNETOTELLURIC SURVEY
Station 34
H_x E_y = ○——○
H_y E_x = □——□
Cagniard Resistivity (ohm-meters)
$\sqrt{\text{Period (sec)}}$
0.1
1.0
10
10^2
10^3
10^4

Figure 17

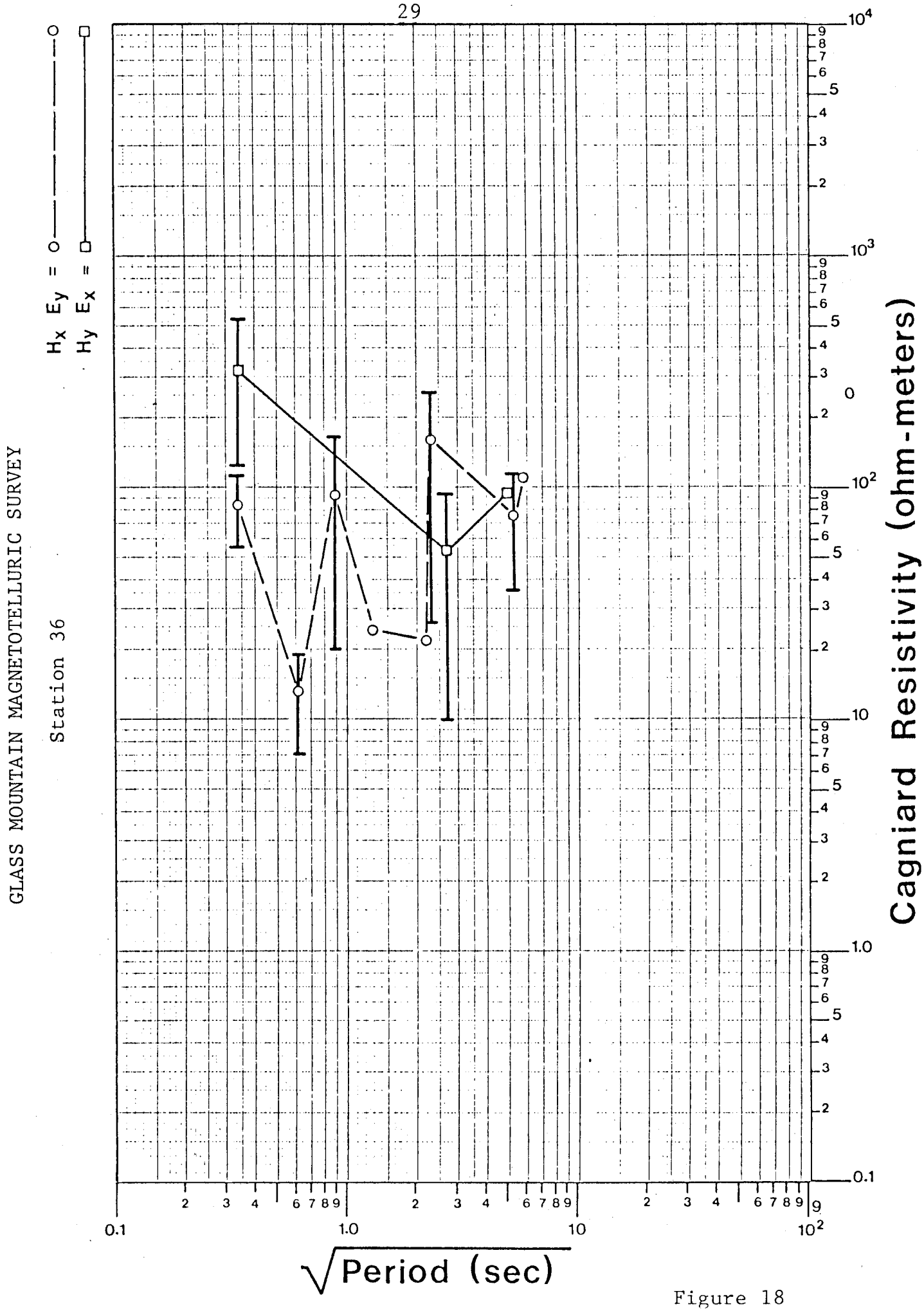

GLASS MOUNTAIN MAGNETOTELLURIC SURVEY
Station 36
H_x E_y = o
H_y E_x = □
Cagniard Resistivity (ohm-meters)
$\sqrt{\text{Period (sec)}}$
0.1
1.0
10
10^2
10^3
10^4

Figure 18

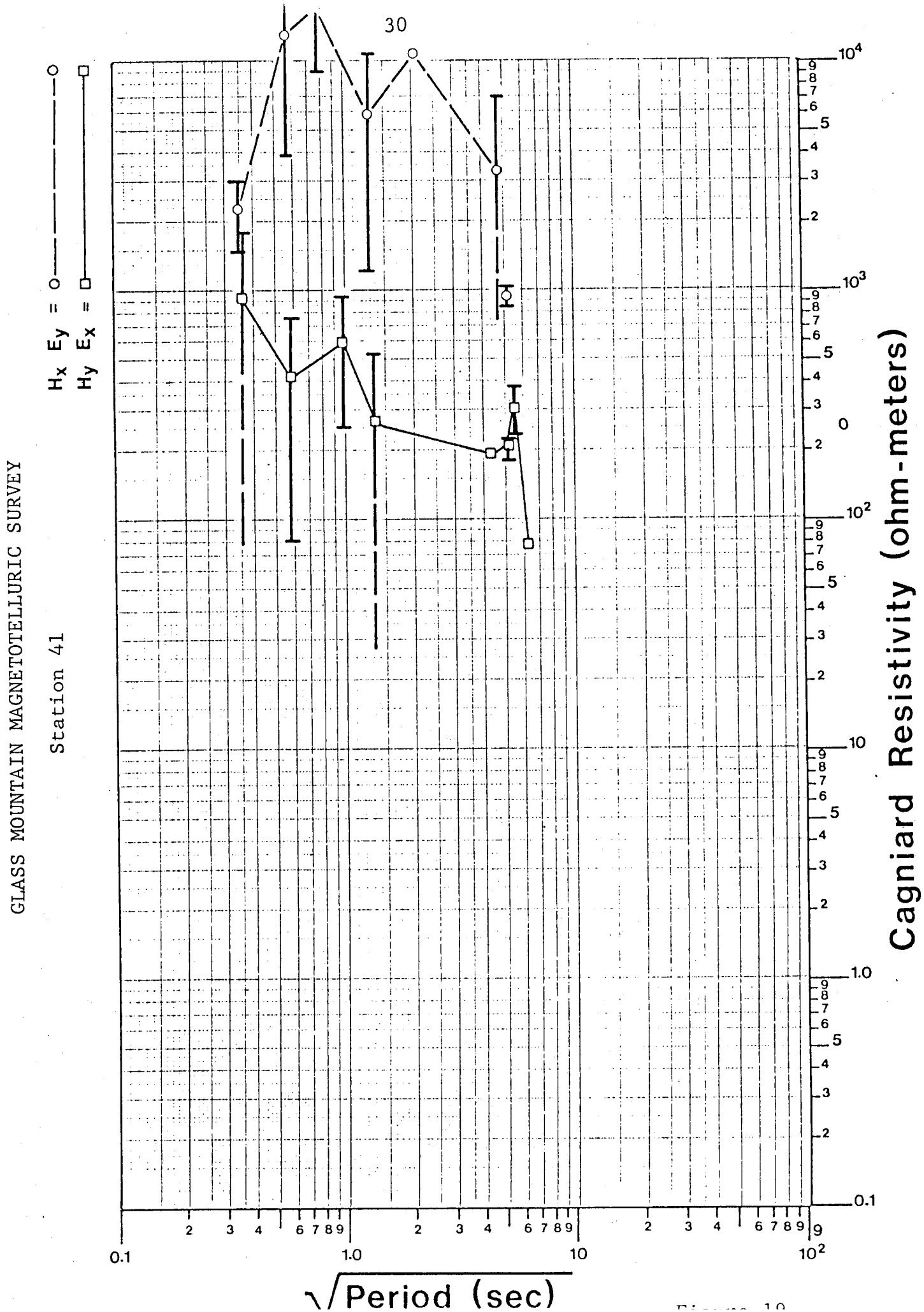

GLASS MOUNTAIN MAGNETOTELLURIC SURVEY
Station 41
H_x E_y = ○——○
H_y E_x = □——□
Cagniard Resistivity (ohm-meters)
$\sqrt{\text{Period (sec)}}$
0.1
1.0
10
10^2
10^3
10^4

Figure 10

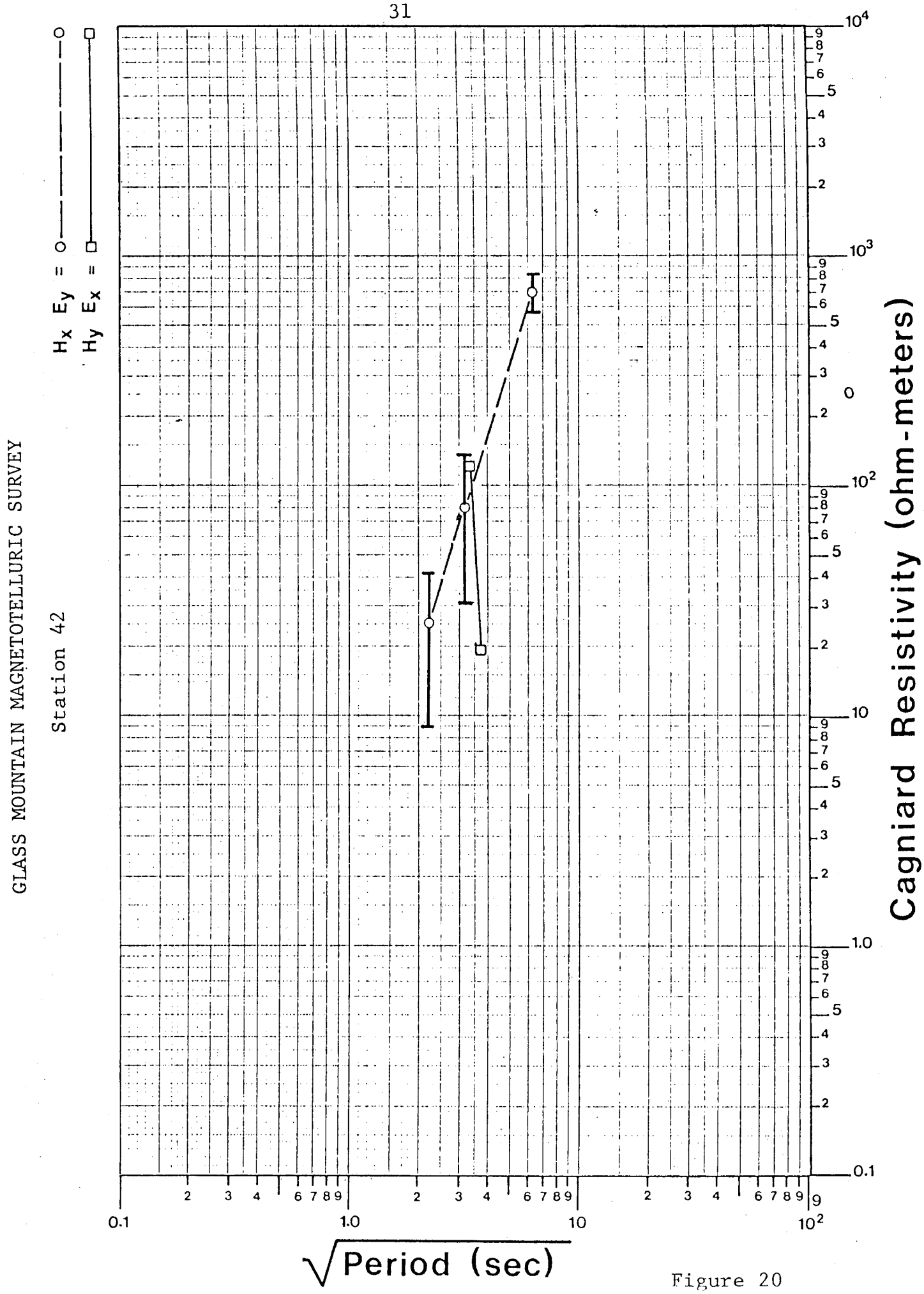

GLASS MOUNTAIN MAGNETOTELLURIC SURVEY
Station 42
H_x E_y = ○
H_y E_x = □
Cagniard Resistivity (ohm-meters)
$\sqrt{\text{Period (sec)}}$
0.1
1.0
10
10^2
10^3
10^4

Figure 20

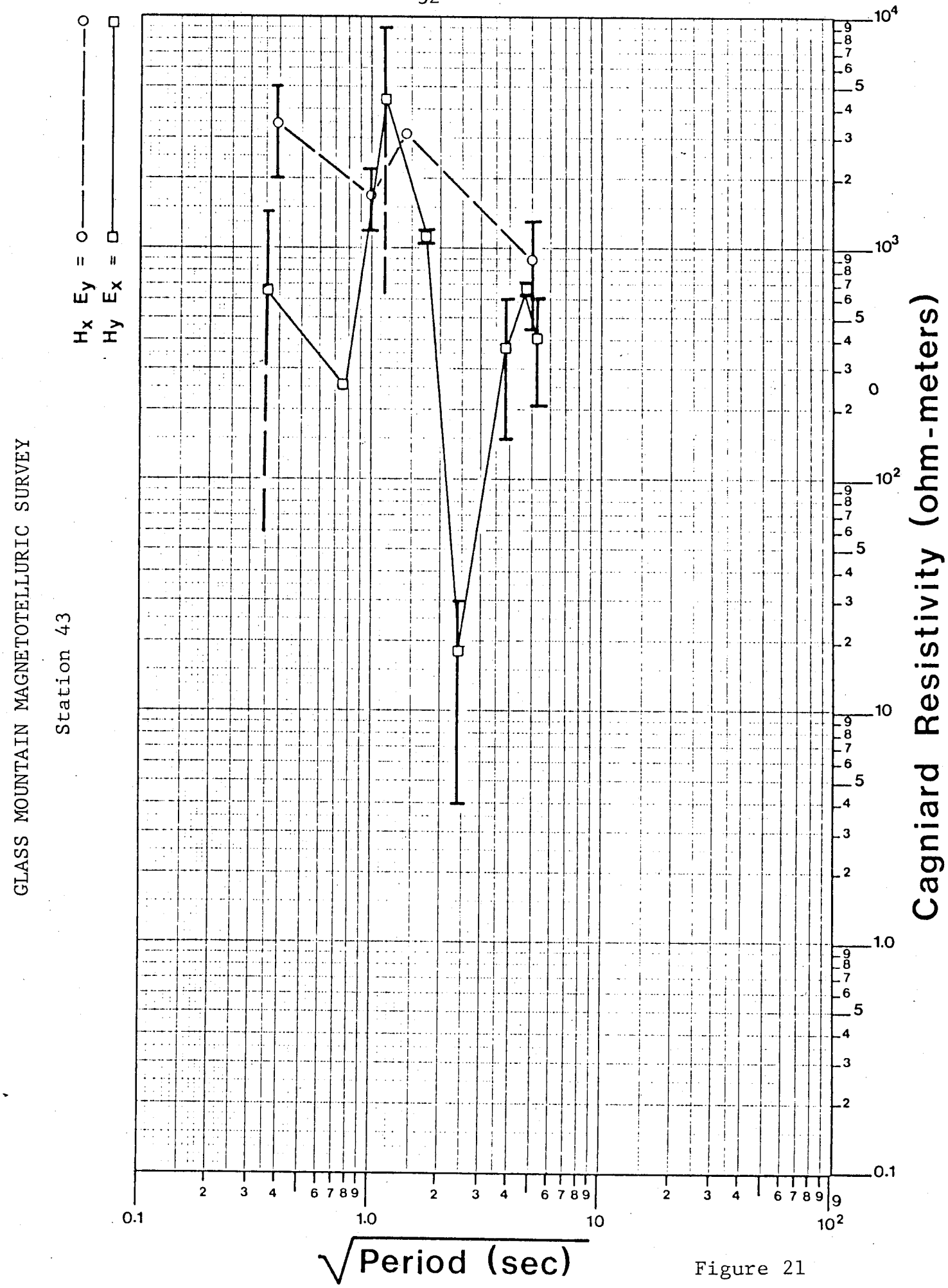

GLASS MOUNTAIN MAGNETOTELLURIC SURVEY
Station 43
Hx Ey = o
Hy Ex = □
Cagniard Resistivity (ohm-meters)
√Period (sec)
0.1
1.0
10
10²
10³
10⁴

Figure 21

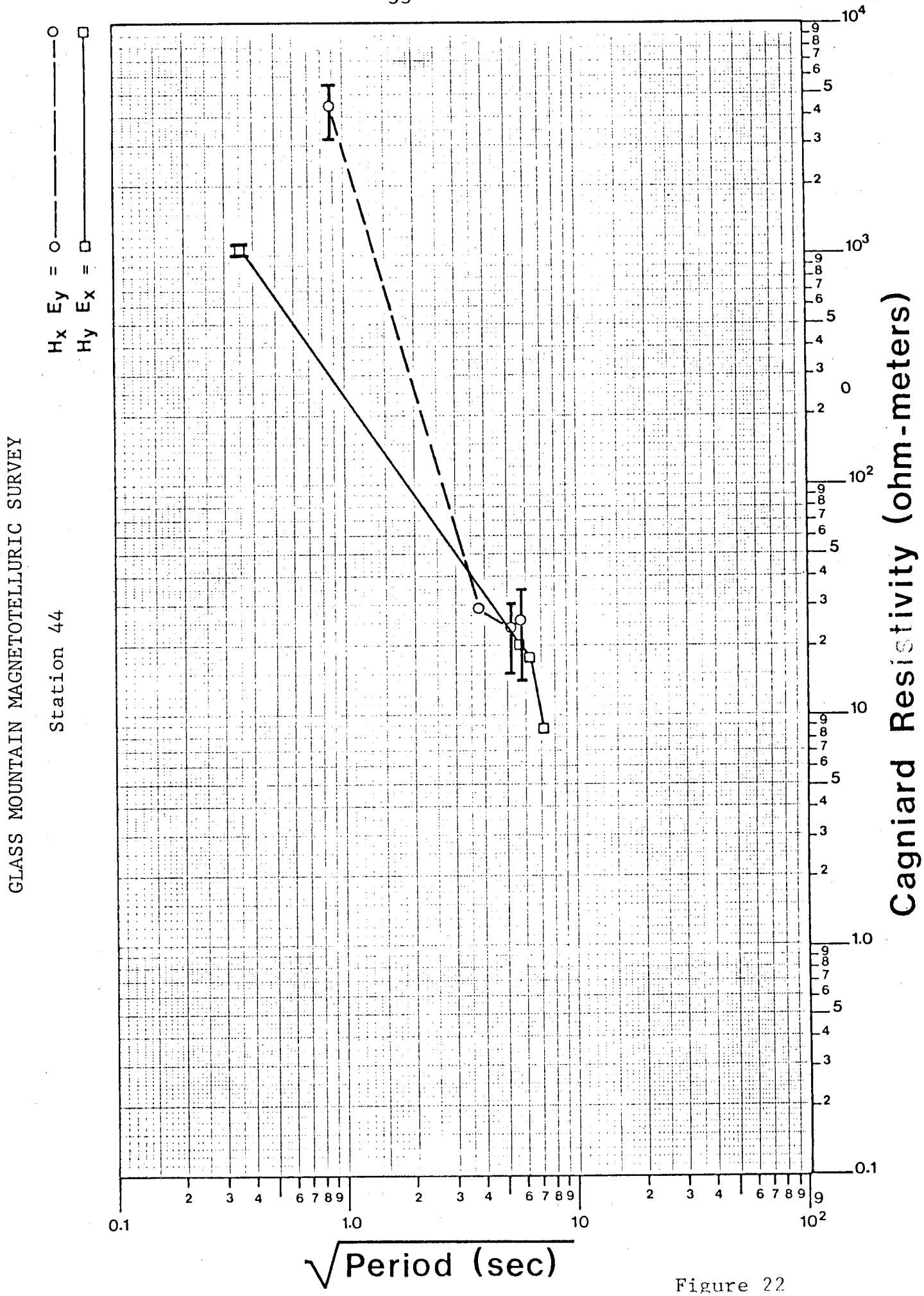

GLASS MOUNTAIN MAGNETOTELLURIC SURVEY
Station 44
H_x E_y = o
H_y E_x = □
Cagniard Resistivity (ohm-meters)
$\sqrt{\text{Period (sec)}}$
0.1
1.0
10
10^2
10^3
10^4

Figure 22

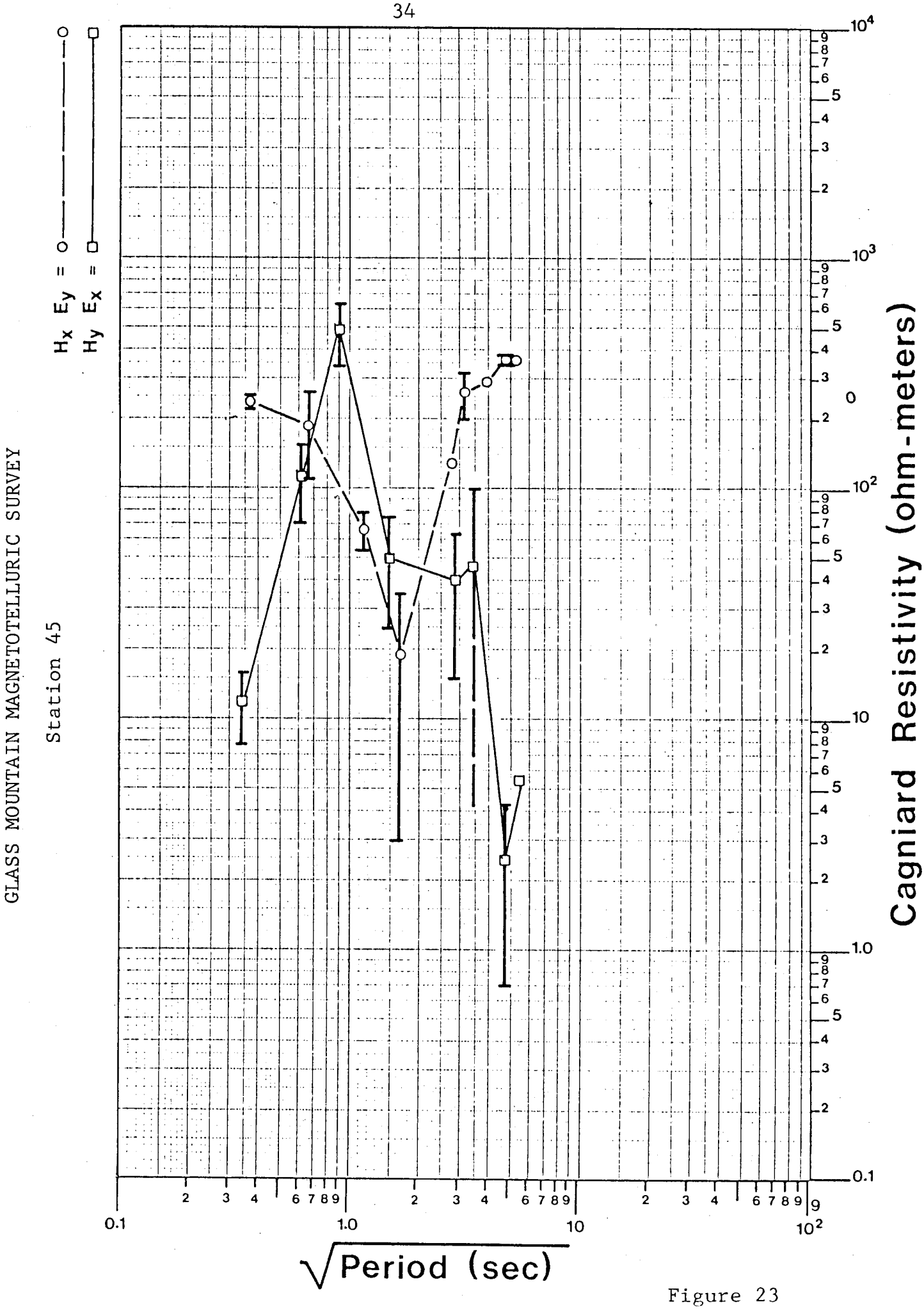

GLASS MOUNTAIN MAGNETOTELLURIC SURVEY
Station 45
Hx Ey = o
Hy Ex = □
Cagniard Resistivity (ohm-meters)
√Period (sec)
0.1
1.0
10
10²
10³
10⁴

Figure 23

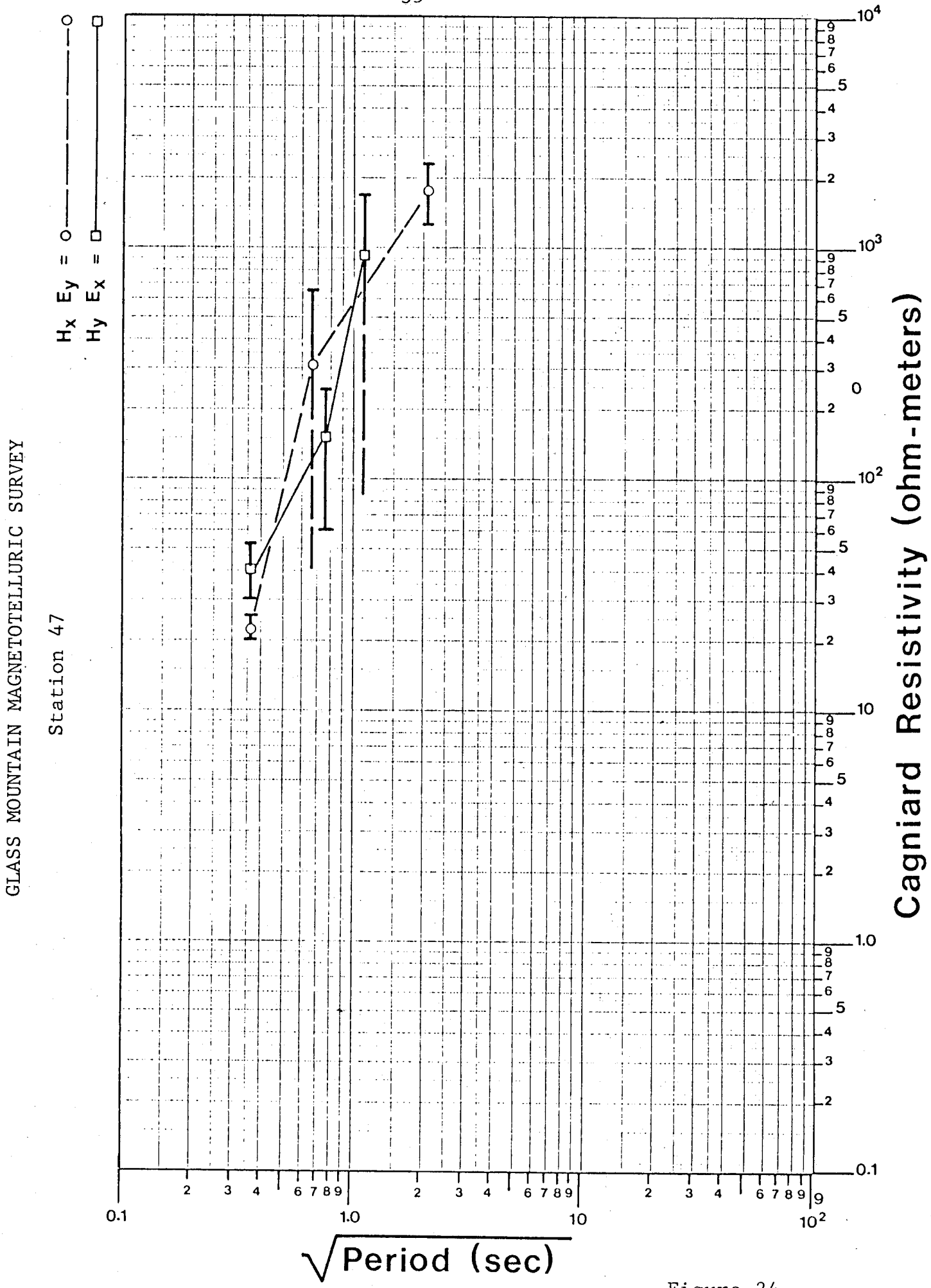

GLASS MOUNTAIN MAGNETOTELLURIC SURVEY
Station 47
H_x E_y = ○
H_y E_x = □
Cagniard Resistivity (ohm-meters)
$\sqrt{\text{Period (sec)}}$
0.1
1.0
10
10^2
10^3
10^4

Figure 24

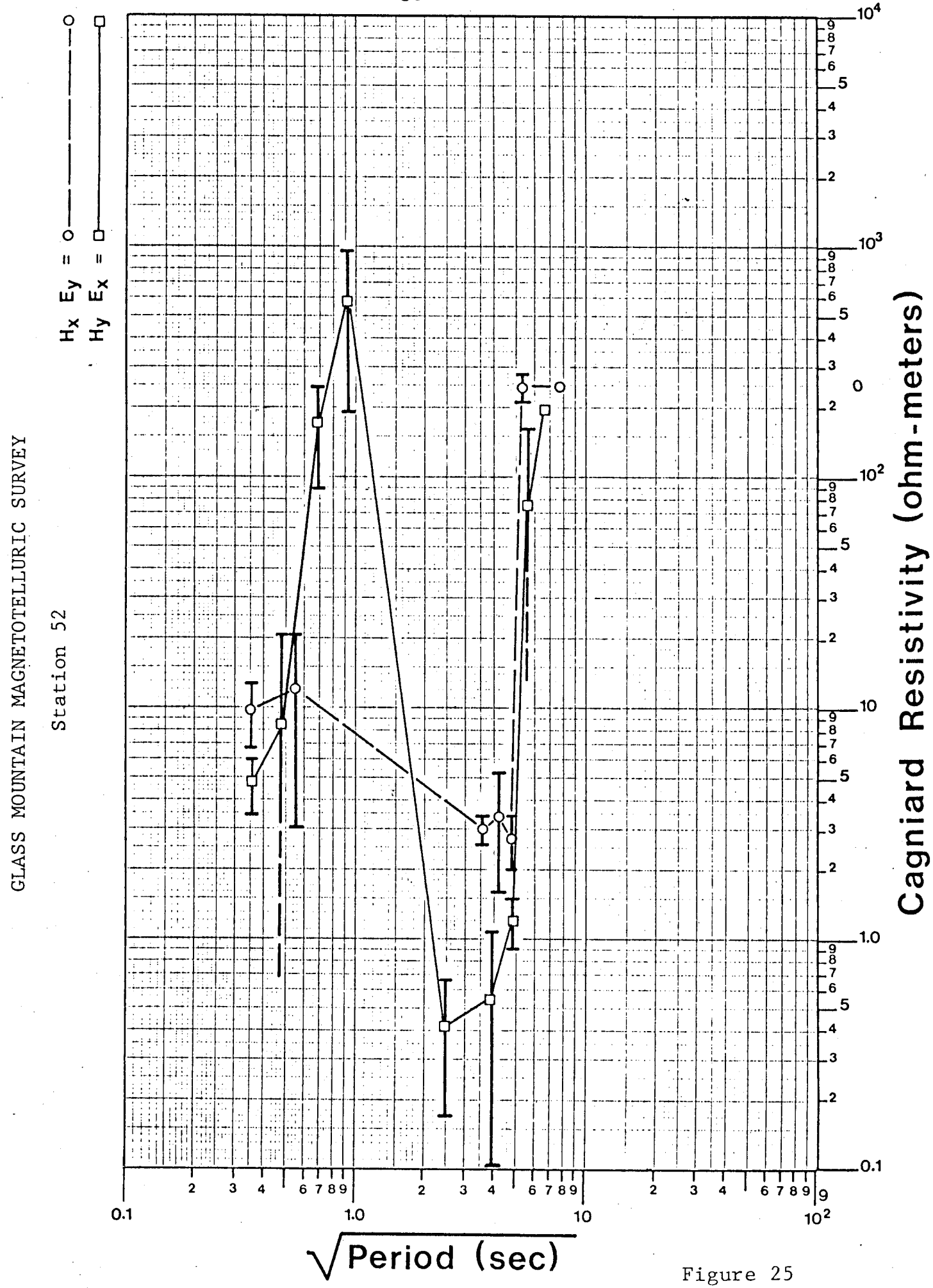

GLASS MOUNTAIN MAGNETOTELLURIC SURVEY
Station 52
H_x E_y = o——o
H_y E_x = □——□
Cagniard Resistivity (ohm-meters)
$\sqrt{\text{Period (sec)}}$
0.1
1.0
10
10^2
10^3
10^4

Figure 25

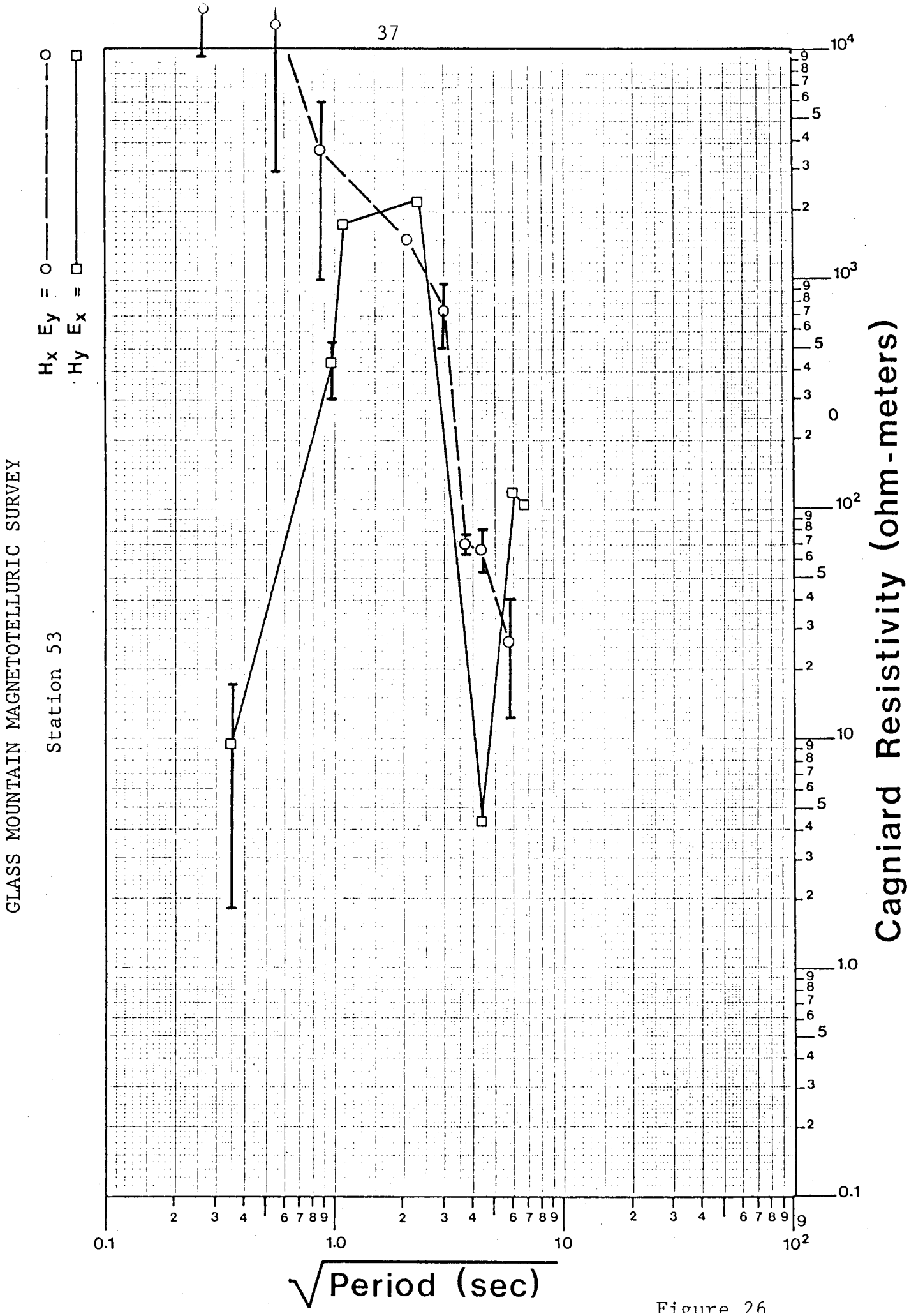

GLASS MOUNTAIN MAGNETOTELLURIC SURVEY
Station 53
H_x E_y = o
H_y E_x =
Cagniard Resistivity (ohm-meters)
$\sqrt{\text{Period (sec)}}$
0.1
1.0
10
10^2
10^3
10^4

Figure 26

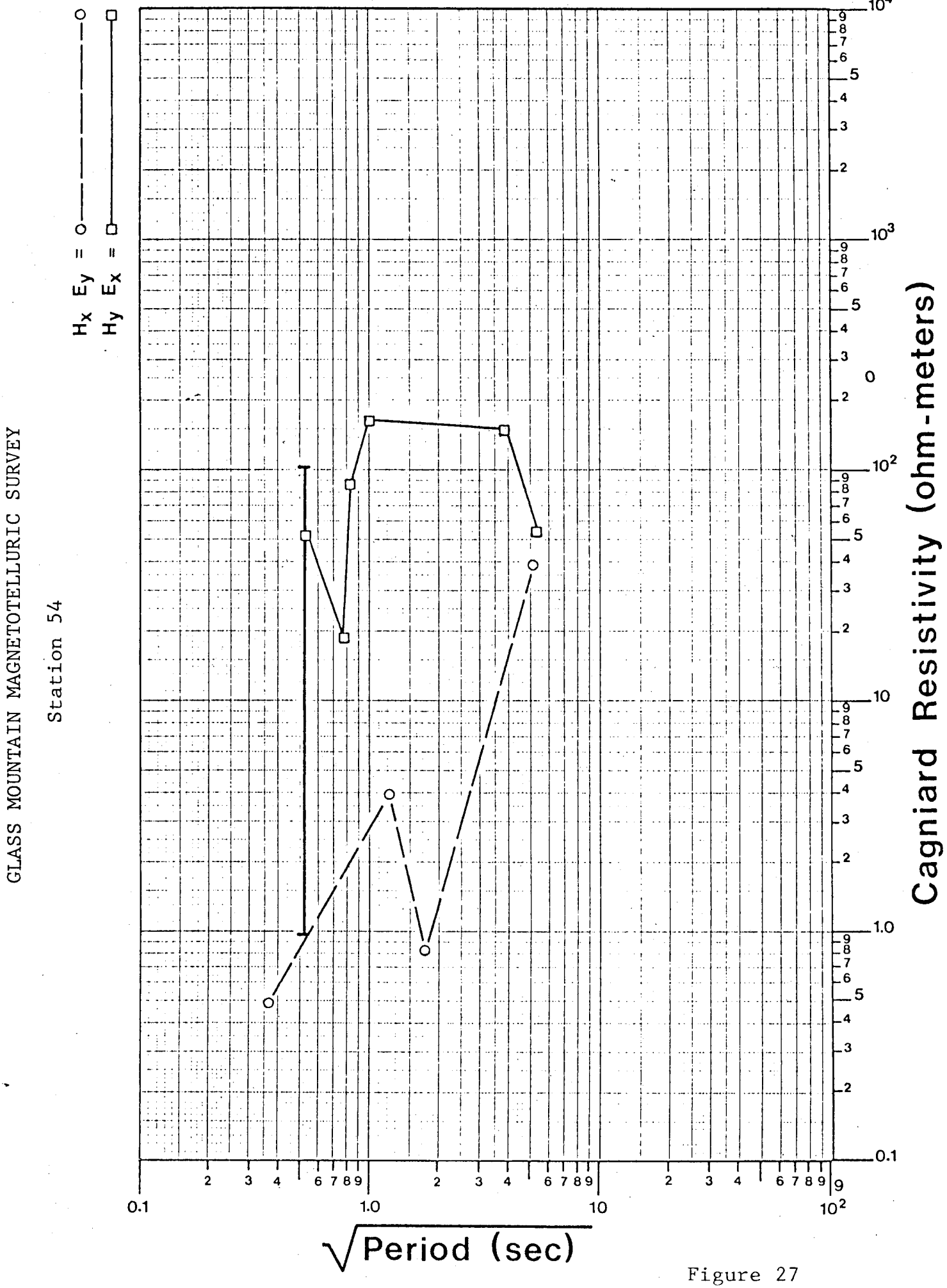

GLASS MOUNTAIN MAGNETOTELLURIC SURVEY
Station 54
Hx Ey = o
Hy Ex = □
Cagniard Resistivity (ohm-meters)
√Period (sec)
0.1
1.0
10
10²
10³
10⁴

Figure 27

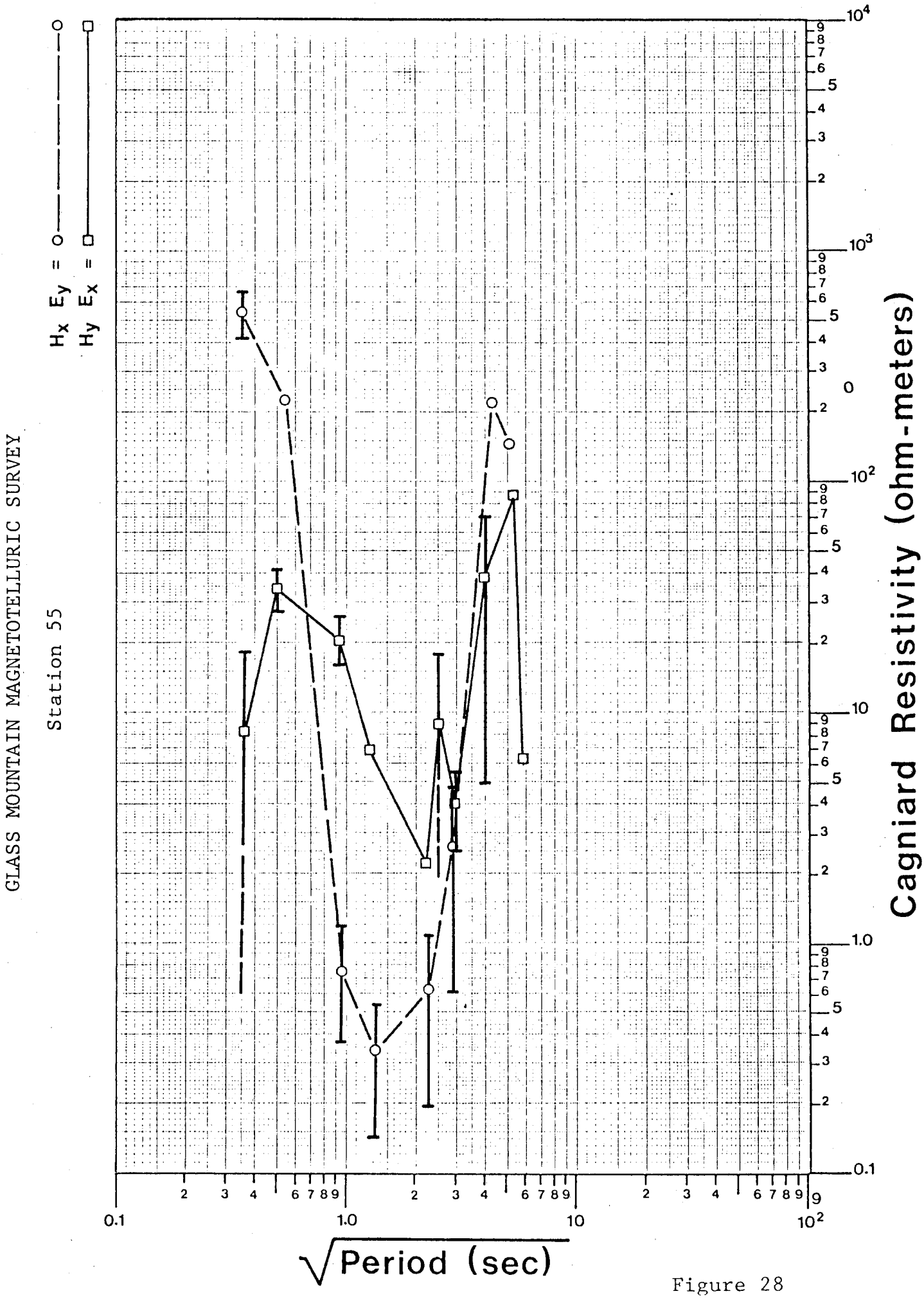

GLASS MOUNTAIN MAGNETOTELLURIC SURVEY
Station 55
Hx Ey = o
Hy Ex = □
Cagniard Resistivity (ohm-meters)
√Period (sec)
0.1
1.0
10
10²
10³
10⁴

Figure 28

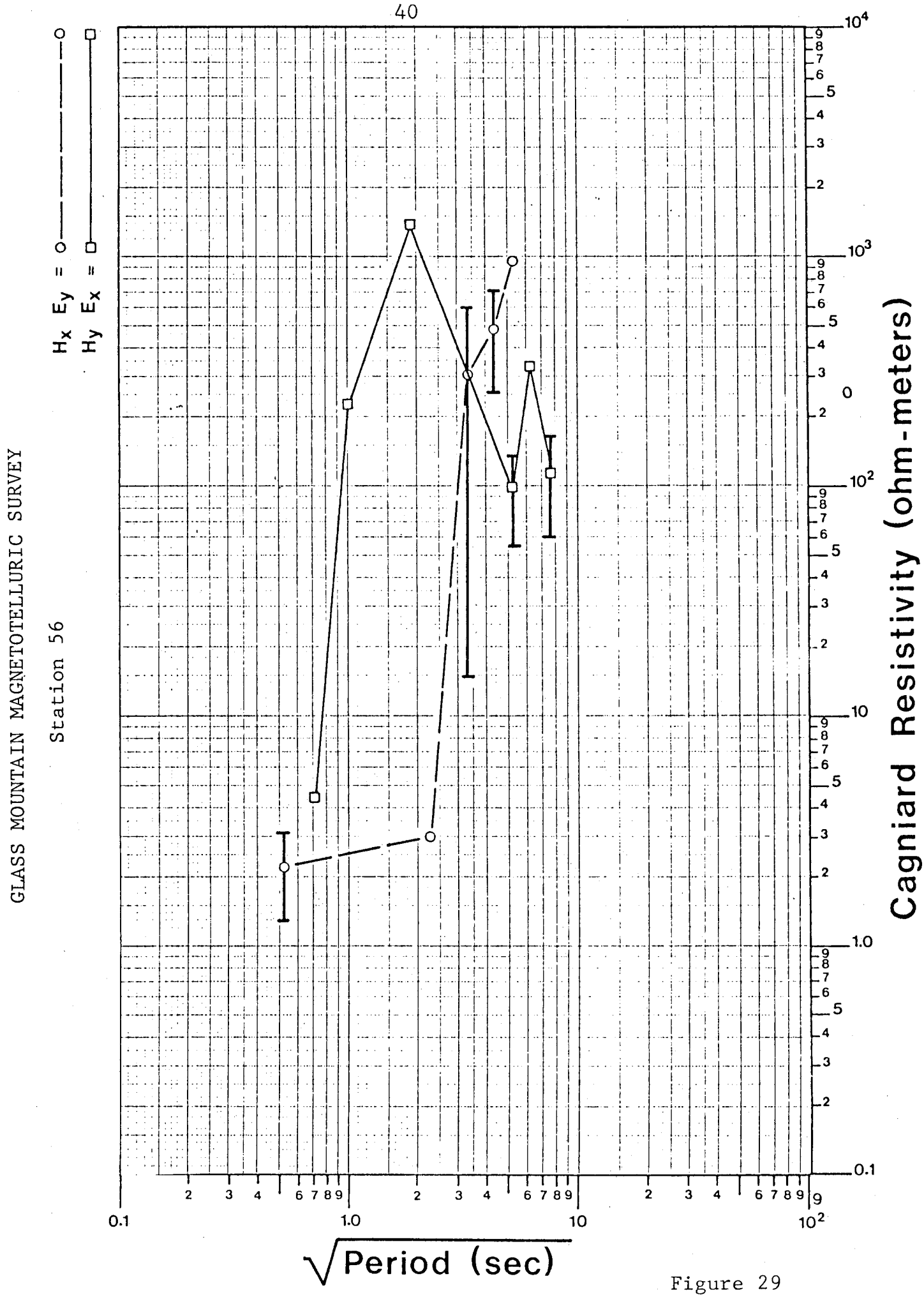

GLASS MOUNTAIN MAGNETOTELLURIC SURVEY
Station 56
Hx Ey = o
Hy Ex = □
Cagniard Resistivity (ohm-meters)
√Period (sec)
0.1
1.0
10
10²
10³
10⁴

Figure 29

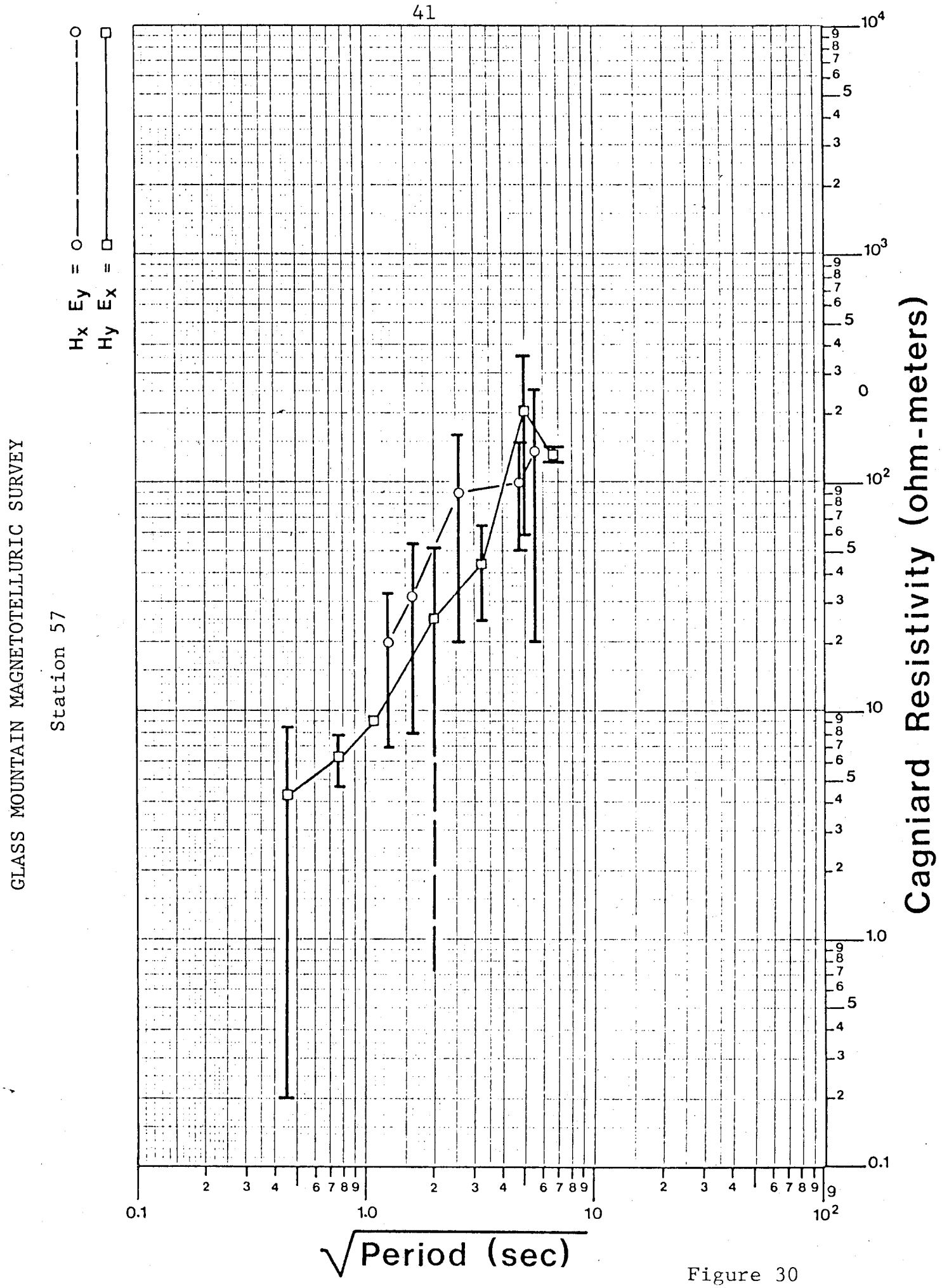
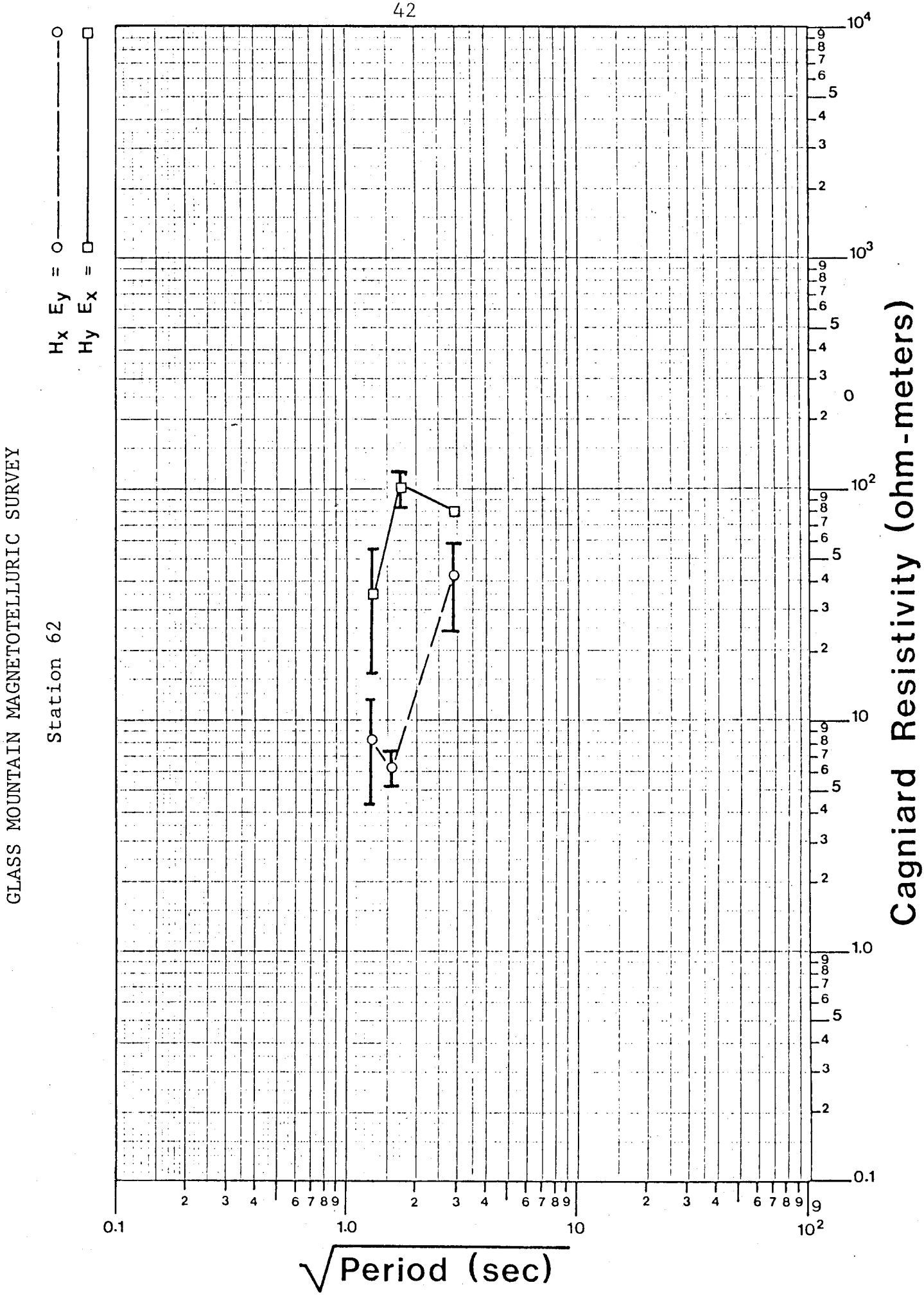

GLASS MOUNTAIN MAGNETOTELLURIC SURVEY
Station 57
Hx Ey = o——o
Hy Ex = □—□
Cagniard Resistivity (ohm-meters)
√Period (sec)
0.1
1.0
10
10²
10³
10⁴

Figure 30


GLASS MOUNTAIN MAGNETOTELLURIC SURVEY
Station 62
H_x E_y = ○
H_y E_x = □
Cagniard Resistivity (ohm-meters)
$\sqrt{\text{Period (sec)}}$
0.1
1.0
10
10^2
10^3
10^4

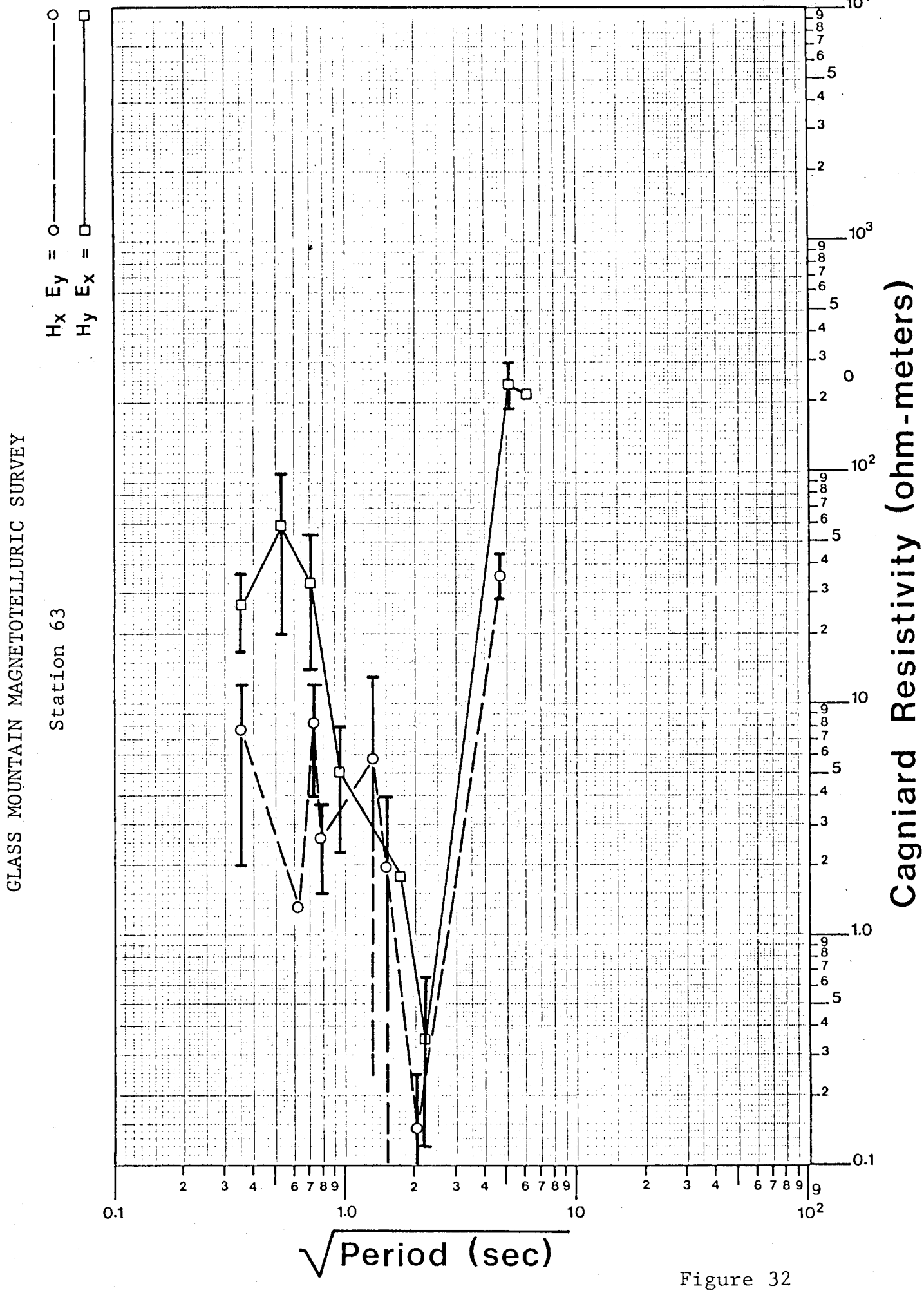

GLASS MOUNTAIN MAGNETOTELLURIC SURVEY
Station 63
H_x E_y = ○
H_y E_x = □
Cagniard Resistivity (ohm-meters)
$\sqrt{\text{Period (sec)}}$
0.1
1.0
10
10^2
10^3
10^4

Figure 32

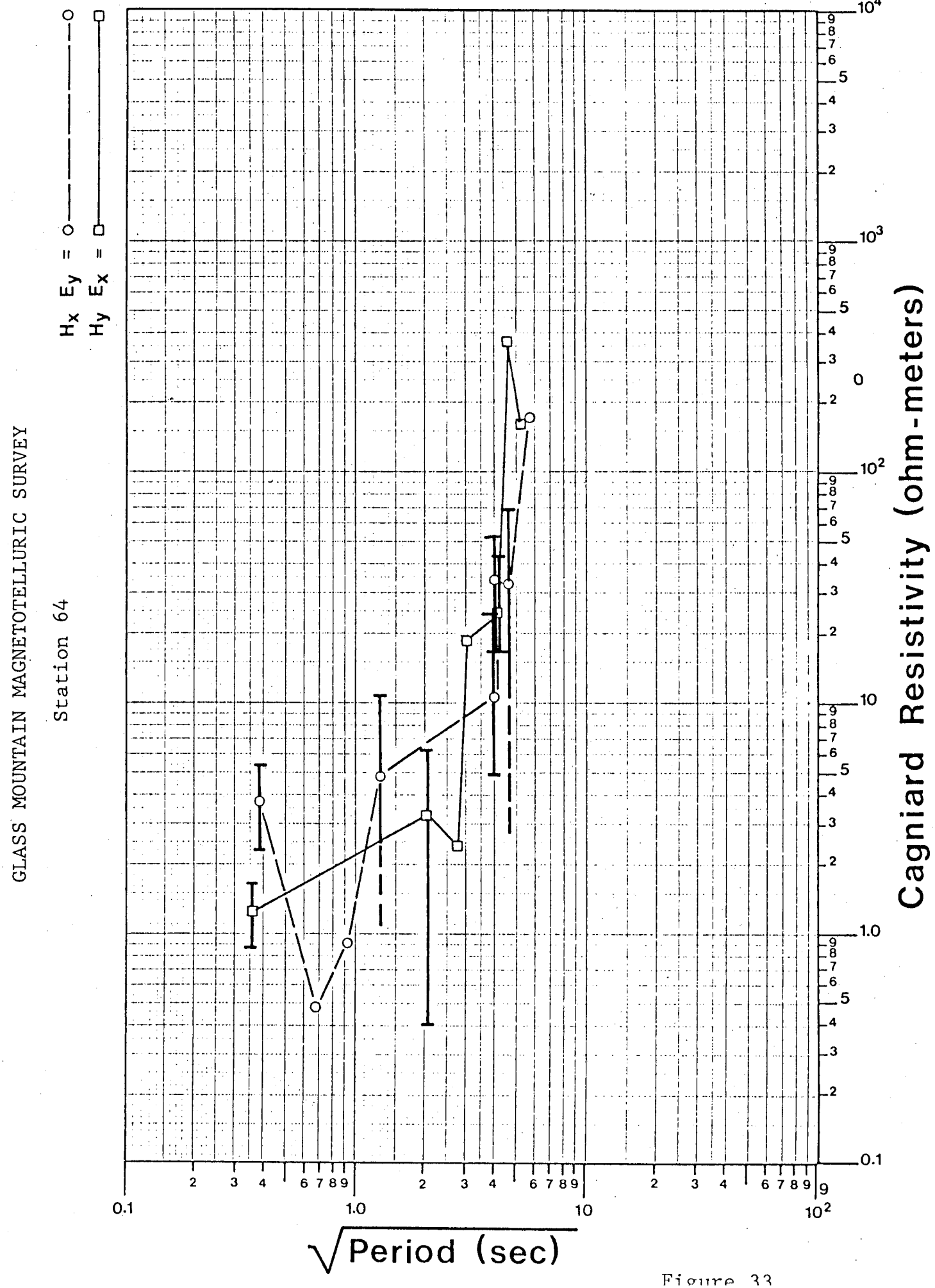

GLASS MOUNTAIN MAGNETOTELLURIC SURVEY
Station 64
H_x E_y = ○
H_y E_x = □
Cagniard Resistivity (ohm-meters)
$\sqrt{\text{Period (sec)}}$
0.1
1.0
10
10^2
10^3
10^4

Figure 33

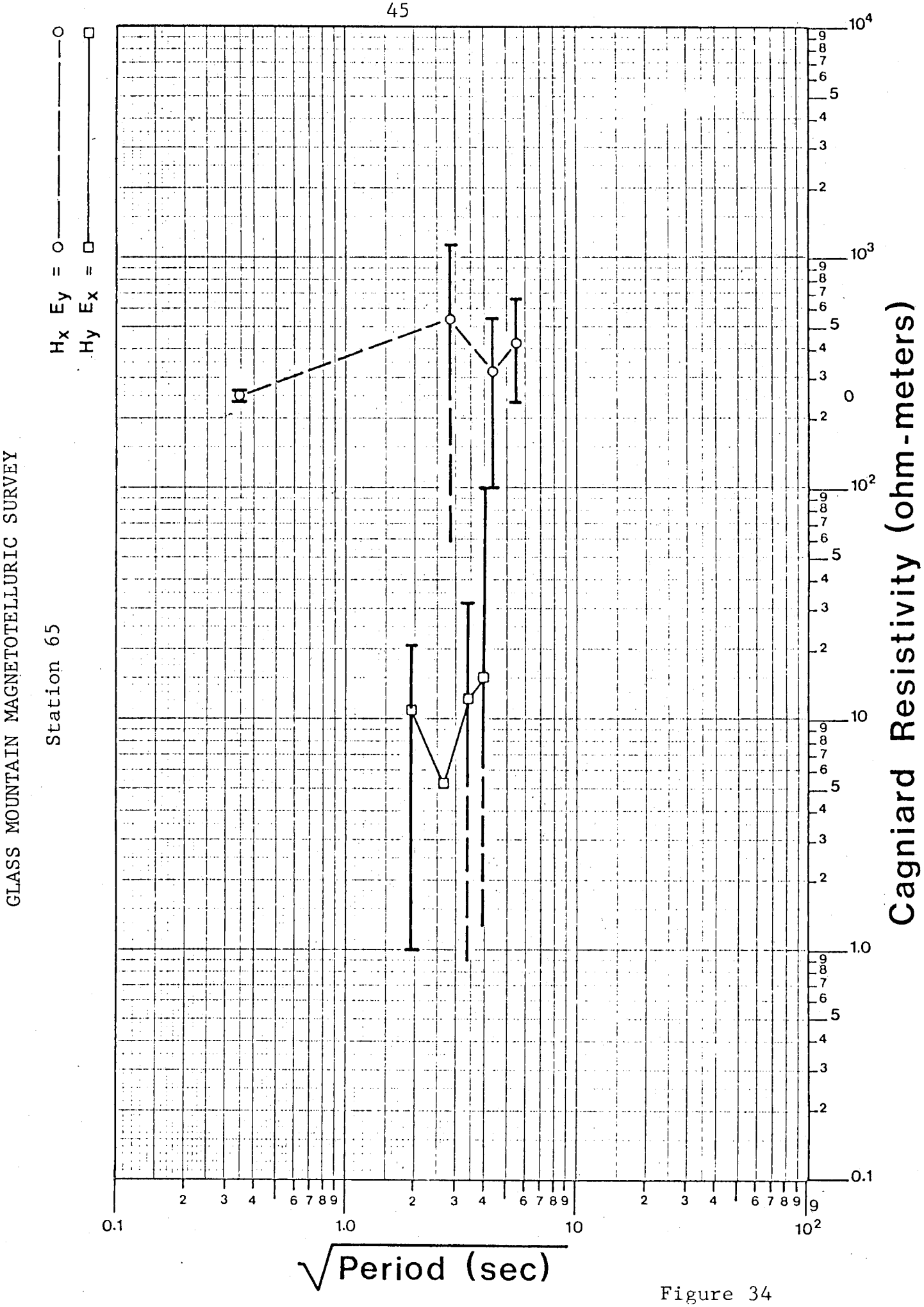
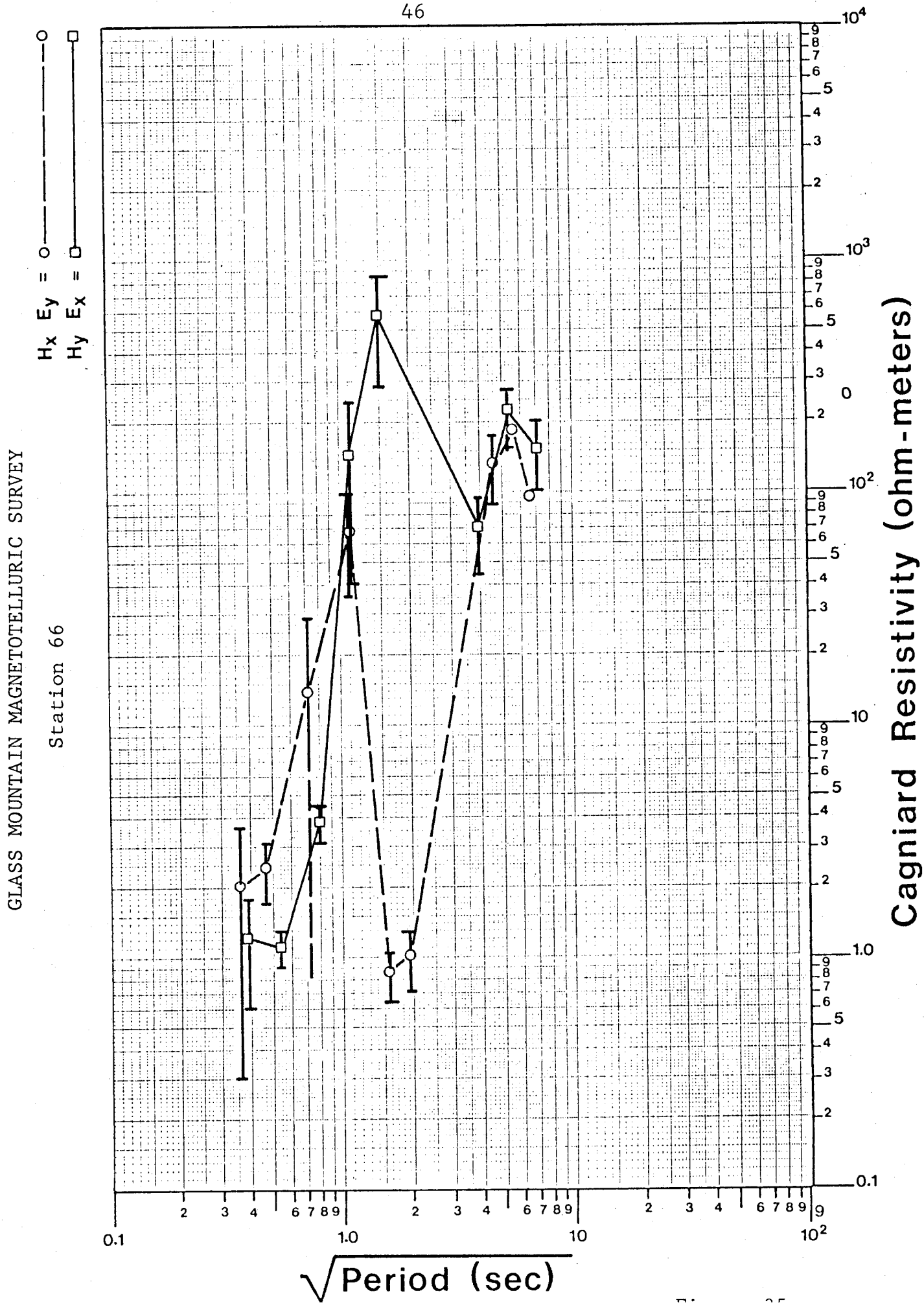

GLASS MOUNTAIN MAGNETOTELLURIC SURVEY
Station 65
Hx Ey = O
Hy Ex = □
Cagniard Resistivity (ohm-meters)
√Period (sec)
0.1
1.0
10
10²
10³
10⁴

Figure 34


GLASS MOUNTAIN MAGNETOTELLURIC SURVEY
Station 66
H_x E_y = ○
H_y E_x = □
Cagniard Resistivity (ohm-meters)
$\sqrt{\text{Period (sec)}}$
0.1
1.0
10
10^2
10^3
10^4

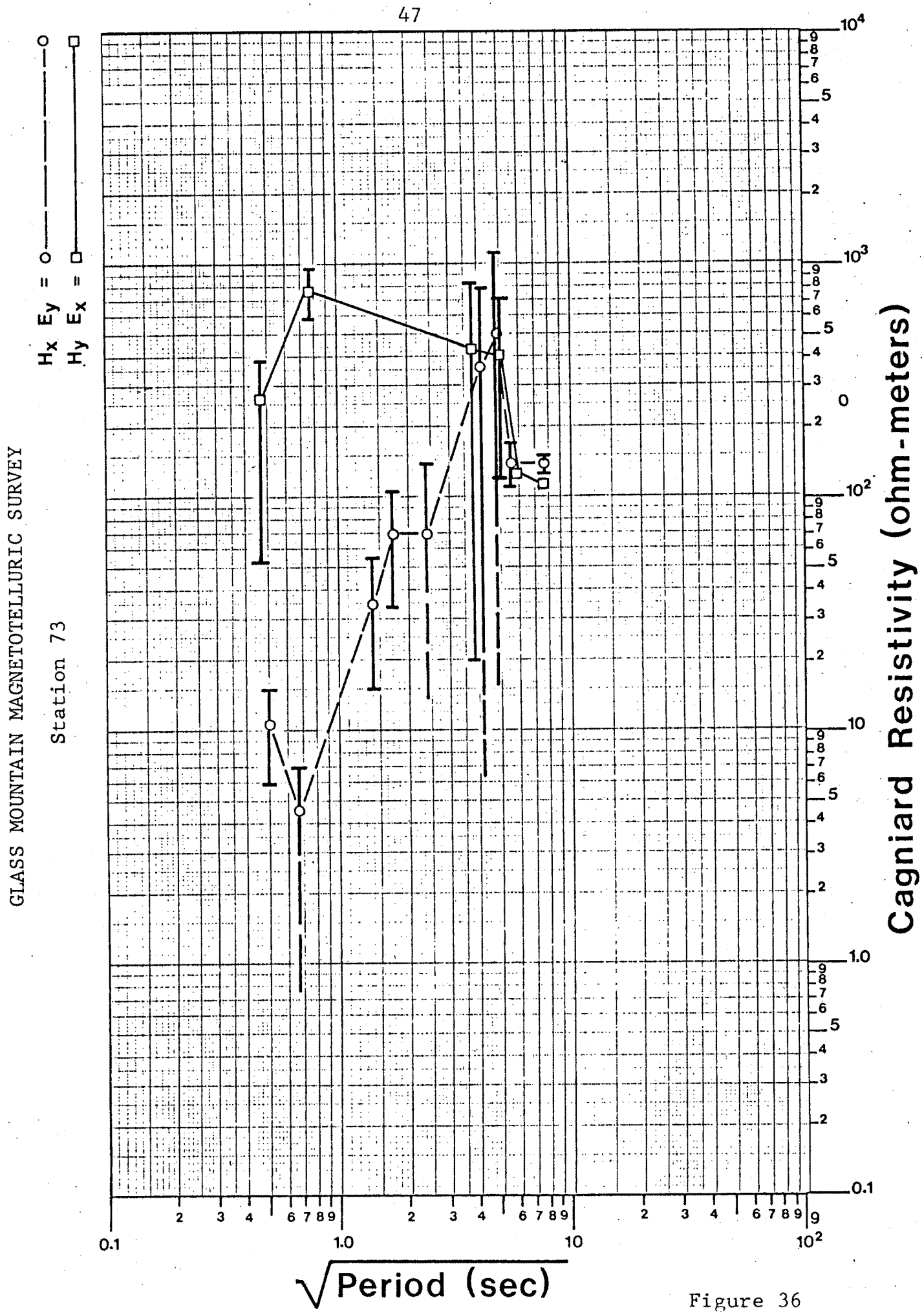

GLASS MOUNTAIN MAGNETOTELLURIC SURVEY
Station 73
Hx Ey = o
Hy Ex = □
Cagniard Resistivity (ohm-meters)
√Period (sec)
0.1
1.0
10
10²
10³
10⁴

Figure 36

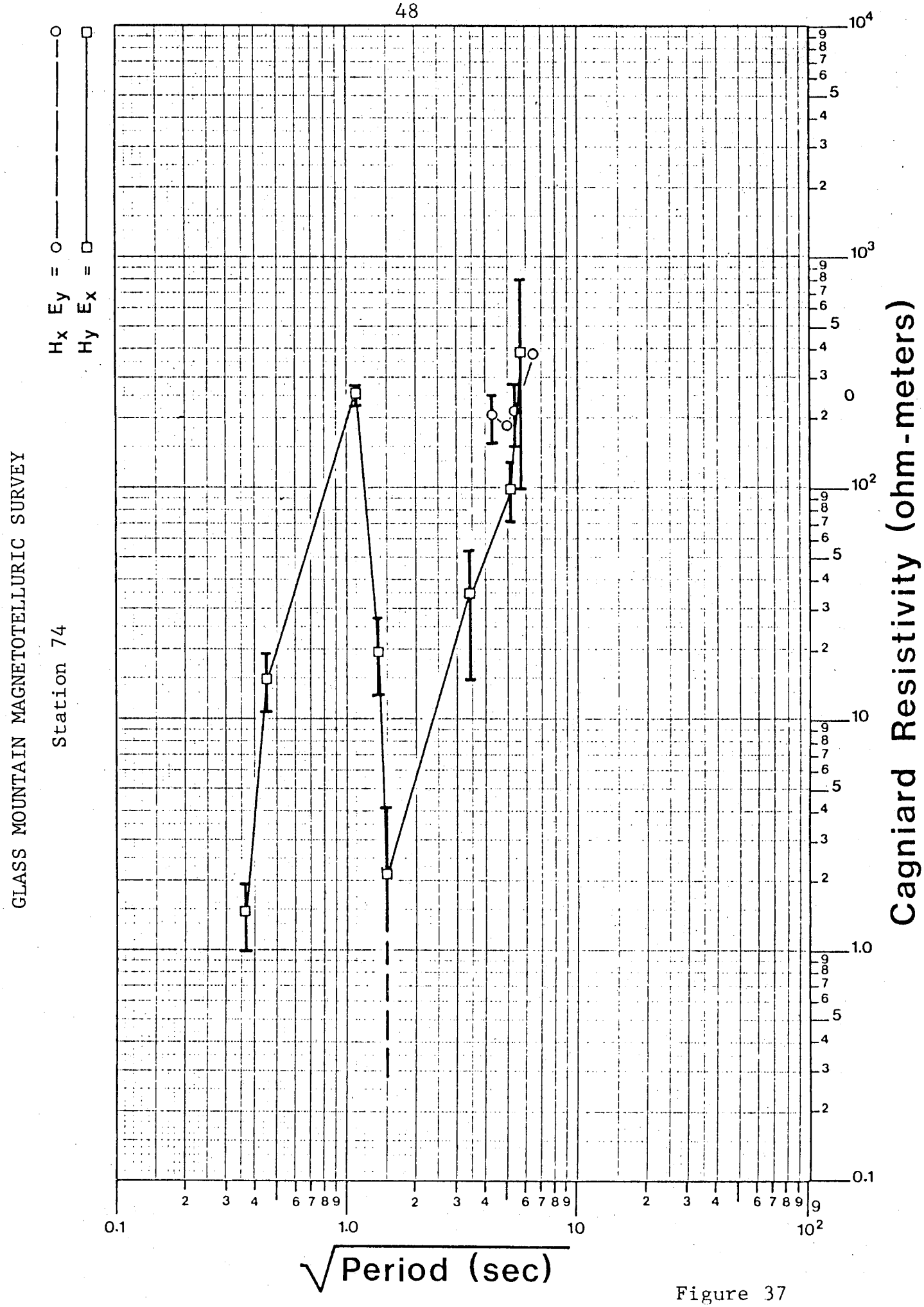

GLASS MOUNTAIN MAGNETOTELLURIC SURVEY
Station 74
H_x E_y = o
H_y E_x = □
Cagniard Resistivity (ohm-meters)
$\sqrt{\text{Period (sec)}}$
0.1
1.0
10
10^2
10^3
10^4

Figure 37

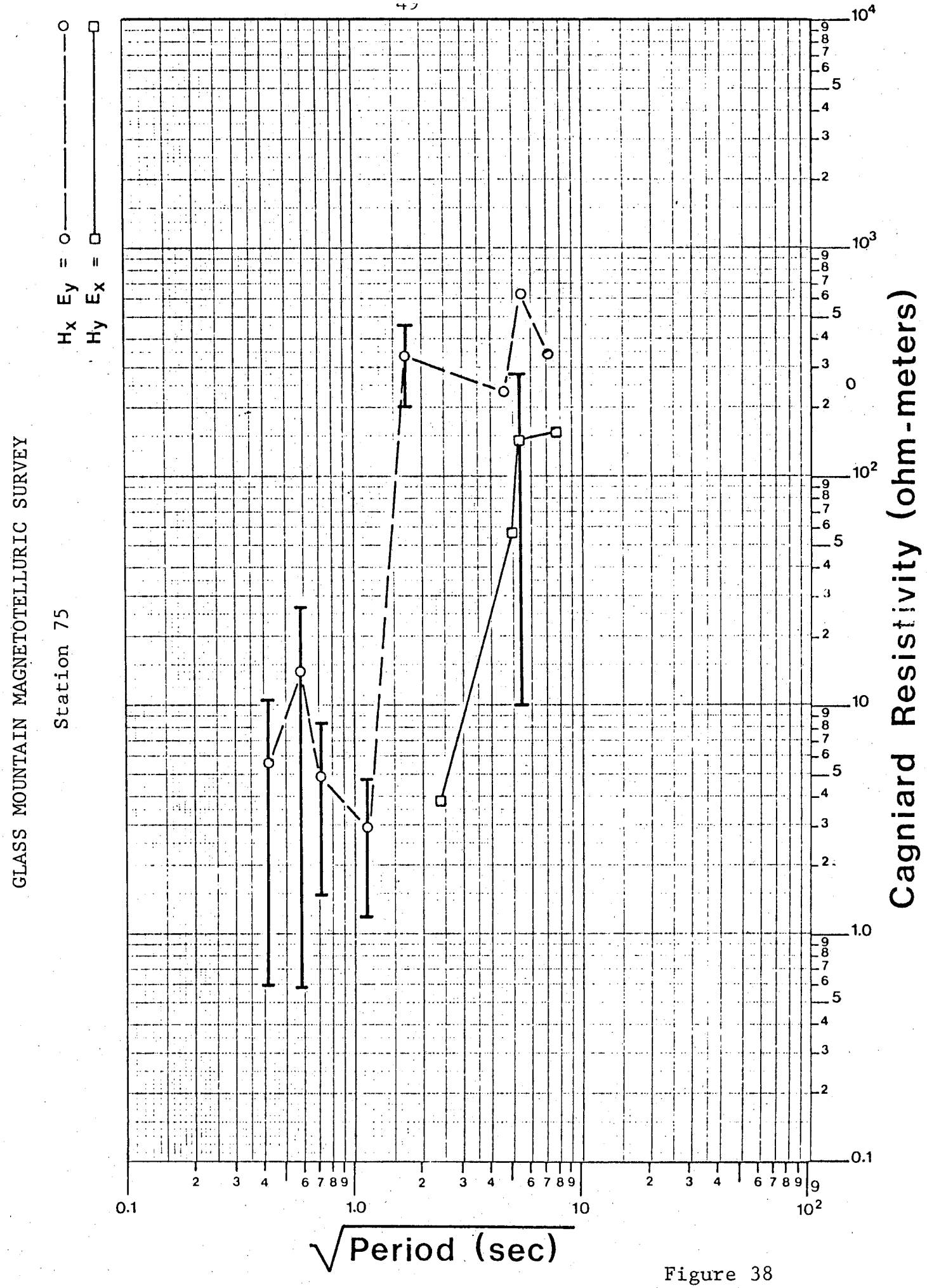
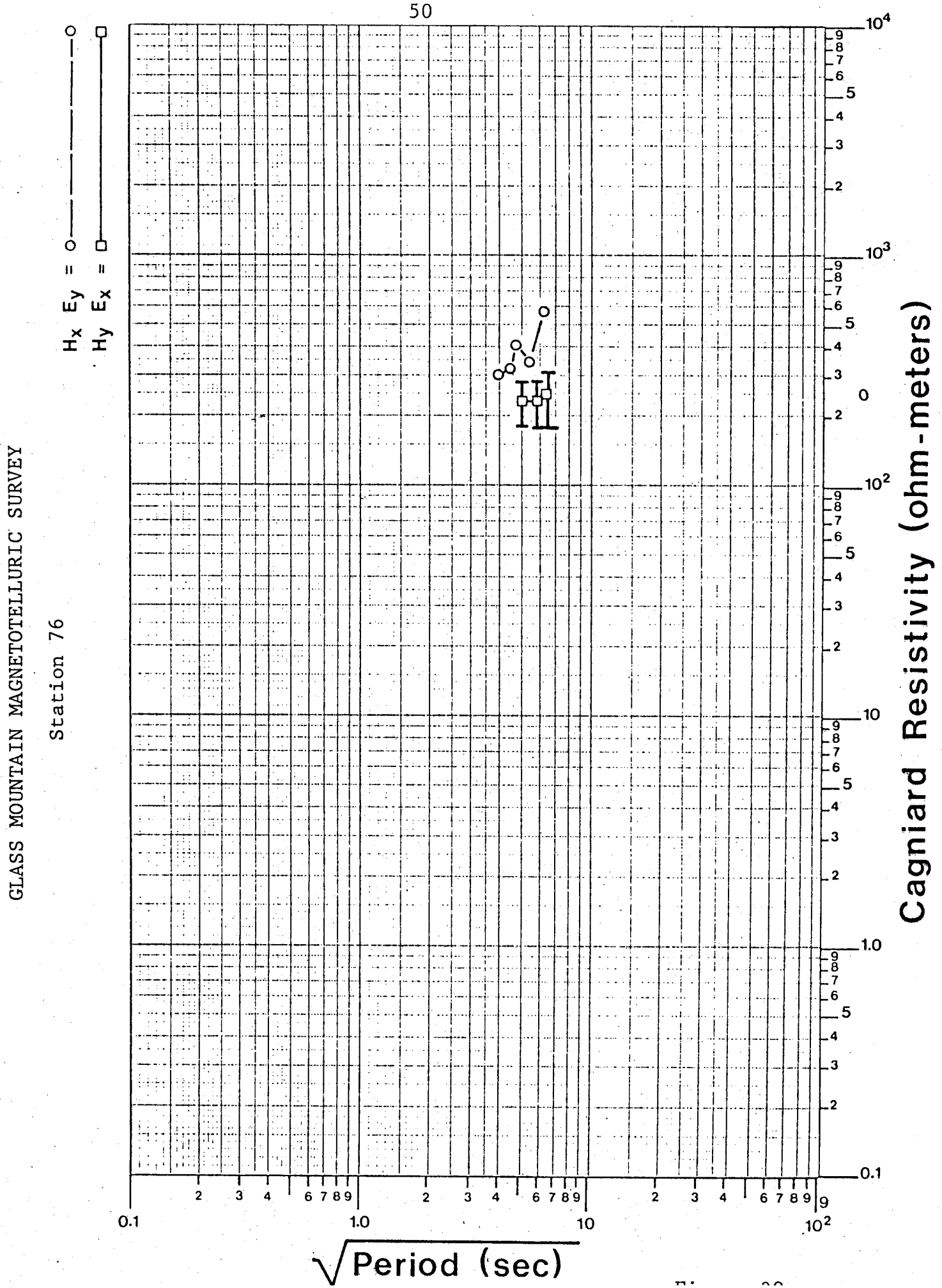

GLASS MOUNTAIN MAGNETOTELLURIC SURVEY
Station 75
H_x E_y = o
H_y E_x = □
Cagniard Resistivity (ohm-meters)
$\sqrt{\text{Period (sec)}}$
0.1
1.0
10
10^2
10^3
10^4

Figure 38


GLASS MOUNTAIN MAGNETOTELLURIC SURVEY
Station 76
H_x E_y = o——o
H_y E_x = □——□
Cagniard Resistivity (ohm-meters)
$\sqrt{\text{Period (sec)}}$
0.1
1.0
10
10^2
10^3
10^4

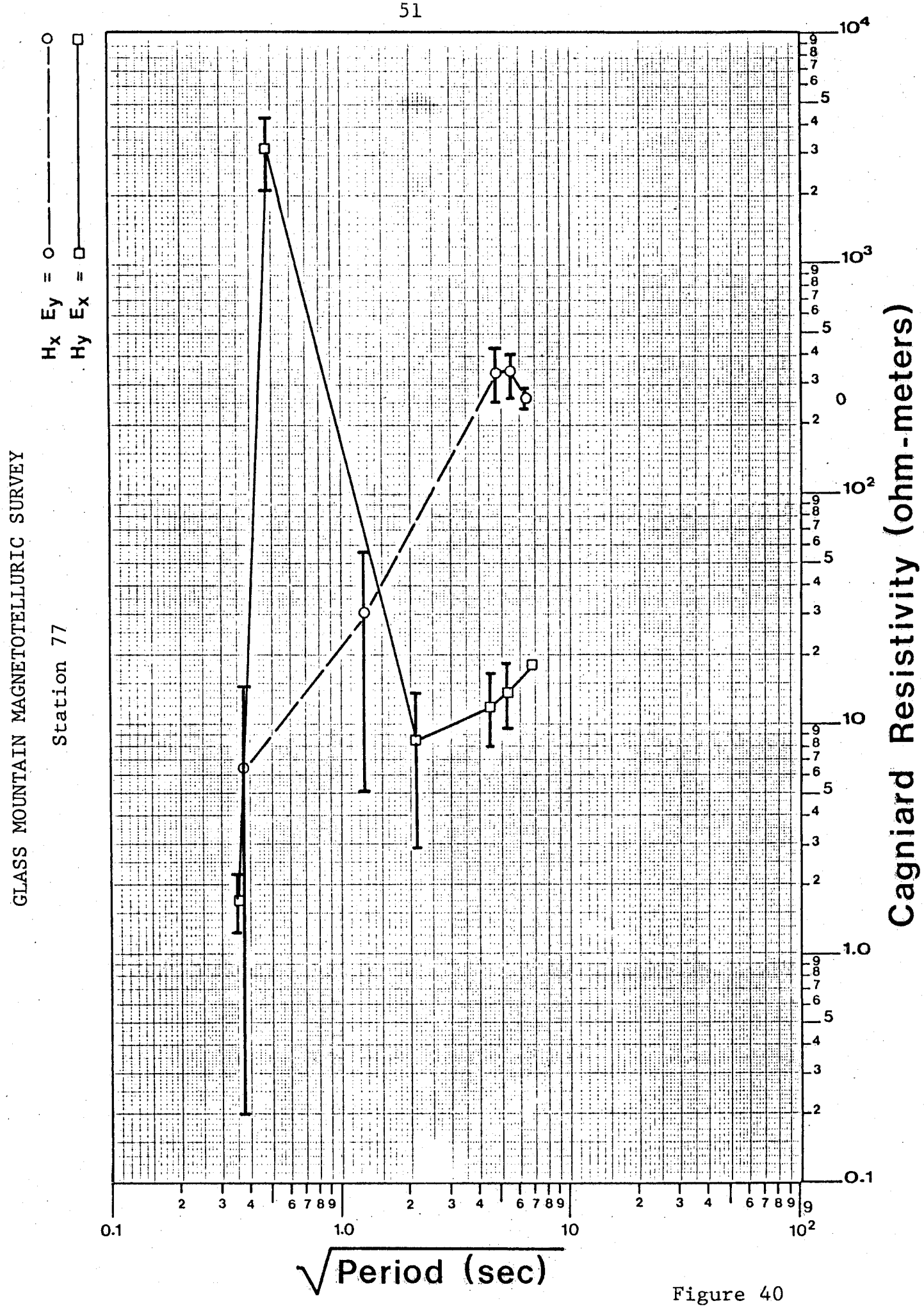

GLASS MOUNTAIN MAGNETOTELLURIC SURVEY
Station 77
Hx Ey = o
Hy Ex = □
Cagniard Resistivity (ohm-meters)
√Period (sec)
0.1
1.0
10
10²
10³
10⁴

Figure 40

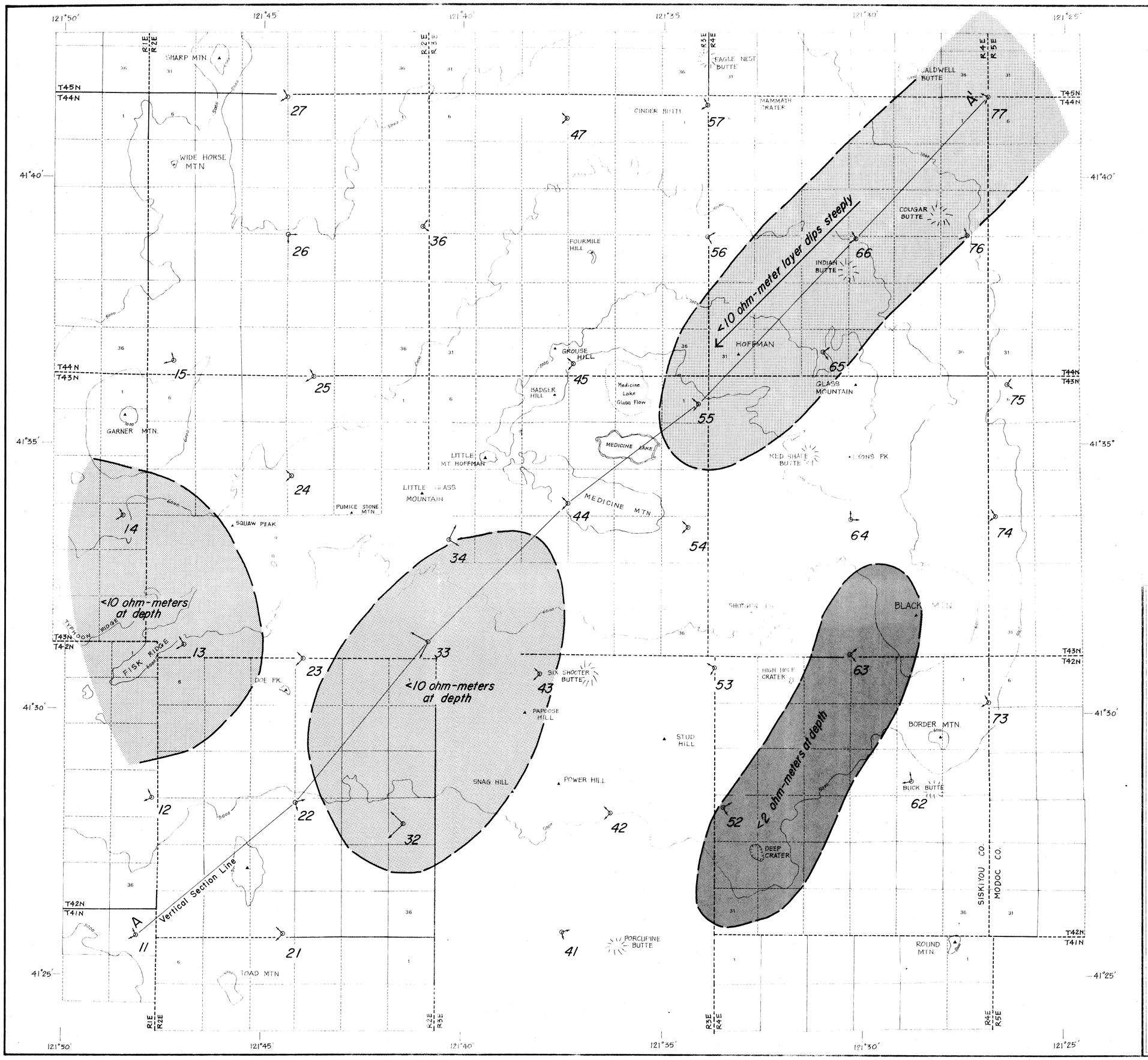


PLATE I

FEB 18 1976

GLASS MOUNTAIN PROSPECT
SISKIYOU COUNTY
CALIFORNIA

PRELIMINARY

MAGNETO-TELLURIC SURVEY

LEGEND

- POTENTIAL ELECTRODE CONFIGURATION (DRAWN TO SCALE)
- 76 — STATION NUMBER
- LOW RESISTIVITY ZONE, ≈ 2 OHM-METERS
- MODERATELY LOW RESISTIVITY ZONE, ≈10 OHM-METERS

SCALE 1:62,500
0 1Mi 2Mi

Prepared for: UNION OIL COMPANY
GEOTHERMAL OPERATIONS
by
GEONOMICS INC., 3165-67 Adeline St. Berkeley, Ca. 94703

APPENDIX O:
Glass Mountain Unit Area 1983 HEM survey

Attachment XIV

CEC-500-2007-XXX-ATXIV

Glass Mountain Unit Area 1983 HEM survey.

This document is an attachment to a report funded by the California Energy Commission's Geothermal Resource Development Account (GRDA) Program. The GRDA Program did not fund this document, but the authors of the GRDA funded report have attached it as a supporting document.

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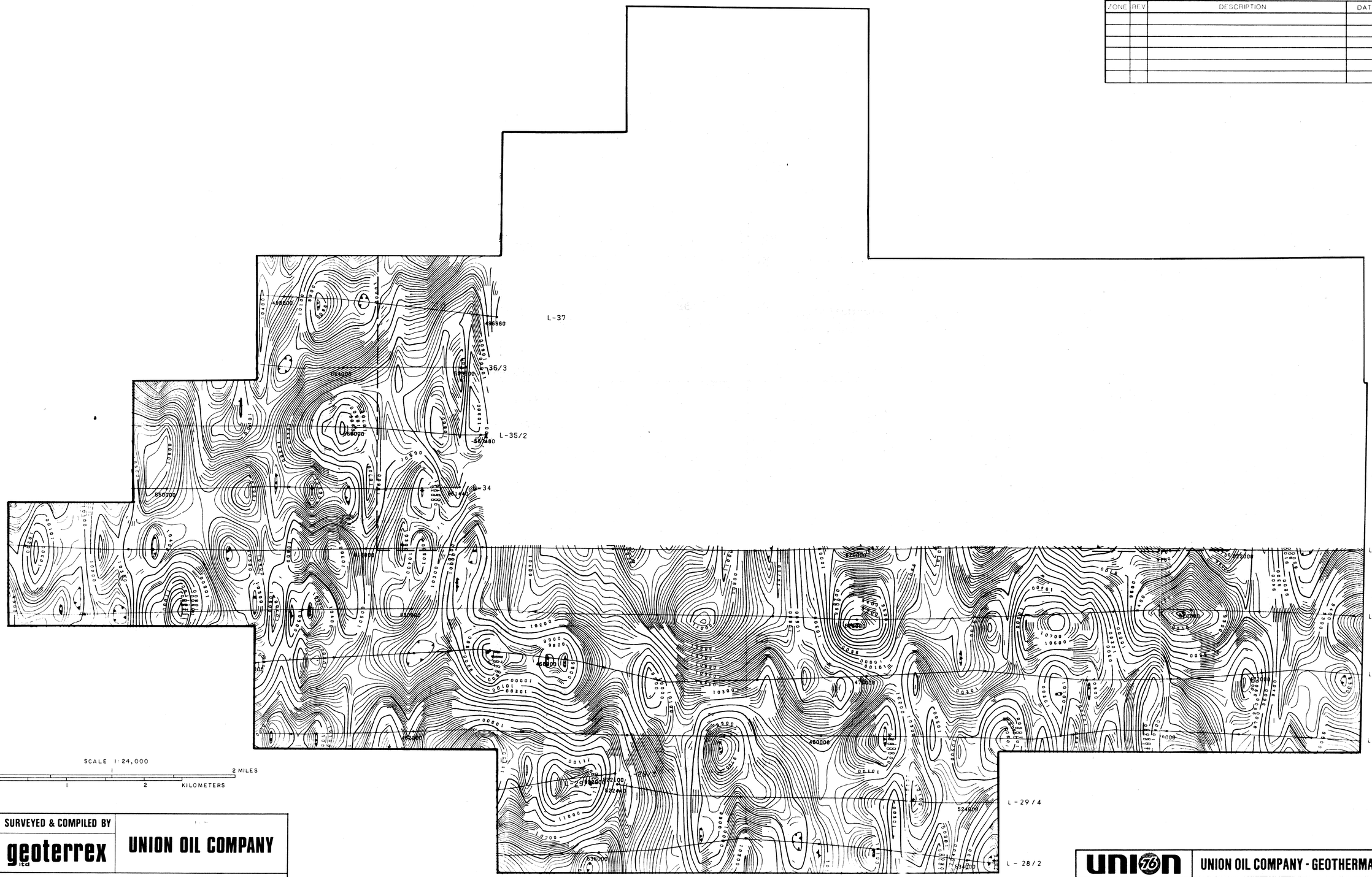
REVISIONS					
ZONE	REV	DESCRIPTION	DATE	BY	APP'D



SURVEYED & COMPILED BY

geoterrex ltd

UNION OIL COMPANY

HELICOPTER-BORNE ELECTROMAGNETIC & MAGNETIC SURVEY

GLASS MOUNTAIN AREA
CALIFORNIA

ISOMAGNETIC CONTOUR MAP

SHEET 2 OF 3 HORIZONTAL DATUM BASED ON CONTOUR INTERVAL 20 GAMMAS 200'

union 76

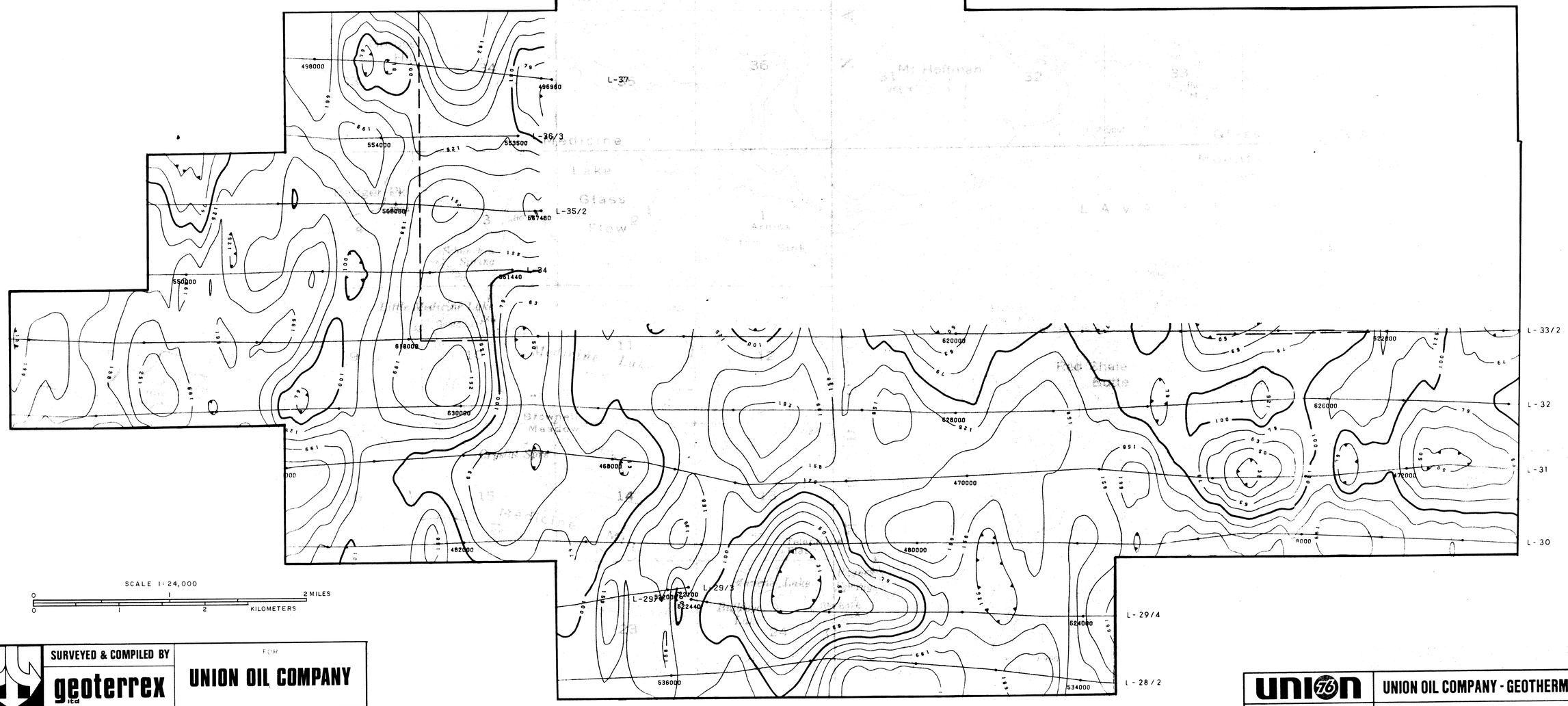
UNION OIL COMPANY - GEOTHERMAL DIVISION

SANTA ROSA DISTRICT

GLASS MOUNTAIN UNIT AREA
1983 HEM SURVEY
ISOMAGNETIC CONTOUR MAP

DESIGN				
DRAWN	VLR			
CHECK	G. Nordquist	SIZE	AFE NO.	DWG NO.	REV
DATE	Nov. 1983	SCALE 1:24,000		SHEET

REVISIONS					
ZONE	REV	DESCRIPTION	DATE	BY	APP'D



SCALE 1: 24,000

0 1 2 MILES

0 1 2 KILOMETERS

SURVEYED & COMPILED BY

geoterrex ltd

FOR

UNION OIL COMPANY

HELICOPTER-BORNE ELECTROMAGNETIC & MAGNETIC SURVEY

GLASS MOUNTAIN AREA
CALIFORNIA

1040 Hz RESISTIVITY CONTOUR MAP

SHEET 3 OF 3 | HORIZONTAL CONTROL BASED ON TOPOGRAPHICAL MAPS | CONTOUR INTERVAL: OHM-METRES FLOWN IN JULY 1983 | FLIGHT ALTITUDE 200' MT. | GEOTERREX PROJECT NO. 92-UH

SCALE 1:24,000

union 76

UNION OIL COMPANY - GEOTHERMAL DIVISION

SANTA ROSA DISTRICT

GLASS MOUNTAIN UNIT AREA

1983 HEM SURVEY

1040 HZ RESISTIVITY CONTOUR MAP

DESIGN	
DRAWN	V L R
CHECK	G. Nordquist
DATE	Nov. 1983

SIZE | AFE NO. | DWG NO. | REV

SCALE 1:24,000 | SHEET

APPENDIX P:
Collected petrographic, fluid inclusion and rock property analyses of cores and drill cuttings from Glass Mountain wells

Attachment XV

CEC-500-2007-XXX-ATXV

Collected petrographic, fluid inclusion and rock property analyses of cores and drill cuttings from Glass Mountain wells

This document is an attachment to a report funded by the California Energy Commission's Geothermal Resource Development Account (GRDA) Program. The GRDA Program did not fund this document, but the authors of the GRDA funded report have attached it as a supporting document.

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November 14, 1991

TO: Kenneth H. Williamson

FM: Richard P. Gunderson

RE: COLLECTED PETROGRAPHIC, MINERALOGICAL, FLUID INCLUSION AND ROCK PROPERTY LABORATORY ANALYSES OF CORES AND DRILL CUTTINGS FROM WELLS IN THE GLASS MOUNTAIN PROSPECT, CALIFORNIA

GM 18.02a

UNIVERSITY OF UTAH RESEARCH INSTITUTE

UURI

EARTH SCIENCE LABORATORY
420 CHIPETA WAY, SUITE 120
SALT LAKE CITY, UTAH 84108
TELEPHONE 801-581-5283

April 16, 1984

Alex Schriener
Area Geologist
Union Geothermal Division
Union Oil Company of California
2099 Range Avenue
Santa Rosa, CA 95406

Dear Alex:

The 34 geochemical pulp samples you submitted earlier this year have been mineralogically analyzed by qualitative X-ray diffraction (XRD). Preliminary results for 13 bulk samples, and for clay fractions extracted from seven of these, were reported to you in my letter of March 5. The present report documents analyses for the entire sample suite, and briefly discusses implications of these analyses for geothermal exploration.

Bulk samples can be grouped broadly into two categories: 1) those dominated by plagioclase and 2) those containing sanidine and cristobalite with minor tridymite and a trace of quartz. These two sample types probably correspond, respectively, to intermediate to mafic volcanic rocks and felsic volcanic rocks.

Plagioclase in type 1 rocks is a variety more calcic than albite, probably andesine or labradorite; it may be accompanied by trace to minor clinopyroxene and apatite, but the X-ray signatures of these phases, if present, are obscured or concealed by the strong, numerous, crowded peaks of the overwhelmingly dominant plagioclase; petrographic examination is suggested for definite identification. Ilmenite, pyrite or marcasite and hematite are other probable trace constituents of many plagioclase-rich samples.

Cristobalite-sanidine rocks are probably rich in devitrifed felsic glass. In several of these rocks, such as well no. 3, 750-800', devitrification may not have proceeded to completion; a prominent, broad glass "hump" is apparent between about 18 and 34°2θ. Alternatively, but less likely, the "hump" could reflect the presence of opal.

Zeolites occur only in wells 1 and 2. In well 1, mordenite is a major constituent of the sample spanning 1900-1950'. In well number 2, zeolites are

zoned with depth; clinoptilolite occurring above 1145' and analcime or wairakite (too little of this phase for a definite identification) below this footage.

Clay minerals occur in all wells, but are most abundant in wells 1 and (particularly) 2. Smectite, the most common, is found in 16 of the 34 bulk samples; it is a major component of three. With a basal spacing of about 14Å, , the smectite probably contains calcium and/or (less likely) magnesium as the principal interlayer cation(s). Illite occurs only in well no. 1; at a depth of 1900' in this well it is accompanied by a trace of randomly-ordered, mixed-layer illite-smectite. Chlorite or kaolinite occur in two samples--one each in wells 2 and 4.

Well number 2 displays a distinct layer silicate zoning which mirrors the zoning of coexisting zeolites. Smectite occurs in the four samples above 1145'; in two of these samples it is accompanied by clinoptilolite. The two samples below 1145' contain conspicuous mixed-layer chlorite-smectite--an ordered variety with about 55% chlorite (Reynolds, 1980). This phase is accompanied in both samples by analcime or wairakite.

Of the five wells investigated, number 2 would appear to be the most encouraging for discovery of a concealed geothermal resource. Its well-developed zeolite and clay mineral zoning may indicate progressively higher-temperature, hydrothermal fluid circulation with increasing depth. Ordered, mixed-layer clays such as those of well 2 almost always develop at relatively high temperatures under conditions of deep diagenesis or hydrothermal alteration (Dunoyer de Segonzac, 1970). Mixed-layer, ordered chlorite-smectites were found in cuttings above productive reservoir at the Tiwi system, Philippines (UURI/ESL reports to Thomas Powell; Nov. 21, 1983 and Feb. 14, 1984), and in cuttings from your Geysers well KC88-24 (UURI/ESL report to Barbara Gallinatti; April 2, 1984), strengthening speculation that an active geothermal system could be present below the sampled depths of well 2. In research well Y-1 at Yellowstone (Honda and Muffler, 1970) clinoptilolite in less altered, high-level rocks gives way to analcime in deeper, more highly altered rocks; this zeolite zoning sequence is very similar to that observed in well 2. Of course, the alteration of well 2 could be entirely paleohydrothermal, so all other downhole data should be compared with the alteration assemblages to determine the probability of a concealed thermal resource at this site.

Thank you very much for submitting these rocks for X-ray analysis. I realize you've had to wait quite a while for the results, and appreciate your patience. The analyses are intriguing; I hope they enable you to bring in a new field.

Sincerely yours,

Jeffrey B. Hulen
Geologist

JBH/jp

REFERENCES

Dunoyer de Segonzac, 1970, The transformation of clay minerals during diagenesis and low-grade metamorphism--a review: Sedimentology, vol. 15, p. 281-346.

Honda, S., and Muffler, L. J. P., 1970, Hydrothermal alteration in core from research drill hole Y-1, Upper Geyser Basin, Yellowstone National Park, Wyoming: American Mineralogist, vol. 55, p. 1714-1737.

Reynolds, R. C., 1980, Interstratified clay minerals in Brindley, G. W., and Brown, G., eds., Crystal structures of clay minerals and their X-ray identification: London, Mineralogical Soc. Mon. 5, p. 411-438.

TABLE 1

WELL No. 1

WELL No. 1 BULK CUTTINGS AND CLAY FRACTIONS (< 5μ) — SAMPLE NO	QUARTZ	CRISTOBALITE	TRIDYMITE	K-FELDSPAR	PLAGIOCLASE	HEMATITE	ILMENITE	PYRITE OR MARCASITE	GOETHITE	ILLITE	SMECTITE	CHLORITE OR KAOLINITE	MIXED-LAYER CHLORITE-SMEC	MIXED-LAYER ILLITE-SMEC	MORDENITE	
	MINERALOGY, APPROX. WT.% ☐ (or) RELATIVE ABUNDANCE ☑															
353-401 BULK					MM			Tr?		Tr?	m					
CLAY					M					m	m	m				
550-600 BULK					MM			Tr?	Tr?							
CLAY					M							m				
850-900 BULK					MM			Tr	Tr?							
CLAY					M							m				
1150-1200 BULK					MM				Tr?	Tr?		Tr				
CLAY					M							m				
1500-1550 BULK					MM				Tr?	Tr?		m				
CLAY					M					Tr?		M				
1900-1950' BULK		m	m?		m?						Tr?	m		Tr?	M	SUSPECT GLASS ALL PROB. KF PKS OVER LAPPED BY MORD. PKS.
CLAY		m	m?		m?						m	M		m	M	
2100-2150 BULK	M	M			M			m?		Tr?		Tr				
CLAY	m	M			M			m?				m				

MM = PREDOMINANT M = MAJOR m = MINOR Tr = TRACE ? = TENTATIVE IDENTIFICATION

WELL No 1

SUMMARY OF X-RAY DIFFRACTION ANALYSIS

UNIVERSITY OF UTAH RESEARCH INSTITUTE , EARTH SCIENCE LABORATORY

WELL No. 2
BULK CUTTINGS
GMF 56-3

MINERALOGY, APPROX. WT.% ☐ (or) RELATIVE ABUNDANCE ✓

SAMPLE NO.	QUARTZ	CRISTOBALITE	TRIDYMITE	K-FELDSPAR	PLAGIOCLASE	HEMATITE	ILMENITE	PYRITE OR MARCASITE	GOETHITE	ILLITE	SMECTITE	CHLORITE OR KAOLINITE	MIXED-LAYER CHLOR-SMEC.	MIXED-LAYER ILLITE-SMEC.	CLINOPTILOLITE	ANALCIME OR WAIRAKITE	CALCITE
205-301'					MM		Tr?	Tr?	Tr?		m						
506-562'					MM			Tr?			M				m		
787-886'					MM			Tr?			m						
1110-1145'	m				MM	?		m?			M	m			Tr?		
1426-1459'	m				MM	?		m?					m			m	m
1727-1760'	m				MM	m							m			m	

MM = PREDOMINANT M = MAJOR m = MINOR Tr = TRACE ? = TENTATIVE IDENTIFICATION

TABLE 2.

WELL No. 2

SUMMARY OF X-RAY DIFFRACTION ANALYSIS

UNIVERSITY OF UTAH RESEARCH INSTITUTE , EARTH SCIENCE LABORATORY

WELL No 3
BULK CUTTINGS

MLF 51-2

MINERALOGY, APPROX. WT.% ☐ (or) RELATIVE ABUNDANCE ☑

SAMPLE NO	QUARTZ	CRISTOBALITE	TRIDYMITE		K-FELDSPAR	PLAGIOCLASE		HEMATITE	ILMENITE	PYRITE OR MARCASITE			ILLITE	SMECTITE	CHLORITE OR KAOLINITE	MIXED-LAYER CHLORITE SMEC	MIXED-LAYER ILLITE-SMEC							NOTES/OTHER PHASES
150-200′	TR	M	TR		M																			
500-550′	TR	M	M		M																			
750-800		M	TR		M																			PROBABLY ABUNDANT GLASS
900-950′	m					MM							M											
1150-1200′						MM		–		TR?														
1500-1550						MM			TR?	TR?														
1800-1840′						MM			TR?	TR?														

MM = PREDOMINANT M = MAJOR m = MINOR Tr = TRACE ? = TENTATIVE IDENTIFICATION

TABLE 3

WELL No 3

SUMMARY OF X-RAY DIFFRACTION ANALYSIS

UNIVERSITY OF UTAH RESEARCH INSTITUTE , EARTH SCIENCE LABORATORY

WELL No. 4
BULK CUTTINGS
52-30

MINERALOGY, APPROX. WT.% ☐ (or) RELATIVE ABUNDANCE ☑

SAMPLE NO.	QUARTZ	CRISTOBALITE	TRIDYMITE	K-FELDSPAR	PLAGIOCLASE	HEMATITE	ILMENITE	PYRITE OR MARCASITE	ILLITE	SMECTITE	CHLORITE OR KAOLINITE	MIXED-LAYER CHLORITE-SMEC.	MIXED-LAYER ILLITE-SMEC.	NOTES/ OTHER PHASES
250-300'					MM		m				TR	TR		
500-550'					M									PROBABLY ABUNDANT GLASS
800-850'		M		m	M		TR?							
1100-1150'					MM						m			
1450-1500'	TR	M	TR	M	M						m			
1700-1750'		M	TR	M	TR?						TR?			
1900-1950'	TR	M	m	M										

MM = PREDOMINANT M = MAJOR m = MINOR Tr = TRACE ? = TENTATIVE IDENTIFICATION

TABLE 4.

WELL No. 4

SUMMARY OF X-RAY DIFFRACTION ANALYSIS

UNIVERSITY OF UTAH RESEARCH INSTITUTE, EARTH SCIENCE LABORATORY

WELL No. 5
BULK CUTTINGS

54-19

MINERALOGY, APPROX. WT.% ☐ (or) RELATIVE ABUNDANCE ☑

SAMPLE NO.	QUARTZ	CRISTOBALITE	TRIDYMITE	K-FELDSPAR	PLAGIOCLASE	HEMATITE	ILMENITE	PYRITE OR MARCASITE	ILLITE	SMECTITE	CHLORITE OR KAOLINITE	MIXED-LAYER CHLORITE-SMEC.	MIXED-LAYER ILLITE-SMECTITE	NOTES/OTHER PHASES
150-200′					MM			Tr?						
500-550′					MM									
850-900′					MM	m?								ALSO UNKNOWN 7.44Å PHASE → PROBABLE ABUNDANT GLASS
1300-1350′					MM	m								
1500-1550′					MM	Tr?				Tr?				
1550-1600′					MM			Tr?						
1900-1950′					MM			Tr?		m				
2150-2200′					MM					m				

MM = PREDOMINANT M = MAJOR m = MINOR Tr = TRACE ? = TENTATIVE IDENTIFICATION

TABLE 5

WELL No. 5

SUMMARY OF X-RAY DIFFRACTION ANALYSIS

UNIVERSITY OF UTAH RESEARCH INSTITUTE , EARTH SCIENCE LABORATORY

GM 18.026

UNIVERSITY OF UTAH RESEARCH INSTITUTE

UURI

EARTH SCIENCE LABORATORY
391 CHIPETA WAY, SUITE C
SALT LAKE CITY, UTAH 84108—1295
TELEPHONE 801-524-3422

June 13, 1984

Alex Schriener
Area Geologist
Union Oil Company of California
2099 Range Avenue
Santa Rosa, California 95406

Dear Alex:

The 51 geochemical pulp samples submitted with your letter of May 3, 1984 have been mineralogically analyzed by qualitative X-ray diffraction (XRD). Tabulated results for these analyses, mailed to arrive at your offices on May 31, are further explained in this report.

Representative one-gram splits of the pulp samples were X-rayed at 2°2θ per minute from 2-65° 2θ. Each sample then was vapor glycolated for one hour at 60°C and re-irradiated from 2-10° 2θ to check for expandable constituents. X-ray diffractograms for all samples are being shipped under separate cover.

These samples, like the 34 discussed in my report of April 16, form two main groups--1) those dominated by plagioclase (probable intermediate to mafic volcanic rocks) and 2) those containing principally sanidine and cristobalite or quartz (probable felsic volcanic rocks). A few type 1 samples also contain trace to minor amounts of ilmenite (?), hematite and pyrite or marcasite. Well No. 8 is particularly enriched in hematite; concentrations of hematite in the deepest three samples from this borehole are accompanied by minor clinoptilolite and abundant smectite. Quartz is a conspicuous and anomalous component of Type 1 rocks in the samples spanning 3400' to 3990' (the deepest) in Well 9. The origin of the quartz--primary or hydrothermal--is unknown; however, the X-ray signature of the plagioclase doesn't change in the quartz-bearing samples, so I suspect the quartz is either secondary or occurs as xenocrysts or other inclusions.

Smectite is the most common clay mineral in these samples, occurring in 32 of 51. The smectite contains calcium as the main interlayer cation, as indicated by a basal spacing of about 14Å. Mixed-layer chlorite-smectite occurs in two of the deepest three samples in Well 9; this is also the quartz-rich interval mentioned above. Illite or mica is present in the two deepest samples of Well 12.

Based strictly on X-ray signatures, Well 9 looks most interesting as a geothermal or precious metal exploration borehole. The mixed-layer clays present in the deepest samples are almost certainly hydrothermal; coexisting quartz also may be secondary. The abundant smectite and hematite in Well 8 also might warrant further investigation.

Thanks for submitting these samples, and please call if I can supply additional information about their interpretation.

Sincerely yours,

Jeff Hulen

Jeffrey B. Hulen
Geologist

JBH/cd

GM 18 02 c

UNIVERSITY OF UTAH RESEARCH INSTITUTE

UURI

EARTH SCIENCE LABORATORY
391 CHIPETA WAY SUITE C
SALT LAKE CITY UTAH 84108—1295
TELEPHONE 801 524 3422

January 23, 1985

Richard Gunderson, Geologist
Union Oil Company of California
Union Geothermal Division
2099 Range Avenue
Santa Rosa, CA 95406

Dear Richard

The 31 Geysers area cuttings samples you recently submitted to our lab have been mineralogically analyzed by qualitative X-ray diffraction (XRD) Results of the analyses, a summary of methods by which the analyses were obtained, and all corresponding diffractograms accompany this letter

Well 17A-6, from which 30 of the samples were obtained, is shown by XRD to be distinctly zoned mineralogically Smectite is confined to the interval between 1400 and 4330 feet (depth) Four samples in this interval contain trace to minor clinoptilolite The lower part of the smectite zone overlaps a chlorite zone which extends from 3940' to the deepest sample at 9590' Epidote accompanies chlorite between 4750' and 7720' Amphibole appears at 4750' and persists to the deepest sample Mica (probably mostly biotite) is prominent below 7550'

The upper part of well 17A-6 apparently penetrates interlayered basic and felsic volcanic rocks the former mostly plagioclase, the latter composed principally of sanidine and cristobalite These volcanics overlie probable metasedimentary rocks, in turn intruded by mica-amphibole quartz diorite(?) Much of the mineralogic zoning revealed by XRD, therefore, reflects rock type rather than alteration Smectite, chlorite and epidote, however, are clearly secondary, as is the minor pyrite between 4750' and 6920' Petrographic examination and clay-fraction XRD might reveal additional alteration phases

Thank you for submitting these cuttings, and please call if I can clarify any aspect of their XRD mineralogy

Sincerely,

Jeff Hulen

Jeffrey B Hulen
Geologist

JBH/jp

BULK XRD

MINERALOGY, APPROX. WT.% [ ] (or) RELATIVE ABUNDANCE [✓]

SAMPLE NO.	QUARTZ ✓	CRISTOBAL. ✓	TRIDYMITE	PLAGIOCL. ✓	K-FELDSP. ✓	CALCITE ✓	HEMATITE ✓	ILMENITE ✓	PYRITE ✓	ILLITE ✓	MICA ✓	CHLORITE ✓	SMECTITE ✓	MIXED-LAYER ILLITE-SMEC. ✓	MIXED-LAYER CHL.-SMEC. ✓	AMPHIBOLE	EPIDOTE	CLINOPTILOL.	LALIMONTITE					
KCF 82-15:																								
FILL BENEATH SHOE	M			m		m			TR?	m		m			m									
17A-6:																								
200-230'				M			TR?	m																
620-650'	m	M	m?	TR?	M		TR																	
950-980'				M			TR	m																
1400-1430'	m			M			TR	m?					m					m						GLASS (M)
1600-1630'				M			TR	m?					m					TR						GLASS (M)
1800-1830'	TR	M	m?	m	M			TR?					m											
2100-2130'	TR	M		m	M		TR						m											
2400-2430'				M									TR											GLASS (M)
2750-2780'				M			TR						m					TR						
3040-3070'	m			M			TR	TR?					M		m			TR						
3400-3430'	M			M				m					m											
3940-3970'	m			M			TR	m				TR*	m											
4300-4330'	m			M			TR?	m?				TR*	m											
4750-4780'	m			M					TR			m*					TR							
5070-5100'	m			M					TR			m			m	m	m							
5400-5430'	m			M	TR	m	TR					m				m	m							
5950-5980'	m			M	TR		TR		TR			m				m	TR							
6300-6330'	m			M	m		TR		TR			m				m								
6600-6630'	M			M	m		TR		TR	m†		m				m	TR							
6900-6930'	M			M	m				TR	m†		m				m	TR							

MM = PREDOMINANT M = MAJOR m = MINOR Tr = TRACE ? = TENTATIVE IDENTIFICATION

† POSSIBLY MICA
* MAY INCLUDE KAOLIN

SUMMARY OF X-RAY DIFFRACTION ANALYSIS

UNIVERSITY OF UTAH RESEARCH INSTITUTE , EARTH SCIENCE LABORATORY

BULK XRD

MINERALOGY, APPROX. WT.% ☐ (or) RELATIVE ABUNDANCE ☑

SAMPLE NO.	QUARTZ	CRISTOBAL.	TRIDYMITE	PLAGIOCL.	K-FELDSP.	CALCITE	HEMATITE	ILMENITE	PYRITE	ILLITE	MICA *	CHLORITE	SMECTITE	MIXED-LAYER ILLITE-SMEC.	MIXED-LAYER CHL.-SMEC.	AMPHIBOLE	CLINOPTIL.	ALUNITE	EPIDOTE					
7200-7230'	M			M	m		TR?					m				m								
7550-7580'	m			M	TR		TR?				m	m				m		m?						
7710-7720'	M			M	m		TR?				m	m				m			TR					
7800-7830'	M			M	m		TR?				m	m				m								
8100-8130'	M			M	m						m	m				m								
8400-8430'	M			M	m						m	m				m								
8700-8730'	M			M	m						m	m				m								
9000-9030'	M			M	m						m	m				m								
9300-9320'	M			M	m						m	m				m								
9590-9620'	M			M	m						m	m				m								

* MAY INCLUDE MINOR ILLITE.

MM = PREDOMINANT M = MAJOR m = MINOR Tr = TRACE ? = TENTATIVE IDENTIFICATION

SUMMARY OF X-RAY DIFFRACTION ANALYSIS

UNIVERSITY OF UTAH RESEARCH INSTITUTE , EARTH SCIENCE LABORATORY

SEMI-QUANTITATIVE MINERALOGIC ANALYSIS BY X-RAY DIFFRACTION

-Methods and Procedures-

Bulk Analysis: Representative one-gram splits of bulk samples are ground in acetone in an agate mortar to <325 mesh (< 45 μ) then scanned at 2°2θ per minute from 2-65°2θ. Diagnostic peaks of minerals identified on resulting diffractograms are re-scanned on duplicate samples. Approximate weight percentages of the minerals are determined by comparing diagnostic peak intensities with those generated by standard pure phases mixed in various known proportions.

Clay Analysis: Bulk samples, at least 35 grams if possible, are sonically disaggregated in deionized water, allowed to settle sufficiently to yield the desired particle size fraction (generally < 2 μ or < 5 μ), decanted and centrifuged. The resulting slurries are smeared on glass slides and X-rayed at 1°2θ per minute following air-drying (2-37°), vapor glycolation for 24 hours at 60°C (2-22°), heating to 250°C for one hour (2-15°) and heating to 550°C for one hour (2-15°). Approximate weight percentages of the layer silicates identified on diffractograms corresponding to these treatments are determined by comparison of diagnostic peak intensities with those generated by pure reference clays in appropriate mixtures.

diffractometer using CuKα radiation at the following instrument settings: accelerating voltage - 40 kv; tube current - 40 ma; full-scale deflection - 2500 counts per second; time constant-one second. All samples were irradiated at 1°2θ per minute after the following treatments: air-drying (2-37°2θ), vapor glycolation at 60°C for 24 hours (2-22°2θ), heating to 250°C for one hour (2-15°2θ) and heating to 550°C for one hour (2-15°2θ). Approximate amounts of layer silicates identified on corresponding diffractograms were determined by comparing diagnostic peak intensities with those generated by reference standards.

Results and Discussion

The 16 samples analyzed comprise principally basalt and andesite, with two samples listed as "tuff or volcaniclastic", one dacite, and one altered silicic flow rock. As expected, plagioclase is the main component of the intermediate- to basic-composition rocks. The plagioclase is accompanied by minor magnetite, ilmenite and hematite, and probably pyroxene. The few and poorly-developed peaks of both clino- and orthopyroxene are masked by the strong and numerous reflections of the abundant plagioclase, and so are difficult to identify reliably; petrographic confirmation is necessary. Above 5000', the intermediate-composition rocks contain minor smectite; below 1200', minor quartz and chlorite and sporadic K-feldspar and calcite are present. Possible traces of analcime or wairakite occur below 4400', and 3% epidote is present in all samples below 4800'.

The rock field-named dacite at 1600' contains appreciable alkali feldspar and may actually be quartz latite or rhyolite. This sample also contains 2% mordenite and 10% smectite, and is probably hydrothermally altered. The altered silicic flow rock at 2200' is very rich in quartz and contains, in addition to minor smectite, 5% illite and 2% chlorite. The "tuff or

ALEX SCHRIENER
NOV 19 1985

volcaniclastic" at 5000' is shown by XRD to be an intermediate-composition rock which has been moderately propylitized.

The clay fractions extracted from the bulk cuttings samples show well-defined layer silicate zoning, probably in response to increasing temperature with depth, either presently or at some time in the past. Smectite and kaolin are strongly concentrated above 1900', below which depth chlorite and minor illite predominate. The rock at 1900' contains smectite-rich interstratified smectite-chlorite; three samples below 1900' contain mixed-layer chlorite-smectite which is much richer in chlorite. If the clay mineral zoning revealed in well 68 reflects the present thermal regime, it may be possible to establish vectors toward heat centers using layer silicate assemblages in combination with other available surface and downhole data.

ALEX SCHRIENER
NOV 19 1985

BULK

MINERALOGY, APPROX. WT.% ✓ (or) RELATIVE ABUNDANCE

SAMPLE NO.	QUARTZ	CRISTOBALITE	K-FELDSP.	PLAGIOCLASE	CALCITE	MORDENITE	MAGNETITE	ILMENITE	HEMATITE	PYRITE	CLINOPYROXENE (G) ORTHOPYROX.	AMPHIBOLE	EPIDOTE	APATITE	SMECTITE	ILLITE ± MICA	CHLORITE	KAOLIN	ANALCIME OR WAIRAKITE	OTHER *
68-400				82			2?	1	1						1					33
68-800				55				1	2		>10?			1?	6					<25
68-1200				58				1	1		>10?			1?	9					<20
68-1600	8	15	40	12		2			1						10		TR?	TR?		12
68-1900	17		5	48	1			2	3		>5?				5		2			<12
68-2200	40		32	17					1						3	5	2			
68-3000	14		2	45	7				4		>10?				2	2	6			<8
68-3400	10		1?	46	3				4		>10?				5		3			<18
68-3800	8			48				2	2		>10?			1?	14		7			<8
68-4400	8			48	8			1	4		>10?				3		8			<10
68-4800	14		2	53				2	2		?	2			TR		5		TR?	20
68-5000	13		2	48	1				2				3				11			20
68-5200	9			53	1				2				3				9			23
68-5600	11		2	47	3				3				3				4		1?	26
68-6000	11		1	52	3				3				3				5		1?	21
68-6400	12		2	55	4				3			2	3				5		TR?	14

* INCLUDES AMORPHOUS PHASES, THOSE BELOW DETECTION LIMIT, AND THOSE WHOSE REFLECTIONS ARE MASKED BY PLAGIOCLASE PEAKS. MAY INCLUDE SOME LOST CIRCULATION MATERIAL.

MM = PREDOMINANT M = MAJOR m = MINOR Tr = TRACE ? = TENTATIVE IDENTIFICATION

SUMMARY OF X-RAY DIFFRACTION ANALYSIS

ALEX SCHRIENER
UNIVERSITY OF UTAH RESEARCH INSTITUTE, EARTH SCIENCE LABORATORY

NOV 19 1985

CLAY FRACTION

MINERALOGY, APPROX. WT.% ✓ (or) RELATIVE ABUNDANCE ☐

SAMPLE NO.	SMECTITE	MIXED-LAYER SMECT.-CHLOR. (A)	MIXED-LAYER CHLOR.-SMEC.	CHLORITE	ILLITE	MIXED-LAYER ILLITE-SMEC. (C)	KAOLIN
68-400	100						
68-800	100						
68-1200	97						3
68-1600	95						5
68-1900		40		50	5	5	
68-2200	55			10	35		
68-3000				90	10		
68-3400	37			60	3		
68-3800	65		15 (E)	20			
68-4400	5			95			
68-4800	3			93	4		
68-5000	Tr			98	2		
68-5200				98	2		
68-5600		5		80	15		
68-6000			10 (D)	75	15		
68-6400			5 (E)	80	15		

(A) >75% SMECTITE
(B) 90% CHLORITE
(C) >80% ILLITE
(D) MAY INCLUDE PRIMARY MICA
(E) ~50% CHLORITE

MM = PREDOMINANT M = MAJOR m = MINOR Tr = TRACE ? = TENTATIVE IDENTIFICATION

SUMMARY OF X-RAY DIFFRACTION ANALYSIS

UNIVERSITY OF UTAH RESEARCH INSTITUTE, EARTH SCIENCE LABORATORY

ALEX SCHRIENER

NOV 19 1985

KEY FOR XRD ANALYSES
FROM MARCH 16, 1988

WELL	SAMPLE NO.	DEPTH (FEET)
GMF17A-6	6-1	7690-7700
	6-2	7160-70
	6-3	6820-30
	6-4	5710-20
	6-5	5260-70
	6-6	4620-30
	6-7	4910-20
	6-8	8230-40

KEY FOR XRD ANALYSES

WELL	SAMPLE NO.	DEPTH (FEET)
GMF68-8	8-1	6460-80
	8-2	6140-60
	8-3	5840-60
	8-4	5400-20
	8-5	4660-80
	8-6	4120-40
	8-7	3200-20
	8-8	2660-2680

GM 18.0L9

ESL-85016R-TR
(Proprietary)

Analysis of 70 Felsic- to Mafic-Composition Volcanic Rock Cuttings Samples by X-ray Diffraction

by

Jeffrey B. Hulen

University of Utah Research Institute
Earth Science Laboratory
391 Chipeta Way, Suite C
Salt Lake City, Utah 84108

for

Union Geothermal Division
Union Oil Company of California
2099 Range Avenue
Santa Rosa, California 95406

August 29, 1985

R. P. GUNDERSON
SEP 04 1985

CA-GMT-113

Introduction

This report documents the results of qualitative X-ray diffraction (XRD) analysis of 70 cuttings samples submitted by Richard Gunderson of Union Oil Company's Union Geothermal Division late in July. Results of the analyses, completed in mid-August, were mailed in preliminary form to Union's Santa Rosa office August 20; they are also appended to this report and briefly discussed in the text which follows. Corresponding X-ray diffractograms have been shipped under separate cover.

Methods and Procedures

Each cuttings sample, in preparation for bulk XRD analysis, was lightly crushed to < 18 mesh (< 1 mm) and thoroughly mixed to ensure homogenization. A representative one-gram split of each then was ground in acetone in an agate mortar to < 325 mesh (< 42 microns). These powders were irradiated at $2°2\theta$ per minute from $2\text{-}65°2\theta$ using $CuK\alpha$ radiation at the following instrument settings: accelerating voltage - 40 kv; tube current - 40 ma; full-scale deflection - 2500 counts per second; time constant - 1/2 second. All samples were vapor glycolated at 60°C for 24 hours and re-scanned (at the same instrument settings) from $2\text{-}10°2\theta$ to check for expandable clays. The relative abundances of the phases identified on the resulting diffractograms were determined by comparing diagnostic peak intensities with those generated by pure reference standards.

Results and Discussion

The X-ray signatures of these 70 samples indicate that the boreholes from which they were collected penetrated principally felsic and intermediate- to mafic-composition volcanic rocks. The dominant minerals in the felsic rocks are sanidine and cristobalite with variable amounts of tridymite and quartz;

plagioclase and hematite are locally present. Calcic (?) plagioclase and glass (± other, less likely amorphous phases) are the principal constituents of the intermediate- to mafic-composition samples, many of which also contain ilmenite, magnetite and hematite in various combinations. The plagioclase may be compositionally zoned. Its many strong peaks mask most of the feeble reflections possibly generated by other minerals suspected to be present in trace to minor amounts -- clinopyroxene, orthopyroxene, olivine and apatite. Confident identification of these minerals must await petrographic confirmation.

Smectite is the most common and abundant layer silicate in these samples, occurring in all wells, but concentrated in 45-36 and 86-23 (from which no felsic rocks were identified). Chlorite is uncommon, occurring only in the deeper portions of 45-36 and 28-32 (in this well, its distribution is antithetic to that of smectite). Abundant chlorite in the sample from 4500' in 28-32 is accompanied by illite (and/or mica), calcite, analcime or wairakite, and pyrite.

Based on XRD alone, most of these samples appear to be only weakly altered, and much of that alteration could be deuteric. The association of quartz, illite, abundant chlorite, calcite, analcime or wairakite and pyrite in cuttings from the deeper portions of well 28-32, however, suggests that these rocks have probably interacted with circulating hydrothermal fluids.

27-27, 3000': → ‡ 2.71 Å PEAK (NOT PY. OR MARC.) MAY BE IMPURE HEMATITE
* MAY INCLUDE OTHER AMORPHOUS PHASES SUCH AS OPAL

MINERALOGY, APPROX. WT.% ☐ (or) RELATIVE ABUNDANCE ✓

SAMPLE NO.	QUARTZ	CRISTOBAL.	TRIDYMITE	K-FELDSP.	PLAGIOCL.	ILMENITE	HEMATITE	MAGNET.	SMECTITE	ILLITE &/OR MICA	CHLORITE	KAOLIN OR SERPENTINE	CALCITE	GLASS *	OTHER PHASES POSSIBLY PRESENT IN TRACE TO MINOR AM'TS.
WELL 14-23															
444'	<m				MM	<m		<m?						m?	CPX, OPX, AP
816'					M	<m								M	AP, GOE
1462'					MM			<m?	m					m?	AP
1903'		m			m									MM	
2325'	<m	m?	m	M	m				<m						
2599'					MM		<m?	<m?	M						AP
2998'					MM			<m?	<m					m?	AP
WELL 18-34															
583'					MM	<m								m?	AP, OLV
1289'														MM	
1983'	m	M	m	M			<m		<m	<m?					
2507'		M		M	m									m?	
2932'					MM	<m	<m		m					m?	AP
3498'					MM	<m	<m?		m					m?	OPX, AP
WELL 27-27															
619'					MM									m?	CPX, AP
1266'					MM		<m?							m?	AP, OLV
1635'					M									M	OLV
2145'					MM	<m	<m?							m?	CPX, AP, OLV
2543'					MM	<m	<m?	<m?						m?	CPX, AP, OLV
3000'					MM		m?‡		<m					m?	AP, OLV

MM = PREDOMINANT M = MAJOR m = MINOR <m = <5WT.% ? = TENTATIVE IDENTIFICATION

SUMMARY OF X-RAY DIFFRACTION ANALYSIS

UNIVERSITY OF UTAH RESEARCH INSTITUTE, EARTH SCIENCE LABORATORY

* MAY INCLUDE OTHER AMORPHOUS PHASES SUCH AS OPAL.

MINERALOGY, APPROX. WT.% ☐ (or) RELATIVE ABUNDANCE ☑

SAMPLE NO.	QUARTZ	CRISTOBAL.	TRIDYMITE	K-FELDSP.	PLAGIOCL.	ILMENITE	HEMATITE	MAGNETITE	SMECTITE	ILLITE &/OR MICA	CHLORITE	KAOLIN &/OR SERPENTINE	CALCITE	GLASS *	ANALCIME OR WAIRAKITE	PYRITE							OTHER PHASES POSSIBLY PRESENT IN TRACE TO MINOR AMOUNTS
WELL 28-32																							
440'		M	m	MM	<m?		<m																
860'	m	M	m	MM					<m														
1280'		M		M	m				<m														
1500'	m	M		M	m				<m?	<m													
1950'	<m?			<m?	MM		M		<m					m?									CPX, AP
2480'		M		M			<m?		m														
2950'	M			MM			<m																
3532'	m			<m?	MM	<m	<m	<m?	M			<m?		m?									CPX, AP
3968'	M			m?	M		m				m		<m										
4500'	m			m?	M					<m	M		<m		<m	m							
WELL 29-1																							
467'					MM									M									AP
1297'		M	m	MM					<m														
1951'		m	M	MM					<m														
2375'								<m						MM									AP
2803'	<m?			<m?	MM	<m?		<m?	M					m?									AP
3088'					MM			<m?	m					m?									CPX, AP

MM = PREDOMINANT M = MAJOR m = MINOR <m = <5 WT.% ? = TENTATIVE IDENTIFICATION

SUMMARY OF X-RAY DIFFRACTION ANALYSIS

UNIVERSITY OF UTAH RESEARCH INSTITUTE , EARTH SCIENCE LABORATORY

* MAY INCLUDE OTHER AMORPHOUS PHASES SUCH AS OPAL

MINERALOGY, APPROX. WT.% ☐ (or) RELATIVE ABUNDANCE ☑

SAMPLE NO.	QUARTZ	CRISTOBAL.	TRIDYMITE	K-FELDSP.	PLAGIOCL.	ILMENITE	HEMATITE	MAGNET.	SMECTITE	ILLITE &/OR MICA	CHLORITE	KAOLIN OR SERPENTINE	CALCITE	GLASS*	PYRITE								OTHER PHASES POSSIBLY PRESENT IN TRACE TO MINOR AM'TS.
WELL 45-36																							
100'					MM	<m	<m							m?									CPX, OPX, AP
480'	m	M	m	MM					<m														
1000'					MM		<m		m					m?									CPX, OPX, AP
1470'					MM	<m	<m		m					m?									CPX, OPX, AP
1860'					MM	<m	m		M					m?									AP
2390'					MM	<m	<m		M			<m		m?									AP
2780'	M			M	m		<m?				<m				<m								
3100'	M			M	M		<m?				<m												
3600'	m				MM	<m?			M					m?									CPX, AP
4000'	m			m	MM			<m			m			m?									AMPH
WELL 57-13																							
781'					<m									MM									CPX
1423'					m									MM									
1637'					<m									MM									
2079'	m	<m	M	MM			<m		<m	<m													
2426'									<m					MM									
2929'					MM				M					m?									CPX

MM = PREDOMINANT M = MAJOR m = MINOR <m = <5 WT.% ? = TENTATIVE IDENTIFICATION

SUMMARY OF X-RAY DIFFRACTION ANALYSIS

UNIVERSITY OF UTAH RESEARCH INSTITUTE , EARTH SCIENCE LABORATORY

* MAY INCLUDE OTHER AMORPHOUS PHASES SUCH AS OPAL.

MINERALOGY, APPROX. WT.% ☐ (or) RELATIVE ABUNDANCE ✓

SAMPLE NO.	QUARTZ	CRISTOBAL.	TRIDYMITE	K-FELDSP.	PLAGIOCL.	ILMENITE	HEMATITE	MAGNETITE	SMECTITE	ILLITE &/OR MICA	CHLORITE	KAOLIN &/OR SERPENTINE	CALCITE	GLASS *	ANALCIME OR WAIRAKITE	CLINOPTILOL.	OPAL-CT						OTHER PHASES POSSIBLY PRESENT IN TRACE TO MINOR AM'TS.
WELL 62-21																							
530'					MM	<m	<m		<m					m?									CPX, OPX, AP
1035'					MM		<m		M					m?		<m	<m?						
1700'					MM				M				<m	m?									CPX, AP
1973'					MM		<m	<m?	M				<m?	m?		<m							CPX, AP
2132'					MM	<m?	<m		M					m?									CPX, AP
WELL 68-16																							
508'		M		MM	m		<m																
1039'		M		MM	m		<m		<m?														
1338'					m								MM										
1740'					M				<m				M										CPX,
1857'					m				<m	<m?			MM										
2227'					MM		<m?		m				m?										CPX, AP
2599'		MM	m	M			<m																
2936'		MM		M			<m		<m														
WELL 86-23																							
694'					MM		<m		<m					m?									CPX, AP
1085'					MM		<m		<m					m?									CPX, OPX, AP
1554'					MM		m		m					m?									CPX, AP
2258'					MM		<m		<m					m?									CPX, AP
3157'					MM		<m		M					m?									CPX, OPX, AP
3497'					M				M					m?	<m								CPX, AP

MM = PREDOMINANT M = MAJOR m = MINOR <m = <5 WT.% ? = TENTATIVE IDENTIFICATION

SUMMARY OF X-RAY DIFFRACTION ANALYSIS

UNIVERSITY OF UTAH RESEARCH INSTITUTE, EARTH SCIENCE LABORATORY

DAN CARRIER

MAR 23 1988

UURI

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JEFFREY B. HULEN
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March 16, 1988

Earth Science Laboratory
University of Utah Research Institute
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Dr. Daniel Carrier
Unocal Geothermal Division
Unocal Corporation
3576 Unocal Place
Santa Rosa, California 95406

Dear Dan:

Attached are tabulated results of XRD analysis and reconnaissance petrographic examination for 16 drill cuttings samples which you submitted in mid-November 1987. These results, initially mailed to you late in December, and which we discussed for several hours by telephone early in 1988, are reiterated and further interpreted in the text which follows.

Eight samples of the "6"-series group are dominated by three principal rock types: hornfels and allied intermediate-composition metavolcanic rock; quartz latite or rhyodacite; and altered basic to intermediate-composition volcanic rocks. The hornfels, restricted to sample 6-1, is essentially a fine-crystalline quartz-plagioclase-biotite rock with minor hornblende and clinopyroxene. Well-developed granoblastic texture is locally present, and a few of the clinopyroxenes are sieve-textured. Many chips, however, although mineralogically similar, lack these well-defined textures, and perhaps could be termed intermediate-composition metavolcanic rocks. Yet other chips are moderately- to well-foliated, and appear to be intermediate between hornfels and phyllite or fine-crystalline schist. Regardless of texture, however, all these rocks appear to have been metamorphosed to amphibolite grade. Hydrothermal biotite and amphibole are also locally present in sample 6-1, but these tend to occur as ragged replacements of metamorphic mafics or in well-defined cross-cutting veinlets. It's possible that sample 6-1 records contact metamorphism closely followed by high-temperature hydrothermal alteration.

Samples 6-2 and 6-3 contain principally chips of quartz latite or rhyodacite, consisting almost entirely of quartz, plagioclase and potassium feldspar (in decreasing order of abundance). This rock type is typically microcrystalline to fine-crystalline and displays well-developed granophyric, micropegmatitic, axiolitic and spherulitic textures. I've observed similar textures in the granophyrically crystallized interiors of the major intracaldera ash-flow sheets of the

Valles caldera. Even where intensely recrystallized, however, these ignimbrites retain at least vestiges of eutaxitic texture -- apparently absent in the 6-2 and 6-3 samples. The spherulitic and axiolitic textures of these samples, however, indicate that the original rock was at least partially glassy and subsequently devitrified. From the thin-sections alone, I can't say for certain if the rock represents a hypabyssal or subvolcanic intrusive, an extrusive dome, or a thick flow.

Samples 6-3 through 6-7 are mostly various textural varieties of altered, intermediate to basic composition volcanic and perhaps subvolcanic intrusive rocks (dikes?). Aphyric clinopyroxene basalt or basaltic andesite is the most common rock type; porphyritic variants are also present, and microdiorite and microdiabase account for trace to major amounts. Original mafics are largely converted to secondary phases (discussed in more detail below).

Sample 6-8 is unique in this group, consisting almost entirely of ~~medium~~ fine-crystalline biotite granodiorite with minor biotite microgranodiorite (possibly a chilled border phase or a dike rock). Basalt and andesite chips accompanying the granodiorite in this sample could represent contamination from higher in the borehole.

Altered, basic- to intermediate-composition volcanic rocks (basalts and basaltic andesites) are also the principal lithologies represented in samples 8-1 through 8-7. These rocks are virtually identical to their counterparts in the "6"-series rocks. Samples 8-3 and 8-4, in addition, also contain porphyritic quartz latite or rhyodacite. Sample 8-8 is the same rock type as 6-2 and 6-3.

The rocks of all these cuttings samples are more or less hydrothermally altered and cut by hydrothermal veinlets; discrete hydrothermal veinlet fragments are also common. Intensity of alteration appears to reflect principally original chemical composition -- the more basaltic rocks tend to be the most thoroughly altered. Principal alteration products in these basic rocks are chlorite (and chloritic mixed-layer clay), epidote and leucoxene (probably mostly microcrystalline sphene); illite (with or without phengite), potassium feldpspar, actinolite, and leucoxene are also present. Illite and phengite predominate as secondary phases in the more felsic rocks in these samples. For example, the quartz latite of 6-3 contains about 11% illite plus phengite. Most of the coarser-crystalline quartz and orthoclase observed in these felsic rocks is believed to be primary rather than hydrothermal; these phases probably crystallized as micropegmatitic intergrowths late in the cooling history of the host rock. Hydrothermal biotite is confined principally to the hornfels of sample 6-1, and may have formed with actinolite shortly after contact metamorphism.

Hydrothermal vein-forming minerals in these samples occur in numerous combinations. The principal vein-forming minerals are quartz, calcite, epidote, chlorite (with mixed-layer chlorite/smectite?) and illite or phengite. Important subordinate phases comprise potassium feldspar, actinolite, prehnite and wairakite. Vein biotite occurs only in sample 6-1. For other vein minerals occuring only locally or in trace amounts, please refer to the attached tables.

The alteration and vein assemblages detected during this study provide general information about the temperatures of the hydrothermal fluids from which these secondary phases were deposited. For example, epidote tends to form above 240°C; prehnite above 215°C; wairakite above 210°C; actinolite above 280°C; and biotite above 220oC (more commonly above 300°C) (e.g Browne, 1978, 1984; Hulen and Nielson, 1986). The mixed-layer chlorite-smectite detected in clay-fractions (especially from the "8"-series samples), if similar to that occurring in analogous rocks in Icelandic geothermal fields, could indicate formation temperatures ranging between 200°C and 270°C (Browne, 1984). Although geothermometry based only on alteration mineralogy is at best an imprecise technique, it seems certain that the rocks represented by the "6" and "8" sample series were once extensively invaded by hydrothermal fluids exceeding 200°C and locally hotter than 300°C.

Thanks very much for the opportunity to work with these particularly interesting drill cuttings. If you have further questions concerning the X-ray or petrographic signatures of these rocks, or if I can further assist you in your geothermal exploration and development work, please write or telephone me at (801)-524-3446.

Sincerely,

Jeff Hulen

Jeffrey B. Hulen

REFERENCES

Browne, P.R.L., 1978, Hydrothermal alteration in active geothermal fields: Ann. Rev. Earth Planet. Sci., 6, 229-250.

Browne, P.R.L., 1984, Lectures on geothermal geology and petrology: United Nations Univ., Geoth. Training Prog., Rept. 1984-2, 92 p.

Hulen, J.B., and Nielson, D.L., 1986, Hydrothermal alteration in the Baca geothermal system, Redondo dome, Valles caldera, New Mexico: J. Geophs. Res., 91, 1867-1886.

for: Unocal Geothermal Division, Unocal Corporation -- Daniel Carrier

16 Cuttings Samples
Bulk XRD

MINERALOGY, APPROX. WT.% [X] (or) RELATIVE ABUNDANCE [ ]

SAMPLE NO.	QUARTZ	PLAGIOCL.	K-FELDSP.	CALCITE	CLINOPYROXN.	ACTINOLITE *	HORNBLENDE	EPIDOTE	PREHNITE	ANHYDRITE	ILMENITE &/OR MAGNETITE	HEMATITE	PYRITE	SPHENE/ LEUCOXENE	WAIRAKITE	SMECTITE	MIXED-LAYER CHLOR./SMEC.	ILLITE AND PHENGITE ⊛	BIOTITE	CHLORITE	TALC	OTHER Ⓐ	
6-1 7690-9700	14	51		TR	3	2	3	1		TR	2	TR	2	TR		1		2	16	3	TR		
6-2 7160-70	42	30	22					TR			TR			TR				4	TR?	2			
6-3 6820-30	45	21	16		TR	2		1		TR	TR	TR	TR	1		TR		11	TR?	3			
6-4 5710-20	4	50	3	2	7	3		6			5	TR	TR	8		TR		1		11			
6-5 5260-70	11	45	11		3	2		7			1	TR	TR	8						12			
6-6 4620-30	11	42	9		1?	3		7	1		1		1	9		2				13			
6-7 4910-20	19	38	10	TR	1?	2		5	2		1		1	8				TR		13			TR. UNKNOWN, HIGH N, HIGH RELIEF, LOW BIREFRINGENCE MINERAL
6-8 8230-40	32	40	17	TR		1		1			1	TR	TR	TR		1	TR	1	5	1			
8-1 6460-80	16	33	9	2	10	1		3			2	5		8		TR	TR	5		6			TR. UNKNOWN, HIGH N, MOD-HIGH BIREFRINGENT SIM. TO ANHYDRITE *
8-2 6140-60	11	34	7	TR	13	2		4			2	5	TR	9	1	TR	TR	2		10			
8-3 5840-60	17	35	11	1	10			2			1	4	TR	6	TR?	TR	TR	3		10			
8-4 5400-20	13	35	8	1	5			5	TR		1	3	1	8	TR?	TR	TR	3		9		8	
8-5 4660-80	20	30	5	1	5			4			TR	4	2	8	5	TR	TR	6		10			
8-6 4120-40	16	35	5	3	5?	1 (OR) 1		TR			2	4	TR	9		TR	+SEE CAL.	3		7+		10	
8-7 3200-20	7	43		2	15						3	3		8		TR	TR	4		3		12	
8-8 2660-80	45	29	19								TR	TR		2		1		2		2			

* REPLACES ORIGINAL MAFICS.

⊛ PHENGITE = BROWN TO GREEN IRON-RICH ILLITE ANALOGUE

+ INCLUDES MINOR MIXED-LAYER CHLOR/SMEC.

* BLIT W/INCLINED EXTINCTION

Ⓐ AMORPHOUS, BELOW DETECTION LIMIT; MAY INCLUDE METASTABLE GLASS.

MM = PREDOMINANT M = MAJOR m = MINOR Tr = TRACE ? = TENTATIVE IDENTIFICATION

SUMMARY OF X-RAY DIFFRACTION ANALYSIS

UNIVERSITY OF UTAH RESEARCH INSTITUTE, EARTH SCIENCE LABORATORY

for: Unocal Geothermal Division, Unocal Corporation -- Daniel Carrier

16 Cuttings Samples
Clay-Fraction XRD

MINERALOGY, APPROX. WT.% [X] (or) RELATIVE ABUNDANCE [ ]

SAMPLE NO.	SMECTITE	ILLITE & PHENG. UNDIVIDED	CHLORITE	MIXED-LAYER CHLOR/SMEC.	BIOTITE	TALC
6-1	5		8		*83	2
6-2	TR?	70	30			
6-3	2	93	5			
6-4	3	5	92			
6-5			100			
6-6	13		87			
6-7	1	2	97			
6-8	15		10	5	*70	
8-1	8	42	44	6		
8-2	5	15	75	5		
8-3	3	16	72	9		
8-4	1	11	82	6		
8-5	1	49	50	TR?		
8-6	4	11	72	13		
8-7	3	*25	58	16		
8-8	26	41	33			

* INCLUDES MINOR PHENGITE

* PROBABLY INCLUDES SOME GLAUCONITE

MM = PREDOMINANT M = MAJOR m = MINOR Tr = TRACE ? = TENTATIVE IDENTIFICATION

SUMMARY OF X-RAY DIFFRACTION ANALYSIS

UNIVERSITY OF UTAH RESEARCH INSTITUTE , EARTH SCIENCE LABORATORY

Sample No.	Rock Types: BASALT OR ANDESITE	Ⓐ PORPHYRITIC BASALT OR ANDESITE	Ⓑ MICRODIABASE & MICRODIORITE	Ⓒ QTZ. LATITE OR RHYODACITE	Ⓓ PORPHYRITIC QTZ. LATITE OR RHYODACITE	QUARTZ MICRO-DIORITE OR MICRO-GRANODIORITE	BIOTITE GRANODIORITE	BIOTITE MICRO-GRANODIORITE	HBL-BTE-QTZ-PLAGIOCLASE HORNFELS	INTERMEDIATE-COMPOSITION METAVOLCANIC ROCK (?) *	YELLOW FRAGMENTS ✦	GOUGE MICROBRECCIA				NOTES, OTHER
6-1 7273-00									MM	m	m					
6-2 7165-70				MM*							TR					
6-3 6820-30		m	m	MM*							m					m-QTZ-SER. ROCK
6-4 7710-20	M	m	M								m	m				TR-QTZ-CHL-ROCK
6-5 6260-70	M	m	TR	m	m						m	TR				RHYODACITE (?) POST-DATES ANDESITE
6-6 [illegible]	MM	m	TR	TR?							m					CHIP OF PERLITE CEMENT
6-7 [illegible]	MM	m	TR								m	TR				
6-8 5230-40	TR						MM	m			TR	TR				‡
8-1	M	M	TR	TR		m					m	TR				ALSO TR LOST CIRCULATION MATERIAL
8-2	MM	m	m	m							m					
8-3	M	m		m	M						TR	m				CHALCEDONY CHIP
8-4	M	m	TR	TR	m						m					"
8-5	M	M	TR		TR?						m					TR-QTZ-SER. ROCK
8-6	MM	m									TR					
8-7	m	MM									TR	m				MICROXLN SER.-QTZ-CHLORITE ROCK
8-8	TR			MM*							TR	TR				

*QUARTZ LATITE. ALL PROBABLY SLIGHT VARIATIONS OF THE SAME ROCK TYPE. PROBABLY INTRUSIVE, PROBABLY INITIALLY GLASSY IN PART. WELL-DEVELOPED SPHERULITIC, GRANOPHYRIC, & MICROPEG-MATITIC TEXTURES (NOTE: COULD ALSO BE A DOME OR THICK FLOW).

‡ ORIGINAL MAFICS IN GRANODIORITE REPLACED BY FINE-CRYSTALLINE, GREEN-BROWN BIOTITE & GREEN ACTINOLITE. BOTH POSSIBLY DELITERIC.

* A FEW FRAGMENTS ARE MODERATELY- TO WELL-FOLIATED, INTERMEDIATE BETWEEN HORNFELS & SCHIST. MAY INCLUDE MINOR INTERMEDIATE-COMPOSITION METAVOLCANIC ROCK.

✦ MASSIVELY REXLZD, BUT RECOGNIZABLE APPARENT VOLCANIC TEXTURE. ?

Ⓐ & Ⓑ PROBABLY JUST DIFFERENT TEXTURAL VARIETIES OF SAME ROCK TYPE.

Ⓒ & Ⓓ AS ABOVE.

16 Cuttings Samples: Rock Types Observed During Reconnaissance Petrography

Sample No.	Veinlets														
	QTZ	CAL	KF ± QTZ	EP ± Q, KF	ACT ± Q, KF, EP	CHL ± QTZ	*PHENGITE ± ILLITE CHL, QTZ	PREHNITE ± EP, QTZ, KF	WAIRAKITE ± EP, QTZ, KF	LEUCOXENE	BIOTITE				
6-1	✓			✓	✓						✓				CPXN
6-2	✓		*✓			✓									
6-3	✓		*✓	✓	✓ BTE?	✓	✓								ILLITE-PYRITE
6-4	✓	✓		✓		✓									CHLORITE-CALCITE
6-5	✓	✓ TR		✓		✓				✓					CHL-EP-LEUCOXN
6-6	✓	✓ TR	✓	✓	✓	✓		✓							" " " WITH PY & KFSP | ACT-Q-CH-EP-PREHN.
6-7	✓	✓	✓?	✓		✓		✓							ONE VNLT. FRAG.: EP + UNKNOWN HIGH RELIEF, HIGH N, LOW BIREF. MINERL. ⊛
6-8															
8-1	✓	✓	✓	✓		✓	✓								CAL-CH-PHENGITE; Q-CAL-ILLITE-CHL
8-2	✓	✓		✓		✓	✓								WAIRAKITE-CHLORITE-LEUCOXENE
8-3	✓	✓		✓		✓	✓								PHENG-CHL-CALCITE
8-4	✓	✓		✓		✓	✓ TR	✓ TR							& CH-EP-LEUC.
8-5	✓	✓		✓		✓	✓		✓						PHENG.-CHL-CHALCEDONY PHENG.-WAIRAKITE
8-6	✓	✓	✓ CAL	✓		✓	✓								CHL-CAL-HEM | CHL-EP-LEUCOX. CHL-CAL-QTZ
8-7	✓	✓													
8-8	✓		*✓												QTZ-HEMATITE

* PROBABLY MICROPEGMATITIC Q-KFSP INTERGROWTH

⊛ POSSIBLY PREHNITE VIEWED ⊥ TO C AXIS

TR = SCATTERED TRACES

* PHENGITE = GREEN TO BROWN (TRANSMITTED LIGHT), IRON-RICH ILLITE ANALOGUE.

16 Cuttings Samples: Veinlets Observed During Reconnaissance Petrography

SEMI-QUANTITATIVE MINERALOGIC ANALYSIS BY X-RAY DIFFRACTION

-Methods and Procedures-

Bulk Analysis: Representative one-gram splits of bulk samples are ground in acetone in an agate mortar to < 325 mesh (< 45 μ) then scanned at 2°2θ per minute from 2-65°2θ. Diagnostic peaks of minerals identified on resulting diffractograms are rescanned on duplicate samples. Approximate weight percentages of the minerals are determined by comparing diagnostic peak intensities with those generated by standard pure phases mixed in various known proportions.

Clay Analysis: Bulk samples, at least 35 grams if possible, are sonically disaggregated in deionized water, allowed to settle sufficiently to yield the desired particle size fraction (generally < 2 μ or < 5 μ), decanted and centrifuged. The resulting slurries are smeared on glass slides and X-rayed at 1°2θ per minute following air-drying (2-37°) vapor glycolation for 24 hours at 60°C (2-22°), heating to 250°C for one hour (2-15°) and heating to 550°C for one hour (2-15°). Approximate weight percentages of the layer silicates identified on diffractograms corresponding to these treatments are determined by comparison of diagnostic peak intensities with those generated by pure reference clays in appropriate mixtures.

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extra 5

UNIVERSITY OF UTAH RESEARCH INSTITUTE

UURI

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TELEPHONE 801-524-3422

October 18, 1988

Dr. Daniel Carrier
Unocal Geothermal Division
Unocal Corporation
3576 Unocal Place
Santa Rosa CA 95406

Dear Dr. Carrier:

Attached are the preliminary results of x-ray diffraction and petrographic analyses for 10 drill cutting samples which you submitted in early August.

These samples of the "8"-series group are predominately andesites or porphyritic andesites with the exception of samples 8-10 and 8-18 which contain principally quartz latite or rhyodacite.

Sample 8-18 consists almost entirely of quartz, plagioclase and potassium feldspar. Sample 8-10 contains more primary quartz with some phenocrysts exhibiting dissolution phenomena. Granophyric, axiolitic and spherulitic textures are well developed in sample 8-10 and in some chips of quartz latite in sample 8-12.

Principal hydrothermal alteration products in these rocks are potassium feldspar, quartz, actinolite, chlorite (and mixed-layer chlorite-smectite), epidote, and leucoxene. Calcite, prehnite, wairakite and phengite are important subordinate vein-forming minerals. In the more porphyritic andesites, actinolite appears to replace primary clinopyroxene phenocrysts, especially in samples 8-13 and 8-16. (However, clinopyroxene in sample 8-11 appears relatively unaltered.) Actinolite also occurs as long prisms within quartz veins in sample 8-13. In sample 8-16, actinolite occurs in a large vein with epidote and chlorite and as a replacement of clinopyroxene phenocrysts.

Potassium feldspar veining and flooding is common in sample 8-13. In samples 8-9 and 8-11, some of the primary plagioclase is

replaced by carbonate and some by sericite. Epidote (with or without leucoxene) also commonly replaces plagioclase phenocrysts.

The quartz latite samples (8-10 and 8-18) contain mostly primary potassium feldspar and quartz as devitrification aggregates. Epidote and chlorite appear as the principal alteration products in these quartz latites or rhyodacittes.

Unfortunately, a thin section of sample 8-17 was not made so it is not possible to determine from the diffraction patterns alone whether the amphibole is primary hornblende or secondary actinolite, and whether the 10 angstrom mica is primary biotite or secondary illite and/or phengite. Another problem is the presence of an unidentified 9.40 angstrom peak in diffractograms of samples 8-11, 8-12 and 8-13 which may represent a talc-group mineral not recognized petrographically (although traces of serpentinite are evident).

As I mentioned in our phone conversation, a more detailed geologic and mineralogic report will be prepared after Jeff returns in a few weeks time. I've sent the "17"-series group out to be made into thin sections and hope to look at them fairly soon.

Thank you for this great introduction to hydrothermal alteration mineralogy. Please call me if you have any questions or if you would prefer only XRD data sent initially.

Sincerely,

Susan Lutz

Susan Lutz
Manager,
X-ray Diffraction Laboratory

SJL:kr

UNOCAL GEOTHERMAL · DANIEL CARRIER

10 CUTTINGS SAMPLES

8-9 TO 8-18

PRELIM. BULK XRD

MINERALOGY, APPROX. WT.% [X] (or) RELATIVE ABUNDANCE [ ]

SAMPLE NO.	QUARTZ	PLAGIOCLASE	K-FELDSPAR	CALCITE	CLINOPYROX.	ACTINOLITE	HORNBLENDE	EPIDOTE	PREHNITE	ANHYDRITE	TOTAL OPAQUES	ILMENITE & OR MAGNETITE	HEMATITE	PYRITE	SPINEL	LEUCOXENE	WAIRAKITE	SMECTITE	MIXED-LAYER CHLOR-SMECT.	ILLITE AND KHENBITE	BIOTITE	CHLORITE	TALC	
8-9	7	45	5	TR	3	7	3	4			20	13	2	5			1				5			TRACE - SERPENTINITE
8-10	43	34	17					1			1						1		2		1			
8-11	9	36	3	1	15	5		5	TR		17						1		1		7			TRACE - SERPENTINITE
8-12	6	40	8	1	6	5	3	6	TR		16	6			10		1				8			
8-13	2	39	7		3	12		7			21	8			13		1				8			
8-14	2	43	3		2	9	1	2			27	14		5	7	?	1				10			
8-15	1	47	6	1	3	10	2	3			20	10		4	6		1				6			
8-16	7	37	2		3	14		11			14						1				11			
8-17	2	35		2	10		•13	9				5		2	5				*11		4			(NO THIN SECTION)
8-18	18	56	14					8			1										3			

PRIMARY ?

SU TRAVEL

• NOTS. - COULD BE ACTINOLITE

* NOTS - COULD INCLUDE BIOTITE

MM = PREDOMINANT M = MAJOR m = MINOR Tr = TRACE ? = TENTATIVE IDENTIFICATION

SUMMARY OF X-RAY DIFFRACTION ANALYSIS

UNIVERSITY OF UTAH RESEARCH INSTITUTE , EARTH SCIENCE LABORATORY

10-13-88
S. Wtz

UNOCAL GEOTHERMAL - DANIEL CARRIER

8-9 TO 8-18

PRELIM. CLAY XRD

SAMPLE NO.	SMECTITE	ILLITE & PHENG. UNDIVIDED	CHLORITE	MIXED LAYER CHLORITE/SMECT.	BIOTITE	TALC
	MINERALOGY, APPROX. WT.% [X] (or) RELATIVE ABUNDANCE [ ]					
8-9	16		79	5		
8-10	6	89	5			
8-11	7	15	72	6		?
8-12	5		89	6		?
8-13	8		90	2		?
8-14	15		85			
8-15	18	3	79			
8-16			100			
8-17	3	*34	63			
8-18			100			

* MAY INCLUDE OTHER 10Å MICA - BIOTITE (NO THIN-SECTION)

? UNIDENTIFIED 9.4Å PEAK

MM = PREDOMINANT M = MAJOR m = MINOR Tr = TRACE ? = TENTATIVE IDENTIFICATION

SUMMARY OF X-RAY DIFFRACTION ANALYSIS

UNIVERSITY OF UTAH RESEARCH INSTITUTE , EARTH SCIENCE LABORATORY

10-13-88
S. Lutz

UNOCAL GEOTHERMAL - DANIEL CARRIER

VEINLETS & VEINLET FRAGMENTS

10 CUTTINGS SAMPLES
8-9 TO 8-18

PRELIM. VEINLETS

MINERALOGY, APPROX. WT.% [ ] (or) RELATIVE ABUNDANCE [ ]

SAMPLE NO.	QTZ	CAL	KF ± QTZ	EP ± Q, KF	ACT ± Q, KF, EP	CHL ± QTZ	PHENGITE ± LL, CHL, QTZ	PREHNITE ± EP, QTZ, KF	WAIRAKITE ± EP, QTZ, KF	LEUCOXENE	BIOTITE	SERICITE ± QTZ												
8-9	°TR	TR	✓	✓	✓	✓	TR		✓			✓												KF, EP-PHENG, EP-WAIRAKITE
8-10	✓		*✓	✓		✓																		EP-CHL
8-11	✓	✓		✓	✓	✓		TR				✓												EP-PREHNITE
8-12	✓	TR	✓	✓	✓	✓	TR	TR		TR														QTZ-ACT, EP-LEUCOXENE
8-13	✓	TR	✓	✓	✓	✓	TR		✓	✓														KF, EP-LEUCOXENE, WAIR-CHL
8-14	✓			✓	✓	✓	TR			TR														QTZ-ACT, KF-CHL, PHENGITE-CHALCEDONY
8-15	✓	TR		✓	✓	✓																		EP-KF-ACT
8-16				✓	✓	✓																		CHL-QTZ (NODULES), EP-CHL-ACT
8-17																								No thin-section
8-18			*✓	✓																				EP-QTZ (NODULE), EP-QTZ (VEIN)

* MICROPEGMATITIC Q-KFSP INTERGROWTH

° CHALCEDONY

TR = SCATTERED TRACES

MM = PREDOMINANT M = MAJOR m = MINOR Tr = TRACE ? = TENTATIVE IDENTIFICATION

SUMMARY OF X-RAY DIFFRACTION ANALYSIS

UNIVERSITY OF UTAH RESEARCH INSTITUTE, EARTH SCIENCE LABORATORY

10-13-88
S. Wtz

UNOCAL GEOTHERMAL - DANIEL CARRIER

ROCK TYPES

10 CUTTINGS SAMPLES
8-9 TO 8-18

MINERALOGY, APPROX. WT.% ☐ (or) RELATIVE ABUNDANCE ☐

PRELIM. ROCK TYPE / SAMPLE NO.	BASALT OR ANDESITE	PORPHYRITIC BASALT-ANDESITE	MICRODIABASE & MICROVOLCANITE	QTZ LATITE OR RHYODACITE	QTZ MICRODIORITE	MICRO GRANODIORITE	MONZONITE																			
8-9	M	M	m	m		TR																				
8-10	m			MM	TR																					
8-11	MM	m	m																							
8-12	M			M																						
8-13	MM	m	m	TR?																						
8-14	M	M	m																							
8-15	M	M	m																							
8-16		MM																								
8-17																										no thin-section
8-18				MM																						

MM = PREDOMINANT M = MAJOR m = MINOR Tr = TRACE ? = TENTATIVE IDENTIFICATION

SUMMARY OF X-RAY DIFFRACTION ANALYSIS

UNIVERSITY OF UTAH RESEARCH INSTITUTE , EARTH SCIENCE LABORATORY

10-13-88
S. Wtz

GM 18.02g

UNIVERSITY OF UTAH RESEARCH INSTITUTE

UURI

EARTH SCIENCE LABORATORY
391 CHIPETA WAY, SUITE C
SALT LAKE CITY, UTAH 84108—1295
TELEPHONE 801-524-3422

November 21, 1988

Dr. Daniel Carrier
Unocal Geothermal Division
Unocal Corporation
3576 Unocal Place
Santa Rosa CA 95406

Dear Dr. Carrier,

Attached are the revised results of XRD analysis and reconnaissance petrographic analysis of cuttings from the "8"-series group. These results, initially mailed to you in mid-October, are further interpreted in the text that follows.

Most of these samples from the "8"-series group (except for 8-10 and 8-18) are dominated by porphyritic to aphyric basalt to basaltic andesite and similar but slightly more coarsely-crystalline microdiabase. All or most appear to have contained primary pyroxene and are altered to a variety of secondary phases. Actinolite has replaced some of the pyroxene and all the primary hornblende, although traces of the latter may still be present in a few chips.

Sample 8-10 is quartz latite to quartz monzonite, essentially identical to that documented for previously analyzed samples 6-2 and 6-3. Well-developed spherulitic, granophyric and micropegmatitic textures are locally present. The lithology and devitrification textures of sample 8-10 may represent either a thick flow, or an extrusive dome, or possibly a shallow (hypabyssal or subvolcanic) intrusive.

Sample 8-18 is a rhyodacite to microgranodiorite with a sub-trachytic texture. It exhibits more flow texture than 8-10 but could also represent a dome or shallow intrusive.

Sample 8-17A may be a hydrothermal breccia; subrounded and altered clasts are present within a fine-grained matrix. The clasts are composed of fragments of porphyritic to aphyric basaltic andesite. Quartz-filled fractures crosscut the clasts within the breccia. Fragments of lineated rock lacking phenocrysts may represent minor amounts of gouge or microbreccia material in samples 8-9 to 8-15.

Like the 6-series rocks, samples 8-9 to 8-17 host a variety of secondary minerals indicative of formation at relatively high temperatures. For example, actinolite generally forms at temperatures above 280°C; biotite forms above 220°C (more commonly above 300°C); and epidote forms above 240°C (e.g. Browne, 1978, 1984; Hulen and Nielson, 1986). Other secondary alteration phases in these samples (such as chlorite) are ambiguous as geothermometers. Some of the actinolite could be deuteric in origin, as could the chlorite and epidote, but the common occurrence of these minerals as well-developed veinlets strongly argues in favor of a fairly high-temperature hydrothermal origin. Minor amounts of discrete smectite in these samples are probably saponite; trioctahedral smectites that are more stable at higher temperatures than their dioctahedral counterparts (Eberl, Whitney and Khoury, 1978).

Traces of subordinate phases such as prehnite and serpentine identified petrographically in samples 8-11 and 8-12 also suggest a fairly high-temperature alteration of these rocks. Prehnite is believed to form between 250°C to 350°C (e.g. Bird et al., 1984).

Thank you for the opportunity to work with these interesting cuttings and for sending another core chip of sample 8-17. Diffraction of the "17"-series group is nearly completed, so those results should be forthcoming in the next few weeks. Please call me at (801) 524-3425 if you have any further questions concerning the x-ray or petrographic signatures of these rocks.

Sincerely,

Susan Lutz

Susan Lutz
Manager,
X-ray Diffraction Laboratory

References:

Browne, P.R.L., 1978, Hydrothermal alteration in active geothermal fields: Ann. Rev. Earth Planet. Sci., v. 6, p. 229-250.

Browne, P.R.L., 1984, Lectures on geothermal geology and petrology: United Nations Univ., Geoth. Training Prog., Rept. 1984-2, 92 p.

Eberl, D., Whitney, G. and Khoury, H., 1978, Hydrothermal reactivity of smectite: American Mineralogist, v. 63, p. 401-409.

Hulen, J.B., and Nielson, D.L., 1986, Hydrothermal alteration in the Baca geothermal system, Redondo dome, Valles caldera, New Mexico: J. Geophs. Res., v. 91, p. 1867-1886.

UNOCAL GEOTHERMAL - DANIEL CARRIER

10 CUTTINGS SAMPLES
8-9 TO 8-18

REVISED BULK XRD

MINERALOGY, APPROX. WT.% [✓] (or) RELATIVE ABUNDANCE [ ]

SAMPLE NO.	QUARTZ	PLAGIOCLASE	K-FELDSPAR	CALCITE	CLINOPYROXENE	ACTINOLITE	EPIDOTE	PREHNITE	ANHYDRITE	ILMENITE AND OR MAGNETITE	HEMATITE	PYRITE	SPHENE/ LEUCOXENE	SMECTITE	MIXED-LAYER CHLOR-SMECT.	ILLITE AND PHENGITE	BIOTITE	CHLORITE	TALC	OTHER				
8-9	7	45	5	TR	3	9 ≠	4			9	2		9	1	TR			5						TR. SERPENTINE
8-10	41	34	17		TR	TR	2			1	TR		3	1				1						
8-11	8	38	5	1	15	5	5			7	2		6	1	1	TR		5	1					TR. SERPENTINE
8-12	4	46	7	TR	3	8 ≠	6	TR		9	TR	TR	7	1		TR		8	1					
8-13	1	49	6		2	10	5		TR	10		TR	7	1		1		7						
8-14	3	51	3		2	9 ≠	3			13		TR	7	1		TR		8						
8-15	2	54	3	TR	2	10 ≠	3			10		TR	6	1		TR		9						
8-16	11	46				7	9			7	TR		11					9						
8-17B	1	41	3	TR		19	5			10		1	7	TR			11	6						
8-18	18	45	18				7					TR	5					7						

≠ POSSIBLY INCLUDING VERY MINOR PRIMARY HORNBLENDE

MM = PREDOMINANT M = MAJOR m = MINOR Tr = TRACE ? = TENTATIVE IDENTIFICATION

SUMMARY OF X-RAY DIFFRACTION ANALYSIS

UNIVERSITY OF UTAH RESEARCH INSTITUTE, EARTH SCIENCE LABORATORY

S. Lutz
11-21-88

ROCK TYPES - REVISED

SAMPLE NO.	BASALT OR BASALTIC ANDESITE		DIABASE (A) / MICRODIABASE	QTZ. LATITE OR (B) / QTZ. MICROMONZONITE	RHYODACITE TO MICROGRANODIORITE (C)		HYDROTHERMAL BRECCIA	GOUGE / MICROBRECCIA	VEIN FRAGMENTS						
8-9	MM		m					m	m						
8-10	TR			MM				TR	m						
8-11	MM		m					m	TR						
8-12	MM		m	TR				m	m						
8-13	MM		m	m				m	m						
8-14		m	MM	M				m	m						
8-15			MM	M				TR	TR						
8-16			MM												
8-17A							MM								
8-17B			MM												
8-18					MM										

(A), (B), & (C) PROBABLY INTRUSIVE WITH (A), (B) & (C) PROBABLY JUST DIFFERENT TEXTURAL VARIETIES OF SAME ROCK TYPE. QTZ LATITE - INITIALLY GLASSY: WELL-DEVELOPED SPHERULITIC, GRANOPHYRIC & MICROPEGMATITIC TEXTURES.

10 CUTTINGS SAMPLES: ROCK TYPES OBSERVED DURING RECONNAISSANCE PETROGRAPHY

SAMPLE NO.	VEINLETS														
	QUARTZ	CALCITE	KF ± QTZ	EP ± Q, KF	ACT ± Q, KF, EP	CHL ± QTZ	ILLITE ± PHENGITE, QTZ	PREHNITE ± EP, QTZ, KF	WAIRAKITE ± EP, QTZ, KF	LEUCOXENE	BIOTITE ± QTZ	TALC - ACT.			
8-9	° TR	TR	✓	✓	✓	✓	TR								KF, EP-PHENGITE CAL-HEM
8-10	✓		* ✓	✓		✓									
8-11	✓	✓		✓	✓	✓		TR							PHENGITE - EP - HEM EP-PREHNITE
8-12	✓	TR	✓	✓	✓	✓	TR	TR		TR		✓			QTZ - ACT EP - LEUCOXENE
8-13	✓	TR	✓	• ✓	✓	✓	TR		?TR	✓					KF, EP-LEUCOXENE QTZ - ANH - EP
8-14	✓			✓	✓	✓	TR			TR					QTZ - ACT, PHENGITE - CHALCEDONY
8-15	✓	TR		✓	✓	✓				TR					EP-KF-ACT
8-16				✓	✓	✓									CHL - QTZ NODULES
8-17A	✓										✓				
8-17B	✓			✓	✓★	✓									ACT - Q - KF - MAG - SPH. ± EP
8-18			* ✓	✓											EP - QTZ NODULE + VEIN

* MICROPEGMATITIC Q-KF INTERGROWTH

° CHALCEDONY

★ WITH SPHENE

TR - SCATTERED TRACES

• WITH ANHYDRITE

10 CUTTINGS SAMPLES : VEINLETS OBSERVED DURING RECONNAISSANCE PETROGRAPHY

UNOCAL GEOTHERMAL - DANIEL CARRIER

8-9 TO 8-18

REVISED CLAY XRD

MINERALOGY, APPROX. WT.% [✓] (or) RELATIVE ABUNDANCE [ ]

SAMPLE NO.	SMECTITE	ILLITE AND PHENGITE (UNDIV.)	CHLORITE	MIXED LAYER CHLOR./SMECT.	BIOTITE	TALC
8-9	16		79	5		
8-10	10	76	14			
8-11	7	15	56	14		8
8-12	4		86			10
8-13	8		92			
8-14	15		85			
8-15	18		82			
8-16			100			
8-17B	3		63		34	
8-18			100			

MM = PREDOMINANT M = MAJOR m = MINOR Tr = TRACE ? = TENTATIVE IDENTIFICATION

SUMMARY OF X-RAY DIFFRACTION ANALYSIS

UNIVERSITY OF UTAH RESEARCH INSTITUTE , EARTH SCIENCE LABORATORY

S. Lutz
11-21-88

KEY FOR XRD ANALYSES
FROM DECEMBER 28, 1988

WELL	SAMPLE NO.	DEPTH (FEET)
GMF31-17	17-1	800-10
	17-2	1100-10
	17-3	1300-10
	17-4	1790-1800
	17-5	2100-20
	17-6	2300-20
	17-7	2840-60
	17-8	3240-60
	17-9	3870-80
	17-10	4220-30
	17-11	4480-90
	17-12	4940-50
	17-13	5230-40
	17-14	5320-30
	17-15	5780-90
	17-16	6080-90
	17-17	6560-70
	17-18	7020-30
	17-19	7450-60
	17-20	8030-40
	17-21	8090-8100
	17-22	8250-60
	17-23	8787
	17-24	8420
	17-25	8422

GM 18.02

UNIVERSITY OF UTAH RESEARCH INSTITUTE

UURI

EARTH SCIENCE LABORATORY
391 CHIPETA WAY, SUITE C
SALT LAKE CITY, UTAH 84108—1295
TELEPHONE 801-524-3422

December 28, 1988

Dr. Daniel Carrier
Unocal Geothermal Division
Unocal Corporation
3576 Unocal Place
Santa Rosa, California 95406

Dear Dr. Carrier,

The x-ray diffraction analysis and reconnaissance petrographic analysis of cuttings from the "17"-series group are complete and appended to this letter. The results are further interpreted in the text that follows.

Rock type and mineralogy-

The "17"-series group is predominantly andesite and dacite. Compositional and textural variations of the andesite are orthopyroxene or clinopyroxene andesites, porphyritic or aphyric andesites, amygdaloidal basaltic andesites, microdiabase and meta-andesite and meta-diabase. Dacitic composition rocks include the varieties, dacite and rhyo-dacite, both porphyritic and aphyric. The lowest part of this group is granodiorite, which may or may not be genetically related to the overlying dacite.

Samples 17-1 through 17-3 exhibit relict perlitic and other devitrification textures preserved in cristobalite which has partially altered to aragonite. Most of the original mafic content of the groundmass has altered to hematite. Aragonite, smectite and traces of analcime are present as amygdule fillings. Hematite has also replaced the aragonite in some of the amygdules. Orthopyroxene phenocrysts are also common in the more phyric andesites. This interval of rocks seems to represent an originally glassy andesite flow.

Samples 17-4 through 17-6 are predominately dacite. Granophyric and spherulitic texture is well developed. Sieve-textured feldspar phenocrysts are also common in this interval. Sample 17-6 is partially silicified and partially granophyric. It could represent the originally glassy border of a shallow dacite intrusive.

The presence of secondary biotite in samples from the bottom of this well is also associated with thermal metamorphism of the granodiorite; the biotite occurs in fine-grained aggregates or poorly defined veinlets. However, the overlying volcanic flow rocks contain well-defined crosscutting veins of biotite-actinolite-talc that are more positively hydrothermal in origin.

Alteration zoning-

The rocks penetrated by this well clearly show well-defined mineralogic zoning which is related to increased temperatures with depth. The problem is distinguishing hydrothermal alteration from contact metamorphism.

The origin of high-level smectite, quartz and calcite, and mid-level epidote, wairakite and prehnite is almost certainly hydrothermal because these minerals occur in veinlets (and in some amygules). Some of the deeper biotite, actinolite (and rare clinopyroxene?) also occur in veins and are probably hydrothermal. However, much of the biotite and especially clinopyroxene in the zone of metamorphism is metamorphic, the rock is trying to become a hornfels.

The vein assemblages do provide information about the temperatures of the hydrothermal fluids from which some of the secondary phases were deposited. Epidote tends to form above 240°C; prehnite above 215°C; wairakite above 210°C; actinolite above 280°C; and biotite above 220°C (more commonly above 300°C) (e.g. Browne, 1978, 1984; Hulen and Nielson, 1986).

The layer silicate mineralogy of this well also reflects zoning related to temperature. Samples 17-1 through 17-4 contain 10% to 20% smectite. The air-dried basal spacing of the smectite at 14A suggests that calcium and/or magnesium are the principal interlayer cations. Because these smectites are high-level and occur in rocks that contain analcime rather than wairakite, they probably formed at low temperatures, below 160°C (Hulen and Nielson, 1986).

Samples 17-5 through 17-15 contain discrete chlorite and some mixed-layer chlorite-smectite. Some samples in this interval also contain mixed-layer illite-smectite. The amount of illite interlayers in the illite-smectite is about 70-90%. These low-expandability mixed-layer clays usually form between 175°C and 220°C (Browne, 1984) from precursor smectites, so they could have been generated during incipient to low-grade metamorphism as well as subsequent hydrothermal alteration.

Below sample 17-16, the chlorites are either discrete forms or they occur in mixed-layer chlorite-smectite. This variety of chlorite-smectite is ordered and contains about 60 to 90% smectite as indicated by a superlattice peak at about 29A (in air-dried samples). Mixed-layer chlorite-smectites are stable between 200°C and 270°C (Browne, 1984), a temperature also

permitting a low-grade metamorphic origin.

Samples 17-19 through 17-25 contain two varieties of mixed-layer chlorite-smectite, one with about 50% chlorite and the other with about 80% chlorite interlayers. The occurrence of the unordered, 50% chlorite variety with clinopyroxene, epidote and biotite, may indicate a cooling trend at depth since the higher temperature phases were formed.

Discussion-

Traces of the high-temperature alteration phases, actinolite and epidote, are present in a few fragments from the highest levels in this well (samples 17-1 and 17-2). The unusual occurrence of these high-temperature alteration phases in lower-temperature argillically-altered rocks may possibly represent lithic fragments of altered rock in dacite dikes at this level.

Veins containing intergrown calcite and quartz are common in sample 17-4. Calcite is replacing both wairakite and epidote in sample 17-7. Both these occurrences of calcite suggest that boiling (and CO^2 exsolution) has occurred at these levels at some time.

Below the depth of samples 17-16 and 17-17, a change in alteration occurs. Samples 17-14 and 17-16 are partially silicified. Samples 17-17 to 17-24 contain less epidote, anhydrite and leucoxene, and more actinolite, biotite, talc and ordered chlorite-smectite as alteration minerals. Perhaps the change in mineralogy reflects the change from a vapor-dominated upper zone to a water-dominated reservoir zone.

To conclude, the alteration in this well is zoned as a result of both metamorphic and hydrothermal processes. A shallow argillic zone contains abundant smectite, illite-smectite and hematite, possibly as a result of hydrothermal alteration. Cristobalite occurs as a devitrification product and aragonite, a low temperature alteration of the glass. The andesitic flow rocks in this interval may be locally cut by dacite dikes. Underneath this zone is a hydrothermal, propylitically-altered zone containing abundant epidote, chlorite and wairakite that probably formed at moderately high temperatures. Subordinate amounts of anhydrite, prehnite and illite-smectite are also present as vein-forming minerals. A silicified interval at the base of this zone may mark the transition into the lower, higher-temperature, more potassic, alteration zone. This interval is characterized by hydrothermal veins of actinolite-biotite-talc. The hydrothermal alteration in this zone seems to be superimposed on an older contact metamorphic zone characterized by biotite and clinopyroxene, which may represent a pyroxene-hornfels facies of metamorphism. The chlorite-poor chlorite-smectite in this zone may be the result of a much later, and cooler, hydrothermal system. Intrusive rocks are penetrated in the lowest part of the well. Some of the secondary biotite in the granodiorite appears to be

of metamorphic rather than hydrothermal origin. This intrusive body may represent the source of thermal metamorphism.

Thanks for the opportunity to work with these interesting cuttings. I realize that this interpretation of the origin of the clinopyroxene at the bottom of the well differs from yours. However, Jeff Hulen and I both looked at the thin-sections and we are fairly confident that most of this pyroxene is neither igneous nor hydrothermal. If you care to discuss this further or if you have any more questions about the x-ray or petrographic signatures of these rocks, please call.

Sincerely,

Susan Lutz

Susan Lutz
Manager,
X-ray Diffraction Laboratory

References

Browne, P.R.L., 1978, Hydrothermal alteration in active geothermal fields: Ann. Rev. Earth Planet. Sci., v. 6, p 229-250.

Browne, P.R.L., 1984, Lectures on geothermal geology and petrology: United Nations Univ., Geoth. Training Prog., Rept. 1984-2, 92 p.

Hulen, J.B. and Nielson, D.L., 1986, Hydrothermal alteration in the Baca geothermal system, Redondo dome, Valles caldera, New Mexico: J. Geophs. Res., v. 91, p. 1897-1886.

UNOCAL GEOTHERMAL - DANIEL CARRIER

17- SERIES

MINERALOGY, APPROX. WT.% ✓ (or) RELATIVE ABUNDANCE

CLAY XRD SAMPLE NO.	SMECTITE	*CHLORITE & MIXED-LAYER CHL-SM UNION	CHLORITE	MIXED-LAYER CHLORITE-SMECT.	MIXED-LAYER ILLITE-SMECTITE	ILLITE	BIOTITE	TALC	ACTINOLITE	% CHL IN M.L. CHL-SM	% IL IN M.L. IL-SM	BASAL SPACING(Å) OF A.D. SMECTITE	CH-SM ORDERED SUPERLATTICE	* MOSTLY CHLORITE BUT MAY CONTAIN SOME CHLORITE - RICH (80-90%) CHLORITE-SMECTITE
17-1	100											14.7		
17-2	100											15.0		
17-3	100											14.7		
17-4	98	2										13.8		
17-5	32	68												
17-6	23	2		75						~70		14.3		
17-7	TR	78		+22						~90				+ MAY CONTAIN SOME ILLITE OR 10Å MICA
17-8		100												
17-9	10	90										12.8	TR	
17-10	1	53		46						~90				
17-11			100											
17-12	4	96												
17-13			64	34			2	TR					TR	
17-14		100			TR		TR	TR					TR	
17-15		100						✓						
17-16	1	99						✓						
17-17		100						✓						
17-18		98		2				TR						
17-19		86		14				TR						
17-20		80		6			+14	TR	✓					
17-21		22		24			19	35	✓					
17-22		66		34									✓	
17-23		29		35			+23	13	TR				✓	+ MAY INCLUDE SOME MIXED LAYER IL-SM
17-24		11		21			19	49						
17-25		15		7			78		TR					

SUMMARY OF X-RAY DIFFRACTION ANALYSIS

UNIVERSITY OF UTAH RESEARCH INSTITUTE, EARTH SCIENCE LABORATORY

S. Lutz
12-28-88

UNOCAL GEOTHERMAL - DANIEL CARRIER

MINERALOGY, APPROX. WT.% [✓] (or) RELATIVE ABUNDANCE [ ]

17- SERIES BULK XRD SAMPLE NO.	CRISTOBALITE	QUARTZ	PLAGIOCLASE	K-FELDSPAR	CALCITE / ARAGONITE	CLINOPYX / ORTHOPYX	ACTINOLITE / HORNBLENDE	EPIDOTE	STHENE & LEUCOXENE UNDIV.	MAGNETITE & ILMENITE UNDIV.	HEMATITE	PYRITE	ANHYDRITE	WAIRAKITE / ANHEUME	SMECTITE	CHLORITE & CHLORITE-SMECT UNDIV.	ILLITE & ILLITE-SMECT UNDIV.	BIOTITE	TALC	AMORPHOUS OR BELOW DETECT.	OTHER	
17-1	24	1	33	7	TR	1/1		TR	5	1	12			TR	12						3	GOETHITE
17-2		TR	31	2?	1	8/TR		TR	11	4	4			TR	17					*22		* MOSTLY GLASS
17-3		TR	26		3	1/TR			9	5	7			TR	22					*27		* MOSTLY GLASS
17-4	25	6	15	26	1	TR			5	1	2	3			8	1				7	TR	LAUMONTITE ? IN QTZ VEIN
17-5	5?	16	30	10	2/1			TR	13	TR		4			4	3				12		
17-6		22	26	15	2			1	6		1	3		TR	4	1	12			7		
17-7		10	26	5	12			8	11		2	TR		7		11	2			6		
17-8		13	25	13	3	7		6	7	5	3			2		4		TR		12		
17-9		10	23	10	1			26	9		2	3	TR	2	1	12					1	PREHNITE
17-10		15	31	15	1	1	TR	13	7	2		3		4		5	2				1	PREHNITE
17-11		8	26	4		1		16	12	1	2	3	1	3		11	1			11		
17-12		6	27	8	TR	11	3	8	11	4	2	1	TR	1		7				11		
17-13		12	28	9	TR	13	3.	8	9	5	1	TR				5			TR	6	1	DRILL STEEL
17-14		8	24	14		1?	2	26	9		TR	TR	TR			5				10	TR	DRILL STEEL
17-15		11	23	4			5	23	13	1		TR				7				13		
17-16		11	22	6			5	17	10	2	TR	1	TR			12				14		
17-17		4	35	5			12	9	7	8		1				8				11		
17-18		8	22	8			3	18	11	4		TR				16				10		
17-19		24	26	17			1	3	*11	1		TR				7				10		* ? VERY FINE-GRAINED
17-20		2	35	4		TR	14	2	5	11		1				8		3	1	14		
17-21		1	38	3		15	4	1	3	9		1				3	5	4	4	9		
17-22		17	40	26		1	1/4	1		3						4				3		
17-23		3	30	8		17	1	TR	10	6						2	5	8		10		
17-24		1	46	2		19			2?	9		TR					5	4	5	7		
17-25		18	35	14		TR	1/3	2	2	7		TR				4		13			1	APATITE

SUMMARY OF X-RAY DIFFRACTION ANALYSIS

UNIVERSITY OF UTAH RESEARCH INSTITUTE, EARTH SCIENCE LABORATORY

S. Lutz
12-28-88

17- SERIES	ROCK TYPES: PPYTIC BASALT/ANDESITE	BASALT	ANDESITE	DACITE, RHYODACITE, PPYTIC DACITE, RHYODACITE	MICRODIABASE	META-ANDESITE & META-BASALT	MICROGRANO-DIORITE	FINE-XLN HBL GRANODIORITE	BRECCIA (INTRUSION?)	MICROBRECCIA	VEIN FRAGMENTS	GOUGE	MICROBRECCIA	PPYTIC MICRO-META DIORITE	
17-1				M*				TR			m(1)				DACITE POST-DATES ANDESITE
17-2			MM								TR				
17-3		Ma	Ma	m							TR				
17-4		m	m	M(2)	M(2)						TR				
17-5		m	M	m	m										
17-6				MM	m					M(3)	M				ONE DACITE FRAG. CONTAINS GRAPHIC MICRO-GRANITE CLAS
17-7				MMa							M				
17-8		m	M	M	m			TR*			TR				
17-9		m	Ma	M(4)				m(5)			M				
17-10		m	m	MM	M(4)			TR(5)		TR	m				
17-11		m	M	m		TR					M				TR HIGH-T GREASE
17-12		M	M	TR	TR						TR				OPHITIC CPXN IN ANDESITE
17-13				M(2)	m(2)	M					m				OPHITIC CPXN IN ANDESITE
17-14		m	M	m	m	m					M				
17-15		m	M	m		m					M				
17-16			M	m?		m		TR			M				
17-17		MM	m	TR							m				
17-18		m	≠M			m					M	m?			
17-19			TR	MM(2)		TR					m				GRANOPHYRE
17-20			MMa								TR				
17-21			TR?				MM				TR				TR. QTZ-BTE. HORNFELS TR. GRAPHIC GRANITE
17-22			TR				TR		MM		TR				
17-23							M								M - METADIABASE
17-24													M		M - METADIORITE
17-25									M						WITH BIOTITE
* PERLITIC, SOME W/ PINPOINT DEVITRIFICATION															/ LOCALLY DEVELOPED GRANOBLASTIC REXLZN
(a) AMYGDALOIDAL															
(1) ALSO POSSIBLY AMYGDULE FRAGMENTS															
(2) PATCHY GRANOPHYRIC DEVITRIFICATION															
(3) COULD BE IN PART HYDROTHERMAL															
* COULD BE GRANOPHYRIC PORTION OF DACITE															
(4), (5) COULD BE JUST DIFFERENT PARTS OF SAME ROCK															
≠ POSSIBLY VERY FINE CRYSTALLINE MICRO DIORITE															

17-SERIES SAMPLE NO:	VEINLETS & VEINLET FRAGS.														
	QUARTZ	CALCITE	PY - QTZ	EP ± Q, KF, CHL	SERICITE	CHL ± QTZ	WAIR ± EP QTZ KF CAL	ANALCIME	SMECTITE	HEMATITE	PREHNITE ± Q, EP KF, CHL	KF ± QTZ	ACTINOLITE ± Q, QTZ BTE, KF, EP		
17-1				✓				✓SM	✓						HEM ± GOE
17-2									✓	✓					
17-3		✓?							✓	✓					
17-4	✓		✓												Q - CALCITE Q - LEUCOXENE
17-5	✓	✓	✓												Q - LEUCOXENE
17-6	✓✓														QUARTZ
17-7	✓	✓		✓	✓	✓	✓								WAI - EP - CAL - CHL QTZ - KF - WAI - AB
17-8	✓	✓		✓		✓	✓								WAI - EP - CHL SIDERITE?
17-9	✓			✓		✓					✓	✓			QTZ - EP - ANH - PREHNITE
17-10	✓			✓			✓				✓		✓TR		
17-11				✓		✓	✓								Q - LEUCOXENE
17-12	✓			✓		✓					✓				EP - ANHYDRITE
17-13	✓			✓											Q - HEMATITE
17-14	✓			✓	✓?										ANHYDRITE
17-15	✓			✓		✓						✓	✓		LEUCOXENE
17-16	✓			✓		✓									
17-17	✓			✓		✓						✓			
17-18	✓			✓								✓	✓		
17-19	✓			✓								✓			
17-20	✓			✓		✓						✓	✓✓		QTZ - ACT - BTE PHENGITE?
17-21	✓											✓	✓✓		KF - QTZ BTE - QTZ
17-22				✓											
17-23	✓	✓		✓									✓		CLINOPYROXENE BTE ± QTZ
17-24															
17-25															

GM 18.02i

UNIVERSITY OF UTAH RESEARCH INSTITUTE

UURI

EARTH SCIENCE LABORATORY
391 CHIPETA WAY, SUITE C
SALT LAKE CITY, UTAH 84108—1295
TELEPHONE 801-524-3422

CA-GM-913-1

April 9, 1990

Randolph C. Thompson
Unocal Geothermal Division
3576 Unocal Place
P.O. Box 6854
Santa Rosa, California 95406

Dear Randy:

The lithologies in well 13 are similar to those previously studied in the "6", "8", and "17" series groups. However, unlike the other wells, no granodiorite or microgranodiorite is present in these samples from well 13.

Three major rock types are present. 1) Porphyritic to aphyric basalts and porphyritic basaltic andesites are commonly amygdular. 2) Coarser-grained rocks with abundant clino- and ortho- pyroxene are termed microdiabase, implying an intrusive origin for this rock type. Some of the microdiabases also contain minor amounts of biotite or hornblende. Phenocrysts in the coarser-grained diabases are ophitically-textured. 3) Quartz latites or rhyodacites exhibit a variety of devitrification textures and probably were originally glassy.

In general, predominantly aphyric and amygdular basaltic andesite flows are present to 1200′. However, at 300′ and 800′, porphyritic dacite is also present. The dacites probably represent flows; they are flow-banded and contain altered phenocrysts of biotite and perthitically intergrown feldspars in glomeroporphyritic aggregates. Angular fragments of oxidized andesitic basalt in sample 1200′ may represent cinders that are part of a volcanic cone at the base of the predominately basaltic flow section.

Samples from 1300′ and 1400′ are mostly porphyritic andesite and represent a flow or possibly, a shallow intrusive body. Sample 1460′ is a mixture of many rock types and represents the contact

between the andesite and an underlying thick (1500'-1800') rhyodacite. The cuttings in 1460' include basalt and andesite flow rocks and rhyodacite flows or tuffs. Because such a variety of lithologies are present in 1460' and not in the overlying section, it is likely that this depth represents an erosional disconformity in the volcanic section.

The rhyodacite displays several different textures. Relict perlitic texture is evident at the top (1500') and near the bottom (at 1800'), coarser-grained rhyodacite is present. This crystallization pattern suggests that the rhyodacite was deposited as a flow or a flow-dome complex; it may have cooled quickly to a glass near the surface (now 1500') and more slowly near its center (now 1800'). Spherulitic devitrification is also common in the center of the rhyodacite body. At the base of the rhyodacite, sample 1890' contains many cuttings with an argillic matrix and rounded andesite clasts along with resorbed quartz phenocrysts. This rock is probably an intraformational mudflow with an ashy matrix. One chip in sample 1890' is of coarse-grained graphic intergrowths of feldspar and quartz which could have been derived from a granitic highland.

Below 2000', the rocks consist predominately of diabase that is gouged or mylonitic and highly altered.

Samples from 2000' to 2200' are mostly microdiabase which probably represents a brecciated intrusive body. Within the microdiabase are altered phenocrysts of a ferromagnesian mineral, probably hornblende but possibly biotite, which are completely altered (deuterically?) to smectite. Clinopyroxene phenocrysts subophitically enclose plagioclase laths in the coarse-grained diabase at 2100'.

Samples from 2300' to 2400' are mostly hornblende microdiabase. The presence of potassium feldspar at 2300' is somewhat problematical. There is certainly secondary adularia in this sample but it is also possible that some of the potassium feldspar is primary. In the latter case and considering the presence of hornblende, some of the lithologies at 2300' and 2400' may be termed porphyritic rhyodacite or quartz latite. Either way, samples 2300' and 2400' represent a different rock unit than from 2000' to 2200'.

Some of the microbreccia in microdiabase at 2300' and in andesite at 2370' may have been caused by hydrothermal brecciation; both samples contain rounded, hematitic fragments within a silicified matrix.

Sample 2450' is nearly identical to sample 2370', and sample 2400' is similar to sample 2300'. Samples 2370' and 2450' are vesicular basaltic andesites and both are intensely mineralized. This phenomenon may indicate that vescicular lithologies provide good permeability pathways for hydrothermal fluids.

Samples 2500′ and 2560′ contain two rock types; fine-grained, glassy andesite and coarser-grained diabase, both of which are probably just textural variations of the same rock. In sample 2500′, both rock types are vesicular and the vesicles are filled with fluid inclusion-rich (hydrothermal) quartz and/or epidote. The glassy, aphyric andesite probably represents the cooled borders of the intrusive body. In chips of diabase at 2500′, the clinopyroxene is coarse-grained and subophitically-encloses plagioclase.

Samples 2560′ and 2600′ are both intensely altered and mineralized, making the original rock type difficult to determine. However, these samples appear to be mostly microdiabase (flooded with secondary K-feldspar?). Sample 2560′ also contains some porphyritic rhyodacite; large quartz and zoned plagioclase phenocrysts are present in a devitrified matrix of quartz and potassium feldspar. Some fragments of the rhyodacite appear seriticized. Relict shard and pumice texture is evident in some chips indicating that the rhyodacite is at least partially tuffaceous.

The rocks from well 13 are mineralogically zoned with depth. Argillic alteration predominates down to about 1000′. Smectite and zeolite-filled amygdules are common in the argillic zone, although some calcite-filled amygdules are present at 600′ and 800′. X-ray diffraction analysis of the zeolite indicates that it is stilbite, a low-temperature, fibrous zeolite.

The first occurrence of hydrothermal veining (chlorite-smectite and quartz+pyrite) is at 1000′. The top of the propylitic zone is at 1100′, where epidote first appears as a trace mineral in veins. Veins of intergrown quartz and calcite (+/- epidote and wairakite) in samples from 1100′ to 1460′ suggest that this may be a zone of extensive boiling. Dark green, highly birefringent smectite is common in this zone and is especially abundant in sample 1400′. All of the lithologies in sample 1460′ are highly altered and it is likely that this interval is a lithologic contact that was permeable and promoted hydothermal alteration.

In general, the rhyodacite flow from 1500′ to 1890′ is not as altered as the overlying and underlying rocks. Chips of andesitic or diabasic rocks within the rhyodacite interval commonly contain veins and much epidote but the rhyodacite itself is commonly just silicified. Some chips of the (originally glassier?) rhyodacite are also sericitized. X-ray diffraction analyses of the clay fractions from samples 1600′, 1710′ and 1890′ indicate the presence of mixed-layer illite-smectite with about 10% smectite interlayers. Such illitic illite-smectites usually indicate temperatures up to 260°C (e.g. McDowell and Elders, 1980).

The microdiabases from 2000′ to 2300′ are brecciated and veined. In thin-section, sheared and microbrecciated or strained crystals in a dark chloritic matrix characterize mylonitic chips of diabase. Traces of talc in this interval may be associated with

the fault gouge. Actinolite is present in this interval both in veins with hydrothermal quartz and as a (deuteric?) alteration product of primary clinopyroxene and/or amphibole in the diabase.

Dark green smectite is also a common alteration mineral in the interval from 2000′ to 2300′. At 2200′, this smectite occurs in veins with actinolite and quartz. Therefore, it must be a high-temperature variety of smectite (e.g. Eberl, Whitney and Khoury, 1978). From the X-ray diffraction pattern, it is not possible to distinguish this clay as saponite (magnesium-rich smectite) or a smectite-rich chlorite-smectite. Nevertheless, it appears to be identical in XRD and in thin-section to the clay in the lower portions of well 8 (termed smectite) and well 17 (termed chlorite-smectite). In well 13, the smectite is mostly absent in the hottest part of the well (below 2300′) and a very chloritic mixed-layer chlorite-smectite is the only clay mineral that persists to the bottom of the well.

From 2300′ down to 2600′, well-defined hydrothermal veins of prehnite+epidote and adularia+quartz (+/- epidote and actinolite) are common. Evidence for hydrothermal brecciation at 2370′ and 2450′ suggests that some boiling may have occurred locally. The presence of veins of anhydrite at 2370′ and 2470′ may indicate increased permeability due to hydrothermal brecciation and boiling.

Potassium feldspar flooding of the diabase below 2300′ is extensive. Because potassic alteration is typical of ascending and cooling solutions, the formation of K-feldspar in this zone may indicate the positioning of these rocks in or close to a major upflow zone (e.g. Giggenbach, 1984).

The secondary mineral assemblage from 2300′ to 2600′ is certainly indicative of deposition from high-temperature hydrothermal fluids. Epidote commonly forms above 240°C; prehnite above 250oC; and actinolite at temperatures greater than 250°C (e.g. Browne, 1978, 1984; Hulen and Nielson, 1986; Bird et al., 1984). Traces of grossular garnet in a vein with prehnite and epidote at 2560′ may indicate temperatures above 300°C in this zone.

To conclude, the rocks in the lower portion of well 13 contain an abundance of unambiguous high-temperature hydrothermal minerals (particularly prehnite) in well-defined veins. The secondary (and perhaps metamorphic) mineral assemblage of biotite, actinolite and clinopyroxene which complicated interpretation of the hydrothermal alteration in the granodiorite of well 17 is not present.

At this point in your investigation, you should have the basis of a stratigraphic and structural framework for this area. If you don't and are willing to provide me with the thin-sections from, the depths of samples from, and the relative position of, wells 6, 8, 13 and 17, I would be very interested in working on this aspect of your investigation. Please contact me if you are interested in this proposal or if you have any questions concerning the X-ray diffraction or petrographic analyses of the rocks from well 13. Thanks for the opportunity to continue working on these interesting rocks.

Sincerely,

Susan Juch Lutz

Susan Juch Lutz
Manager,
X-ray Diffraction Lab

References:

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UNOCAL GEOTHERMAL DIVISION - RANDOLPH THOMPSON

WELL 13
MEDICINE LAKE

BULK + CLAY XRD

MINERALOGY, APPROX. WT.% [✓] (or) RELATIVE ABUNDANCE [ ]

SAMPLE NO.		CRISTOBALITE	QUARTZ	PLAGIOCLASE	K-FELDSPAR	CALCITE	ANHYDRITE	MAGNETITE	HEMATITE	PYRITE	SPHENE, RUTILE, LEUCOXENE, UNIDIV	CLINOPYROXENE	AMPHIBOLE / ACTINOLITE	EPIDOTE	PREHNITE	WAIRAKITE	STILBITE	TALC	SMECTITE	MIXED-LAYER CHLORITE-SMECTITE	MIXED-LAYER ILLITE-SMECTITE	AMORPHOUS? BELOW DETECTION	
160	BULK		TR	44				14	3			2							10				'27	' GLASS
200	BULK	3	TR	61				20	TR			7							5				3	
	CLAY																		100					
300	BULK	61		5	27			1	x 2			TR					TR		4				—	x WITH GOETHITE
400	BULK	4		29				10	x 2								4		43				8	x WITH GOETHITE
	CLAY																•TR		100					•COARSE-GRAINED ZEOLITE
600	BULK	3		42		6		13	16								2		8				10	
	CLAY																TR		100					
800	BULK		TR	52		3		18	1			' 4					TR		• 18					' WITH ORTHOPYROXENE • WAS BIOTITE
	CLAY																		100					
1000	BULK		4	34		5		15	3	1		2							31	2			3	
1100	BULK		6	37		8		16	6	1	2	1		TR					9	5			9	
	CLAY																		55	45				
1200	BULK		14	15	2?	10		13	12	1	6	TR				3			4	11			9	
	CLAY																		18	82				
1300	BULK		5	27	4	12		10	1	2	7	8		1		TR			2	14			7	
1400	BULK		2	35		3		22	1	2	2	13				TR			1	11			8	
	CLAY																		82	18				
1460	BULK		7	32	5	4		11	1	3	10	3		TR					8	9			7	
1500	BULK	5	30	12	32	2		2	TR	1		1		1		5			1	1	TR		7	
1600	BULK	4	26	19	33	2		3	1	2	1	1		2					2	2			2	
	CLAY																		19	57	+24			+ ~ 10% SM IN M.L. ILISM
1710	BULK	5	25	17	37	TR		2		2	2			2					1	2			5	CEMENT
	CLAY																		3	36	+61			+ ~ 10% SM IN M.L. ILSM

MM = PREDOMINANT M = MAJOR m = MINOR Tr = TRACE ? = TENTATIVE IDENTIFICATION

SUMMARY OF X-RAY DIFFRACTION ANALYSIS

UNIVERSITY OF UTAH RESEARCH INSTITUTE , EARTH SCIENCE LABORATORY

S. Lutz
3-9-90

UNOCAL GEOTHERMAL DIVISION - RANDOLPH THOMPSON

WELL 13
MEDICINE LAKE

BULK + CLAY XRD

MINERALOGY, APPROX. WT.% [✓] (or) RELATIVE ABUNDANCE [ ]

SAMPLE NO.	CRISTOBALITE	QUARTZ	PLAGIOCLASE	K-FELDSPAR	CALCITE	ANHYDRITE	MAGNETITE	HEMATITE	PYRITE	SPHENE, RUTILE LEUCOXENE UNDIV.	CLINO-PYROXENE / AMPHIBOLE	ACTINOLITE	EPIDOTE	PREHNITE	WAIRAKITE	TALC	SMECTITE	MIXED-LAYER CHLORITE-SMECTITE	MIXED-LAYER ILLITE-SMECTITE	AMORPHOUS / BELOW DETECTION	
1800 BULK	2	14	19	32	3		3		2	3	1		TR					9	4			8	CEMENT W/PERLITE
1890 BULK	2	20	14	30	4		3		4	7			TR		4				9	3		—	
CLAY																		TR	46	+54			+ ~10% SM IN M.L. 1/1 SM
2000 BULK		2	30	9	4		9		2	2	15	1/1	1				1	16	1			6	
2100 BULK		5	35	6	3		10	1	2	4	9		TR		1			10	4			10	
CLAY																		44	56				
2200 BULK		2	45		3		15		2	3	10	TR?/TR	TR	TR				16	1			3	
CLAY												TR					2	44	54				
2300 BULK		9	31	10	2		9		1	12	8	2/	1	TR			1	9	5			—	
2370 BULK		10	26	11		2	5	1	1	13			14	5					11			1	
CLAY																			•99	1			• ESSENTIALLY PURE CHLORITE
2400 BULK		6	45	11	2		10		1	4	7	1/	1					8	1			3	CEMENT W/PERLITE
2450 BULK		10	23	6		3	3	1	TR	15			16	6					11			6	
CLAY																			•100				• ESSENTIALLY PURE CHLORITE
2500 BULK		5	40	11	1		4		3	10	6	2/	8						10			—	
2560 BULK		7	31	7	1		7		3	13	3	1/1	12	1					11	2		—	
CLAY												5							•91	+4			+ ~10% SM IN M.L. 1/1 SM • VERY CHLORITIC
* 2600 (?) BULK		10	26	5	1		4	1		17			15	4					9			8	

* dupl. of 2450'

MM = PREDOMINANT M = MAJOR m = MINOR Tr = TRACE ? = TENTATIVE IDENTIFICATION

SUMMARY OF X-RAY DIFFRACTION ANALYSIS

UNIVERSITY OF UTAH RESEARCH INSTITUTE , EARTH SCIENCE LABORATORY

S. Lutz
3-9-90

SAMPLE FOOTAGE	BASALT	PORPHYRITIC ANDESITE	MICRODIORITE + MICRODIABASE	RHYODACITE OR QTZ. LATITE	PORPHYRITIC RHYODACITE	MICRO GRANODIORITE	HORNBLENDE MICROGRANODIORITE	DACITE	RHYOLITE ASH FLOW TUFF	VOLCANIC CONGLOMERATE	GOUGE	MICROBRECCIA	VEIN FRAGS.	
160	aMM	m												
200	m	'MM												'FLOW-BANDED
300								'MM						'DEVITRIFIED, SOME PERLITIC TEX, ALTER. BIOTITE — GRAPHIC FS
400	aMM		TR											
600	aMM													
800								'MM						'MUCH ALTERED BIOTITE. SOME CPX + OPX. — MORE XLN THAN 300'
1000	aM	m	tm									m		+ FLOW-BANDED
1100	aMM										TR	m		
1200	aMM											m		ANGULAR FRAGS. + HEM. = CINDERS?
1300		aMM		'm								m		'SPHERULITIC
1400	'm	MM									m	m		•ALTERED
1460	am	M		'M					'm?		m	m		'DEVITRIFIED, ALSO RELICT SHARD TEX. — MIXTURE OF ROCKS
1500			TR	'MM								TR		'RELICT PERLITIC TEX. SPHERULITIC DEVITR.
1600	am		'm	M							TR	TR		•EPIDOTE
1710			m	'MM										'SPHERULITIC DEVITR. CEMENT
1800	m		'm	M								TR		'COARSE GR. W/CPX + OPX CEMENT
1890	aM			M		'TR?				•M				'ONE CLAST GRAPHIC FSPAR a-FILLED W/ QTZ — •ROUND ANDESITE CLASTS IN CLAYEY MATRIX
2000			MM								M	m		CPX > BIO BIOTITE → SMECTITE
2100	aTR		'MM	'TR							M	m		CPX + OPX >> BIO, COARSE 'RELICT PERLITIC TEX.
2200			'MM								m	m		CPX + OPX >> BIO •COARSE GR. = DIABASE
2300			*MM								'M	'm		XCPX + HB 'HYDROTHERMAL BRECCIA? 'CROSS-CUTTING VEINS
2370	aMM										'm	M		a-FILLED WITH QTZ, EP 'HYDROTHERMAL BRECCIA
2400			'MM								'M	m		•SIM TO 2300' 'MYLONITE
2450	aMM											M		a-MINERALIZED SIM TO 2370'
2500	aM		aM								M	m		a-FILLED WITH QTZ, EP •SAME ROCK-DIFF. TEX.
2560	m		M		'm				m?		m	m		'LARGE PLAG IN DEVITRIFIED MATRIX
* 2600	m		M								m	m		

a = AMYGDULAR

* [illegible] of 2450

WELL 13
MEDICINE LAKE

ROCK TYPES OBSERVED DURING
RECONNAISSANCE PETROGRAPHY

SAMPLE FOOTAGE	VEINLETS & VEINLET FRAGMENTS														
	QTZ	QTZ + PY	QTZ + CC	ANH ± CC	CALCITE	CHL ± CC	SMECTITE	WAIR ± CC, EP, QTZ	EP + CC	EPIDOTE	PREHNITE	KF + QTZ	ACT + QTZ	TALC	
160															MAGN → HEM, GLASSY
200															SOME SMECTITE
300															BIO → SMECT
400															SMECT, ZEOLITES IN AMYGDULES, MAGN → HEM
600															CC-FILLED AMYGDULES, HEM
800					✓										ZEOLITE, CC, SMECT-FILLED AMYGDULES
1000		✓			✓	✓									FIRST PY, CHL
1100	✓	✓ LEUC	✓		✓	✓			• ✓ QTZ						• FIRST EP BOILING ASSEMBLAGE?
1200	✓	✓	✓			✓		✓ CC							MAGN → HEM QTZ + WAIR IN AMYGDULES
1300	✓	✓	✓		✓	✓		✓	✓	✓					EP + CHL + PY, LEUCOXENE
1400		✓	✓					✓							MUCH DK. GREEN SMECTITE, TR CHALCOPYRITE
1460	✓		✓		✓		✓ QTZ			✓					PLAG → EP + CHL, LEUCOXENE,
1500	✓				✓			✓ EP QTZ							SILICIFIED, BIG WAIR VEINS
1600	✓	✓	✓		✓					✓					EP IN MICRODIABASE SILICIFIED RHYODACITE
1710	✓									✓					"
1800	✓	✓								✓ CHL					" LEUCOXENE
1890	✓	✓			✓			✓ EP CC PY		✓					SOME SERICITE
2000		✓				✓				✓ QTZ			✓ EP	✓	FIRST ACTINOLITE, TALC MUCH SMECTITE
2100	✓						✓ QTZ	✓	✓			✓			
2200					✓		✓		✓	✓		✓	✓ ACT		ACT + QTZ + SMECTITE FIRST PREHNITE
2300	✓ CHL	✓	• ✓ EP							✓ QTZ	✓	✓		✓	• BOILING ASSEMBLAGE? / KF FLOODING?
2370				• ✓ EP		✓		✓		✓	✓ EP	✓ EP			INTENSELY MINERALIZED, PANH + GYPSUM HEM
2400	✓									✓ QTZ		✓ ACT	✓ EP		KF + QTZ + ACT + EP VEINS KF FLOODING
2450				✓ EP		✓				✓ QTZ	✓ EP	✓			MINERALIZED, HEM, LEUCOXENE
2500		✓			✓				✓	✓ QTZ	✓ EP	✓	✓ EP		KF FLOODING
2560						✓				✓ QTZ	✓ EP		✓		LOTS OF ACTINOLITE + CHL IN DIABASE, SOME SERICITE, TR. GARNET + PREHN + EP
* 2600	✓					✓				✓ QTZ	✓ EP	✓ EP PREH			HEM + LEUCOXENE KF FLOODING, MINERALIZED

* dup' of 2452'

WELL 13
MEDICINE LAKE

VEINLETS OBSERVED DURING
RECONNAISSANCE PETROGRAPHY

GM 18.02j

WELL Nos. 8, 10, 11
BULK CUTTINGS
(WELL No. 9 ON FOLLOWING PAGE)

MINERALOGY, APPROX. WT.% [ ] (or) RELATIVE ABUNDANCE [✓]

SAMPLE NO.	QUARTZ	CRISTOBALITE	TRIDYMITE	K-FELDSPAR	PLAGIOCLASE	HEMATITE	ILMENITE	PYRITE	ILLITE	SMECTITE	CHLORITE	MIXED-LAYER ILLITE-SMEC.	MIXED-LAYER CHLOR.-SMEC.	CLINOPTILOL.	ANALCIME	NOTES/ OTHER PHASES
No. 8 242-270'		M		M	m					m						
461-487'					M	M				m				m		
633-661'					MM	m				M				m		
825-851'					MM	m	Tr?			M				Tr		
No. 10 300-390'					MM	m				m						
570-630'		M		M	m			*Tr?		Tr						PROBABLY ABUNDANT GLASS
870-930'					M					Tr						"
1170-1230'					M					m						"
1440-1470'	m			Tr	M											"
1710-1740'	M	m		M							Tr?					
1920-1950'	M	m		M												
2200-2230'	M	m		M				m		m						
No. 11 300-350'					MM											
550-600'					MM											
800-850'					MM	Tr?	Tr?			m						
1100-1150'					MM					m						
1450-1500'					MM					m						
1850-1900'					MM					m		Tr?				
																2140-2795 No [illegible]
																[illegible] TD 2795
																No [illegible]
																* OR MARCASITE

MM = PREDOMINANT M = MAJOR m = MINOR Tr = TRACE ? = TENTATIVE IDENTIFICATION

SUMMARY OF X-RAY DIFFRACTION ANALYSIS

UNIVERSITY OF UTAH RESEARCH INSTITUTE, EARTH SCIENCE LABORATORY

27-27, 3000': → ‡ 2.71 Å PEAK (NOT PY. OR MARC.) MAY BE IMPURE HEMATITE
* MAY INCLUDE OTHER AMORPHOUS PHASES SUCH AS OPAL

MINERALOGY, APPROX. WT.% ☐ (or) RELATIVE ABUNDANCE ✓

SAMPLE NO.	QUARTZ	CRISTOBAL.	TRIDYMITE	K-FELDSP.	PLAGIOCL.	ILMENITE	HEMATITE	MAGNET.	SMECTITE	ILLITE &/OR MICA	CHLORITE	KAOLIN OR SERPENTINE	CALCITE	GLASS *	OTHER PHASES POSSIBLY PRESENT IN TRACE TO MINOR AM'TS.
WELL 14-23															
444'	<m				MM	<m		<m?						m?	CPX, OPX, AP
816'					M	<m								M	AP, GOE
1462'					MM			<m?	m					m?	AP
1903'		m			m									MM	
2325'	<m	m?	m	M	m				<m						
2599'					MM		<m?	<m?	M						AP
2998'					MM			<m?	<m					m?	AP
WELL 18-34															
583'					MM	<m								m?	AP, OLV
1289'														MM	
1983'	m	M	m	M			<m		<m	<m?					
2507'		M		M	m									m?	
2932'					MM	<m	<m		m					m?	AP
3498'					MM	<m	<m?		m					m?	OPX, AP
WELL 27-27															
619'					MM									m?	CPX, AP
1266'					MM		<m?							m?	AP, OLV
1635'					M									M	OLV
2145'					MM	<m	<m?							m?	CPX, AP, OLV
2543'					MM	<m	<m?	<m?						m?	CPX, AP, OLV
3000'					MM		m?‡		<m					m?	AP, OLV

MM = PREDOMINANT M = MAJOR m = MINOR <m = <5WT.% ? = TENTATIVE IDENTIFICATION

SUMMARY OF X-RAY DIFFRACTION ANALYSIS

UNIVERSITY OF UTAH RESEARCH INSTITUTE, EARTH SCIENCE LABORATORY

WELL No. 9
BULK CUTTINGS

MINERALOGY, APPROX. WT.% ☐ (or) RELATIVE ABUNDANCE ✓

SAMPLE NO.	QUARTZ	CRISTOBALITE	TRIDYMITE	K-FELDSPAR	PLAGIOCLASE	HEMATITE	ILMENITE	PYRITE	ILLITE	SMECTITE	CHLORITE	MIXED-LAYER ILLITE-SMEC.	MIXED-LAYER CHLOR.-SMEC.	CLINOPTILOL.	ANALCIME	NOTES/ OTHER PHASES
270-330'					MM	TR	TR			TR						
420-470'				TR?	MM	TR	TR			TR						
720-780'		M	TR	M						TR						
960-1020'					MM		TR			TR						
1260-1380'					MM					m				m	m	
1770-1860'					MM		TR			m						
2280-2300'					MM					m						
2620-2680'					MM	TR				m						
3040-3100'					MM	m	TR			m						
3400-3460'	M			m?	MM			♯TR?		TR	m					
3460-3670'	m				MM					m			m			
3940-3990'	m				MM		TR			m	TR*					♯ OR MARCASITE * OR KAOLINITE

MM = PREDOMINANT M = MAJOR m = MINOR Tr = TRACE ? = TENTATIVE IDENTIFICATION

17-6 IF-6

SUMMARY OF X-RAY DIFFRACTION ANALYSIS

UNIVERSITY OF UTAH RESEARCH INSTITUTE, EARTH SCIENCE LABORATORY

WELL Nos. 12 & 13
BULK CUTTINGS

MINERALOGY, APPROX. WT.% [ ] (or) RELATIVE ABUNDANCE [✓]

SAMPLE NO.	QUARTZ	CRISTOBALITE	TRIDYMITE	K-FELDSPAR	PLAGIOCLASE	HEMATITE	ILMENITE	PYRITE	ILLITE OR MICA	SMECTITE	MIXED-LAYER ILLITE-SMEC.	MIXED-LAYER CHLOR.-SMEC.	STILBITE	OTHER PHASES/NOTES
WELL No. 12														
450-500'					MM									
750-800'					MM	m								
1050-1100'					MM		Tr?							
1350-1400'	Tr	M	m	M										
1600-1650'	Tr	M	Tr	M										
1850-1900'		M	m	M					m					
2100-2150'		m	M	M					Tr?					
WELL No. 13														
304-336'					M									PROBABLY ABUNDANT GLASS
564-605'					MM									
829-863'		M		M	M									
1178-1208'					MM					Tr				
1419-1448'					M	m				M			m	
1588-1617'		M		M						m				

MM = PREDOMINANT M = MAJOR m = MINOR Tr = TRACE ? = TENTATIVE IDENTIFICATION

SUMMARY OF X-RAY DIFFRACTION ANALYSIS

UNIVERSITY OF UTAH RESEARCH INSTITUTE, EARTH SCIENCE LABORATORY

R. T. GUNDERSON

AUG 15 1985

MINERALOGY, APPROX. WT.% [ ] (or) RELATIVE ABUNDANCE [✓]

SAMPLE NO.	QUARTZ	CRISTOBAL.	TRIDYMITE	K-FELDSP.	PLAGIOCL.	OLIVINE	CLINOPYROXENE	ORTHOPYROXENE	ILMENITE	HEMATITE	APATITE	SMECTITE	ILLITE &/OR MICA	CHLORITE	GOETHITE	GLASS *	MAGNETITE
14-23																	
444'	<m				MM		<m?	<m??	<m		<m?					m?	<m?
816'					M				<m		<m?				<m?	M	
1462'					MM						<m?	m				m?	<m?
1903'		m			m											MM	
2325'	<m	m?	m	M	m							<m					
2599'					MM				<m?	<m?	M						<m?
2998'					MM					<m?	<m					m?	<m?
18-34				✓					✓		✓	✓			✓		
583'					MM	m			<m	<m?						m?	
1289'							<m?									MM	
1983'	m	M	m	M						<m		<m	<m?				
2507'		M		M	m											m?	
2932'					MM				<m	<m	<m?	m				m?	
3498'					MM			<m??	<m	<m?	<m?	m				m?	
27-27						✓			✓	✓		✓			✓		
619'					MM		<m?				<m?					m?	
1266'					MM	<m				<m?	<m?					m?	
1635'					M	<m										M	
2145'					MM	<m	<m?		<m	<m?	<m?					m?	
2543'					MM	<m	<m?		<m	<m?	<m?					m?	<m?
3000'					MM	<m				‡	<m?	<m				m?	

* NOTE: "GLASS" CATEGORY MAY INCLUDE OTHER AMORPHOUS PHASES IN MINOR AMOUNTS.

‡ NOTE: UNIDENTIFIED 2.71Å PEAK (MINOR); NOT PYRITE OR MARCASITE; POSSIBLY IMPURE HEMATITE

MM = PREDOMINANT M = MAJOR m = MINOR <m = <5 WT. % ? = TENTATIVE IDENTIFICATION

SUMMARY OF X-RAY DIFFRACTION ANALYSIS

UNIVERSITY OF UTAH RESEARCH INSTITUTE, EARTH SCIENCE LABORATORY

08/08

RICHARD —

HERE ARE THE RESULTS FOR THE FIRST FIVE DRILL HOLES — THE REST SHOULD BE FINISHED WITHIN A WEEK.

JEFF HULEN

* MAY INCLUDE OTHER AMORPHOUS PHASES SUCH AS OPAL.

SAMPLE NO.	MINERALOGY, APPROX. WT.% ☐ (or) RELATIVE ABUNDANCE ✓																						
	QUARTZ	CRISTOBAL.	TRIDYMITE	K-FELDSP.	PLAGIOCL.	ILMENITE	HEMATITE	MAGNETITE	SMECTITE	ILLITE &/OR MICA	CHLORITE	KAOLIN &/OR SERPENTINE	CALCITE	GLASS *	ANALCIME OR WAIRAKITE	CLINOPTILOL.	OPAL-CT						OTHER PHASES POSSIBLY PRESENT IN TRACE TO MINOR AM'TS.
WELL 62-21					✓		✓		✓				✓	✓		✓							
530'					MM	<m	<m		<m					m?									CPX, OPX, AP
1035'					MM		<m		M					m?		<m	<m?						
1700'					MM				M				<m	m?									CPX, AP
1973'					MM		<m	<m?	M				<m?	m?		<m							CPX, AP
2132'					MM	<m?	<m		M					m?									CPX, AP
WELL 68-16				✓					✓	✓				✓									
508'		M		MM	m		<m																
1039'		M		MM	m		<m		<m?														
1338'					m									MM									
1740'					M				<m					M									CPX,
1857'					m				<m	<m?				MM									
2227'					MM		<m?		m					m?									CPX, AP
2599'		MM	m	M			<m																
2936'		MM		M			<m		<m														
WELL 86-23					✓		✓		✓				✓	✓	✓								
694'					MM		<m		<m					m?									CPX, AP
1085'					MM		<m		<m					m?									CPX, OPX, AP
1554'					MM		m		m					m?									CPX, AP
2258'					MM		<m		<m					m?									CPX, AP
3157'					MM		<m		M					m?									CPX, OPX, AP
3497'					M				M					m?	<m								CPX, AP

MM = PREDOMINANT M = MAJOR m = MINOR <m = <5 WT.% ? = TENTATIVE IDENTIFICATION

SUMMARY OF X-RAY DIFFRACTION ANALYSIS

UNIVERSITY OF UTAH RESEARCH INSTITUTE, EARTH SCIENCE LABORATORY

* MAY INCLUDE OTHER AMORPHOUS PHASES SUCH AS OPAL

MINERALOGY, APPROX. WT.% ☐ (or) RELATIVE ABUNDANCE ✓

SAMPLE NO.	QUARTZ	CRISTOBAL.	TRIDYMITE	K-FELDSP.	PLAGIOCL.	ILMENITE	HEMATITE	MAGNET.	SMECTITE	ILLITE & OR MICA	CHLORITE	KAOLIN OR SERPENTINE	CALCITE	GLASS*	PYRITE									OTHER PHASES POSSIBLY PRESENT IN TRACE TO MINOR AM'TS.
WELL 45-36																								
100'					MM	<m	<m							m?										CPX, OPX, AP
480'	m	M	m	MM					<m															
1000'					MM		<m		m					m?										CPX, OPX, AP
1470'					MM	<m	<m		m					m?										CPX, OPX, AP
1860'					MM	<m	m		M					m?										AP
2390'					MM	<m	<m		M			<m		m?										AP
2780'	M			M	m		<m?			<m					<m									
3100'	M			M	M		<m?			<m														NOTE: PLAGIOCLASE IS PROBABLY ALBITE
3600'	m				MM	<m?			M					m?										CPX, AP
4000'	m			m	MM			<m			m			m?										AMPH
WELL 57-13	✓			✓			✓		✓	✓				✓										
781'					<m									MM										CPX
1423'					m									MM										
1637'					<m									MM										
2079'	m	<m	M	MM			<m		<m	<m														
2426'									<m					MM										
2929'					MM				M					m?										CPX

MM = PREDOMINANT M = MAJOR m = MINOR <m = <5 WT.% ? = TENTATIVE IDENTIFICATION

SUMMARY OF X-RAY DIFFRACTION ANALYSIS

UNIVERSITY OF UTAH RESEARCH INSTITUTE , EARTH SCIENCE LABORATORY

R. P. GUNDERSON

AUG 1 5 1985

MINERALOGY, APPROX. WT.% ☐ (or) RELATIVE ABUNDANCE ☑

SAMPLE NO.	QUARTZ	CRISTOBALITE	TRIDYMITE	K-FELDSP.	PLAGIOCL.	OLIVINE	CLINOPYROXENE	ORTHOPYROXENE	ILMENITE	HEMATITE	MAGNETITE	APATITE	SMECTITE	ILLITE MICA	CHLORITE	CALCITE	GLASS *	WAIRAKITE OR ANALCIME	SERPENTINE	PYRITE	AMPHIBOLE	
28-32																						
440'		M	m	MM	<m?					<m												
860'	m	M	m	MM									<m									
1280'		M		M	m								<m									
1500'	m	M		M	m								<m?	<m								
1950'	<m?			<m?	MM		<m?			M		<m?	<m				m?					
2480'		M		M						<m?			m									
2950'	M			MM						<m												
3532'	m			<m?	MM				<m	<m	<m?	<m?	M				m?		<m?			← NOTE: SERPENTINE POSSIBLY ± KAOLIN (DISORDERED)
3968'	M			m?	M					m					m	<m						
4500'	m			m?	M									<m	M	<m		<m		m		
29-1																						
467'					MM							<m?					M					
1297'		M	m	MM									<m									
1951		m	M	MM									<m									
2375'											<m	<m					MM					
2803	<m?			<m?	MM				<m?		<m?	<m?	M				m?				<m?	
3088'					MM		<m?	<m?			<m?	<m?	m				m?					

* NOTE: "GLASS" CATEGORY MAY INCLUDE OTHER AMORPHOUS PHASES IN MINOR AMOUNTS.

MM = PREDOMINANT M = MAJOR m = MINOR <m = <5 WT. % ? = TENTATIVE IDENTIFICATION

SUMMARY OF X-RAY DIFFRACTION ANALYSIS

UNIVERSITY OF UTAH RESEARCH INSTITUTE, EARTH SCIENCE LABORATORY

R. P. GUNDERSON

AUG 15 1985

MINERALOGY, APPROX. WT.% [ ] (or) RELATIVE ABUNDANCE [✓]

SAMPLE NO.	QUARTZ	CRISTOBAL.	TRIDYMITE	K-FELDSP.	PLAGIOCL.	OLIVINE	CLINOPYROXENE	ORTHOPYROXENE	ILMENITE	HEMATITE	APATITE	SMECTITE	ILLITE &/OR MICA	CHLORITE	GOETHITE	GLASS *	MAGNETITE
14-23	✓	✓	✓	✓	✓				✓			✓				✓	✓
444'	<m				MM		<m?	<m??	<m		<m?					m?	<m?
816'					M				<m		<m?				<m?	M	
1462'					MM						<m?	m				m?	<m?
1903'		m			m											MM	
2325'	<m	m?	m	M	m							<m					
2599'					MM					<m?	<m?	M					<m?
2998'					MM						<m?	<m				m?	<m?
18-34	✓	✓		✓	✓				✓			✓	✓			✓	
583'					MM	m			<m		<m?					m?	
1289'							<m?									MM	
1983'	m	M	m	M						<m		<m	<m?				
2507'		M		M	m											m?	
2932'					MM				<m	<m	<m?	m				m?	
3498'					MM			<m??	<m	<m?	<m?	m				m?	
27-27					✓	✓			✓	✓		✓				✓	
619'					MM		<m?				<m?					m?	
1266'					MM	<m				<m?	<m?					m?	
1635'					M	<m										M	
2145'					MM	<m	<m?		<m	<m?	<m?					m?	
2543'					MM	<m	<m?		<m	<m?	<m?					m?	<m?
3000'					MM	<m				±	<m?	<m				m?	

* NOTE: "GLASS" CATEGORY MAY INCLUDE OTHER AMORPHOUS PHASES IN MINOR AMOUNTS.

± NOTE: UNIDENTIFIED 2.71A PEAK (MINOR); NOT PYRITE OR MARCASITE; POSSIBLY IMPURE HEMATITE

MM = PREDOMINANT M = MAJOR m = MINOR <m = <5 WT. % ? = TENTATIVE IDENTIFICATION

SUMMARY OF X-RAY DIFFRACTION ANALYSIS

UNIVERSITY OF UTAH RESEARCH INSTITUTE, EARTH SCIENCE LABORATORY

WELL Nos. 6 & 7
BULK CUTTINGS

MINERALOGY, APPROX. WT.% ☐ (or) RELATIVE ABUNDANCE ✓

SAMPLE NO.	QUARTZ	CRISTOBALITE	TRIDYMITE	K-FELDSPAR	PLAGIOCLASE	HEMATITE	ILMENITE	PYRITE	ILLITE	SMECTITE	CHLORITE OR KAOLINITE	MIXED-LAYER CHLOR.-SMEC.	MIXED-LAYER ILLITE-SMEC.	NOTES/OTHER PHASES
WELL No. 6														
350-400'					MM	Tr?								
600-650'					MM			Tr?						
800-850'					MM	m	Tr							
1050-1100'					MM	Tr?	Tr			m				
1450-1500'	m			Tr?	m					m				ABUNDANT GLASS
1750-1800'	Tr				MM					m				
1950-2000'					MM					m				
(2-81)														
WELL No. 7														
700-730'	Tr		m	m?	MM					Tr				

MM = PREDOMINANT M = MAJOR m = MINOR Tr = TRACE ? = TENTATIVE IDENTIFICATION

SUMMARY OF X-RAY DIFFRACTION ANALYSIS

UNIVERSITY OF UTAH RESEARCH INSTITUTE, EARTH SCIENCE LABORATORY

* MAY INCLUDE OTHER AMORPHOUS PHASES SUCH AS OPAL

SAMPLE NO.	MINERALOGY, APPROX. WT.% ☐ (or) RELATIVE ABUNDANCE ✓																							OTHER PHASES POSSIBLY PRESENT IN TRACE TO MINOR AM'TS.
	QUARTZ	CRISTOBAL.	TRIDYMITE	K-FELDSP.	PLAGIOCL.	ILMENITE	HEMATITE	MAGNET.	SMECTITE	ILLITE & / OR MICA	CHLORITE	KAOLIN OR SERPENTINE	CALCITE	GLASS *	PYRITE									
WELL 45-36																								
100'					MM	<m	<m							m?										CPX, OPX, AP
480'	m	M	m	MM					<m															
1000'					MM		<m		m					m?										CPX, OPX, AP
1470'					MM	<m	<m		m					m?										CPX, OPX, AP
1860'					MM	<m	m		M					m?										AP
2390'					MM	<m	<m		M			<m		m?										AP
2780'	M			M	m		<m?				<m				<m									
3100'	M			M	M		<m?				<m													NOTE: PLAGIOCLASE IS PROBABLY ALBITE
3600'	m				MM	<m?			M					m?										CPX, AP
4000'	m			m	MM			<m			m			m?										AMPH
WELL 57-13							✓																	
781'					<m									MM										CPX
1423'					m									MM										
1637'					<m									MM										
2079'	m	<m	M	MM			<m		<m	<m														
2426'									<m					MM										
2929'					MM				M					m?										CPX

MM = PREDOMINANT M = MAJOR m = MINOR <m = <5 WT.% ? = TENTATIVE IDENTIFICATION

SUMMARY OF X-RAY DIFFRACTION ANALYSIS

UNIVERSITY OF UTAH RESEARCH INSTITUTE, EARTH SCIENCE LABORATORY

R. P. GUNDERSON

AUG 15 1985

MINERALOGY, APPROX. WT.% ☐ (or) RELATIVE ABUNDANCE ✓

SAMPLE NO.	QUARTZ	CRISTOBAL.	TRIDYMITE	K-FELDSP.	PLAGIOCL.	OLIVINE	CLINOPYROXENE	ORTHOPYROXENE	ILMENITE	HEMATITE	APATITE	SMECTITE	ILLITE &/OR MICA	CHLORITE	GOETHITE	GLASS *	MAGNETITE
14-23	✓	✓	✓	✓	✓					✓		✓				✓	✓
444'	<m				MM		<m?	<m??	<m		<m?					m?	<m?
816'					M				<m		<m?				<m?	M	
1462'					MM						<m?	m				m?	<m?
1903'		m			m											MM	
2325'	<m	m?	m	M	m							<m					
2599'					MM					<m?	<m?	M					<m?
2998'					MM						<m?	<m				m?	<m?
18-34	✓	✓		✓	✓					✓		✓	✓			✓	
583'					MM	m			<m		<m?					m?	
1289'							<m?									MM	
1983'	m	M	m	M						<m		<m	<m?				
2507'		M		M	m											m?	
2932'					MM				<m	<m	<m?	m				m?	
3498'					MM			<m??	<m	<m?	<m?	m				m?	
27-27					✓	✓			✓	✓		✓				✓	
619'					MM		<m?				<m?					m?	
1266'					MM	<m				<m?	<m?					m?	
1635'					M	<m										M	
2145'					MM	<m	<m?		<m	<m?	<m?					m?	
2543'					MM	<m	<m?		<m	<m?	<m?					m?	<m?
3000'					MM	<m				±	<m?	<m				m?	

* NOTE: "GLASS" CATEGORY MAY INCLUDE OTHER AMORPHOUS PHASES IN MINOR AMOUNTS.

± NOTE: UNIDENTIFIED 2.71Å PEAK (MINOR); NOT PYRITE OR MARCASITE; POSSIBLY IMPURE HEMATITE

MM = PREDOMINANT M = MAJOR m = MINOR <m = <5 WT. % ? = TENTATIVE IDENTIFICATION

SUMMARY OF X-RAY DIFFRACTION ANALYSIS

UNIVERSITY OF UTAH RESEARCH INSTITUTE, EARTH SCIENCE LABORATORY

ML 36-28

WELL No. 1
BULK CUTTINGS AND CLAY FRACTIONS (< 5μ)

ML 36-28

MINERALOGY, APPROX. WT.% [ ] (or) RELATIVE ABUNDANCE [✓]

SAMPLE NO.	QUARTZ	CRISTOBALITE	TRIDYMITE	K-FELDSPAR	PLAGIOCLASE	HEMATITE	ILMENITE	PYRITE OR MARCASITE	GOETHITE	ILLITE	SMECTITE	CHLORITE OR KAOLINITE	MIXED-LAYER CHLORITE-SMEC.	MIXED-LAYER ILLITE-SMEC.	MORDENITE						
353-401' BULK					MM		TR?		TR?	m											
CLAY					M				m	m	m										
550-600' BULK					MM		TR?	TR?													
CLAY					M						m										
850-900' BULK					MM		TR	TR?													
CLAY					M						m										
1150-1200' BULK					MM			TR?	TR?		TR										
CLAY					M						m										
1500-1550' BULK					MM			TR?	TR?		m										
CLAY					M				TR?		M										
1900-1950' BULK		m	m?	m?						TR?	m		TR?		M						
CLAY		m	m?	m?						m	M		m		M						
2100-2150' BULK	M	M		M		m?		TR?			TR										
CLAY	m	M		M		m?					m										

SUSPECT GLASS
ALL PROB. KF PKS. OVERLAPPED BY MORD. PKS.

Quartz at 2084'

MM = PREDOMINANT M = MAJOR m = MINOR Tr = TRACE ? = TENTATIVE IDENTIFICATION

TABLE 1.

WELL No. 1

SUMMARY OF X-RAY DIFFRACTION ANALYSIS

UNIVERSITY OF UTAH RESEARCH INSTITUTE, EARTH SCIENCE LABORATORY

R. P. GUNDERSON

AUG 1 5 1985

MINERALOGY, APPROX. WT.% [ ] (or) RELATIVE ABUNDANCE [✓]

SAMPLE NO.	QUARTZ	CRISTOBALITE	TRIDYMITE	K-FELDSP.	PLAGIOCL.	OLIVINE	CLINOPYROXENE	ORTHOPYROXENE	ILMENITE	HEMATITE	MAGNETITE	APATITE	SMECTITE	ILLITE &/OR MICA	CHLORITE	CALCITE	GLASS *	WAIRAKITE OR ANALCIME	SERPENTINE	PYRITE	AMPHIBOLE	
28-32																						
440'		M	m	MM	<m?					<m												
860'	m	M	m	MM									<m									
1280'		M		M	m								<m									
1500'	m	M		M	m								<m?	<m								
1950'	<m?			<m?	MM		<m?			M		<m?	<m				m?					
2480'		M		M						<m?			m									
2950'	M			MM						<m												
3532'	m			<m?	MM				<m	<m	<m?	<m?	M				m?		<m?			← NOTE: SERPENTINE POSSIBLY ± KAOLIN (DISORDERED)
3968'	M			m?	M					m					m	<m						
4500'	m			m?	M									<m	M	<m		<m		m		
29-1																						
467'					MM							<m?					M					
1297'		M	m	MM									<m									
1951		m	M	MM									<m									
2375'											<m	<m					MM					
2803	<m?			<m?	MM			<m?		<m?	<m?	M					m?			<m?		
3088'					MM		<m?	<m?			<m?	<m?	m				m?					

* NOTE: "GLASS" CATEGORY MAY INCLUDE OTHER AMORPHOUS PHASES IN MINOR AMOUNTS.

MM = PREDOMINANT M = MAJOR m = MINOR <m = <5 WT. % ? = TENTATIVE IDENTIFICATION

SUMMARY OF X-RAY DIFFRACTION ANALYSIS

UNIVERSITY OF UTAH RESEARCH INSTITUTE, EARTH SCIENCE LABORATORY

mc 51-2

WELL No. 3
BULK CUTTINGS

MINERALOGY, APPROX. WT.% ☐ (or) RELATIVE ABUNDANCE ☑

SAMPLE NO.	QUARTZ	CRISTOBALITE	TRIDYMITE	K-FELDSPAR	PLAGIOCLASE	HEMATITE	ILMENITE	PYRITE OR MARCASITE	ILLITE	SMECTITE	CHLORITE OR KAOLINITE	MIXED-LAYER CHLORITE-SMEC.	MIXED-LAYER ILLITE-SMEC.	NOTES/OTHER PHASES
150-200′	TR	M	TR		M									
500-550′	TR	M	M		M									
750-800′		M	TR		M									PROBABLY ABUNDANT GLASS
900-950′	m					MM					M			
1150-1200′						MM		–	TR?					
1500-1550′						MM		TR?	TR?					
1800-1840′						MM		TR?	TR?					no glass

MM = PREDOMINANT M = MAJOR m = MINOR Tr = TRACE ? = TENTATIVE IDENTIFICATION

TABLE 3

WELL No. 3

SUMMARY OF X-RAY DIFFRACTION ANALYSIS

UNIVERSITY OF UTAH RESEARCH INSTITUTE , EARTH SCIENCE LABORATORY

ML 52-30

WELL No. 4
BULK CUTTINGS

ML 52-30

MINERALOGY, APPROX. WT.% [ ] (or) RELATIVE ABUNDANCE [✓]

SAMPLE NO.	QUARTZ	CRISTOBALITE	TRIDYMITE	K-FELDSPAR	PLAGIOCLASE	HEMATITE	ILMENITE	PYRITE OR MARCASITE	ILLITE	SMECTITE	CHLORITE OR KAOLINITE	MIXED-LAYER CHLORITE-SMEC.	MIXED-LAYER ILLITE-SMEC.	NOTES/ OTHER PHASES
250-300'					MM		m				TR	TR		
500-550'					M									PROBABLY ABUNDANT GLASS
800-850'		M		m	M		TR?							
1100-1150'					MM						m			
1450-1500'	TR	M	TR	M	M						m			
1700-1750'		M	TR	M	TR?						TR?			
1900-1950'	TR	M	m	M										qtz, [illegible]

MM = PREDOMINANT M = MAJOR m = MINOR Tr = TRACE ? = TENTATIVE IDENTIFICATION

TABLE 4.

WELL No. 4

SUMMARY OF X-RAY DIFFRACTION ANALYSIS

UNIVERSITY OF UTAH RESEARCH INSTITUTE, EARTH SCIENCE LABORATORY

* MAY INCLUDE OTHER AMORPHOUS PHASES SUCH AS OPAL.

MINERALOGY, APPROX. WT.% ☐ (or) RELATIVE ABUNDANCE ✓

SAMPLE NO.	QUARTZ	CRISTOBAL.	TRIDYMITE	K-FELDSP.	PLAGIOCL.	ILMENITE	HEMATITE	MAGNETITE	SMECTITE	ILLITE &/OR MICA	CHLORITE	KAOLIN &/OR SERPENTINE	CALCITE	GLASS *	ANALCIME OR WAIRAKITE	CLINOPTILOL.	OPAL-CT	OTHER PHASES POSSIBLY PRESENT IN TRACE TO MINOR AM'TS.
WELL 62-21																		
530'					MM	<m	<m		<m					m?				CPX, OPX, AP
1035'					MM		<m		M					m?		<m	<m?	
1700'					MM				M				<m	m?				CPX, AP
1973'					MM		<m	<m?	M				<m?	m?		<m		CPX, AP
2132'					MM	<m?	<m		M					m?				CPX, AP
WELL 68-16																		
508'		M		MM	m		<m											
1039'		M		MM	m		<m		<m?									
1338'					m									MM				
1740'					M				<m					M				CPX,
1857'					m				<m	<m?				MM				
2227'					MM		<m?		m					m?				CPX, AP
2599'		MM	m	M			<m											
2936'		MM		M			<m		<m									
WELL 86-23																		
694'					MM		<m		<m					m?				CPX, AP
1085'					MM		<m		<m					m?				CPX, OPX, AP
1554'					MM		m		m					m?				CPX, AP
2258'					MM		<m		<m					m?				CPX, AP
3157'					MM		<m		M					m?				CPX, OPX, AP
3497'					M				M					m?	<m			CPX, AP

MM = PREDOMINANT M = MAJOR m = MINOR <m = <5 WT.% ? = TENTATIVE IDENTIFICATION

SUMMARY OF X-RAY DIFFRACTION ANALYSIS

UNIVERSITY OF UTAH RESEARCH INSTITUTE, EARTH SCIENCE LABORATORY

ML 54-19

WELL No. 5
BULK CUTTINGS

ML-54-19

MINERALOGY, APPROX. WT.% [ ] (or) RELATIVE ABUNDANCE [✓]

SAMPLE NO.	QUARTZ	CRISTOBALITE	TRIDYMITE	K-FELDSPAR	PLAGIOCLASE	HEMATITE	ILMENITE	PYRITE OR MARCASITE	ILLITE	SMECTITE	CHLORITE OR KAOLINITE	MIXED-LAYER CHLORITE-SMEC.	MIXED-LAYER ILLITE-SMECTITE	NOTES/OTHER PHASES
150-200′					MM			Tr?						
500-550′					MM									
850-900′					MM	m?								
1300-1350′					MM	m								ALSO UNKNOWN 7.44Å PHASE → PROBABLE ABUNDANT GLASS
1500-1550′					MM	Tr?				Tr?				
1550-1600′					MM			Tr?						
1900-1950′					MM			Tr?		m				
2150-2200′					MM					m				no gb

MM = PREDOMINANT M = MAJOR m = MINOR Tr = TRACE ? = TENTATIVE IDENTIFICATION

TABLE 5

WELL No. 5

SUMMARY OF X-RAY DIFFRACTION ANALYSIS

UNIVERSITY OF UTAH RESEARCH INSTITUTE, EARTH SCIENCE LABORATORY

GMF 56-3

WELL No. 2
BULK CUTTINGS

MINERALOGY, APPROX. WT.% [ ] (or) RELATIVE ABUNDANCE [✓]

SAMPLE NO.	QUARTZ	CRISTOBALITE	TRIDYMITE	K-FELDSPAR	PLAGIOCLASE	HEMATITE	ILMENITE	PYRITE OR MARCASITE	GOETHITE	ILLITE	SMECTITE	CHLORITE OR KAOLINITE	MIXED-LAYER CHLOR.-SMEC.	MIXED-LAYER ILLITE-SMEC.	CLINOPTILOLITE	ANALCIME OR WAIRAKITE	CALCITE	Qtz.
205-301'					MM		TR?	TR?	TR?		m							
506-562'					MM			TR?			M				m			
787-886'					MM			TR?			m							
1110-1145'	m				MM	?		m?			M	m			TR?			1031 + Ca [illegible] 1058 [illegible]
1426-1459'	m				MM	?		m?					m			m	m	
1727-1760'	m				MM	m							m			m		

1055 [illegible]
1113' - calcite

MM = PREDOMINANT M = MAJOR m = MINOR Tr = TRACE ? = TENTATIVE IDENTIFICATION

TABLE 2.

WELL No. 2

SUMMARY OF X-RAY DIFFRACTION ANALYSIS

UNIVERSITY OF UTAH RESEARCH INSTITUTE , EARTH SCIENCE LABORATORY

* MAY INCLUDE OTHER AMORPHOUS PHASES SUCH AS OPAL.

MINERALOGY, APPROX. WT.% ☐ (or) RELATIVE ABUNDANCE ☑

SAMPLE NO.	QUARTZ	CRISTOBAL.	TRIDYMITE	K-FELDSP.	PLAGIOCL.	ILMENITE	HEMATITE	MAGNETITE	SMECTITE	ILLITE &/OR MICA	CHLORITE	KAOLIN &/OR SERPENTINE	CALCITE	GLASS *	ANALCIME OR WAIRAKITE	CLINOPTILOL.	OPAL-CT						OTHER PHASES POSSIBLY PRESENT IN TRACE TO MINOR AM'TS.
WELL 62-21																							
530'					MM	<m	<m		<m					m?									
1035'					MM		<m		M					m?		<m	<m?						CPX, OPX, AP
1700'					MM				M				<m	m?									
1973'					MM		<m	<m?	M				<m?	m?		<m							CPX, AP
2132'					MM	<m?	<m		M					m?									CPX, AP
																							CPX, AP
WELL 68-16																							
508'		M		MM	m		<m																
1039'		M		MM	m		<m		<m?														
1338'					m									MM									
1740'					M				<m					M									CPX,
1857'					m				<m	<m?				MM									
2227'					MM		<m?		m					m?									CPX, AP
2599'		MM	m	M			<m																
2936'		MM		M			<m		<m														
WELL 86-23																							
694'					MM		<m		<m					m?									CPX, AP
1085'					MM		<m		<m					m?									CPX, OPX, AP
1554'					MM		m		m					m?									CPX, AP
2258'					MM		<m		<m					m?									CPX, AP
3157'					MM		<m		M					m?									CPX, OPX, AP
3497'					M				M					m?	<m								CPX, AP

MM = PREDOMINANT M = MAJOR m = MINOR <m = <5 WT.% ? = TENTATIVE IDENTIFICATION

SUMMARY OF X-RAY DIFFRACTION ANALYSIS

UNIVERSITY OF UTAH RESEARCH INSTITUTE, EARTH SCIENCE LABORATORY

for: Unocal Geothermal Division, Unocal Corporation -- Daniel Carrier

16 Cuttings Samples
Bulk XRD

MINERALOGY, APPROX. WT.% [X] (or) RELATIVE ABUNDANCE [ ]

DAN CARRIER

JAN 20 1988

SAMPLE NO.	QUARTZ	PLAGIOCL.	K-FELDSP.	CALCITE	CLINOPYROXN.	ACTINOLITE *	HORNBLENDE	EPIDOTE	PREHNITE	ANHYDRITE	ILMENITE &/OR MAGNETITE	HEMATITE	PYRITE	SPHENE/ LEUCOXENE	WAIRAKITE	SMECTITE	MIXED-LAYER CHLOR./SMEC.	ILLITE AND PHENGITE	BIOTITE	CHLORITE	TALC	
7200 6-1	14	51		TR	3	2	3	1		TR	2	TR	2	TR		1		2	16	3	TR	
7210 6-2	42	30	22					TR			TR			TR				4	TR?	2		
6-3	45	21	16		TR	2		1		TR	TR	TR	TR	1		TR		11	TR?	3		
6-4	4	50	3	2	7	3		6			5	TR	TR	8		TR		1		11		
6-5	11	45	11		3	2		7			1	TR	TR	8						12		
6-6	11	42	9		1?	3		7	1		1		1	9		2				13		
6-7	19	38	10	TR	1?	2		5	2		1		1	8				TR		13		TR. UNKNOWN HIGH N HIGH RELIEF, LOW BIREFRINGENCE MINERAL
6-8	32	40	17	TR		1		1			1	TR	TR	TR		1	TR	1	3	1		
8-1	16	33	9	2	10	1		3			2	5		8		TR	TR	5		6		TR UNKNOWN, HIGH N, MOD-HIGH BIREFRINGENT SIM. TO ANHYDRITE *
8-2	11	34	7	TR	13	2		4			2	5	TR	9	1	TR	TR	2		10		
8-3	17	35	11	1	10			2			1	4	TR	6	TR?	TR	TR	3		10		
8-4	13	35	8	1	5			5	TR		1	3	1	8	TR?	TR	TR	3		9	8	
8-5	20	30	5	1	5			4			TR	4	2	8	5	TR	TR	6		10		
8-6	16	35	5	3	5?	1 (OR) 1		TR			2	4	TR	9		TR	‡ SEE CHL.	3		7‡	10	
8-7	7	43		2	15						3	3		8		TR	TR	4		3	12	
8-8	45	29	19								TR	TR		2		1		2		2		

* REPLACES ORIGINAL MAFICS.

‡ INCLUDES MINOR MIXED-LAYER CHLOR/SMEC.

* BLIT W/INCLINED EXTINCTION

MM = PREDOMINANT M = MAJOR m = MINOR Tr = TRACE ? = TENTATIVE IDENTIFICATION

SUMMARY OF X-RAY DIFFRACTION ANALYSIS

UNIVERSITY OF UTAH RESEARCH INSTITUTE , EARTH SCIENCE LABORATORY

for: Unocal Geothermal Division, Unocal Corporation -- Daniel Carrier

16 Cuttings Samples
Clay-Fraction XRD

MINERALOGY, APPROX. WT.% [X] (or) RELATIVE ABUNDANCE [ ]

SAMPLE NO.	SMECTITE	ILLITE & PHENG. UNDIVIDED	CHLORITE	MIXED-LAYER CHLOR/SMEC.	BIOTITE	TALC
6-1	5		8		*83	2
6-2	TR?	70	30			
6-3	2	93	5			
6-4	3	5	92			
6-5			100			
6-6	13		87			
6-7	1	2	97			
6-8	15		10	5	*70	
8-1	8	42	44	6		
8-2	5	15	75	5		
8-3	3	16	72	9		
8-4	1	11	82	6		
8-5	1	49	50	TR?		
8-6	4	11	72	13		
8-7	3	*23	58	16		
8-8	26	41	33			

* INCLUDES MINOR PHENGITE

* PROBABLY INCLUDES SOME GLAUCONITE

MM = PREDOMINANT M = MAJOR m = MINOR Tr = TRACE ? = TENTATIVE IDENTIFICATION

SUMMARY OF X-RAY DIFFRACTION ANALYSIS

UNIVERSITY OF UTAH RESEARCH INSTITUTE , EARTH SCIENCE LABORATORY

Sample No.	Veinlets														
	QTZ	CAL	KF ± QTZ	EP ± Q, KF	ACT ± Q, KF, EP	CHL ± QTZ	*PHENGITE ± ILLITE CHL, QTZ	PREHNITE ± EP, QTZ, KF	WAIRAKITE ± EP, QTZ, KF	LEUCOXENE	BIOTITE				
6-1	✓			✓	✓						✓				CPXN
6-2	✓		*✓			✓									
6-3	✓		*✓	✓	✓ BIE?	✓	✓								ILLITE-PYRITE
6-4	✓	✓		✓		✓									CHLORITE-CALCITE
6-5	✓	✓ TR		✓		✓				✓					CHL-EP-LEUCOXN
6-6	✓	✓ TR	✓	✓	✓	✓		✓							" " WITH PY & KFSP | ACT-Q-CH-EP-PREHN.
6-7	✓	✓	✓?	✓		✓		✓							ONE VNLT. FRAG.: EP + UNKNOWN HIGH RELIEF, HIGH N, LOW BIREF. MINERL. ⊛
6-8															
8-1	✓	✓	✓	✓		✓	✓								CAL-CH-PHENGITE; Q-CAL-ILLITE-CHL
8-2	✓	✓		✓		✓	✓								WAIRAKITE-CHLORITE-LEUCOXENE
8-3	✓	✓		✓		✓	✓								PHENG-CHL-CALCITE
8-4	✓	✓		✓		✓	✓ TR	✓ TR							& CH-EP-LEUC.
8-5	✓	✓		✓		✓	✓		✓						PHENG.-CHL-CHALCEDONY PHENG.-WAIRAKITE
8-6	✓	✓	✓ CAL	✓		✓	✓								CHL-CAL-HEM | CHL-EP-CHL-CAL-QTZ | LEUCOX.
8-7	✓	✓													
8-8	✓		*✓												QTZ-HEMATITE

* PROBABLY MICROPEGMATITIC Q-KFSP INTERGROWTH

⊛ POSSIBLY PREHNITE VIEWED ⊥ TO C AXIS

TR = SCATTERED TRACES

★ PHENGITE = GREEN TO BROWN (TRANSMITTED LIGHT), IRON-RICH ILLITE ANALOGUE.

16 Cuttings Samples: Veinlets Observed During Reconnaissance Petrography

Sample No.	Rock Types: BASALT OR ANDESITE	PORPHYRITIC BASALT OR ANDESITE	MICRODIABASE & MICRODIORITE	QTZ. LATITE OR RHYODACITE	PORPHYRITIC QTZ. LATITE OR RHYODACITE	QUARTZ MICRO- OR MICRO- DIORITE GRANODIORITE	BIOTITE GRANODIORITE	BIOTITE MICRO- GRANODIORITE	HBL-BIT-QTZ-PLAGIOCLASE HORNFELS	INTERMEDIATE COMPOSITION METAVOLCANIC ROCK (?) *	VEIN FRAGMENTS +	GOUGE MICROBRECCIA			NOTES, OTHER
7690/00 6-1									MM	m	m				
7160/70 6-2				MM*							TR				
6820/30 6-3		m	m	MM*							m				m-QTZ-SER. ROCK
5700/00 6-4	M	m	M								m	m			TR-QTZ-CHL-ROCK
5260/70 6-5	M	m	TR	m	m						m	TR			RHYODACITE (?) POST-DATES ANDESITE
4620/80 6-6	MM	m	TR	TR?							m				CHIP OF PERLITE CEMENT
4910/00 6-7	MM	m	TR								m	TR			
3250/0 6-8	TR						MM	m			TR	TR			‡
8-1	M	M	TR	TR		m					m	TR			ALSO TR LOST CIRCULATION MATERIAL
8-2	MM	m	m	m							m				
8-3	M	m		m	M						TR	m			CHALCEDONY CHIP
8-4															"
8-5	M	M	TR		TR?						m				TR-QTZ-SER. ROCK
8-6	MM	m									TR				
8-7	m	MM									TR	m			MICROXLN SER.-QTZ-CHLORITE ROCK
8-8	TR			MM*							TR	TR			

*QUARTZ LATITE. ALL PROBABLY SLIGHT VARIATIONS OF THE SAME ROCK TYPE. PROBABLY INTRUSIVE, PROBABLY INITIALLY GLASSY IN PART. WELL-DEVELOPED SPHERULITIC, GRANOPHYRIC, & MICROPEGMATITIC TEXTURES

‡ ORIGINAL MAFICS IN GRANODIORITE REPLACED BY FINE-CRYSTALLINE, GREEN-BROWN BIOTITE & GREEN ACTINOLITE. BOTH POSSIBLY DELITERIC.

* A FEW FRAGMENTS ARE MODERATELY- TO WELL-FOLIATED, INTERMEDIATE BETWEEN HORNFELS & SCHIST. MAY INCLUDE MINOR INTERMEDIATE-COMPOSITION METAVOLCANIC ROCK

+ MASSIVELY REXLZD, BUT RECOGNIZABLE APPARENT VOLCANIC TEXTURE. ?

16 Cuttings Samples: Rock Types Observed During Reconnaissance Petrography

BULK

Note: 9-CP-[illegible] NOT 9-26 68-8 which will [illegible] of [illegible]

MINERALOGY, APPROX. WT.% [✓] (or) RELATIVE ABUNDANCE [ ]

SAMPLE NO.	QUARTZ	CRISTOBALITE	K-FELDSP.	PLAGIOCLASE	CALCITE	MORDENITE	MAGNETITE	ILMENITE	HEMATITE	PYRITE	CLINOPYROXENE & ORTHOPYROX.	AMPHIBOLE	EPIDOTE	APATITE	SMECTITE	ILLITE ± MICA	CHLORITE	KAOLIN	ANALCIME OR WAIRAKITE	OTHER *
68-400				82			2?	1	1						1					33
68-800				55				1	2		>10?			1?	6					<25
68-1200				58				1	1		>10?			1?	9					<20
68-1600	8	15	40	12		2			1						10		Tr?	Tr?		12
68-1900	17		5	48	1			2	3		>5?				5		2			<12
68-2200	40		32	17					1						3	5	2			
68-3000	14		2	45	7				4		>10?				2	2	6			<8
68-3400	10		1?	46	3				4		>10?				5		3			<18
68-3800	8			48				2	2		>10?			1?	14		7			<8
68-4400	8			48	8			1	4		>10?				3		8			<10
68-4800	14		2	53				2	2		?	2			Tr		5		Tr?	20
68-5000	13		2	48	1				2				3				11			20
68-5200	9			53	1				2				3				9			23
68-5600	11		2	47	3				3				3				4		1?	26
68-6000	11		1	52	3				3				3				5		1?	21
68-6400	12		2	55	4				3			2	3				5		Tr?	14

* INCLUDES AMORPHOUS PHASES, THOSE BELOW DETECTION LIMIT, AND THOSE WHOSE REFLECTIONS ARE MASKED BY PLAGIOCLASE PEAKS. MAY INCLUDE SOME LOST CIRCULATION MATERIAL.

ALEX SCHRIENER
OCT 10 1985

MM = PREDOMINANT M = MAJOR m = MINOR Tr = TRACE ? = TENTATIVE IDENTIFICATION

SUMMARY OF X-RAY DIFFRACTION ANALYSIS

UNIVERSITY OF UTAH RESEARCH INSTITUTE , EARTH SCIENCE LABORATORY

CLAY FRACTION

MINERALOGY, APPROX. WT.% ✓ (or) RELATIVE ABUNDANCE ☐

ALEX SCHRIENER
OCT 10 1985

SAMPLE NO.	SMECTITE	MIXED-LAYER SMECT.-CHLOR. (A)	MIXED-LAYER CHLOR.-SMEC.	CHLORITE	ILLITE	MIXED-LAYER ILLITE-SMEC. (C)	KAOLIN
68-400	100						
68-800	100						
68-1200	97						3
68-1600	95						5
68-1900		40		50	5	5	
68-2200	55			10	35		
68-3000				90	10		
68-3400	37			60	3		
68-3800	65		15 (E)	20			
68-4400	5			95			
68-4800	3			93	4		
68-5000	Tr			98	2		
68-5200				98	2		
68-5600		5		80	15		
68-6000			10 (B)	75	15		
68-6400			5 (E)	80	15		

(A) >75% SMECTITE
(B) 90% CHLORITE
(C) >80% ILLITE
(D) MAY INCLUDE PRIMARY MICA
(E) ~50% CHLORITE

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SUMMARY OF X-RAY DIFFRACTION ANALYSIS

UNIVERSITY OF UTAH RESEARCH INSTITUTE , EARTH SCIENCE LABORATORY

A. F. GUNDERSON

AUG 15 1985

MINERALOGY, APPROX. WT.% ☐ (or) RELATIVE ABUNDANCE ✓

SAMPLE NO.	QUARTZ	CRISTOBALITE	TRIDYMITE	K-FELDSP.	PLAGIOCL.	OLIVINE	CLINOPYROXENE	ORTHOPYROXENE	ILMENITE	HEMATITE	MAGNETITE	APATITE	SMECTITE	ILLITE & OR MICA	CHLORITE	CALCITE	GLASS *	WAIRAKITE OR ANALCIME	SERPENTINE	PYRITE	AMPHIBOLE	
28-32																						
440'		M	m	MM	<m?					<m												
860'	m	M	m	MM									<m									
1280'		M		M	m								<m									
1500'	m	M		M	m								<m?	<m								
1950'	<m?			<m?	MM		<m?			M		<m?	<m				m?					
2480'		M		M						<m?			m									
2950'	M			MM						<m												
3532'	m			<m?	MM				<m	<m	<m?	<m?	M				m?		<m?			← NOTE: SERPENTINE POSSIBLY ± KAOLIN (DISORDERED)
3968'	M			m?	M					m					m	<m						
4500'	m			m?	M									<m	M	<m		<m		m		
29-1																						
467'					MM							<m?					M					
1297'		M	m	MM									<m									
1951		m	M	MM									<m									
2375'											<m	<m					MM					
2803	<m?			<m?	MM				<m?		<m?	<m?	M				m?				<m?	
3088'					MM		<m?	<m?			<m?	<m?	m				m?					

* NOTE: "GLASS" CATEGORY MAY INCLUDE OTHER AMORPHOUS PHASES IN MINOR AMOUNTS.

MM = PREDOMINANT M = MAJOR m = MINOR <m = <5 WT. % ? = TENTATIVE IDENTIFICATION

SUMMARY OF X-RAY DIFFRACTION ANALYSIS

UNIVERSITY OF UTAH RESEARCH INSTITUTE, EARTH SCIENCE LABORATORY

*MAY INCLUDE OTHER AMORPHOUS PHASES SUCH AS OPAL.

MINERALOGY, APPROX. WT.% ☐ (or) RELATIVE ABUNDANCE ✓

SAMPLE NO.	QUARTZ	CRISTOBAL.	TRIDYMITE	K-FELDSP.	PLAGIOCL.	ILMENITE	HEMATITE	MAGNETITE	SMECTITE	ILLITE &/OR MICA	CHLORITE	KAOLIN &/OR SERPENTINE	CALCITE	GLASS *	ANALCIME OR WAIRAKITE	PYRITE	OTHER PHASES POSSIBLY PRESENT IN TRACE TO MINOR AMOUNTS
WELL 28-32																	
440'		M	m	MM	<m?		<m										
860'	m	M	m	MM					<m								
1280'		M		M	m				<m								
1500'	m	M		M	m				<m?	<m							
1950'	<m?			<m?	MM		M		<m					m?			CPX, AP
2480'		M		M			<m?		m								
2950'	M			MM			<m										
3532'	m			<m?	MM	<m	<m	<m?	M			<m?		m?			CPX, AP
3968'	M			m?	M		m				m		<m				
4500'	m			m?	M					<m	M		<m		<m	m	
WELL 29-1																	
467'					MM									M			AP
1297'		M	m	MM					<m								
1951'		m	M	MM					<m								
2375'								<m						MM			AP
2803'	<m?			<m?	MM	<m?		<m?	M					m?			AP
3088'					MM			<m?	m					m?			CPX, AP

MM = PREDOMINANT M = MAJOR m = MINOR <m = <5 WT.% ? = TENTATIVE IDENTIFICATION

SUMMARY OF X-RAY DIFFRACTION ANALYSIS

UNIVERSITY OF UTAH RESEARCH INSTITUTE , EARTH SCIENCE LABORATORY

BULK XRD

MINERALOGY, APPROX. WT.% ☐ (or) RELATIVE ABUNDANCE ☑

SAMPLE NO.	QUARTZ	CRISTOBAL.	TRIDYMITE	PLAGIOCL.	K-FELDSP.	CALCITE	HEMATITE	ILMENITE	PYRITE	ILLITE	MICA	CHLORITE	SMECTITE	MIXED-LAYER ILLITE-SMEC.	MIXED-LAYER CHL.-SMEC.	AMPHIBOLE	EPIDOTE	CLINOPTILOL.	LAUMONTITE				
KCF 82-15:																							
FILL BENEATH SHOE	M			m		m			TR?	m		m			m								
17A-6:																							
200-230′				M			TR?	m															
620-650′	m	M	m?	TR?	M		TR																
950-980′				M			TR	m															
1400-1430′	m			M			TR	m?					m					m					GLASS (M)
1600-1630′				M			TR	m?					m					TR					GLASS (M)
1800-1830′	TR	M	m?	m	M			TR?					m										
2100-2130′	TR	M		m	M		TR						m										
2400-2430′				M									TR										GLASS (M)
2750-2780′				M			TR						m					TR					
3040-3070′	m			M			TR	TR?					M		m			TR					
3400-3430′	M			M				m					m										
3940-3970′	m			M			TR	m				TR*	m										
4300-4330′	m			M			TR?	m?				TR*	m										
4750-4780′	m			M					TR			m*					TR						
5070-5100′	m			M					TR			m			m	m	m						TR
5400-5430′	m			M	TR	m	TR					m				m	m						
5950-5980′	m			M	TR		TR		TR			m				m	TR						
6300-6330′	m			M	m		TR		TR			m				m							
6600-6630′	M			M	m		TR		TR	m*		m				m	TR						
6900-6930′	M			M	m				TR	m*		m				m	TR						

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SUMMARY OF X-RAY DIFFRACTION ANALYSIS

UNIVERSITY OF UTAH RESEARCH INSTITUTE, EARTH SCIENCE LABORATORY

* POSSIBLY MICA
* MAY INCLUDE KAOLIN

BULK XRD

MINERALOGY, APPROX. WT.% ☐ (or) RELATIVE ABUNDANCE ☑

SAMPLE NO.	QUARTZ	CRISTOBAL.	TRIDYMITE	PLAGIOCL.	K-FELDSP.	CALCITE	HEMATITE	ILMENITE	PYRITE	ILLITE	MICA *	CHLORITE	SMECTITE	MIXED-LAYER ILLITE-SMEC.	MIXED-LAYER CHL.-SMEC.	AMPHIBOLE	CLINOPTIL.	ALUNITE	EPIDOTE				
7200-7230'	M			M	m		TR?					m				m							
7550-7580'	m			M	TR		TR?				m	m				m		m?					
7710-7720'	M			M	m		TR?				m	m				m			TR				
7800-7830'	M			M	m		TR?				m	m				m							
8100-8130'	M			M	m						m	m				m							
8400-8430'	M			M	m						m	m				m							
8700-8730'	M			M	m						m	m				m							
9000-9030'	M			M	m						m	m				m							
9300-9320'	M			M	m						m	m				m							
9590-9620'	M			M	m						m	m				m							

* MAY INCLUDE MINOR ILLITE

MM = PREDOMINANT M = MAJOR m = MINOR Tr = TRACE ? = TENTATIVE IDENTIFICATION

SUMMARY OF X-RAY DIFFRACTION ANALYSIS

UNIVERSITY OF UTAH RESEARCH INSTITUTE , EARTH SCIENCE LABORATORY

WELL Nos. 12 & 13
BULK CUTTINGS

MINERALOGY, APPROX. WT.% [ ] (or) RELATIVE ABUNDANCE [✓]

SAMPLE NO.	QUARTZ	CRISTOBALITE	TRIDYMITE	K-FELDSPAR	PLAGIOCLASE	HEMATITE	ILMENITE	PYRITE	ILLITE OR MICA	SMECTITE	MIXED-LAYER ILLITE-SMEC.	MIXED-LAYER CHLOR.-SMEC.	STILBITE	OTHER PHASES/ NOTES
WELL No. 12														
450-500'					MM									
750-800'					MM	m								
1050-1100'					MM		Tr?							
1350-1400'	Tr	M	m	M										
1600-1650'	Tr	M	Tr	M										
1850-1900'		M	m	M					m					
2100-2150'		m	M	M					Tr?					
WELL No. 13														
304-336'					M									PROBABLY ABUNDANT GLASS
564-605'					MM									
829-863'		M		M	M									
1178-1208'					MM					Tr				
1419-1448'					M	m				M			m	
1588-1617'		M		M						m				

MM = PREDOMINANT M = MAJOR m = MINOR Tr = TRACE ? = TENTATIVE IDENTIFICATION

SUMMARY OF X-RAY DIFFRACTION ANALYSIS

UNIVERSITY OF UTAH RESEARCH INSTITUTE, EARTH SCIENCE LABORATORY

ML 65-266

ML 84-17

WELL No. 9
BULK CUTTINGS

MINERALOGY, APPROX. WT.% ☐ (or) RELATIVE ABUNDANCE ✓

SAMPLE NO.	QUARTZ	CRISTOBALITE	TRIDYMITE	K-FELDSPAR	PLAGIOCLASE	HEMATITE	ILMENITE	PYRITE	ILLITE	SMECTITE	CHLORITE	MIXED-LAYER ILLITE-SMEC.	MIXED-LAYER CHLOR.-SMEC.	CLINOPTILOL.	ANALCIME	NOTES/ OTHER PHASES
270-330'					MM		TR	TR			TR					
420-470'				TR?	MM		TR	TR			TR					
720-780'		M	TR	M							TR					
960-1020'					MM			TR			TR					
1260-1380'					MM						m			m	m	
1770-1860'					MM			TR			m					
2280-2300'					MM						m					
2620-2680'					MM		TR				m					
3040-3100'					MM		m	TR			m					
3400-3460'	M			m?	MM			TR?			TR	m				
3460-3670'	m				MM						m		m			
3940-3990'	m				MM			TR			m	TR*				≠ OR MARCASITE * OR KAOLINITE

MM = PREDOMINANT M = MAJOR m = MINOR Tr = TRACE ? = TENTATIVE IDENTIFICATION

SUMMARY OF X-RAY DIFFRACTION ANALYSIS

UNIVERSITY OF UTAH RESEARCH INSTITUTE, EARTH SCIENCE LABORATORY

WELL Nos. 8, 10, 11
BULK CUTTINGS
(WELL No. 9 ON FOLLOWING PAGE)

MINERALOGY, APPROX. WT.% [ ] (or) RELATIVE ABUNDANCE [✓]

SAMPLE NO.	QUARTZ	CRISTOBALITE	TRIDYMITE	K-FELDSPAR	PLAGIOCLASE	HEMATITE	ILMENITE	PYRITE	ILLITE	SMECTITE	CHLORITE	MIXED-LAYER ILLITE-SMEC.	MIXED-LAYER CHLOR.-SMEC.	CLINOPTILOL.	ANALCIME	NOTES/ OTHER PHASES
No. 8 242-270'		M		M	m					m						
461-487'					M	M				m				m		
633-661'					MM	m				M				m		
825-851'					MM	m	Tr?			M				Tr		
No. 10 300-390'					MM	m				m						
570-630'		M		M	m			*Tr?		Tr						PROBABLY ABUNDANT GLASS
870-930'					M					Tr						"
1170-1230'					M					m						"
1440-1470'	m			Tr	M											"
1710-1740'	M	m		M							Tr?					
1920-1950'	M	m		M												
2200-2230'	M	m		M				m		m						
No. 11 300-350'					MM											
550-600'					MM											
800-850'					MM	Tr?	Tr?			m						
1100-1150'					MM					m						
1450-1500'					MM					m						
1850-1900'					MM					m		Tr?				

*OR MARCASITE

MM = PREDOMINANT M = MAJOR m = MINOR Tr = TRACE ? = TENTATIVE IDENTIFICATION

SUMMARY OF X-RAY DIFFRACTION ANALYSIS

UNIVERSITY OF UTAH RESEARCH INSTITUTE, EARTH SCIENCE LABORATORY

WELL Nos. 6 & 7
BULK CUTTINGS

MINERALOGY, APPROX. WT.% [ ] (or) RELATIVE ABUNDANCE [✓]

SAMPLE NO.	QUARTZ	CRISTOBALITE	TRIDYMITE	K-FELDSPAR	PLAGIOCLASE	HEMATITE	ILMENITE	PYRITE	ILLITE	SMECTITE	CHLORITE OR KAOLINITE	MIXED-LAYER CHLOR.-SMEC.	MIXED-LAYER ILLITE-SMEC.	NOTES/OTHER PHASES
WELL No. 6														
350-400'					MM	TR?								
600-650'					MM			TR?						
800-850'					MM	m	TR							
1050-1100'					MM	TR?	TR			m				
1450-1500'	m			TR?	m					m				ABUNDANT GLASS
1750-1800'	TR				MM					m				
1950-2000'					MM					m				
WELL No. 7														
700-730'	TR		m		m?	MM				TR				

MM = PREDOMINANT M = MAJOR m = MINOR Tr = TRACE ? = TENTATIVE IDENTIFICATION

SUMMARY OF X-RAY DIFFRACTION ANALYSIS

UNIVERSITY OF UTAH RESEARCH INSTITUTE, EARTH SCIENCE LABORATORY

ML 7576

GM 1904

April 16, 1987

DAN CARRIER

MAY 8 1987

FLUID INCLUSION STUDIES OF TWO SAMPLES FROM A GEOTHERMAL SYSTEM

OBJECTIVE OF STUDY: To characterize temperatures and salinities of fluids from which the alteration minerals formed

RESULTS:

45-36-3448 Vein quartz: 170-180°C, <1 wt% NaCl eq
Wallrock prehnite(?): 175-185°C, <1 wt% NaCl eq
Late vein calcite: 160-175°C, <1 wt% NaCl eq

45 36-3905 Vein quartz: 180-190°C, <1 wt% NaCl eq
Vein laumontite: 190-220°C, <1 wt% NaCl eq
Vein prehnite: 170-180°C
Wallrock prehnite: 175-185°C, <3 5 wt% NaCl eq

SUBMITTED TO: Brian Smith
Union Science and Technology

SUBMITTED BY: T James Reynolds
FLUID INC
Denver, CO
303-388-6583

PROCEDURE

Two samples were submitted by Brian Smith for routine fluid inclusion analysis: Thin (<200μm) doubly-polished plates were prepared without subjecting the samples to temperatures exceeding room temperature during the polishing process Plates were then surveyed to determine fluid inclusion shapes and sizes spatial relationships among inclusions, and phases present within inclusions; and to assess paragenetic relations among alteration minerals Temperature and salinity determinations from select inclusions (see below) were obtained with a FLUID INC. adapted U.S.G.S. Gas-Flow Heating/Freezing System which operates by passing preheated or cooled N_2 gas directly over the sample Homogenization temperature accuracy is better than 1% of the measured value Freezing point depressions are accurate within 0 5°C Fluid inclusions were homogenized before they were subjected to freezing tests Weight percent NaCl eq salinities were computed by the method of Potter Clynne, and Brown (1978, EG, 73 p 284)

RESULTS

Types of Fluid Inclusions Studied

Only two-phase aqueous inclusions which homogenize by disappearance of

the vapor bubble were identified and studied Many one-phase, liquid-filled inclusions exist as do vapor-rich inclusions, but these types of inclusions probably result from necking and were not studied further (see below)

Selection of Inclusions for Study

The first assumption of fluid inclusion research is that a homogeneous phase must be enclosed at the time of trapping; if another phase nucleates within the cavity upon cooling prior to complete healing (sealing-off of an individual cavity), then the first assumption is violated, and incorrect, typically random liquid to vapor volumetric ratios result in highly variable homogenization temperatures These variable ratios resulted from the healing ("necking") process described above and NOT from "boiling", as is evidenced by the existence of one-phase, liquid-filled inclusions in proximity to vapor-rich inclusions Therefore, inclusions selected for homogenization temperature determination in the samples are from areas in growth bands which contain several inclusions (typically the smallest-<7μm) with nearly equal liquid to vapor ratios

Origin of Fluid Inclusions Studied

All inclusions studied are of primary origin (form during crystal growth thus trapping the fluids from which the crystals grew) and are distinguished as occurring defining growth zones

Data

The fluid inclusion data are presented in tabular format below

- quartz with minor epidote fill fractures with late calcite
- prehnite (?) replaces minerals in wallrock

Primary Incs in Quartz

T_h	T_{mp}	sal
171°C		
172		
172	-0 1°C	0 2 wt% NaCl eq
175	-0 1	0 2
176		
177	-0 1	0 2
178		
179		

Primary Incs in Prehnite(?)

T_h	T_{mp}	sal
176°C	-0 6°C	1 1 wt% NaCl eq
177	-0 5	0 9
177		
178		
178	-0 2	0 3
179	-0 5	0 9
180	-0 5	0 9
182	-0 2	0 3
185	-0 8	1 4
197	-0 7	1 2

Primary Incs in Calcite

T_h	T_{mp}	sal
155°C		
163	-0 1°C	0 2 wt% NaCl eq
169	-0 2	0 3
170	-0 2	0 3
170	-0 2	0 3
172		
174		
174	-0 1	0 2
175	-0 1	0 2
176	-0 1	0 2

- quartz, epidote prehnite, and laumontite are filling fractures
- some quartz is definitely early
- laumontite is the latest vein filling
- prehnite also replaces wallrock phenocrysts

Primary Incs in Quartz

T_h	T_{mp}	sal
175°C	-0 4°C	0 7 wt% NaCl eq
177	-0 2	0 3
180		
181		
182	-0 5	0 9
183	-0 3	0 5
184	-0 5	0 9
187	-0 2	0 3
189	-0 3	0 5
189	-0 5	0 9
190	-0 4	0 7

Primary Incs in Laumontite

T_h	T_{mp}	sal
193°C	-0 2°C	0 3 wt% NaCl eq
195	-0 2	0 3
197	-0 2	0 3
199	-0 2	0 3
199		
200		
201		
202		
203		
205	-0 5	0 9
208	-0 4	0 7
209		
212	-0 2	0 3
213		
216	-0 3	0 5
217		
219		

Primary Incs in Wallrock Prehnite

T_h	T_{mp}	sal
177°C		
178	-0 5°C	0 9 wt% NaCl eq
178	-0 5	0 9
178	-1 4	2 4
178	-1 9	3 2
179	-2 0	3 4
180	-2 0	3 4
180	-2 0	3 4
180		
181	-0 4	0 7
181	-1 5	2 6
182	-0 6	1 1
183	-1 8	3 1
184		
186		
186		
187		
197	-2 0	3 4

Primary Incs in Vein Prehnite

T_h
172°C
178
179
179
179
180
180

ELLIOT GEOPHYSICAL CO., INC.

4653 EAST PIMA STREET TUCSON, ARIZONA 85712 TEL. (602) 323-2421

GM 30.03

14 October, 1982 Ref. ME23P

Robert B. Dickerson
UNION OIL CO. OF CALIFORNIA
2099 Range Ave.
P.O. Box 6854
Santa Rosa, CA 95406

Dear Robert:

RE: Physical Property Laboratory Determinations

The 14 samples that were received on 10-13-82 have been run in the physical property laboratory of ELLIOT GEOPHYSICAL CO., INC. to determine the requested physical properties. The following physical property methods were run:

- Volume Magnetic Susceptibility
- Wet Bulk Density

The physical property procedures were performed following conventional techniques of laboratory analysis and are described in the attachments. The resulting data with the specific parameters and units employed are presented on the accompanying tables.

A one-inch diameter core was cut from each of the submitted samples in order to provide appropriate means for measurement of the requested physical properties.

The samples are being returned to you via United Parcel Service.

Sincerely yours,

ELLIOT GEOPHYSICAL CO., INC.

Charles L. Elliot

Charles L. Elliot, Pres.

Registered Professional Engineer (Geophysical) CERTIFICATE NO. 6877 CHARLES L. ELLIOT Date Signed 10-14-82 Arizona U. S. A.

ATTACHMENTS: Tables
Physical Property Procedures

PROCEDURES FOR THE DETERMINATION OF VOLUME MAGNETIC SUSCEPTIBILITIES

The volume magnetic susceptibility measurements made in the physical property laboratory utilizes a magnetic susceptibility bridge type instrument operating at a frequency of 400 Hertz. The limits of detectibility of the bridge are approximately 1.0 micro cgs units (12.6E-05 SI units). Resulting data are presented in micro cgs units of volume magnetic susceptibility. The SI unit conversion is:

$$k_{SI} = (12.566)\,k_{cgs}$$

Magnetic susceptibility measurements are made on a 1.0 inch diameter bicylindrical core cut from each submitted sample to facilitate the determination. Sometimes surface samples may be broken to chip size which can be run with appropriate correction for the rock/void ratio of material. Also, sand, mud or chip samples can be utilized in the determination of volume magnetic susceptibility with appropriate corrections for porosity and/or voids.

PROCEDURES FOR THE DETERMINATION OF WET BULK DENSITIES

The density determinations made in the physical property laboratory are determined following conventional laboratory procedures for determining bulk rock densities utilizing the bouyancy method. The accuracy of the bouyancy technique of density measurement is better than 0.01 grams per cubic centimeter (10.0 SI units). The results of the laboratory density determinations are reported in grams per cubic centimeter. The SI unit conversion is:

$$D_{kg/m3} = (1000.0)\,D_{gms/cc}$$

Density measurements can be made on bicylindrical cores, grab samples or drill cores. Cuttings or sand samples can be measured but with some loss in accuracy.

ROCK PHYSICAL PROPERTY LABORATORY DETERMINATIONS

UNION OIL CO. OF CALIFORNIA

14 OCTOBER, 1982 REF. ME23P

REF. NO.	SAMPLE DESIGNATION	VOLUME MAGNETIC SUSCEPTIBILITY (k) micro cgs units	WET BULK DENSITY grams/cc
1	G4000	340.	2.47
2	GMF56-3 227	2800.	2.78
3	GMF56-3 299	93.	2.64
4	GMF56-3 410	450.	1.80
5	GMF56-3 678	930.	2.45
6	GMF56-3 696	2000.	2.52
7	GMF56-3 746	560.	2.33
8	GMF56-3 938	730.	2.37
9	GMF56-3 953	31.	1.92 ?
10	GMF56-3 1058	1300.	2.39
11	GMF56-3 1113	530.	2.38
12	GMF56-3 1322	190.	2.39
13	GMF56-3 1676	880.	2.13
14	GMF56-3 1724	1700.	2.32

NOTE: ? = Incompetent sample. Reported wet bulk density is best average value with uncertain accuracy.

Charles Elliot

Registered Professional Engineer (Geophysical)
CERTIFICATE NO. 5977
CHARLES L. ELLIOT
Date Signed 10-14-82
Arizona U. S. A.

815	1.10 (-3)	2.00	1.89	+56
888	1.75 (-2)	2.57	5.86	-40
902	1.82 (-3)	1.87	0.86	-57
906	9.47 (-3)	2.02	3.70	+76
916	2.06 (-3)	1.82	4.08	-7

NKGW 2.36 ± 0.30 [illegible]

(w/ 4 surface samples)

w/o samples from [illegible] (27 samples) 2.42 ± .30

w/ samples from [illegible] (91 samples) 2.[illegible] ± .30 471 ? 561

(only surface [illegible] (surface rx samples) + down to 300') 2.76 ± 0.12

APPENDIX Q:
Glass Mountain Well 17A-6 Schlumberger Dual Induction Resistivity log, averaged at 100’ intervals

Attachment XVI

CEC-500-2007-XXX-ATXVI

Glass Mountain Well 17A-6 Schlumberger Dual Induction Resistivity log, averaged at 100' intervals

This document is an attachment to a report funded by the California Energy Commission's Geothermal Resource Development Account (GRDA) Program. The GRDA Program did not fund this document, but the authors of the GRDA funded report have attached it as a supporting document.

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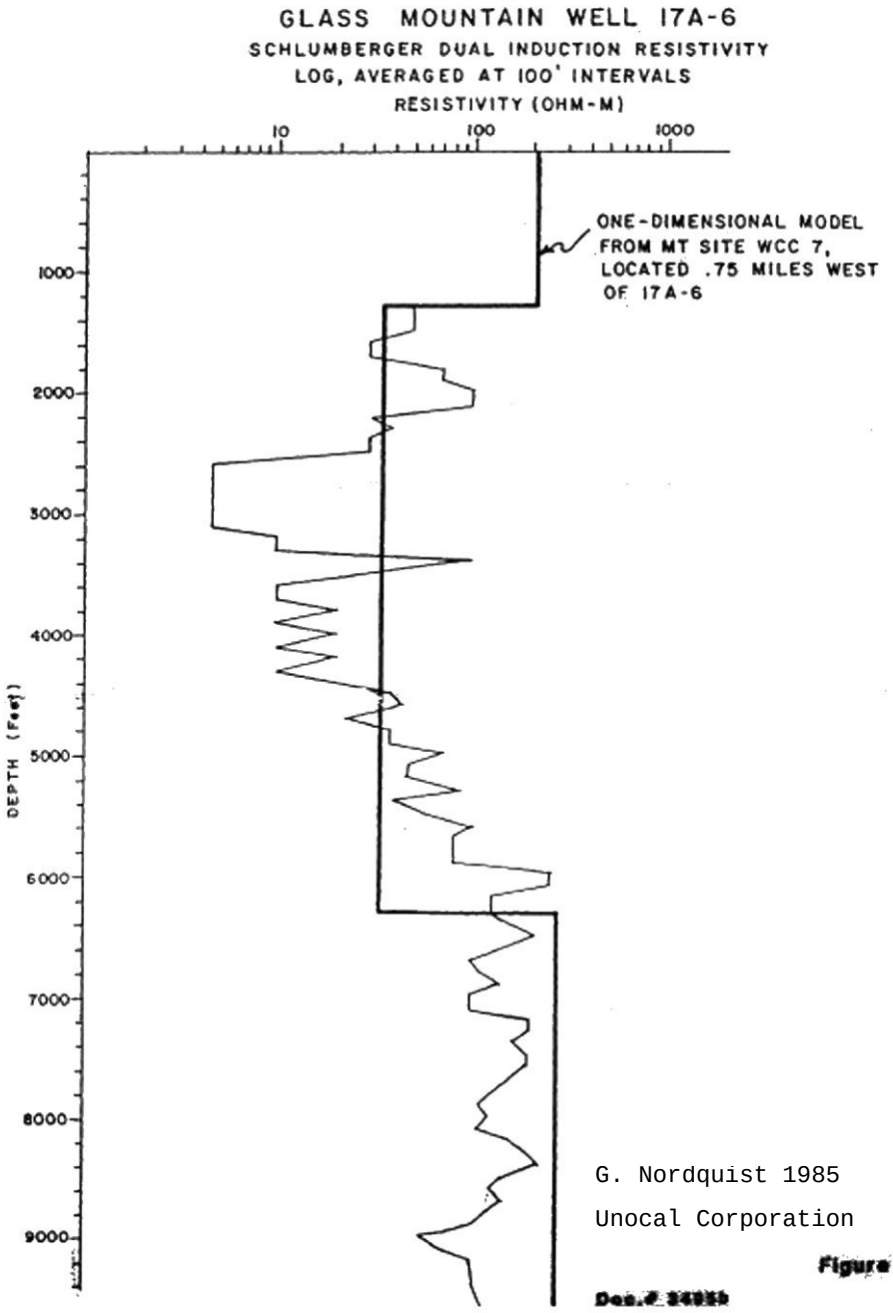

G. Nordquist 1985

Unocal Corporation

Figure 7