GL01030

PART B

RESULTS OF THE GEOPHYSICAL SURVEYS
in the
BEOWAWE PROSPECT

SUBMITTED TO
GETTY OIL COMPANY

NU/BEO/Ga-1
Part B
27 Pages

by

ELECTRODYNE SURVEYS
Reno, Nevada

September, 1979

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INTRODUCTION

One hundred sixteen (116) Time Domain Electromagnetic stations were performed as part of the Beowawe Prospect. The listings of the processed stations are presented alphabetically and by component, eg., D14:Hz, Ep and Eper. Hz is the vertical magnetic field measurement. Ep represents the horizontal electric field parallel to the source, and Eper is the horizontal electric field perpendicular to the source.

There are 16 stations at which one of the two E field could not be processed due to extremely low signal to noise condition.

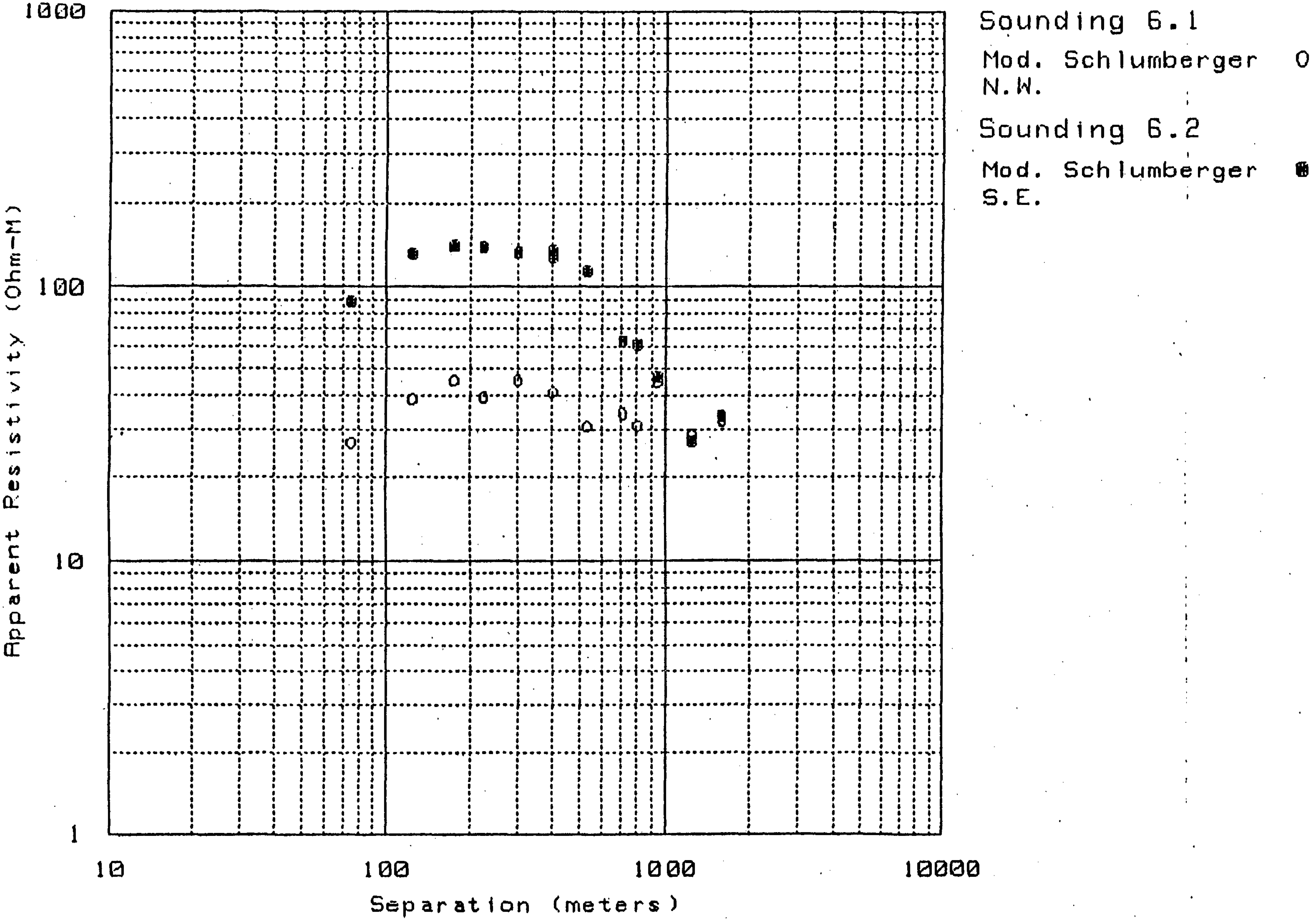
Stations H11, M11, I14 (source 1) and R5 could not be digitized from the analog tape due to frequency interference.

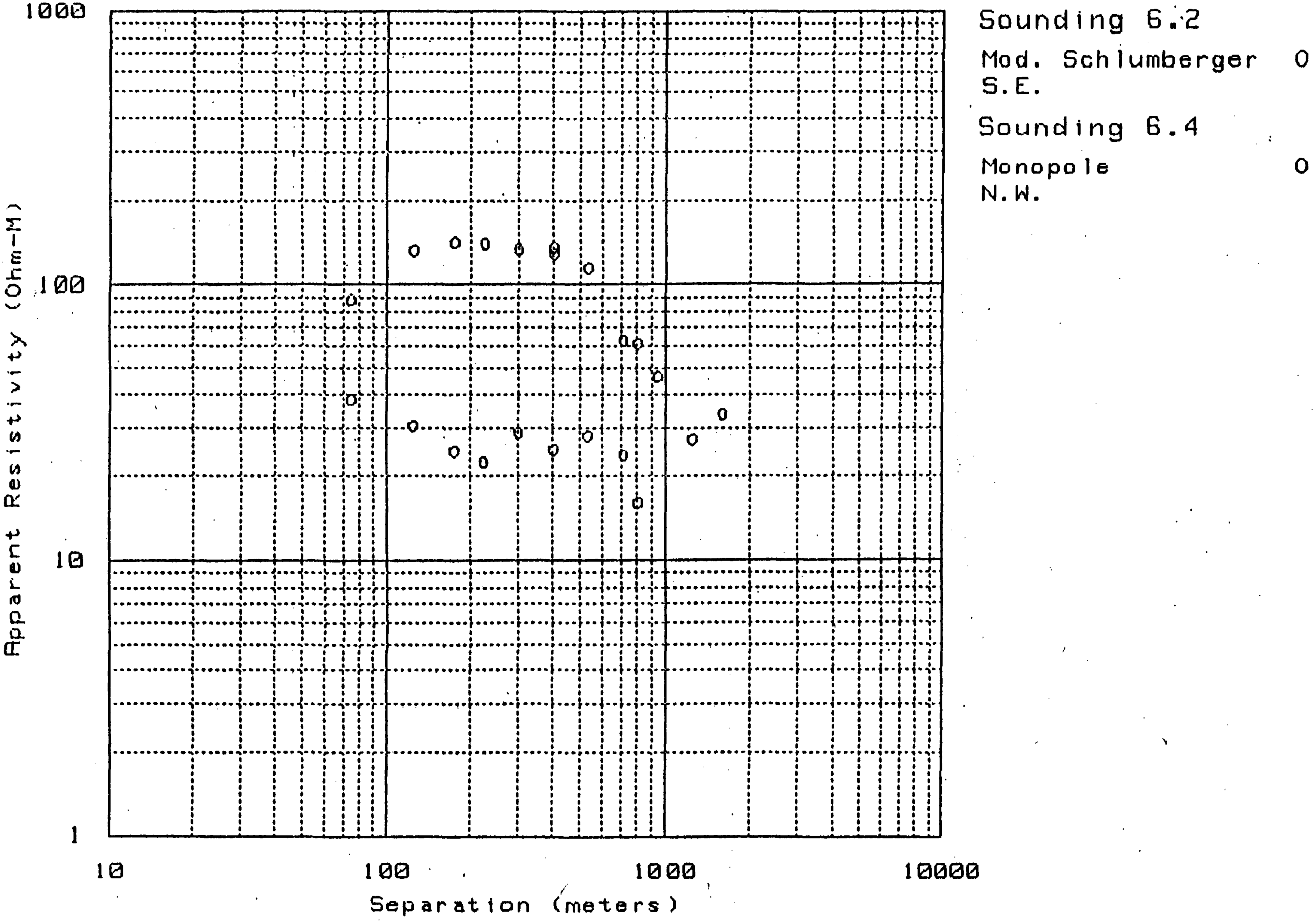
APPENDIX II

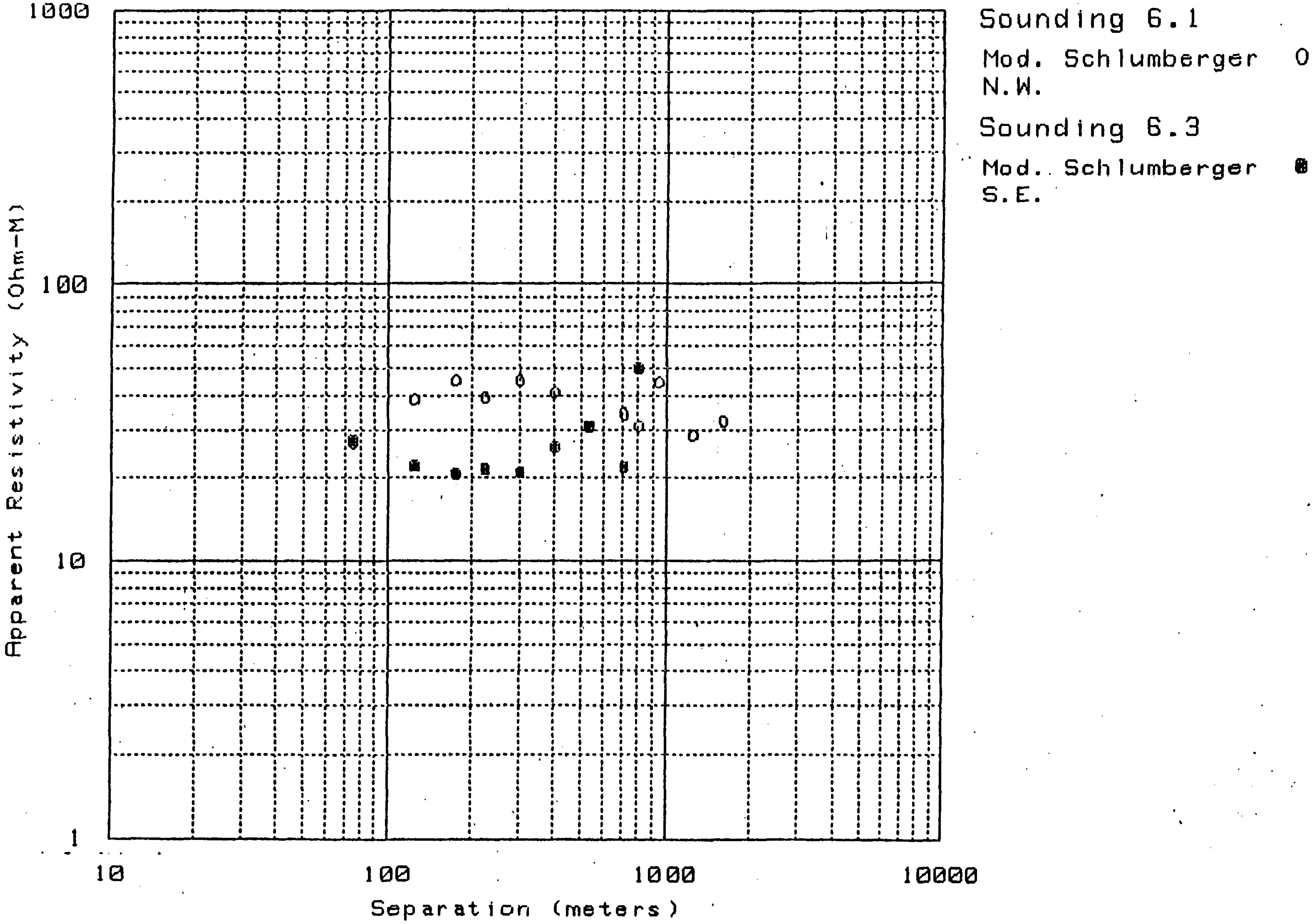
GALVANIC (DC) SOUNDING DATA

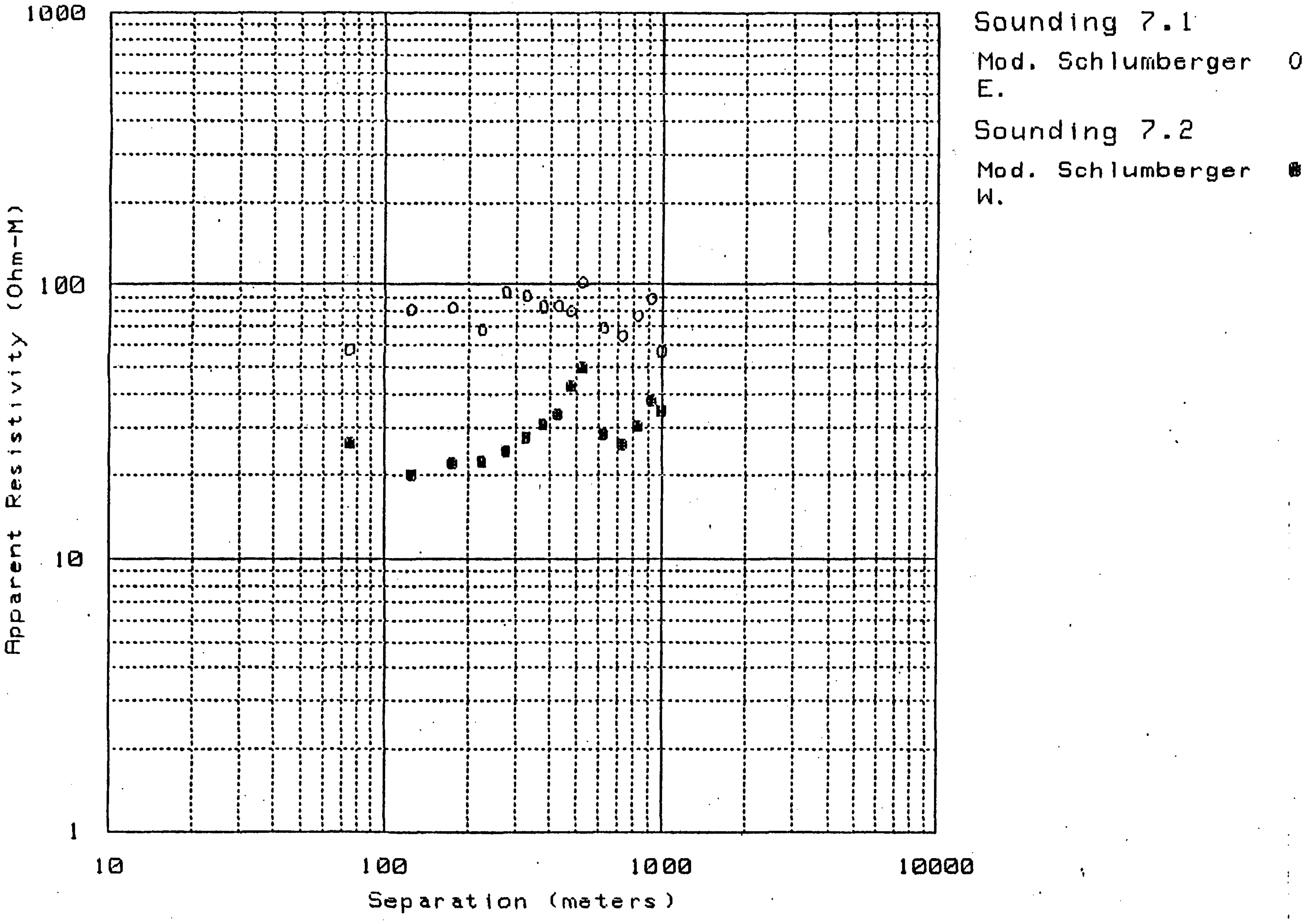
DC SOUNDING INTERPRETATION

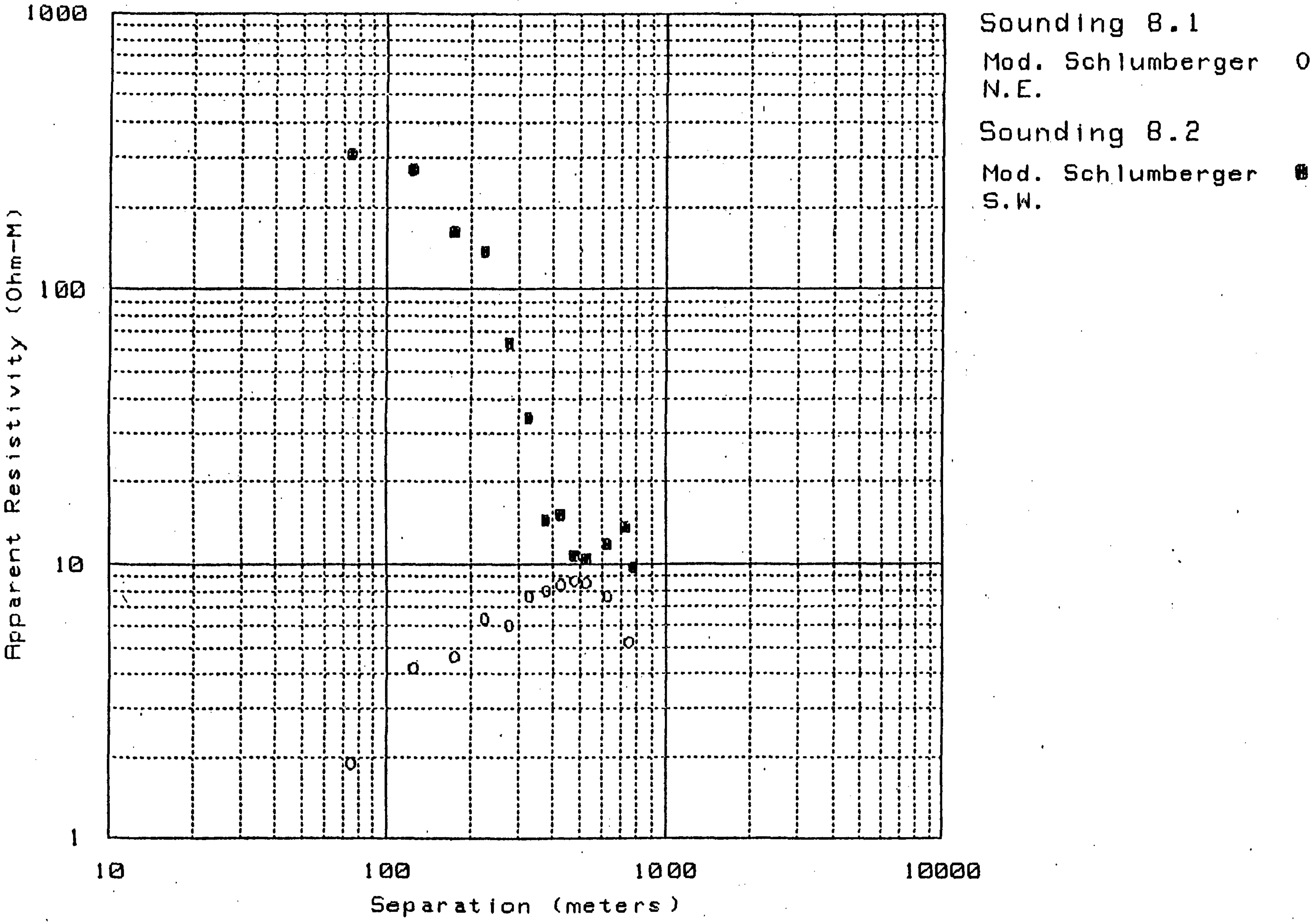
SOUNDING NO.	APPARENT RESISTIVITY (ohm-m)	THICKNESS (m)	DEPTH (m)
6.2	50	32	32
	350	88	120
	32	≥1380	1500
	<32 ?	?	?
6.4	50	≈49	49
	≈20	>180	>229
	>100	?	?
6.3	35	44	44
	15	220	264
	>100	?	?
6.1	27	65	65
	240	31	96
	≈23	1080	2076
7.1	54	67	67
	216	134	201
	≈55	≈890	1091
7.2	36	34	34
	15	170	204
	>150	?	?
8.1	2.1	53	53
	19	160	213
	≤2	?	?
8.2	300	100	
	≈4	Lateral Variation	
9.1	18	56	56
	160	500	556
	<5	≥150	≥306
9.2	18	56	56
	160	280	336
	<10	≥155	491

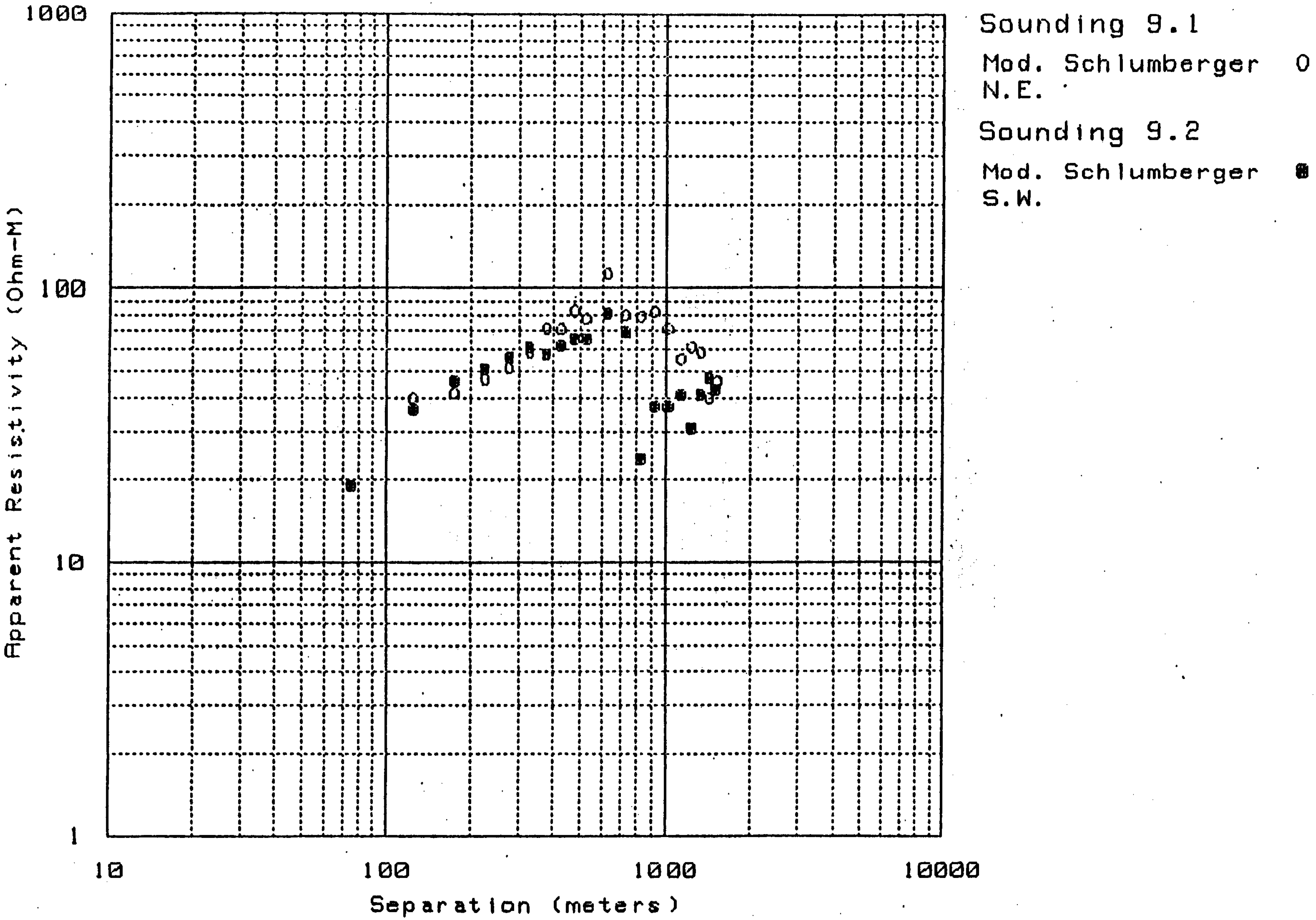

Sounding 6.1
Mod. Schlumberger O
N.W.
Sounding 6.2
Mod. Schlumberger ■
S.E.
Apparent Resistivity (Ohm-M)
1000
100
10
1
10
100
1000
10000
Separation (meters)


1000
100
10
1
Apparent Resistivity (Ohm-M)
10
100
1000
10000
Separation (meters)
Sounding 6.2
Mod. Schlumberger O
S.E.
Sounding 6.4
Monopole O
N.W.


Sounding 6.1
Mod. Schlumberger O
N.W.
Sounding 6.3
Mod. Schlumberger ■
S.E.
1000
100
10
1
Apparent Resistivity (Ohm-M)
10
100
1000
10000
Separation (meters)


1000
100
10
1
Apparent Resistivity (Ohm-M)
10
100
1000
10000
Separation (meters)
Sounding 7.1
Mod. Schlumberger O
E.
Sounding 7.2
Mod. Schlumberger ■
W.


Sounding 8.1
Mod. Schlumberger O
N.E.
Sounding 8.2
Mod. Schlumberger ▨
S.W.
Apparent Resistivity (Ohm-M)
1000
100
10
1
10
100
1000
10000
Separation (meters)


Sounding 9.1
Mod. Schlumberger O
N.E.
Sounding 9.2
Mod. Schlumberger ■
S.W.
1000
100
10
1
Apparent Resistivity (Ohm-M)
10
100
1000
10000
Separation (meters)

APPENDIX III

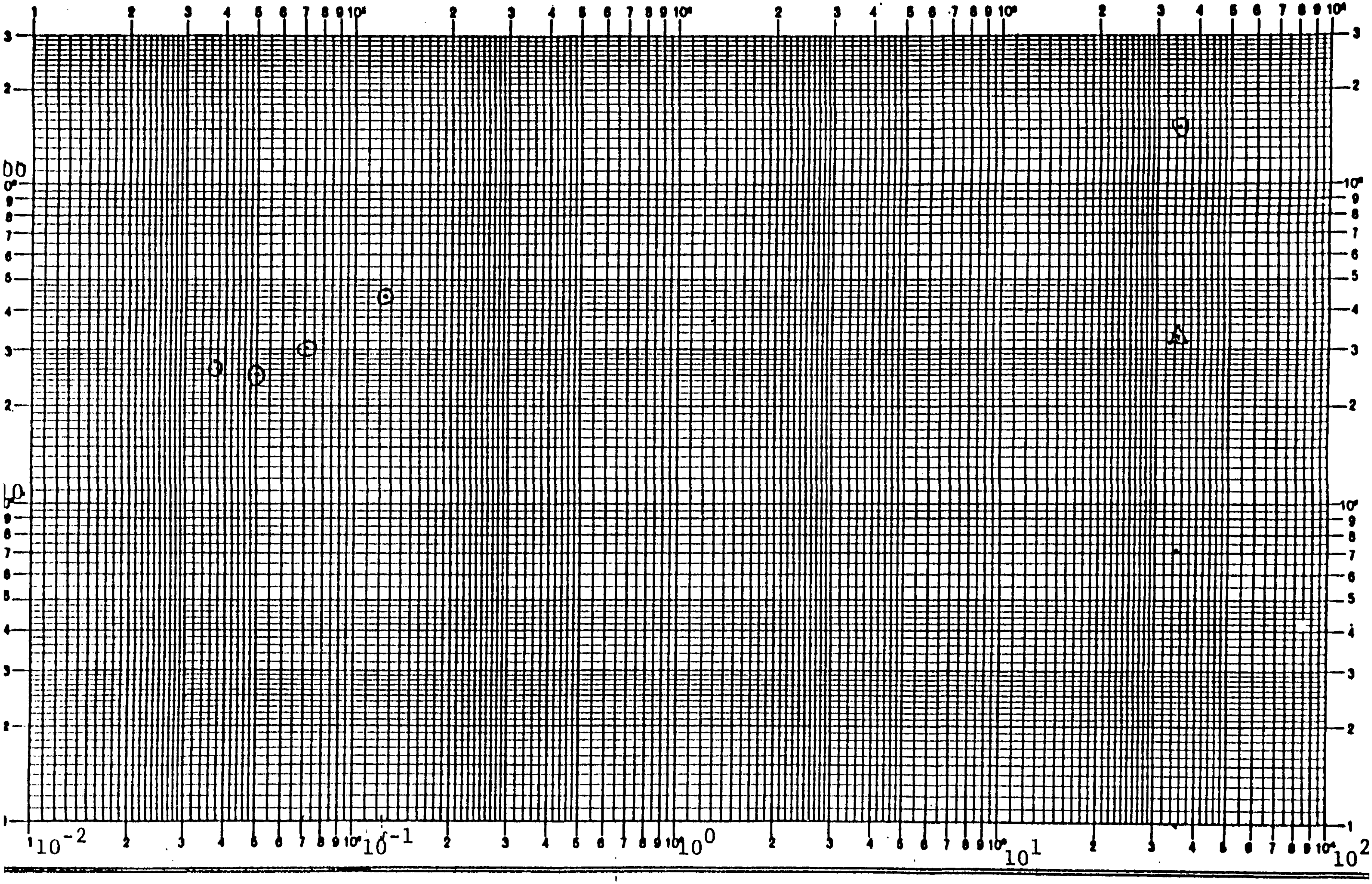
MAGNETOTELLURIC SOUNDING DATA

AMT - MT LEGEND

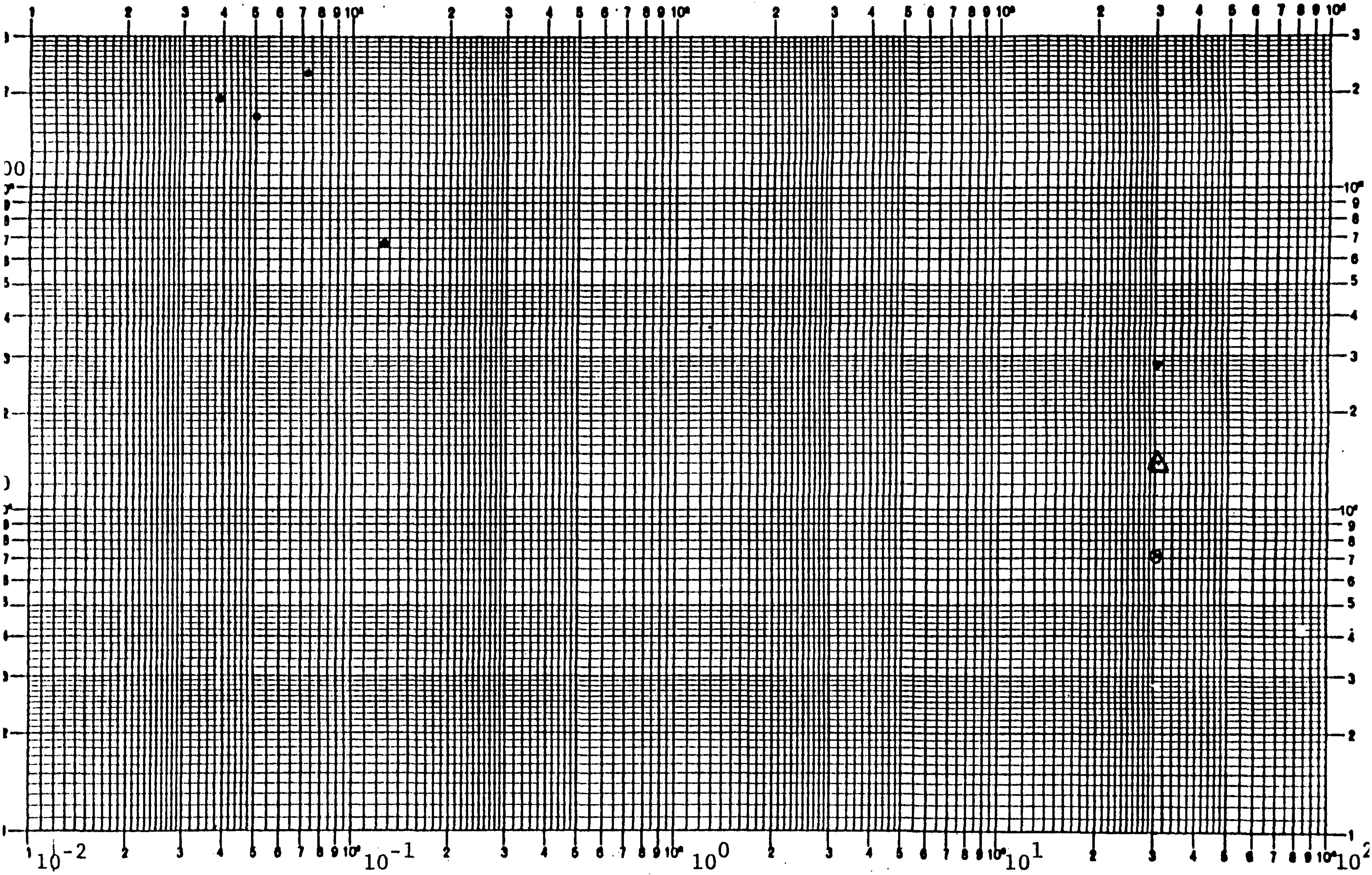
● $\rho_{a_{xy}}$ - Apparent resistivity (ohm-meters)

⊙ $\rho_{a_{yx}}$ - Apparent resistivity (ohm-meters)

◬ $\rho_{a_{eff}}$ - Effective apparent resistivity (ohm-meters)



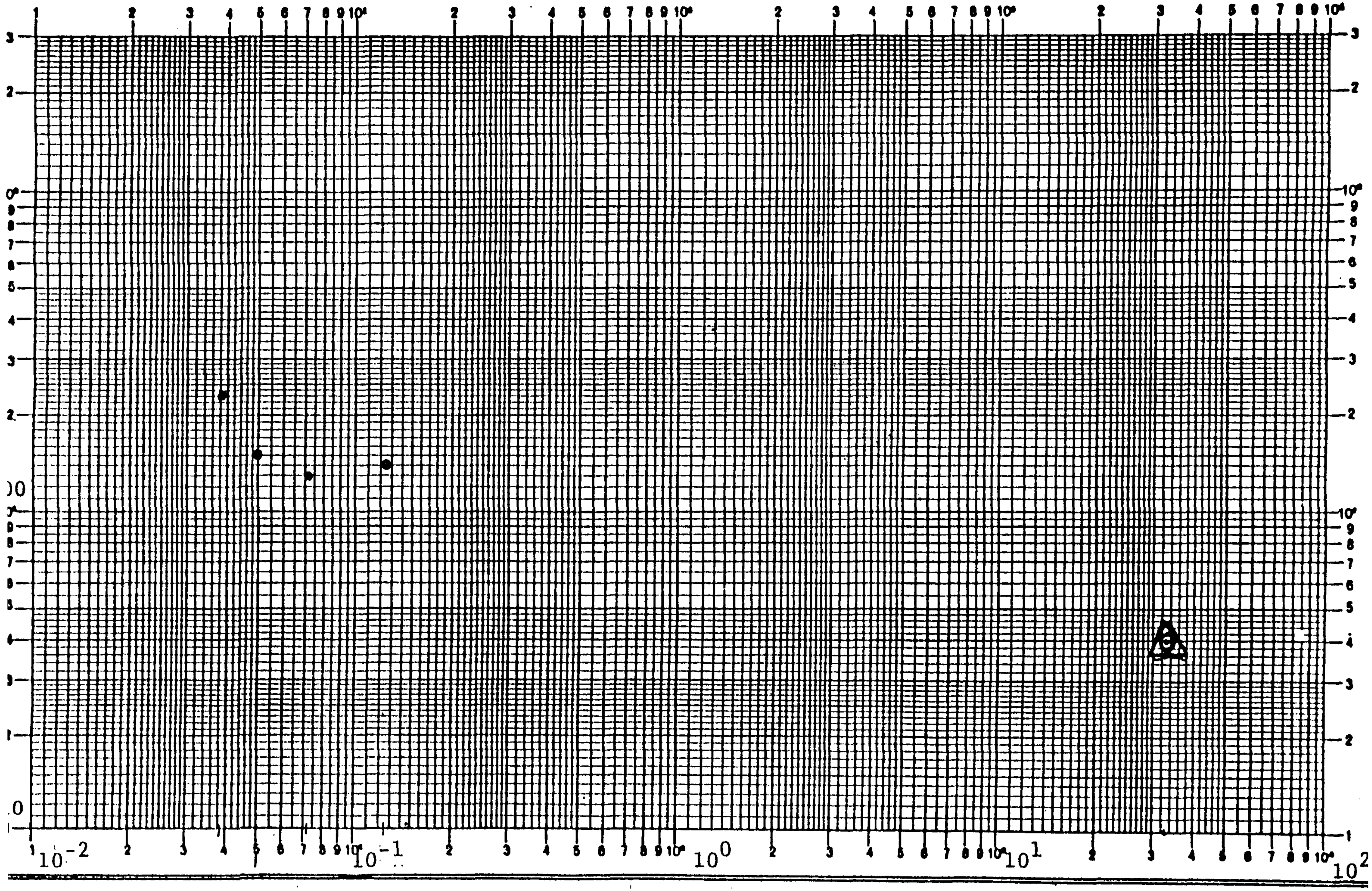
STATION F-11 AMT-MT **Wave Period** BEOWAWE PROSPECT JOB #811



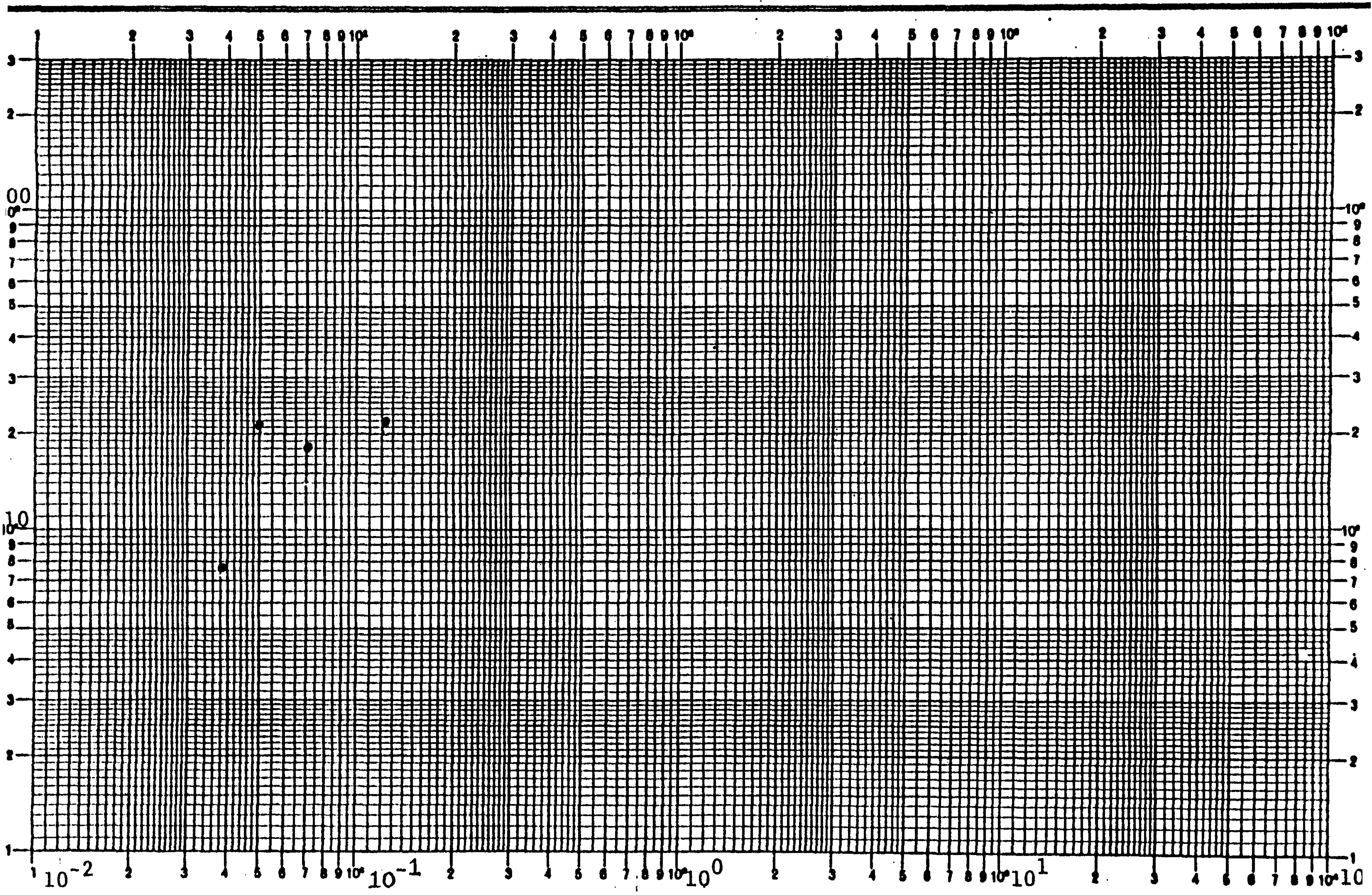
STATION L-5 AMT-MT

Wave Period

BEOWAWE PROSPECT JOB #811



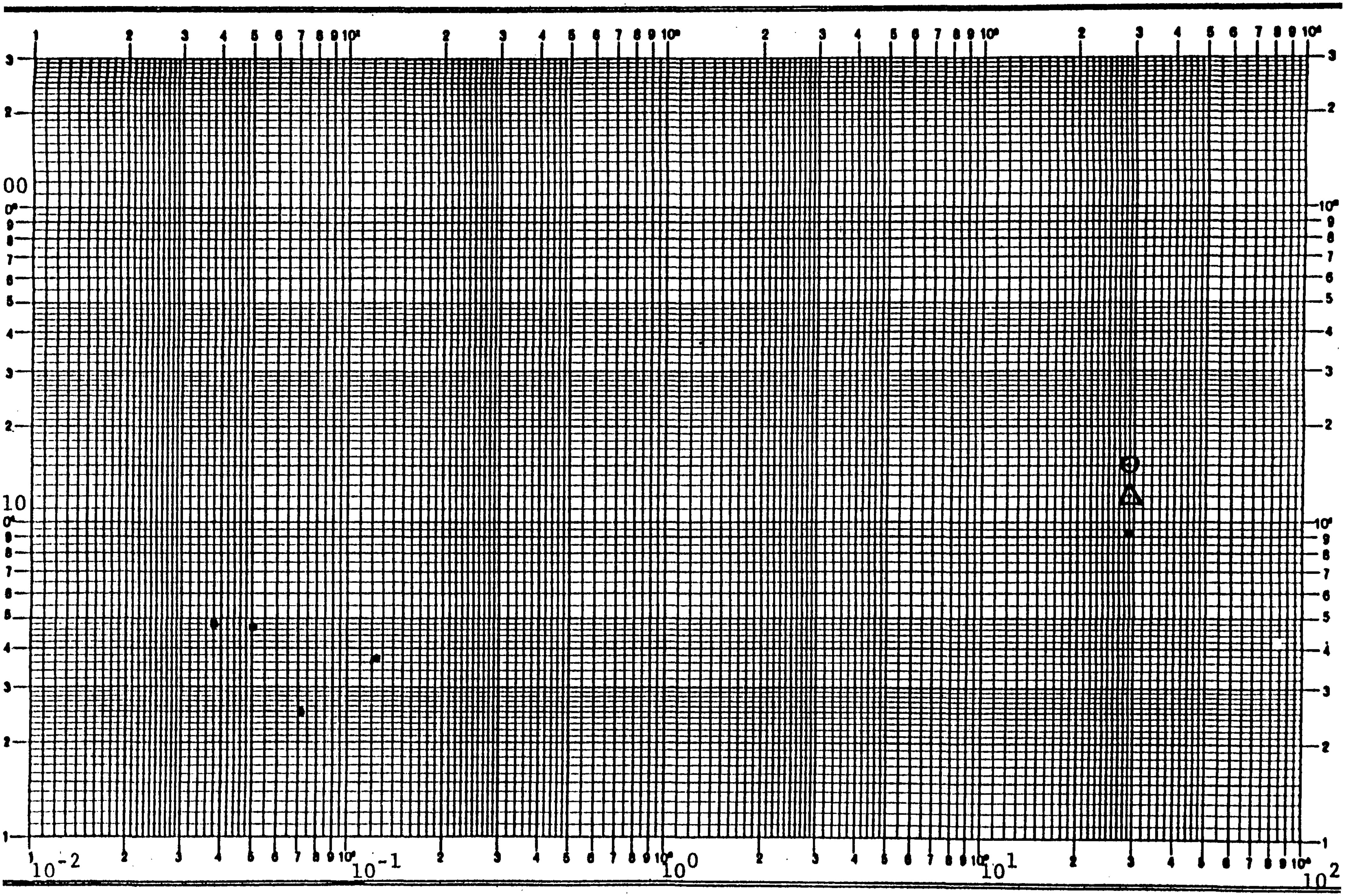
STATION L-9 AMT-MT Wave Period BEOWAWE PROSPECT JOB #811



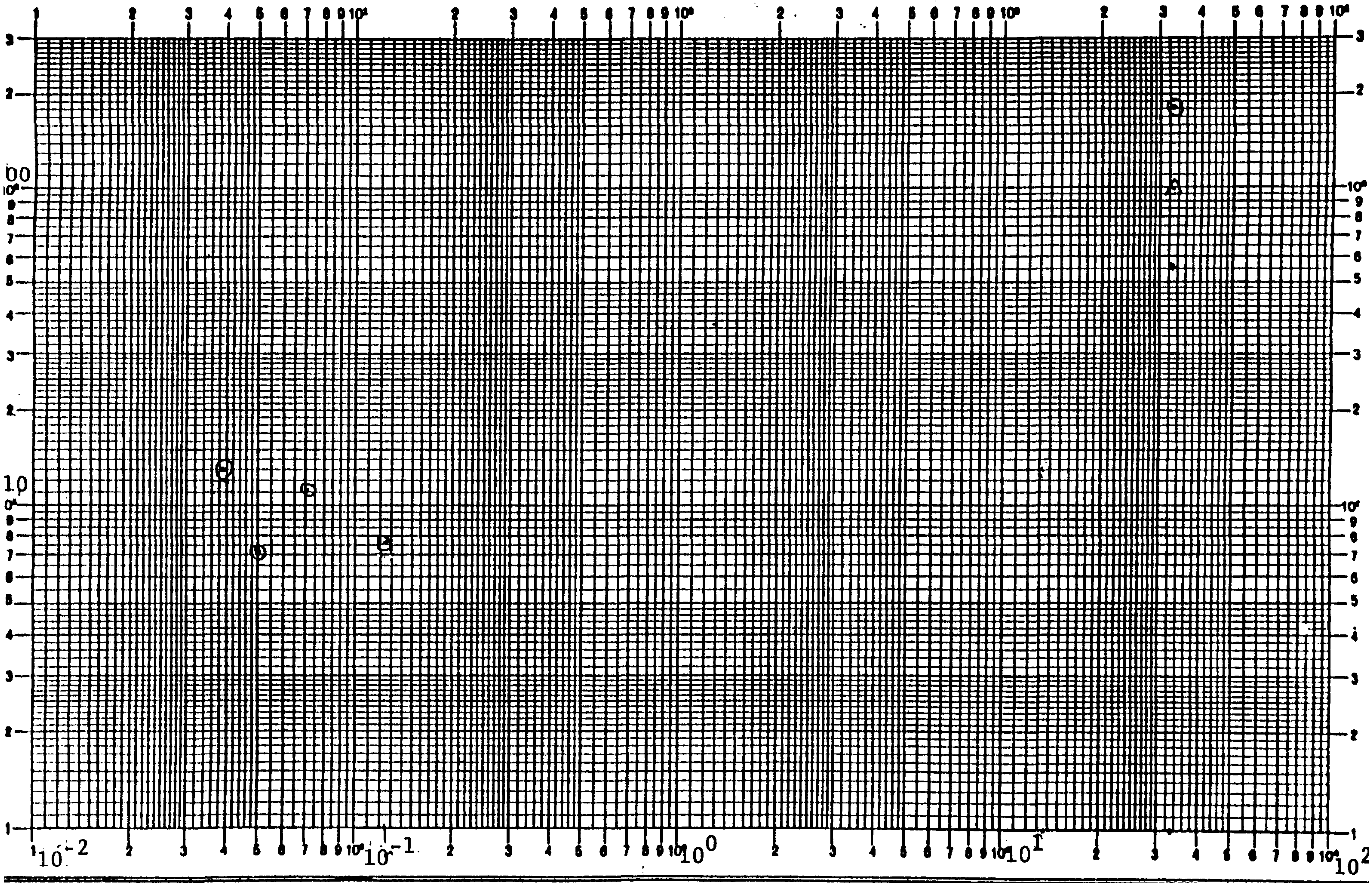
Wave Period

STATION L-10 AMT-MT

BEOWAWE PROSPECT JOB #811



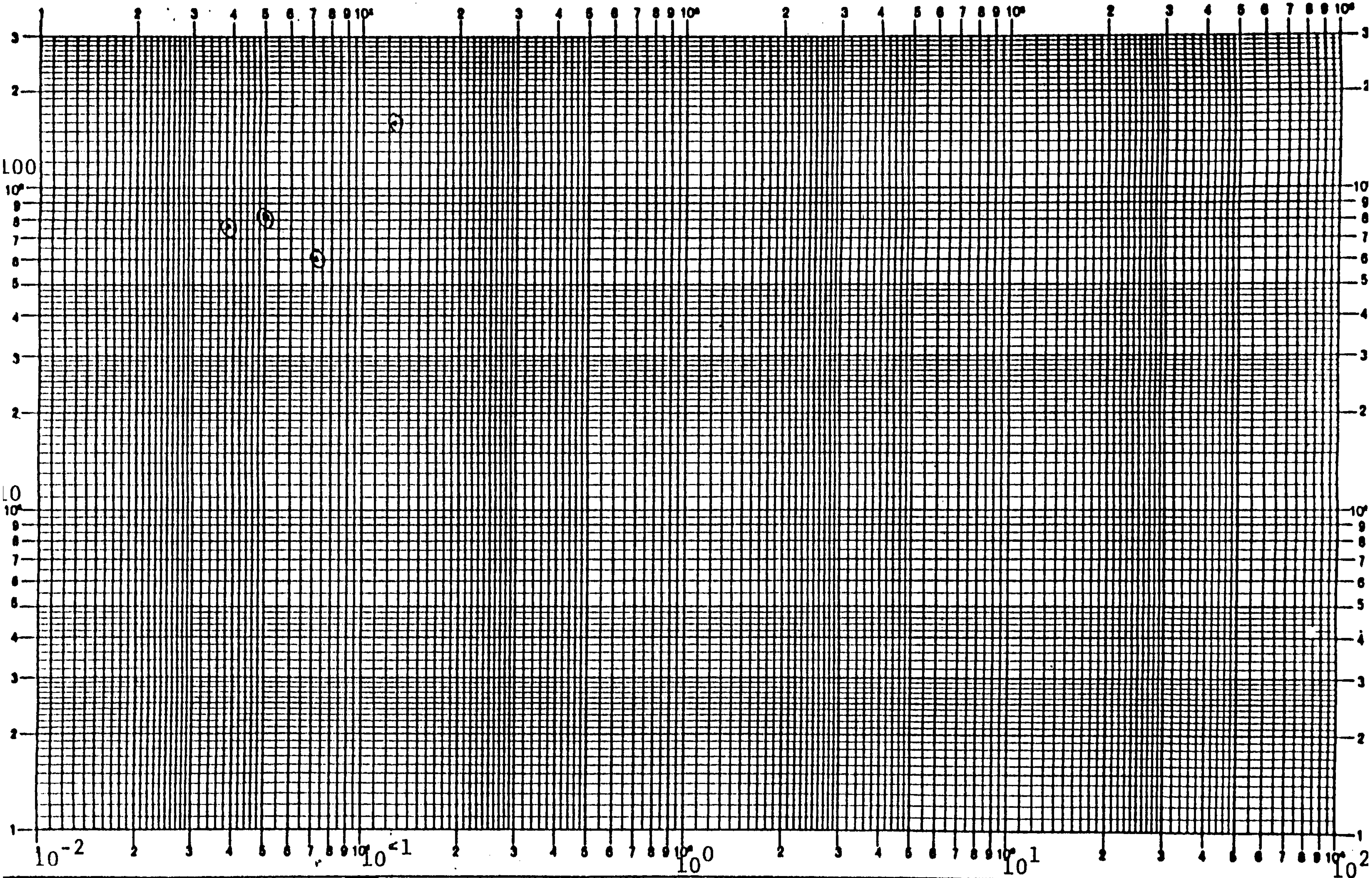
STATION I-11 AMT-MT Wave Period BEOWAWE PROSPECT JOB #811



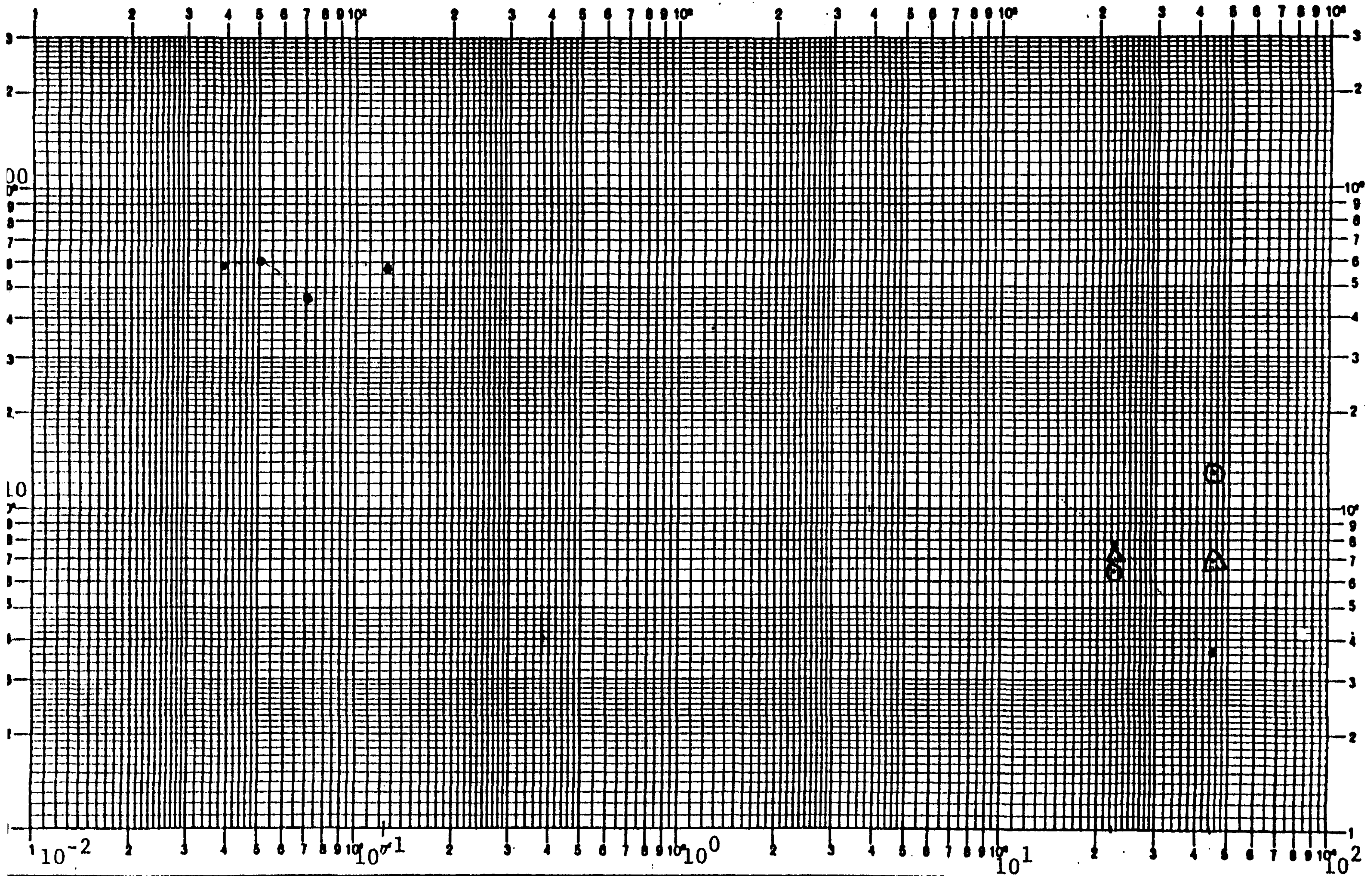
STATION Q-15 AMT-MT

Wave Period

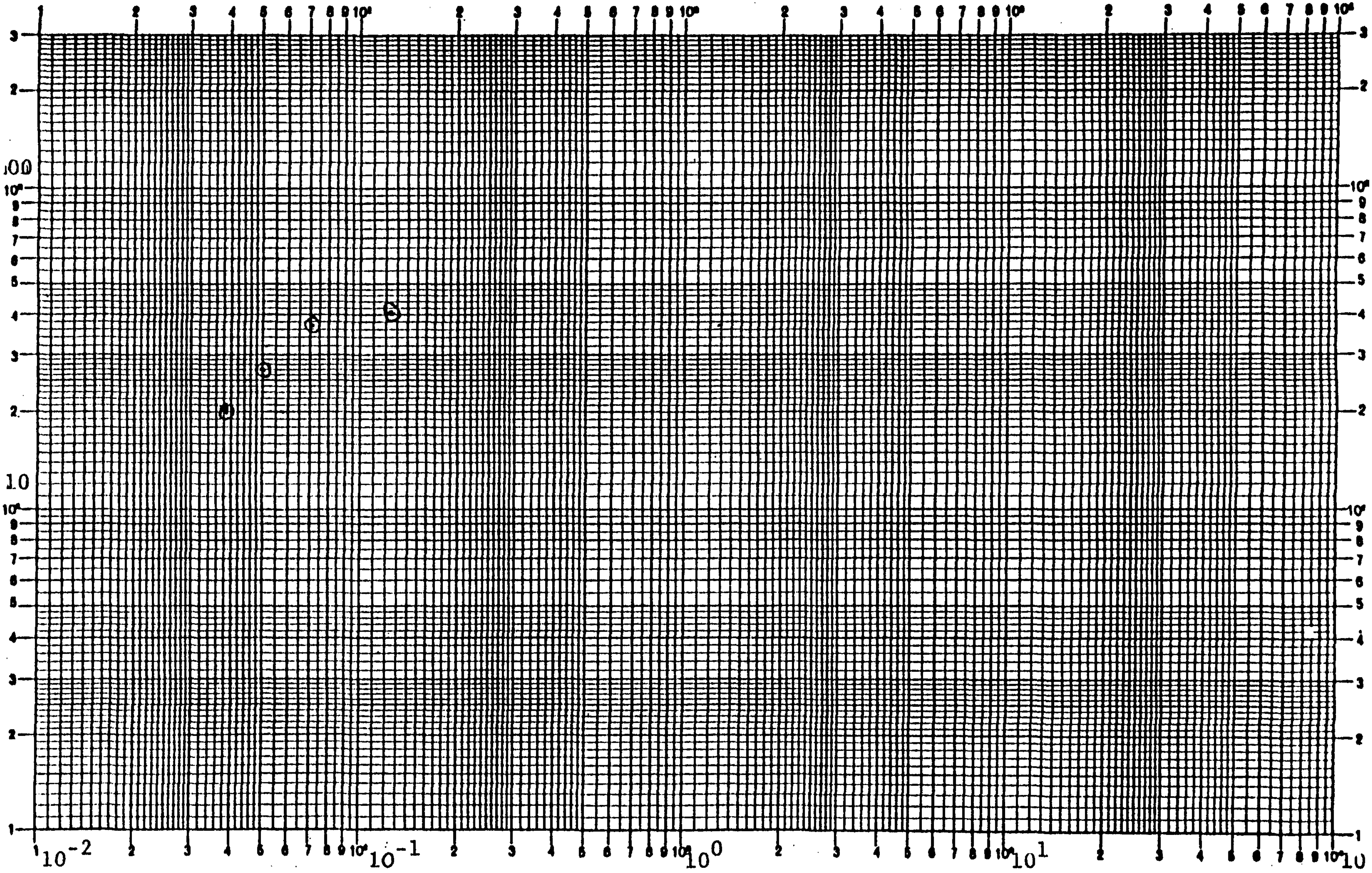
BEOWAWE PROSPECT JOB #811



STATION R-11 AMT-MT Wave Period BEOWAWE PROSPECT JOB #811



STATION S-3 AMT-MT Wave Period BEOWAWE PROSPECT JOB #811



STATION S-5 AMT-MT **Wave Period** BEOWAWE PROSPECT JOB #811

APPENDIX IV

GRAVITY SURVEY DATA

GRAVITY SURVEY DATA
BEOWAWE PROSPECT

STA. NUMBER	LATITUDE (d,m,s)	ELEV. (ft)	OBSERVED GRAVITY (mgal)	TERRAIN CORR. (mgal)	REDUCED GRAVITY (mgal)	THEORETICAL GRAVITY (mgal)	BOUGUER ANOMALY (mgal)
A15	40, 31, 23	4743.4	979756.2	.2	980040.7	980227.0	-186.3
B14	40, 31, 24	4959.9	979743.1	.5	980041.0	980227.0	-186.1
B15	40, 31, 34	4795.1	979753.3	.1	980040.9	980227.3	-186.4
C14	40, 31, 37	5076.4	979736.3	.5	980041.1	980227.4	-186.2
C15	40, 31, 48	4839.9	979750.9	.2	980041.3	980227.6	-186.3
D7	40, 31, 02	5033.0	979736.6	.2	980038.5	980226.5	-188.0
D11	40, 31, 25	4953.5	979743.7	.1	980040.8	980227.1	-186.3
D14	40, 31, 48	5079.1	979735.9	.5	980040.9	980227.6	-186.8
D15	40, 31, 59	4902.6	979746.9	.3	980041.1	980227.9	-186.8
E05	40, 31, 02	5111.0	979732.9	.1	980039.4	980226.5	-187.1
E07	40, 31, 13	5069.3	979734.8	.1	980038.9	980226.8	-187.9
E09	40, 31, 26	5019.9	979737.6	.1	980038.7	980227.1	-188.4
E11	40, 31, 38	4999.0	979741.4	.1	980041.2	980227.4	-186.2
E13	40, 31, 48	5057.8	979738.4	.4	980042.1	980227.6	-185.6
E14	40, 31, 54	5215.9	979727.8	.7	980041.2	980227.8	-186.6
E15	40, 32, 14	4977.3	979743.7	.4	980042.5	980228.3	-185.8
E16	40, 32, 23	4822.4	979753.2	.2	980042.6	980228.5	-185.9
F05	40, 31, 13	5157.7	979730.7	.2	980040.1	980226.8	-186.7
F07	40, 31, 27	5114.8	979733.0	.1	980039.7	980227.1	-187.4
F09	40, 31, 38	5064.8	979735.3	.1	980039.0	980227.4	-188.4
F11	40, 31, 54	5051.4	979738.6	.1	980041.5	980227.8	-186.2
F13	40, 32, 02	5098.9	979736.6	.5	980042.8	980228.0	-185.2
F14	40, 32, 14	5218.8	979728.7	.7	980042.3	980228.3	-186.0
F15	40, 32, 23	4993.3	979742.9	.4	980042.7	980228.5	-185.8
F16	40, 32, 35	4872.0	979750.3	.2	980042.6	980228.8	-186.2
G05	40, 31, 25	5161.4	979731.4	.2	980041.1	980227.1	-186.0
G07	40, 31, 38	5153.6	979731.0	.1	980040.1	980227.4	-187.3
G09	40, 31, 50	5111.2	979733.5	.2	980040.1	980227.7	-187.6
G11	40, 32, 03	5080.9	979736.6	.1	980041.3	980228.0	-186.7
G13	40, 32, 13	5085.1	979737.9	.4	980043.2	980228.3	-185.1
G14	40, 32, 24	5343.7	979720.7	.9	980042.0	980228.5	-186.6
G15	40, 32, 35	5031.4	979740.7	.6	980043.0	980228.8	-185.8
G16	40, 32, 47	4917.1	979747.9	.3	980043.0	980229.1	-186.1
H04	40, 31, 28	5275.6	979725.0	.2	980041.5	980227.1	-185.6
H05	40, 31, 38	5259.7	979725.5	.2	980041.0	980227.4	-186.4
H07	40, 31, 42	5204.8	980227.5	.5	980540.0	980227.5	+312.5
H09	40, 32, 03	5161.7	979731.4	.1	980041.0	980228.0	-187.0
H11	40, 32, 16	5134.3	979733.7	.2	980041.7	980228.3	-186.6
H13	40, 32, 24	5137.2	979735.4	.4	980043.8	980228.5	-184.7
H14	40, 32, 35	5404.5	979717.6	.9	980042.5	980228.8	-186.3
H15	40, 32, 47	5039.2	979740.6	.5	980043.2	980229.1	-185.9
H16	40, 32, 58	4971.2	979745.2	.4	980043.6	980229.4	-185.8
H17	40, 33, 04	4922.8	979746.3	.2	980041.6	980229.5	-187.9
I03	40, 31, 21	5374.6	979717.7	.5	980040.5	980227.0	-186.5
I04	40, 31, 37	5279.4	979725.5	.2	980042.2	980227.4	-185.2
I05	40, 31, 49	5269.5	979725.5	.2	980041.6	980227.7	-186.1
I07	40, 32, 00	5259.0	980227.9	1.2	980544.4	980227.9	+316.5
I09	40, 32, 11	5204.9	979729.2	.1	980041.4	980228.2	-186.8
I11	40, 32, 28	5129.7	979734.4	.3	980042.2	980228.6	-186.4
I13	40, 32, 36	5215.5	979731.2	.3	980044.2	980228.8	-184.6

GRAVITY SURVEY DATA
BEOWAWE PROSPECT

STA. NUMBER	LATITUDE (d,m,s)	ELEV. (ft)	OBSERVED GRAVITY (mgal)	TERRAIN CORR. (mgal)	REDUCED GRAVITY (mgal)	THEORETICAL GRAVITY (mgal)	BOUGUER ANOMALY (mgal)
I14	40, 32, 47	5429.6	979717.4	.6	980043.6	980229.1	-185.5
I15	40, 32, 58	5272.2	979726.9	.8	980043.7	980229.4	-185.6
I16	40, 33, 02	5051.0	979740.0	.8	980043.7	980229.5	-185.8
I17	40, 33, 16	4948.4	979745.4	.2	980042.3	980229.8	-187.5
J02	40, 31, 25	5547.5	979707.9	.4	980040.9	980227.1	-186.2
J03	40, 31, 33	5430.3	979715.1	.5	980041.2	980227.3	-186.1
J04	40, 31, 48	5325.9	979723.6	.4	980043.3	980227.6	-184.3
J05	40, 32, 00	5341.6	979721.6	.3	980042.1	980227.9	-185.8
J07	40, 32, 12	5348.6	979720.8	.2	980041.7	980228.2	-186.6
J09	40, 32, 21	5257.0	979725.8	.1	980041.1	980228.5	-187.3
J11	40, 32, 35	5172.7	979732.0	.2	980042.3	980228.8	-186.5
J13	40, 32, 46	5280.2	979727.4	.3	980044.3	980229.1	-184.8
J14	40, 32, 59	5552.5	979708.9	.8	980042.6	980229.4	-186.8
J15	40, 33, 10	5306.5	979724.9	.8	980043.9	980229.7	-185.8
J16	40, 33, 14	5101.2	979736.7	.2	980042.8	980229.8	-187.0
J17	40, 33, 24	5032.9	979740.8	.5	980043.1	980230.0	-187.0
K02	40, 31, 46	5626.3	979703.1	1.1	980041.5	980227.6	-186.1
K03	40, 31, 50	5495.7	979712.6	.9	980043.0	980227.7	-184.7
K04	40, 32, 00	5425.8	979717.5	.3	980043.0	980227.9	-184.9
K05	40, 32, 12	5434.4	979716.3	.3	980042.5	980228.2	-185.8
K07	40, 32, 26	5318.1	979723.1	.2	980042.1	980228.6	-186.4
K09	40, 32, 36	5355.7	979719.5	.2	980040.8	980228.8	-188.0
K13	40, 32, 59	5381.1	979721.9	.5	980045.0	980229.4	-184.4
K14	40, 33, 10	5504.1	979713.7	.8	980044.5	980229.7	-185.2
K15	40, 33, 20	5392.4	979719.1	.7	980043.1	980229.9	-186.8
K16	40, 33, 25	5156.0	979733.9	.3	980043.3	980230.0	-186.7
K17	40, 33, 38	5197.6	979730.8	.7	980043.1	980230.4	-187.2
L02	40, 31, 50	5736.9	979696.7	1.2	980041.8	980227.7	-185.8
L04	40, 32, 14	5458.7	979716.3	.4	980043.9	980228.3	-184.3
L05	40, 32, 24	5394.6	979720.4	.2	980044.0	980228.5	-184.5
L07	40, 32, 36	5327.6	979723.3	.2	980042.9	980228.8	-185.9
L09	40, 32, 45	5253.1	979730.8	.2	980046.0	980229.0	-183.1
L11	40, 32, 57	5225.8	979730.7	.3	980044.3	980229.3	-185.1
L13	40, 33, 10	5425.0	979719.3	.5	980045.1	980229.7	-184.6
L14	40, 33, 17	5805.3	979691.4	1.5	980040.9	980229.8	-188.9
L15	40, 33, 20	5752.4	979694.7	.6	980040.2	980229.9	-189.7
L16	40, 33, 37	5239.5	979729.4	.3	980043.8	980230.3	-186.5
L17	40, 33, 50	5323.7	979723.6	.5	980043.3	980230.7	-187.4
M02	40, 32, 00	5681.0	979700.8	.8	980042.2	980227.9	-185.7
M04	40, 32, 25	5586.7	979707.6	1.2	980043.7	980228.6	-184.9
M05	40, 32, 35	5527.5	979711.9	.5	980043.8	980228.8	-185.0
M07	40, 32, 51	5466.0	979714.8	.1	980042.6	980229.2	-186.6
M09	40, 33, 02	5370.9	979721.4	.3	980043.7	980229.5	-185.7
M11	40, 33, 11	5267.0	979729.5	.2	980045.5	980229.7	-184.2
M13	40, 33, 26	5392.9	979721.9	1.0	980046.2	980230.1	-183.8
M14	40, 33, 38	5797.6	979693.8	3.0	980044.4	980230.4	-186.0
M15	40, 33, 47	5493.2	979714.4	.9	980044.6	980230.6	-186.0
M16	40, 33, 47	5500.5	979712.3	.5	980042.6	980230.6	-188.0
M17	40, 34, 00	5232.5	979730.6	1.3	980045.6	980230.9	-185.3
M18	40, 34, 34	5226.8	979729.3	1.5	980044.1	980231.7	-187.6

GRAVITY SURVEY DATA
BEOWAWE PROSPECT

STA. NUMBER	LATITUDE (d,m,s)	ELEV. (ft)	OBSERVED GRAVITY (mgal)	TERRAIN CORR. (mgal)	REDUCED GRAVITY (mgal)	THEORETICAL GRAVITY (mgal)	BOUGUER ANOMALY (mgal)
N02	40, 32, 15	5128.4	979732.4	1.2	980041.0	980228.3	-187.3
N03	40, 32, 26	5120.2	979733.6	1.9	980042.5	980228.6	-186.1
N05	40, 32, 49	5650.8	979703.2	1.2	980043.2	980229.1	-185.9
N06	40, 32, 53	5557.0	979710.3	.2	980043.7	980229.2	-185.5
N07	40, 32, 59	5511.8	979713.1	.7	980044.2	980229.4	-185.2
N08	40, 33, 03	5492.6	979713.9	.4	980043.6	980229.5	-185.9
N09	40, 33, 11	5502.2	979714.3	.5	980044.6	980229.7	-185.1
N10	40, 33, 19	5361.7	979724.8	.5	980046.8	980229.9	-183.1
N11	40, 33, 21	5266.8	979730.9	.3	980047.0	980229.9	-183.0
N12	40, 33, 29	5120.8	979740.1	.4	980047.5	980230.1	-182.6
N13	40, 33, 36	5279.7	979729.9	1.9	980048.4	980230.3	-181.9
N14	40, 33, 47	5519.7	979713.9	2.5	980047.3	980230.6	-183.3
N15	40, 33, 59	5303.9	979728.1	.7	980046.8	980230.9	-184.1
N16	40, 34, 04	5161.4	979735.1	.5	980045.0	980231.0	-186.0
N17	40, 34, 10	5129.6	979736.9	.8	980045.2	980231.2	-186.0
N18	40, 34, 23	4884.1	979753.3	.9	980047.0	980231.5	-184.5
O01	40, 32, 13	5196.0	979730.0	2.2	980043.7	980228.3	-184.6
O02	40, 32, 25	5001.6	979742.0	1.4	980043.2	980228.6	-185.3
O03	40, 32, 39	4962.2	979745.5	.9	980043.9	980228.9	-185.0
O04	40, 32, 52	4983.5	979743.8	2.5	980045.1	980229.2	-184.2
O07	40, 33, 14	5603.7	979706.9	.7	980043.6	980229.8	-186.2
O08	40, 33, 17	5448.3	979719.0	.2	980045.8	980229.8	-184.0
O09	40, 33, 23	5452.5	979719.0	.8	980046.7	980230.0	-183.3
O10	40, 33, 29	5412.2	979721.5	.8	980046.8	980230.1	-183.4
O11	40, 33, 35	5384.5	979723.0	.7	980046.5	980230.3	-183.8
O12	40, 33, 39	5276.5	979729.7	.9	980047.0	980230.4	-183.4
O13	40, 33, 46	5313.8	979726.8	3.0	980048.4	980230.6	-182.2
O14	40, 33, 57	5316.8	979727.5	1.5	980047.8	980230.8	-183.1
O15	40, 34, 05	5238.4	979732.2	.6	980046.9	980231.0	-184.1
O16	40, 34, 10	5030.1	979743.6	.3	980045.5	980231.2	-185.6
O17	40, 34, 31	4905.2	979750.4	1.9	980046.4	980231.7	-185.3
O18	40, 34, 43	4706.2	979763.0	.7	980045.8	980232.0	-186.1
P01	40, 32, 25	5073.2	979739.2	.9	980044.3	980228.6	-184.3
P02	40, 32, 35	4994.5	979744.0	.7	980044.2	980228.8	-184.6
P03	40, 32, 48	4974.0	979746.4	.6	980045.2	980229.1	-184.0
P04	40, 33, 00	4974.9	979746.0	1.1	980045.4	980229.4	-184.0
P05	40, 33, 11	4909.5	979749.9	1.4	980045.7	980229.7	-184.0
P06	40, 33, 16	5047.8	979740.7	.5	980043.8	980229.8	-186.0
P07	40, 33, 24	5524.2	979711.3	.9	980043.4	980230.0	-186.6
P08	40, 33, 28	5510.2	979713.0	.7	980044.1	980230.1	-186.1
P09	40, 33, 34	5502.9	979713.6	.9	980044.4	980230.3	-185.8
P10	40, 33, 40	5455.8	979716.1	4.3	980047.5	980230.4	-182.9
P11	40, 33, 45	5429.0	979717.5	1.1	980044.1	980230.5	-186.5
P12	40, 33, 51	5215.4	979732.4	1.5	980046.6	980230.7	-184.1
P14	40, 34, 08	4848.5	979757.3	1.3	980049.3	980231.1	-181.8
P15	40, 34, 19	4937.5	979750.6	.4	980047.1	980231.4	-184.3
P17	40, 34, 44	4683.4	979764.2	.5	980045.5	980232.0	-186.5
Q01	40, 32, 36	5040.5	979742.3	.4	980044.9	980228.8	-183.9
Q02	40, 32, 47	5038.4	979743.1	.3	980045.5	980229.1	-183.6
Q03	40, 32, 58	5004.6	979745.6	.3	980045.9	980229.4	-183.4

GRAVITY SURVEY DATA
BEOWAWE PROSPECT

STA. NUMBER	LATITUDE (d,m,s)	ELEV. (ft)	OBSERVED GRAVITY (mgal)	TERRAIN CORR. (mgal)	REDUCED GRAVITY (mgal)	THEORETICAL GRAVITY (mgal)	BOUGUER ANOMALY (mgal)
Q04	40, 33, 18	4925.1	979749.8	.5	980045.6	980229.7	-184.1
Q05	40, 33, 25	5187.2	979733.5	2.0	980046.5	980230.0	-183.6
Q06	40, 33, 30	5179.1	980230.2	1.7	980541.4	980230.2	+311.2
Q07	40, 33, 37	4930.1	979749.9	.4	980045.9	980230.3	-184.5
Q08	40, 33, 41	5080.5	979739.4	.4	980044.4	980230.4	-186.0
Q09	40, 33, 47	4918.5	979749.3	.6	980044.8	980230.6	-185.8
Q10	40, 33, 52	4867.4	979752.6	1.8	980046.2	980230.7	-184.5
Q11	40, 33, 57	4821.9	979755.3	.7	980045.1	980230.8	-185.7
Q12	40, 34, 04	4805.0	979757.5	1.0	980046.6	980231.0	-184.4
Q13	40, 34, 07	4821.5	979757.4	1.3	980047.8	980231.1	-183.3
Q14	40, 34, 23	4719.3	979764.2	.7	980047.9	980231.5	-183.6
Q15	40, 34, 32	4782.1	979761.0	.9	980048.6	980231.7	-183.1
Q16	40, 34, 43	4677.1	979765.4	1.2	980046.0	980232.0	-186.0
Q17	40, 34, 56	4671.9	979765.1	.9	980046.1	980232.3	-186.2
R01	40, 32, 48	5119.8	979738.9	.9	980046.7	980229.1	-182.4
R02	40, 32, 59	5067.1	979742.0	.2	980046.0	980229.4	-183.4
R03	40, 33, 11	5003.2	979746.4	.1	980046.5	980229.7	-183.2
R04	40, 33, 24	4912.2	979749.8	.2	980044.5	980230.0	-185.5
R05	40, 33, 37	4880.6	979752.7	1.4	980046.7	980230.3	-183.6
R07	40, 33, 45	4841.5	979754.9	.2	980045.3	980230.5	-185.2
R09	40, 33, 59	4816.3	979755.9	.4	980045.0	980230.9	-185.8
R11	40, 34, 08	4764.9	979758.9	.7	980045.3	980231.1	-185.8
R13	40, 34, 19	4762.2	979760.1	.6	980046.2	980231.4	-185.2
R14	40, 34, 34	4698.9	979765.5	.3	980047.5	980231.7	-184.2
R15	40, 34, 41	4699.4	979766.4	.9	980049.0	980231.9	-182.9
R16	40, 34, 55	4678.1	979766.2	.2	980046.9	980232.3	-185.4
S02	40, 33, 12	5075.3	979742.5	.1	980046.9	980229.7	-182.8
S03	40, 33, 24	4989.4	979747.6	.1	980046.9	980230.0	-183.1
S04	40, 33, 36	4909.9	979752.0	.1	980046.5	980230.3	-183.8
S05	40, 33, 50	4838.7	979756.3	.4	980046.8	980230.7	-183.9
S07	40, 33, 59	4814.4	979757.4	.4	980046.5	980230.9	-184.4
S09	40, 34, 09	4780.6	979759.0	.5	980046.1	980231.1	-185.0
S11	40, 34, 21	4744.0	979760.5	.7	980045.6	980231.4	-185.8
S13	40, 34, 35	4714.6	979763.7	.4	980046.7	980231.8	-185.0
S14	40, 34, 43	4695.5	979766.0	.2	980047.8	980232.0	-184.2
S15	40, 34, 54	4786.5	979757.3	.4	980044.6	980232.2	-187.6
T02	40, 33, 28	5117.8	979739.0	.1	980046.0	980230.1	-184.2
T03	40, 33, 35	4986.5	979747.9	.1	980047.0	980230.3	-183.3
T04	40, 33, 47	4893.5	979753.0	.2	980046.6	980230.6	-184.0
T05	40, 34, 00	4843.1	979756.3	.2	980046.8	980230.9	-184.1
T07	40, 34, 09	4804.4	979758.4	.4	980046.9	980231.1	-184.2
T09	40, 34, 20	4771.6	979759.7	.3	980046.1	980231.4	-185.3
T11	40, 34, 33	4740.5	979761.1	.7	980046.0	980231.7	-185.7
T13	40, 34, 43	4722.2	979763.1	.1	980046.3	980232.0	-185.6
T14	40, 34, 55	4703.5	979765.8	.0	980047.8	980232.3	-184.4
U02	40, 33, 36	5060.7	979742.7	.3	980046.4	980230.3	-183.9
U03	40, 33, 47	4978.1	979748.3	.3	980047.1	980230.6	-183.5
U04	40, 33, 58	4904.4	979752.8	.1	980047.0	980230.9	-183.9
U05	40, 34, 11	4845.5	979756.2	.6	980047.3	980231.2	-183.9
U07	40, 34, 21	4802.9	979758.7	.1	980046.8	980231.4	-184.6

GRAVITY SURVEY DATA
BEOWAWE PROSPECT

STA. NUMBER	LATITUDE (d,m,s)	ELEV. (ft)	OBSERVED GRAVITY (mgal)	TERRAIN CORR. (mgal)	REDUCED GRAVITY (mgal)	THEORETICAL GRAVITY (mgal)	BOUGUER ANOMALY (mgal)
U09	40, 34, 32	4770.4	979760.3	.1	980046.4	980231.7	-185.3
U11	40, 34, 45	4747.0	979761.5	.8	980046.9	980232.0	-185.1
V02	40, 33, 48	5052.3	979744.0	.2	980047.1	980230.6	-183.5
V03	40, 34, 00	4979.8	979748.3	.2	980047.0	980230.9	-183.9
V04	40, 34, 10	4915.0	979752.4	.2	980047.2	980231.2	-183.9
V05	40, 34, 23	4851.0	979756.5	.3	980047.6	980231.5	-183.9
V07	40, 34, 33	4804.9	979759.2	.1	980047.4	980231.7	-184.3
V09	40, 34, 46	4779.0	979760.9	.1	980047.6	980232.0	-184.5
V11	40, 35, 58	4759.8	979761.7	.2	980047.3	980233.8	-186.5
W03	40, 34, 10	5030.0	979745.6	.5	980047.7	980231.2	-183.5
W04	40, 34, 23	4931.8	979751.8	.2	980047.7	980231.5	-183.8
W05	40, 34, 35	4862.2	979756.4	.3	980048.2	980231.8	-183.6
W07	40, 34, 48	4805.1	979760.1	.1	980048.3	980232.1	-183.8
W09	40, 35, 58	4784.7	979761.3	.0	980048.2	980233.8	-185.6
W11	40, 35, 10	4777.4	979761.4	.3	980048.1	980232.6	-184.5
X03	40, 34, 21	5072.8	979743.1	.3	980047.5	980231.4	-183.9
X04	40, 34, 33	4941.2	979752.2	.4	980048.8	980231.7	-182.9
X05	40, 34, 45	4905.3	979754.5	.2	980048.7	980232.0	-183.3
X07	40, 35, 57	4828.4	979759.5	.1	980049.1	980233.8	-184.7
X09	40, 35, 09	4804.1	979760.9	.1	980049.0	980232.6	-183.6
X11	40, 35, 20	4800.6	979761.0	.1	980049.0	980232.9	-183.9
Y03	40, 34, 32	5158.2	979739.0	.5	980048.8	980231.7	-182.9
Y04	40, 34, 34	5042.6	979746.2	.4	980048.9	980231.7	-182.9
Y05	40, 34, 55	4978.1	979751.1	.1	980049.7	980232.3	-182.6
Z03	40, 34, 42	5263.1	979733.0	.6	980049.1	980231.9	-182.8
Z04	40, 34, 55	5154.9	979739.8	.6	980049.4	980232.3	-182.8
BA2	40, 32, 15	5767.7	979692.3	.8	980038.9	980228.3	-189.4

PART A

RESULTS OF THE GEOPHYSICAL SURVEYS
in the
BEOWAWE PROSPECT

SUBMITTED TO
GETTY OIL COMPANY

by

ELECTRODYNE SURVEYS
Reno, Nevada

September, 1979

Original

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INTRODUCTION

A combined ground magnetics, gravity and electrical resistivity survey was completed in the Beowawe Geysers area, Nevada, by Electrodyne Surveys of Reno, Nevada for the Getty Oil Company of Bakersfield, California. This survey was conducted during February and March of 1979. The objective of the survey was to determine areas of geothermal interest within the Beowawe Prospect and to recommend locations of drill holes to evaluate the geothermal potential of these areas. This prospect lies within T31N to T32N, R47E to R48E, and covers approximately 27 square miles of the Whirlwind Valley and the Malpais (see Plate I).

A total of 226 ground magnetics and gravity stations were occupied using a grid pattern (see Plate I) over the prospect area. The gravity data are referenced to a gravity base station located at the Lander County, Nevada, airport and are reduced to a complete Bouguer anomaly using a combined elevation-Bouguer correction factor corresponding to a density of 2.67 g/cm^3. Position and elevation control for the gravity stations were determined by a surveying crew using an electronic distance measuring device. All gravity observations were obtained with a La Coste and Romberg Model D gravimeter. The gravity and survey data is listed in Appendix IV of PART B of this report. A magnetic base recorder was used during the survey to determine magnetic field fluctuations, and these fluctuations were subsequently removed from the observed data.

Three electrical resistivity techniques were utilized because of the suspected complexity of the area. These techniques are time domain electromagnetic soundings (TDEM), magnetotelluric-audiomagnetotelluric soundings (MT-AMT), and galvanic soundings (DC). Plate II shows the locations of the 106 TDEM soundings, the 9 MT-AMT soundings and the 5 sets of modified Schlumberger (DC) soundings. Note that the TDEM and MT-AMT soundings normally occupy gravity/magnetics stations. The TDEM soundings were obtained from source bipoles 1, 3, 4, and 5, and the DC soundings from source bipoles 6A, 6B, 7, 8, and 9. An additional 9 reoccupations of TDEM soundings from various source combinations were also completed to help determine lateral resistivity effects upon the TDEM soundings.

The TDEM sounding data, the galvanic (DC) sounding curves, and the MT-AMT sounding curves are in Appendices I, II, and III, PART B of this report. Over seventy-five percent of the data acquisition was augmented by helicopter support due to the rugged terrain of the area, and the poor field conditions (muddy) during the late winter months.

GEOLOGIC SUMMARY

The only available geologic description of this area is a report on the Geology of the Frenchie Creek Quadrangle, (Muffler, 1964). This quadrangle is directly southeast of the prospect area.

The Frenchie Creek quadrangle was probably the site of carbonate deposition in the early Paleozoic time with eugeosynclinal deposition occuring tens of miles to the west. During the Antler Orogeny (late Devonian to early Pennsylvanian) the western assemblage was thrust over the eastern assemblage of carbonate rocks. Near-shore marine conglomerates and dolomites were unconformably deposited on Ordovician eugeosynclinal rocks during the late Pennsylvanian or Permian. This late Paleozoic deposition may have continued into the early Mesozoic when extrusion of silicic ash-flow tuffs, and rhyodocite and rhyolite flows occurred (Jurassic?) and intrusion of a few related rhyolite (?) plugs.

Diorite to alaskite plutons were intruded during the early Cretaceous (?) and accompanied by intense local deformation and followed by hydrothermal alteration. Uplift of the area may have occurred in early Tertiary time. In Cenozoic time rhyodacite flows were extruded and diabase dikes were emplaced in the Cortez Mountains (approximately 15 miles southeast of the prospect area) during the Pliocene. Normal faulting also began during the Cenozoic and produced the high angle, Beowawe-Geysers fault. The resulting Basin and Range type fault block is tilted to the southeast.

Most of the fault block within the prospect is covered by extrusive volcanic rocks (rhyodacite?) with the exception of western assemblage sedimentary rocks that occur in the vicinity of S15, T32N, and R48E. A south-southeast trending ridge extends through this assemblage of rocks from the northern portion of the Shoshone Range and terminates near the southern border of the prospect. Hot springs and man-made geysers (steam wells) occur along the Beowawe Geysers fault scarp in S17, T32N, and R47E, with less active geothermal pools occurring north-northwest of the geysers. The average maximum temperature determined during the drilling of the magma wells along the fault scarp was 210° C. Much lower temperatures were encountered 1,200 feet south of the fault scarp (<100°C). Estimated reservoir temperatures determined from the hot springs are between 196° and 252° C (Hose and Taylor, 1974). A horst-type structure occurs southwest of the geysers in the adjacent section and extends along the fault scarp. The existence of geothermal activity in the area is evident as well as a very complex structural setting.

GRAVITY SURVEY RESULTS

The complete Bouguer gravity map is given on Plate III with relative apparent high and low density areas noted. A simple Bouguer map of the Shoshone Range area is given on Figure 1. The gravity anomalies determined by this survey are complex and generally trend along a northwest-southeast or southwest-northeast direction. The prospect has been divided into six areas which have diagnostic gravity character. A discussion of each area follows.

Area I - Sections 1, 2, 11, 12, 13, 14, and 23, T31N, R46E; and Sections 6 and 7, T31N, R48E.

The depths of the Whirlwind Valley gradually decreases to the west and north in this area as indicated by the general increase in the gravity values. This graben should be shallow as indicated by the small amplitude of the gravity anomaly ($\sim$1.4 mgals).

Area II - Sections 4, 5, 8, and 9, T31N, R48E.

East of Area I a gravity minimum of approximately 2.2 mgals occurs and is interpreted as a graben structure. Closure of the anomaly to the south and east is accomplished by a set of two maximum gravity anomalies (Area VI) associated with the front range fault and a northwest trending ridge. The larger of the two maximum gravity anomalies may be due in part to the extension of the ridge beneath the valley floor; consequently, the western portion of Whirlwind Valley may be hydraulically isolated from the eastern portion of the basin.

Area III - Sections 24 and 25, T32N, R47E, and Sections 19, 20, 29, and 30, T31N, R48E.

Within this area there are alternating gravity maximum and minimum anomalies elongated in a northeast-southwest direction. The gravity relief in this area exceeds 2 mgals and occurs within 4,000 feet of horizontal distance. The relatively large amplitude and high frequency content of the major gravity minimum is indicative of a shallow volume of low density material extending along the front range fault. Igneous intrusions along this portion of the fault could explain this unusual anomaly, but more detailed information would be required to be sure.

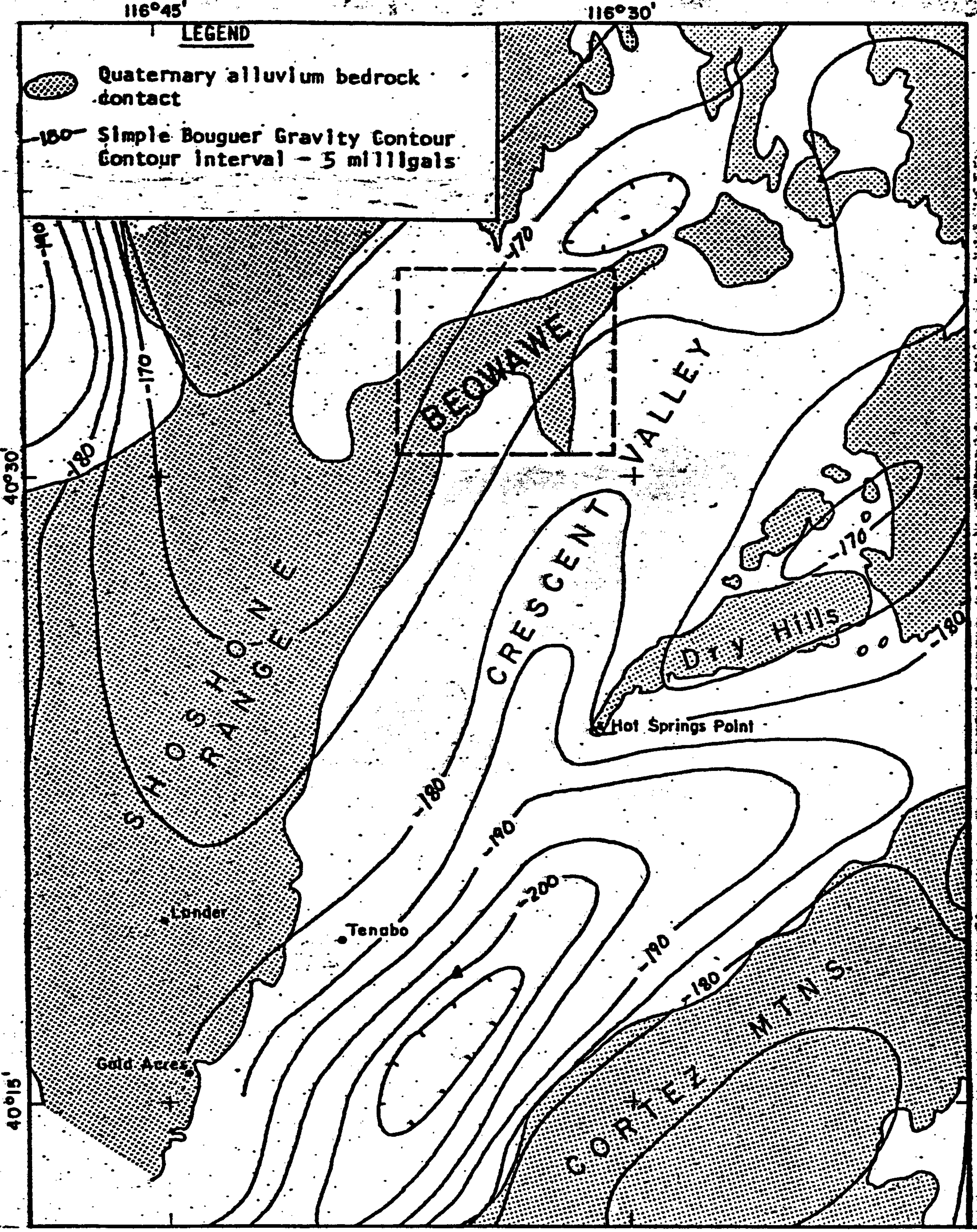

Figure 1. Simple Bouguer gravity map (after Mabey, 1964) of the Crescent Valley. Scale is 1:250,000.

Area IV Sections 28, 33, and 34, T31N, R48E.

In this area, a small graben feature such as seen in Area II is found. Its axis is also interpreted to be in the northwest direction. If these two graben features were part of a single graben in the geologic past, then a strike-slip fault could be postulated along the major fault scarp through the prospect.

Area V. Sections 11, 12, 14, 15, 23, and 26, T31B, R48E, and the area to the east.

The decrease in the gravity to the east indicates a deepening of a graben structure in that direction. The front range fault, and the northwest trending ridge, border this graben to the northwest and southwest.

Area VI The remaining prospect area surrounded by the other five areas.

Geologically and gravimetrically, this is the most complex area within the prospect. This area extends northeast and east along the front range fault from the monadnock structure (Sec., 18, T31N, R48E) southwest of the Beowawe Geysers to the cirque-like structure in Section 15, T31N, R48E.

The gravity maximum associated with the monadnock suggests that the structure has lateral subsurface extent to the north, west and and east.

A set of two maximum gravity anomalies exist a mile east of the monadnock and south of the Geysers (Sec. 16, 17 and 10). These anomalies trend in a northeast direction with the second and larger of the two anomalies extending also in a northwest direction. As mentioned above, this extension of the anomaly into Whirlwind Valley is associated with the northwest trending ridge and indicates an extension of the ridge beneath the valley to the Shoshone Range. The topography northwest of the gravity anomaly supports this idea.

A moderate density high, trending north-northwest to south-southeast, is found in Sections 22 and 27 just to the west of the ridge of lava flows. A density low with relatively high contrast (4 to 5 5 mgals) is found in the southern half of Section 15. This low corresponds closely to an eroded cirque-like feature. It is possible that this feature is an acid volcanic (granite) intrusive. If this is the case, it should be of much greater age than the basic Tertiary intrusives of the area. North of the gravity minimum is an outcrop of Paleozoic western assemblage rocks which have an average density of $2.6gm/cm^3$ (Mabey, 1964) which is less than the density of the Tertiary basalts which cover most of the area. The density contrast between the two could explain the anomaly, bu but not the maximum gravity anomaly that is also associated with the Paleozoic outcrop.

In conclusion, the data suggests two significant structural control lineations in the prospect area:

1. The northeast to east-northeast Beowawe Geysers fault as evidenced by the surface fault scarp through Sections 16, 17 and 19, and

2. A north-northwest trending lineation, which may be a normal fault dipping west at the western edge of the ridge through Sections 22, 27 and 16.

These two major lineations intersect in Section 16, which would then be a hub of tectonic activity in the area. The present steam wells or so-called geysers are located to the west in Section 17.

MAGNETIC SURVEY RESULTS

The magnetic survey map (Plate IV) shows a sectioning of the prospect area similar to the gravity map discussed above. The significant structural control lineations are shown on the map.

It is noteworthy that there are several single-point anomalies that vary by over 500 gammas within the prospect area. The regional aeromagnetic map of the Crescent Valley (Figure 2) does not indicate any such variations; therefore, these anomalies must be very local effects, and are not necessarily caused by geologic noise.

Description of the magnetic anomalies in the areas indicated in the gravity discussion are as follows:

Area I In a fashion similar to the gravity values, the magnetic values generally increase towards the Shoshone Range (west and northwest) indicating a shallowing of the basin as expected. The two maximum magnetic anomalies in this area (Sec. 12, and Sec. 23, T31N, R47E) overlie the two maximum gravity anomalies and suggest anomalous decreases in the basin depths in these two areas.

Areas II and IV Both of the possible northwest-trending graben strucutures of these two areas occur where there is a minimum of magnetic variation (less than 250 gammas chanage). A explanation for this diminished magnetic variation is that there is a considerable amount of sediments deposited within each graben (more than 2,500 feet). Deep basins often exhibit a lack of magnetic variation.

Area III A series of alternating maximum and minimum anomalies elongated in a northeasterly direction are located in this area. Both the magnetic and gravity anomalies occur in the same area and trend in the same direction, but the minimum magnetic and maximum gravity anomalies are associated and vice versa. The Malpais is composed of a series of rotated fault blocks with the maximum magnetic values being associated with the crest of the fault blocks, and the minimum magnetic anomalies associated with the alluvial filled troughs created by the rotated fault blocks. A distortion of the direction of the maximum magnetic anomaly occurs in Sections 17, and 18, T31N, R47E, and is probably due to the effect of the thermal alteration of the rocks in the area by the thermal springs at the Beowawe Geysers.

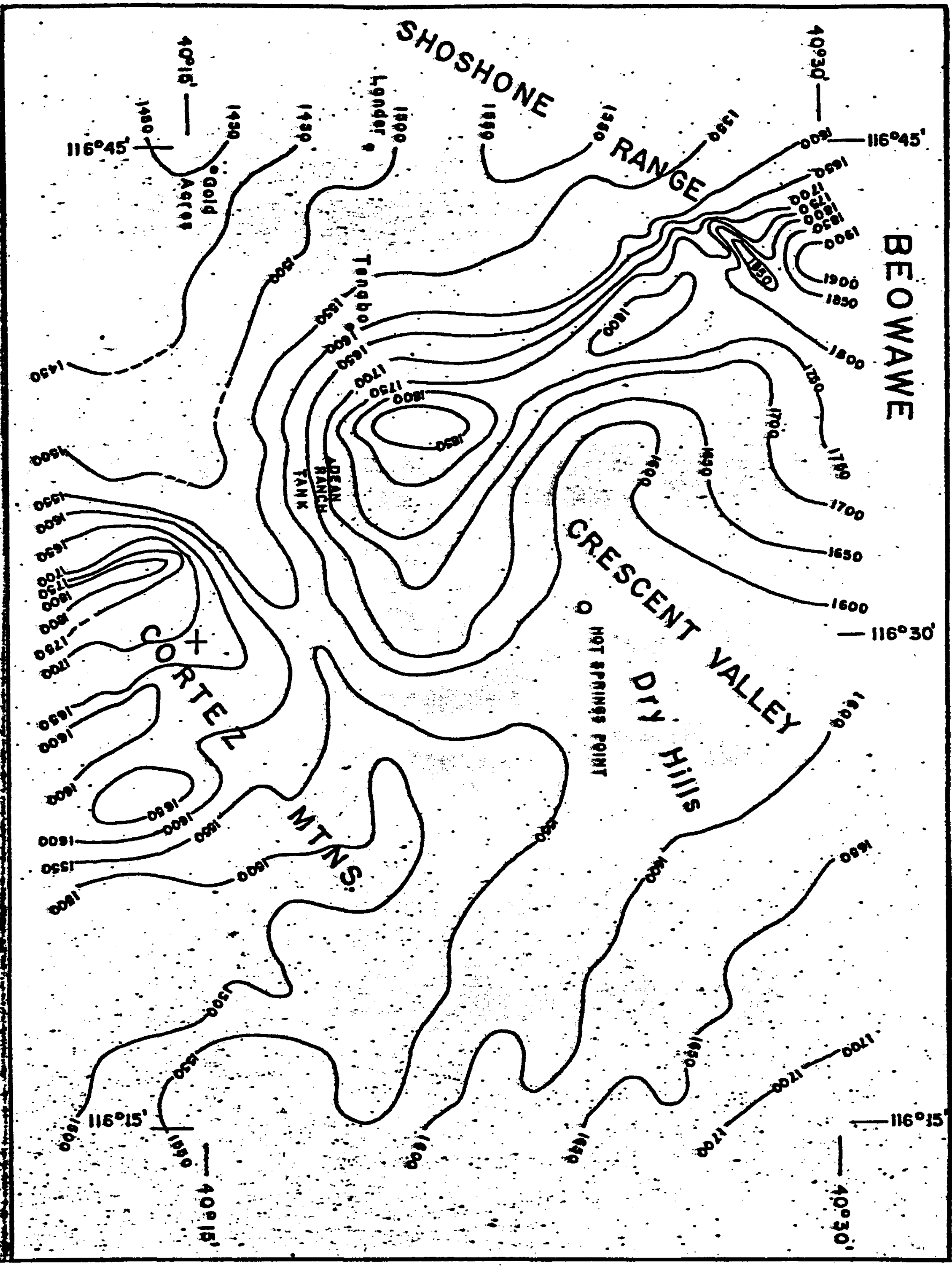

Figure 2. Aeromagnetic map of the Dry Hills and Central Crescent Valley area. Magnetic contours show total intensity magnetic field of the earth in gamma. Contour interval is 50 gammas. Scale is 1:250,000 (after Philbin, et.al,, 1963).

Areas V and VI The magnetic anomalies within these two areas are controlled by the two structural control lineations (northwest-southeast and southwest-northeast) as shown in Plate IV and generally correlate with gravity anomalies of opposite sign. Three sets of maximum-minimum magnetic anomaly pairs occur along the extension of the northwest trending ridge, and nearly all the anomalies are elongated in the northeasterly direction. The central minimum anomaly is the largest of the minimum anomalies in size and amplitude and is bordered by two maximum anomalies that contain the largest positive anomaly values. The total magnetic relief is greater than 1,700 gammas. The northern maximum anomaly in Section 15, T31N, R48E, is similar in shape and location to the maximum gravity anomaly in the same section.

North of this anomaly set, the magnetic variation diminishes until nearly half-way across Whirlwind Valley, at which time the magnetic values increases. It is interesting that this lack of magnetic character is coincident with the maximum gravity anomaly. The other gravity maximum in Section 17, T31N, R48E, is coincident with a minimum magnetic anomaly, as is the monadnock structure.

Normally, maximum and minimum magnetic and gravity anomalies correlate because the low density sediments that cause the gravity lows cover and diminish the strength of the subsurface basement magnetic anomalies. One situation where this does not hold true is in areas of secondary deposition of travertine or sinter by thermal waters. Maximum gravity anomalies will be created with very little magnetic signature. This is not the situation in the vicinity of the Beowawe Geysers where magnetic character is associated with a gravity high. Previous drilling by Magma and Sierra into this anomaly (1,200 feet south of the Beowawe Geysers) produced the poorest results of their drilling program - 81 C versus 184 C just north of the magnetic low-gravity high anomaly. (Hose and Taylor, 1974). The lack of magnetic signature with the gravity anomaly east of the geysers could have geothermal significance.

The magnetic anomalies along the northwest trending ridge could be related to igneous intrusives which could act as potential heat sources in the area. The intersection of the two structure control lineations in Section 22, T31N, R48E, would become a drilling target because of the potential fracturing created by tectonic activity at the trend intersection.

ELECTRICAL RESISTIVITY SURVEY RESULTS

The galvanic (DC) resistivity soundings (Figures 1 through 6 in Appendix II, PART B) indicate that a highly variable upper geologic section exists within the prospect. The soundings to the north of the fault scarp, performed along source locations 8 and 9, indicate subsurface volcanics near the fault scarp and the monadnock near the springs. Further out in the basin, considerable thicknesses of clay alteration and playa-type deposition are expected and indicated by the low apparent resistivity values in the valley. Both of these types of deposits may be a few thousand feet thick and must be penetrated before reaching a heat conduction and/or heat convection system.

The soundings to the south of the fault scarp, performed along sources 6 and 7, indicate a very thin overburden, 100 to 200 feet of fractured flows and alluvium, which are underlain by a resistive section (assumed to correlate with competent volcanics) with thicknesses greater than a few hundred feet. There may be some lateral non-competent channels within this general resistive zone that may locally carry heat away from an areaof interest. Therefore, we recommend an initial thermal gradient (T.G.) drilling program to depths of 1,500 feet. One should expect some slow drilling through the intermediate resistive zones.

The TDEM vertical magnetic field (H_Z), horizontal electric field (E_N), scalar MT (0.02 - 0.6 Hz), and AMT measurements throughout the prospect indicate an even more complex picture than the gravity and magnetic investigations suggest. This complexity is shown by the H_Z and E_N apparent resistivity profiles (Plates V - VIII). A brief summary of the data reduction procedures is in Appendix I, PART B.

Examination of the profiles reveals that:

(1) Lateral resistivity variations are very common in the prospect area, and the inferred geoelectric structure is very complex.

(2) The apparent resistivity values encountered along the H_Z profiles are greater than the corresponding E_N values.

(3) The vertical component of the magnetic field will couple best to large, horizontal conductors and should be used as an indication of anomalous resistivity character.

(4) The E_N profiles exhibit more lateral resistivity variations and less profile-to-profile continuity than the corresponding H_Z profiles (see Profiles G, H, L, 5, and 16).

(5) The two sets of perpendicular E_N Profiles (NW-SE and SW-NE) normally exhibit opposite anomalous resistivity character, ie., stations along the NW-SE Profiles will be anomalously resistive while the same stations along the SW-NE Profiles will be anomalously conductive and vice versa (see Stations H9 through O9, Plates VIII, IX and X).

(6) Three areas within the prospect do not conform to the previous observation (#6), ie., both the E_N components (the parallel and perpendicular) at a station exhibit similar anomalous character. These three areas are the central portion of Whirlwind Valley, and the central and southern portions of the northwest extending ridge (Sec. 14, 15, 22, 23, 26, and 27, T31N, R48E; See Plate II and Plates V through X).

(7) Whirlwind Valley is generally more conductive and more laterally homogeneous than the Malpais cuesta.

(8) The significant structural control lineations observed in the gravity and magnetic data are also present in the TDEM sounding data.

(9) Anomalous conductance within the geoelectric section is encountered at depths of approximately 6,000 feet on the Malpais, with some areas displaying anomalous conductance at depths of 3,000 feet or less.

The complexity of the geoeletric structure within the Beowawe Prospect is readily shown by the large number of lateral resistivity variations which occur over short horizontal distances (less than 1,300 feet in many cases) and the different types of sounding curves determined by the TDEM soundings. Generally, the curves can be classed as two types: Q ($\rho_1>\rho_2>\rho_3$) and K ($\rho_1<\rho_2>\rho_3$) types. The Q type is the most prevalent and is indicative of a resistive overburden underlain by more conductive sediments. Because of the very obvious two and three dimensional structural relationships affecting the TDEM sounding curves, no precise curve matching techniques were employed in interpreting the data. The estimated depths and resistivities can be off by over 200% given the lack of horizontal homogeneity and would have little relevance to portions of the prospect where the geoelectric structure is not layered, but vertically standing. However, this does not alter the fact that the profiles and TDEM soundings can be used to delineate areas of anomalous structure and conductance.

Soundings such as K13 which exhibit anomalous conductance at shallow apparent depths, and which are flanked by more resistive sections, indicate the possible existence of vertically standing conductors. Such vertical structure should be related to fracturing or faulting within the subsurface with mineralization or thermal fluids along the structure providing the anomalous conductance in the zone.

Indirect evidence for the prevalence of such structure within the prospect is provided by the TDEM sounding results. The two sounding types used, the horizontal electric and vertical magnetic soundings, are sensitive to different conductive targets: the electric field soundings are more sensitive to vertical conductors than the vertical magnetic component which is more sensitive to horizontal conductors. The fact that the E_N Profiles are generally more conductive than the H_Z Profiles, and indicate more lateral resistivity variation, indicates the predominance of vertical conductors in the area. For this reason, the vertical magnetic sounding Profiles were utilized to indicate the most interesting target areas because they should differentiate better between the insignificant conductive targets (see Plate XI).

Another indication of the complexity of the geoelectric structure is shown by comparison of the E_N soundings in the two orthogonal directions. The plotted results are the horzontal electric field soundings normal to the particular profile; consequently, the sounding will be either the component parallel to the source bipole or perpendicular to it. Comparison of the individual orthogonal components at a particular site yield the results that in many portions of the prospect, a conductive anomaly determined by the northwest component of the electric field, will be a resistive anomaly as determined by the orthogonal southeast component of the electric field. This is true of the Beowawe Geysers area, the area southeast of the Geysers extending along the slope of the Malpais, and in Section 9 and 10, T31N, R48E, where the maximum gravity anomaly extends into Whirlwind Valley. These anomaly reversals are again indicative of a very complex geoelectric structure that is skewing the induced electric fields. Fortunately, the vertical magnetic field is much less affected by this skewing.

Significantly, three anomalous areas did not show a reversal of anomalies by different electric field components. The central area of Whirlwind Valley (along Profiles S, T and U) is anomalously conductive, the central area of the northwest trending ridge associated with the minimum magnetic anomaly (Sec. 14, 15, and 33, T31N, R48E) is anomalously conductive and the area bordering this anomaly to the south (Sec. 22, 23, 26, and 27, T31N, R48E) is anomalously resistive.

Verification of an anomaly by the two electric field components adds credence to its existence. The conductive anomaly within Whirlwind Valley is expected due to the alluvial fill of the valley and the existence of the Beowawe Geysers and other thermal expressions along the front range fault bordering the valley.

The lateral homogeneity of the conductive anomaly indicates that it is relatively uniform and large in size. Conductive clays and thermal waters are likely to be the cause of this anomaly.

The juxtaposition of the conductive and resistive anomaly within the northwest trending ridge is of more interest because a conductive anomaly associated with a volcanic ridge has fewer possible explanations. This anomaly will be discussed later with regard to the other geophysical anomalies.

These two anomalies, as well as most of the other anomalies determined by the resistivity survey, appear to be controlled by the structural lineations in the northeast-southwest and northwest-southeast directions as noted in the description of the gravity and magnetic anomalies. The fact that all three geophysical techniques locked onto these trends denote that they must be related to the major tectonic forces within the area, as would any geothermal activity.

The structural lineations determined by the H_z soundings are shown on Plate XI. This Plate represents the contoured apparent resistivity values determined by an apparent depth of apparoximately 2,000 meters (6,560 feet). The structural trends as determined by the horizontal electric field soundings are not significantly different.

The Beowawe Geysers area is conductive and is bordered to the northwest by a resistive anomaly of small lateral extent. The resistor may be associated with a buildup of travertine at depth, but the gravity does not lend much support to this idea. Southeast of the Geysers and the monadnock, the Malpais is characterized by relatively high apparent resistivity. Bifurcation of the resistive anomaly occurs in Section 16, T31N, R48E, by a small conductive anomaly that may be related to the much larger conductive anomaly occurring in Sections 9, 10, and 11, T31N, R48E.

Elongation of this large anomaly occurs in the southeast direction and this axis of this structural trend passes through another conductive anomaly south in Section 22, T31N, R48E. This anomaly is coincident with the conductive anomaly determined by the two electric field component soundings and it occurs at the intersection of two structural trends. Another conductive anomaly in Sections 21, 28 and 29, T31N, R48E, occurs southwest of the trend intersection. Southeast of the trend intersection is a resistive anomaly that shifts the southern extension of the northwest-southeast trend to the southwest. Generally, the apparent depth to each of these conductors approaches 6,000 feet except at the following sites: J9, K13 and Q14. At these three sites apparent depths to the conductor are less than 3,000 feet and nearby vertical conductors are expected to exist.

The total apparent conductance determined by the MT soundings are in good agreement with the TDEM data. Two of the three MT sites with the minimum conductance, F11 and L9 ($\sim$500 mhos), occur within or close to the resistive anomalies of the Malpais and the ridge.

The maximum conductance was determined in Whirlwind Valley at site 53 (890 mhos), and the maximum conductance determined south of the range fault occurs at I11 (780 mhos) on the edge of the southern conductive anomaly (see Plate XI). Given 780 mhos and a section conductance of 3 ohm-m, the depth to the base of the conductor (electrical basement) is 2,340 meters. MT sounding Q15 has the minimum determined conductance for the area (290 mhos) and yet, lies on the valley side of the range fault and within the conductive anomaly determined by the H_z TDEM soundings. This discrepancy may be explained by lateral resistivity variations within the area (the two orthogonal electric fields indicated anomaly reversals in this area).

The most interesting area within the prospect occurs at the intersection of the structural trends in Section 22, T31N, R48E. The conductive anomaly occurring at this intersection coincides with the elongated minimum magnetic anomaly that extends along the northeast-southwest structural trend. The resistive anomaly south of the intersection coincides with a maximum magnetic anomaly, and the minimum gravity anomaly occurs in the northeast quadrant created by the intersecting structural trends. This is a very complex area and one that should be investigated for geothermal potential.

The magnetic anomalies are probably due to igneous intrusives that could be related to the diabase dike emplacement in the Cortez mountains during the Pliocene. Intersection of the structural trends is a good indication of fracturing, this providing channels for water to percolate down to the intrusives. The conductive anomaly is not large in lateral extent, but one would not be expected if a fracture dominated system is encountered. The existence of the conductor astride the ridge is significant by itself. The fact that these unusual anomalous condition are coincident or in such close proximity is intriguing and certainly the result of some complex tectonic activity.

The northern conductive anomaly in Section 9, T31N, R48E, is associated with a gravity maximum but no significant magnetic expression. The extreme anisotropy exhibited by the electric field sounding indicated geoelectric complexity, but its extension into the conductive valley diminishes the enthusiasm for this anomaly.

The conductive anomaly southwest of the structural intersection occurs within Area IV and the interepreted graben structure. The conductive anomaly shape and trend differs from that expected for the graben; consequently, thickening of conductive sediments in the graben may not adequately explain the anomaly and add significance to the anomaly.

No other general comments regarding the correlation of the resistivity anomalies and the gravity and magnetic anomalies can be made ~~made~~.

SUMMARY AND RECOMMENDATIONS

Each of the three geophysical methods employed in the Beowawe Prospect; magnetics, gravity and electrical resistivity, indicate that this area is structurally very complex. That in itself is significant since large scale tectonic activity is the earmark of most important geothermal systems. The existence of hot springs occurs along the front range fault and drilling has proven the existence of high subsurface temperature (>165°C).

Areas I and II within the western portion of Whirlwind Valley (see Plate III) are not believed to be important due to their lack of any unusual geophysical character. Conductive clays and silts probably fill the basin area and provide a poor reservoir for any geothermal sources flanking the valley. No igneous intrusives were determined. More detailed gravity interpretation may yield residual gravity maximums within the valley that may be related to subsurface travertine deposition.

Area III (see Plate III) is characterized by relatively high apparent resistivity, and an alternating set of elongated northeast-southwest gravity and magnetic maximum and minimum anomalies. The minimum gravity anomaly associated with the front range fault is difficult to interpret but may be due to intrusives. The lack of a conductive resistivity anomaly diminishes interest for this area.

Area IV (see Plate III) is characterized by a minimum gravity and conductive resistivity anomaly. A general increase in the magnetic values occurs to the southwest but no major structural features is indicated by the magnetics. The orientation and shape of the resistivity anomaly differs from the inferred graben structure, so, fortunately, the conductor may not be due entirely to a thickening of the overburden. The graben may be related to the graben in Area II and thus indicating strike slip movement has occurred in the past. The resistivity trend east of Area IV indicates the same type of strike-slip movement.

The conductive anomaly is aligned along an interpreted southwest structural trend and may be related to the resistivity anomaly northeast in Area VI.

Area V (see Plate III) is characterized by a minimum gravity anomaly extending east, southeast and is interpreted as a graben structure. A magnetic low extending along the northeast-southwest structural trend spreads out into the area. The southern portion of Area V in the vicinity of the ridge contains a general gravity minimum, a magnetic maximum and a resistive anomaly.

Area VI (see Plate III) is the most complex and most interesting of the areas. The area adjacent and south of the Beowawe Geysers has a gravity maximum, magnetic maximum and a resistive anomaly associated with it. Drilling in this area determined disappointing subsurface temperatures at depths less than 1,000 feet (≤81 C). The existence of the magnetic maximum with the gravity maximum indicates that travertine accumulation and geothermal activity were not the cause of the gravity anomaly as indicated by the drilling. The Beowawe Geysers are associated with a conductive anomaly bordered by a resistive anomaly and the lateral extent of the anomaly is approximately one mile.

Ine Sections 16 and 19, T31N, R48E, a gravity maximum with little magnetic character is generally associated with a conductive anomaly. The geoelectric structure is very anisotropic in this area. The gravity and resistivity anomalies lie along the northwest-southeast trending structural lineation that occurs along the volcanic ridge. The resistivity anomaly may not be as significant geothermally because it occurs in the conductive valley fill, but there is some extension of the anomaly southeast into the fault-block. The gravity anomaly may be related to the extension of the volcanic ridge beneath the valley floor, but it may be due, in part, to geothermal activity. The gravity anomaly also extends to the southwest in Section 16 and a small conductive anomaly occurs in the southwest quarter of the section.

The most significant anomaly occurs south along the ridge in Section 22, T31N, R48E. A minimum gravity anomaly corresponds to a magnetic high and borders a minimum magnetic and conductive anomaly. The magnetic and resistivity anomalies occur at the intersection of the significant structural trends in the prospect (northeast-southwest, northwest-southeast). The elongation of the magnetic anomaly perpendicular to the ridge implies igneous intrusion, possible as early as Pliocene time when diabase intrusions occurred in the Cortez Mountains south of the Beowawe Prospect. The resistivity and magnetic anomalies are bordered to the south by magnetic and resistivity high anomalies. The complexity of the anomaly set, the possibility of fracturing associated with the trend intersection and the existence of low apparent resistivity with little anisotropy make this area the most promising target for future exploration work. If this is a fracture dominated system, then the conductor should be encountered at depths as shallow as 3,000 feet.

Low resistivity values are associated with Area VI and there are indications from two TDEM soundings that a fracture-dominated situation may exist here. If this is the situation, the potential geothermal plumbing system would be encountered at approximately 3,000 feet instead of 6,000 feet as indicated for Area VI.

Two initial test holes (see Plate XI) are recommended to probe the thermal gradient (TG) of the area and to calibrate the geophysical results with the observed geologic section. Because of the complexity of this area, this calibration of the geophysical results is essential in order to obtain the best results from this survey and subsequent drilling. These holes should be drilled in the order shown and to a depth of 1,500 feet so that more conclusive results can be obtained from the drill hole data. Shallower TG holes can lead to misleading conclusions. In one case, shallow, high temperature gradients can become isothermal at greater depth and thus provide disappointing deep temperatures or, in another case, lateral movement of water can produce disappointing shallow TG results while at depth very high temperature gradients could be encountered. After re-evaluating the geophysical survey with the TG data, two additional drill holes will be recommended.

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PART A

RESULTS OF THE GEOPHYSICAL SURVEYS
in the
BEOWAWE PROSPECT

SUBMITTED TO
GETTY OIL COMPANY

by

ELECTRODYNE SURVEYS
Reno, Nevada

September, 1979

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INTRODUCTION

A combined ground magnetics, gravity and electrical resistivity survey was completed in the Beowawe Geysers area, Nevada, by Electrodyne Surveys of Reno, Nevada for the Getty Oil Company of Bakersfield, California. This survey was conducted during February and March of 1979. The objective of the survey was to determine areas of geothermal interest within the Beowawe Prospect and to recommend locations of drill holes to evaluate the geothermal potential of these areas. This prospect lies within T31N to T32N, R47E to R48E, and covers approximately 27 square miles of the Whirlwind Valley and the Malpais (see Plate I).

A total of 226 ground magnetics and gravity stations were occupied using a grid pattern (see Plate I) over the prospect area. The gravity data are referenced to a gravity base station located at the Lander County, Nevada, airport and are reduced to a complete Bouguer anomaly using a combined elevation-Bouguer correction factor corresponding to a density of 2.67 g/cm^3. Position and elevation control for the gravity stations were determined by a surveying crew using an electronic distance measuring device. All gravity observations were obtained with a La Coste and Romberg Model D gravimeter. The gravity and survey data is listed in Appendix IV of PART B of this report. A magnetic base recorder was used during the survey to determine magnetic field fluctuations, and these fluctuations were subsequently removed from the observed data.

Three electrical resistivity techniques were utilized because of the suspected complexity of the area. These techniques are time domain electromagnetic soundings (TDEM), magnetotelluric-audiomagnetotelluric soundings (MT-AMT), and galvanic soundings (DC). Plate II shows the locations of the 106 TDEM soundings, the 9 MT-AMT soundings and the 5 sets of modified Schlumberger (DC) soundings. Note that the TDEM and MT-AMT soundings normally occupy gravity/magnetics stations. The TDEM soundings were obtained from source bipoles 1, 3, 4, and 5, and the DC soundings from source bipoles 6A, 6B, 7, 8, and 9. An additional 9 reöccupations of TDEM soundings from various source combinations were also completed to help determine lateral resistivity effects upon the TDEM soundings.

The TDEM sounding data, the galvanic (DC) sounding curves, and the MT-AMT sounding curves are in Appendices I, II, and III, PART B of this report. Over seventy-five percent of the data acquisition was augmented by helicopter support due to the rugged terrain of the area, and the poor field conditions (muddy) during the late winter months.

GEOLOGIC SUMMARY

The only available geologic description of this area is a report on the Geology of the Frenchie Creek Quadrangle, (Muffler, 1964). This quadrangle is directly southeast of the prospect area.

The Frenchie Creek quadrangle was probably the site of carbonate deposition in the early Paleozoic time with eugeosynclinal deposition occuring tens of miles to the west. During the Antler Orogeny (late Devonian to early Pennsylvanian) the western assemblage was thrust over the eastern assemblage of carbonate rocks. Near-shore marine conglomerates and dolomites were unconformably deposited on Ordovician eugeosynclinal rocks during the late Pennsylvanian or Permian. This late Paleozoic deposition may have continued into the early Mesozoic when extrusion of silicic ash-flow tuffs, and rhyodocite and rhyolite flows occurred (Jurassic?) and intrusion of a few related rhyolite (?) plugs.

Diorite to alaskite plutons were intruded during the early Cretaceous (?) and accompanied by intense local deformation and followed by hydrothermal alteration. Uplift of the area may have occurred in early Tertiary time. In Cenozoic time rhyodacite flows were extruded and diabase dikes were emplaced in the Cortez Mountains (approximately 15 miles southeast of the prospect area) during the Pliocene. Normal faulting also began during the Cenozoic and produced the high angle, Beowawe-Geysers fault. The resulting Basin and Range type fault block is tilted to the southeast.

Most of the fault block within the prospect is covered by extrusive volcanic rocks (rhyodacite?) with the exception of western assemblage sedimentary rocks that occur in the vicinity of S15, T32N, and R48E. A south-southeast trending ridge extends through this assemblage of rocks from the northern portion of the Shoshone Range and terminates near the southern border of the prospect. Hot springs and man-made geysers (steam wells) occur along the Beowawe Geysers fault scarp in S17, T32N, and R47E, with less active geothermal pools occurring north-northwest of the geysers. The average maximum temperature determined during the drilling of the magma wells along the fault scarp was 210° C. Much lower temperatures were encountered 1,200 feet south of the fault scarp (<100° C). Estimated reservoir temperatures determined from the hot springs are between 196° and 252° C (Hose and Taylor, 1974). A horst-type structure occurs southwest of the geysers in the adjacent section and extends along the fault scarp. The existence of geothermal activity in the area is evident as well as a very complex structural setting.

GRAVITY SURVEY RESULTS

The complete Bouguer gravity map is given on Plate III with relative apparent high and low density areas noted. A simple Bouguer map of the Shoshone Range area is given on Figure 1. The gravity anomalies determined by this survey are complex and generally trend along a northwest-southeast or southwest-northeast direction. The prospect has been divided into six areas which have diagnostic gravity character. A discussion of each area follows.

Area I - Sections 1, 2, 11, 12, 13, 14, and 23, T31N, R46E; and Sections 6 and 7, T31N, R48E.

The depths of the Whirlwind Valley gradually decreases to the west and north in this area as indicated by the general increase in the gravity values. This graben should be shallow as indicated by the small amplitude of the gravity anomaly (~1.4 mgals).

Area II Sections 4, 5, 8, and 9, T31N, R48E.

East of Area I a gravity minimum of approximately 2.2 mgals occurs and is interpreted as a graben structure. Closure of the anomaly to the south and east is accomplished by a set of two maximum gravity anomalies (Area VI) associated with the front range fault and a northwest trending ridge. The larger of the two maximum gravity anomalies may be due in part to the extension of the ridge beneath the valley floor; consequently, the western portion of Whirlwind Valley may be hydraulically isolated from the eastern portion of the basin.

Area III Sections 24 and 25, T32N, R47E, and Sections 19, 20, 29, and 30, T31N, R48E.

Within this area there are alternating gravity maximum and minimum anomalies elongated in a northeast-southwest direction. The gravity relief in this area exceeds 2 mgals and occurs within 4,000 feet of horizontal distance. The relatively large amplitude and high frequency content of the major gravity minimum is indicative of a shallow volume of low density material extending along the front range fault. Igneous intrusions along this portion of the fault could explain this unusual anomaly, but more detailed information would be required to be sure.

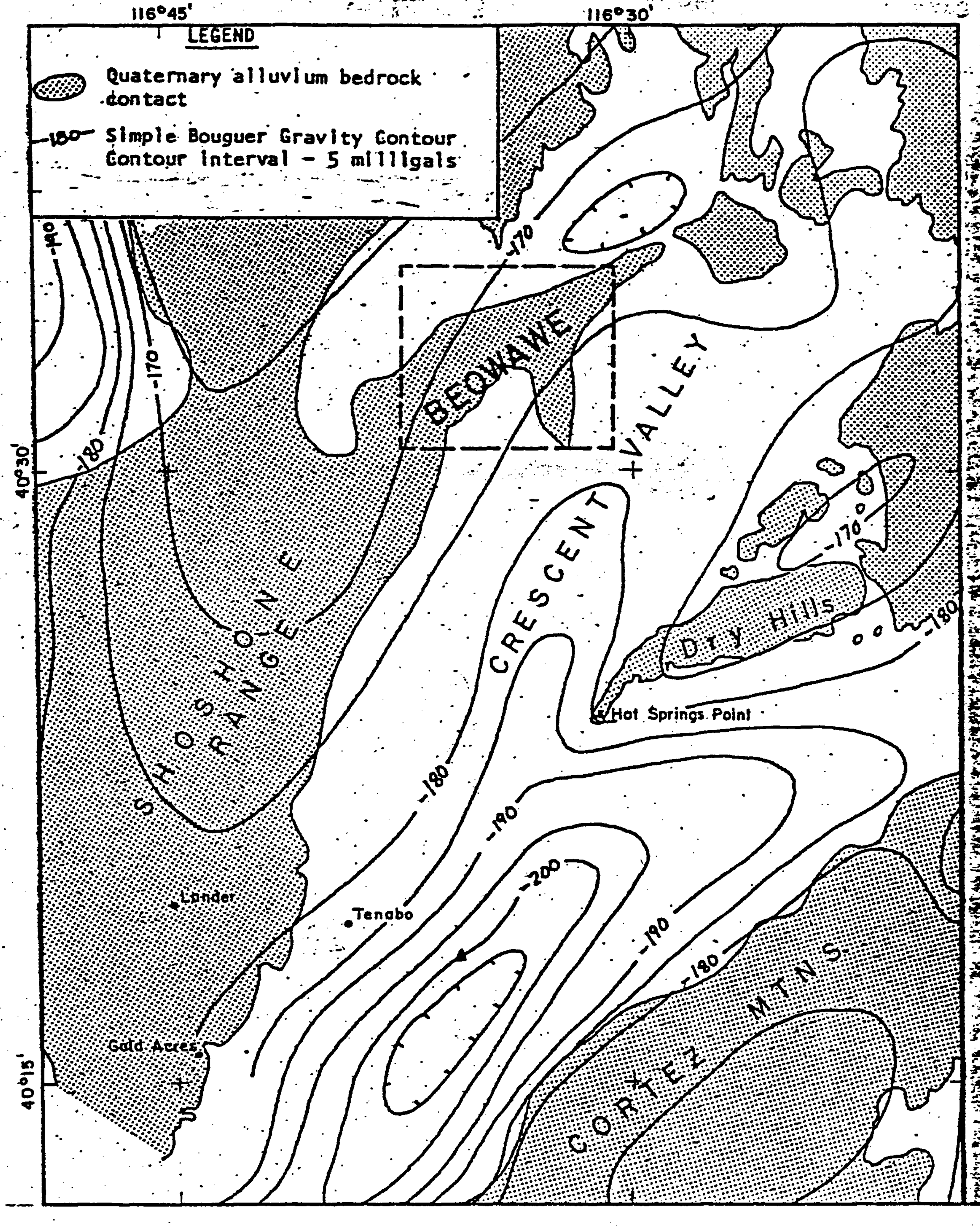

Figure 1. Simple Bouguer gravity map (after Mabey, 1964) of the Crescent Valley. Scale is 1:250,000.

Area IV   Sections 28, 33, and 34, T31N, R48E.

In this area, a small graben feature such as seen in Area II is found. Its axis is also interpreted to be in the northwest direction. If these two graben features were part of a single graben in the geologic past, then a strike-slip fault could be postulated along the major fault scarp through the prospect.

Area V.   Sections 11, 12, 14, 15, 23, and 26, T31B, R48E, and the area to the east.

The decrease in the gravity to the east indicates a deepening of a graben structure in that direction. The front range fault, and the northwest trending ridge, border this graben to the northwest and southwest.

Area VI - The remaining prospect area surrounded by the other five areas.

Geologically and gravimetrically, this is the most complex area within the prospect. This area extends northeast and east along the front range fault from the monadnock structure (Sec., 18, T31N, R48E) southwest of the Beowawe Geysers to the cirque-like structure in Section 15, T31N, R48E.

The gravity maximum associated with the monadnock suggests that the structure has lateral subsurface extent to the north, west and and east.

A set of two maximum gravity anomalies exist a mile east of the monadnock and south of the Geysers (Sec. 16, 17 and 10). These anomalies trend in a northeast direction with the second and larger of the two anomalies extending also in a northwest direction. As mentioned above, this extension of the anomaly into Whirlwind Valley is associated with the northwest trending ridge and indicates an extension of the ridge beneath the valley to the Shoshone Range. The topography northwest of the gravity anomaly supports this idea.

A moderate density high, trending north-northwest to south-southeast, is found in Sections 22 and 27 just to the west of the ridge of lava flows. A density low with relatively high contrast (4 to 5 5 mgals) is found in the southern half of Section 15. This low corresponds closely to an eroded cirque-like feature. It is possible that this feature is an acid volcanic (granite) intrusive. If this is the case, it should be of much greater age than the basic Tertiary intrusives of the area. North of the gravity minimum is an outcrop of Paleozoic western assemblage rocks which have an average density of 2.6gm/cm^3 (Mabey, 1964) which is less than the density of the Tertiary basalts which cover most of the area. The density contrast between the two could explain the anomaly, but not the maximum gravity anomaly that is also associated with the Paleozoic outcrop.

In conclusion, the data suggests two significant structural control lineations in the prospect area:

1. The northeast to east-northeast Beowawe Geysers fault as evidenced by the surface fault scarp through Sections 16, 17 and 19, and

2. A north-northwest trending lineation, which may be a normal fault dipping west at the western edge of the ridge through Sections 22, 27 and 16.

These two major lineations intersect in Section 16, which would then be a hub of tectonic activity in the area. The present steam wells or so-called geysers are located to the west in Section 17.

MAGNETIC SURVEY RESULTS

The magnetic survey map (Plate IV) shows a sectioning of the prospect area similar to the gravity map discussed above. The significant structural control lineations are shown on the map.

It is noteworthy that there are several single-point anomalies that vary by over 500 gammas within the prospect area. The regional aeromagnetic map of the Crescent Valley (Figure 2) does not indicate any such variations; therefore, these anomalies must be very local effects, and are not necessarily caused by geologic noise.

Description of the magnetic anomalies in the areas indicated in the gravity discussion are as follows:

Area I In a fashion similar to the gravity values, the magnetic values generally increase towards the Shoshone Range (west and northwest) indicating a shallowing of the basin as expected. The two maximum magnetic anomalies in this area (Sec. 12, and Sec. 23, T31N, R47E) overlie the two maximum gravity anomalies and suggest anomalous decreases in the basin depths in these two areas.

Areas II and IV Both of the possible northwest-trending graben strucutures of these two areas occur where there is a minimum of magnetic variation (less than 250 gammas chanage). A explanation for this diminished magnetic variation is that there is a considerable amount of sediments deposited within each graben (more than 2,500 feet). Deep basins often exhibit a lack of magnetic variation.

Area III A series of alternating maximum and minimum anomalies elongated in a northeasterly direction are located in this area. Both the magnetic and gravity anomalies occur in the same area and trend in the same direction, but the minimum magnetic and maximum gravity anomalies are associated and vice versa. The Malpais is composed of a series of rotated fault blocks with the maximum magnetic values being associated with the crest of the fault blocks, and the minimum magnetic anomalies associated with the alluvial filled troughs created by the rotated fault blocks. A distortion of the direction of the maximum magnetic anomaly occurs in Sections 17, and 18, T31N, R47E, and is probably due to the effect of the thermal alteration of the rocks in the area by the thermal springs at the Beowawe Geysers.

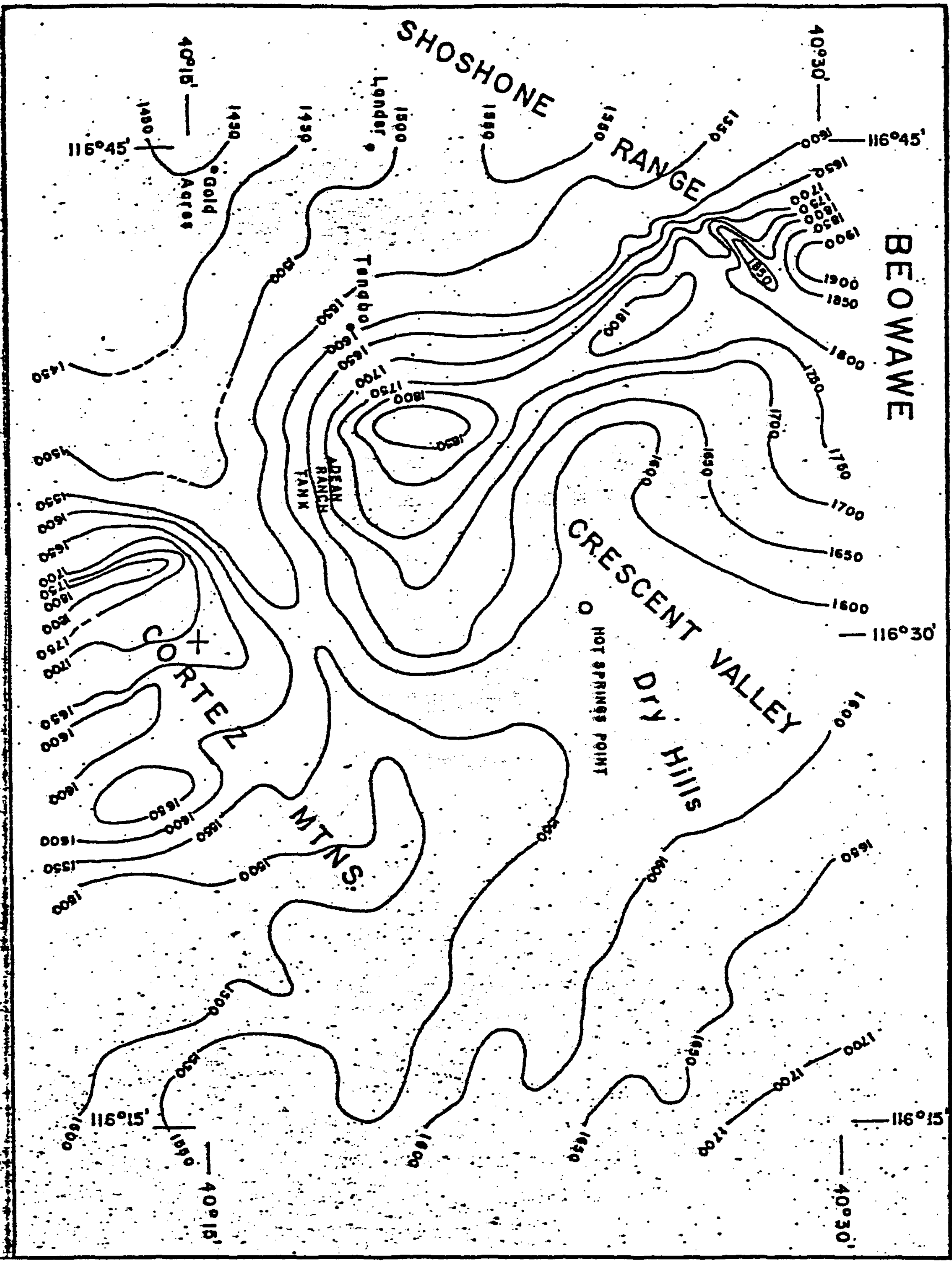

Figure 2. Aeromagnetic map of the Dry Hills and Central Crescent Valley area. Magnetic contours show total intensity magnetic field of the earth in gamma. Contour interval is 50 gammas. Scale is 1:250,000 (after Philbin, et.al,, 1963).

Areas V and VI The magnetic anomalies within these two areas are controlled by the two structural control lineations (northwest-southeast and southwest-northeast) as shown in Plate IV and generally correlate with gravity anomalies of opposite sign. Three sets of maximum-minimum magnetic anomaly pairs occur along the extension of the northwest trending ridge, and nearly all the anomalies are elongated in the northeasterly direction. The central minimum anomaly is the largest of the minimum anomalies in size and amplitude and is bordered by two maximum anomalies that contain the largest positive anomaly values. The total magnetic relief is greater than 1,700 gammas. The northern maximum anomaly in Section 15, T31N, R48E, is similar in shape and location to the maximum gravity anomaly in the same section.

North of this anomaly set, the magnetic variation diminishes until nearly half-way across Whirlwind Valley, at which time the magnetic values increases. It is interesting that this lack of magnetic character is coincident with the maximum gravity anomaly. The other gravity maximum in Section 17, T31N, R48E, is coincident with a minimum magnetic anomaly, as is the monadnock structure.

Normally, maximum and minimum magnetic and gravity anomalies correlate because the low density sediments that cause the gravity lows cover and diminish the strength of the subsurface basement magnetic anomalies. One situation where this does not hold true is in areas of secondary deposition of travertine or sinter by thermal waters. Maximum gravity anomalies will be created with very little magnetic signature. This is not the situation in the vicinity of the Beowawe Geysers where magnetic character is associated with a gravity high. Previous drilling by Magma and Sierra into this anomaly (1,200 feet south of the Beowawe Geysers) produced the poorest results of their drilling program - 81 C versus 184 C just north of the magnetic low-gravity high anomaly. (Hose and Taylor, 1974). The lack of magnetic signature with the gravity anomaly east of the geysers could have geothermal significance.

The magnetic anomalies along the northwest trending ridge could be related to igneous intrusives which could act as potential heat sources in the area. The intersection of the two structure control lineations in Section 22, T31N, R48E, would become a drilling target because of the potential fracturing created by tectonic activity at the trend intersection.

ELECTRICAL RESISTIVITY SURVEY RESULTS

The galvanic (DC) resistivity soundings (Figures 1 through 6 in Appendix II, PART B) indicate that a highly variable upper geologic section exists within the prospect. The soundings to the north of the fault scarp, performed along source locations 8 and 9, indicate subsurface volcanics near the fault scarp and the monadnock near the springs. Further out in the basin, considerable thicknesses of clay alteration and playa-type deposition are expected and indicated by the low apparent resistivity values in the valley. Both of these types of deposits may be a few thousand feet thick and must be penetrated before reaching a heat conduction and/or heat convection system.

The soundings to the south of the fault scarp, performed along sources 6 and 7, indicate a very thin overburden, 100 to 200 feet of fractured flows and alluvium, which are underlain by a resistive section (assumed to correlate with competent volcanics) with thicknesses greater than a few hundred feet. There may be some lateral non-competent channels within this general resistive zone that may locally carry heat away from an area of interest. Therefore, we recommend an initial thermal gradient (T.G.) drilling program to depths of 1,500 feet. One should expect some slow drilling through the intermediate resistive zones.

The TDEM vertical magnetic field (H_Z), horizontal electric field (E_N), scalar MT (0.02 - 0.6 Hz), and AMT measurements throughout the prospect indicate an even more complex picture than the gravity and magnetic investigations suggest. This complexity is shown by the H_Z and E_N apparent resistivity profiles (Plates V - VIII). A brief summary of the data reduction procedures is in Appendix I, PART B.

Examination of the profiles reveals that:

(1) Lateral resistivity variations are very common in the prospect area, and the inferred geoelectric structure is very complex.

(2) The apparent resistivity values encountered along the H_Z profiles are greater than the corresponding E_N values.

(3) The vertical component of the magnetic field will couple best to large, horizontal conductors and should be used as an indication of anomalous resistivity character.

(4) The E_N profiles exhibit more lateral resistivity variations and less profile-to-profile continuity than the corresponding H_Z profiles (see Profiles G, H, L, 5, and 16).

(5) The two sets of perpendicular E_N Profiles (NW-SE and SW-NE) normally exhibit opposite anomalous resistivity character, ie., stations along the NW-SE Profiles will be anomalously resistive while the same stations along the SW-NE Profiles will be anomalously conductive and vice versa (see Stations H9 through O9, Plates VIII, IX and X).

(6) Three areas within the prospect do not conform to the previous observation (#6), ie., both the E_N components (the parallel and perpendicular) at a station exhibit similar anomalous character. These three areas are the central portion of Whirlwind Valley, and the central and southern portions of the northwest extending ridge (Sec. 14, 15, 22, 23, 26, and 27, T31N, R48E; See Plate II and Plates V through X).

(7) Whirlwind Valley is generally more conductive and more laterally homogeneous than the Malpais cuesta.

(8) The significant structural control lineations observed in the gravity and magnetic data are also present in the TDEM sounding data.

(9) Anomalous conductance within the geoelectric section is encountered at depths of approximately 6,000 feet on the Malpais, with some areas displaying anomalous conductance at depths of 3,000 feet or less.

The complexity of the geoeletric structure within the Beowawe Prospect is readily shown by the large number of lateral resistivity variations which occur over short horizontal distances (less than 1,300 feet in many cases) and the different types of sounding curves determined by the TDEM soundings. Generally, the curves can be classed as two types: Q ($\rho_1 > \rho_2 > \rho_3$) and K ($\rho_1 < \rho_2 > \rho_3$) types. The Q type is the most prevalent and is indicative of a resistive overburden underlain by more conductive sediments. Because of the very obvious two and three dimensional structural relationships affecting the TDEM sounding curves, no precise curve matching techniques were employed in interpreting the data. The estimated depths and resistivities can be off by over 200% given the lack of horizontal homogeneity and would have little relevance to portions of the prospect where the geoelectric structure is not layered, but vertically standing. However, this does not alter the fact that the profiles and TDEM soundings can be used to delineate areas of anomalous structure and conductance.

Soundings such as K13 which exhibit anomalous conductance at shallow apparent depths, and which are flanked by more resistive sections, indicate the possible existence of vertically standing conductors. Such vertical structure should be related to fracturing or faulting within the subsurface with mineralization or thermal fluids along the structure providing the anomalous conductance in the zone.

Indirect evidence for the prevalence of such structure within the prospect is provided by the TDEM sounding results. The two sounding types used, the horizontal electric and vertical magnetic soundings, are sensitive to different conductive targets: the electric field soundings are more sensitive to vertical conductors than the vertical magnetic component which is more sensitive to horizontal conductors. The fact that the E_N Profiles are generally more conductive than the H_Z Profiles, and indicate more lateral resistivity variation, indicates the predominance of vertical conductors in the area. For this reason, the vertical magnetic sounding Profiles were utilized to indicate the most interesting target areas because they should differentiate better between the insignificant conductive targets (see Plate XI).

Another indication of the complexity of the geoelectric structure is shown by comparison of the E_N soundings in the two orthogonal directions. The plotted results are the horzontal electric field soundings normal to the particular profile; consequently, the sounding will be either the component parallel to the source bipole or perpendicular to it. Comparison of the individual orthogonal components at a particular site yield the results that in many portions of the prospect, a conductive anomaly determined by the northwest component of the electric field, will be a resistive anomaly as determined by the orthogonal southeast component of the electric field. This is true of the Beowawe Geysers area, the area southeast of the Geysers extending along the slope of the Malpais, and in Section 9 and 10, T31N, R48E, where the maximum gravity anomaly extends into Whirlwind Valley. These anomaly reversals are again indicative of a very complex geoelectric structure that is skewing the induced electric fields. Fortunately, the vertical magnetic field is much less affected by this skewing.

Significantly, three anomalous areas did not show a reversal of anomalies by different electric field components. The central area of Whirlwind Valley (along Profiles S, T and U) is anomalously conductive, the central area of the northwest trending ridge associated with the minimum magnetic anomaly (Sec. 14, 15, and 33, T31N, R48E) is anomalously conductive and the area bordering this anomaly to the south (Sec. 22, 23, 26, and 27, T31N, R48E) is anomalously resistive.

Verification of an anomaly by the two electric field components adds credence to its existence. The conductive anomaly within Whirlwind Valley is expected due to the alluvial fill of the valley and the existence of the Beowawe Geysers and other thermal expressions along the front range fault bordering the valley.

The lateral homogeneity of the conductive anomaly indicates that it is relatively uniform and large in size. Conductive clays and thermal waters are likely to be the cause of this anomaly.

The juxtaposition of the conductive and resistive anomaly within the northwest trending ridge is of more interest because a conductive anomaly associated with a volcanic ridge has fewer possible explanations. This anomaly will be discussed later with regard to the other geophysical anomalies.

These two anomalies, as well as most of the other anomalies determined by the resistivity survey, appear to be controlled by the structural lineations in the northeast-southwest and northwest-southeast directions as noted in the description of the gravity and magnetic anomalies. The fact that all three geophysical techniques locked onto these trends denote that they must be related to the major tectonic forces within the area, as would any geothermal activity.

The structural lineations determined by the H_Z soundings are shown on Plate XI. This Plate represents the contoured apparent resistivity values determined by an apparent depth of apparoximately 2,000 meters (6,560 feet). The structural trends as determined by the horizontal electric field soundings are not significantly different.

The Beowawe Geysers area is conductive and is bordered to the northwest by a resistive anomaly of small lateral extent. The resistor may be associated with a buildup of travertine at depth, but the gravity does not lend much support to this idea. Southeast of the Geysers and the monadnock, the Malpais is characterized by relatively high apparent resistivity. Bifurcation of the resistive anomaly occurs in Section 16, T31N, R48E, by a small conductive anomaly that may be related to the much larger conductive anomaly occurring in Sections 9, 10, and 11, T31N, R48E.

Elongation of this large anomaly occurs in the southeast direction and this axis of this structural trend passes through another conductive anomaly south in Section 22, T31N, R48E. This anomaly is coincident with the conductive anomaly determined by the two electric field component soundings and it occurs at the intersection of two structural trends. Another conductive anomaly in Sections 21, 28 and 29, T31N, R48E, occurs southwest of the trend intersection. Southeast of the trend intersection is a resistive anomaly that shifts the southern extension of the northwest-southeast trend to the southwest. Generally, the apparent depth to each of these conductors approaches 6,000 feet except at the following sites: J9, K13 and Q14. At these three sites apparent depths to the conductor are less than 3,000 feet and nearby vertical conductors are expected to exist.

The total apparent conductance determined by the MT soundings are in good agreement with the TDEM data. Two of the three MT sites with the minimum conductance, F11 and L9 (∿500 mhos), occur within or close to the resistive anomalies of the Malpais and the ridge.

The maximum conductance was determined in Whirlwind Valley at site 53 (890 mhos), and the maximum conductance determined south of the range fault occurs at I11 (780 mhos) on the edge of the southern conductive anomaly (see Plate XI). Given 780 mhos and a section conductance of 3 ohm-m, the depth to the base of the conductor (electrical basement) is 2,340 meters. MT sounding Q15 has the minimum determined conductance for the area (290 mhos) and yet, lies on the valley side of the range fault and within the conductive anomaly determined by the H_z TDEM soundings. This discrepancy may be explained by lateral resistivity variations within the area (the two orthogonal electric fields indicated anomaly reversals in this area).

The most interesting area within the prospect occurs at the intersection of the structural trends in Section 22, T31N, R48E. The conductive anomaly occurring at this intersection coincides with the elongated minimum magnetic anomaly that extends along the northeast-southwest structural trend. The resistive anomaly south of the intersection coincides with a maximum magnetic anomaly, and the minimum gravity anomaly occurs in the northeast quadrant created by the intersecting structural trends. This is a very complex area and one that should be investigated for geothermal potential.

The magnetic anomalies are probably due to igneous intrusives that could be related to the diabase dike emplacement in the Cortez mountains during the Pliocene. Intersection of the structural trends is a good indication of fracturing, this providing channels for water to percolate down to the intrusives. The conductive anomaly is not large in lateral extent, but one would not be expected if a fracture dominated system is encountered. The existence of the conductor astride the ridge is significant by itself. The fact that these unusual anomalous condition are coincident or in such close proximity is intriguing and certainly the result of some complex tectonic activity.

The northern conductive anomaly in Section 9, T31N, R48E, is associated with a gravity maximum but no significant magnetic expression. The extreme anisotropy exhibited by the electric field sounding indicated geoelectric complexity, but its extension into the conductive valley diminishes the enthusiasm for this anomaly.

The conductive anomaly southwest of the structural intersection occurs within Area IV and the interepreted graben structure. The conductive anomaly shape and trend differs from that expected for the graben; consequently, thickening of conductive sediments in the graben may not adequately explain the anomaly and add significance to the anomaly.

No other general comments regarding the correlation of the resistivity anomalies and the gravity and magnetic anomalies can be made here.

SUMMARY AND RECOMMENDATIONS

Each of the three geophysical methods employed in the Beowawe Prospect; magnetics, gravity and electrical resistivity, indicate that this area is structurally very complex. That in itself is significant since large scale tectonic activity is the earmark of most important geothermal systems. The existence of hot springs occurs along the front range fault and drilling has proven the existence of high subsurface temperature (>165°C).

Areas I and II within the western portion of Whirlwind Valley (see Plate III) are not believed to be important due to their lack of any unusual geophysical character. Conductive clays and silts probably fill the basin area and provide a poor reservoir for any geothermal sources flanking the valley. No igneous intrusives were determined. More detailed gravity interpretation may yield residual gravity maximums within the valley that may be related to subsurface travertine deposition.

Area III (see Plate III) is characterized by relatively high apparent resistivity, and an alternating set of elongated northeast-southwest gravity and magnetic maximum and minimum anomalies. The minimum gravity anomaly associated with the front range fault is difficult to interpret but may be due to intrusives. The lack of a conductive resistivity anomaly diminishes interest for this area.

Area IV (see Plate III) is characterized by a minimum gravity and conductive resistivity anomaly. A general increase in the magnetic values occurs to the southwest but no major structural feature is indicated by the magnetics. The orientation and shape of the resistivity anomaly differs from the inferred graben structure, so, fortunately, the conductor may not be due entirely to a thickening of the overburden. The graben may be related to the graben in Area II and thus indicating strike slip movement has occurred in the past. The resistivity trend east of Area IV indicates the same type of strike-slip movement.

The conductive anomaly is aligned along an interpreted southwest structural trend and may be related to the resistivity anomaly northeast in Area VI.

Area V (see Plate III) is characterized by a minimum gravity anomaly extending east, southeast and is interpreted as a graben structure. A magnetic low extending along the northeast-southwest structural trend spreads out into the area. The southern portion of Area V in the vicinity of the ridge contains a general gravity minimum, a magnetic maximum and a resistive anomaly.

Area VI (see Plate III) is the most complex and most interesting of the areas. The area adjacent and south of the Beowawe Geysers has a gravity maximum, magnetic maximum and a resistive anomaly associated with it. Drilling in this area determined disappointing subsurface temperatures at depths less than 1,000 feet (≤81 C). The existence of the magnetic maximum with the gravity maximum indicates that travertine accumulation and geothermal activity were not the cause of the gravity anomaly as indicated by the drilling. The Beowawe Geysers are associated with a conductive anomaly bordered by a resistive anomaly and the lateral extent of the anomaly is approximately one mile.

Ine Sections 16 and 19, T31N, R48E, a gravity maximum with little magnetic character is generally associated with a conductive anomaly. The geoelectric structure is very anisotropic in this area. The gravity and resistivity anomalies lie along the northwest-southeast trending structural lineation that occurs along the volcanic ridge. The resistivity anomaly may not be as significant geothermally because it occurs in the conductive valley fill, but there is some extension of the anomaly southeast into the fault-block. The gravity anomaly may be related to the extension of the volcanic ridge beneath the valley floor, but it may be due, in part, to geothermal activity. The gravity anomaly also extends to the southwest in Section 16 and a small conductive anomaly occurs in the southwest quarter of the section.

The most significant anomaly occurs south along the ridge in Section 22, T31N, R48E. A minimum gravity anomaly corresponds to a magnetic high and borders a minimum magnetic and conductive anomaly. The magnetic and resistivity anomalies occur at the intersection of the significant structural trends in the prospect (northeast-southwest, northwest-southeast). The elongation of the magnetic anomaly perpendicular to the ridge implies igneous intrusion, possible as early as Pliocene time when diabase intrusions occurred in the Cortez Mountains south of the Beowawe Prospect. The resistivity and magnetic anomalies are bordered to the south by magnetic and resistivity high anomalies. The complexity of the anomaly set, the possibility of fracturing associated with the trend intersection and the existence of low apparent resistivity with little anisotropy make this area the most promising target for future exploration work. If this is a fracture dominated system, then the conductor should be encountered at depths as shallow as 3,000 feet.

Low resistivity values are associated with Area VI and there are indications from two TDEM soundings that a fracture-dominated situation may exist here. If this is the situation, the potential geothermal plumbing system would be encountered at approximately 3,000 feet instead of 6,000 feet as indicated for Area VI.

Two initial test holes (see Plate XI) are recommended to probe the thermal gradient (TG) of the area and to calibrate the geophysical results with the observed geologic section. Because of the complexity of this area, this calibration of the geophysical results is essential in order to obtain the best results from this survey and subsequent drilling. These holes should be drilled in the order shown and to a depth of 1,500 feet so that more conclusive results can be obtained from the drill hole data. Shallower TG holes can lead to misleading conclusions. In one case, shallow, high temperature gradients can become isothermal at greater depth and thus provide disappointing deep temperatures or, in another case, lateral movement of water can produce disappointing shallow TG results while at depth very high temperature gradients could be encountered. After re-evaluating the geophysical survey with the TG data, two additional drill holes will be recommended.

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PART A
RESULTS OF THE GEOPHYSICAL SURVEYS
in the
BEOWAWE PROSPECT

SUBMITTED TO
GETTY OIL COMPANY

by

ELECTRODYNE SURVEYS
Reno, Nevada

September, 1979

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INTRODUCTION

A combined ground magnetics, gravity and electrical resistivity survey was completed in the Beowawe Geysers area, Nevada, by Electrodyne Surveys of Reno, Nevada for the Getty Oil Company of Bakersfield, California. This survey was conducted during February and March of 1979. The objective of the survey was to determine areas of geothermal interest within the Beowawe Prospect and to recommend locations of drill holes to evaluate the geothermal potential of these areas. This prospect lies within T31N to T32N, R47E to R48E, and covers approximately 27 square miles of the Whirlwind Valley and the Malpais (see Plate I).

A total of 226 ground magnetics and gravity stations were occupied using a grid pattern (see Plate I) over the prospect area. The gravity data are referenced to a gravity base station located at the Lander County, Nevada, airport and are reduced to a complete Bouguer anomaly using a combined elevation-Bouguer correction factor corresponding to a density of 2.67 g/cm^3. Position and elevation control for the gravity stations were determined by a surveying crew using an electronic distance measuring device. All gravity observations were obtained with a La Coste and Romberg Model D gravimeter. The gravity and survey data is listed in Appendix IV of PART B of this report. A magnetic base recorder was used during the survey to determine magnetic field fluctuations, and these fluctuations were subsequently removed from the observed data.

Three electrical resistivity techniques were utilized because of the suspected complexity of the area. These techniques are time domain electromagnetic soundings (TDEM), magnetotelluric-audiomagnetotelluric soundings (MT-AMT), and galvanic soundings (DC). Plate II shows the locations of the 106 TDEM soundings, the 9 MT-AMT soundings and the 5 sets of modified Schlumberger (DC) soundings. Note that the TDEM and MT-AMT soundings normally occupy gravity/magnetics stations. The TDEM soundings were obtained from source bipoles 1, 3, 4, and 5, and the DC soundings from source bipoles 6A, 6B, 7, 8, and 9. An additional 9 reöccupations of TDEM soundings from various source combinations were also completed to help determine lateral resistivity effects upon the TDEM soundings.

The TDEM sounding data, the galvanic (DC) sounding curves, and the MT-AMT sounding curves are in Appendices I, II, and III, PART B of this report. Over seventy-five percent of the data acquisition was augmented by helicopter support due to the rugged terrain of the area, and the poor field conditions (muddy) during the late winter months.

GEOLOGIC SUMMARY

The only available geologic description of this area is a report on the Geology of the Frenchie Creek Quadrangle, (Muffler, 1964). This quadrangle is directly southeast of the prospect area.

The Frenchie Creek quadrangle was probably the site of carbonate deposition in the early Paleozoic time with eugeosynclinal deposition occuring tens of miles to the west. During the Antler Orogeny (late Devonian to early Pennsylvanian) the western assemblage was thrust over the eastern assemblage of carbonate rocks. Near-shore marine conglomerates and dolomites were unconformably deposited on Ordovician eugeosynclinal rocks during the late Pennsylvanian or Permian. This late Paleozoic deposition may have continued into the early Mesozoic when extrusion of silicic ash-flow tuffs, and rhyodocite and rhyolite flows occurred (Jurassic?) and intrusion of a few related rhyolite (?) plugs.

Diorite to alaskite plutons were intruded during the early Cretaceous (?) and accompanied by intense local deformation and followed by hydrothermal alteration. Uplift of the area may have occurred in early Tertiary time. In Cenozoic time rhyodacite flows were extruded and diabase dikes were emplaced in the Cortez Mountains (approximately 15 miles southeast of the prospect area) during the Pliocene. Normal faulting also began during the Cenozoic and produced the high angle, Beowawe-Geysers fault. The resulting Basin and Range type fault block is tilted to the southeast.

Most of the fault block within the prospect is covered by extrusive volcanic rocks (rhyodacite?) with the exception of western assemblage sedimentary rocks that occur in the vicinity of S15, T32N, and R48E. A south-southeast trending ridge extends through this assemblage of rocks from the northern portion of the Shoshone Range and terminates near the southern border of the prospect. Hot springs and man-made geysers (steam wells) occur along the Beowawe Geysers fault scarp in S17, T32N, and R47E, with less active geothermal pools occurring north-northwest of the geysers. The average maximum temperature determined during the drilling of the magma wells along the fault scarp was 210° C. Much lower temperatures were encountered 1,200 feet south of the fault scarp (<100° C). Estimated reservoir temperatures determined from the hot springs are between 196° and 252° C (Hose and Taylor, 1974). A horst-type structure occurs southwest of the geysers in the adjacent section and extends along the fault scarp. The existence of geothermal activity in the area is evident as well as a very complex structural setting.

GRAVITY SURVEY RESULTS

The complete Bouguer gravity map is given on Plate III with relative apparent high and low density areas noted. A simple Bouguer map of the Shoshone Range area is given on Figure 1. The gravity anomalies determined by this survey are complex and generally trend along a northwest-southeast or southwest-northeast direction. The prospect has been divided into six areas which have diagnostic gravity character. A discussion of each area follows.

Area I - Sections 1, 2, 11, 12, 13, 14, and 23, T31N, R46E; and Sections 6 and 7, T31N, R48E.

The depths of the Whirlwind Valley gradually decreases to the west and north in this area as indicated by the general increase in the gravity values. This graben should be shallow as indicated by the small amplitude of the gravity anomaly (~1.4 mgals).

Area II - Sections 4, 5, 8, and 9, T31N, R48E.

East of Area I a gravity minimum of approximately 2.2 mgals occurs and is interpreted as a graben structure. Closure of the anomaly to the south and east is accomplished by a set of two maximum gravity anomalies (Area VI) associated with the front range fault and a northwest trending ridge. The larger of the two maximum gravity anomalies may be due in part to the extension of the ridge beneath the valley floor; consequently, the western portion of Whirlwind Valley may be hydraulically isolated from the eastern portion of the basin.

Area III - Sections 24 and 25, T32N, R47E, and Sections 19, 20, 29, and 30, T31N, R48E.

Within this area there are alternating gravity maximum and minimum anomalies elongated in a northeast-southwest direction. The gravity relief in this area exceeds 2 mgals and occurs within 4,000 feet of horizontal distance. The relatively large amplitude and high frequency content of the major gravity minimum is indicative of a shallow volume of low density material extending along the front range fault. Igneous intrusions along this portion of the fault could explain this unusual anomaly, but more detailed information would be required to be sure.

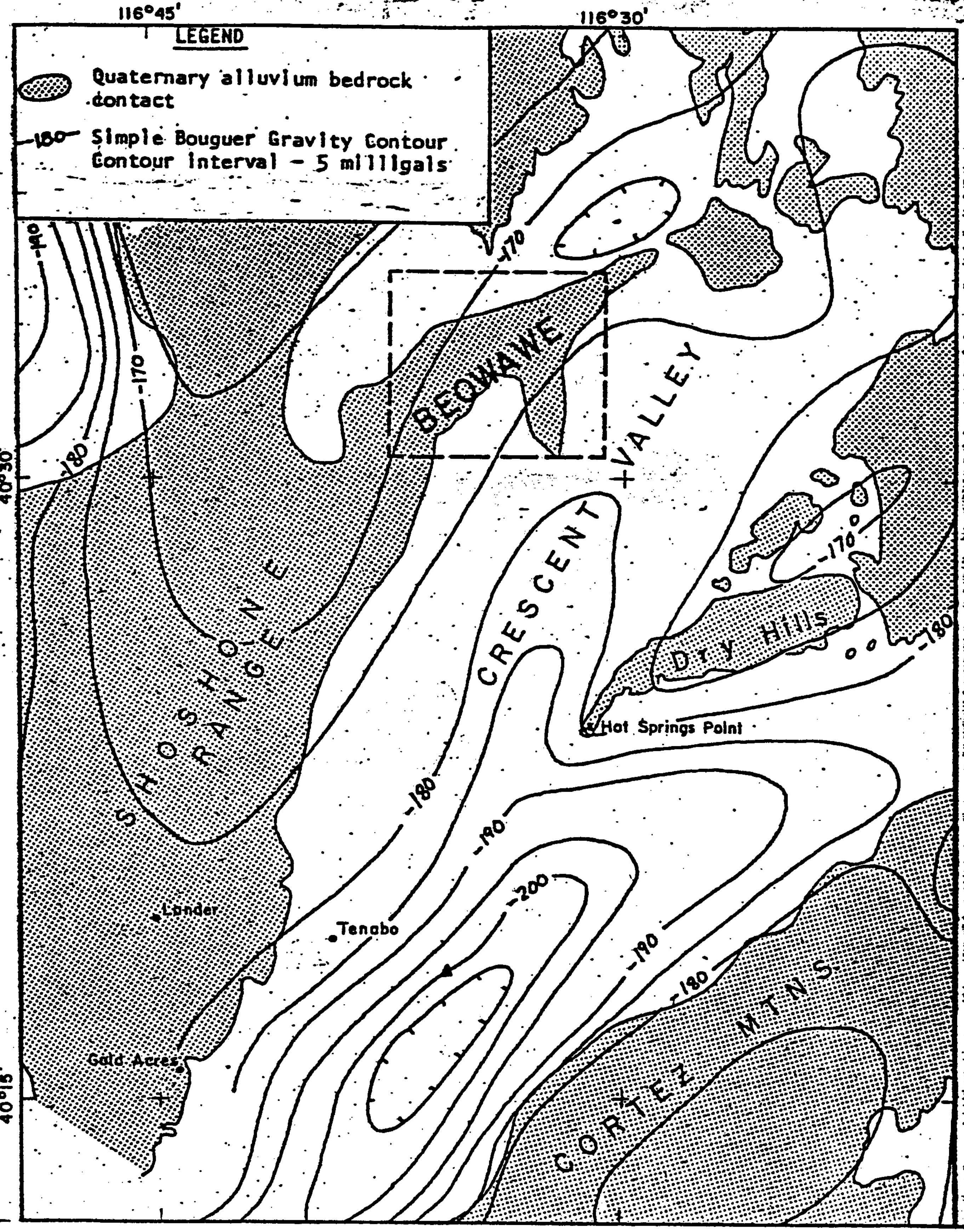

Figure 1. Simple Bouguer gravity map (after Mabey, 1964) of the Crescent Valley. Scale is 1:250,000.

Area IV Sections 28, 33, and 34, T31N, R48E.

In this area, a small graben feature such as seen in Area II is found. Its axis is also interpreted to be in the northwest direction. If these two graben features were part of a single graben in the geologic past, then a strike-slip fault could be postulated along the major fault scarp through the prospect.

Area V. Sections 11, 12, 14, 15, 23, and 26, T31B, R48E, and the area to the east.

The decrease in the gravity to the east indicates a deepening of a graben structure in that direction. The front range fault, and the northwest trending ridge, border this graben to the northwest and southwest.

Area VI - The remaining prospect area surrounded by the other five areas.

Geologically and gravimetrically, this is the most complex area within the prospect. This area extends northeast and east along the front range fault from the monadnock structure (Sec., 18, T31N, R48E) southwest of the Beowawe Geysers to the cirque-like structure in Section 15, T31N, R48E.

The gravity maximum associated with the monadnock suggests that the structure has lateral subsurface extent to the north, west and and east.

A set of two maximum gravity anomalies exist a mile east of the monadnock and south of the Geysers (Sec. 16, 17 and 10). These anomalies trend in a northeast direction with the second and larger of the two anomalies extending also in a northwest direction. As mentioned above, this extension of the anomaly into Whirlwind Valley is associated with the northwest trending ridge and indicates an extension of the ridge beneath the valley to the Shoshone Range. The topography northwest of the gravity anomaly supports this idea.

A moderate density high, trending north-northwest to south-southeast, is found in Sections 22 and 27 just to the west of the ridge of lava flows. A density low with relatively high contrast (4 to 5 5 mgals) is found in the southern half of Section 15. This low corresponds closely to an eroded cirque-like feature. It is possible that this feature is an acid volcanic (granite) intrusive. If this is the case, it should be of much greater age than the basic Tertiary intrusives of the area. North of the gravity minimum is an outcrop of Paleozoic western assemblage rocks which have an average density of 2.6gm/cm^3 (Mabey, 1964) which is less than the density of the Tertiary basalts which cover most of the area. The density contrast between the two could explain the anomaly, bu but not the maximum gravity anomaly that is also associated with the Paleozoic outcrop.

In conclusion, the data suggests two significant structural control lineations in the prospect area:

1. The northeast to east-northeast Beowawe Geysers fault as evidenced by the surface fault scarp through Sections 16, 17 and 19, and

2. A north-northwest trending lineation, which may be a normal fault dipping west at the western edge of the ridge through Sections 22, 27 and 16.

These two major lineations intersect in Section 16, which would t then be a hub of tectonic activity in the area. The present steam wells or so-called geysers are located to the west in Section 17.

MAGNETIC SURVEY RESULTS

The magnetic survey map (Plate IV) shows a sectioning of the prospect area similar to the gravity map discussed above. The significant structural control lineations are shown on the map.

It is noteworthy that there are several single-point anomalies that vary by over 500 gammas within the prospect area. The regional aeromagnetic map of the Crescent Valley (Figure 2) does not indicate any such variations; therefore, these anomalies must be very local effects, and are not necessarily caused by geologic noise.

Description of the magnetic anomalies in the areas indicated in the gravity discussion are as follows:

Area I In a fashion similar to the gravity values, the magnetic values generally increase towards the Shoshone Range (west and northwest) indicating a shallowing of the basin as expected. The two maximum magnetic anomalies in this area (Sec. 12, and Sec. 23, T31N, R47E) overlie the two maximum gravity anomalies and suggest anomalous decreases in the basin depths in these two areas.

Areas II and IV Both of the possible northwest-trending graben strucutures of these two areas occur where there is a minimum of magnetic variation (less than 250 gammas chanage). A explanation for this diminished magnetic variation is that there is a considerable amount of sediments deposited within each graben (more than 2,500 feet). Deep basins often exhibit a lack of magnetic variation.

Area III A series of alternating maximum and minimum anomalies elongated in a northeasterly direction are located in this area. Both the magnetic and gravity anomalies occur in the same area and trend in the same direction, but the minimum magnetic and maximum gravity anomalies are associated and vice versa. The Malpais is composed of a series of rotated fault blocks with the maximum magnetic values being associated with the crest of the fault blocks, and the minimum magnetic anomalies associated with the alluvial filled troughs created by the rotated fault blocks. A distortion of the direction of the maximum magnetic anomaly occurs in Sections 17, and 18, T31N, R47E, and is probably due to the effect of the thermal alteration of the rocks in the area by the thermal springs at the Beowawe Geysers.

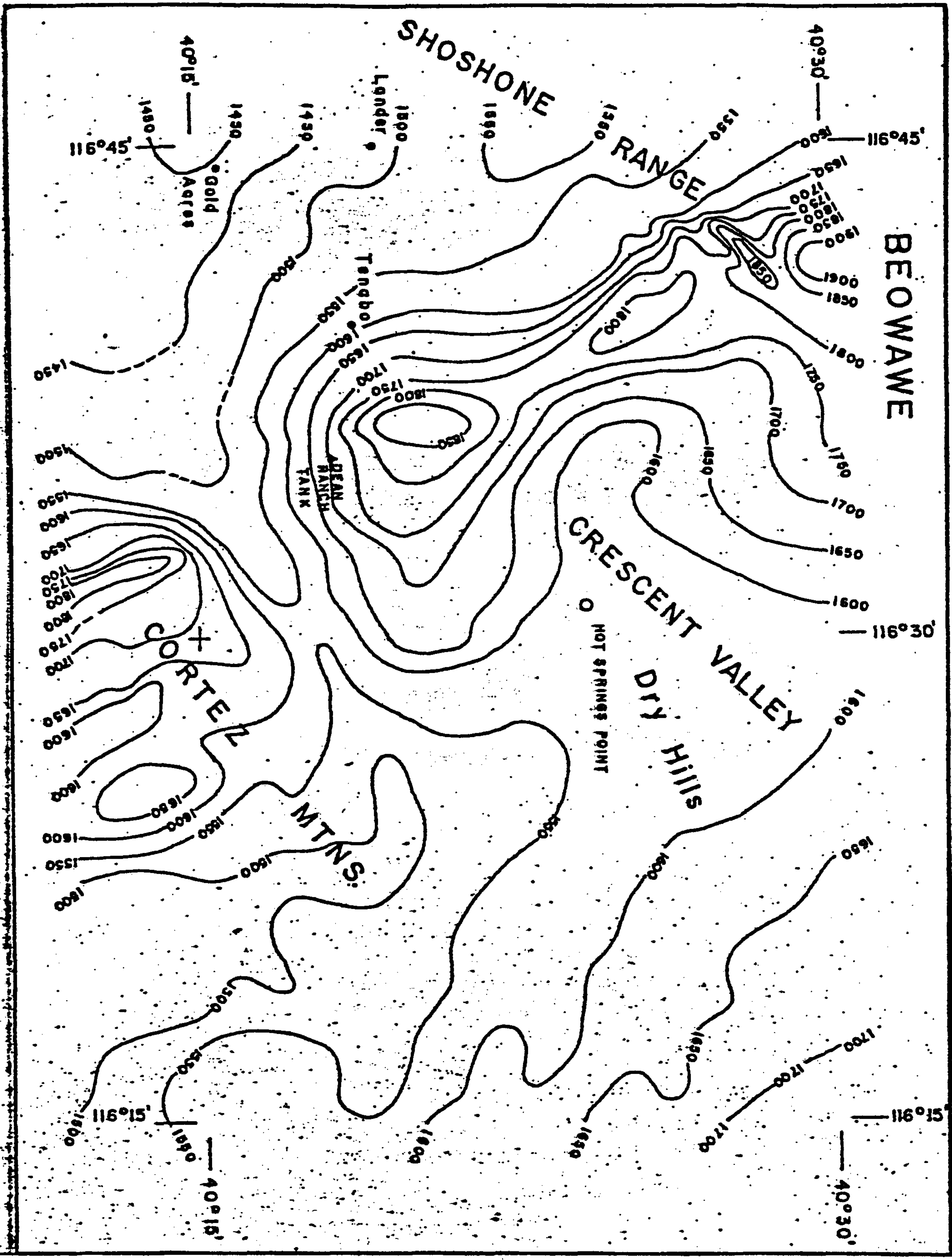

Figure 2. Aeromagnetic map of the Dry Hills and Central Crescent Valley area. Magnetic contours show total intensity magnetic field of the earth in gamma. Contour interval is 50 gammas. Scale is 1:250,000 (after Philbin, et.al,, 1963).

Areas V and VI The magnetic anomalies within these two areas are controlled by the two structural control lineations (northwest-southeast and southwest-northeast) as shown in Plate IV and generally correlate with gravity anomalies of opposite sign. Three sets of maximum-minimum magnetic anomaly pairs occur along the extension of the northwest trending ridge, and nearly all the anomalies are elongated in the northeasterly direction. The central minimum anomaly is the largest of the minimum anomalies in size and amplitude and is bordered by two maximum anomalies that contain the largest positive anomaly values. The total magnetic relief is greater than 1,700 gammas. The northern maximum anomaly in Section 15, T31N, R48E, is similar in shape and location to the maximum gravity anomaly in the same section.

North of this anomaly set, the magnetic variation diminishes until nearly half-way across Whirlwind Valley, at which time the magnetic values increases. It is interesting that this lack of magnetic character is coincident with the maximum gravity anomaly. The other gravity maximum in Section 17, T31N, R48E, is coincident with a minimum magnetic anomaly, as is the monadnock structure.

Normally, maximum and minimum magnetic and gravity anomalies correlate because the low density sediments that cause the gravity lows cover and diminish the strength of the subsurface basement magnetic anomalies. One situation where this does not hold true is in areas of secondary deposition of travertine or sinter by thermal waters. Maximum gravity anomalies will be created with very little magnetic signature. This is not the situation in the vicinity of the Beowawe Geysers where magnetic character is associated with a gravity high. Previous drilling by Magma and Sierra into this anomaly (1,200 feet south of the Beowawe Geysers) produced the poorest results of their drilling program - 81 C versus 184 C just north of the magnetic low-gravity high anomaly. (Hose and Taylor, 1974). The lack of magnetic signature with the gravity anomaly east of the geysers could have geothermal significance.

The magnetic anomalies along the northwest trending ridge could be related to igneous intrusives which could act as potential heat sources in the area. The intersection of the two structure control lineations in Section 22, T31N, R48E, would become a drilling target because of the potential fracturing created by tectonic activity at the trend intersection.

ELECTRICAL RESISTIVITY SURVEY RESULTS

The galvanic (DC) resistivity soundings (Figures 1 through 6 in Appendix II, PART B) indicate that a highly variable upper geologic section exists within the prospect. The soundings to the north of the fault scarp, performed along source locations 8 and 9, indicate subsurface volcanics near the fault scarp and the monadnock near the springs. Further out in the basin, considerable thicknesses of clay alteration and playa-type deposition are expected and indicated by the low apparent resistivity values in the valley. Both of these types of deposits may be a few thousand feet thick and must be penetrated before reaching a heat conduction and/or heat convection system.

The soundings to the south of the fault scarp, performed along sources 6 and 7, indicate a very thin overburden, 100 to 200 feet of fractured flows and alluvium, which are underlain by a resistive section (assumed to correlate with competent volcanics) with thicknesses greater than a few hundred feet. There may be some lateral non-competent channels within this general resistive zone that may locally carry heat away from an area of interest. Therefore, we recommend an initial thermal gradient (T.G.) drilling program to depths of 1,500 feet. One should expect some slow drilling through the intermediate resistive zones.

The TDEM vertical magnetic field (H_Z), horizontal electric field (E_N), scalar MT (0.02 - 0.6 Hz), and AMT measurements throughout the prospect indicate an even more complex picture than the gravity and magnetic investigations suggest. This complexity is shown by the H_Z and E_N apparent resistivity profiles (Plates V - VIII). A brief summary of the data reduction procedures is in Appendix I, PART B.

Examination of the profiles reveals that:

(1) Lateral resistivity variations are very common in the prospect area, and the inferred geoelectric structure is very complex.

(2) The apparent resistivity values encountered along the H_Z profiles are greater than the corresponding E_N values.

(3) The vertical component of the magnetic field will couple best to large, horizontal conductors and should be used as an indication of anomalous resistivity character.

(4) The E_N profiles exhibit more lateral resistivity variations and less profile-to-profile continuity than the corresponding H_Z profiles (see Profiles G, H, L, 5, and 16).

(5) The two sets of perpendicular E_N Profiles (NW-SE and SW-NE) normally exhibit opposite anomalous resistivity character, ie., stations along the NW-SE Profiles will be anomalously resistive while the same stations along the SW-NE Profiles will be anomalously conductive and vice versa (see Stations H9 through O9, Plates VIII, IX and X).

(6) Three areas within the prospect do not conform to the previous observation (#6), ie., both the E_N components (the parallel and perpendicular) at a station exhibit similar anomalous character. These three areas are the central portion of Whirlwind Valley, and the central and southern portions of the northwest extending ridge (Sec. 14, 15, 22, 23, 26, and 27, T31N, R48E; See Plate II and Plates V through X).

(7) Whirlwind Valley is generally more conductive and more laterally homogeneous than the Malpais cuesta.

(8) The significant structural control lineations observed in the gravity and magnetic data are also present in the TDEM sounding data.

(9) Anomalous conductance within the geoelectric section is encountered at depths of approximately 6,000 feet on the Malpais, with some areas displaying anomalous conductance at depths of 3,000 feet or less.

The complexity of the geoeletric structure within the Beowawe Prospect is readily shown by the large number of lateral resistivity variations which occur over short horizontal distances (less than 1,300 feet in many cases) and the different types of sounding curves determined by the TDEM soundings. Generally, the curves can be classed as two types: Q ($\rho_1 > \rho_2 > \rho_3$) and K ($\rho_1 < \rho_2 > \rho_3$) types. The Q type is the most prevalent and is indicative of a resistive overburden underlain by more donductive sediments. Because of the very obvious two and three dimensional structural relationships affecting the TDEM sounding curves, no precise curve matching techniques were employed in interpreting the data. The estimated depths and resistivities can be off by over 200% given the lack of horizontal homogeneity and would have little relevance to portions of the prospect where the geoelectric structure is not layered, but vertically standing. However, this does not alter the fact that the profiles and TDEM soundings can be used to delineate areas of anomalous structure and conductance.

Soundings such as K13 which exhibit anomalous conductance at shallow apparent depths, and which are flanked by more resistive sections, indicate the possible existence of vertically standing conductors. Such vertical structure should be related to fracturing or faulting within the subsurface with mineralization or thermal fluids along the structure providing the anomalous conductance in the zone.

Indirect evidence for the prevalence of such structure within the prospect is provided by the TDEM sounding results. The two sounding types used, the horizontal electric and vertical magnetic soundings, are sensitive to different conductive targets: the electric field soundings are more sensitive to vertical conductors than the vertical magnetic component which is more sensitive to horizontal conductors. The fact that the E_N Profiles are generally more conductive than the H_Z Profiles, and indicate more lateral resistivity variation, indicates the predominance of vertical conductors in the area. For this reason, the vertical magnetic sounding Profiles were utilized to indicate the most interesting target areas because they should differentiate better between the insignificant conductive targets (see Plate XI).

Another indication of the complexity of the geoelectric structure is shown by comparison of the E_N soundings in the two orthogonal directions. The plotted results are the horzontal electric field soundings normal to the particular profile; consequently, the sounding will be either the component parallel to the source bipole or perpendicular to it. Comparison of the individual orthogonal components at a particular site yield the results that in many portions of the prospect, a conductive anomaly determined by the northwest component of the electric field, will be a resistive anomaly as determined by the orthogonal southeast component of the electric field. This is true of the Beowawe Geysers area, the area southeast of the Geysers extending along the slope of the Malpais, and in Section 9 and 10, T31N, R48E, where the maximum gravity anomaly extends into Whirlwind Valley. These anomaly reversals are again indicative of a very complex geoelectric structure that is skewing the induced electric fields. Fortunately, the vertical magnetic field is much less affected by this skewing.

Significantly, three anomalous areas did not show a reversal of anomalies by different electric field components. The central area of Whirlwind Valley (along Profiles S, T and U) is anomalously conductive, the central area of the northwest trending ridge associated with the minimum magnetic anomaly (Sec. 14, 15, and 33, T31N, R48E) is anomalously conductive and the area bordering this anomaly to the south (Sec. 22, 23, 26, and 27, T31N, R48E) is anomalously resistive.

Verification of an anomaly by the two electric field components adds credence to its existence. The conductive anomaly within Whirlwind Valley is expected due to the alluvial fill of the valley and the existence of the Beowawe Geysers and other thermal expressions along the front range fault bordering the valley.

The lateral homogeneity of the conductive anomaly indicates that it is relatively uniform and large in size. Conductive clays and thermal waters are likely to be the cause of this anomaly.

The juxtaposition of the conductive and resistive anomaly within the northwest trending ridge is of more interest because a conductive anomaly associated with a volcanic ridge has fewer possible explanations. This anomaly will be discussed later with regard to the other geophysical anomalies.

These two anomalies, as well as most of the other anomalies determined by the resistivity survey, appear to be controlled by the structural lineations in the northeast-southwest and northwest-southeast directions as noted in the description of the gravity and magnetic anomalies. The fact that all three geophysical techniques locked onto these trends denote that they must be related to the major tectonic forces within the area, as would any geothermal activity.

The structural lineations determined by the H_z soundings are shown on Plate XI. This Plate represents the contoured apparent resistivity values determined by an apparent depth of apparoximately 2,000 meters (6,560 feet). The structural trends as determined by the horizontal electric field soundings are not significantly different.

The Beowawe Geysers area is conductive and is bordered to the northwest by a resistive anomaly of small lateral extent. The resistor may be associated with a buildup of travertine at depth, but the gravity does not lend much support to this idea. Southeast of the Geysers and the monadnock, the Malpais is characterized by relatively high apparent resistivity. Bifurcation of the resistive anomaly occurs in Section 16, T31N, R48E, by a small conductive anomaly that may be related to the much larger conductive anomaly occurring in Sections 9, 10, and 11, T31N, R48E.

Elongation of this large anomaly occurs in the southeast direction and this axis of this structural trend passes through another conductive anomaly south in Section 22, T31N, R48E. This anomaly is coincident with the conductive anomaly determined by the two electric field component soundings and it occurs at the intersection of two structural trends. Another conductive anomaly in Sections 21, 28 and 29, T31N, R48E, occurs southwest of the trend intersection. Southeast of the trend intersection is a resistive anomaly that shifts the southern extension of the northwest-southeast trend to the southwest. Generally, the apparent depth to each of these conductors approaches 6,000 feet except at the following sites: J9, K13 and Q14. At these three sites apparent depths to the conductor are less than 3,000 feet and nearby vertical conductors are expected to exist.

The total apparent conductance determined by the MT soundings are in good agreement with the TDEM data. Two of the three MT sites with the minimum conductance, F11 and L9 ($\sim$500 mhos), occur within or close to the resistive anomalies of the Malpais and the ridge.

The maximum conductance was determined in Whirlwind Valley at site 53 (890 mhos), and the maximum conductance determined south of the range fault occurs at I11 (780 mhos) on the edge of the southern conductive anomaly (see Plate XI). Given 780 mhos and a section conductance of 3 ohm-m, the depth to the base of the conductor (electrical basement) is 2,340 meters. MT sounding Q15 has the minimum determined conductance for the area (290 mhos) and yet, lies on the valley side of the range fault and within the conductive anomaly determined by the H_z TDEM soundings. This discrepancy may be explained by lateral resistivity variations within the area (the two orthogonal electric fields indicated anomaly reversals in this area).

The most interesting area within the prospect occurs at the intersection of the structural trends in Section 22, T31N, R48E. The conductive anomaly occurring at this intersection coincides with the elongated minimum magnetic anomaly that extends along the northeast-southwest structural trend. The resistive anomaly south of the intersection coincides with a maximum magnetic anomaly, and the minimum gravity anomaly occurs in the northeast quadrant created by the intersecting structural trends. This is a very complex area and one that should be investigated for geothermal potential.

The magnetic anomalies are probably due to igneous intrusives that could be related to the diabase dike emplacement in the Cortez mountains during the Pliocene. Intersection of the structural trends is a good indication of fracturing, this providing channels for water to percolate down to the intrusives. The conductive anomaly is not large in lateral extent, but one would not be expected if a fracture dominated system is encountered. The existence of the conductor astride the ridge is significant by itself. The fact that these unusual anomalous condition are coincident or in such close proximity is intriguing and certainly the result of some complex tectonic activity.

The northern conductive anomaly in Section 9, T31N, R48E, is associated with a gravity maximum but no significant magnetic expression. The extreme anisotropy exhibited by the electric field sounding indicated geoelectric complexity, but its extension into the conductive valley diminishes the enthusiasm for this anomaly.

The conductive anomaly southwest of the structural intersection occurs within Area IV and the interepreted graben structure. The conductive anomaly shape and trend differs from that expected for the graben; consequently, thickening of conductive sediments in the graben may not adequately explain the anomaly and add significance to the anomaly.

No other general comments regarding the correlation of the resistivity anomalies and the gravity and magnetic anomalies can be made here.

SUMMARY AND RECOMMENDATIONS

Each of the three geophysical methods employed in the Beowawe Prospect; magnetics, gravity and electrical resistivity, indicate that this area is structurally very complex. That in itself is significant since large scale tectonic activity is the earmark of most important geothermal systems. The existence of hot springs occurs along the front range fault and drilling has proven the existence of high subsurface temperature (>165°C).

Areas I and II within the western portion of Whirlwind Valley (see Plate III) are not believed to be important due to their lack of any unusual geophysical character. Conductive clays and silts probably fill the basin area and provide a poor reservoir for any geothermal sources flanking the valley. No igneous intrusives were determined. More detailed gravity interpretation may yield residual gravity maximums within the valley that may be related to subsurface travertine deposition.

Area III (see Plate III) is characterized by relatively high apparent resistivity, and an alternating set of elongated northeast-southwest gravity and magnetic maximum and minimum anomalies. The minimum gravity anomaly associated with the front range fault is difficult to interpret but may be due to intrusives. The lack of a conductive resistivity anomaly diminishes interest for this area.

Area IV (see Plate III) is characterized by a minimum gravity and conductive resistivity anomaly. A general increase in the magnetic values occurs to the southwest but no major structural features is indicated by the magnetics. The orientation and shape of the resistivity anomaly differs from the inferred graben structure, so, fortunately, the conductor may not be due entirely to a thickening of the overburden. The graben may be related to the graben in Area II and thus indicating strike slip movement has occurred in the past. The resistivity trend east of Area IV indicates the same type of strike-slip movement.

The conductive anomaly is aligned along an interpreted southwest structural trend and may be related to the resistivity anomaly northeast in Area VI.

Area V (see Plate III) is characterized by a minimum gravity anomaly extending east, southeast and is interpreted as a graben structure. A magnetic low extending along the northeast-southwest structural trend spreads out into the area. The southern portion of Area V in the vicinity of the ridge contains a general gravity minimum, a magnetic maximum and a resistive anomaly.

Area VI (see Plate III) is the most complex and most interesting of the areas. The area adjacent and south of the Beowawe Geysers has a gravity maximum, magnetic maximum and a resistive anomaly associated with it. Drilling in this area determined disappointing subsurface temperatures at depths less than 1,000 feet (≤81 C). The existence of the magnetic maximum with the gravity maximum indicates that travertine accumulation and geothermal activity were not the cause of the gravity anomaly as indicated by the drilling. The Beowawe Geysers are associated with a conductive anomaly bordered by a resistive anomaly and the lateral extent of the anomaly is approximately one mile.

Ine Sections 16 and 19, T31N, R48E, a gravity maximum with little magnetic character is generally associated with a conductive anomaly. The geoelectric structure is very anisotropic in this area. The gravity and resistivity anomalies lie along the northwest-southeast trending structural lineation that occurs along the volcanic ridge. The resistivity anomaly may not be as significant geothermally because it occurs in the conductive valley fill, but there is some extension of the anomaly southeast into the fault-block. The gravity anomaly may be related to the extension of the volcanic ridge beneath the valley floor, but it may be due, in part, to geothermal activity. The gravity anomaly also extends to the southwest in Section 16 and a small conductive anomaly occurs in the southwest quarter of the section.

The most significant anomaly occurs south along the ridge in Section 22, T31N, R48E. A minimum gravity anomaly corresponds to a magnetic high and borders a minimum magnetic and conductive anomaly. The magnetic and resistivity anomalies occur at the intersection of the significant structural trends in the prospect (northeast-southwest, northwest-southeast). The elongation of the magnetic anomaly perpendicular to the ridge implies igneous intrusion, possible as early as Pliocene time when diabase intrusions occurred in the Cortez Mountains south of the Beowawe Prospect. The resistivity and magnetic anomalies are bordered to the south by magnetic and resistivity high anomalies. The complexity of the anomaly set, the possibility of fracturing associated with the trend intersection and the existence of low apparent resistivity with little anisotropy make this area the most promising target for future exploration work. If this is a fracture dominated system, then the conductor should be encountered at depths as shallow as 3,000 feet.

Low resistivity values are associated with Area VI and there are indications from two TDEM soundings that a fracture-dominated situation may exist here. If this is the situation, the potential geothermal plumbing system would be encountered at approximately 3,000 feet instead of 6,000 feet as indicated for Area VI.

Two initial test holes (see Plate XI) are recommended to probe the thermal gradient (TG) of the area and to calibrate the geophysical results with the observed geologic section. Because of the complexity of this area, this calibration of the geophysical results is essential in order to obtain the best results from this survey and subsequent drilling. These holes should be drilled in the order shown and to a depth of 1,500 feet so that more conclusive results can be obtained from the drill hole data. Shallower TG holes can lead to misleading conclusions. In one case, shallow, high temperature gradients can become isothermal at greater depth and thus provide disappointing deep temperatures or, in another case, lateral movement of water can produce disappointing shallow TG results while at depth very high temperature gradients could be encountered. After re-evaluating the geophysical survey with the TG data, two additional drill holes will be recommended.

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