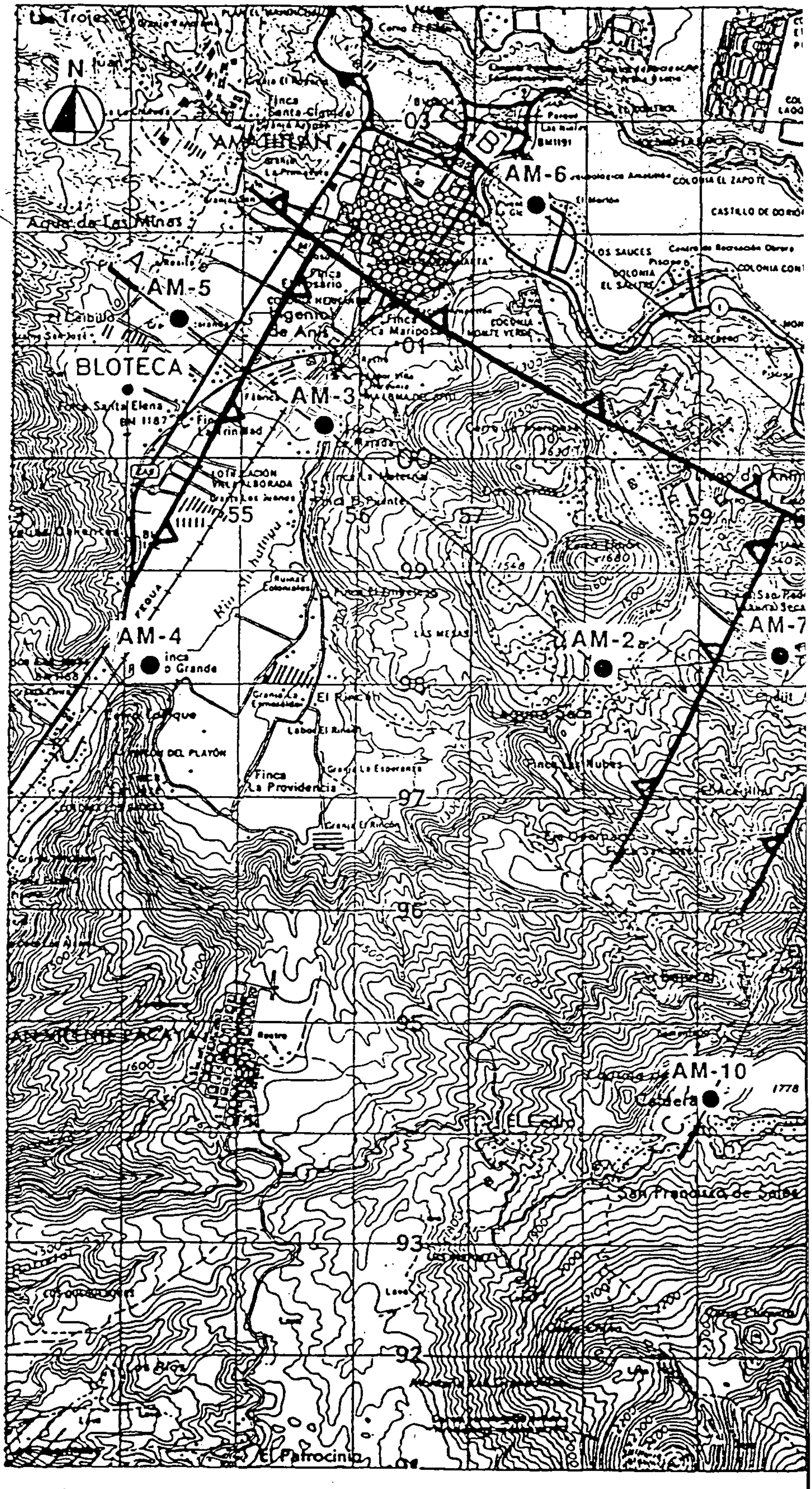
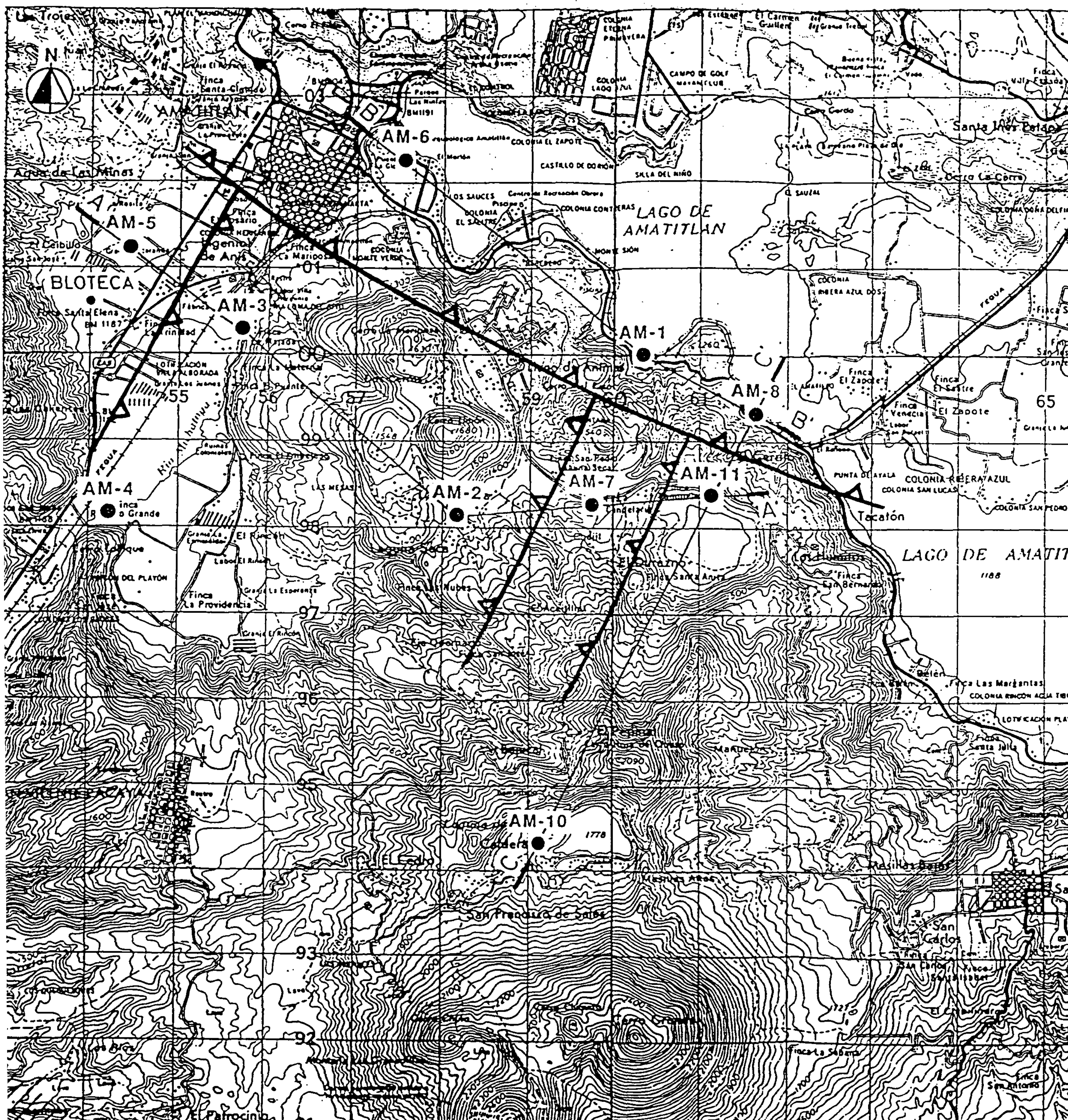
GL01507

AMATITLAN

Guatemala




N
AMATITLAN
AM-6
AM-5
BLOTECA
AM-3
AM-1
AM-8
AM-4
AM-2
AM-7
AM-11
AM-10
LAGO DE AMATITLAN
LAGO DE AMATITLAN
Tacatón
Agua de Las Minas
Santa Inés Petapa
CAMPO DE GOLF
COLONIA EL ZAPOTE
CASTILLO DE DORIÓN
SILLA DEL NIÑO
COLONIA CONTRERAS
COLONIA RIBERA AZUL
COLONIA SAN LUCAS
COLONIA SAN PEDRO
PUNTA DE AYALA
El Zapote
Finca Venecia
El Durazno
Finca Santa Anita
Finca Las Nubes
Finca La Providencia
Candelaria
Caldera
San Francisco de Sales
El Cedro
San Carlos
Finca Las Margaritas
Finca San Bernardo
El Patrocinio
Finca La Sabana
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A
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C
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A'
1188
1778

Pozo de Amatitlán

		after pozo
AM-1	105°C @ 20-40m; then decr rapidly - near surface outflow plume	10½ days
AM-2	175°C @ 490m; continued good gradient, no reversal	20 days
AM-3	83°C @ 505m; +ve gradient from 400m	12 days
AM-4	lost hole (?) @ 64.6 m	—
AM-5 (on Luis' lot)	++ 125°C @ 363m; +ve gradient from 200m did not measure T to full depth of 435 m Tmeas. before hole completed	during drilling
AM-6	68°C max @ 50m; then -ve grad. to 200m, cont decr. near surface outflow plume	30 da.
AM-7	180°C @ 350m; then -ve grad to 500m. near fault; slow reversal; deep lateral flow-	12 mo. ~~12 mo.~~
AM-8	75°C @ 50m; then gradual -ve grad to 563m. - incr @ depth shallow plume along fault? outflow - weak incr @ depth	~~22 hrs.~~ 40 hrs.
AM-9	(?)	
AM-10	170°C @ 625m; then 1pt. reversal?); higher w. time	15 days 22hrs.
AM-11	170°C @ 445-560m; then reversal to 80°C @ 680 m near fault carrying T.	

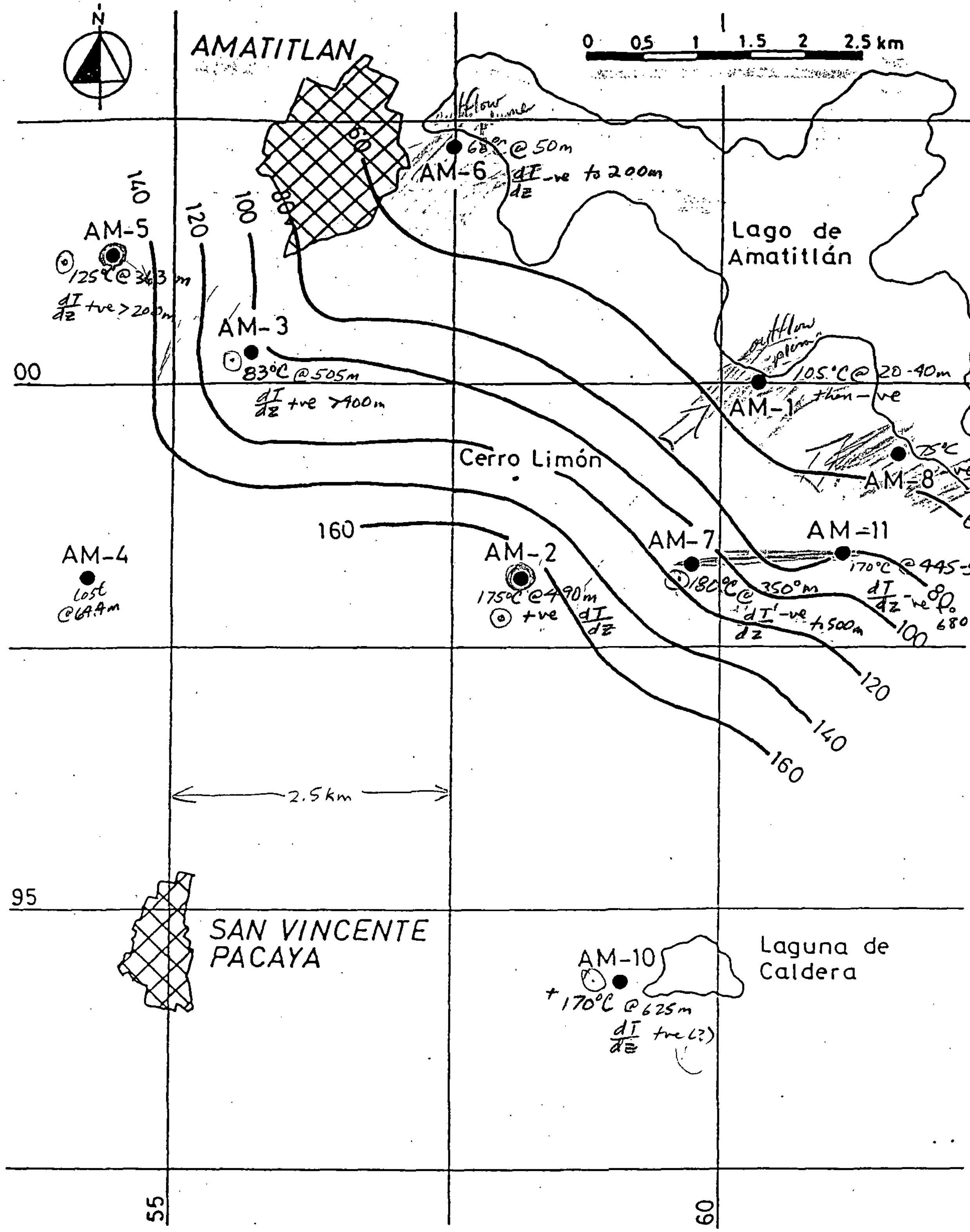


Fig. 4-1a - Curvas de Isotemperatura - Cota 600 m s.n.m.

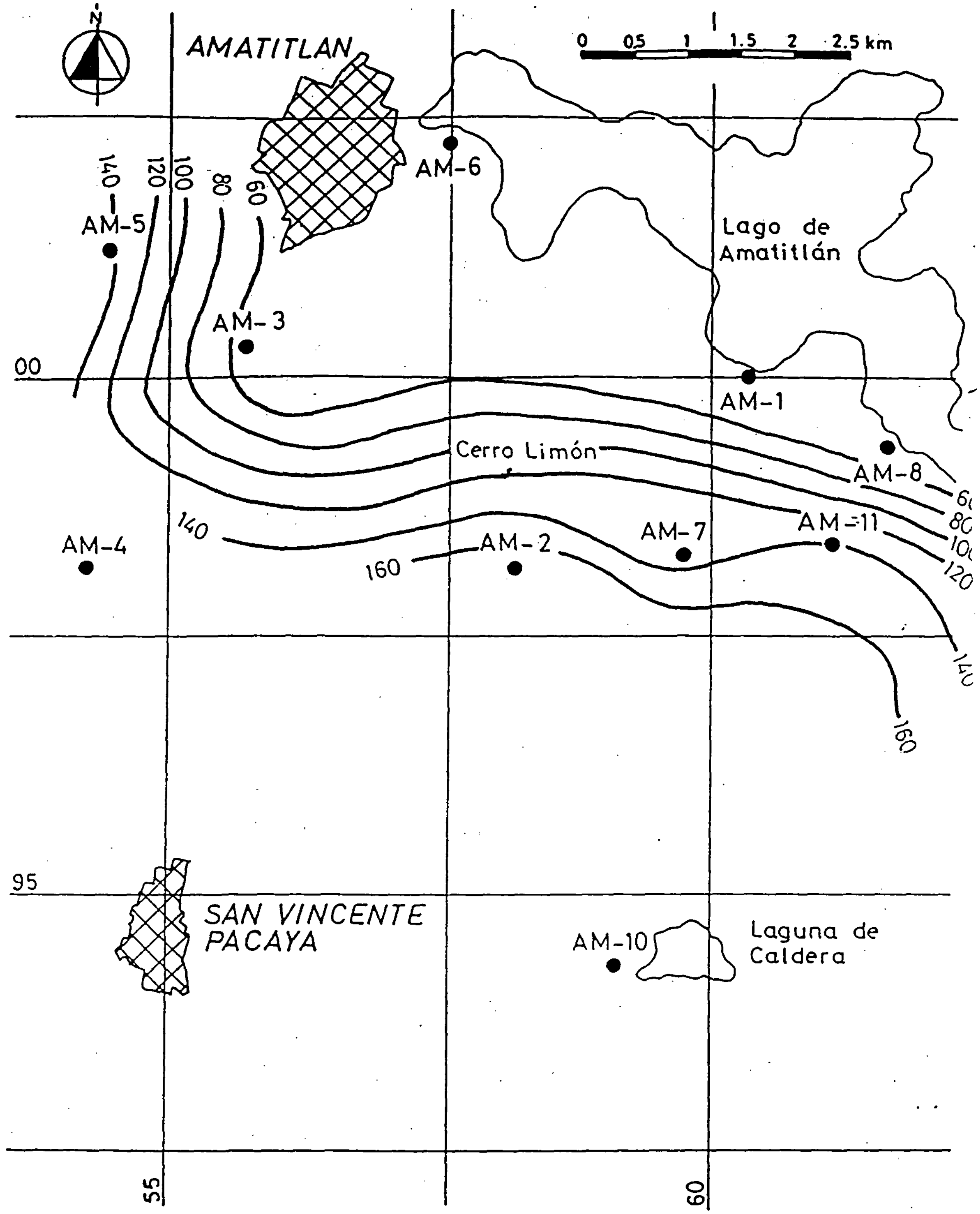


Fig. 4-1b - Curvas de Isotemperatura - Cota 800 m s.n.m.

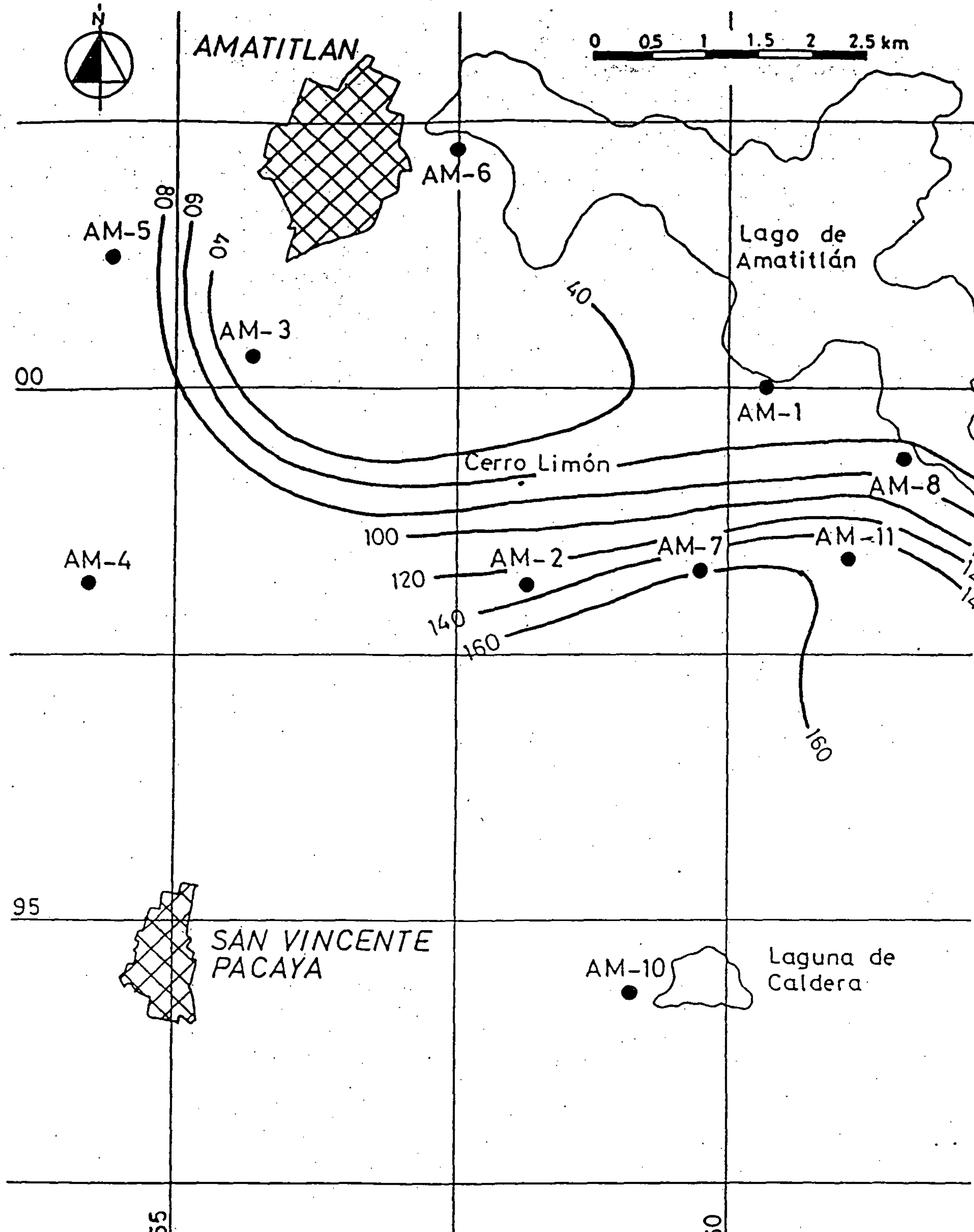


Fig. 4-1c - Curvas de Isotemperatura - Cota 1000 m s.n.m.

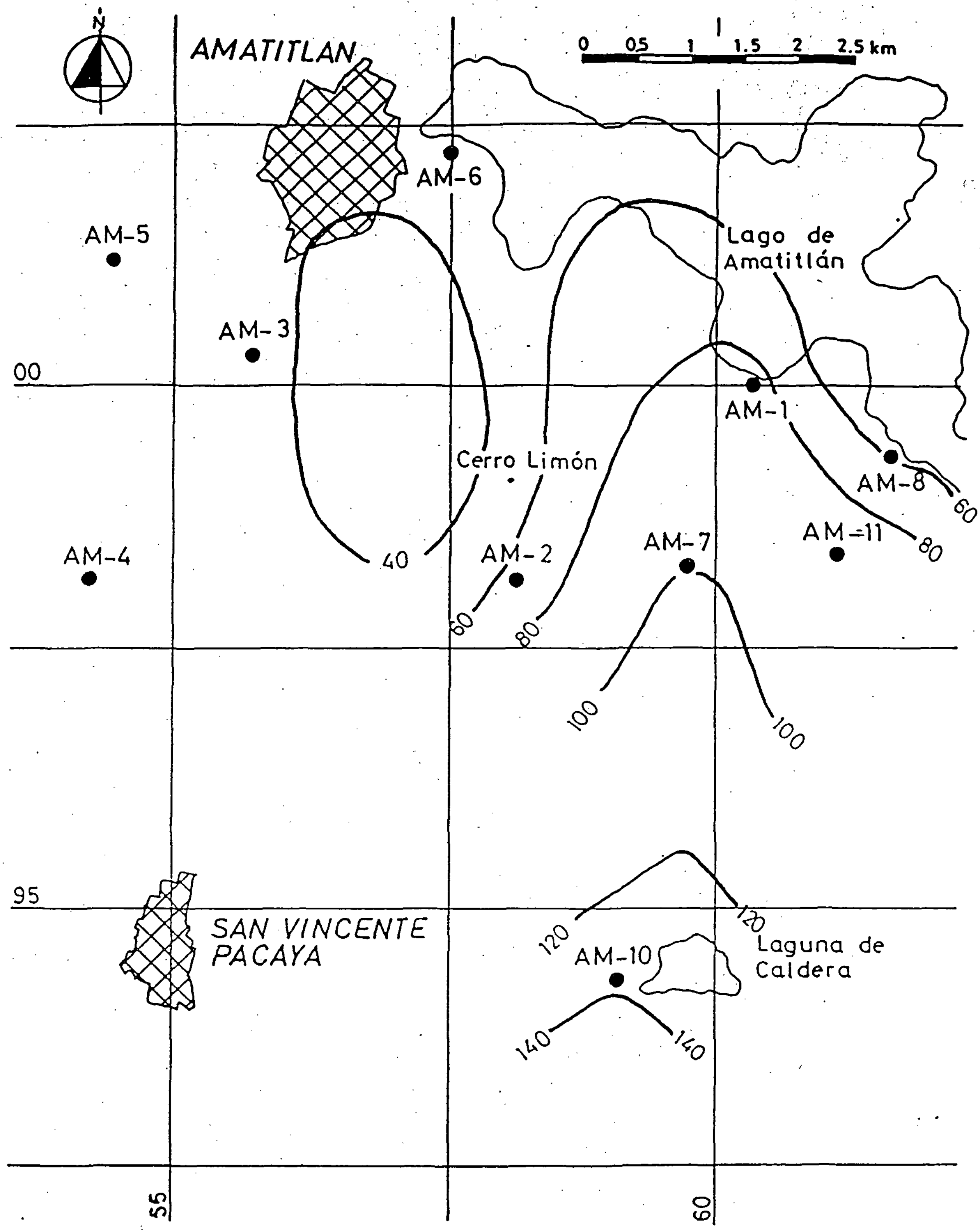
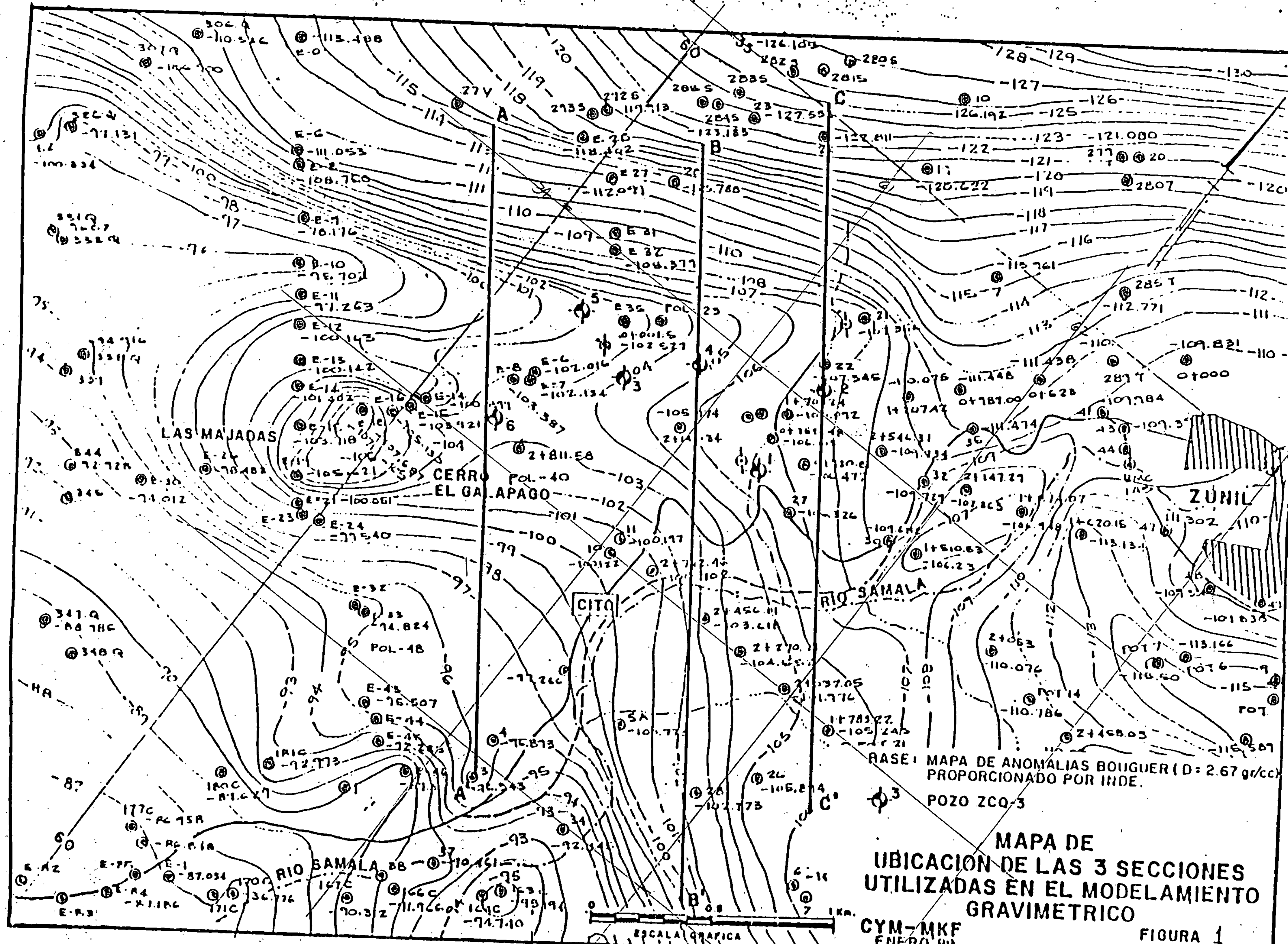


Fig. 4-1d - Curvas de Isotemperatura - Cota 1200 m s.n.m.

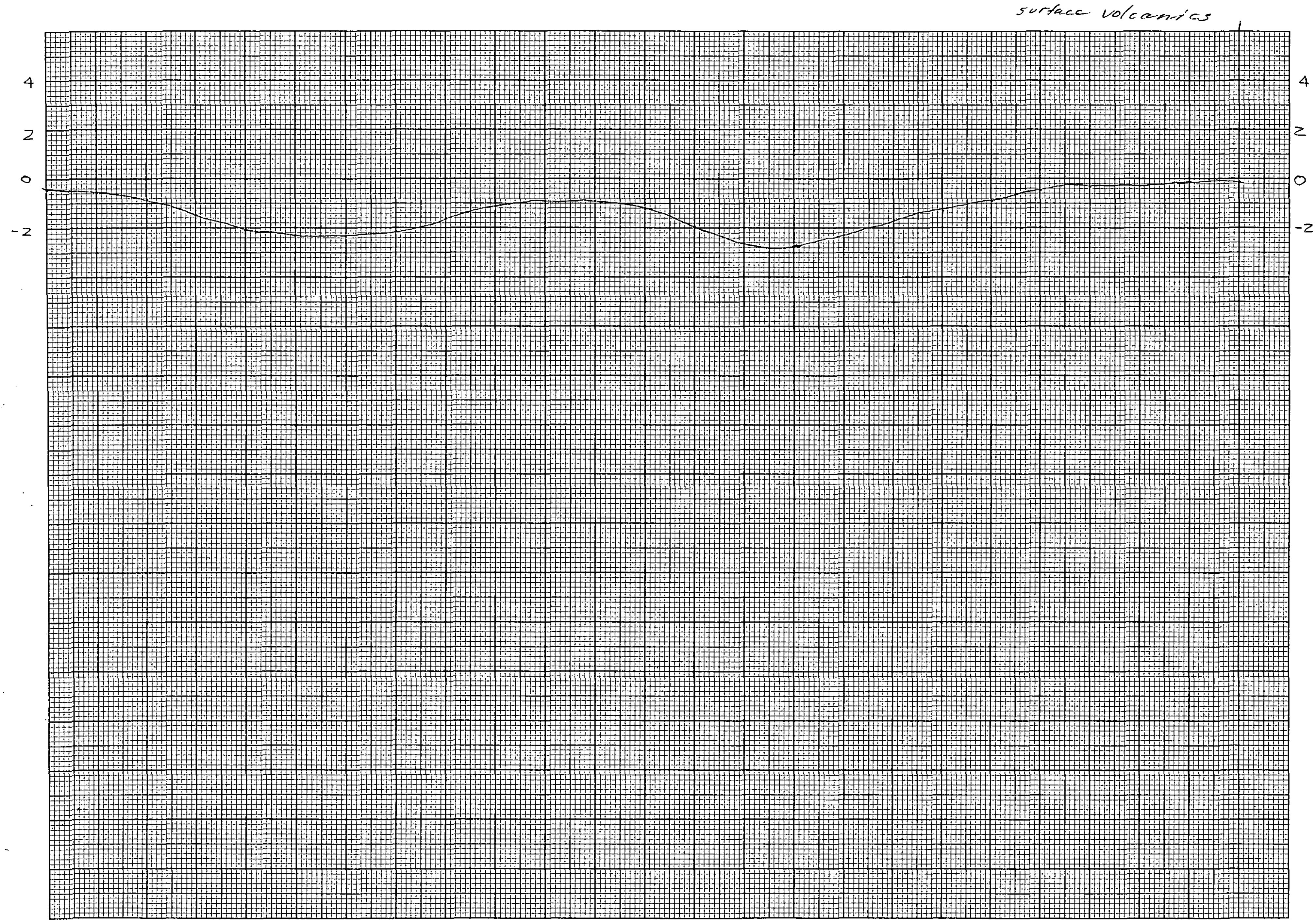
1:20,000 scale



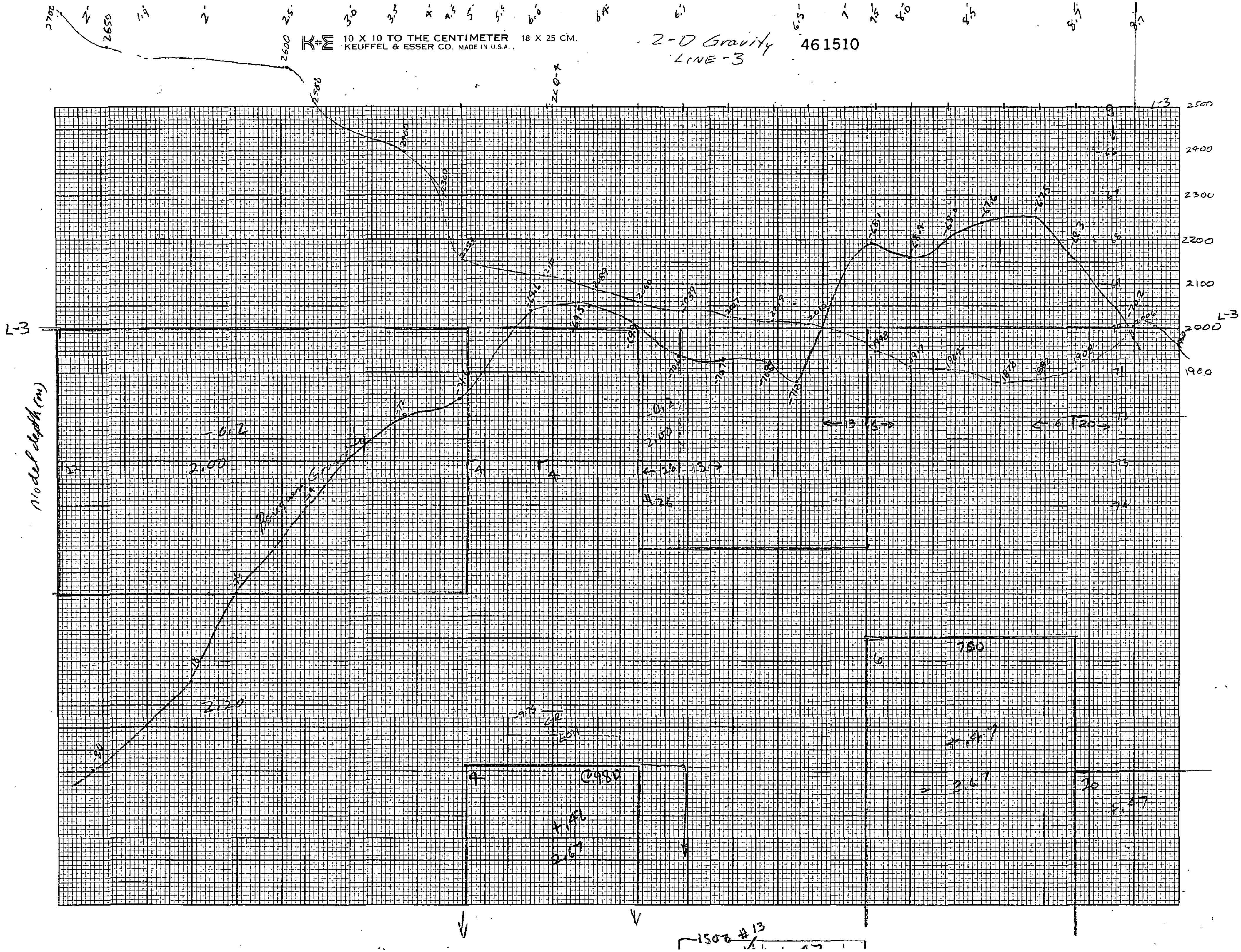
MAPA DE UBICACION DE LAS 3 SECCIONES UTILIZADAS EN EL MODELAMIENTO GRAVIMETRICO

CYM-MKF
ENERO 89

FIGURA 1


surface volcanics
4
2
0
-2
4
2
0
-2

2-D Gravity LINE-3



AUG 01 '89 20:31 MKE C636 GUATEMALA CITY P.1

3,95" ~ 10,000 / 5.18 = 1.3114

1.20 × 1.09

CyM Cordón y Mérida, Ings.
8a. Ave. 6-94 zona 9 - Guatemala, C.A. Teléfonos 317972, 318631, 318612

F A X

Fecha: Agust 1st, 1989
Proyecto Zunil I

A : Dr. Joe Moore/ Dr. Howard Ross — Fax No.: (801) 524 - 3453

De: Ing. Luis Felipe Mérida I. — Fax No.: (011) 502 2 34 06 27

Asunto: Geophysics studies Zunil I.

Total de páginas enviadas: 14
(incluyendo esta)

Dear Joe :

Enclosed please find the Principal Facts for the detailed gravimetric survey (year '89) for densities 2.0 and 2.67. Tomorrow I'll be sending you the coordinates (UTM) and the rest of the data for the line extensions (Lines 2, 4 and 8). This data goes with maps I have send you previously (1: 5000). The terrain corrections were calculated with the corresponding densities (2.0 and 2.67). A de B stands for Anomalia de Bouger. Thank you

Regards.

LINEA # 1 GRAVIMETRIA DE ZUNIL A DETALLE ZUNIL I

$\rho = 2.00$ gr/cm³

	EST.	ELEV	A de B	Corr Top	A de Boug c/corrt
	1+297.70	2031.43	-55.302	4.986	-50.316
	1+200.00	2036.75	-55.106	5.052	-50.054
	1+211.91	2069.28	-54.601	4.791	-49.810
	1+000.00	2084.36	-54.296	4.745	-49.551
	0+900.00	2090.32	-54.588	4.546	-50.042
*	0+800.00	2086.59	-55.243	4.751	-50.492
	0+706.80	2097.98	-55.847	5.435	-50.412
*	0+600.00	2111.87	-56.935	6.274	-50.661
*	0+493.00	2136.12	-57.283	6.870	-50.412
	0+408.00	2146.18	-57.802	7.762	-50.040
	0+302.00	2201.37	-58.560	8.170	-50.390
	0+197.00	2249.83	-58.945	7.994	-50.951

LINEA #2 GRAVIMETRIA ZUNIL A_ DETALLE ZUNIL I

$\rho = 2.00\ gr/cm^3$

ESTACIÓN	ELEVACIÓN	A DE B	CORR. TOP.	A DE B c/corr top.
0+928.67	2014.73	-52.110	6.645	-45.465
0+820.09	2041.99	-52.504	5.605	-46.899
0+741.68	2080.72	-53.948	6.817	-47.01
0+637.72	1984.49	-55.476	7.546	-47.93
* 0+525.08	1890.87	-59.018	10.776	-48.242
0+412.10	1953.69	-56.081	7.981	-48.100
0+330.31	1953.90	-56.037	7.768	-48.269
0+240.78	1992.83	-55.581	6.381	-49.200
0+130.02	2018.32	-56.126	6.21[illegible]	-49.910
0+850.00	2042.36	-55.262	6.052	-49.210
0+071.51	2032.90	-56.371	6.329	-50.042
0+168.49	2017.82	-57.330	7.455	-49.875
0+274.86	2031.34	-57.782	7.958	-49.824
0+372.00	2042.02	-59.330	9.325	-50.005
0+470.47	2082.97	-59.410	9.714	-49.696
0+570.63	2152.43	-58.847	9.096	-49.751
0+661.85	2226.04	-58.821	8.445	-50.376

3.23 ; 2.295 ; ?

LINEA # 3 GRAVIMETRIA Zunil a Detalle Zunil 1

$\rho = 2.00$ gr/cm³

Estación	Elev	A de B	Corr Top	A de B c/corr top
1+000.00	2006.50	-54.058	6.404	-47.650
0+871.00	1908.13	-55.571	8.200	-47.371
0+800.00	1881.82	-56.247	9.234	-47.013
0+718.20	1877.49	-56.791	9.480	-47.311
0+593.20	1904.29	-56.484	9.065	-47.419
0+510.20	1916.59	-56.845	9.176	-47.669
0+434.00	1948.15	-55.867	8.693	-47.174
0+285.00	2010.22	-55.265	6.097	-49.168
0+203.00	2018.54	-55.010	6.391	-48.619
0+100.00	2027.70	-55.210	6.737	-48.473
0+364.98	2038.92	-55.747	7.392	-48.355
0+101.70	2060.05	-55.914	8.364	-47.55
0+200.00	2089.17	-56.139	9.090	-47.049
0+300.00	2117.23	-57.497	10.42	-47.077
0+491.00	2253.21	-57.644	10.22	-47.424

LINEA # 4 GRAVIMETRIA ZUNIL A DETALLE. ZUNIL I

$\rho = 2.00\ gr/cm^3$

	ESTACION	ELEVACION	A DE B	CORR TOP	A DE B c/corr.
	1+221.70	1858.08	- 56.107	9.498	- 46.609
96.2	1+125.50	1878.11	- 55.789	9.396	- 46.393
90.8	1+034.70	1902.97	- 55.399	9.167	- 46.232
112.0	0+922.70	1977.20	- 54.231	7.671	- 46.560
97.7	0+825.00	1998.27	- 53.303	6.949	- 46.354
100	0+725.00	2010.85	- 52.909	? 6.714	- 46.195
100	0+625.00	2026.27	- 52.942	6.530	- 46.412
106.9	0+518.10	2035.44	- 53.156	6.367	- 46.789
93	0+425.00	2050.85	- 52.777	6.409	- 46.368
100	0+325.00	2057.29	- 53.179	6.733	- 46.446
100	0+225.00	2067.44	- 53.477	7.362	- 46.115
100	0+125.00	2072.36	- 54.318	8.074	- 46.244
[?]	0+100.30 - LB	2070.24	- 55.764	9.646	- 46.118
[?]	0+071.40	2089.03	- 55.526	9.983	- 45.543
77.6	0+175.00	2127.05	- 55.902	10.170	- 45.732
74.8	0+249.80	* 2182.34	- 55.577	9.426	- 46.151
125.2	0+375.00	2249.97	- 55.558	9.81	- 45.748
99	0+474.00	2328.34	- 55.270	9.776	- 45.494
101.8	0+575.80	2402.01	- 54.613	9.657	- 44.956

LINEA H 5 GRAVIMETRIA ZUNIL A DETALLE ZUNIL I

ρ = 2.00 gr/cm³

ESTACIÓN	ELEVACIÓN	A DE B	Corr top	A DE B c/corr top
1+100.09	1864.17	-53.944	9.222	-44.722
1+200.07	1899.01	-54.306	9.234	-45.072
1+000.23	1937.96	-54.236	9.277	-44.963
1+797.32	1971.40	-54.531	8.712	-45.813
0+600.02	2049.13	-52.433	6.617	-45.816
0+399.81	2083.37	-52.302	6.149	-46.153
0+200.22	2104.22	-52.280	6.328	-45.952
0+290.04	2116.74	-53.091	7.814	-45.277
0+199.99	2131.44	-54.546	9.263	-45.283
0+399.84	2234.86	-54.848	8.946	-45.902

LINEA 6 GRAVIMETRIA ZUNIL A DETALLE ZUNIL I

ρ = 2.00 gr/cm³

ESTACIÓN	ELEVACIÓN	A DE B	Corr top	A DE B c/corr top
0+311.58	2167.96	-50.335	6.933	-43.402
0+200.30	2167.47	-50.420	6.733	-43.687 *
0+117.63	2197.56	-49.884	6.423	-43.465 *
0+510.00	2171.03	-50.163	7.267	-42.896 *
0+105.69	2189.53	50.673	7.684	-42.989 *
0+178.73	2237.60	-51.061	7.039	-44.022 *
0+303.82	2240.30	-52.188	7.964	-44.224 *
0+405.11	2223.24	-53.693	9.925	-43.768 *
0+488.99	2288.77	-52.993	8.379	-44.614 *
0+602.34	2342.58	-52.561	8.815	-43.746 *

LINEA # 7

ρ = 2.00 gr/cm³

ESTACION	ELEV	A de B	cor Top	A de B c/cor Top.
0+462.60	2268.37	49.331	8.143	41.188
0+280.00	2235.93	48.462	7.588	40.874
0+145.70	2271.20	47.868	7.271	40.597
0+010.00	2259.16	48.293	6.968	41.325
0+655.00 LB	2234.38	48.699	6.942	41.757
0+120.00	2247.70	48.837	7.333	41.504
0+320.00	2303.88	49.815	7.178	42.637
0+540.20	2355.97	50.637	8.389	42.248
0+598.00	2374.57	50.892	8.413	42.479

LIN 8

ESTACION	ELEV	A de B	Corr Top.	A de B c/correc Top.
0+094.80	2503.02	- 50.900	11.831	- 39.069
0+144.00	2464.35	- 48.244	8.523	- 39.721
0+268.00	2493.16	- 50.744	10.026	- 40.718
0+400.8	2520.91	- 51.673	10.17	- 41.503
0+337.60	2578.17	- 51.416	8.763	- 42.653

LINEA # 1

GRAV. ZUNIL

$\rho = 2.67\ gr/cm^3$

ESTACIÓN	ELEVACIÓN	A DE B	CORR TOP.	A DE B C/CORR TOP.
1+297.70	2031.93	-112.297	6.668	105.629
1+200.00	2036.75	-112.238	6.836	105.402
1+211.91	2069.28	-112.642	6.396	106.246
1+000 00	2084.36	-112.763	6.432	106.331
0+900 00	2090.32	-113.221	6.070	107.151
0+800.00	2086.59	-113.772	6.342	107.430
0+706.80	2097.98	-114.693	7.256	107.437
0+600.00	2111.87	-116.174	8.376	107.798
0+493.00	2136.12	-117.200	9.158	108.042
0+408.00	2146.18	-118.000	10.362	107.638
0+302.00	2201.37	-120.309	10.907	109.402
0+197.00	2249.83	-122.055	10.672	111.383

LINEA # 2

GRAV ZUNIL

$\rho = 2.67\ gr/cm^3$

ESTACIÓN	ELEVACIÓN	A DE B	CORR TOP.	A DE B c/CORR TOP.
0+928.67	2014.73	-108.622	8.871	-99.751
0+820.69	2041.99	-109.779	7.46.	-102.319
0+741.68	2080.72	-112.292	9.100	-103.192
0+637.72	1984.49	-111.141	10.074 [14.311]	-101.067
0+525.00	1890.87	-112.058	14.385 ?	-97.673 ?
0+412.10	1953.69	-110.882	10.655 [3.733]	-100.227.
0+330.31	1953.90	-110.844	10.369	-100.475
0+240.78	1992.83	-111.478	8.519	-102.959
0+130.02	2018.32	-112.739	8.298	-104.441
0+850.00	2042.36	-112.551	8.079	-104.472
0+071.51	2032.90	-113.394	8.447	-104.947
0+168.49	2017.82	-113.929	9.956	-103.973
0+274.86	2031.34	-114.128	10.623	-103.505
0+372.00	2042.06	-116.608	12.448	-104.160
0+470.47	2082.97	-117.84	12.968	-104.872
0+570.63	2152.43	-119.222	12.144	-107.078
0+661.85	2226.04	-121.26	11.240	-116.020

LINEA #

GRAV. ZUNIL

$\rho = 2.67$ gr/cm³.

ESTACIÓN	ELEVACIÓN	A DE B	CORR TOP	A DE B c/CORR TOP.
1+000.00	2006.50	-110.341	8.549	-101.792
0+871.00	1908.13	-109.093	10.948	-98.145
0+800.00	1881.82	-109.031	12.340	-96.691
0+718.20	1877.49	-109.455	12.694	-96.761
0+593.20	1904.29	-109.897	12.102	-97.795
0+510.20	1916.59	-110.605	12.250	-98.355
0+434.00	1948.15	-110.514	11.764	-98.750
0+285.00	2010.22	-111.651	8.139	-103.512
0+203.00	2018.54	-111.628	8.532	-103.096
0+100.00	2027.70	-112.087	8.992	-103.095
0+364.98	2038.92	-112.944	9.869	-103.075
0+101.70	2060.05	-113.700	11.120	-102.580
0+200.00	2089.17	-114.741	12.136	-102.605
0+300.00	2117.23	-116.884	13.913	-102.971
0+491.00	2253.21	-120.846	13.635	-107.211

LINEA # 4 GRAV. ZUNIL.

$\rho = 2.67\ gr/cm^3$

ESTACIÓN	ELEVACIÓN	A DE B	CORR TOPOGRAF	A DE B c/corr top
1+221.70	1858.08	-108.227	12.64	-95.587
1+125.50	1878.11	-108.470	12.517	-95.953
1+034.70	1902.97	-108.775	12.239	-96.536
0+922.70	1977.20	-109.691	10.24	-99.451
0+825.00	1998.27	-109.355	9.242	-100.113
0+725.00	2010.85	-109.314	8.963	-100.351
0+[illegible]25.00	2026.27	-107.780	8.637	-99.143
0+518.10	2035.45	-110.248	8.503	-101.745
0+425.00	2050.85	-110.305	8.557	-101.748
0+325.00	2057.29	-110.886	8.989	-101.897
0+225.00	2067.44	-111.467	9.828	-101.639
0+125.00	2076.36	-112.449	10.779	-101.670
0+100.30 LB	2070.24	-113.833	12.877	-100.956
0+071.40	2089.03	-114.122	13.327	-100.795
0+175.00	2127.05	-115.567	13.576	-101.991
0+249.80	2182.34	-116.790	12.589	-104.201
0+315.00	2249.97	-118.668	13.094	-105.574
0+474.00	2328.34	-120.579	13.051	-107.528
0+575.80	2402.01	-121.989	12.892	-109.097

LINEA # 6

GRAV. ZUNIL

$\rho = 2.67\ gr/cm^3$.

Estación	Elevación	Ano B	Corr Top.	AnoB c/corr Top
0+311.58	2167 96	-111.145	9.255	-101.890
0+200.30	2167.47	-111.218	8.992	-102.226
0+117.63	2192.56	-111.370	8.548	-102.822
0+510.00	2171.03	-111.059	9.738	-101.321
0+105 69	2189.53	-112.088	10.259	-101.829
0+198.73	2237.60	-113.825	9.511	-104.314
0+303.82	2242.30	-115.084	10.630	-104.454
0+405.11	2223.24	-116.054	13.250	-102.804
0+488.99	2288.97	-117.197	11.282	-105.915
0+602 34	2342.58	-118.271	11.806	-106.465

LINEA 5

GRAV. ZUNIL

$\rho = 2.67\ g/cm^3$

ESTACIÓN	ELEVACIÓN	A DE B	CORR. TOP.	A DE B C/CORR TOP.
1+400.09	1864.17	-106.235	12.306	-93.929
1+200.07	1899.01	-107.573	12.424	-95.149
1+000.23	1937.96	-108.593	12.381	-96.212
1+797.32	1981.40	-110.109	11.817	-98.292
0+600.02	2049.13	-109.910	8.833	-101.077
0+399.81	2083.37	-110.741	8.210	-102.531
0+200 22	2104.22	-111.303	8.448	-102.855
0+290 04	2116.74	-112.465	10.431	-102.034
0+199.99	2131.44	-114.332	12.364	-101.968
0+399.84	2234.86	-117.537	11.943	-105.594

Grav. Zunil Linea 4

$\rho = 2.67$ gr/cm³

Estación	Elevación	A de B	Corr Top.	A de B c/corr
0+311.58	2167.96	-111.145	9.255	-101.89
0+200.30	2167.47	-111.218	8.992	-102.22
0+117.63	2192.56	-111.370	8.548	-102.82
0+510.00	2171.03	-111.059	9.738	-101.321
0+105.69	2189.53	-112.088	10.259	-101.829
0+198.73	2237.60	-113.825	9.511	-104.314
0+303.82	2242.30	-115.084	10.630	-104.454
0+405.11	2223.24	-116.054	13.250	-102.804
0+488.99	2288.97	-117.197	11.282	-105.915
0+602.34	2342.58	-118.271	11.80[illegible]	[illegible]

Linea 5

Grav. Zunil

$\rho = 2.67$ g/cm³

Estación	Elevación	A de B	Corr Top.	A de B c/corr
1+400.09	1864.17	-106.235	12.306	-93.929
1+200.07	1899.01	-107.573	12.424	-95.149
1+000.23	1937.96	-108.593	12.381	-96.212
1+797.32	1981.40	-110.109	11.817	-98.292
0+600.02	2049.13	-109.910	8.833	-101.077
[illegible]	[illegible]	-110.741	8.210	-102.53

Línea 7

LINEA 7

GRAV ZUNIL

$\rho = 2.67\ gr/cm^3$

Estación	Elevación	A de B.	Corr Top.	A de B c/corr Top.
0+4[redacted]	2268.37	-112.959	10.872	-102.087
0+2[redacted]	2235.93	-111.179	10.130	-101.049
0+14[redacted]	2271.20	-111.575	9.709	-101.866
0+08[redacted]	2259.46	-111.672	9.338	-102.334
0+65[redacted]	2234.38	-111.374	9.253	-102.121
0+12[redacted]	2247.70	-111.885	9.789	-102.096
0+3[redacted]	2303.88	-114.440	9.568	-104.872
0+540[redacted]	2355.97	-116.706	11.199	-105.507
0+59[redacted]	2374.57	-117.499	11.250	-106.294

Línea 8 -

8 GRAV. ZUNIL

$\rho = 2.67\ gr/cm^3$.

Estación	Elevación	A de B.	Corr Top.	A de B c/corr Top.
0+394[redacted]	2503.02	-121.109	15.797	-105.312
0+144[redacted]	2464.35	-117.370	11.375	-105.995
0+268.[redacted]	2493.16	-120.678	13.386	-107.292
0+400[redacted]	2520.91	-122.384	13.558	-108.826
0+737.[redacted]	2578.17	-123.735	12.009	-111.726

ZUNIL I

LINEA #8				d=2.00 gr/cm3		d=2.30 gr/cm3		d=2.35 gr/cm3		d=2.40 gr/cm3		d=2.45 gr/cm3		d=2.50 gr/cm3		d=2.67 gr/cm3		d=3.00 gr/cm3	
ESTACION	ELEVACION	X	Y	A de B	Corr.Top.	A.de B	Corr.Top.	A de B	Corr.Top.	A de B	Corr.Top.	A de B	Corr.Top.	A de B	Corr.Top.	A de B	Corr.Top.	A de B	Corr.Top.
0+394.80	2503.02	65998758	163290743	-50.900	11.831											-121.109	15.797		
0+144.00	2464.35	65991881	163303405	-48.244	8.523											-117.370	11.375		
0+268.00	2493.16	65985976	163314309	-50.744	10.026											-120.678	13.386		
0+400.80	2520.91	65979652	163325987	-51.673	10.170											-122.384	13.558		
0+467.60	2521.75	65976470	163351861																
0+737.60	2578.17	65963613	163355603	-51.416	8.876											-123.735	12.009		
0+804.30	2590.43	65960437	163361468	-51.520	8.247	-84.054		-89.477		-94.899		-100.322		-105.744		-124.180		-159.968	
0+840.00	2588.30	65958736	163364607																
0+919.20	2590.40	65954965	163371571	-52.104	8.009	-84.972		-90.450		-95.928		-101.405		-106.883		-125.508		-161.662	
0+936.60	2615.50	65954136	163373101																
0+973.20	2604.32	65952393	163376320																
1+000.00	2607.79	65951117	163378676	-50.871	5.996	-83.624		-89.083		-94.542		-100.000		-105.459		-124.019		-160.048	
1+100.00	2613.31	65946355	163387470		5.234														
1+144.45	2587.72	65944236	163391383	-49.514	4.629	-82.007		-87.423		-92.838		-98.254		-103.669		-122.082		-157.824	
1+158.90	2579.95	65943550	163392649																
1+219.50	2617.00	65940664	163397978	-49.856	4.787	-82.725		-88.203		-93.681		-99.159		-104.637		-123.263		-159.418	
1+276.00	2633.68	65936830	163402128	-49.645	4.763	-82.762		-88.282		-93.802		-99.321		-104.841		-123.607		-160.036	
1+337.00	2653.05	65932659	163406579																
1+371.90	2652.09	65929954	163408784	-49.719	5.136	-83.029		-88.580		-94.132		-99.684		-105.235		-124.111		-160.751	
1+417.50	2646.63	65927175	163412399																
1+472.70	2651.13	65923617	163416619	-49.500	4.686	-82.797		-88.347		-93.896		-99.446		-104.995		-123.963		-160.490	
1+554.60	2651.86	65918414	163422944	-50.104	5.403	-83.411		-88.962		-94.513		-100.064		-105.615		-124.489		-161.127	
1+587.40	2651.89	65916257	163425415																
1+615.30	2655.15	65914247	163427350																
1+696.00	2658.32	65908518	163433034																
1+777.40	2640.08	65902530	163438547	-50.481	5.076	-83.640		-89.167		-94.693		-100.219		-105.746		-124.336		-161.011	

HP Ross Copy
from:
Louis Merida @
GRC.
Final data set.

LINEA #7

				d=2.00 gr/cm3		d=2.30 gr/cm3		d=2.35 gr/cm3		d=2.40 gr/cm3		d=2.45 gr/cm3		d=2.50 gr/cm3		d=2.67 gr/cm3		d=3.00 gr/cm3	
ESTACION	ELEVACION	X	Y	A de B	Corr.Top.	A de B	Corr.Top.	A de B	Corr.Top.	A de B	Corr.Top.	A de B	Corr.Top.	A de B	Corr.Top.	A de B	Corr.Top.	A de B	Corr.Top.
0+462.60	2268.37	66047639	163281061	-49.331	8.143											-112.959	10.872		
0+280.00	2235.93	66035868	163296305	-48.462	7.588											-111.179	10.013		
0+145.70	2271.21	66027660	163306935	-47.868	7.271											-111.575	9.709		
0+080.00	2259.46	66023644	163312135	-48.293	6.968											-111.672	9.338		
0+655.00	2234.38	66018755	163318467	-48.699	6.942											-111.374	9.253		
0+120.00	2247.70	66011421	163327965	-48.837	7.333											-111.885	9.789		
0+320.00	2303.88	65999197	163343795	-49.815	7.178											-114.440	9.568		
0+540.20	2355.38	65985739	163361223	-50.637	8.389											-116.706	11.199		
0+598.20	2374.57	65982194	163365814	-50.892	8.413											-117.499	11.250		

EA #6

STACION	ELEVACION	X	Y	d=2.00 gr/cm3 A de B	d=2.00 gr/cm3 Corr.Top.	d=2.30 gr/cm3 A de B	d=2.30 gr/cm3 Corr.Top.	d=2.35 gr/cm3 A de B	d=2.35 gr/cm3 Corr.Top.	d=2.40 gr/cm3 A de B	d=2.40 gr/cm3 Corr.Top.	d=2.45 gr/cm3 A de B	d=2.45 gr/cm3 Corr.Top.	d=2.50 gr/cm3 A de B	d=2.50 gr/cm3 Corr.Top.	d=2.67 gr/cm3 A de B	d=2.67 gr/cm3 Corr.Top.	d=3.00 gr/cm3 A de B	d=3.00 gr/cm3 Corr.Top.
311.58	2167.96	66046078	163305709	-50.335	6.933											-111.145	9.255		
200.30	2167.47	66039277	163314516	-50.420	6.733											-111.218	8.992		
117.63	2192.56	66034224	163321060	-49.868	6.403											-111.370	8.548		
110.00	2171.03	66027035	163330370	-50.163	7.267											-111.059	9.738		
105.69	2189.53	66020575	163338735	-50.673	7.684											-112.088	10.259		
198.73	2237.60	66014889	163346099	-51.061	7.039											-113.825	9.511		
303.82	2242.30	66008466	163354417	-52.188	7.964											-115.084	10.630		
405.11	2223.24	66002275	163362434	-53.693	9.925											-116.054	13.250		
388.99	2288.97	65997149	163369073	-52.993	8.379											-117.197	11.282		
302.34	2342.58	65990221	163378045	-52.561	8.815											-118.271	11.806		

LINEA #5

				d=2.00 gr/cm3		d=2.30 gr/cm3		d=2.35 gr/cm3		d=2.40 gr/cm3		d=2.45 gr/cm3		d=2.50 gr/cm3		d=2.67 gr/cm3		d=3.00 gr/cm3	
ESTACION	ELEVACION	X	Y	A de B	Corr.Top.	A de B	Corr.Top.	A de B	Corr.Top.	A de B	Corr.Top.	A de B	Corr.Top.	A de B	Corr.Top.	A de B	Corr.Top.	A de B	Corr.Top.
1+400.09	1864.17	66125163	163237614	-53.944	9.222											-106.235	12.306		
1+200.07	1899.01	66112938	163253446	-54.306	9.234											-107.573	12.424		
1+000.23	1937.96	66100724	163269263	-54.236	9.277											-108.593	12.381		
1+797.32	1981.40	66088323	163385323	-54.531	8.712											-110.109	11.817		
0+600.02	2049.13	66076264	163300939	-52.433	6.617											-109.910	8.833		
0+399.81	2083.37	66064028	163316785	-52.302	6.149											-110.741	8.210		
0+200.22	2104.22	66051829	163332583	-52.280	6.328											-111.303	8.448		
0+290.04	2116.74	66039592	163348430	-53.091	7.814											-112.465	10.431		
0+199.99	2131.44	66027369	163364259	-54.546	9.263											-114.332	12.364		
0+399.84	2234.86	66015155	163380077	-54.848	8.946											-117.537	11.943		

LINEA #4				d=2.00 gr/cm3		d=2.30 gr/cm3		d=2.35 gr/cm3		d=2.40 gr/cm3		d=2.45 gr/cm3		d=2.50 gr/cm3		d=2.67 gr/cm3		d=3.00 gr/cm3	
ESTACION	ELEVACION	X	Y	A de B	Corr.Top.	A de B	Corr.Top.	A de B	Corr.Top.	A de B	Corr.Top.	A de B	Corr.Top.	A de B	Corr.Top.	A de B	Corr.Top.	A de B	Corr.Top.
1+221.70	1858.08	66125100	163267306	-56.107	9.498											-108.297	12.640		
1+125.50	1878.11	66119221	163274920	-55.789	9.396											-108.470	12.517		
1+034.70	1902.97	66113671	163282107	-55.399	9.167											-108.775	12.239		
0+922.70	1977.20	66106826	163200971	-54.231	7.671											-109.691	10.240		
0+825.00	1998.27	66100854	163297804	-53.303	6.949											-109.355	9.242		
0+725.00	2010.85	66094743	163306619	-52.909	6.714											-109.314	8.963		
0+625.00	2026.27	66088631	163314534	-52.942	6.530											-107.780	8.637		
0+518.10	2035.44	66082097	163322995	-53.156	6.367											-110.248	8.503		
0+425.00	2050.85	66076407	163330364	-52.777	6.409											-110.305	8.557		
0+325.00	2057.29	66070295	163338279	-53.179	6.733											-110.886	8.989		
0+225.00	2067.44	66064184	163346193	-53.477	7.362											-111.467	9.828		
0+125.00	2072.36	66058072	163354108	-54.318	8.074											-112.449	10.779		
0+100.30	2070.24	66050432	163364002	-55.764	9.646											-113.833	12.877		
0+071.40	2089.03	66046068	163367653	-55.526	9.983											-114.122	13.327		
0+175.00	2127.05	66039736	163377853	-55.902	10.170											-115.567	13.576		
0+249.80	2182.34	66035165	163383773	-55.577	9.426											-116.790	12.589		
0+375.00	2249.97	66027513	163393683	-55.558	9.810											-118.668	13.094		
0+474.00	2328.34	66021462	163401519	-55.270	9.776											-120.579	13.051		
0+575.80	2402.01	66015240	163409576	-54.613	9.657											-121.989	12.892		
0+599.94				-54.354	9.582	-84.738		-89.802		-94.866		-99.930		-104.995		-122.212		-155.635	
0+680.56	2496.02	66008837	163417868																
0+700.00				-53.637	8.382	-85.189		-90.447		-95.706		-100.964		-106.223		-124.102		-158.808	
0+795.45	2596.56	66001816	163426961																
0+811.36				-54.050	7.374	-86.751		-92.201		-95.651		-103.101		-108.551		-127.081		-160.051	
0+896.43	2633.69	65995644	163434954																
0+900.00				-53.818	6.424	-86.774		-92.266		-97.759		-103.251		-108.744		-127.419		-163.669	
1+011.56	2697.38	65988607	163444066	-54.050	8.501	-88.570		-94.217		-99.863		-105.509		-111.156		-130.354		-167.620	
1+094.36	2721.44	65983547	163450620																
1+100.10	2720.89	65983202	163451066	-53.439	8.392	-87.612		-93.308		-99.004		-104.699		-110.395		-129.760		-167.331	
1+190.00				-51.895	6.639	-86.139		-91.846		-97.533		-103.261		-108.968		-128.373		-166.041	
1+225.46	2731.60	65975534	163460996																
1+300.00	2785.83	65970978	163466896	-53.748	7.459	-88.737		-94.568		-100.400		-106.231		-112.063		-131.890		-170.377	
1+408.64	2806.87	65964338	163475494	-53.157	7.650	-88.411		-94.287		-100.162		-106.038		-111.914		-131.891		-170.670	
1+500.00	2841.41	65958755	163482726	-53.640	6.708	-89.327		-95.275		-101.223		-107.171		-113.119		-133.341		-172.597	
1+600.62	2849.29	65952605	163490690	-53.277	6.547	-89.063		-95.027		-100.992		-106.956		-112.920		-133.199		-171.564	
1+674.64	2835.67	65948081	163496548	-53.161	5.662	-88.777		-94.712		-100.648		-106.584		-112.520		-132.702		-171.879	

LINEA #3				d=2.00 gr/cm3		d=2.30 gr/cm3		d=2.35 gr/cm3		d=2.40 gr/cm3		d=2.45 gr/cm3		d=2.50 gr/cm3		d=2.67 gr/cm3		d=3.00 gr/cm3	
ESTACION	ELEVACION	X	Y	A de B	Corr.Top.	A de B	Corr.Top.	A de B	Corr.Top.	A de B	Corr.Top.	A de B	Corr.Top.	A de B	Corr.Top.	A de B	Corr.Top.	A de B	Corr.Top.
1+000.00	2006.50	66153687	163295633	-54.058	6.404											-110.341	8.549		
0+871.20	1908.13	66145815	163305827	-55.571	8.200											-109.093	10.948		
0+800.00	1881.82	66141464	163311463	-56.247	9.234											-109.031	12.340		
0+718.20	1877.49	66136464	163317937	-56.791	9.480											-109.455	12.694		
0+593.20	1904.29	66128824	163327831	-56.484	9.065											-109.897	12.102		
0+510.20	1916.59	66123751	163334400	-56.845	9.176											-110.605	12.250		
0+434.00	1948.15	66119094	163340431	-55.867	8.639											-110.514	11.764		
0+285.00	2010.22	66109988	163352225	-55.265	6.097											-111.651	8.139		
0+203.00	2018.54	66104976	163358715	-55.010	6.395											-111.628	8.532		
0+100.00	2027.70	66098681	163366867	-55.210	6.737											-112.087	8.992		
0+364.98	2038.92	66092569	163374782	-55.747	7.392											-112.944	9.869		
0+101.70	2060.05	66086353	163382831	-55.914	8.364											-113.700	11.120		
0+200.00	2089.17	66080345	163390612	-56.139	9.090											-114.741	12.136		
0+300.00	2117.23	66074234	163398527	-57.497	10.420											-116.884	13.913		
0+491.00	2253.21	66062560	163413644	-57.644	10.220											-120.846	13.635		

LINEA #2

ESTACION	ELEVACION	X	Y	d=2.00 gr/cm3 A de B	d=2.00 gr/cm3 Corr.Top.	d=2.30 gr/cm3 A de B	d=2.30 gr/cm3 Corr.Top.	d=2.35 gr/cm3 A de B	d=2.35 gr/cm3 Corr.Top.	d=2.40 gr/cm3 A de B	d=2.40 gr/cm3 Corr.Top.	d=2.45 gr/cm3 A de B	d=2.45 gr/cm3 Corr.Top.	d=2.50 gr/cm3 A de B	d=2.50 gr/cm3 Corr.Top.	d=2.67 gr/cm3 A de B	d=2.67 gr/cm3 Corr.Top.	d=3.00 gr/cm3 A de B	d=3.00 gr/cm3 Corr.Top.
0+928.67	2014.73	66197712	163304662	-52.110	6.645											-108.622	8.871		
0+820.69	2041.99	66191112	163313208	-52.504	5.605											-109.779	7.460		
0+741.68	2080.72	66186283	163319462	-53.948	6.817											-112.292	9.100		
0+637.72	1984.49	66179929	163327690	-55.476	7.546											-111.141	10.074		
0+525.00	1890.87	66173040	163336612	-59.018	10.776											-112.058	14.388		
0+412.10	1953.69	66166140	163345548	-56.081	7.981											-110.882	10.655		
0+330.31	1953.90	66161141	163352021	-56.037	7.768											-110.844	10.369		
0+240.78	1992.83	66155667	163359107	-55.581	6.381											-111.478	8.519		
0+130.02	2018.32	66148900	163367874	-56.126	6.210											-112.739	8.298		
0+850.00	2042.36	66140953	163378165	-55.262	6.052											-112.551	8.079		
0+071.51	2032.90	66136582	163383825	-56.371	6.239											-113.394	8.447		
0+168.49	2017.82	66130655	163391501	-57.330	7.455											-113.929	9.956		
0+274.86	2031.34	66124154	163399920	-57.782	7.952											-114.128	10.623		
0+372.00	2042.06	66118217	163407608	-59.330	9.325											-116.608	12.448		
0+470.47	2082.97	66112199	163415402	-59.410	9.714											-117.840	12.968		
0+570.63	2152.43	66106077	163423330	-58.847	9.096											-119.222	12.144		
0+661.85	2226.04	66139083	163380586	-58.840	8.445											-121.260	11.240		
0+683.36	2216.21	66099187	163432252																
0+736.44	2195.00	66095943	163436454	-59.497	10.414	-87.066		-91.661		-96.255		-100.850		-105.445		-121.067		-151.392	
0+856.91	2311.17	66088580	163445989	-58.333	8.985	-87.361		-92.199		-97.037		-101.875		-106.713		-123.162		-155.092	
0+942.12	2382.26	66083372	163452733																
0+971.53	2404.37	66081575	163455061	-58.534	8.836	-88.732		-93.765		-98.798		-103.831		-108.864		-125.977		-159.194	
1+046.34	2459.89	66077003	163460982																
1+092.19	2489.66	66074200	163464611		8.133														
1+138.39	2518.74	66071377	163468267																
1+189.12	2544.88	66068276	163472283	-58.231	7.893	-90.194		-94.960		-100.849		-106.176		-111.503		-128.044		-162.441	
1+235.38	2573.71	66065449	163475944																
1+271.49	2591.70	66063242	163478802	-58.541	7.152	-91.095		-96.520		-101.946		-107.371		-112.797		-131.244		-167.053	
1+334.09	2639.12	66059416	163483757	-60.398	7.246	-93.544		-99.096		-104.593		-110.117		-115.642		-134.219		-170.753	
1+371.32	2644.36	66057140	163486704	-60.043	6.586	-93.256		-98.792		-104.327		-109.863		-115.398		-134.219		-170.753	
1+493.42	2625.38	66047695	163494442	-57.796	4.857	-90.770		-96.266		-101.761		-107.257		-112.753		-131.438		-167.710	
1+567.60	2625.47	66041956	163499143	-57.911	4.644	-90.887		-96.383		-101.878		-107.374		-112.870		-131.566		-167.829	
1+676.35	2644.44	66033544	163506034	-58.325	4.507	-91.537		-97.073		-102.608		-108.144		-113.679		-132.500		-169.034	
1+792.31	2672.99	66024574	163513383	-59.224	4.807	-92.795		-98.390		-103.985		-109.580		-115.175		-134.199		-171.127	
1+880.57	2676.17	66017746	163518976	-58.369	4.673	-91.981		-97.583		-103.185		-108.787		-114.389		-133.436		-170.409	
1+986.21	2707.54	66009574	163525671	-57.295	4.729	-91.300		-96.968		-102.635		-108.303		-113.971		-133.240		-170.646	
2+092.62	2745.46	66001343	163532414																
2+095.22	2745.62	66001142	163532579	-57.597	4.927	-92.079		-97.826		-103.573		-109.320		-115.067		-134.608		-172.538	
2+189.42	2799.47	65993855	163538549	-58.180	5.185	-93.341		-99.201		-105.061		-110.921		-116.781		-136.706		-175.383	

LINEA #1

				d=2.00 gr/cm3		d=2.30 gr/cm3		d=2.35 gr/cm3		d=2.40 gr/cm3		d=2.45 gr/cm3		d=2.50 gr/cm3		d=2.67 gr/cm3		d=3.00 gr/cm3	
ESTACION	ELEVACION	X	Y	A de B	Corr.Top.	A de B	Corr.Top.	A de B	Corr.Top.	A de B	Corr.Top.	A de B	Corr.Top.	A de B	Corr.Top.	A de B	Corr.Top.	A de B	Corr.Top.
1+297.70	2031.43	66186999	163361323	-55.302	4.986											-112.297	6.669		
1+200.00	2036.75	66182537	163370015	-55.106	5.052											-112.238	6.963		
1+211.91	2069.28	66177056	163380690	-54.601	4.791											-112.642	6.396		
1+000.00	2084.36	66173402	163387807	-54.296	4.745											-112.763	6.432		
0+900.00	2090.32	66168835	163396703	-54.588	4.546											-113.221	6.070		
0+800.00	2086.59	66164268	163405599	-55.243	4.751											-113.772	6.342		
0+706.80	2097.98	66160011	163413890	-55.487	5.435											-114.693	7.256		
0+600.00	2111.87	66155134	163423391	-56.735	6.274											-116.174	8.376		
0+493.00	2136.12	66150247	163432910	-57.283	6.870											-117.200	9.158		
0+408.00	2146.18	66146365	163440472	-57.802	7.762											-118.000	10.362		
0+302.00	2201.37	66141524	163449902	-58.560	8.170											-120.309	10.907		
0+197.00	2249.83	66136728	163459243	-58.945	7.994											-122.055	10.672		

CYM Cordón y Mérida, Ings.
6a. Ave. 6-94 zona 9 - Guatemala, C.A. Teléfonos 317872, 318631, 318612

F A X

Fecha: Agust 1st, 1989
Proyecto Zunil I

A : Dr. Joe Moore/ ~~Dr. Howard Ross~~ — Fax No.: (801) 524 - 3453

De: Ing. Luis Felipe Mérida I. — Fax No.: (011) 502 2 34 06 27

Asunto: Geophysics studies Zunil I.

Total de páginas enviadas: 4
(incluyendo esta)

DEAR JOE;

I CALLED YOU HOME LAST NIGHT. UNFORTUNATELY YOU WERE NOT IN (ANSWERING MACHINE). I WANTED TO DISCUSS WITH YOU THE FOLLOWING:

1. ENCLOSED PLEASE FIND A SAMPLE OF A WORKING SHEET FOR THE DATA REQUIRED FOR THE GRAVITY MODELING, PARTLY COVERING THE PRINCIPAL FACTS (ITEM 2) YOU MENTIONED IN YOUR LAST MEMO: JULY 27, 1989.

   IN THE SAMPLE SHEET IT IS ONLY MISSING ITEM B WHICH ARE THE COORDINATES OF EACH STATION, WHICH ARE READILY AVAILABLE. THE TERRAIN CORRECTIONS FOR THIS PARTICULAR EXAMPLE IS FOR A DENSITY OF 2.67. I HAD THE DOUBT OF WHETHER THIS TERRAIN CORRECTIONS HAVE LINEAR RELATIONSHIP FOR DIFFERENT DENSITIES FOR A PARTICULAR STATION. I ASKED PALMA AND HE SAID YES; ALSO I CHECKED A SIMILAR WORKING SHEET FOR DENSITY 2.0 AND THEY ARE LINEARLY VERY CLOSE. THE PROBLEM IS THAT THE DATA TO CALCULATE TERRAIN CORRECTION IS SUCH A BULK OF FIGURES THAT USING A LINEAR RELATIONSHIP WOULD SAVE QUITE SOME TIME.

   I CAN SEND YOU THE REST OF THE DATA ON WORKING SHEETS LIKE THE ENCLOSED, PLUS THE COORDINATES, SO YOU CAN MAKE YOUR OWN CALCULATION FOR ANY DENSITY (2.30, 2.35... ETC.) AND PROCEED WITH THE MODELING OF THE CROSS SECTIONS REQUIRED BY THE PANEL. PLEASE ADVICE ASAP.

   TWO PIECES OF INFORMATION: YESTERDAY I ATTENDED A MEETING WITH INDE PEOPLE, WITH THE FOLLOWING RESULTS: THEY EXPRESSED ME THEIR DISSATISFACTION WITH OUR RESULTS ON GEOPHYSIC (AS YOU MIGHT REMEMBER THERE IS A PREVIOUS MODELING) AND PALMA SHOWED TO ME HIS RESULTS OF A 3D MODELING ON A COMPUTER PLOT, (A GEOPHYSIST FINK HAS BEEN WORKING WITH THEM).

2. I TALKED TO ROY BY PHONE THIS MORNING. I WANTED TO HAVE HIS AUTHORIZATION TO MAKE ANY ARRANGEMENT WITH YOU. HE WAS IN YELLOWSTONE AND THE PHONE LINE WAS NOT THE BEST, SO WE COULD NOT FINISH TALKING; BUT I AM SURE HIS ANSWER IS AFFIRMATIVE.

3. ENCLOSED I AM SENDING YOU A COPY OF WHAT WE PROPOSED TO INDE. ALL OF IT WAS REQUIRED BY THE PANEL AND HAS TO BE PRESENTED AT THE END OF THE MONTH. SO PLEASE LET ME KNOW WHAT ELSE DO YOU WANT. THIS WAS MY REFERENCE ON MY LAST MESSAGE THAT THE GEOPHYSICS WAS FAR BEHIND THE REST OF THE STUDIES.

4. TODAY I WILL BE SENDING YOU THE MATERIAL WE COLLECTED FROM ZCQ-5.

5. SINCE YOU ARE LISTED AS WRITER OF THE FINAL REPORT ON HG CONTENT, I WONDER IF YOU CAN SEND ME A COPY OF IT FOR REPORT PROPOSE AND TRANSLATION.

   THANKS A LOT JOE. PLEASE REPLY THIS SO YOU LET ME KNOW ABOUT SENDING THE REST OF THE DATA.

   BEST REGARDS,

GRAV. ZUNIL

$\rho = 2.67\ gr/cm^3$

ESTACIÓN	ELEVACIÓN	A DE B	CORR TOP.	A DE B C/CORR TOP
1+297.70	2031.93	-112.297	6.668	105.629
1+200.00	2036.75	-112.238	6.836	105.402
1+211.91	2069.28	-112.642	6.396	106.246
1+000 00	2084.36	-112.763	6.432	106.331
0+900 00	2090.32	-113.221	6.070	107.151
0+800.00	2086.59	-113.772	6.342	107.430
0+706.80	2097.98	-114.693	7.256	107.437
0+600.00	2111.87	-116.174	8.376	107.798
0+493.00	2136.12	-117.200	9.158	108.042
0+408.00	2146.18	-118.000	10.362	107.638
0+302.00	2201.37	-120.309	10.907	109.402
0+197.00	2249.83	-122.055	10.672	111.383
	↑ Item c	↑ Item a	↑ Item d	

The fluid inclusion and paragenetic relationships among the minerals studied will be combined with fluid analyses of springs and wells to develop a detailed hydrogeochemical model of the geothermal system. The circulation patterns within the reservoir and changes in chemistry and temperature of the reservoir with respect of time will be obtained.

4.4 Stable Isotope Studies

Stable isotope studies (oxigen-18, deuterium) will be carried out on selected samples of fluids and rocks. The primary objective of the fluid analyses is to determine the location of the recharge zones. Samples of the production fluids, thermal and non-thermal springs will be obtained. (See Geohydrology - Geochemical Sampling Plan). Data from the non-thermal springs (or local precipitation) will be used to construct a local meteoric water line. The thermal waters will be compared to the meteoric oxygen-deuterium relationships to establish the elevation of the recharge zones, the relative extent of interaction with the reservoir rocks, and the importance of boiling, mixing, based on the results of the alteration studies. Rock samples will be selected for stable isotope analysis. If appropriate, samples of unaltered and altered rocks produced by the geothermal fluids will also be selected. From these data, the isotopic composition of the fluids, and data on the temperatures of alteration the integrated fluid flux through the system will be estimated.

remember this?

starts here

4.5 Geophysical Studies

4.5.1 Electrical Resistivity

4.5.1.1 Methods

Electrical surveys by JICA and INDE, (1976-77) consisted of Schulumberger arrays and were conducted in the area of Zunil I southwest of the village of Zunil. Several resistivity anomalies were observed. These could be due to clay alteration, the presence of saline fluids differences in rock lithologies. As a result a quantitative interpretation of the existing electrical soundings has been recommended. The objective of this interpretation will be to provide a better structural outline of the area covered by the electrical resistivity surveys.

4.5.1.2 Result

The quantitative interpretation of the existing electrical data will be designed towards producing a resistive substrate ceiling map. The map should show the substrate ceiling near the granodiorite ceiling and should indicate more exact information on the location of principal discontinuities which relate to the granodiorite basement.

4.5.2 Gravity Modeling

4.5.2.1 Methods

Modeling of the Zunil I area using existing data has been recommended by the Advisory Panel to better define the subsurface structure beneath the Zunil ZCQ well field. The modeling will use formation densities as represented from the different formations. The densities recommended are as follows:

- upper level with and high density (d=2.6) low ? 2.0 ?
- intermediate level with a lower density (d=2.4)
- Granodiorite basement (d=2.65)

The above density values are indicative of typical volcanic granodiorite rocks. Measurements of densities from borehole samples should be used to refine the above suggested values. The modeling should use actual densities taken from borehole samples. The model selected to be used is the MAGIX gravity forward and inverse model for personal computers. The model is a real time interactive interpretation program which uses an interactive graphically oriented earth model editor in conjunction with the real-time calculation and display of the forward response curve. As the earth model is varied on the screen, the forward response curve for the new model is calculated and displayed on the screen automatically. Forward modeling the MAGIX model provides a synthetic gravity curve up to 9 bodies with a total of 80 vertices spread among the bodies. Each body is calculated from published Talwani-style polygon algorithms with the density specified in terms of density contrast. MAGIX will provide inverse solutions from a starting model within the same parameters as mentioned above. The user can fix parameters of the body he wishes to remain unchanged. The Imman style inversion routine contained in the program will vary the other parameters to obtain the least squares fit. The parameters of a body that are variable include its vertices and physical property.

In normal operation the best fit to the observed data would be obtained using the interactive forward model then optimize the model parameters using the inverse solution features. Output is in the form of graphics with the operator setting the dimensions of the plot. The screen display is generally used for review prior to plotting the output.

4.5.2.2 Result

With the modeling, considering the geometry of the sections and densities used, a theoretical curve will be calculated which can be compared to the measured curve. This will allow a better interpretation of the anomaly which is presently interpreted as the Zunil Graben.

These cross sections will be generated as a result of the modeling. These cross sections will be perpendicular to the Zunil Graben and go through the ZCQ-4 and ZCQ-6 well zones. The granodiorite contact, amount of overlying volcanics and tectonic nature of the top of the granodiorite will be deduced from the existing ZCQ well data for input into the interpretation.

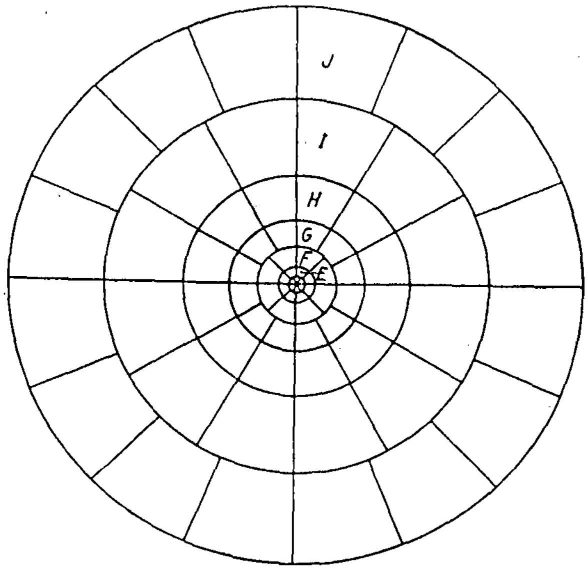


Fig. 11-9. Terrain correction zone chart designed by Hammer, used in conjunction with Table 11-1 for zones through J. Scale is 1/175,000. (*Gulf Research and Development Co., published in Geophysics*, 1939.)

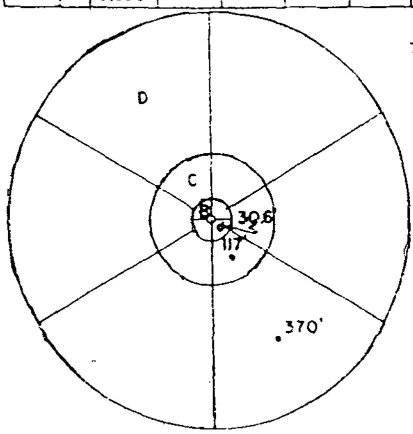
TABLE 11-1. Terrain-correction Tables to Be Used with Chart

Zone B, 4 compartments, 6.56 to 54.6†		Zone C, 6 compartments, 54.6 to 175		Zone D, 6 compartments, 175 to 558		Zone E, 8 compartments, 558 to 1,280		Zone F, 8 compartments, 1,280 to 2,936		Zone G, 12 compartments, 2,936 to 5,018	
Zone H, 12 compartments, 5,018 to 8,578		**Zone I, 12 compartments, 8,578 to 14,662**		**Zone J, 16 compartments, 14,662 to 21,826**		**Zone K, 16 compartments, 21,826 to 32,490**		**Zone L, 16 compartments, 32,490 to 48,365**		**Zone M, 16 compartments, 48,365 to 71,996,**	
±*h*, ft	*T*	±*h*, ft	*T*	±*h*, ft	*T*	±*h*, ft	*T*	±*h*, ft	*T*	±*h*, ft	*T*

INNER TERRAIN CORRECTION ONLY

Zone \ Compartment			1	2	3	4	5	6	Corr. x0.01 Mg.
6.56' to 54.6'	B	Elev. Diff.					X	X	
		Corr.					X	X	
54.6' to 175'	C	Elev. Diff.							
		Corr.							
175' to 558'	D	Elev Diff.							
		Corr.							

Total Corr.= ______ Mg.



ROCKDENSITY = 2.00
INNER TERRAIN CORRECTION TABLES

ZONE B 4 Compartments 6.56' to 54.6'		ZONE C 6 Compartments 54.6' to 175'		ZONE D 6 Compartments 175' to 558'	
±h, ft.	T	±h, ft.	T	±h, ft.	T
0 - 1.1	0	0 - 4.3	0	0 - 7.7	0
1.1- 1.9	0.1	4.3- 7.5	0.1	7.7-13.4	0.1
1.9- 2.5	0.2	7.5- 9.7	0.2	13.4-17.3	0.2
2.5- 2.9	0.3	9.7-11.5	0.3	17.3-20.5	0.3
2.9- 3.4	0.4	11.5-13.1	0.4	20.5-23.2	0.4
3.4- 3.7	0.5	13.1-14.5	0.5	23.2-25.7	0.5
3.7- 7	1	14.5-24	1	25.7-43	1
7 - 9	2	24 -32	2	43 -56	2
9 -12	3	32 -39	3	56 -66	3
12 -14	4	39 -45	4	66 -76	4
14 -16	5	45 -51	5	76 -84	5
16 -19	6	51 -57	6	84 -92	6
19 -21	7	57 -63	7	92 -100	7
21 -24	8	63 -68	8	100 -107	8
24 -27	9	68 -74	9	107 -114	9
27 -30	10	74 -80	10	114 -120	10
		80 -86	11	120 -127	11
		86 -91	12	127 -133	12
		91 -97	13	133 -140	13
		97 -104	14	140 -146	14
		104 -110	15	146 -152	15

Prospect ______________ Date ______________

Station # ______________

Surveyor ______________ Computed By ______________

Note: Values are in feet to center of compartment.

DENSITY MEASUREMENTS OF ZUNIL CORE SAMPLES

Sample #	Dry weight (g)	Suspended weight (g)	Saturated weight (g)	Vol (cu. cm)	Density (g/cu. cm)	U.J. Cordon Density (g/cu. cm)
Z-11 89m	283.61	167.95	297.30	129.35	2.19	2.21 avg.
Z-11 476m	211.00	130.30	222.65	92.35	2.28	2.32 avg.
Z-11 165m	305.30	173.05	312.60	139.55	2.19	2.21 avg.
Z-2 580m	295.05	175.65	308.00	132.35	2.23	
Z-11 590m	148.50	89.21	152.10	62.89	2.36	2.46 avg
ZCQ-2 103m	610.06	365.00	616.50	251.50	2.43	
Z-2 624m	205.80	119.12	218.60	99.48	2.07	
ZCQ-4 1015m (granodior.) altered, w. qtz, cal	821.00	512.50	830.40	317.90	2.58	
				Average:	2.29	(2.25 w/o Granodior.)

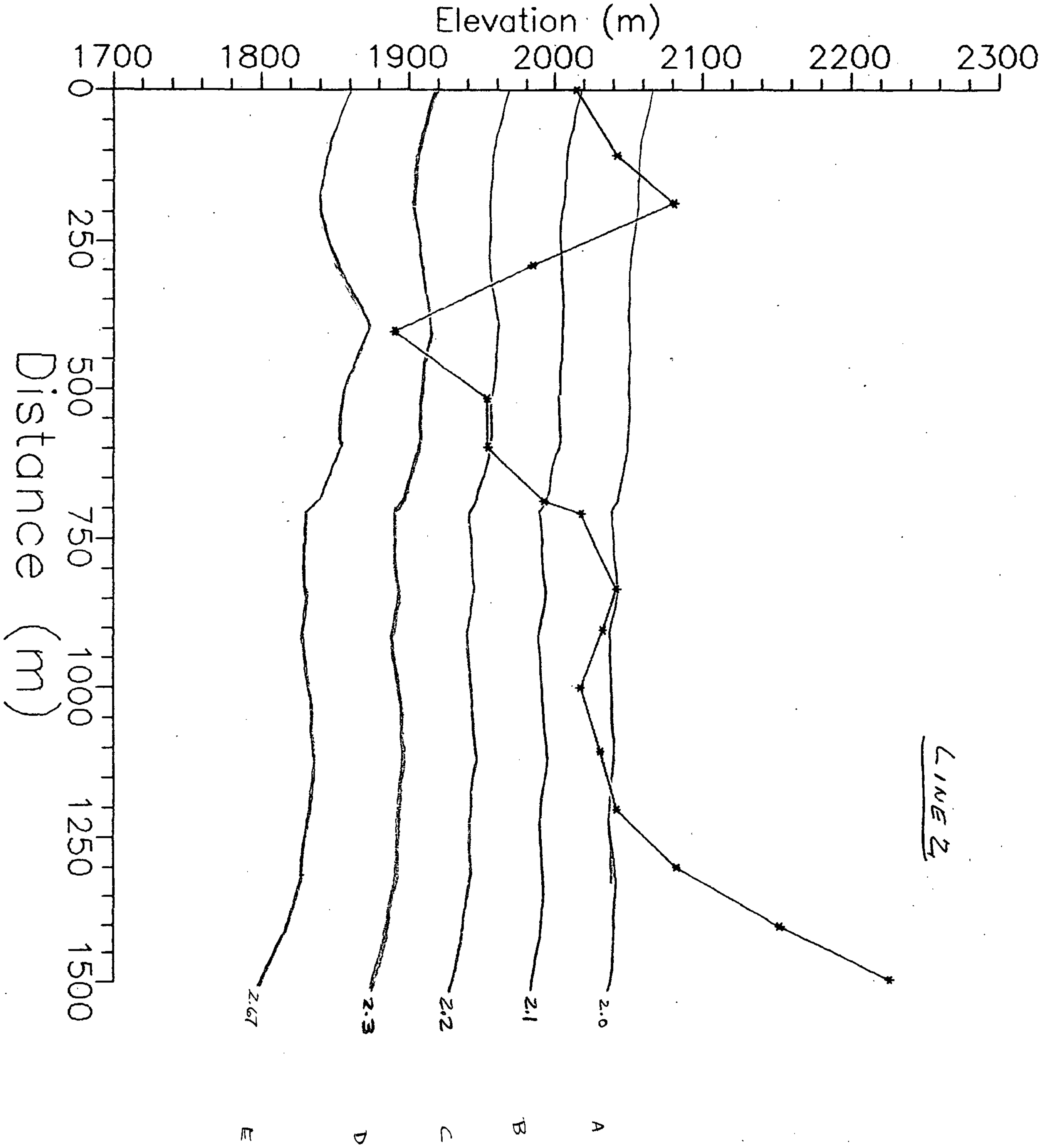
qtz 2.65
cal 2.72

DENSITY MEASUREMENTS OF ZUNIL CORE SAMPLES

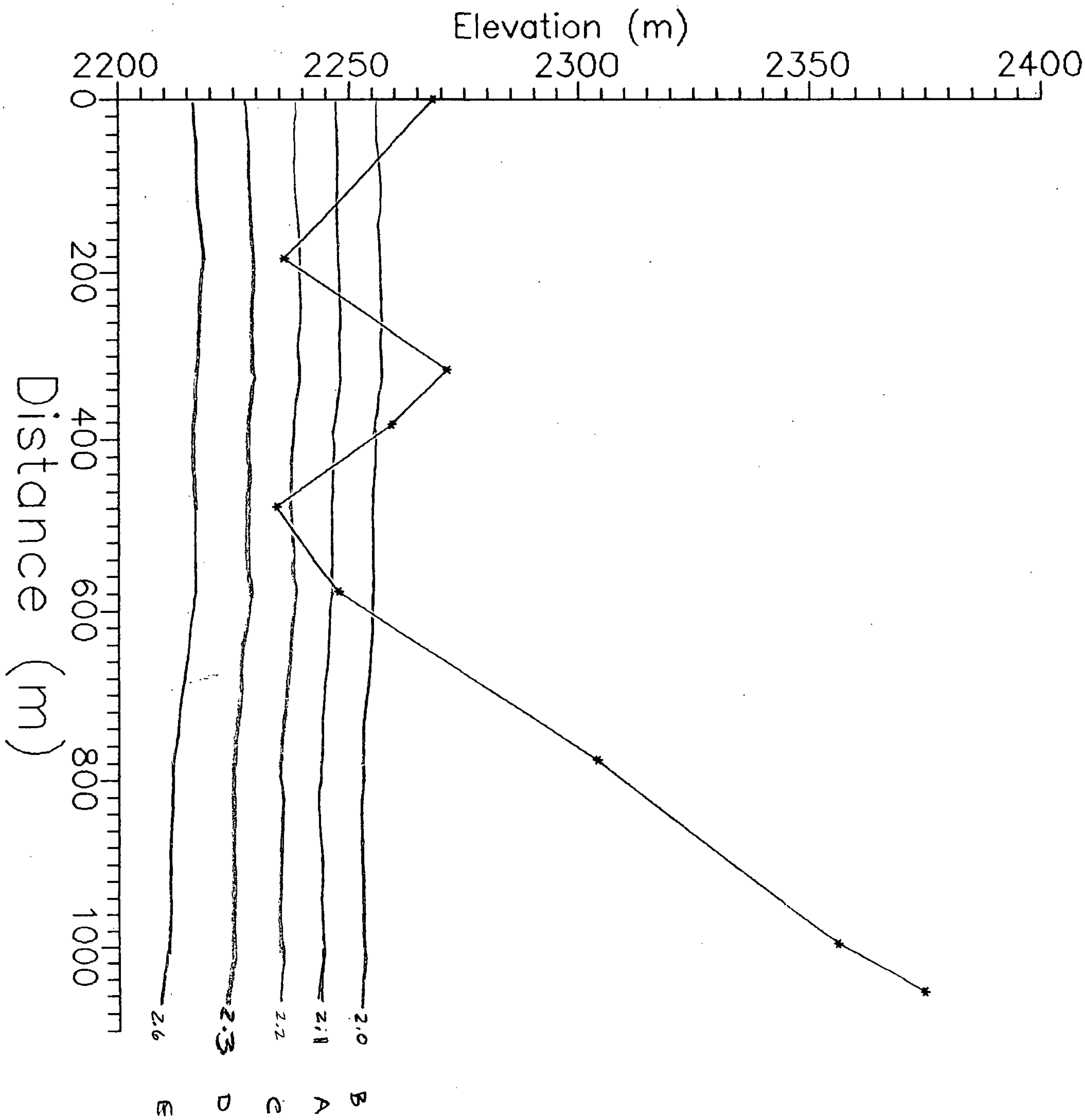
Sample #	Dry weight (g)	Suspended weight (g)	Saturated weight (g)	Vol (cu. cm)	Density (g/cu. cm)
Z-11 89m	283.61	167.95	297.30	129.35	2.19
Z-11 476m	211.00	130.30	222.65	92.35	2.28
Z-11 165m	305.30	173.05	312.60	139.55	2.19
Z-2 580m	295.05	175.65	308.00	132.35	2.23
Z-11 590m	148.50	89.21	152.10	62.89	2.36
ZCQ-2 103m	610.06	365.00	616.50	251.50	2.43
Z-2 624m	205.80	119.12	218.60	99.48	2.07
ZCQ-4 1015m (granodior.)	821.00	512.50	830.40	317.90	2.58
				Average:	2.29

DENSITY MEASUREMENTS OF ZUNIL CORE SAMPLES

Sample #	Dry weight (g)	Suspended weight (g)	Saturated weight (g)	Vol (cu. cm)	Density (g/cu. cm)
Z-11 89m	283.61	167.95	297.30	129.35	2.19
Z-11 476m	211.00	130.30	222.65	92.35	2.28
Z-11 165m	305.30	173.05	312.60	139.55	2.19
Z-2 580m	295.05	175.65	308.00	132.35	2.23
Z-11 590m	148.50	89.21	152.10	62.89	2.36
ZCQ-2 103m	610.06	365.00	616.50	251.50	2.43
Z-2 624m	205.80	119.12	218.60	99.48	2.07
ZCQ-4 1015m (granodior.)	821.00	512.50	830.40	317.90	2.58
				Average:	2.29



Elevation (m)
1700
1800
1900
2000
2100
2200
2300
0
250
500
750
1000
1250
1500
Distance (m)
LINE 2
2.0
2.1
2.2
2.3
2.67
A
B
C
D
E



Elevation (m)
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2300
2350
2400
Distance (m)
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400
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800
1000
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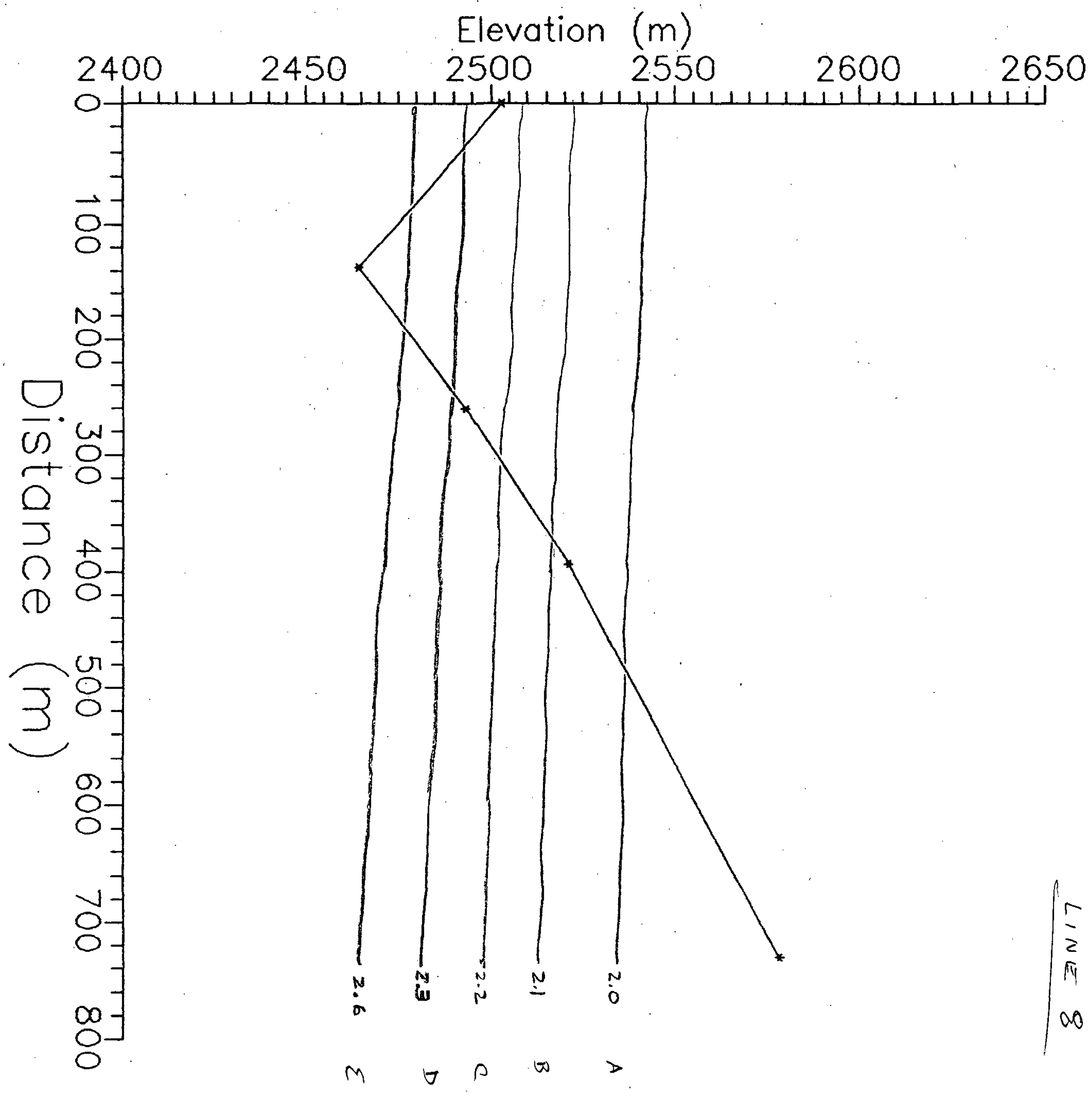
2.1
2.2
2.3
2.6
B
A
C
D
E

LINE 7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Distance (m)
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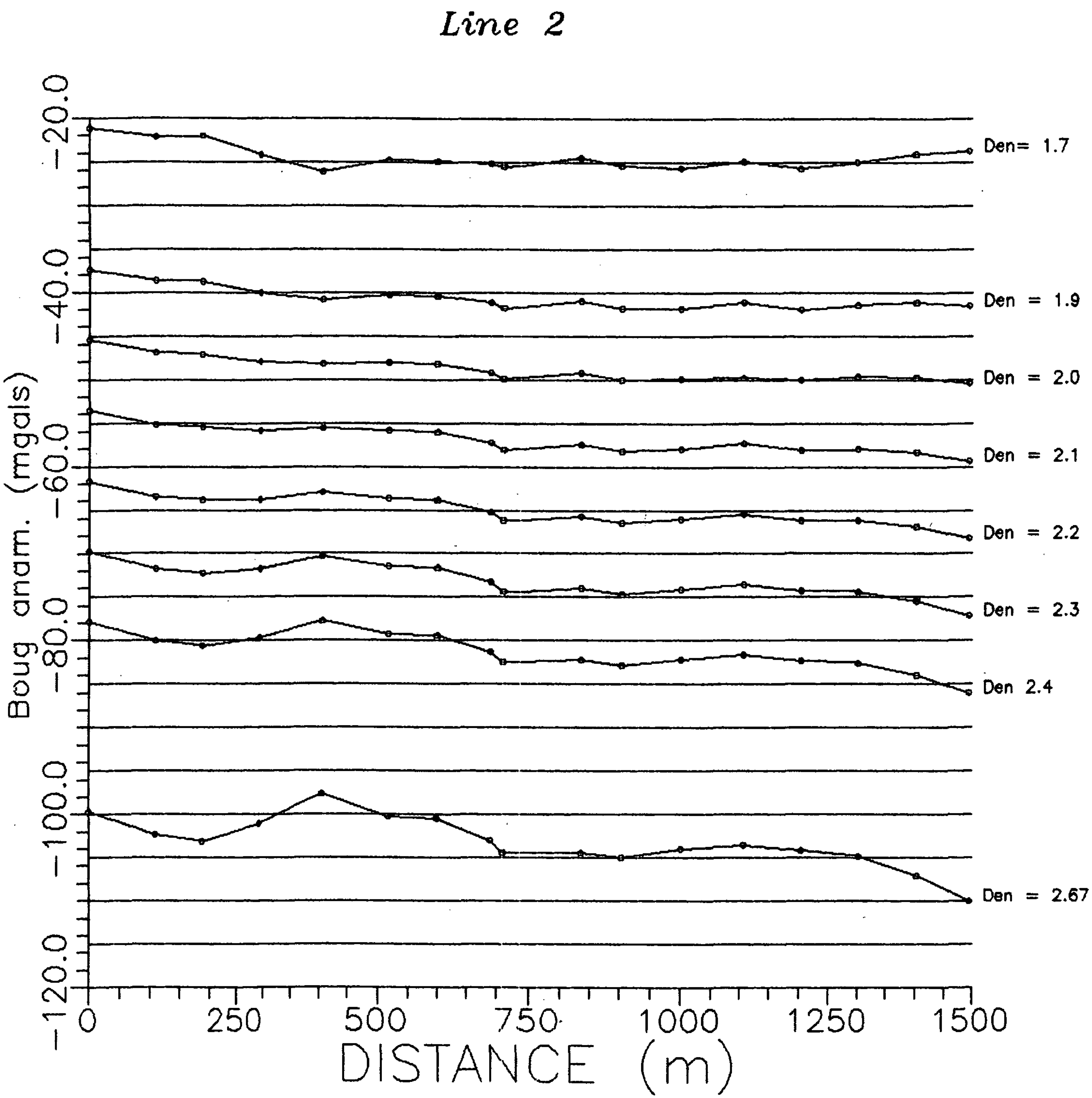
2.1 B
2.2 C
2.3 D
2.6 E
LINE 8



Line 2
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Den = 2.1
Den = 2.2
Den = 2.3
Den 2.4
Den = 2.67
Boug anom. (mgals)
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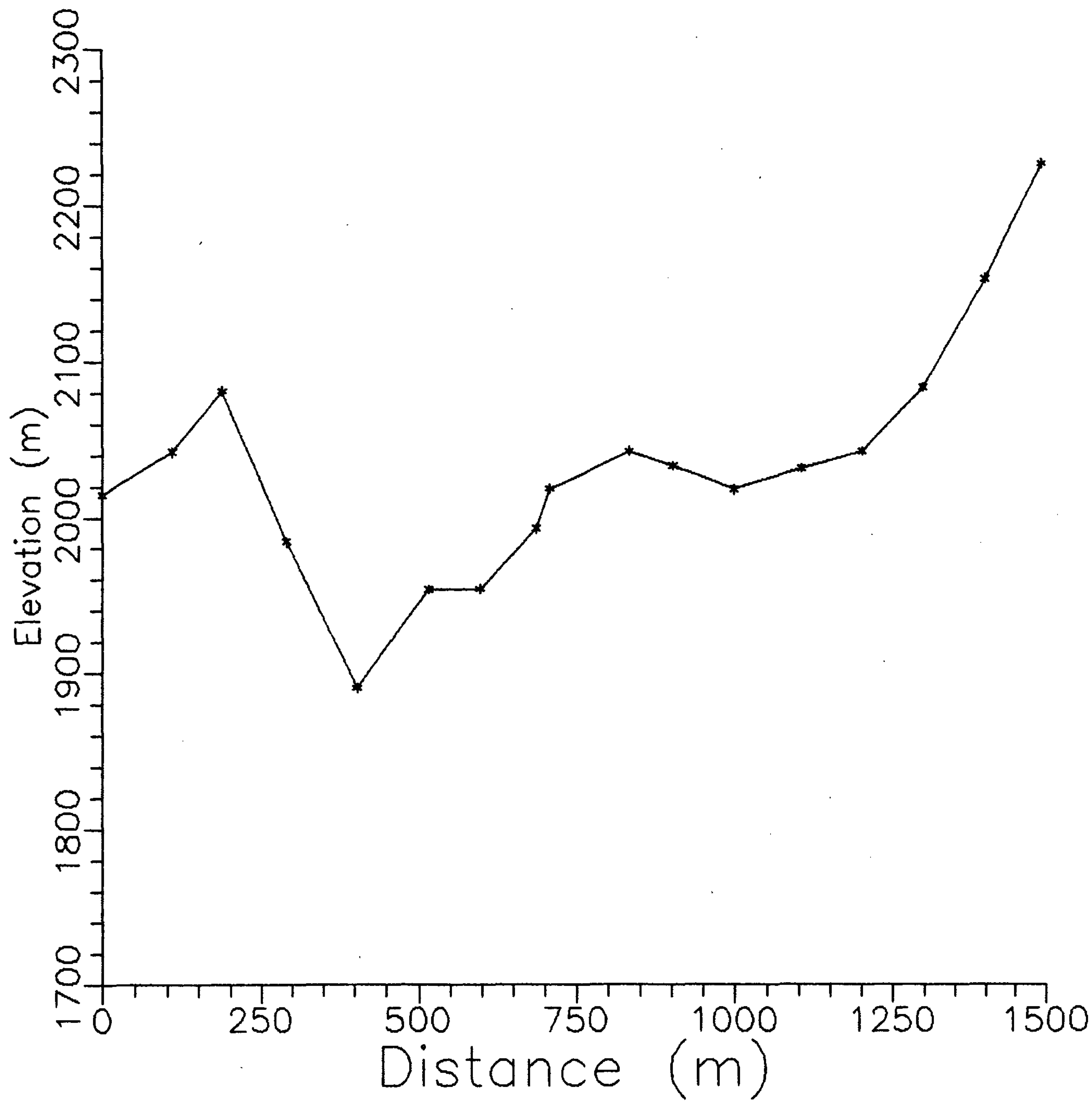
500
750
1000
1250
1500
DISTANCE (m)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Distance (m)
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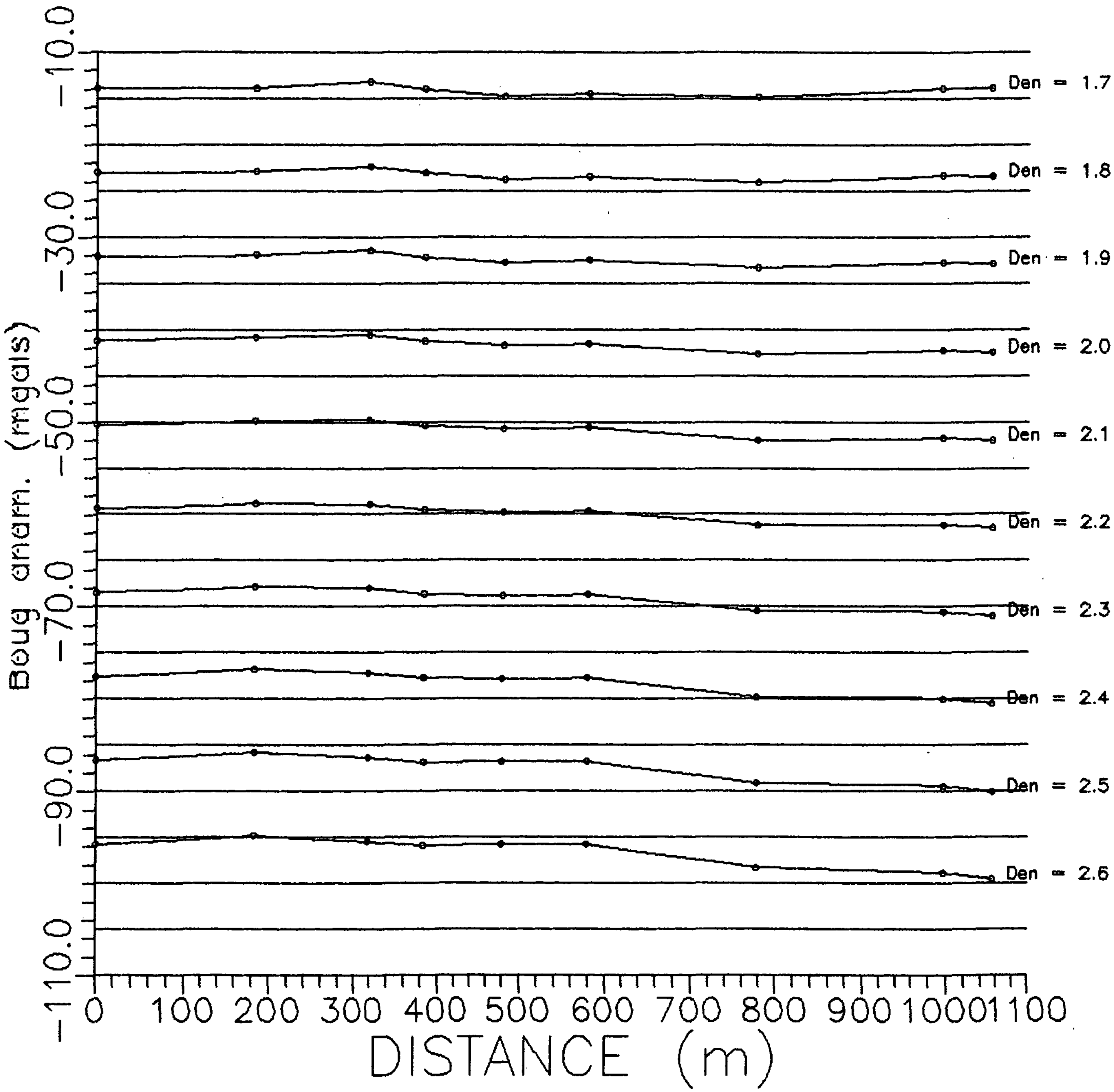
1250
1500



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Den = 2.2
Den = 2.3
Den = 2.4
Den = 2.5
Den = 2.6
Boug anam. (mgals)
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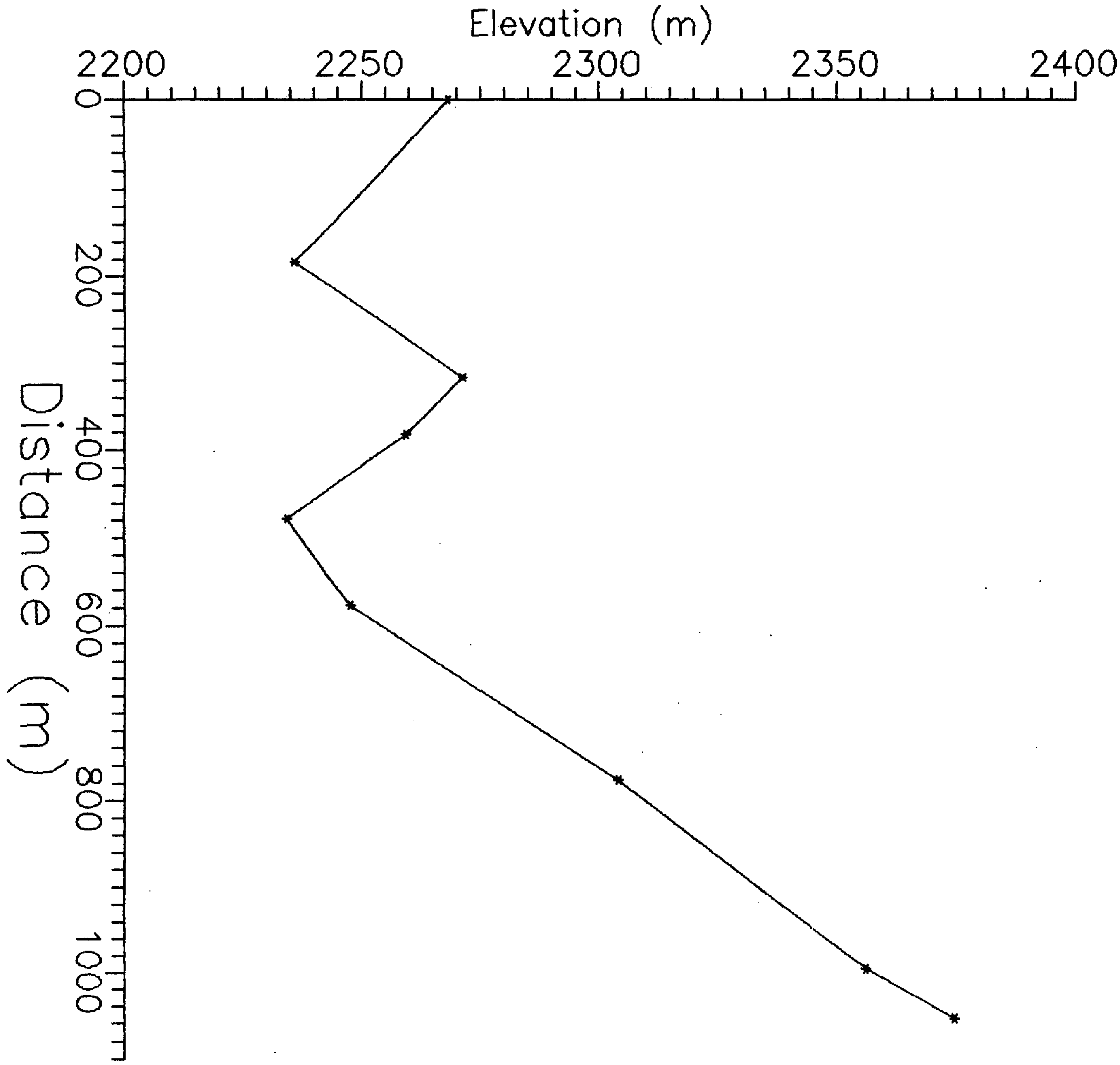
−50.0
−70.0
−90.0
−110.0
0 100 200 300 400 500 600 700 800 900 1000 1100
DISTANCE (m)



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Distance (m)
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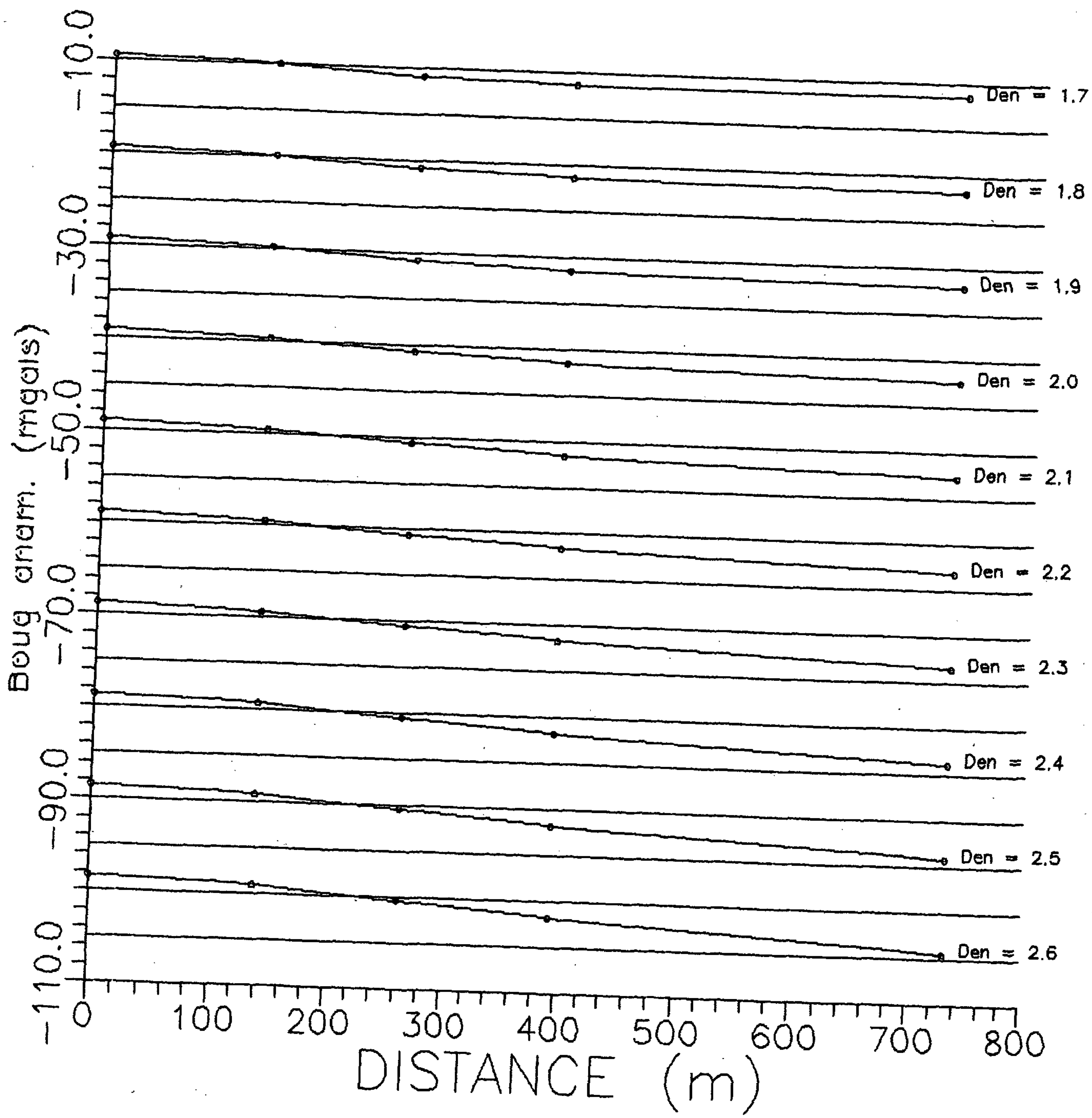
600
800
1000

Line 8



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Den = 1.9
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Den = 2.1
Den = 2.2
Den = 2.3
Den = 2.4
Den = 2.5
Den = 2.6
Boug anom. (mgals)
-10.0
-30.0
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0
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200
300
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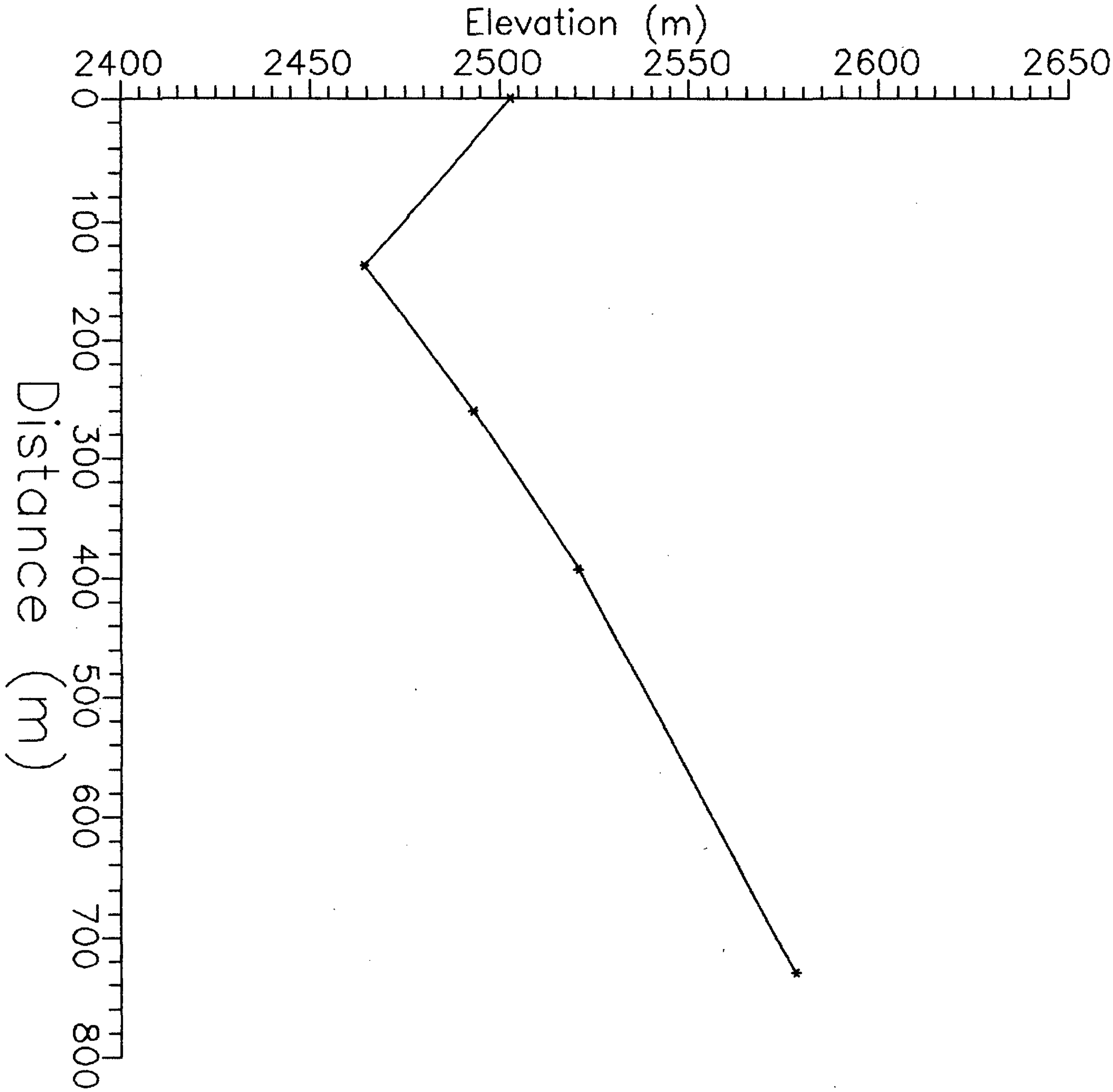
500
600
700
800
DISTANCE (m)


Elevation (m)
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2550
2600
2650
Distance (m)
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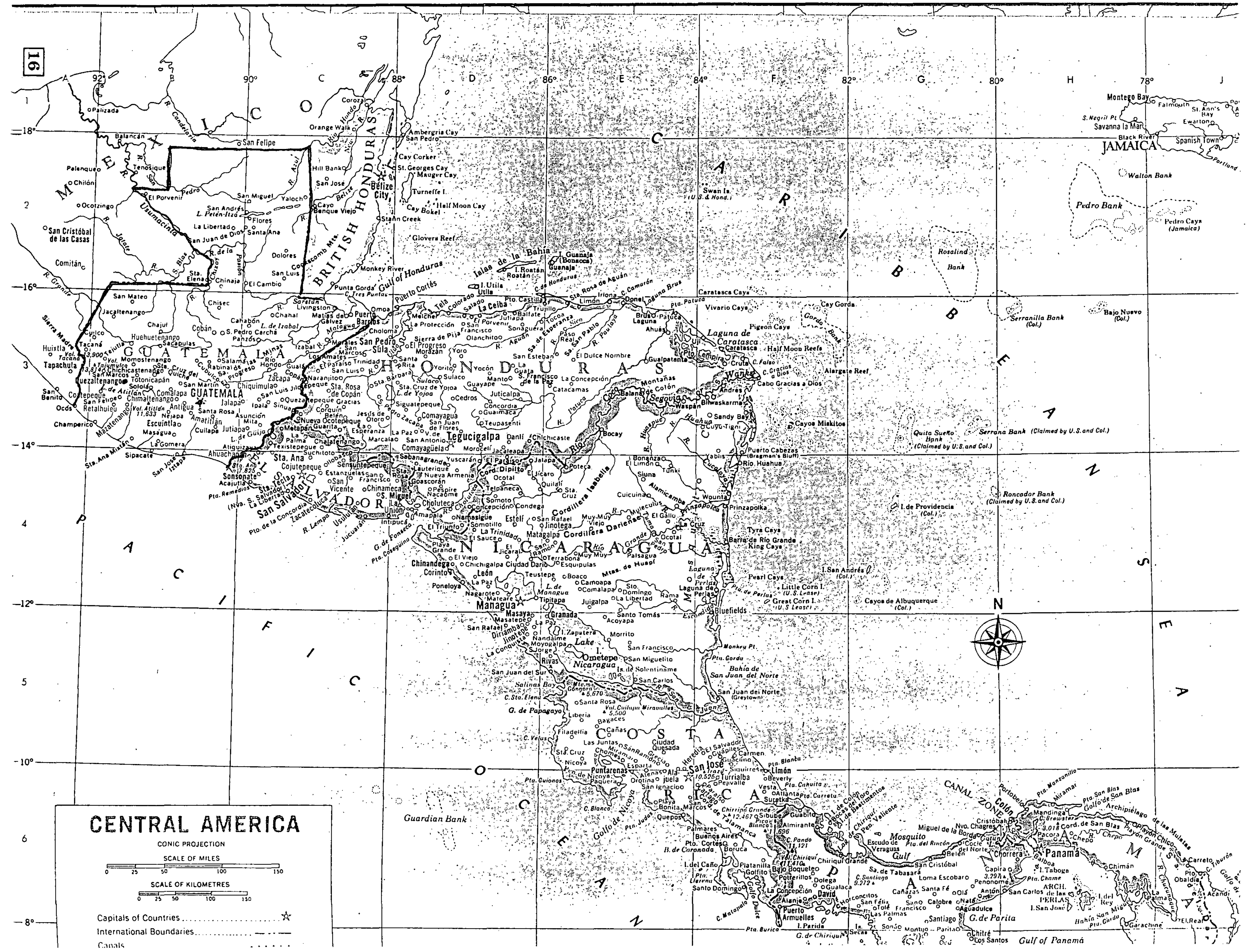
200
300
400
500
600
700
800


CENTRAL AMERICA
CONIC PROJECTION
SCALE OF MILES
0 25 50 100 150
SCALE OF KILOMETRES
0 25 50 100 150
Capitals of Countries
International Boundaries
Canals
MEXICO
BRITISH HONDURAS
GUATEMALA
HONDURAS
EL SALVADOR
NICARAGUA
COSTA RICA
PANAMA
CANAL ZONE
JAMAICA
CARIBBEAN SEA
PACIFIC OCEAN
Gulf of Honduras
Gulf of Panama
Mosquito Gulf
G. de Fonseca
G. de Papagayo
Golfo de Nicoya
Golfo Dulce
G. de Chiriquí
G. de Parita
Islas de la Bahía
Belize City
Guatemala
Tegucigalpa
San Salvador
Managua
San José
Panamá
Colón
Bluefields
Puerto Cortés
San Pedro Sula
La Ceiba
León
Granada
Puntarenas
Limón
David
Laguna de Caratasca
Lake Nicaragua
L. de Managua
Swan Is. (U.S. & Hond.)
Rosalind Bank
Pedro Bank
Walton Bank
Serranilla Bank (Col.)
Bajo Nuevo (Col.)
Quita Sueño Bank (Claimed by U.S. and Col.)
Serrana Bank (Claimed by U.S. and Col.)
Roncador Bank (Claimed by U.S. and Col.)
I. de Providencia (Col.)
I. San Andrés (Col.)
Cayos de Albuquerque (Col.)
Guardian Bank
Montego Bay
Spanish Town
Black River
Portland
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18° 16° 14° 12° 10° 8°
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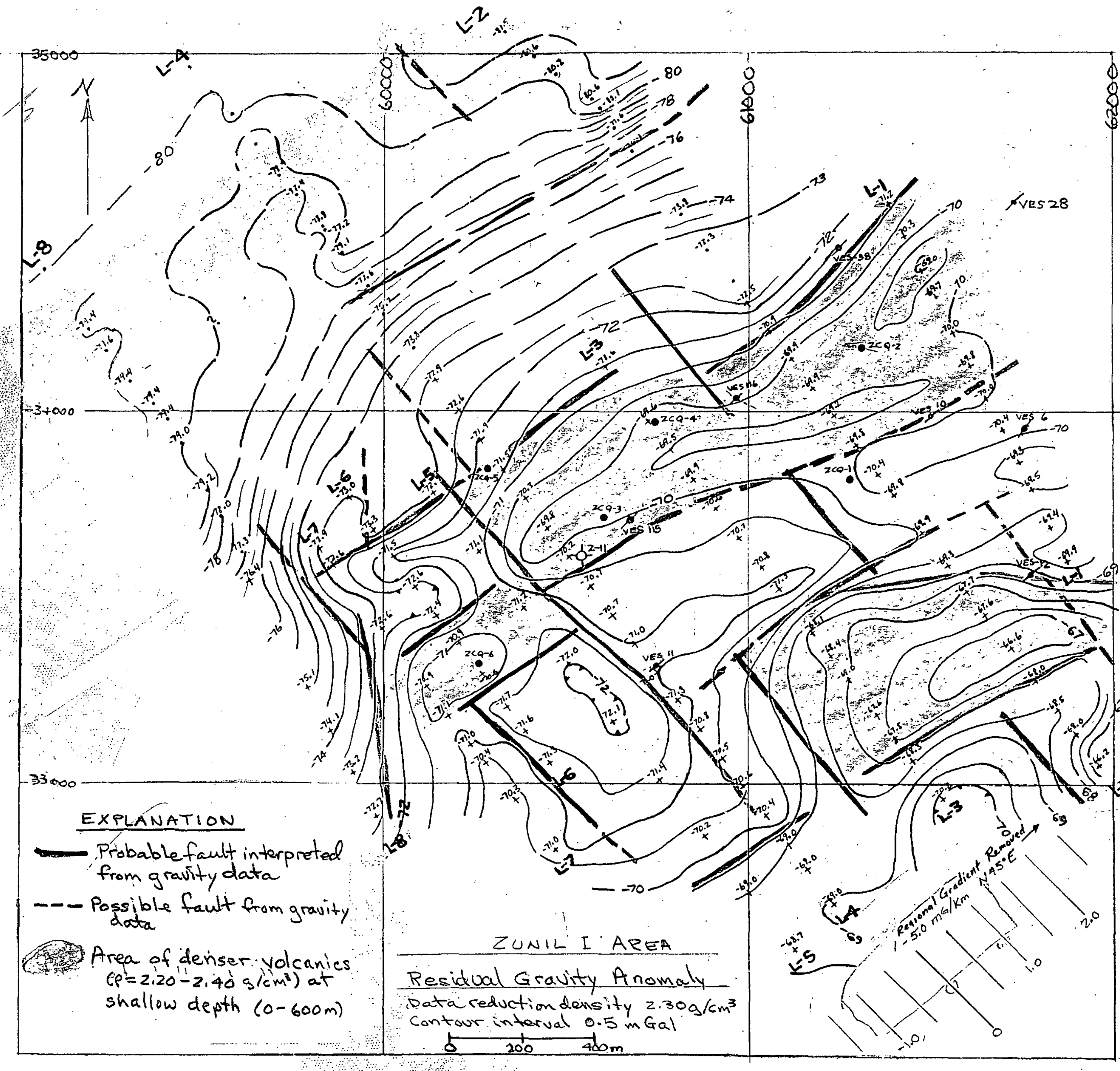
1 2 3 4 5 6
N


EXPLANATION
Probable fault interpreted from gravity data
Possible fault from gravity data
Area of denser volcanics (ρ = 2.20 - 2.40 g/cm³) at shallow depth (0-600m)
ZUNIL I AREA
Residual Gravity Anomaly
Data reduction density 2.30 g/cm³
Contour interval 0.5 mGal
0 200 400m
Regional Gradient Removed
1-5.0 mG/km N45°E
N
L-1
L-2
L-3
L-4
L-5
L-6
L-7
L-8
VES 28
VES 11
VES 15
ZCQ-1
ZCQ-2
ZCQ-3
ZCQ-4
ZCQ-5
ZCQ-6
35000
34000
33000
60000
61000
62000

new report were much better than the Mision de Enfoque report of a year ago.

3.5 Geophysics

3.5.1 Gravimetry

..LAYOUT 2
During 1989 MKF made a detailed gravimetric study in the Zunil I field. The results of these study have been presented: Bouguer anomaly with more densities, residuals (regional anomaly = "plano inclinado") which permitted the drawing of main gravimetric discontinuities for each density. The Nettleton profile shows that the more convenient density correction is between 1.9 and 2.2.
A map of d = 2.3 has been chosen for interpretation, MKF modeled only one profile with very simple parameters (2 layers with basement density of 2.6).

3.5.2 Electrical

Referring to the electrical study, only one qualitative differentiation was performed for electric soundings: resistive substrate and conductive substrate.

We may suggest to MKF:

- To establish electric sections (quantitatively) in the invested data of the electric soundings. For each sounding which has reached the resistive substrate perform a equivalence test for the conductive layer over the substrate.

- Using this completed electric data, with the lithologic and quantitative information of the deep wells, perform a series of sections (with one density, 2.2 for example) in the Zunil field.

It can be started with a 4 layer model:
1. Superficial layer (volcanites).
2. Altered formations representative layer (conductive layer from the electric soundings).
3. Andesitic layer representing the reservoir.
4. Basement

Since the field geometry is well known it could be attempted (setting the quantitative data) to study the possibilities of variation of densities in the interior of each layer and particularly the basement.

This set of profiles should permit to locate more precisely the main discontinuities (greater fractures zones) and contributing to a better understanding of the Zunil I field structure.

3.6 Well Testing

3.6.1 Short Term Test

These tests consisted in running one well at a time during one week or less, wells ZCQ-3, -5 and -6. Allowing them to discharge free to the silencer with a fix valve position. During production, water and steam flow were measured, pressure temperature and spinner profiles and chemical samples were obtained. Before closing production a pressure element was lowered and then with no flow the build-up test was performed (this only

3. ZUNIL I (Morrison Knudsen, MK-Ferguson, Cordón y Mérida)

3.1 General Comments (R. Dipippo)

The Panel bases its remarks on the following reports by MK-F an C y M

- Geoscientific studies, Report No. 1, August 1989
- Well Testing, Production-Interference, and Chemical Tests, August/89
- ZD Production wells, August 1989, and on the oral presentations made during the meeting.

As far as geological studies are concerned, the main question remains -- about the location and nature of the principal and minor faults. Since these are assumed to be the conduits for the geothermal fluid their --- identification and characterization is crucial. It is clear that potential landslide areas must be avoided in sitting wells and other plant facilities.

In the area of geochemistry, it is not certain yet whether or not the mercury studies will prove useful in locating good well targets. The - fluid inclusion studies are quite comprehensive and should prove quite useful. The main point seems to be that the open fractures in the granodiorite appear to be manifestations of the present geothermal system, and not ancient relies.

The hydrogeological study is good, but much remains to be done. The Panel was disappointed in that the data of the fluid sampling that was done during the flow tests was not presented in an acceptable and useful - manner.

With respect to the geophysics, the Panel offers suggestions as to how to interpret the results of the gravity survey using a 4-layer model with a variable density, but with layer thickness determined from lithology - according to drill logs.

The well test results were misleading in that much more data interpretation is needed before clear conclusions can be drawn about the production characteristics of the wells. The long-term behavior of the Zunil I field cannot be predicted at this time. It is clear that all wells are flashing in the formation, a situation that may have detrimental long-term effects on production. Much work must be done in the interpretation of the interference tests.

The reservoir model should be calibrated using all reliable test data - from the very first well tests. Any discrepancies among test results - must be explained, a recommendation that the Panel has made in each of - its reports.

The hydrology study is very simplistic and does not resolve the question of the recharge to the field.

The power potential of the wells has been recalculated in light of the - new tests, but caution is advised in using this value because the wells were not flowing simultaneously and the effect of interference has not been factored in because the numerical reservoir model is not available.

The Panel accepts most of the drilling targets proposed by the consul - tants but recommends that the decision tree be deferred until the results of the drilling of the first well is available. We endorse the idea of directional drilling but suggest that fewer well pads be used to drill - the targets, in accordance with accepted methods.

3.2 Geología (G. Marinelli)

3.2.1 Neotectónica

Cuando el objetivo de una exploración en el subsuelo se encuentra a importante profundidad (por ejemplo, mayor de 100 m), el costo de la perforación es tan elevado que se justifica el empleo de varios métodos de exploración, para disminuir el riesgo de fracaso.

Esta consideración tiene validez, a pesar del valor comercial de la sustancia buscada; es decir, petróleo, gas, fluidos geotérmicos. El valor comercial del producto afecta solamente la utilización de metodologías de costo elevado. Por ejemplo, la sísmica de reflexión, que es empleada en forma generalizada en la exploración petrolífera, es utilizada poco y solamente en casos particulares en la exploración geotérmica. Las metodologías fotogeológicas y geológicas de campo son, por otra parte, de uso generalizado, en consideración a su costo tan bajo. Por estas razones, en el caso particular de Zunil I, la identificación esmerada de los sistemas de fallas y fracturas en el área geotérmica había sido recomendada por el Panel. Esta investigación puede indicar el más probable sistema de fracturas que alimenta el supuesto reservorio profundo, disminuyendo así el riesgo de fracaso en la localización de las perforaciones profundas inclinadas.

Los estudios del Consultor han llevado a la conclusión que son productoras tanto las fallas o fracturas de rumbo NE-SO (Falla de Zunil) como aquellas de rumbo ortogonal. El Panel no sabe cómo se haya alcanzado este resultado y lo considera poco probable, porque, en general, en un área de tamaño tan reducido (unos km^2), el sistema activo de fallas o fracturas de carácter tensional es uno solamente. De todas formas se re comienda que el objetivo de los pozos inclinados no debe ser el punto de intersección de los dos sistemas de fallas. La experiencia minera muestra, en efecto, que en estos puntos donde la circulación inicial de los fluidos es mayor ocurre una mayor deposición de minerales debido a la disminución de la velocidad de los fluidos. Estas zonas, las cuales son favorables en el campo minero porque son lugares de concentración de los minerales útiles, pueden perder rapidamente su permeabilidad por "self - sealing" de incrustación.

El Panel recomienda, por lo tanto, que los pozos no sean localizados según la figura 1, sino conforme a la figura 2 :

Fig. 1

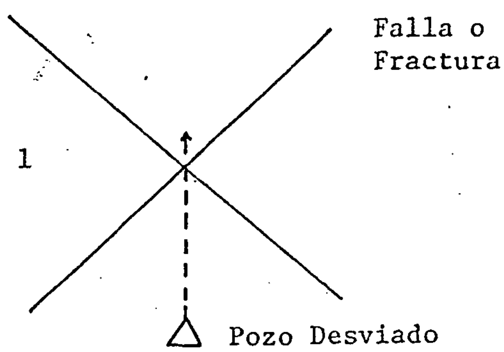
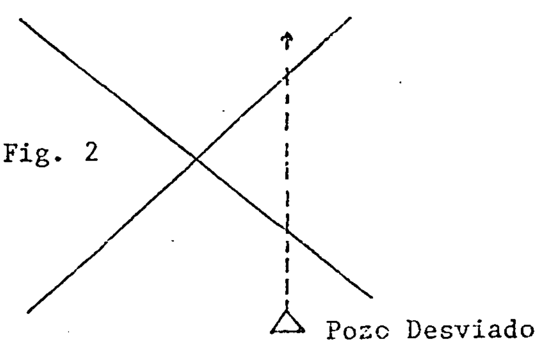


Fig. 2



3.2.2 Mineralogía de alteración

En lo que se refiere a la mayor o menor permeabilidad de los reservorios por fracturación, ésta es, si es igual al modelo tectónico, proporcional a la rigidez (y por ende, a la fragilidad) de las rocas encajantes.

Las cuarzitas, las calizas dolomíticas y las calizas son, por lo tanto, rocas ideales, así como las rocas magmáticas intrusivas ricas en cuarzo (granitos, granodioritas) siempre y cuando estas rocas no sean alteradas. La alteración hidrotermal, produce en estas rocas un cierto grado de plasticidad, particularmente en profundidad. En efectos los feldespatos, la hornblenda y las biotitas se transforman en filosilicatos muy hidra - tados (caolín, ilitas, smectitas) o poco hidratados (sericitas, clori -

tas): los planos de "Cleavage" muy fáciles de estos minerales hidrotermales, facilitan la modificación de forma bajo el efecto de la presión litostática. Pero estas rocas se vuelven nuevamente rígidas y frágiles cuando la alteración hidrotermal ocurre a temperaturas elevadas. En efecto, a 300°C y a temperaturas mayores, los minerales de alteración hidrotermal estables : cuarzo, epidota, albita, adularia, anhidrita, vuelven las características mecánicas de estas rocas similares y quizas aún mejores de las de las rocas no alteradas.

Los estudios petrográficos de la granodiorita procedente de los pozos de Zunil I muestran una alteración hidrotermal típica de la zona a filosilicatos; sin embargo, ya se observan vetas de cuarzo y epidota que anuncian equilibrios de temperaturas más elevadas. Por lo tanto, el Panel sugiere que la búsqueda del reservorio en la granodiorita sea efectuada a profundidades lo más elevadas posible de manera que aumente la probabilidad de encontrar un sistema de fracturas altamente productivo.

3.2.3 Deslizamientos

Para la elección de los sitios de ubicación de los pozos profundos de Zunil I hay que tomar en cuenta la presencia en la zona de derrumbes y de deslizamientos.

3.3 Geochemistry (Fraser Goff)

3.3.1 Mercury Anomalies

In the past, I have never been very impressed by mercury (or radon) anomaly maps because I have always felt that good geologic mapping and surface alteration studies in combination with the distribution of thermal features would yield nearly the same information. we --

already know, for example, that there is cinnibar in the altered rocks near ZCQ-4 and that the cinnibar is deposited as a result of volatilization at depth. None the less, MKF performed a Hg-survey of approximately 40 soil samples laid out in a grid and by contouring the data, have found a "best target area" for drilling on the basis of correlations of anomalies with mapped fault and fault intersections. I give MKF credit for initiating the study on their own and acknowledge that they may have identified a productive target zone. Only drilling will prove it.

I'd also like to mention that soil mercury is not in the form of cinnibar but rather as elemental mercury or complex organic compounds. This requires that the anomalies be very young and must, therefore be manifestations of open fractures.

3.3.2 Fluid Inclusions

Although fluid inclusion measurements were first used to study deposition temperatures and fluid compositions of ore deposits, the science of fluid inclusions has advanced rapidly in recent years because of its application to active geothermal systems. This application is particularly enhanced where reservoir chemistry, hydrothermal alterations, and measured temperatures in wells are available.

The fluid inclusion investigation performed by MKF is a very nice integration and is typical of similare studies now widely carried out in Japanese, New Zealand, and US geothermal systems. The major results are these :

1. The alteration and vein minerals observed in the cuttings and cores from Zunil I were formed from hydrothermal solutions very similar to those now circulating at Zunil I today.

2. The types of fluid inclusions, their salinities, and their distribution with depth are similar to the configuration of vapor, $Na-HCO_3$ and Na-Cl fluids observed at the surface and in the existing wells at Zunil I.

3. The homogenization temperatures closely approximate the measured well temperatures. Where they do not, the T_h is only a few degrees lower than T_m suggesting that, locally, the system may be heating up (in geologic time).

4. Most important, the fluid inclusions in vein minerals from granodiorite cores and cuttings are no different in salinity or T_h than similar inclusions in overlying rocks. Clearly, the open fractures in the granodiorite are a manifestation of the present geothermal system. They are not a relict of an ancient hydrothermal went.

3.3.3 Hidrogeochemistry

I was less impressed by the interpretations made with the new MKF hydrogeochemical data. Also, some data was still incomplete (stable isotopes) or poorly analyzed (tritium data). The basic water types and their general configuration in the system was already known. Of major interest was to aquire a set of internally consistent analyses (same laboratory) from all features (surface and wells) in order to interpret the wide array of mixing, boiling, and cooling processes occuring in the reservoir. Also of major interest was to obtain a comprehensive set of stable isotope data on cold waters around the area (10 km radius) to find the recharge areas. Neither problem was adequetty answered. In particular :

1. I firmly believe that all hydrogeochemical interpretations start with simple plots and tables to charactarize water types, identify mixing processes and tabulate the standard sweater of chemical geothermometers (specially those with a proven track record like Na/k and Na-K-Ca). Instead, chloride enthalphy diagrams were analyzed with little back - ground interpretation.

2. The chloride-enthalphy diagram that was stressed used enthalphy based on a somewhat obscure geothermometer, k-Mg. The accuracy of this geo thermometer is still not widely proven but, in any event, the plot - compared data from two different types of springs, Na-HCO_3 and Na-Cl. The latter is the one of greatest interest (or mixtures of Na-Cl with other types). Also, all data were thrown on the plot (who knows how reliable they all are), making a confusing array of data clusters and trends. The new set of internally consistent data should have been used first and then older data compared. The point of all this is - that there may be no strong evidence for temperatures of 325°C existing in the reservoir.

3. Another way to assess the reservoir temperature of the "mother fluid" is to compare geothermometers from the least boiled and least mixed - fluid. Don't stop with the chemical ones; use $S^{18}O$-SO_4 and the gas geothermometer of D'Amori and Panichi as independent checks. If they all agree reasonably well (remember, these geothermometers have errors as high as ± 30°C), then you may not get a lot more out of your chlo ride enthalphy diagrams. The temperatures that I calculated on data from ZCQ-6 were fairly consistent at 270 to 300°C very similar to the measured temperature of 280°C.

4. Since MKF now has quality samples taken from miniseperators during - the latest flow tests the quartz geothermometer should be useful when applied to the flash corrected analysis.

5. Also, an MKF subcontractor made the horrible statement that since Zunil I reservoir fluids are dilute, they can't cause scaling or sealing problems if the fluids flash in the formation. Since silica concentration is wholly dependent on temperature in neutral-chloride reservoir fluids (like Zunil I), a 280°C fluid with 500 mg/kg TDS will have - the same silica concentration as a 280°C fluid with 50,000 TDS. And if the fluid boils, it will precipitate silica.

6. With no new isotope data to present, the location of recharge areas - is still one of speculation.

7. There are more up to date ways of interpreting tritium data based on a short paper by Pearson and Truesdell (1928). An application of this method was developed for Central American geothermal waters by Goff- et al (1987) in a Los Alamos report on Honduras. It should be viewed qualitatively. Write me for a reprint. Also, doesn't it strike MKF as unusual that the Zunil I reservoir fluids (mother fluid) would have more tritium than overlying Na-HCO_3 waters?. The data must originate from different labs, or some data must come from a lab with poor precision, or the wells contain some young water from injection or - other operations.

3.3.4 Fluid Sampling During Flow tests

It was unfortunate that the reconstituted analyses of the well samples including their isotopic results were not available for scrutiny. These - analyses and similar ones that will follow as the field is developed and produced will become one of the very best tools to monitor the "health" of individual wells and of the entire field at relatively low cost.

3.4 Hydrology (Fraser Goff)

The simple hydrologic models that were presented were interesting but were very simplistic. In addition, without the results of the stable isotope survey of cold waters, it is still not clear if the region north west of Zunil I is the recharge area. Once the latter issue is resolved, the models can be constained with realistic boundaries, structures, permeabilities, etc.

If the Quetzaltenango Caldera indeed exists, the depression that it created would serve as a gigantic recharge area for the Zunil reservoir, which occurs at a lower elevation than the postulated caldera floor. There would be some merit in establishing whether or not this caldera indeed exists, in defining its subsurface structure, and in particular, defining its southeastern boundary zone (beneath the underlying young volcanic rocks) and understanding the structural and hidrologic significance of the Q.Cal to the Zunil fault zone and the geothermal system. Similar features have a profound influence on the hydrologic control of the geothermal system at Valles Caldera, New Mexico, as stated in your new report. At the present time, the Panel is not recommending a reprograming of funds to unravel this problem but, if the Zunil I field is developed, the problem should be addressed. By the way, the style and presentation of the new report were much better than the Mision de Enfoque report of a year ago.

3.5 Geofísica (A. Duprat)

3.5.1 Gravimetría

En el año 1989 MKF efectuó un estudio gravimétrico de detalle en el campo de Zunil I. Los resultados de este estudio han sido presentados: Anomalía de Bouguer con más densidades, residuales (anomalía regional escogida = plano inclinado) que permitieron trazar las discontinuidades gravimétricas principales para cada una de las densidades. El perfil de Nettleton muestra que la densidad de corrección más conveniente está comprendida entre 1.9 y 2.2.

Un mapa con d = 2.3 ha sido escogido para la interpretación, MKF modeló solamente un perfil con parámetros demasiados sencillos (2 capas con densidad del basamento de 2.6).

3.5.2 Eléctrica

Para lo que concierne el estudio eléctrico, solo se efectuó una diferenciación cualitativa entre sondeos eléctricos: los que han alcanzado un substrato resistivo y los que han alncanzado un substrato conductor.

Se puede sugerir a MKF :

- De establecer cortes eléctricos cuantitativos en los datos de inversión de los sondeos eléctricos. Para cada sondeo que ha alcanzado el substrato resistivo efectuar una prueba de equivalencia para la capa conductora que sobre yace el substrato.
- Utilizando estos datos eléctricos completados, con las informaciones litológicas y cuantitativas de los pozos profundos, de realizar una

serie de perfiles (con una sola densidad, 2.2 por ejemplo) sobre el campo de Zunil I.

Se podría empezar con un modelo de 4 capas :

1. Capa superficial (volcanitas)
2. Capa representativa de las formaciones alteradas (capa conductora de los sondeos eléctricos)
3. Capa andesitica que representa el reservorio
4. Basamento

Siendo la geometría del campo bastante bien conocida se podría intentar (fijando los datos cuantitativos) estudiar las posibilidades de variaciones de las densidades en el interior de cada capa y en modo particular en el basamento.

Este conjunto de perfiles tendría que permitir localizar con más precisión las principales discontinuidades (zonas de mayor fracturación probable) y contribuir a un mejor conocimiento de la estructura de el campo de Zunil I.

3.6 Pruebas de Pozo (P.E. Liguori)

3.6.1 Pruebas de corta duración

Estas pruebas consistieron en poner en producción uno a la vez, durante una semana más o menos, los tres pozos ZCQ-3, 5 y 6 dejándoles descargar libremente el silenciador con posición de válvula fija. Durante la producción se midieron caudales de agua y vapor, se sacaron unos perfiles de presión, temperatura y "spinner" y se tomaron muestras químicas. Antes de terminar la producción se bajó en el pozo un elemento de presión y, al cerrar el pozo, se llevó a cabo la prueba de "build-up", limitadamente a los pozos ZCQ-3 y 5. Los datos se han presentado bien organizados y están claros lo suficiente como para apreciar los resultados de las pruebas aún cuando estos no estén ampliamente descritos.

La interpretación de las pruebas de corta duración ha sido dirigida a dos fines :

- Establecer la potencia eléctrica disponible y;
- Determinar las características hidráulicas de cada pozo probado.

Sobre la potencia disponible se comenta en otra parte de este informe, sin embargo, se recuerda aquí que la potencia disponible a la fecha de pozos descargando uno a la vez y sin soporte de estudios de reservorios es únicamente un ejercicio peligroso, que puede llevar a injustificados optimismos, por no contener el abatimiento de la producción que necesariamente ocurrirá con el tiempo. Sobre las características hidráulicas de los pozos, ellos han sido calculados según los métodos clásicos de la ingeniería de transientes de presión.

Los valores obtenidos para la transmisivilidad de la formación y el factor de daño de los pozos se enmarcan en un cuadro normal para campos geotérmicos en ambiente volcánico, inclusive el hecho de que el factor de daño es negativo.

Cabe hacer notar que los tres pozos tienen columna totalmente bifásica, significando que el punto de "flash" se encuentra en la formación; aún si esto puede aparecer como una ventaja, en cuanto se tiene menos agua líquida que desechar, en efecto no es muy buen indicio con respecto a la capacidad del pozo de mantener su caudal de vapor a largo plazo.

3.6.2 Pruebas de larga duración

Estas pruebas consistieron en descargar el pozo ZCQ-3 durante casi cuatro meses, con posición de válvula fija, midiendo al mismo tiempo la presión de fondo en los cuatro pozos de observación ZCQ-1, 4, 5 y 6. Después de dos meses de producción se empezó a reinyectar el agua separada en el pozo ZCQ-2 lo que se hizo durante un mes y medio. Durante este plazo se midieron los caudales en producción y en reinyección, se sacaron unos perfiles de presión y temperatura y se tomaron muestras químicas. Se está midiendo todavía la presión en los pozos de observación para tener registros del período de recuperación.

Tal como para las pruebas de corto plazo la interpretación ha sido dirigida a dos fines : establecer la potencia eléctrica disponible (de solo el pozo ZCQ-3 en este caso) y determinar las características hidráulicas del reservorio. Sobre la potencia se comenta en otra parte del presente informe.

Es sorprendente observar que la interpretación de las pruebas de interferencia a fines de reservorio no se hizo, cuando al contrario justamente esta interpretación constituye la razón para hacer estas pruebas. Bajo la definición "interpretación a fines de reservorio" se entiende la búsqueda, a través de la respuesta de los pozos de observación, de características fundamentales del reservorio como son al menos la existencia de barreras y de alimentaciones profundas, valorización de las eventuales recargas, ubicación de fallas de alimentación (para dirigir los pozos desviados)

La interpretación presentada se ha limitado a reinterpretar las características hidráulicas y a comentarios generales sobre la comunicación o me -

nos de los pozos entre ellos. Los valores presentados por las caracte-rísticas hidráulicas vienen acompañados de comentarios genéricos del tipo "normal para campos geotérmicos" o "congruentes entre ellos", cuando al contrario habría mucho que hablar.

La impresión general es que la interpretación de estas pruebas prácticamente no se hizo, limitándose a presentar los datos e interpretaciones standard, (como se encuentran en los textos básicos), sin ninguna tentativa de comprender lo que efectivamente ocurre en el reservorio superficial.

Cabe notar que la interpretación estandard de la respuesta del pozo ZCQ-4 no ha individualizado rasgos muy importantes y valiosos en ellos contenidos y que en general muchas interpretaciones son superficiales y discutibles. Considerando que todavía se está monitoreando la recuperación en los pozos y hay que probar en producción corta el pozo ZCQ-4, la sugerencia que se puede dar es la siguiente :

- Continuar la observación en los pozos ZCQ-1 y ZCQ-5 también durante la prueba de producción del pozo ZCQ-4.
- Pedir a MKF que haga una interpretación cuidadosa y completa de las pruebas de interferencia.
- Con base en la interpretación completa, revisar los comentarios genéricos como "producción estable" y hacer una evaluación sería de la declinación de producción que ocurriría en el reservorio somero bajo explotación.

3.6.3 Modelo del Campo

La respuesta de MK-F (Dr. Subir Sanyal) a las observaciones sobre la falta de una interpretación adecuada de las pruebas de larga duración se ha desarrollado en dos líneas :

- Que las pruebas todavía están en curso
- Que la ocurrencia de la fase vapor hace necesario el uso de un modelo que no estaba previsto a la fecha.

Puesto que hay tiempo hasta el inicio de las perforaciones derivadas para tener los resultados de una interpretación adecuada y la actividad de modelado se pone en paralelo con otros, el Dr. S. Sanyal se ha comprometido hacer el modelo y entregar los resultados hasta Diciembre de 1,989.

Es oportuno entonces, establecer los fines y los límites del modelo, quienes son los siguientes :

- Que esté estructurado conteniendo los rasgos del modelo conceptual del sistema geotérmico (geometría, litología, tectónica, hidrología, termalismo)
- Que maneje fluidos mono y bi-fásicos con inclusión de gases (por lo menos CO_2).
- Que consiga reproducir de manera satisfactoria las pruebas de interferencia con producción-reinyección.
- Que consiga reproducir las declinaciones de caudal que se observaron en los años de 1,981 a 1,985.

Una vez que se tenga este modelo funcionando, será muy fácil incorporar en él los resultados de perforaciones y pruebas que se lleven a cabo en un futuro hasta que el modelo se vuelva en la mejor herramienta para -

evaluar el potencial del campo y luego para manejarlo durante la explotación.

3.6.4 Conclusiones

Las pruebas de producción/reinyección en los pozos ZCQ se han llevado a cabo siguiendo en principio las recomendaciones del Grupo Consultivo (segunda Reunión), con cambios menores que no han modificado la validez de los resultados.

Los datos han sido tomados con buena técnica y buen equipo y también han sido bien presentados.

Atrás de esta muy buena presentación se manifiestan todavía fallas importantes, unas de ellas ya subrayadas por el Grupo Consultivo anteriormente, como son :

- Se insiste en despreciar la importancia de la valoración de las pruebas de producción anteriores, que indicaron una declinación preocupante en la producción de los pozos.

- Puesto que, en base a las pruebas de corta duración, se encontró que el método del vertedero resulta mejor que él del orificio en la determinación del caudal, se sostiene ahora que las mediciones anteriores son malas (durante la Segunda Reunión MK-F había sostenido que el orificio era mejor que el vertedero), borrando de una vez una declinación de caudal cuya importancia no puede ser olvidada.

- La interpretación de las pruebas de interferencia ha sido conducida según métodos correctos pero muy elementales y no aceptables en el marco de un proyecto de envergadura.

- Números importantes, como son caudales de vapor, índices de productividad/inyectividad, se siguen cambiando de un informe a otro con mucha facilidad y sin dar explicaciones.

La impresión general sobre las pruebas es entonces que hace falta la necesaria dedicación en la elaboración e interpretación de los datos.

Respondiendo a las críticas, el Dr. S. Sanyal dijo que el campo es difícil por tener presencia de la fase vapor y que entonces se necesita de un modelo para interpretar correctamente las pruebas.

Es cierto que un modelo es importante y ayuda en la interpretación, sin embargo se subraya que hasta ahora se ha seguido presentado en forma contradictoría y con cambios repentinos injustificados una parte de los resultados; se recomienda por lo tanto que el modelo sea utilizado en forma clara y que sus voluminosos datos de salida sean bien presentados e interpretados.

3.7 Power Potential of Existing Wells (R. Dipippo)

In this section we will update our estimate of the electric power potential of the existing wells. The basis for the calculation is the set of data taken during the well tests conducted from February until July 1989.

3.7.1 Revised Estimate of Power Potential

On page 39 of the Report of the Second Meeting of the Advisory Panel, we presented an estimate of the potential power output of the existing ZCQ-wells.

In table 3.7.1 we present revised values using the test data for the -

short-term tests on wells ZCQ-5 and ZCQ-6 and the end-point of the long-term test on well ZCQ-3. Earlier data was used for well ZCQ-4 and may not be reliable, as was discussed in the Panel's previous report. Including the possibly questionable data on well ZCQ-4, the total estimated power comes to about 13.6 MW, or 3.4 MW/well.

However, great caution must be used in interpreting this total. Wells ZCQ-3, ZCQ-5 and ZCQ-6 were each tested separately, and thus any effects of interference are neglected. The consultants have reported that all the wells are in communication with each other, except for well ZCQ-6. When all the wells are opened simultaneously as they must to feed the power plant, the power potential will decrease. This problem will be discussed in the next section.

3.7.2 Effect of Production Decline in Well ZCQ-3 on Its Estimated Power Potential

The Panel was told by Dr. S. Sanyal that there was no decline in power during the long-term flow test on well ZCQ-3. It was reported that the following changes took place during the test :

- Total flow rate : 120 to 80 t/h (33.3 to 22.2 kg/s)
- Steam mass fraction : 30 to 40% (approx)
- Enthalpy : 310 to 360 cal/g (1297.0 to 1506.2 kj/kg)
- Wellhead pressure : 9.5 to 6.8 kg/cm^2, abs (9.3 to 6.7 bar, abs)

Dr. Sanyal assumed a constant specific steam consumption of 7.7 (t/h)/MW or 2.14 (kg/s)/ MW arriving at his conclusion that the power potential would remain constant at 4 MW.

TABLE 3.7.1

REVISED ESTIMATE OF POWER POTENTIAL OF ZCQ-WELLS

WELL No.	Steam Quality At Separ.	Turbine Inlet Pressure bar, abs	Total Mass Flow kg/s	Estimate Electric Power MW
ZCQ-1	(Not productive	at presente)		
ZCQ-2	(Proposed injection well; best power est. = 5.7MW)			
ZCQ-3	0.396	6.0	22.2	4.37
ZCQ-4	0.199	6.0	27.8	2.75
ZCQ-5	0.829	6.0	9.17	3.78
ZCQ-6	0.396	6.0	13.89	2.73
			TOTAL :	13.63 MW

NOTES :

1. All wells have separators operating at 6.5 bar, abs.
2. ZCQ-4 data is from earlier testing and may not be reliable.
3. ZCQ-5 is an average of reported data
4. Condenser operates at 41°C, 0.078 bar.
5. Turbine insetropic efficiency = 77%.
6. ZCQ-2 not included in total.
7. ZCQ-3, ZCQ-5, ZCQ-6 tested separately with other wells closed.

A more detailed thermodynamic analysis of this data reveals that the power potential in fact declined by 10.5% during the period of the long-term test. Furthermore, if one takes into account the power potential calculated during the earlier short-term test, the decline in power from that time to the end of the long-term test is actually about 19%.

These results follow from the analysis of the turbine which receives - steam separated at 6.5 bar, abs and delivered as a satured vapor at 6.0 bar, abs. A turbine isentropic efficiency of 77% is assumed and a con - denser pressure of 0.078 bar is assumed. The specific output of the turbine is 496.9 kj/kg of steam. The power is found by multiplying this by the steam mass flow rate which is the product of the quality and the total mass flow rate. At the start of the long-term test, these values are 0.295 and 33.3 kg/s, respectively; at the end, they are 0.396 and 22.2 kg/s, respectively. Thus, the initial power is 4.88 MW and the final - value is 4.37 MW. This is a loss of 10.5%. The stabilized conditions during the short-term test were 0.356, 30.56 kg/s, and 5.41 MW.

Thus, the power potential of well ZCQ-3 fell from 5.41 MW to 4.37 MW during the 5 month test period from 6 February 1989 to 13 July 1989. This is a drop of 19% which may be partly attributed to the effect on well ZCQ-3 of the flow tests on well ZCQ-5 and, perhaps, on well ZCQ-6.

3.7.3 Conclusion

Although the revised power potential of wells ZCQ-3 through ZCQ-6 is - 13.6 MW compared with 8.6-11.2 MW reported in the Panel's previous report it must be undestood that this total will decline when all four wells - are flowing simultaneously.

The data shown in table 3.7.1 for well ZCQ-4 are based on a test conducted during 1983-84 when four wells were tested simultaneously. Finally, it is unknow how much of a decline will occur with time, but the results obtained during the 5 months of testing on well ZCQ-3 may give some idea of the size of this effect.

3.8 Drilling Program

In this section we will discuss several aspects of the drilling program proposed by MK-F and CyM as well as certain matters relating to the bidding document for a drilling contractor.

3.8.1 Deviated Wells

The Panel agrees with the plan to drill future wells at Zunil -I as deviated wells. This scheme is logical given the steeply dipping faults in - the area which are assumed to be carrying geothermal fluid.

3.8.2 Targets

The Panel concurs that the drilling targets should be in the granodiorite in the neighborhood of intersections of major open faults and fractures. MKF and CYM have identified seven targets.

We agree that the targets (except for the deepening of wells ZCQ-5 and ZCQ-6) acceptable, based on the state of knowledge of the field. Considering the anticipated capacity of the drilling rig, it seems that targets should be held to depths of about 1700-2000m. The Panel, however, feels that a rig with a greater capacity (2500-3000 m) would allow for more flexibility in this phase of drilling. Since the purpose of these wells is to find permeability in a formation where essentially no permeability has been found before, it may be necessary to drill below 2000 m to find good production.

3.8.3 Drill Pads

One of the advantages of directional drilling is that several wells can be located on a single pad. This has not be utilized in the MK-F and CyM plan. They propose to drill up to five wells, each from a separate pad. The Panel believes this is not necessary and that one pad at the proposed site 2A can be used to drill three targets : The ones from pads 1, 2A, and MC. These targets can be reached from pad 2A without exceeding a desviation angle of 10° with a kick-off point at 700 m, as proposed by MK-F and CyM. Pad 2A is the one proposed by the consultants. It is relatively close to the proposed plant site and could be equipped with a large capacity separator to handle the total flow from the three wells if they are all good producers.

This new plan would also result in a savings in the length of pipe that would be needed to transmit the steam and hot water to the plant and injection well (s), respectively.

In a similar manner, proposed pad 2B can be eliminated. The same target can be drilled using a new well sited on the same pad as well ZCQ-5. The whole matter of where are the faults and what are their orientations and strikes is still controversial. The targets may have to be revised in light of the drilling results.

In this regard it is worth noting that the Panel recommended in its First Report (April 1986) that a microseismic survey of the Zunil I area would be very useful in defining the fault system and fluid novement within -

the fault system. The Panel understood that such a series of measurements might not be easy to carry out, but we now feel the lack of such information that would aid in siting the ZD wells.

The whole matter of where are the faults and what are their orientations and strikes is still controversial. The targets may have to be revised in light of drilling results.

3.8.4 Selection and testing of Production Zones

The productive wells in the area of wells ZCQ-3 through ZCQ-6 have encountered hot fluids at or near the top of the granodiorite basement. Presumably, the new ZD wells will also find this production horizon at a true depth of between 1000-1100 m. Since these wells are programmed for 1700-2000 m, the question arises as to what to do about this "shallow" production horizon. If the wells are cased to 700 m, the kick-off started at 700 m, and a build of 10° requires 150 m, then the shallow zone will be found while drilling the deviated straight section.

In the event that unsatisfactory production is found at depth, the shallow zone must be available for production.

In the event that satisfactory production is found at depth, it may be necessary to seal off the shallow zone. However, the Panel believes that production from both the shallow and the deep zones may be acceptable.

3.8.5 Decision Tree for ZD Wells

MK-F and CyM presented a decision tree for ZD well development. The primary well ZD-1 is directed at target T1. If well ZD-1 is "poor" or "good" then well ZD-2 will be aimed at target t2; if it is "moderate", then ZD-2 will be aimed at target T3. Their decision tree went to the next level, but the Panel believes it is not necessary to decide this level at this time.

Although no rationale was given in their report to support the decision tree, in their oral presentation they defined a "poor" well as one with less than 2 MW power potential and a "good" well as one with more than 4 MW potential.

Since the ZD wells are aimed at a new region of the "reservoir", they - must be viewed, at least partly, as exploration wells. As such, the definition of a "good" well will involve more than simply its power production. It is also important to learn which of the faults are open and - acting as conduits for the parent reservoir fluid.

The Panel does not believe that deepening and diverting wells ZCQ-5 and ZCQ-6 is worth the risk of losing the wells.

The Panel recommends that the decision tree be developed bases on the - findings of the well ZD-1.

3.8.6 Drilling Bidding Document

The Panel urges INDE and its consultants to add an addendum to the bidding document stating clearly that the wells will be directionally drilled. The Panel suggests that, if possible, the document call for a rig with at least 2500 m capability as well and that it allow sufficient flexibility to drill below 2000 m.

MK-ENVIRONMENTAL SERVICES
A DIVISION OF MK-FERGUSON

MORRISON-KNUDSEN PLAZA
P.O. BOX 79/BOISE, IDAHO U.S.A. 83707
PHONE: (208) 386-5000/TELEX: 368439
FAX: (208) 386-6656/6669

October 17, 1989

University of Utah Research Institute (UURI)
391 Chipeta Way, Suite C
Salt Lake City, UT 84108-1295

Attention: Dr. Joseph N. Moore

Subject: ZUNIL I, GUATEMALA
AUGUST 1989 PANEL REPORT

Dear Sir:

Please find enclosed:

1) Zunil I, August '89 Panel Report
(Note that only the Frazer and Dipippo portions were written in English, the other portions are translations).

2) Translation of INDE letter of 4 October 1989

We request that you review the work requirements stated in INDE's letter. Do not start any of this work prior to further notice from Morrison-Knudsen.

At this time please provide your itemized estimate of man-days, or other costs, for accomplishing the work requirements of INDE's letter as pertinent to your area of the work.

Sincerely,

Martin Anderson

MA/mlp
ENCLOSURE

3MP003/521

TRANSLATION
INDE LTR OF 4 OCT 89
RE AUGUST 89 PANEL REPORT
ZUNIL I

****

Guatemala, October 4th 1989

This letter is to communicate our requirements previous to the approval of the Reports: Geocientific Studies Report No. 1, Integrated Test (when the final report is finished) and Production Wells ZD, according to the Consultant Panel recommendations during the third meeting which took place from 28/8/89 through 1/9/89.

It is important to mention that we are seriously concerned because UDG did not have the opportunity to analyze and comment the mentioned reports. This was due to the delay in the delivery of the reports, which was requested several times by this Unit and specifically one working day before the initiation of the Panel Meeting. It is necessary that, in the future, your company shows more seriousness regarding this matter to prevent us from taking drastic decisions.

We will focus our requirements based in the comments and recommendations of the Consultant Panel. These respond to the lack of profundity and omission in some studies performed or must have been performed to obtain the adequate information for the location of the new drilling sites. These studies form part of the scope of work of the additional geocientific studies in which we had agreed. For this reason the following must be included in the report previous to its final approval.

Our requirements are the following:

NEOTECTONICS

To describe the basis which lead the consultant to conclude that the NE-SW (Zunil Fault) and the orthogonal faults are productive. Considering that during the meeting this was not proved, the Panel in their neotectonics comments considers that this is not very probable to occur due to the kind of forces that they produce. Nevertheless later in the report in the geochemical section, specifically in the mercury surveys, Dr. Goff gave favorable comments.

HYDROGEOCHEMISTRY

1. Due to the lack of evidence in the existence of a 325oC temperature in the reservoir, it is necessary to elaborate new chloride-enthalpy graphs, both for K/Mg and K/Na geothermometers, and separating the graphs for the various springs (Na-HCO3 and NaCl). It is necessary to use first the new set of data and then the old set, to make the comparison and to confirm the interpretations presented during the meeting.

2. Using the samples that represent the low boiling point and lower mixture (Mother Fluid) the reservoir temperature must be determined using S18O-SO4 and the D'Amori and Panich geothermometer as an independent test.

3. The recharge zones must be defined perfectly according to the information obtained in hydrogeochemistry (isotopes), because the data presented are mainly speculations as stated by the Panel in its report. It is important to mention to you that this is an acquired agreement of your company (point 1.2, Investigation Focus, Hydrochemical Study, geochemical investigation: Recharge Zone Survey ...

4. Due to the lack of consistency in the tritium analyses, the procedure recommended by the Panel must be followed, based in the short note made by Pearson and Truesdell (1928). It is also necessary to clear the comment of Dr. Goff in which he refers to the lack of surprise from the Consultant in the fact the reservoir fluid in Zunil I (Mother Fluid) must have more tritium than the Na-HCO3 waters.

HYDROLOGY

The presented model must confirm the real boundaries, structure and permeability, etc., and to determine with the best precision possible the recharge zones using the stable isotopes in cold waters in the hydrogeochemical study.

GRAVIMETRY

To establish the quantitative sections in the inversion data of the electric soundings. For each sounding that has reached the resistive substrate a equivalence test to the conductive layer that lays over the substrate should be performed.

Using this electric data completed with the lithologic and quantitative information of the deep wells, to elaborate a series of profiles (with one density, 2.2- for example) in the Zunil I field. To initiate with a four layer model: superficial layer (volcanites), altered formations representative layer (electric soundings conductive layer), andesitic layer that represents the reservoir and the basement.

Since the geometry of the field is well known, try to (setting the quantitative data) study the possibilities of density variation in the inside of each layer and particularly, the basement.

With this set of sections locate precisely the main discontinuities (Mayor Fractures Zones).

INTEGRATED TEST

The advance report of the integrated test presented during the Panel Meeting contains in some part very elemental interpretations for a major project. In other part, it presents a series of affirmations in which the previous production data are not taken in consideration and data are changed radically, without any explanation. These are important numbers, like steam flow, productivity/injectivity indexes, making the general impression that there is lack of work dedication in the performance and interpretation of the data.

Therefore the Integrated Test final report must contain as a minimum the following:

1. The consultant affirmed in this occasion that the weir box method is better than the orifice method in determining the flow, and affirmed the contrary in the previous meeting. It is necessary that those questions be cleared thoroughly interpreting old and recent data. The conclusion should be supported by firm and concrete reasonings and not only by the fact that the previous tests were not performed by your company.

2. The numeric simulation of the reservoir, that is supposed to be the search, through the observation of the wells response, of the main characteristics of the reservoir like the existence of boundaries and deep feeding zones, eventual recharge evaluation, feeding faults location, to better understand the superficial reservoir behavior.

3. Concerning the potential energy in the existent wells, care should be taken in the estimated total power, through the independent well test in ZCQ-3, -4 , -5 and -6, where the interference effect is omitted.

   A detailed thermodynamic analysis performed by the Panel reveals that the power declined 10.5% during the long term test; they took into account the energy potential calculated during the recent short term test and observed that the decline in power during this period of time was 19%.

   There is no doubt that the power potential of the wells will decline when the four wells are flowing simultaneously, and the affirmation made by Dr. Sanyal that this did not happened must be reconsidered. The amount of decline in time must be estimated, using the results obtained during the months of the recent ZCQ-3 test.

ZD WELLS DRILLING

For the drilling of the new wells the recommendation made by the Panel must be considered, that the drilling objective must be to intercept the faults separately forming a triangle in the intersection point. It is also suggested that the location of the wells must not be located near landslide zones.

Concerning the drilling platforms we think the suggestion of the Consultant Panel is correct in choosing the 2A platform presented by yourselves, since that it could be used to drill the three proposed points, 1, 2A and MC, without exceeding a 10% deviation changing it direction to 700 meters. This is a site relatively near the possible plant location which will decrease costs in steam and hot water conduction tubing longitude to the plant and injection wells. The fact that it could be equipped with a high capacity separator to manage the total fluid of the three wells according to its production is also useful.

Because the ZD wells are directed to a new region of the reservoir, they must be reviewed at least partially as exploratory wells, because the definition of a good well involves more than its production capacity.

After clearly defining the fault location and their orientation and intersections, the drilling sites must be reviewed and decided about providing supporting facts. It is important that in the final proposal of the sites the platforms of the existent wells are taken in consideration as eligible.

After drilling ZD-1 and based in the results obtained from this well, the other selected drilling sites must be reviewed and adjusted.

To select the productive zones it should be considered that the upper production zone must be available in case of an unsatisfactory production in the lower zone. The Panel thinks that any production (upper and lower) will be acceptable.

[redacted] [redacted]

FIELD MODEL

As agreed on the third meeting, due to the lack of an adequate interpretation of the long term tests, a official request of performing a field model is made, that must be delivered no later than this December.

The objectives and limitations of the model should be the following:

- To be structured containing the conceptual model of the geothermal system characteristics (geometry, lithology, tectonics, hydrology, thermalism).

- It should manage mono and bi-phasic fluids with gas inclusions (at least CO_2).

- To satisfactorily reproduce the interference tests with production and reinjection.

- To reproduce the flow decreases that were observed from 1981 to 1985.

It should be mentioned that the present model is not additional to the one contemplated by the contract. Our intention is that it should be performed previously in the program using the ZCQ data and then to be calibrated with the results of the ZD wells, so it must not be understand as an independent work.

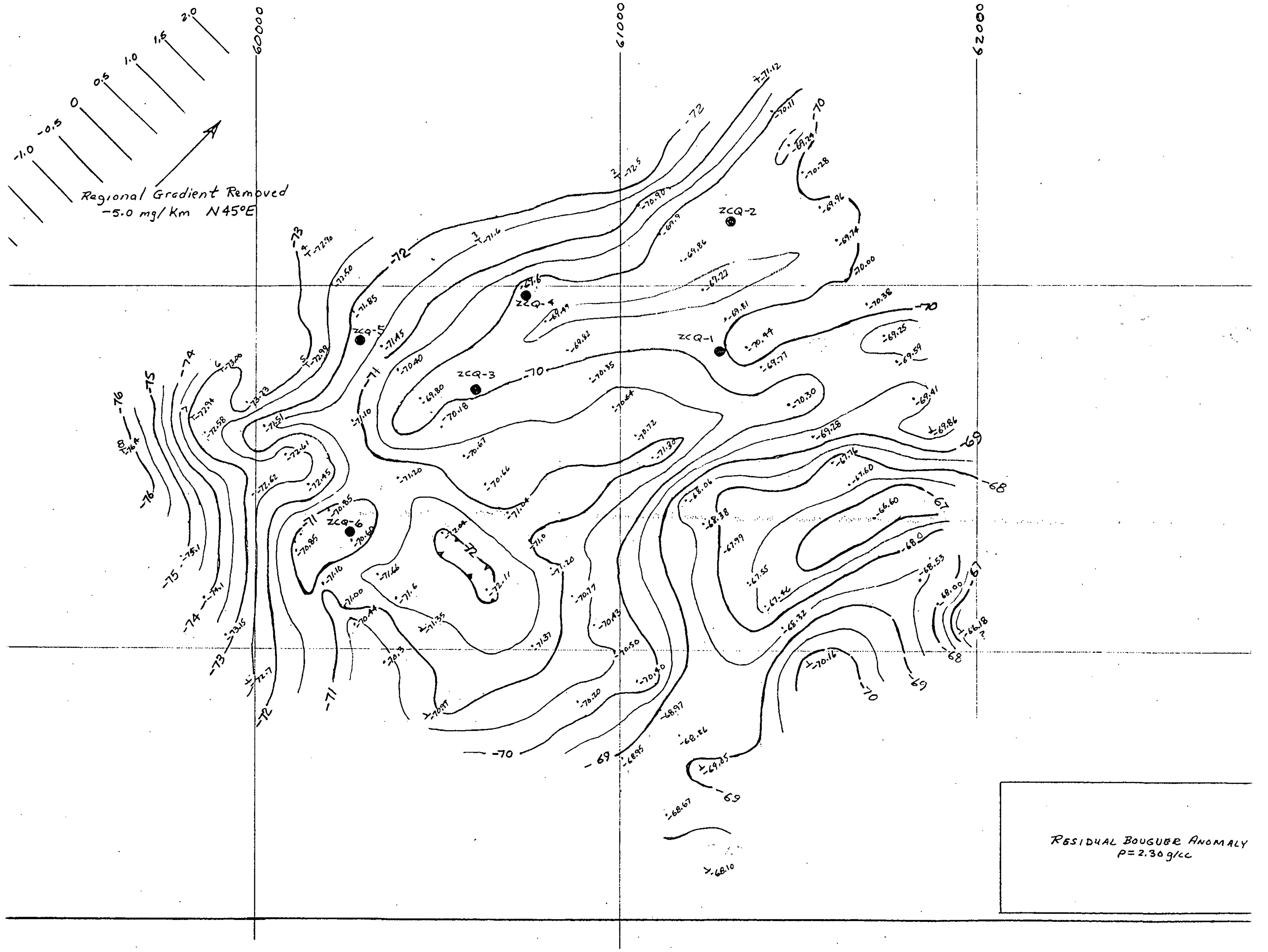
Regards,

MMMM

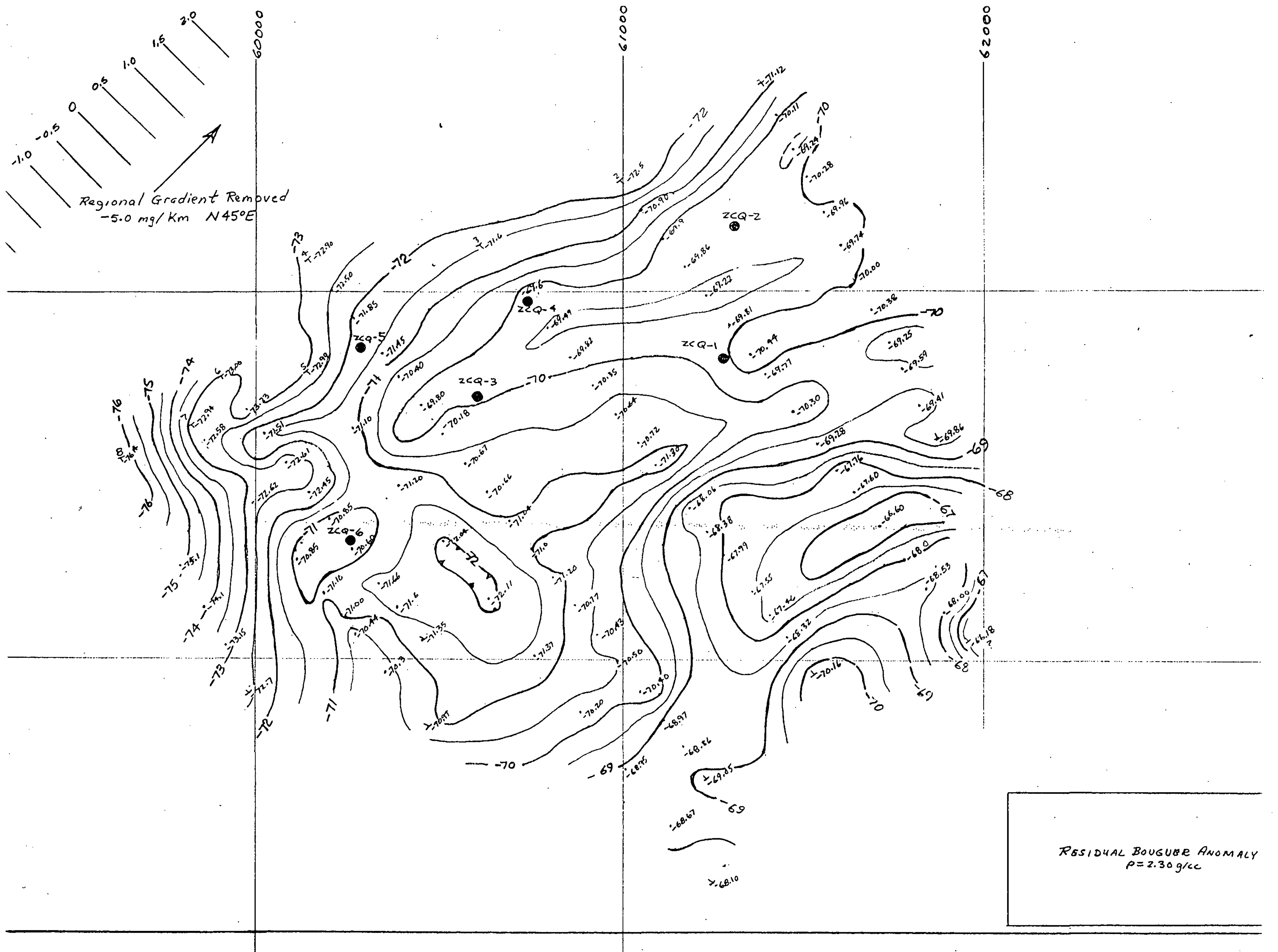
[redacted] [redacted]

ZONIL GRAVITY MODELS

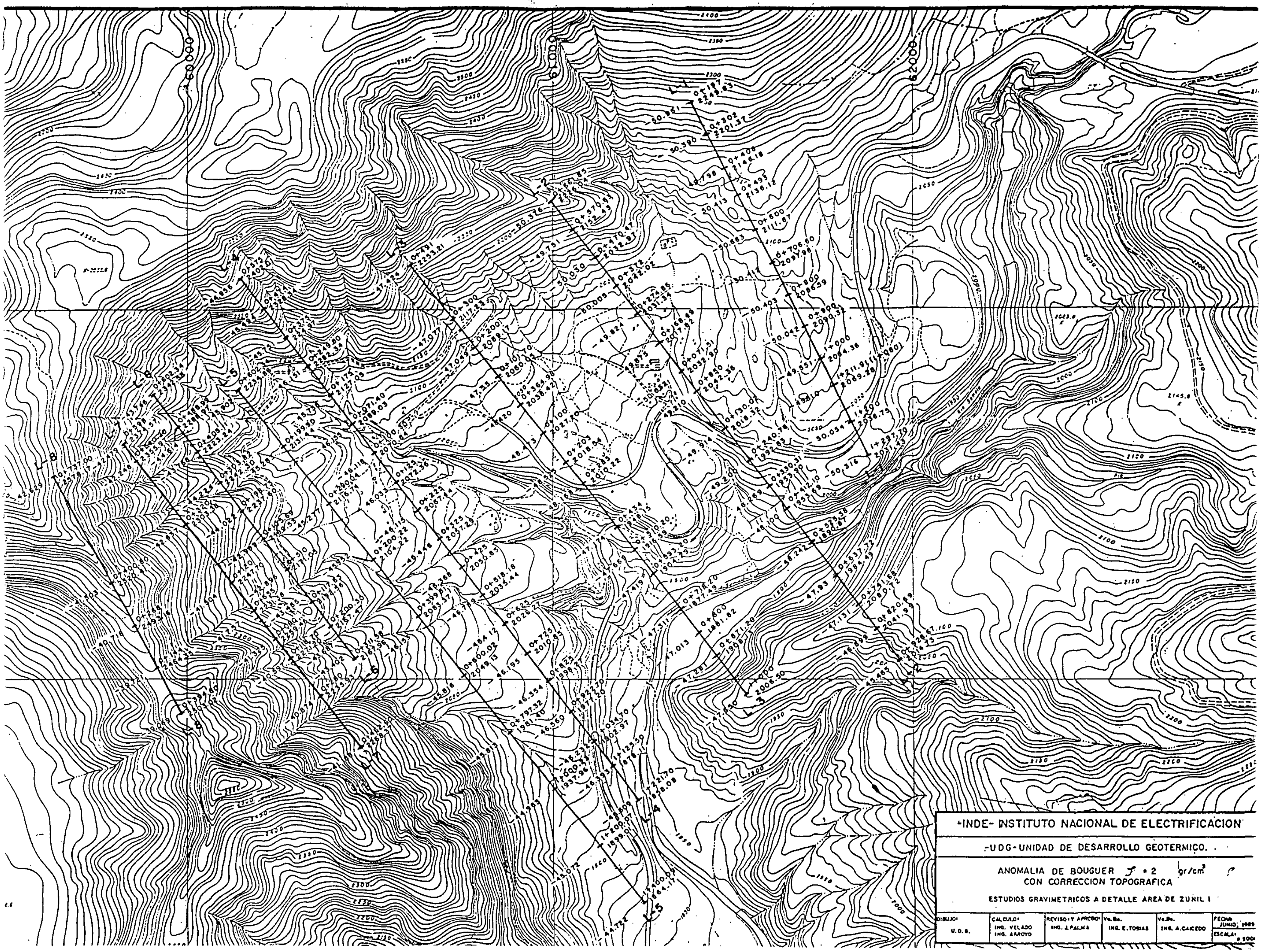
Fig #	Model #, it	Desc	
	1 it 3	Varying depth to granite + ld volc to NW	29 □s, σ= +.47; 0; -.20 ρ= 2.67 (21); 2.20 bkg; 2.00 (6)
1	1 it 2	" " " "	23 □s, 2.67 (21); 2.20 bkg; 2.00 (2)
2	1 it 4	" " " "	30 □s, 2.67 (21); 2.20; 2.00 9
3	1 it 1	Deep Granite Structure	7 □s, +0.47; 0; 2.67 (2); 2.20 bkg
4	1 it 1	Surface Volcanics	5 □ +.10; 0; -.20; -.30 2.30 (2); 2.20; 2.00 (2); 1.90 (1)



RESIDUAL BOUGUER ANOMALY
ρ=2.30 g/cc



RESIDUAL BOUGUER ANOMALY
$\rho = 2.30$ g/cc


-INDE- INSTITUTO NACIONAL DE ELECTRIFICACION
-UDG-UNIDAD DE DESARROLLO GEOTERMICO.
ANOMALIA DE BOUGUER ρ = 2 gr/cm³
CON CORRECCION TOPOGRAFICA
ESTUDIOS GRAVIMETRICOS A DETALLE AREA DE ZUNIL I
DIBUJO: U.D.G.
CALCULO: ING. VELADO ING. ARROYO
REVISO Y APROBO: ING. J. PALMA
Vo.Bo. ING. E. TOBIAS
Vo.Bo. ING. A. CAICEDO
FECHA: JUNIO, 1989
ESCALA:
L-1
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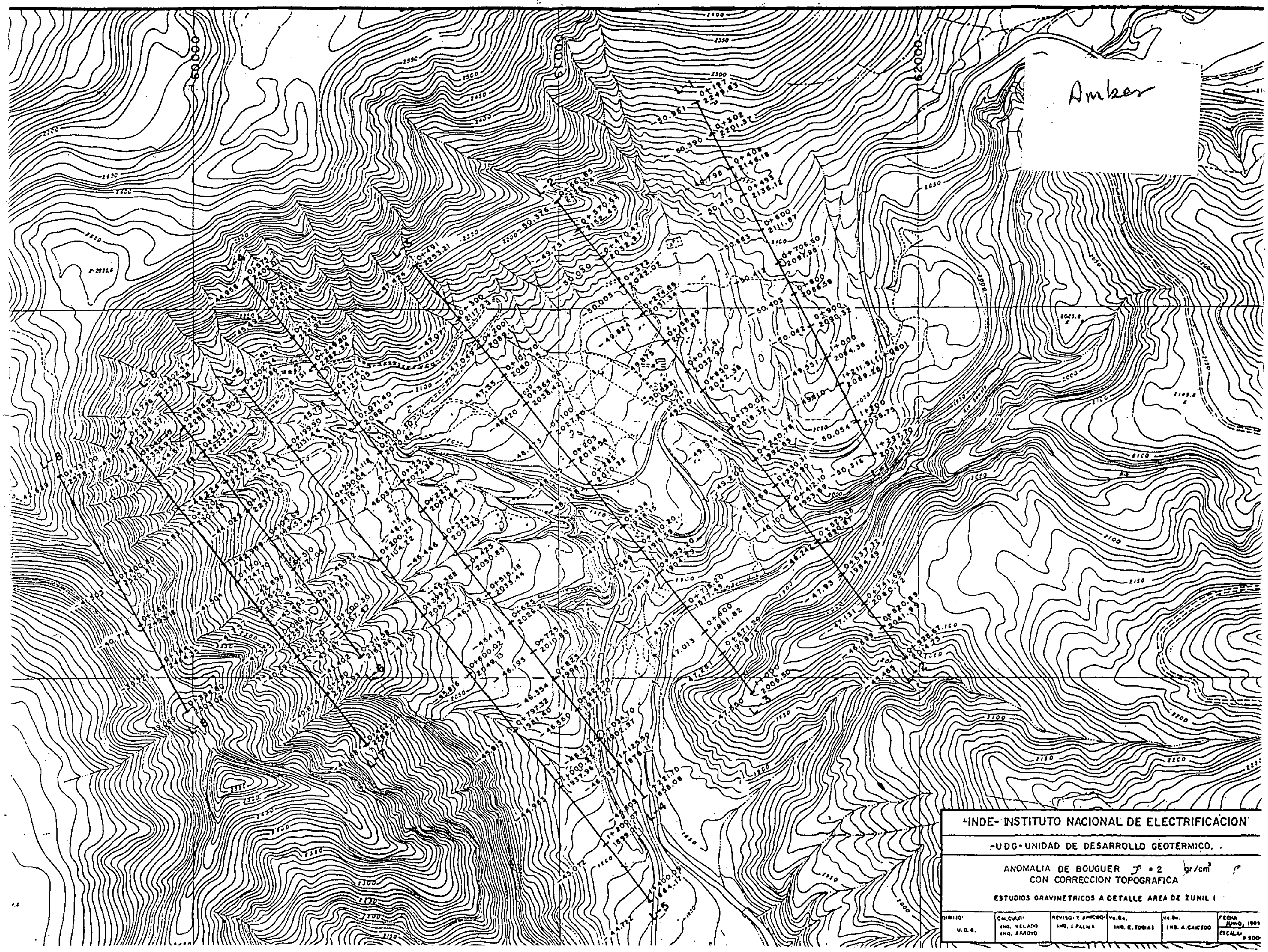

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60000
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-INDE- INSTITUTO NACIONAL DE ELECTRIFICACION
-UDG- UNIDAD DE DESARROLLO GEOTERMICO.
ANOMALIA DE BOUGUER ρ = 2 gr/cm³
CON CORRECCION TOPOGRAFICA
ESTUDIOS GRAVIMETRICOS A DETALLE AREA DE ZUNIL I
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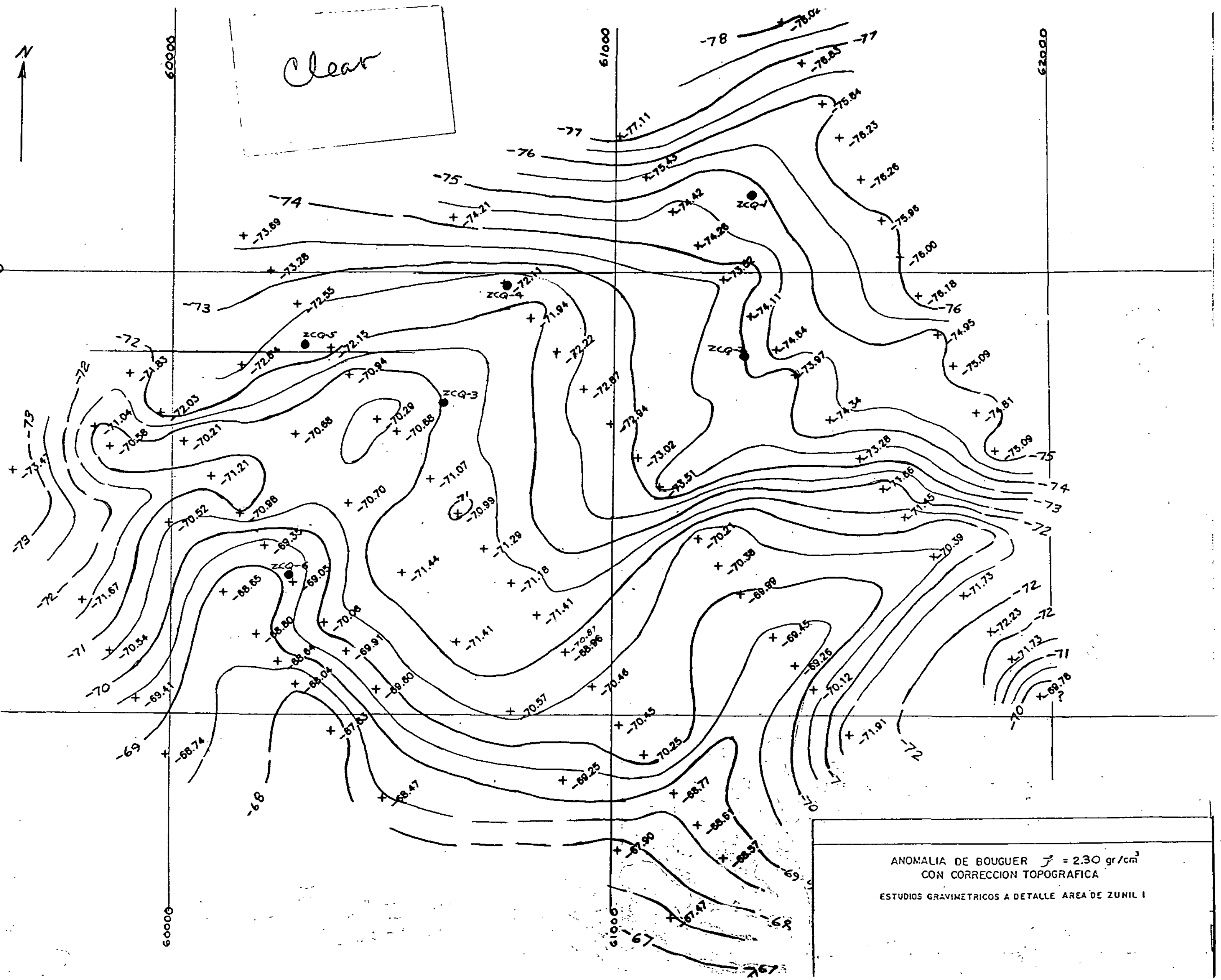
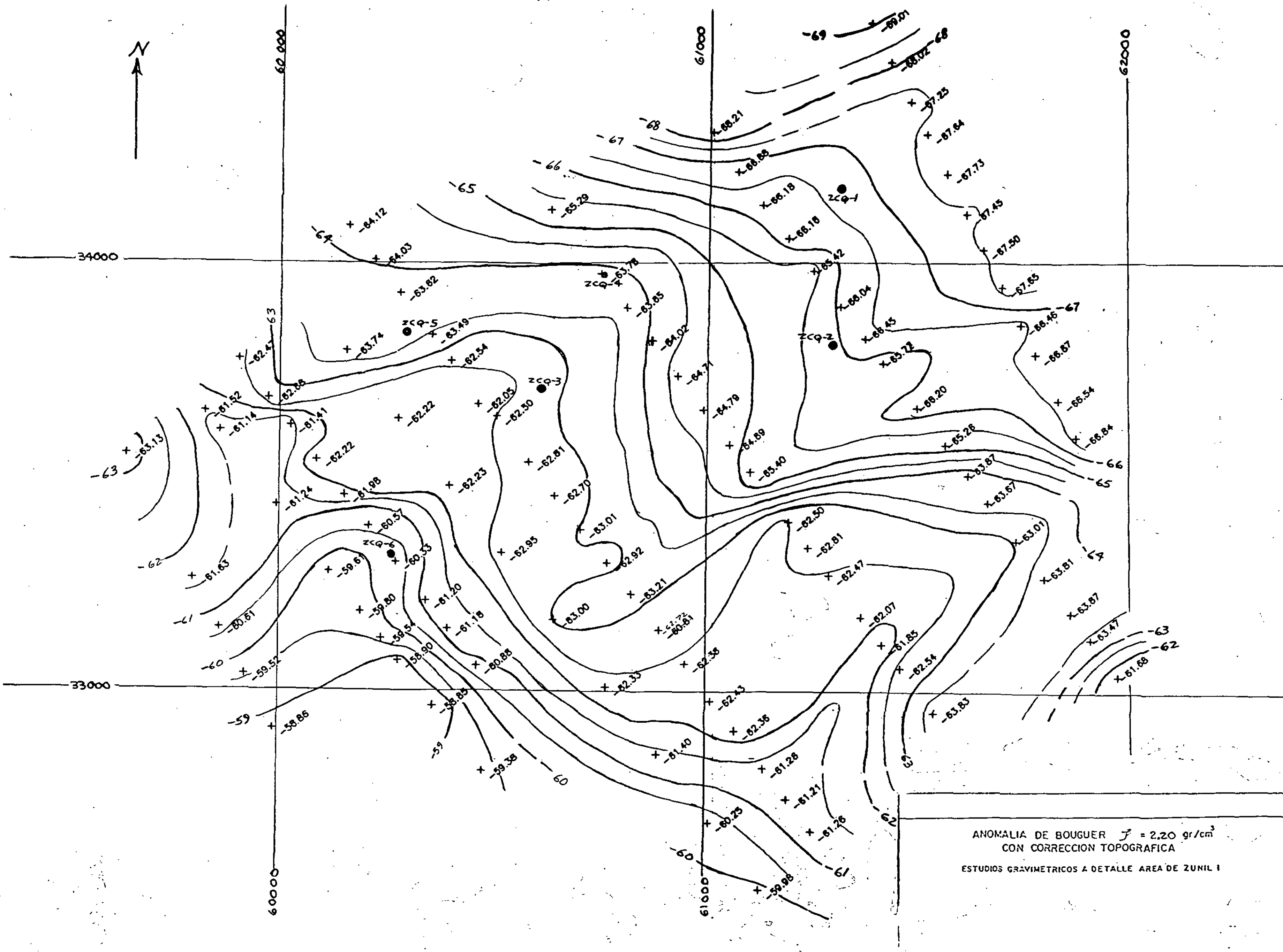
Vo.Bo. ING. A. CAICEDO
FECHA:
ESCALA:



ANOMALIA DE BOUGUER ρ = 2.30 gr/cm³
CON CORRECCION TOPOGRAFICA

ESTUDIOS GRAVIMETRICOS A DETALLE AREA DE ZUNIL I



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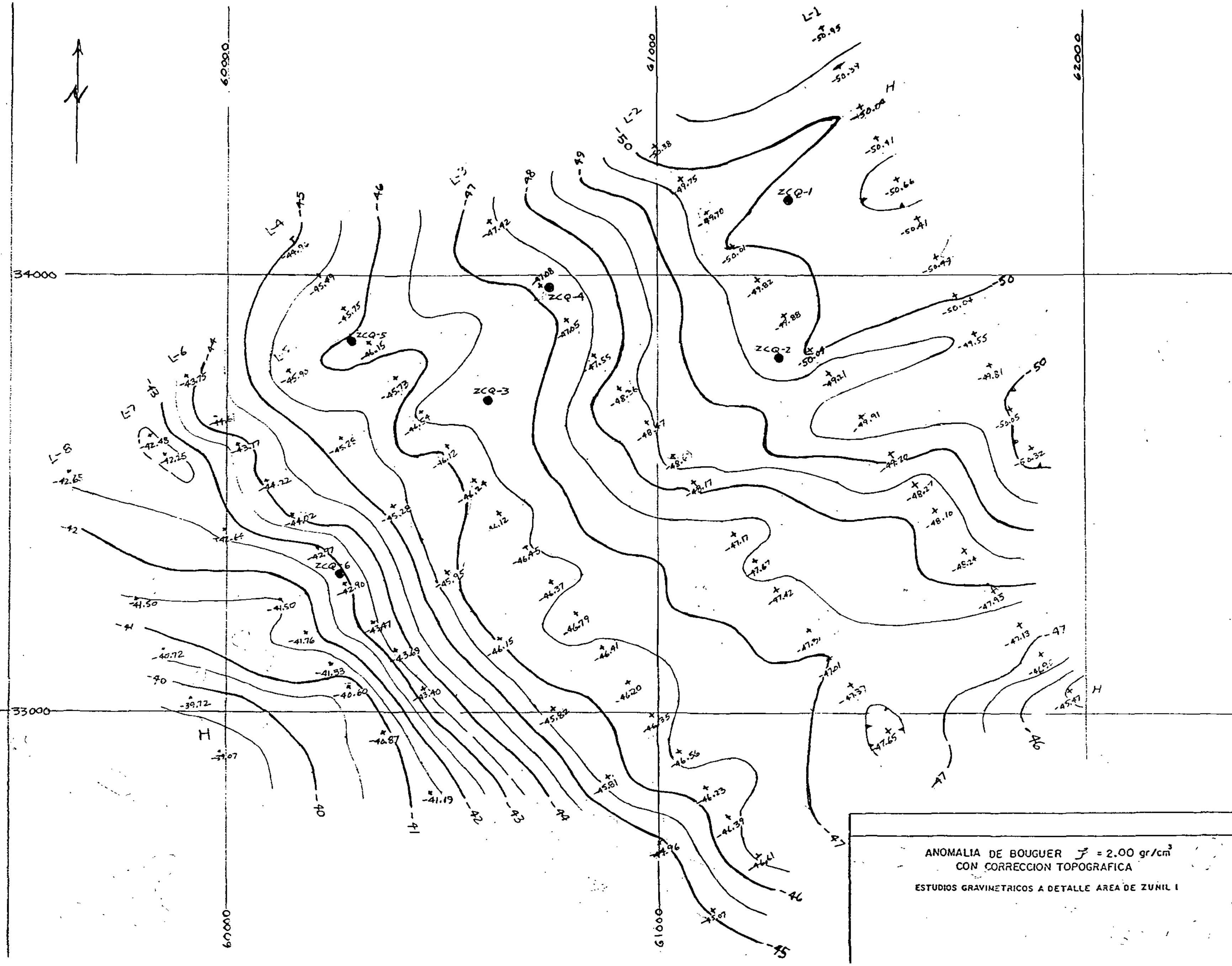
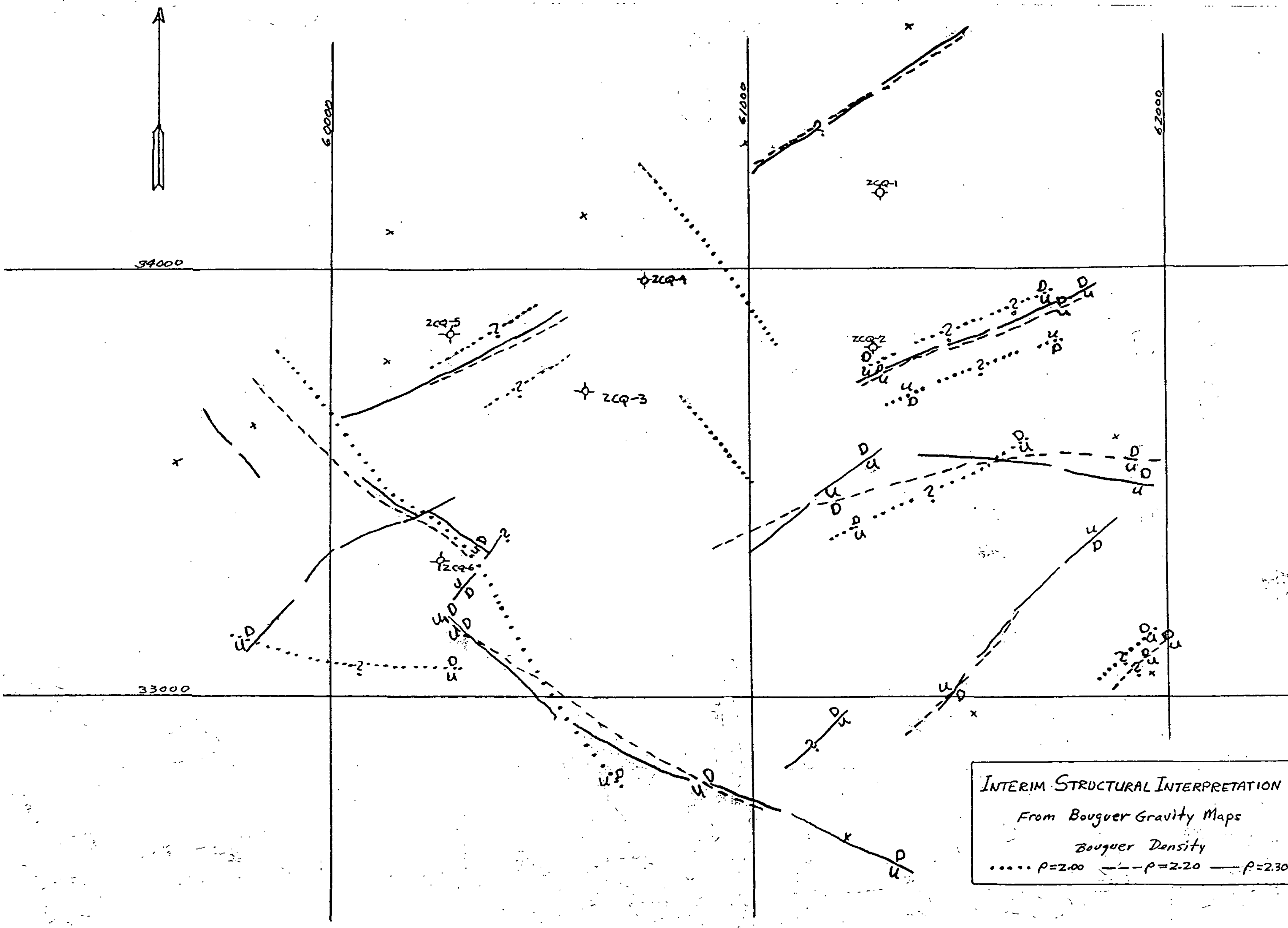
CON CORRECCION TOPOGRAFICA

ESTUDIOS GRAVIMETRICOS A DETALLE AREA DE ZUNIL I

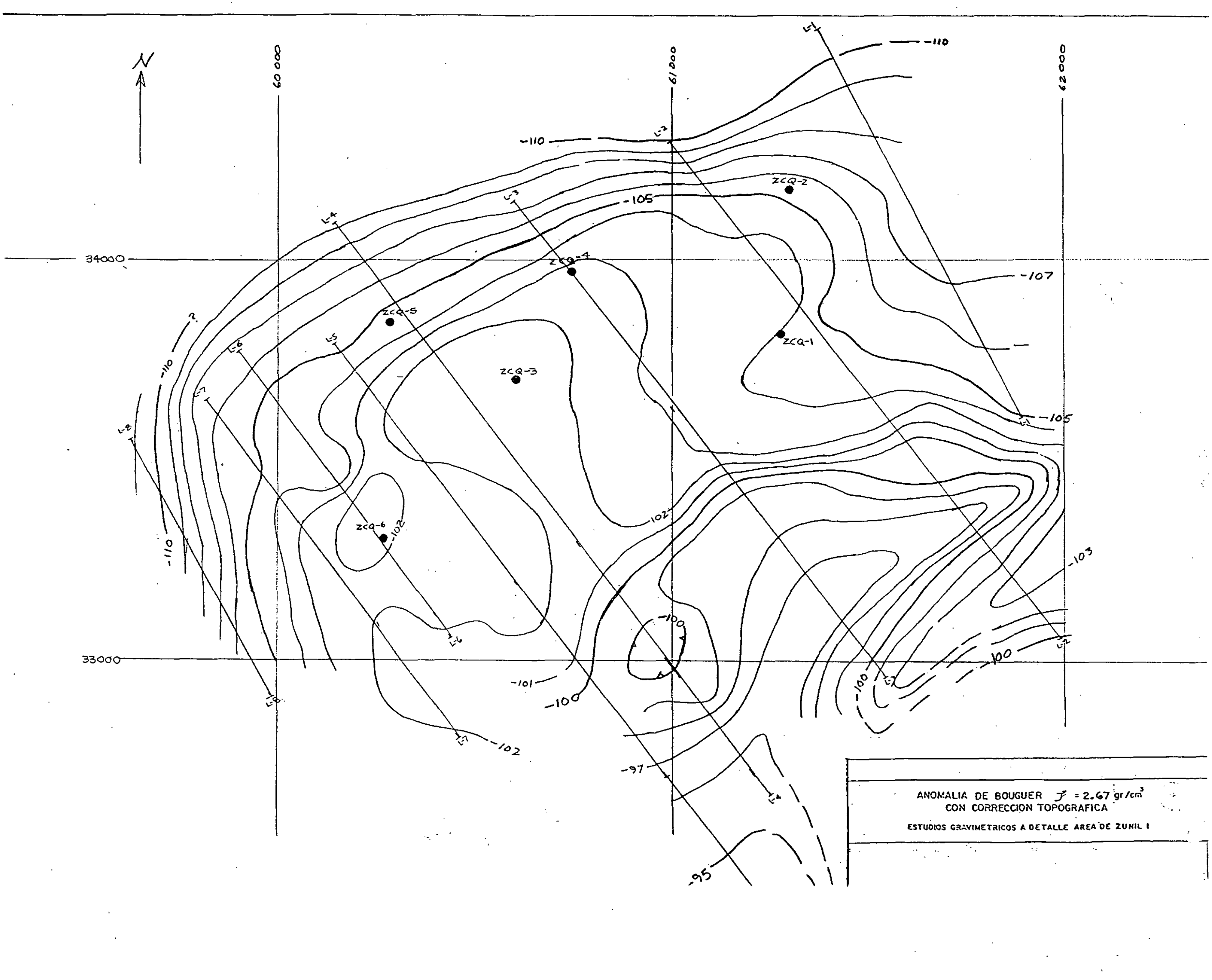


ANOMALIA DE BOUGUER ρ = 2.00 gr/cm^3
CON CORRECCION TOPOGRAFICA

ESTUDIOS GRAVIMETRICOS A DETALLE AREA DE ZUNIL I



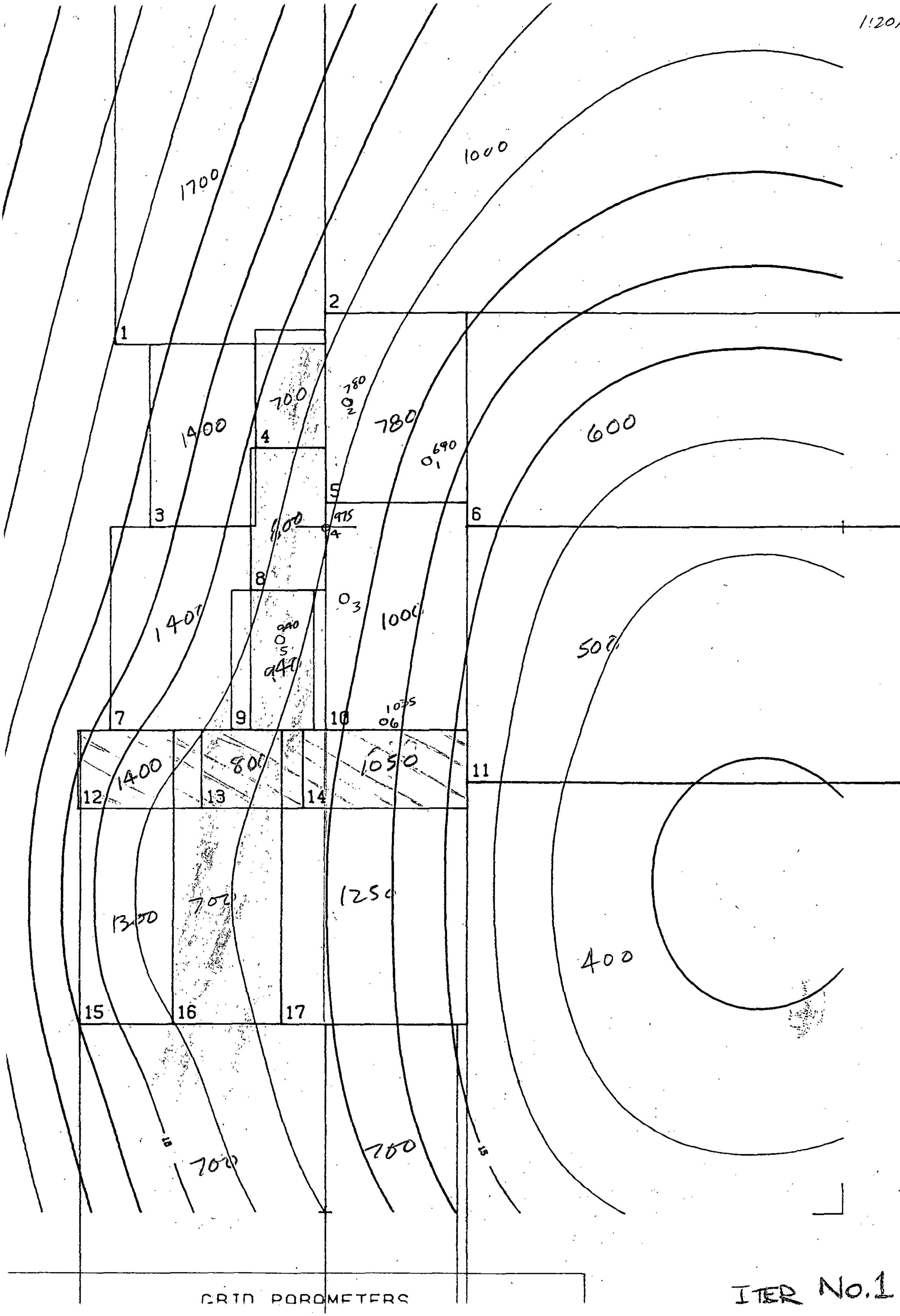
60000
61000
62000
34000
33000
ZCQ-1
ZCQ-2
ZCQ-3
ZCQ-4
ZCQ-5
ZCQ-6
INTERIM STRUCTURAL INTERPRETATION
From Bouguer Gravity Maps
Bouguer Density
ρ=2.00
ρ=2.20
ρ=2.30



ANOMALIA DE BOUGUER ρ = 2.67 gr/cm³
CON CORRECCION TOPOGRAFICA

ESTUDIOS GRAVIMETRICOS A DETALLE AREA DE ZUNIL I

1:20,000



ITER No.1

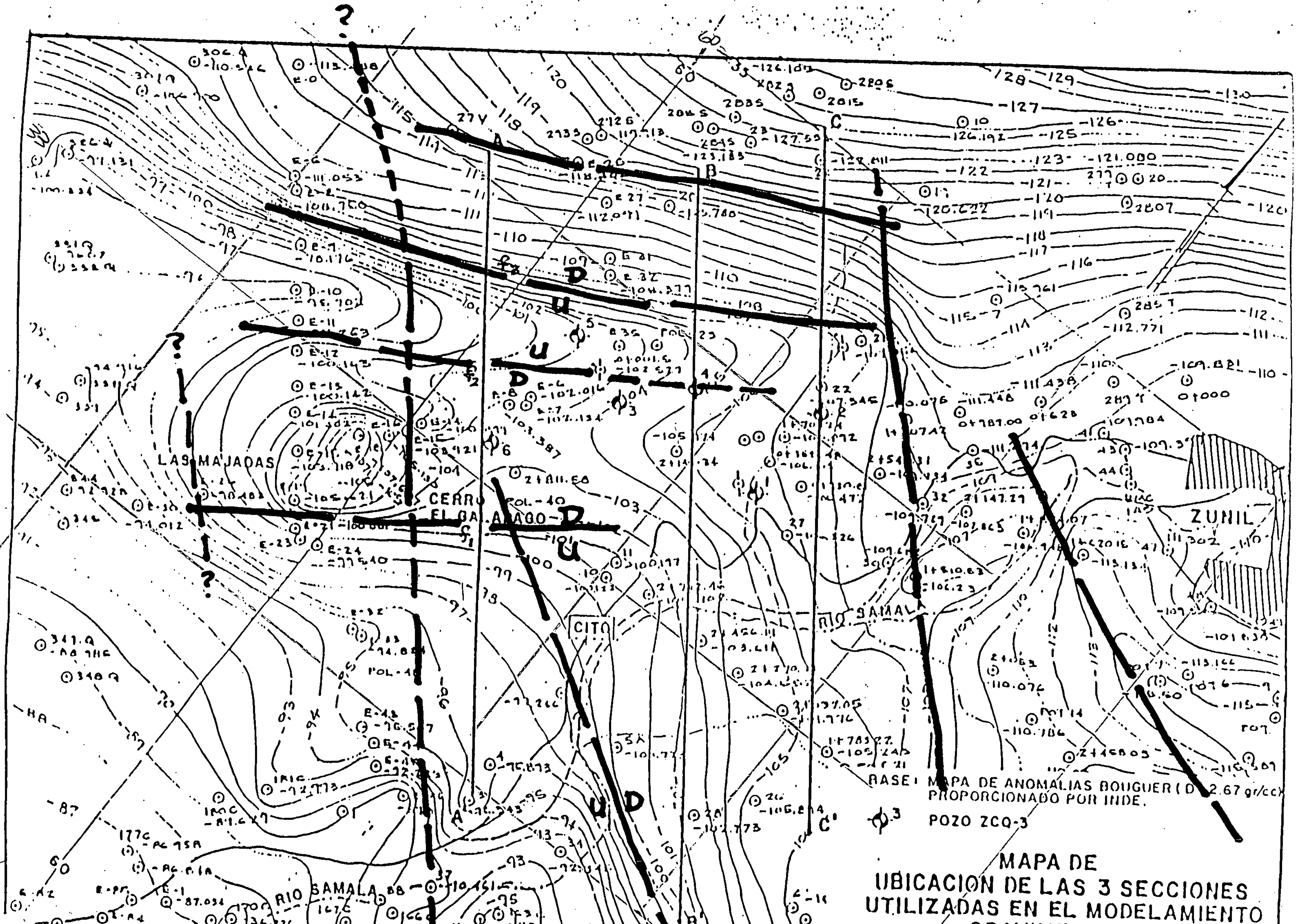
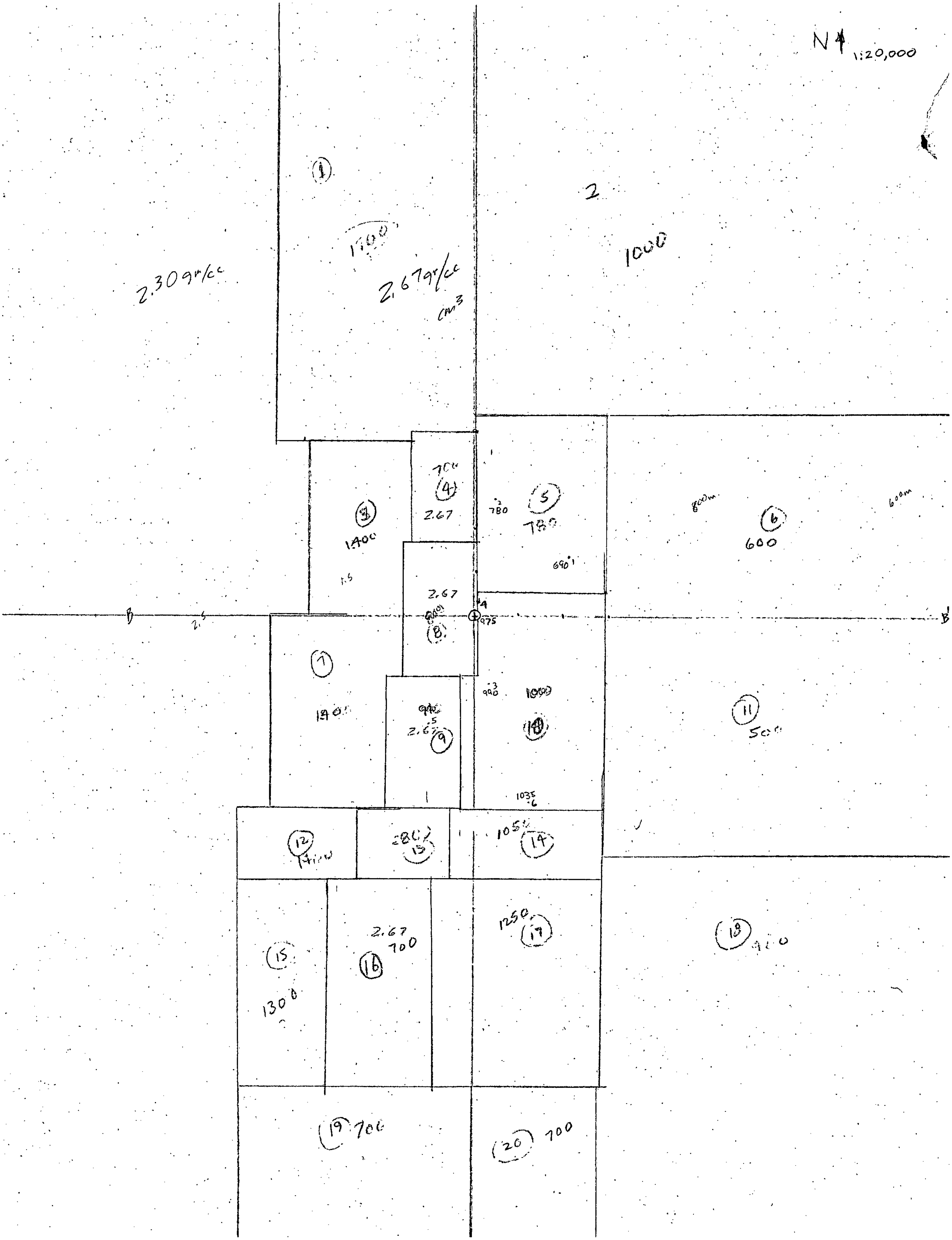


Figure 4. Location of faults in the Zunil 1 area as inferred from the detailed gravity survey. This interpretation has not been supported by numerical modeling.



N
1:20,000
1
1700
2.67gr/cc
cm3
2.30gr/cc
2
1000
3
1400
4
700
2.67
5
780
6
600
800m
600m
B
B'
2.67
8
7
1400
9
2.67
10
1000
11
500
12
13
14
15
1300
16
2.67
700
17
1250
18
19
700
20
700

Charge 587113

GM-3 ZUNIL Gravity

ZCQ Wells 1

Distance in: meters

Grid: 23 pts X, 29 pts Y

Plot: scale 1:20,000

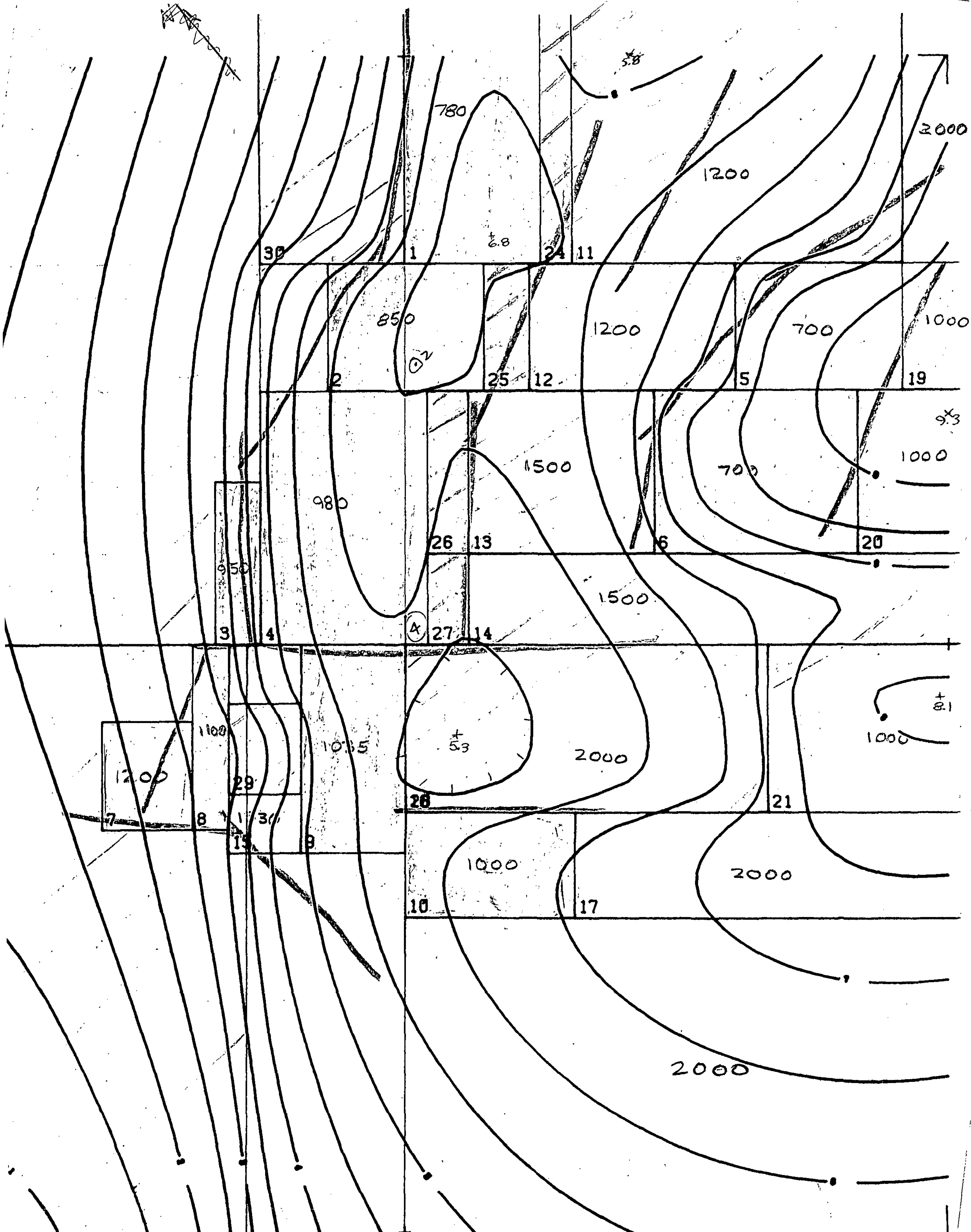
ΔX, ΔY = 200m

contour Int. 1 mg

Body #	1 West X_1	2 East X_2	3 South Y_1	4 North Y_2	5 Depth t D_1	6 Depth b D_2	7 Density Contr. DC	8 Susc. Cont. SC	9	
1	-900	0	770	4000	1700	2500	+0.37	0		
2	0	4000	900	4000	1000	2500	+0.37			
3	-750	-300	0	770	1400	2500				
4	-300	0	330	830	700					
5	0	600	100	900	780					
6	600	4000	0	900	600					
7	-920	-320	-860	0	1400					
8	-320	0	-270	330	800					
9	-400	-50	-860	-270	940					
10	0	600	-860	100	1000					
11	600	4000	-1080	0	500					
12	-1060	-530	-1190	-860	1400					
13	-530	-100	-1190	-860	800					
14	-100	600	-1190	-860	1050					
15	-1050	-650	-2110	-860	1300					
16	-650	-190	-2110	-860	700					
17	-190	600	-2110	-860	1250					
18	600	4000	-4000	-1080	400					
19	-1050	0	-4000	-2110	700					
20	0	560	-4000	-2110	700	2500	+0.37	0		
21										
22										
23										
24										
25										
26										
27										
28										
29										
30										
31										

Plot values

EFFICIENCY LINE® 22-206 AMPAD



AME

ITER No.4

:

PRISMS: 30.

ODEL (MILLIGALS)

GRID PARAMETERS

GRID POINTS X 25. : Y 27.

GRID SPACING : 100. METERS

GRID DIMENSIONS X 2400. : Y 2600. METERS

GRID OFFSET X: 0. Y: 0. METERS

SCALE 1:10000.

DATA MAXIMUM: 9.

DATA MINIMUM: 1.

CONTOUR INTERVAL 1.

18

Granodiorite 2.6'
ρ = 2.67 ±
depth to top sh

Volcanics, ρ = 2.
0 < d < 500 m

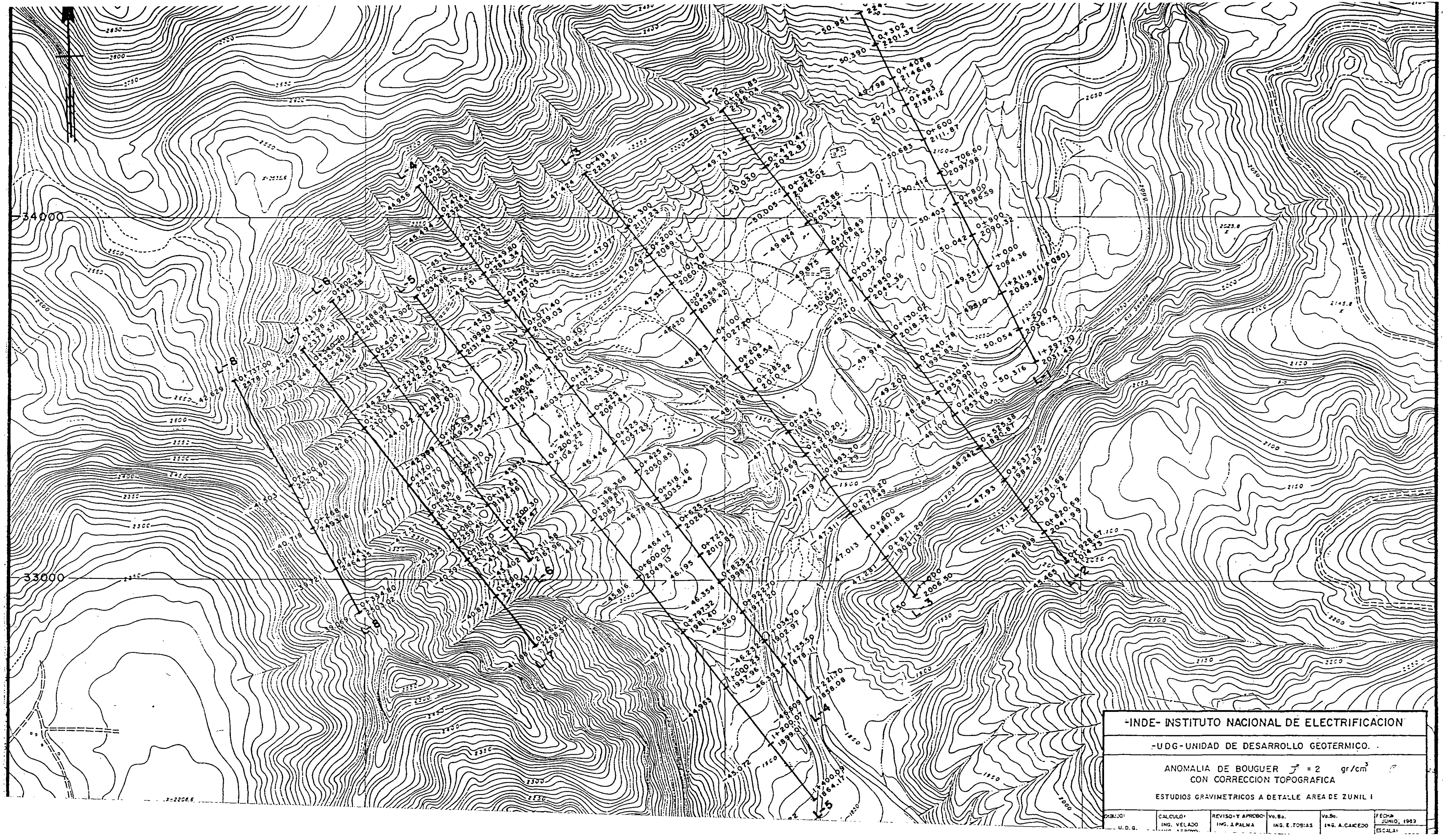
Background
ρ = 2.20

Project name: ZUNIL
MODEL 1, Iter No.4
Model: MODEL 1

Units in Meters

MAGNETIC PARAMETERS
Earth"s field: 0. gammas.
Inclination = 0. degrees Declination = 0. degrees.

PRISM	X1	X2	Y1	Y2	D1	D2	DC	SC
1	0.	370.	840.	2000.	780.	4000.	0.47	0.
2	-170.	275.	560.	840.	850.	4000.	0.47	0.
3	-420.	-320.	0.	360.	950.	4000.	0.47	0.
4	-320.	140.	0.	560.	980.	4000.	0.47	0.
5	730.	2000.	560.	840.	700.	4000.	0.47	0.
6	550.	1000.	200.	560.	700.	4000.	0.47	0.
7	-670.	-470.	-410.	-170.	1200.	4000.	0.47	0.
8	-470.	-390.	-410.	0.	1100.	4000.	0.47	0.
9	-230.	0.	-460.	0.	1035.	4000.	0.47	0.
10	0.	375.	-600.	-370.	1000.	4000.	0.47	0.
11	370.	1100.	840.	2000.	1200.	4000.	0.47	0.
12	275.	730.	560.	840.	1200.	4000.	0.47	0.
13	140.	550.	200.	560.	1500.	4000.	0.47	0.
14	140.	2000.	0.	200.	1500.	4000.	0.47	0.
15	-390.	-230.	-460.	0.	1530.	4000.	0.47	0.
16	0.	800.	-370.	0.	2000.	4000.	0.47	0.
17	375.	2000.	-600.	-370.	2000.	4000.	0.47	0.
18	0.	2000.	-2000.	-600.	2000.	4000.	0.47	0.
19	1100.	2000.	560.	2000.	1000.	4000.	0.47	0.
20	1000.	2000.	200.	560.	1000.	4000.	0.47	0.
21	800.	2000.	-370.	0.	1000.	4000.	0.47	0.
22	-1200.	-320.	0.	2000.	0.	600.	-0.20	0.
23	-1200.	-350.	-2000.	0.	0.	600.	-0.20	0.
24	300.	1100.	840.	2000.	0.	500.	-0.20	0.
25	175.	730.	560.	840.	0.	500.	-0.20	0.
26	50.	550.	200.	560.	0.	500.	-0.20	0.
27	50.	2000.	0.	200.	0.	500.	-0.20	0.
28	0.	800.	-370.	0.	0.	500.	-0.20	0.
29	-390.	-230.	-330.	-130.	0.	500.	-0.20	0.
30	-320.	0.	840.	2000.	0.	500.	-0.20	0.



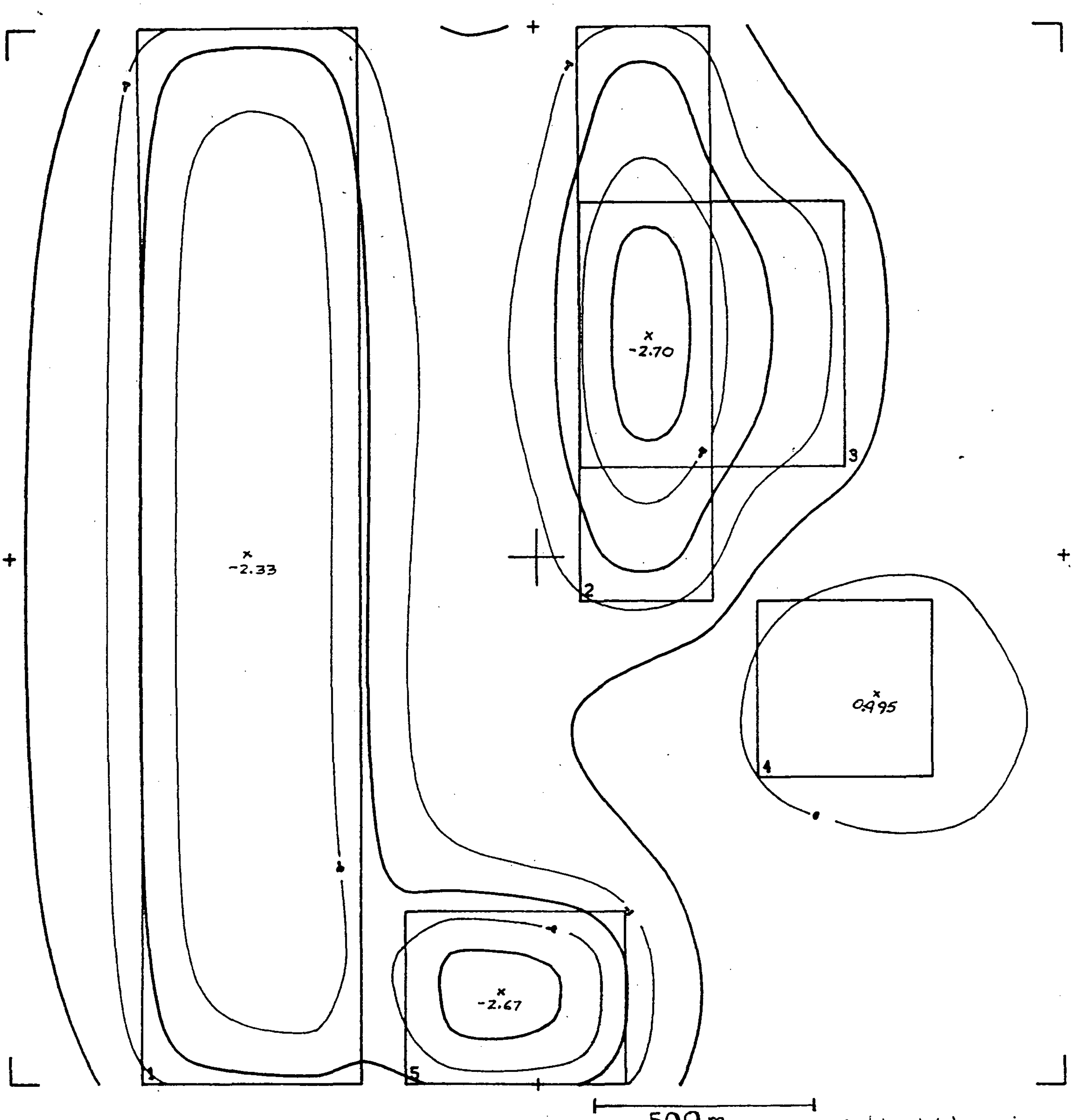
-INDE- INSTITUTO NACIONAL DE ELECTRIFICACION

-UDG-UNIDAD DE DESARROLLO GEOTERMICO.

ANOMALIA DE BOUGUER $\rho = 2$ gr/cm^3
CON CORRECCION TOPOGRAFICA

ESTUDIOS GRAVIMETRICOS A DETALLE AREA DE ZUNIL I

DIBUJO:	CALCULO:	REVISO Y APROBO:	Vo.Bo.	Vo.Bo.	FECHA:
U.D.G.	ING. VELADO	ING. J. PALMA	ING. E. TOBIAS	ING. A. CAICEDO	JUNIO, 1989
					ESCALA:



Variable Volcanics

PROJECT NAME

ZUNIL

SURFACE VOLCANICS

MODEL NAME

SURFACE VOLCANICS

NUMBER OF PRISMS: 5.

GRAVITY MODEL (MILLIGALS)

GRID PARAMETERS

GRID POINTS X 25. : Y 25.

GRID SPACING : 100. METERS

GRID DIMENSIONS X 2400. : Y 2400. METERS

GRID OFFSET X: 0. Y: 0. METERS

SCALE 1:10000.

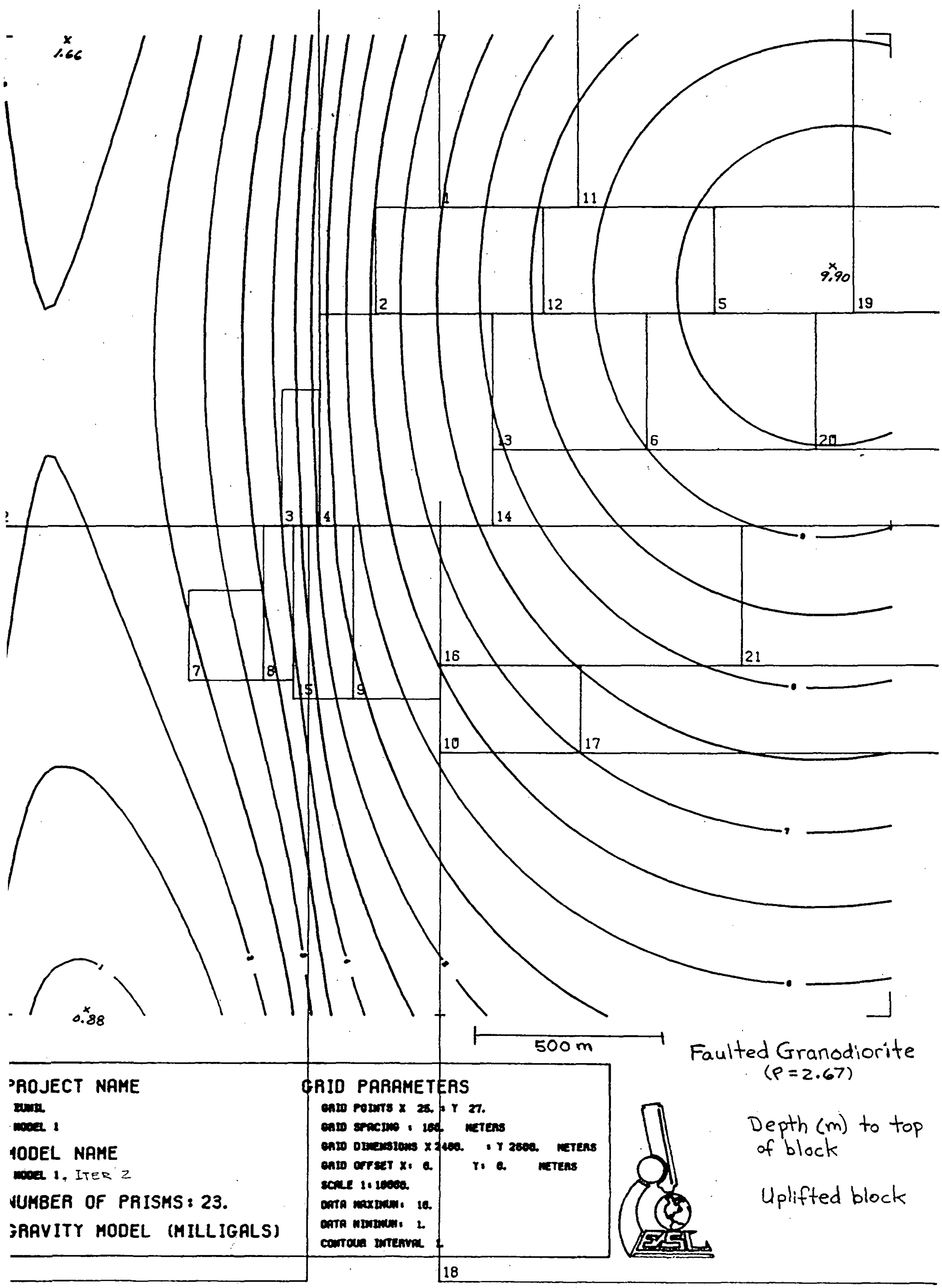
DATA MAXIMUM: 0.

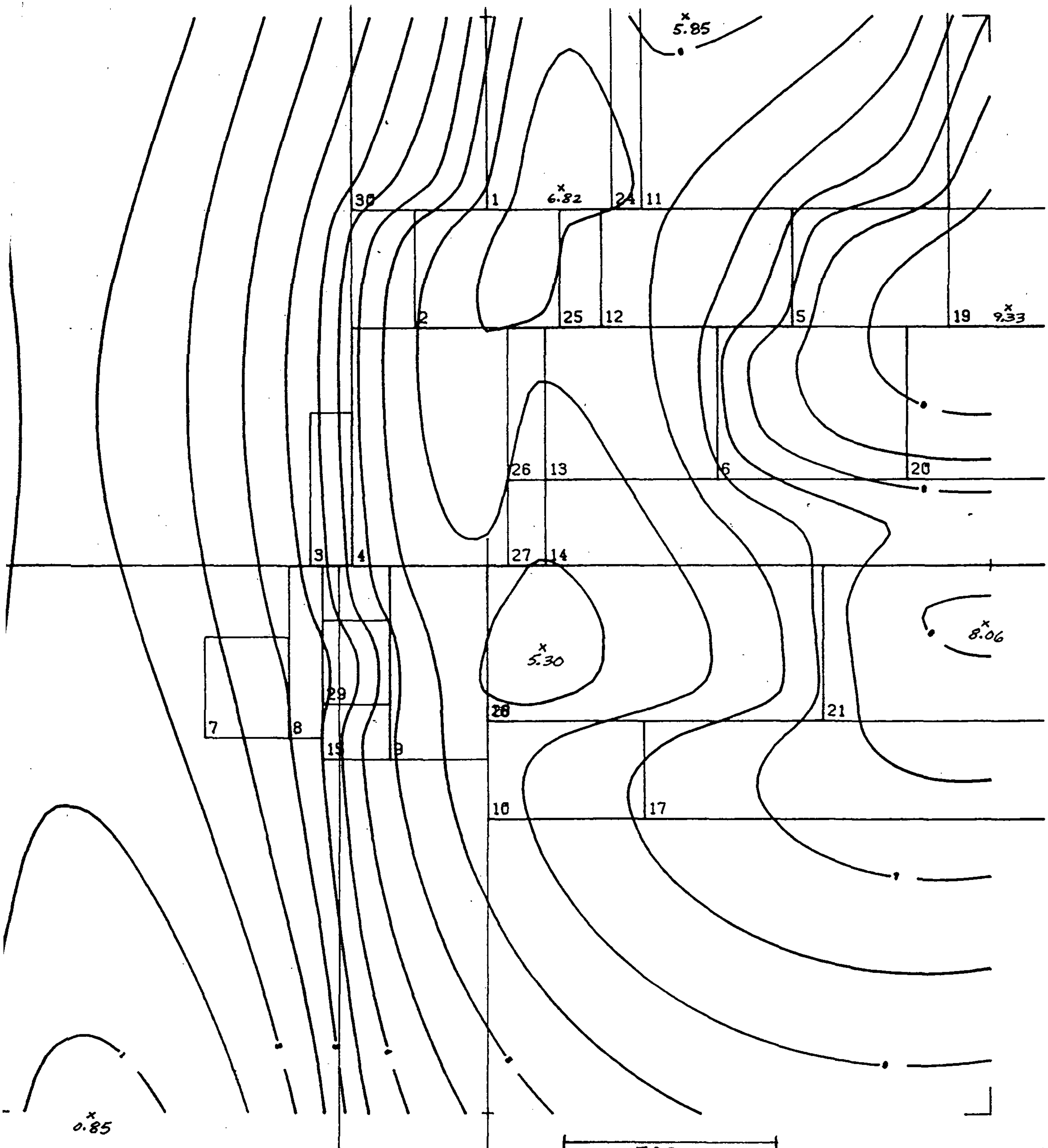
DATA MINIMUM: -3.

CONTOUR INTERVAL 1.

Density Contrast (g/cc)

All blocks are 0-500 m deep.


1.66
9.90
0.88
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
500 m
Faulted Granodiorite
(ρ = 2.67)
Depth (m) to top of block
Uplifted block
PROJECT NAME
ZUNIL
MODEL 1
MODEL NAME
MODEL 1, ITER 2
NUMBER OF PRISMS: 23.
GRAVITY MODEL (MILLIGALS)
GRID PARAMETERS
GRID POINTS X 25. : Y 27.
GRID SPACING : 100. METERS
GRID DIMENSIONS X 2400. : Y 2600. METERS
GRID OFFSET X: 0. Y: 0. METERS
SCALE 1:10000.
DATA MAXIMUM: 10.
DATA MINIMUM: 1.
CONTOUR INTERVAL 1.
ESL



Faulted Granodiorite & Variable Volcanics

Shallow Granodiorite ($\rho = 2.67$)

Volcanics, $\rho = 2.00$ (0 – 500 m)

Volcanics, bkgd, $\rho = 2.20$

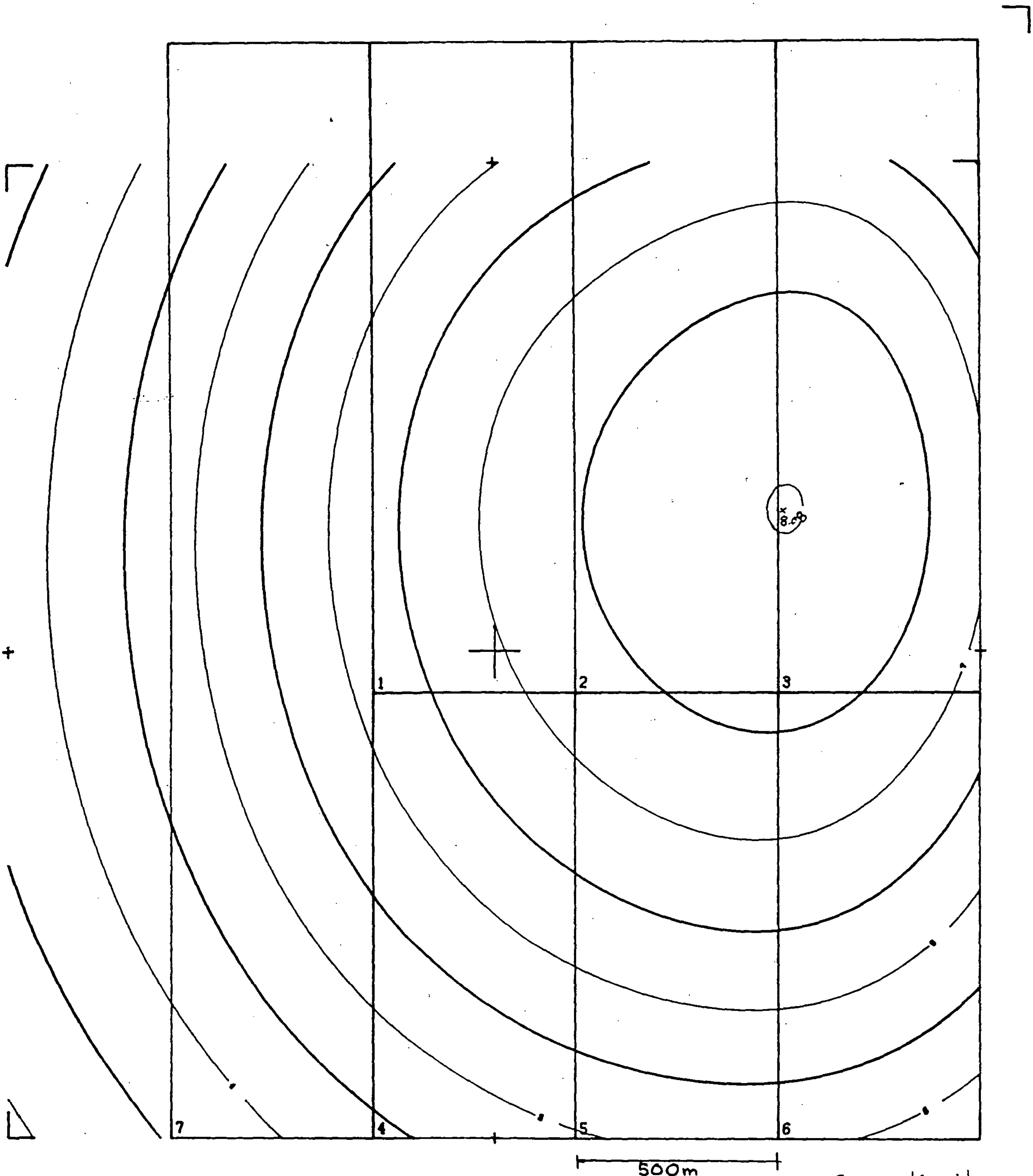
PROJECT NAME
[illegible]
MODEL 1

MODEL NAME
MODEL 1, ITER 4

NUMBER OF PRISMS: 30.

GRAVITY MODEL (MILLIGALS)

GRID PARAMETERS
GRID POINTS X 25. : Y 27.
GRID SPACING : 100. METERS
GRID DIMENSIONS X 2400. : Y 2600. METERS
GRID OFFSET X: 0. Y: 0. METERS
SCALE 1:10000.
DATA MAXIMUM: 9.
DATA MINIMUM: 1.
CONTOUR INTERVAL 1.



Granodiorite
($\rho = 2.47$)
depth (m) to top
Uplifted block

Volcanics, $\rho = 2.20$

PROJECT NAME
[illegible]
DEEP GRANITE STRUCTURE

MODEL NAME
DEEP GRANITE STRUCTURE

NUMBER OF PRISMS: 7.

GRAVITY MODEL (MILLIGALS)

GRID PARAMETERS
GRID POINTS X 25. : Y 25.
GRID SPACING : 100. METERS
GRID DIMENSIONS X 2400. : Y 2400. METERS
GRID OFFSET X: 0. Y: 0. METERS
SCALE 1:10000.
DATA MAXIMUM: 8.
DATA MINIMUM: 3.
CONTOUR INTERVAL 1.

Project name: ZUNIL
MODEL 1, Iter #[illegible]

Model: MODEL 1

Units in Meters

Model info backup (not on transparencies)

MAGNETIC PARAMETERS
Earth"s field: 0. gammas.
Inclination = 0. degrees Declination = 0. degrees.

PRISM	X1	X2	Y1	Y2	D1	D2	DC	SC
1	0.	370.	840.	2000.	780.	4000.	0.47	0.
2	-170.	275.	560.	840.	850.	4000.	0.47	0.
3	-420.	-320.	0.	360.	950.	4000.	0.47	0.
4	-320.	140.	0.	560.	980.	4000.	0.47	0.
5	730.	2000.	560.	840.	700.	4000.	0.47	0.
6	550.	1000.	200.	560.	700.	4000.	0.47	0.
7	-670.	-470.	-410.	-170.	1200.	4000.	0.47	0.
8	-470.	-390.	-410.	0.	1100.	4000.	0.47	0.
9	-230.	0.	-460.	0.	1035.	4000.	0.47	0.
10	0.	375.	-600.	-370.	1000.	4000.	0.47	0.
11	370.	1100.	840.	2000.	1200.	4000.	0.47	0.
12	275.	730.	560.	840.	1200.	4000.	0.47	0.
13	140.	550.	200.	560.	1500.	4000.	0.47	0.
14	140.	2000.	0.	200.	1500.	4000.	0.47	0.
15	-390.	-230.	-460.	0.	1530.	4000.	0.47	0.
16	0.	800.	-370.	0.	2000.	4000.	0.47	0.
17	375.	2000.	-600.	-370.	2000.	4000.	0.47	0.
18	0.	2000.	-2000.	-600.	2000.	4000.	0.47	0.
19	1100.	2000.	560.	2000.	1000.	4000.	0.47	0.
20	1000.	2000.	200.	560.	1000.	4000.	0.47	0.
21	800.	2000.	-370.	0.	1000.	4000.	0.47	0.
22	-1200.	-320.	0.	2000.	0.	600.	-0.20	0.
23	-1200.	-350.	-2000.	0.	0.	600.	-0.20	0.

Project name: ZUNIL
SURFACE VOLCANICS
Model: SURFACE VOLCANICS

Units in Meters

MAGNETIC PARAMETERS
Earth"s field: 0. gammas.
Inclination = 0. degrees Declination = 0. degrees.

PRISM	X1	X2	Y1	Y2	D1	D2	DC	SC
1	-900.	-400.	-1200.	1200.	0.	500.	-0.20	0.
2	100.	400.	-100.	1200.	0.	500.	-0.20	0.
3	700.	100.	200.	800.	0.	500.	0.10	0.
4	500.	900.	-500.	-100.	0.	500.	0.10	0.
5	-300.	200.	-1200.	-800.	0.	500.	-0.30	0.

Project name: ZUNIL
DEEP GRANITE STRUCTURE
Model: DEEP GRANITE STRUCTURE

Units in Meters

MAGNETIC PARAMETERS
Earth"s field: 0. gammas.
Inclination = 0. degrees Declination = 0. degrees.

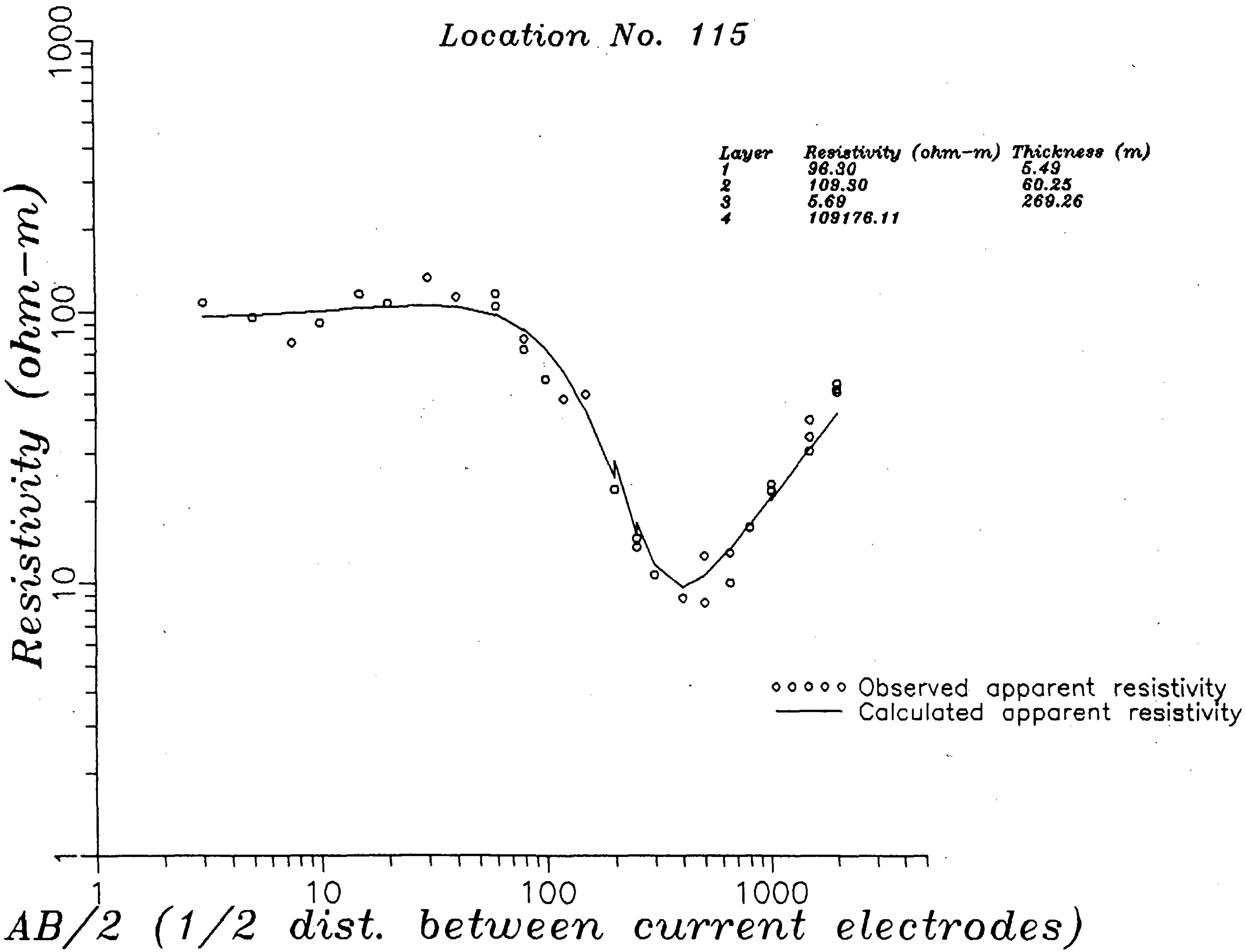
PRISM	X1	X2	Y1	Y2	D1	D2	DC	SC
1	-300.	200.	-100.	1500.	800.	4000.	0.47	0.
2	200.	700.	-100.	1500.	1200.	4000.	0.47	0.
3	700.	1200.	-100.	1500.	500.	4000.	0.47	0.
4	-300.	200.	-1200.	-100.	1000.	4000.	0.47	0.
5	200.	700.	-1200.	-100.	1400.	4000.	0.47	0.
6	700.	1200.	-1200.	-100.	700.	4000.	0.47	0.
7	-800.	-300.	-1200.	1500.	3000.	4000.	0.47	0.

Project name: ZUNIL
MODEL 1
Model: MODEL 1 ITER No4

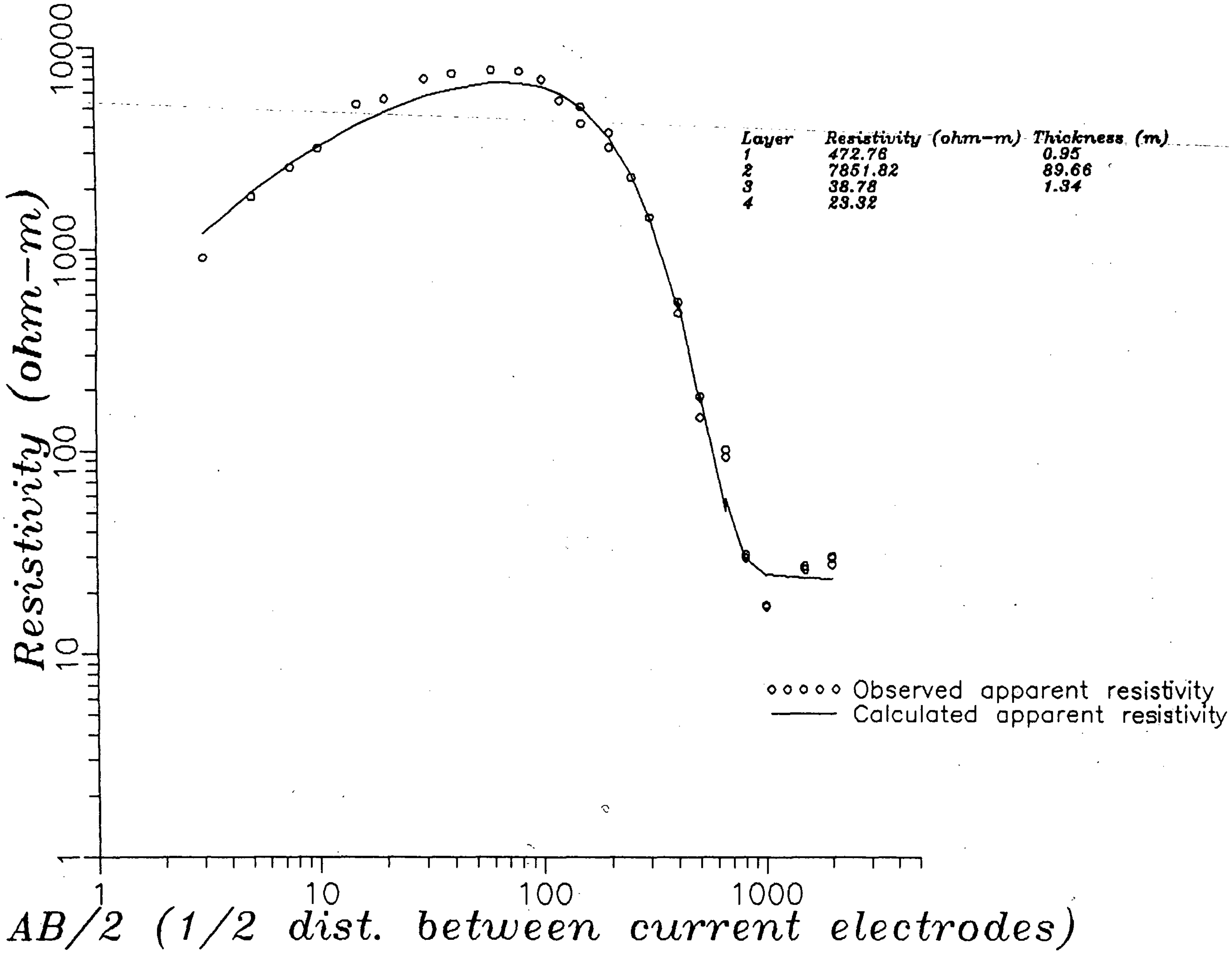
Units in Meters

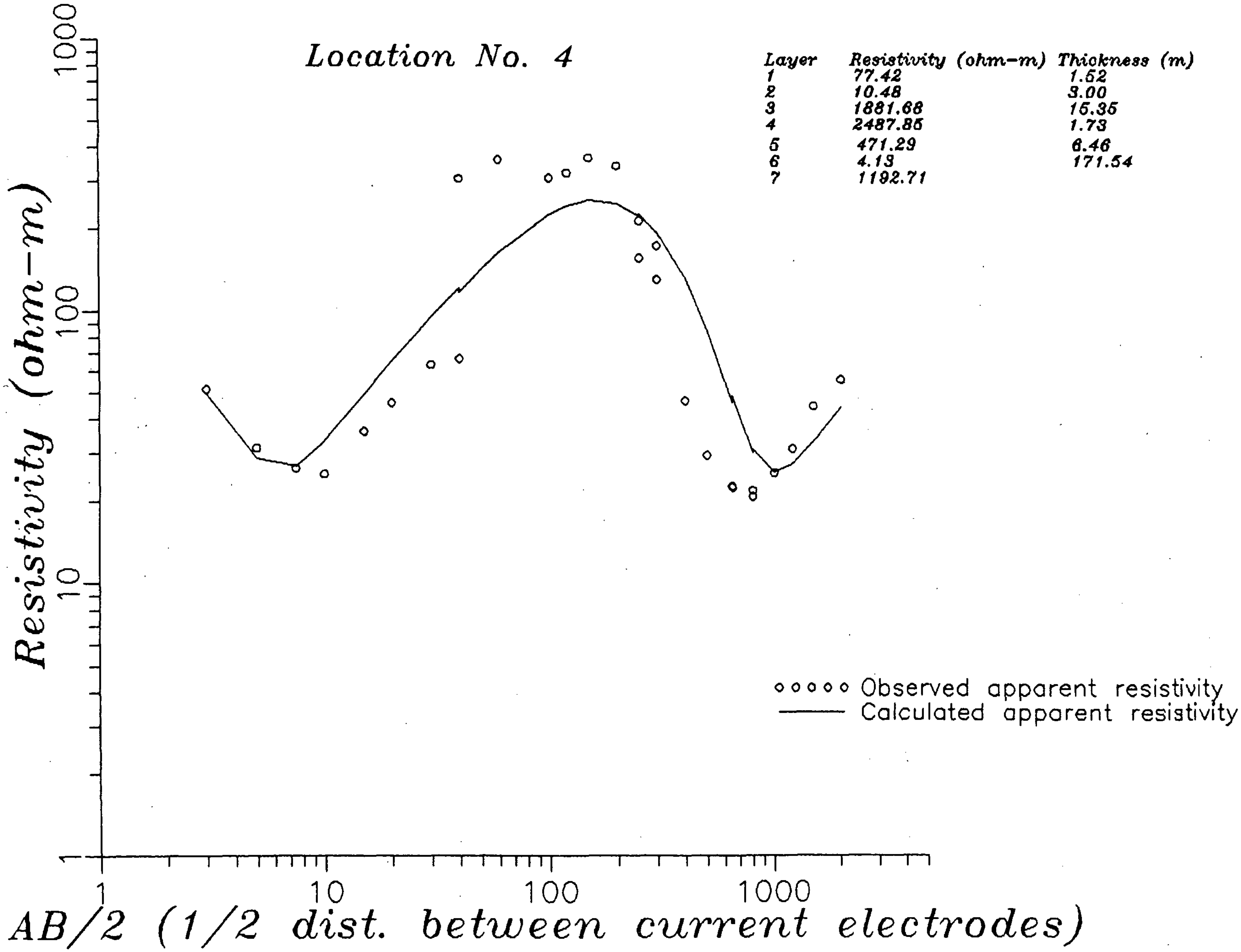
MAGNETIC PARAMETERS
Earth"s field: 0. gammas.
Inclination = 0. degrees Declination = 0. degrees.

PRISM	X1	X2	Y1	Y2	D1	D2	DC	SC
1	0.	370.	840.	2000.	780.	4000.	0.47	0.
2	-170.	275.	560.	840.	850.	4000.	0.47	0.
3	-420.	-320.	0.	360.	950.	4000.	0.47	0.
4	-320.	140.	0.	560.	980.	4000.	0.47	0.
5	730.	2000.	560.	840.	700.	4000.	0.47	0.
6	550.	1000.	200.	560.	700.	4000.	0.47	0.
7	-670.	-470.	-410.	-170.	1200.	4000.	0.47	0.
8	-470.	-390.	-410.	0.	1100.	4000.	0.47	0.
9	-230.	0.	-460.	0.	1035.	4000.	0.47	0.
10	0.	375.	-600.	-370.	1000.	4000.	0.47	0.
11	370.	1100.	840.	2000.	1200.	4000.	0.47	0.
12	275.	730.	560.	840.	1200.	4000.	0.47	0.
13	140.	550.	200.	560.	1500.	4000.	0.47	0.
14	140.	2000.	0.	200.	1500.	4000.	0.47	0.
15	-390.	-230.	-460.	0.	1530.	4000.	0.47	0.
16	0.	800.	-370.	0.	2000.	4000.	0.47	0.

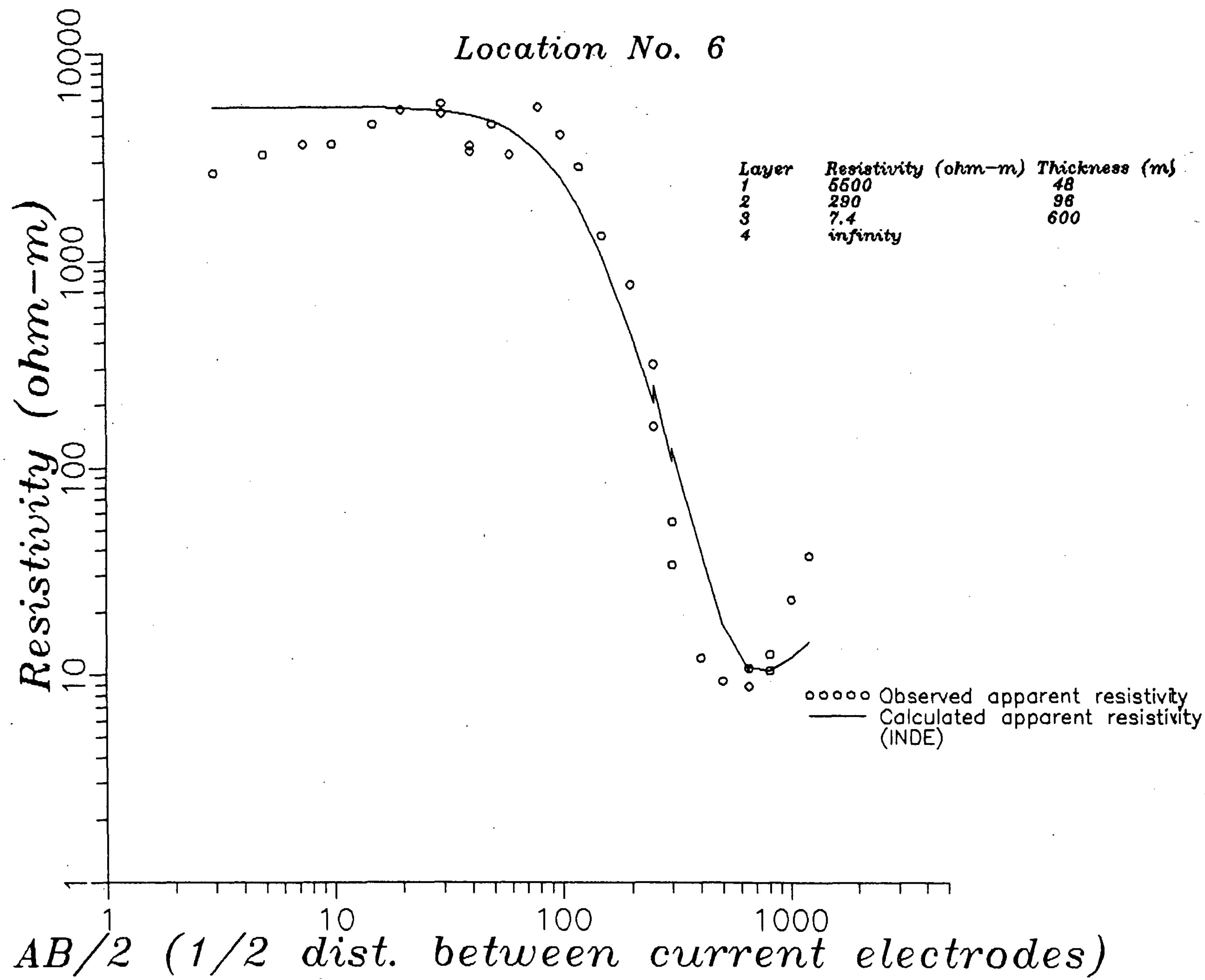

Location No. 115
Layer Resistivity (ohm-m) Thickness (m)
1 96.30 5.49
2 109.30 60.25
3 5.69 269.26
4 109176.11
Resistivity (ohm-m)
1000
100
10
1
10
100
1000
Observed apparent resistivity
Calculated apparent resistivity
AB/2 (1/2 dist. between current electrodes)

Location No. 38

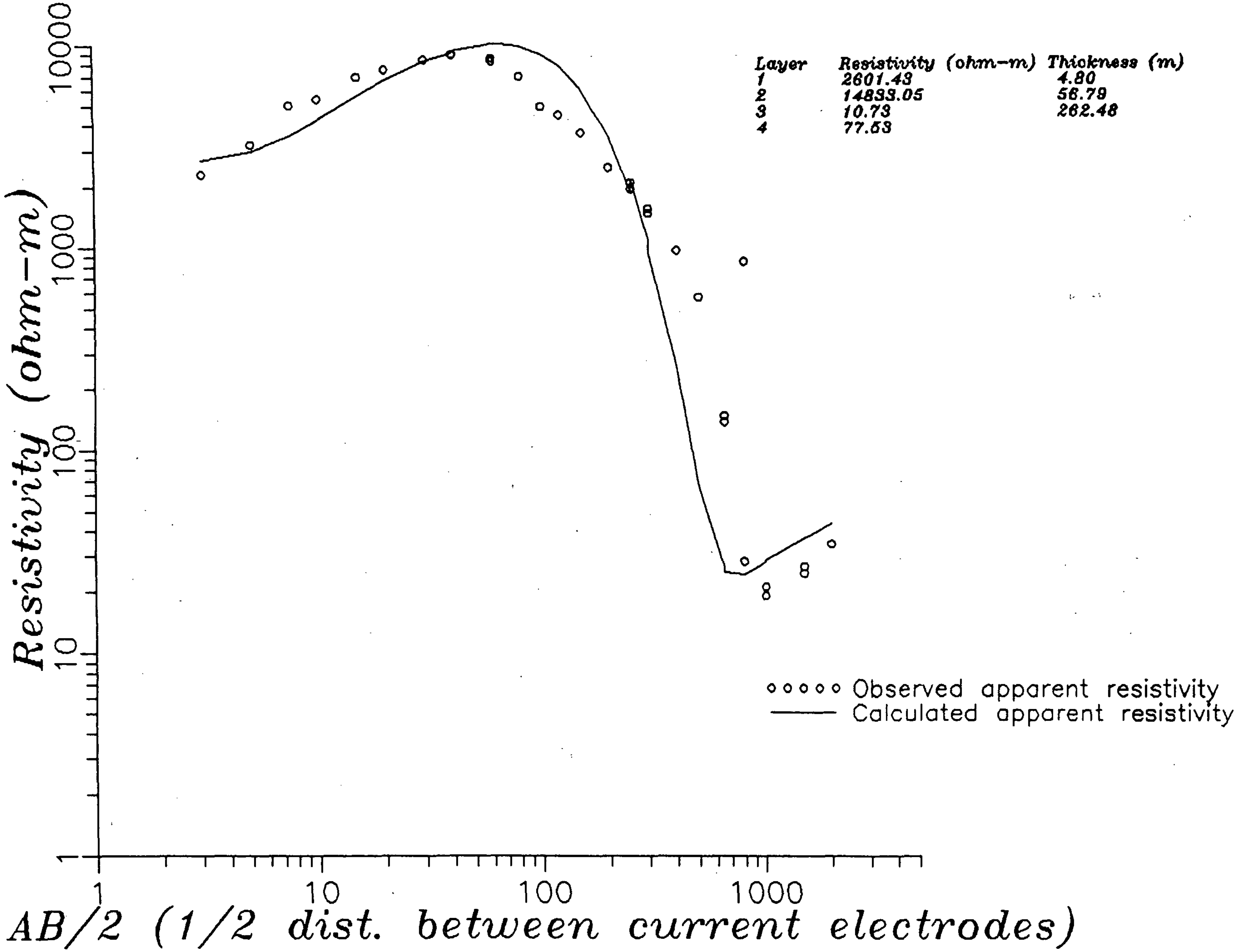




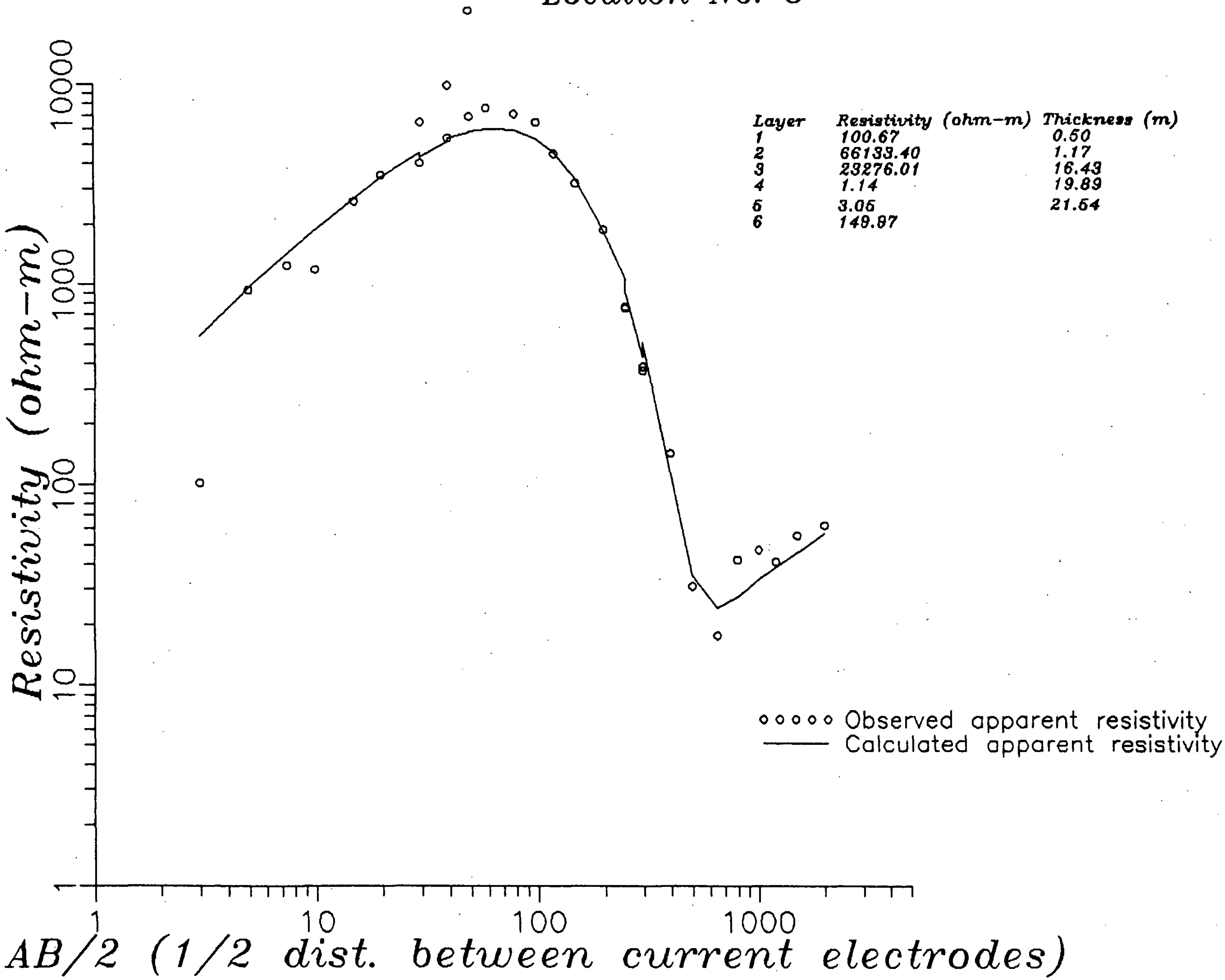
Layer	Resistivity (ohm-m)	Thickness (m)
1	77.42	1.52
2	10.48	3.00
3	1881.68	15.35
4	2487.85	1.73
5	471.29	6.46
6	4.13	171.54
7	1192.71	


Location No. 6
Resistivity (ohm-m)
10000
1000
100
10
Layer Resistivity (ohm-m) Thickness (m)
1 5500 48
2 290 96
3 7.4 600
4 infinity
ooooo Observed apparent resistivity
Calculated apparent resistivity (INDE)
1
10
100
1000
AB/2 (1/2 dist. between current electrodes)

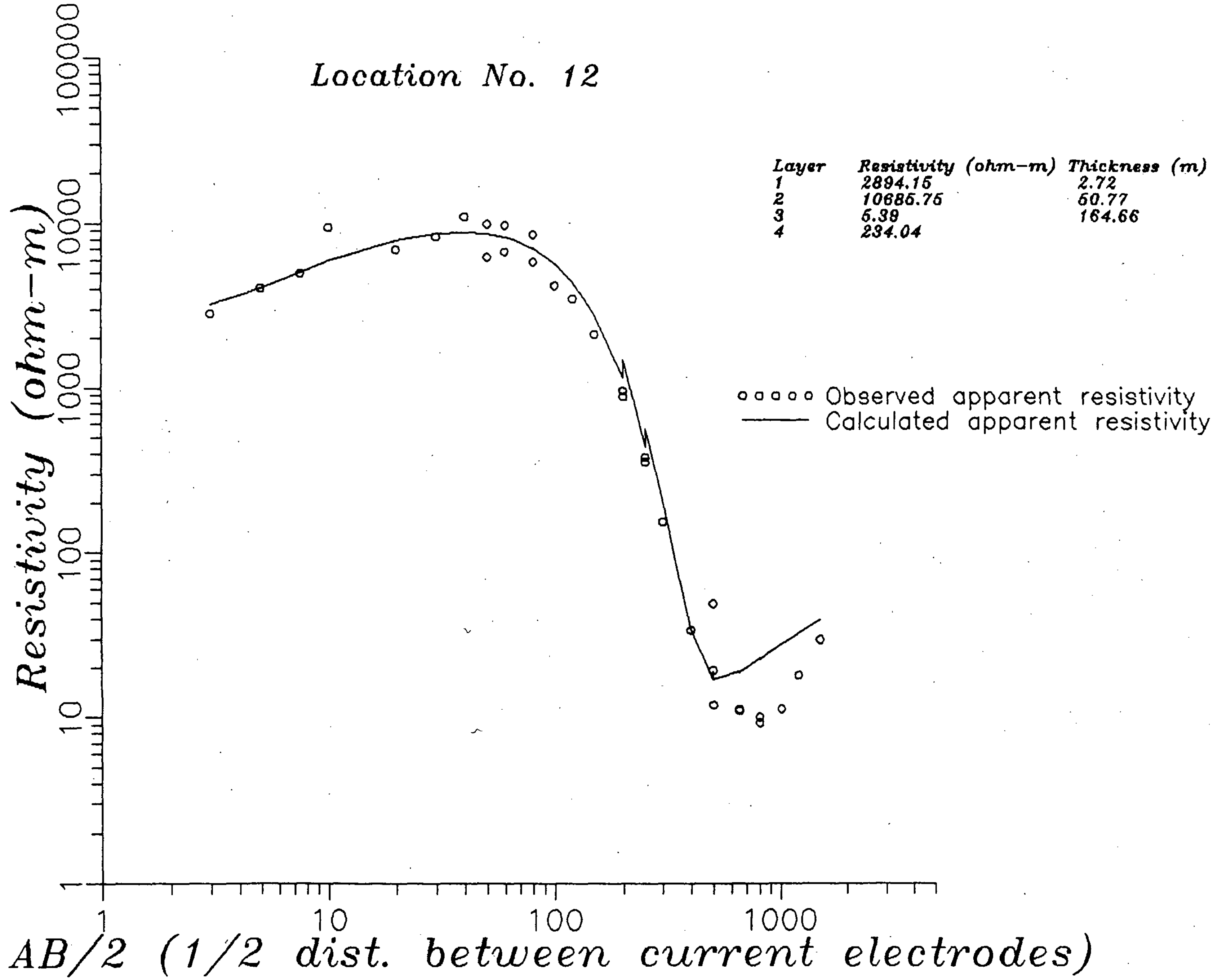
Location No. 28



Location No. 8



Layer	Resistivity (ohm-m)	Thickness (m)
1	100.67	0.50
2	66133.40	1.17
3	23276.01	16.43
4	1.14	19.89
5	3.06	21.54
6	149.87	


Location No. 12
Layer Resistivity (ohm-m) Thickness (m)
1 2894.15 2.72
2 10685.75 50.77
3 5.39 164.66
4 234.04
Observed apparent resistivity
Calculated apparent resistivity
Resistivity (ohm-m)
100000
10000
1000
100
10
1
10
100
1000
AB/2 (1/2 dist. between current electrodes)

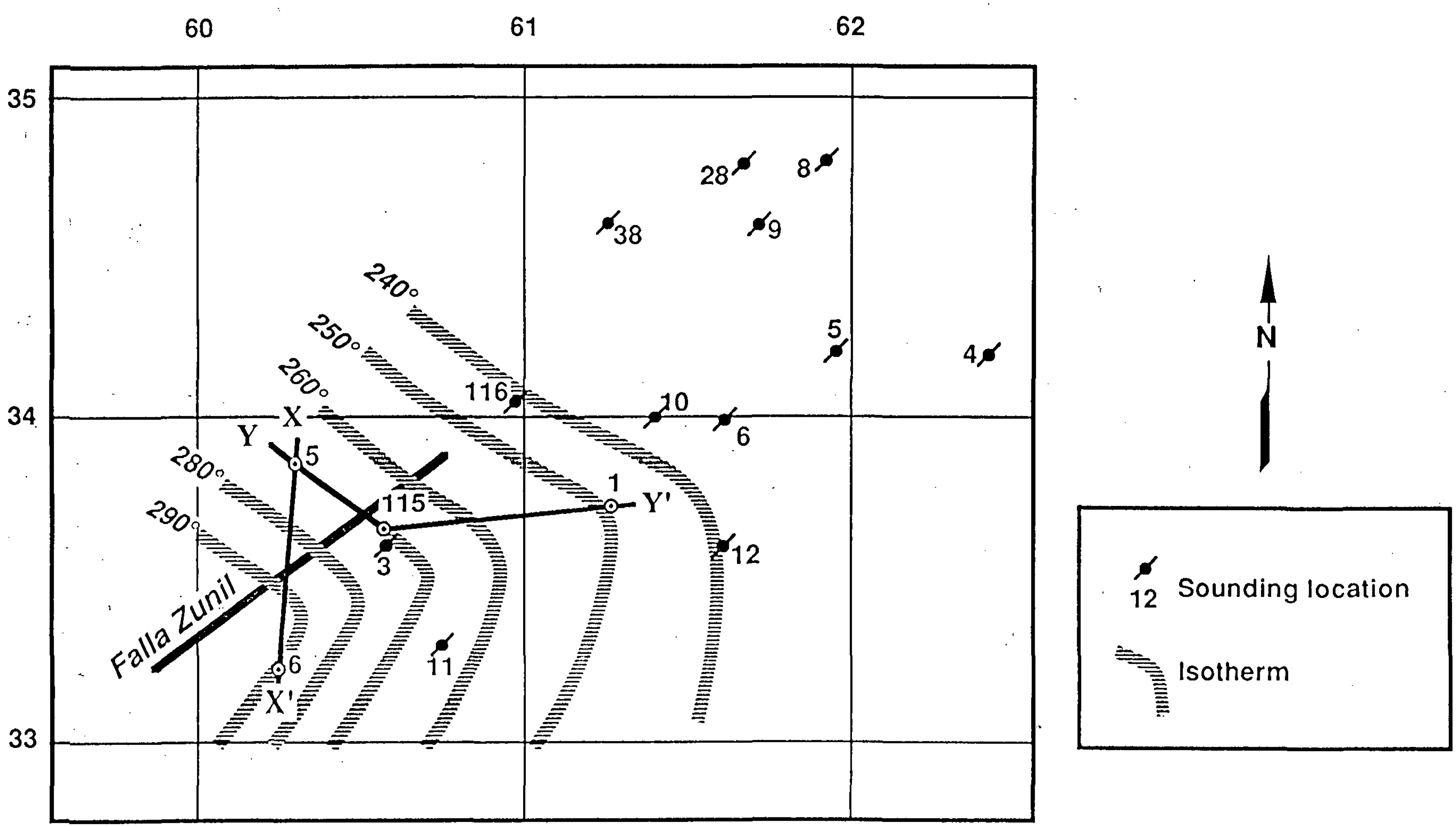

60
61
62
35
34
33
240°
250°
260°
280°
290°
X
X'
Y
Y'
Falla Zunil
28
8
38
9
5
4
116
10
6
1
115
3
12
11
N
Sounding location
Isotherm

Figure 2

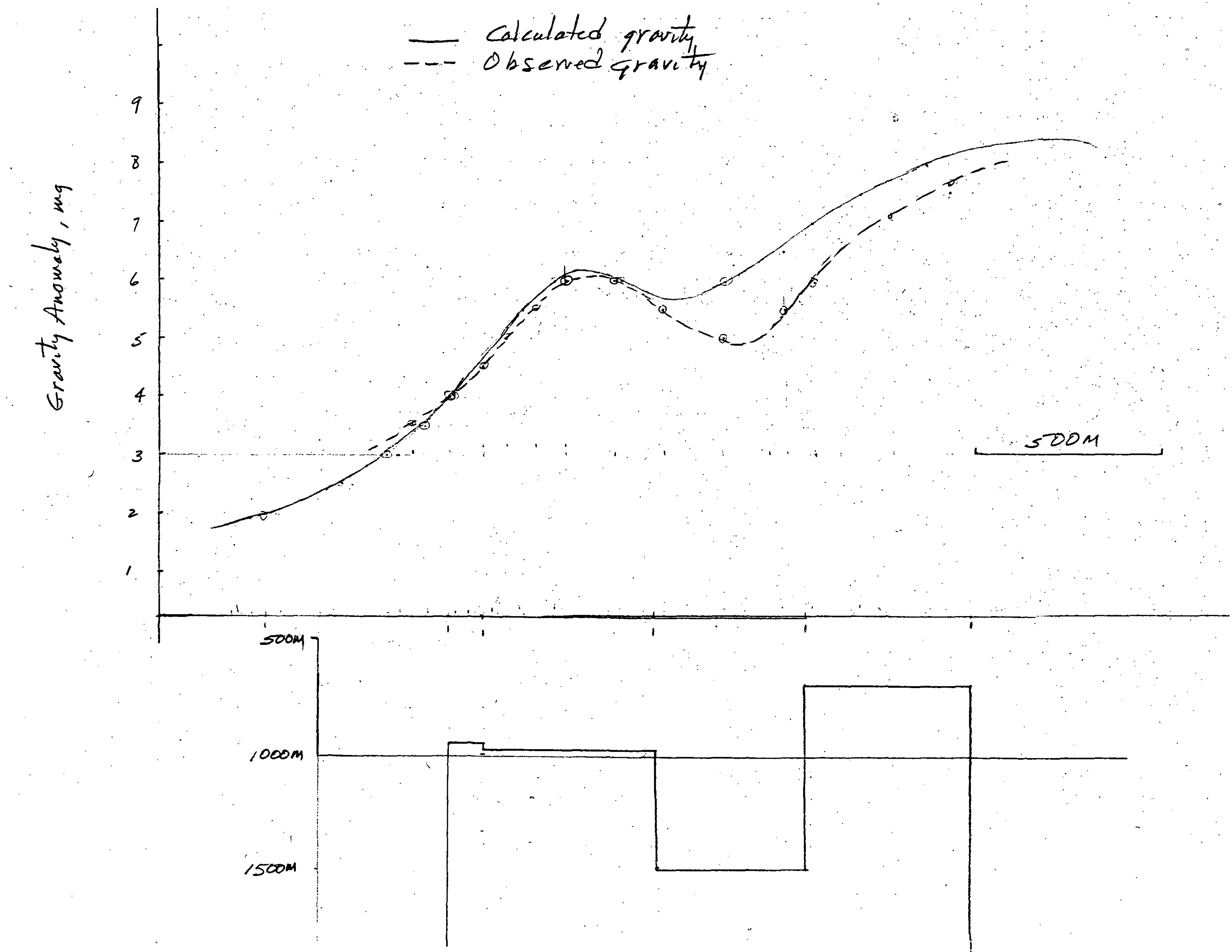
SUMMARY OF GEOPHYSICAL RESULTS

GRAVITY

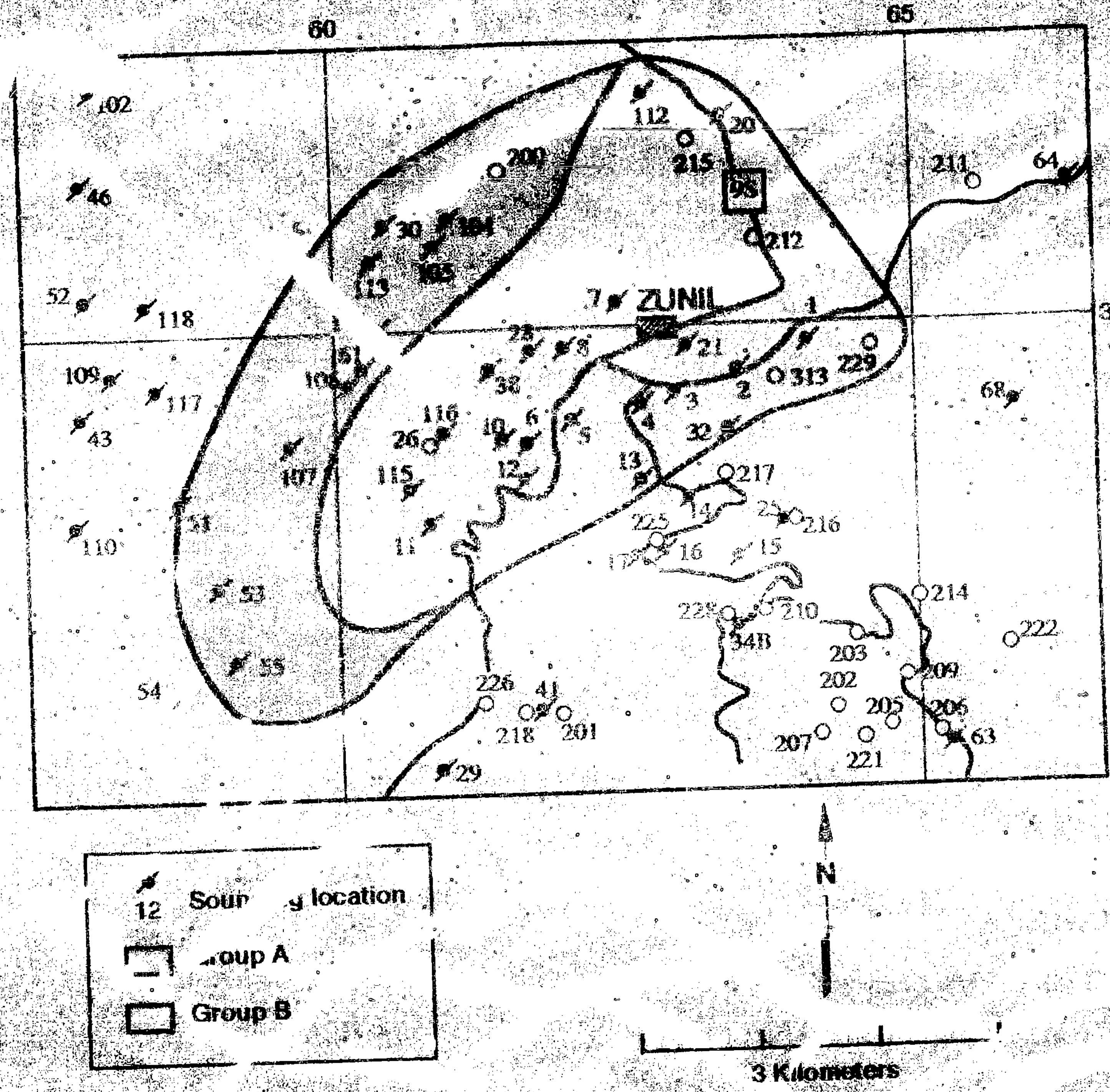
- Interpreted structure supports geologic mapping and indicates faulting in vicinity of recommended well locations.

RESISTIVITY

- Conductive region indicated at approximate depth of 50m to top, interpreted to be caused by geothermal fluids and/or hydrothermal alteration.



Calculated gravity
Observed gravity
Gravity Anomaly, mg
9
8
7
6
5
4
3
2
1
500M
500M
1000M
1500M



60
65
35
ZUNIL
Sounding location
Group A
Group B
N
3 Kilometers

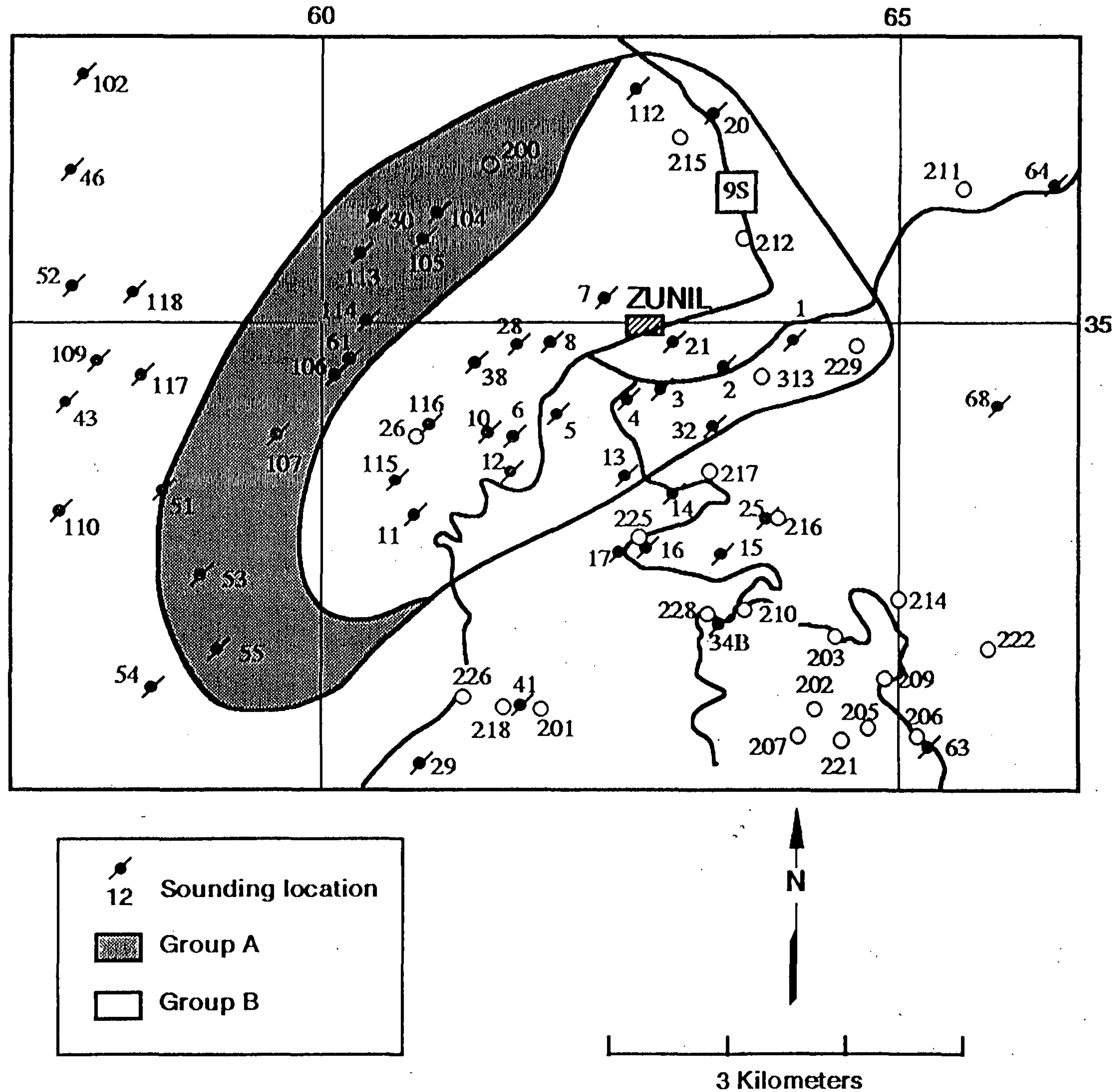
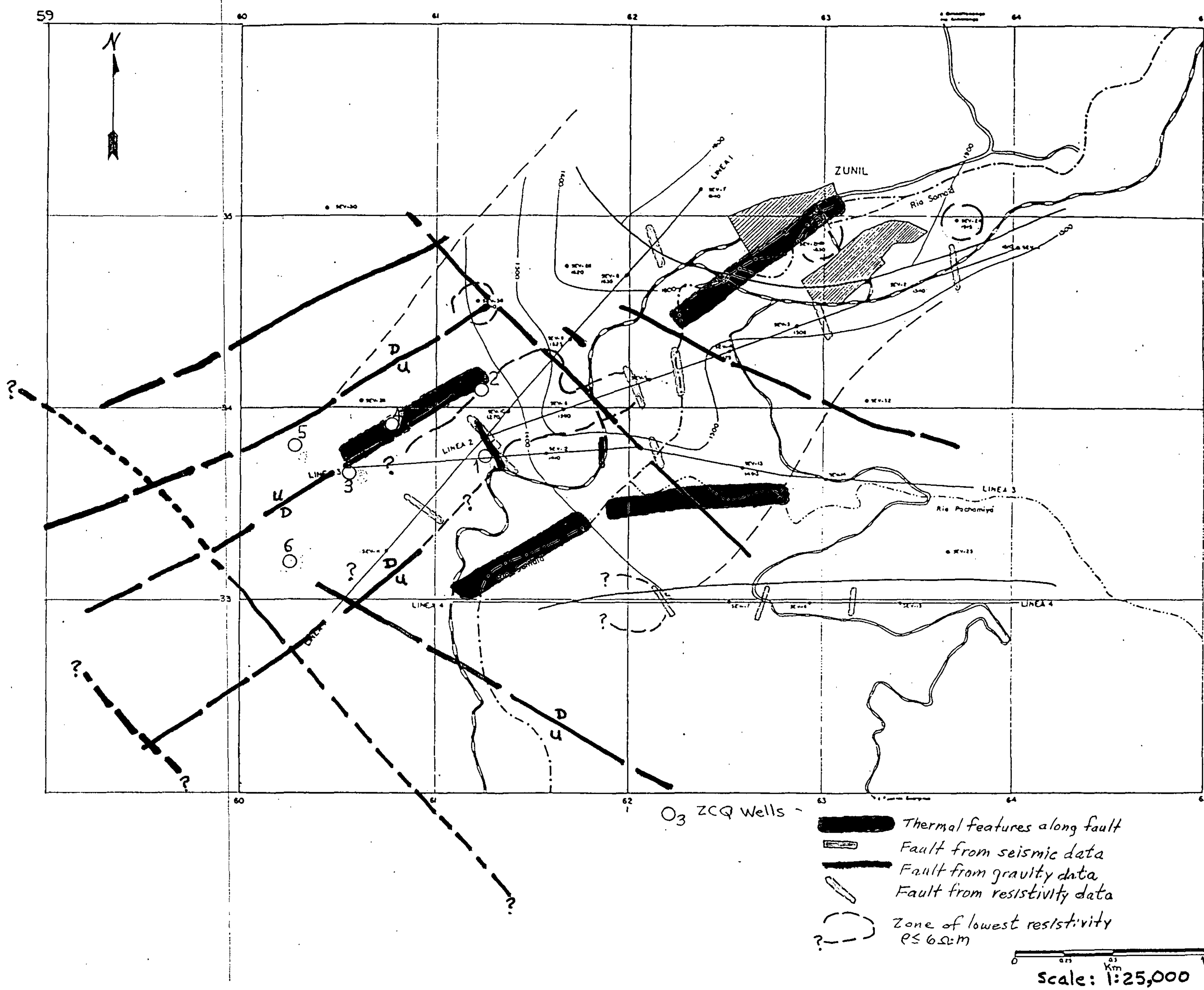
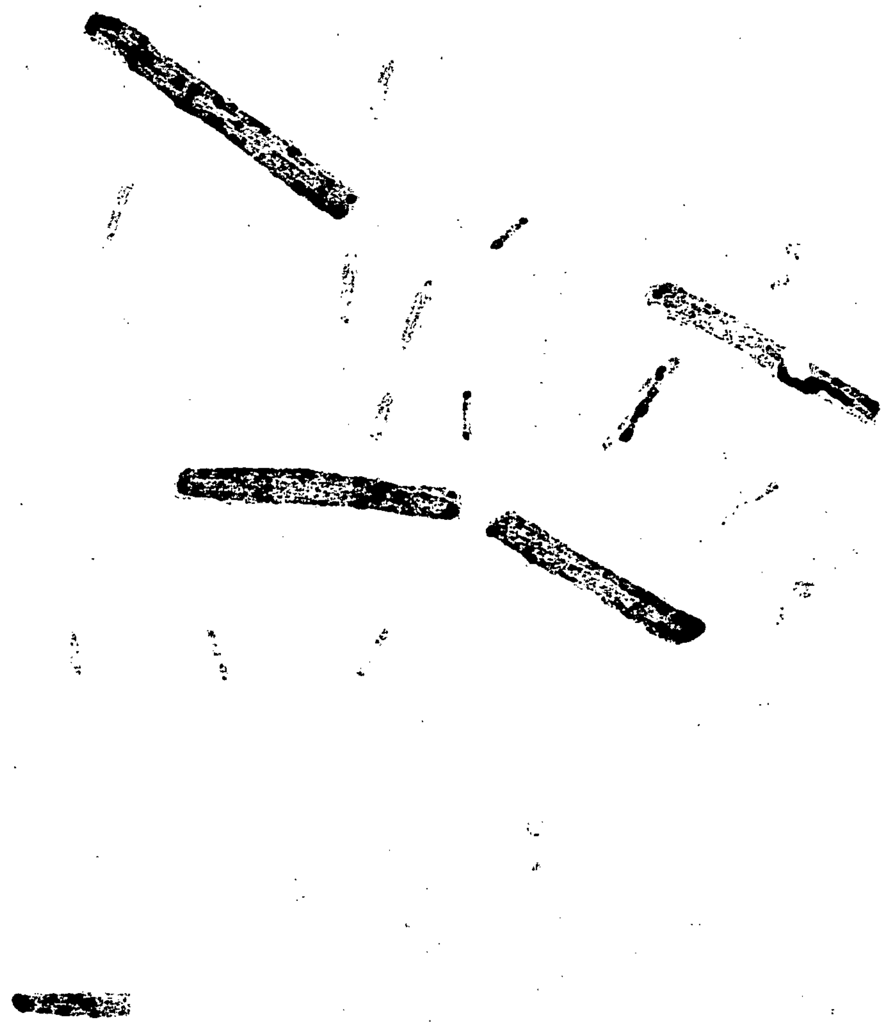
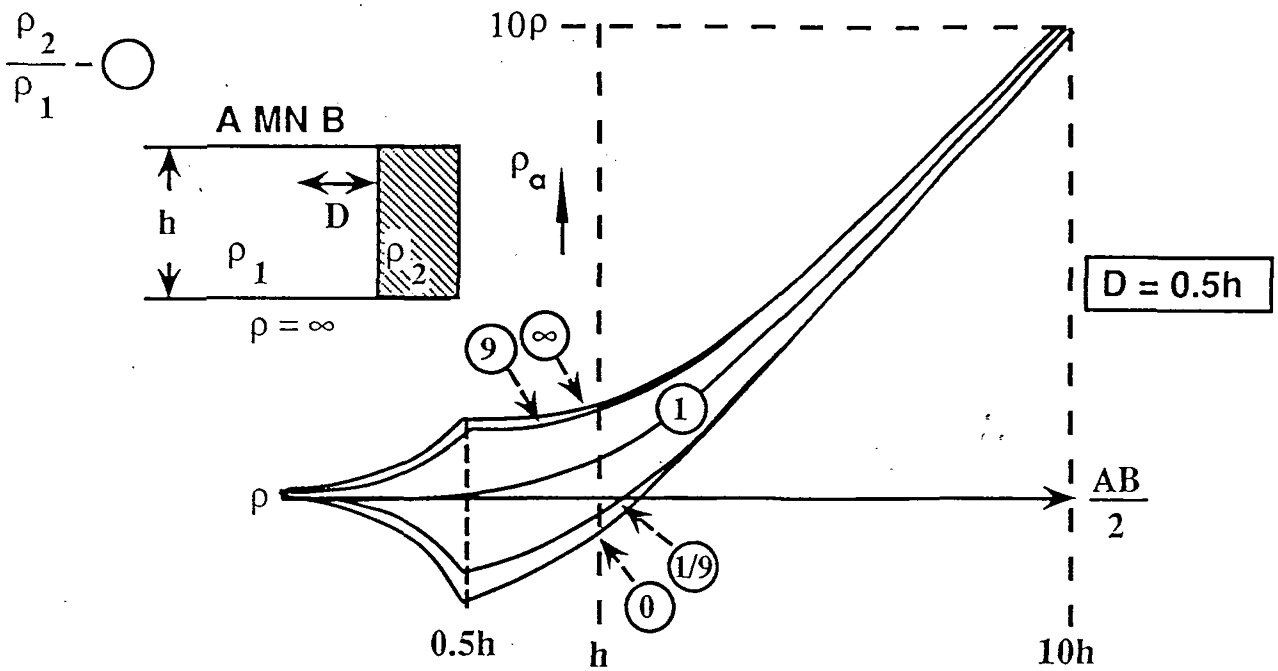

60
65
35
ZUNIL
9S
102
46
52
118
109
117
43
110
54
200
30
104
105
113
114
61
106
107
51
53
55
112
20
215
212
7
28
8
38
21
1
2
3
4
313
229
211
64
68
116
26
10
6
5
115
12
11
32
13
217
14
225
25
216
17
16
15
228
210
34B
214
203
222
202
209
205
206
207
221
63
226
41
218
201
29
Sounding location
12
Group A
Group B
N
3 Kilometers

Figure 1

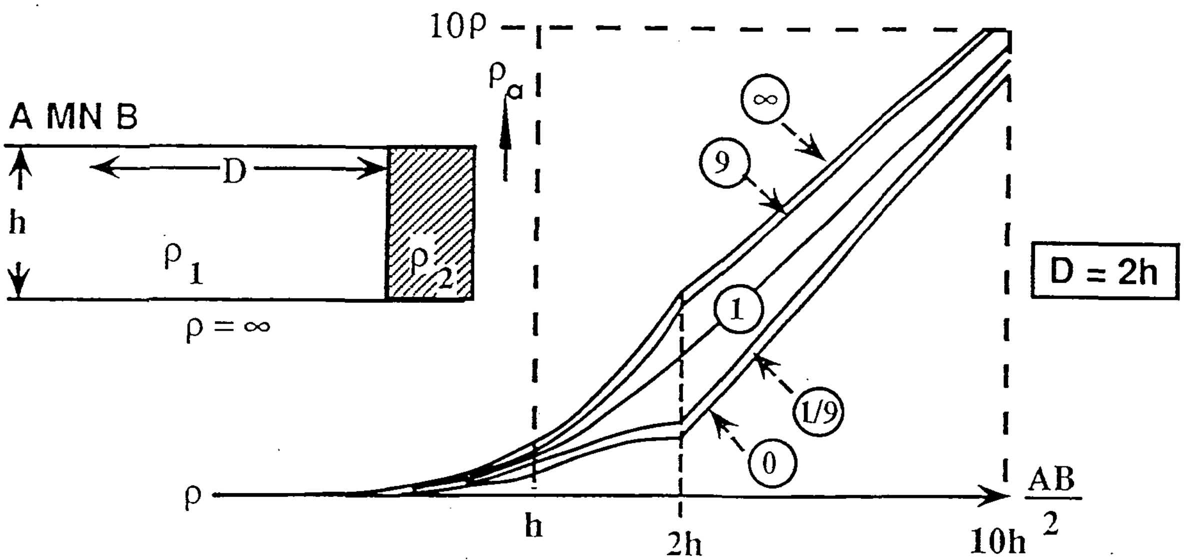


N
ZUNIL
Rio Samalá
LINEA 1
LINEA 2
LINEA 3
LINEA 4
Rio Pachamiyá
D
U
ZCQ Wells
Thermal features along fault
Fault from seismic data
Fault from gravity data
Fault from resistivity data
Zone of lowest resistivity ρ≤ 6Ω·m
Km
Scale: 1:25,000





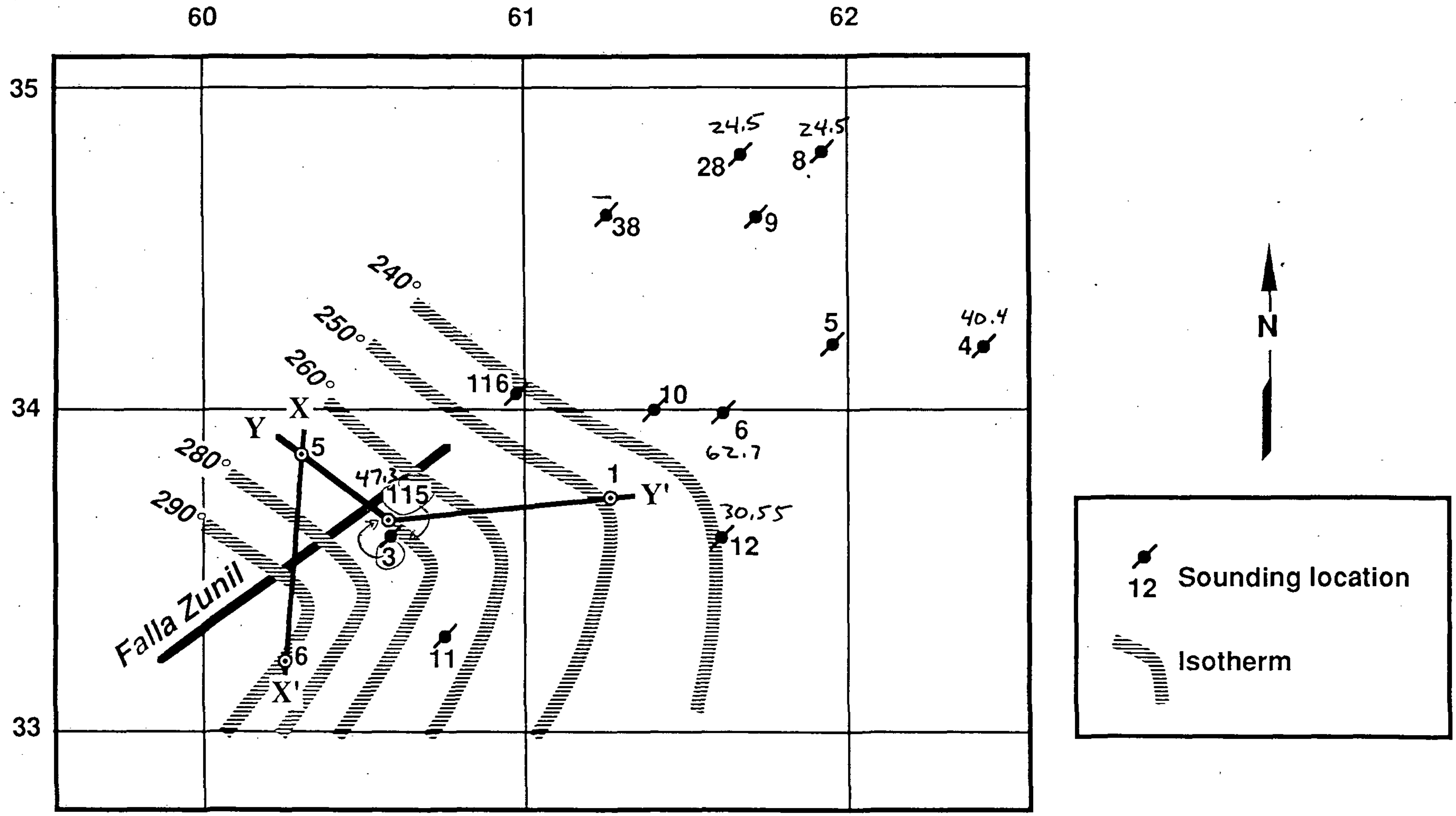
$\frac{\rho_2}{\rho_1}$ - ○
A MN B
h
D
ρ_1
ρ_2
$\rho = \infty$
10ρ
ρ_a
D = 0.5h
9
∞
1
ρ
AB/2
1/9
0
0.5h
h
10h



10ρ
ρ_a
A MN B
D
h
ρ_1
ρ_2
$\rho = \infty$
∞
9
D = 2h
1
1/9
0
ρ
AB/2
h
2h
10h

Figure 4

Conductance Map



ZUNIL ELECTRICAL RESISTIVITY STUDIES

ZUNIL GEOTHERMAL AREA, GUATEMALA

REVIEW COMMENTS

by

Howard P. Ross

June 1, 1989

Earth Science Laboratory

University of Utah Research Institute
391 Chipeta Way, Suite C
Salt Lake City, Utah 84108
(801) 524-3422

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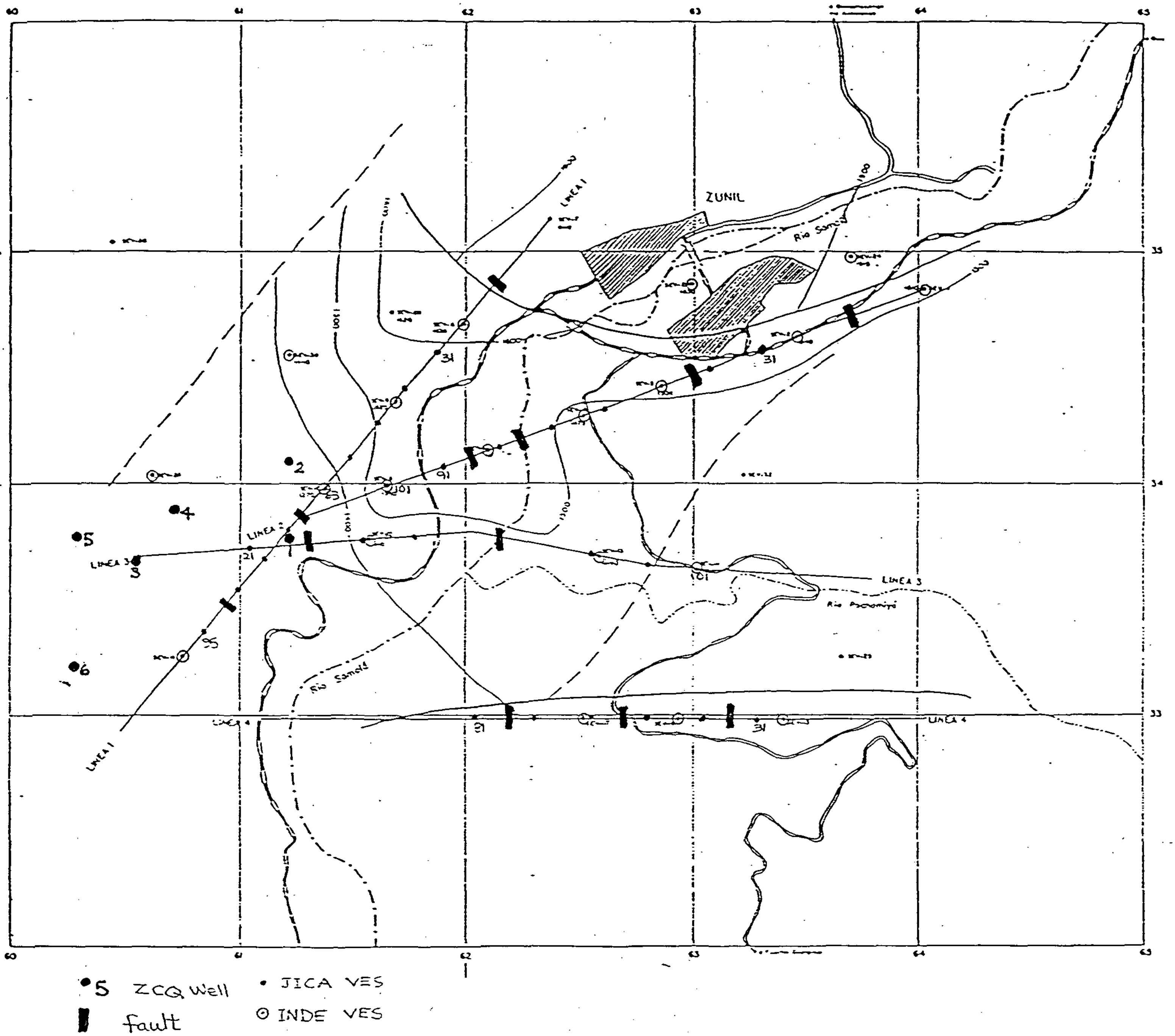
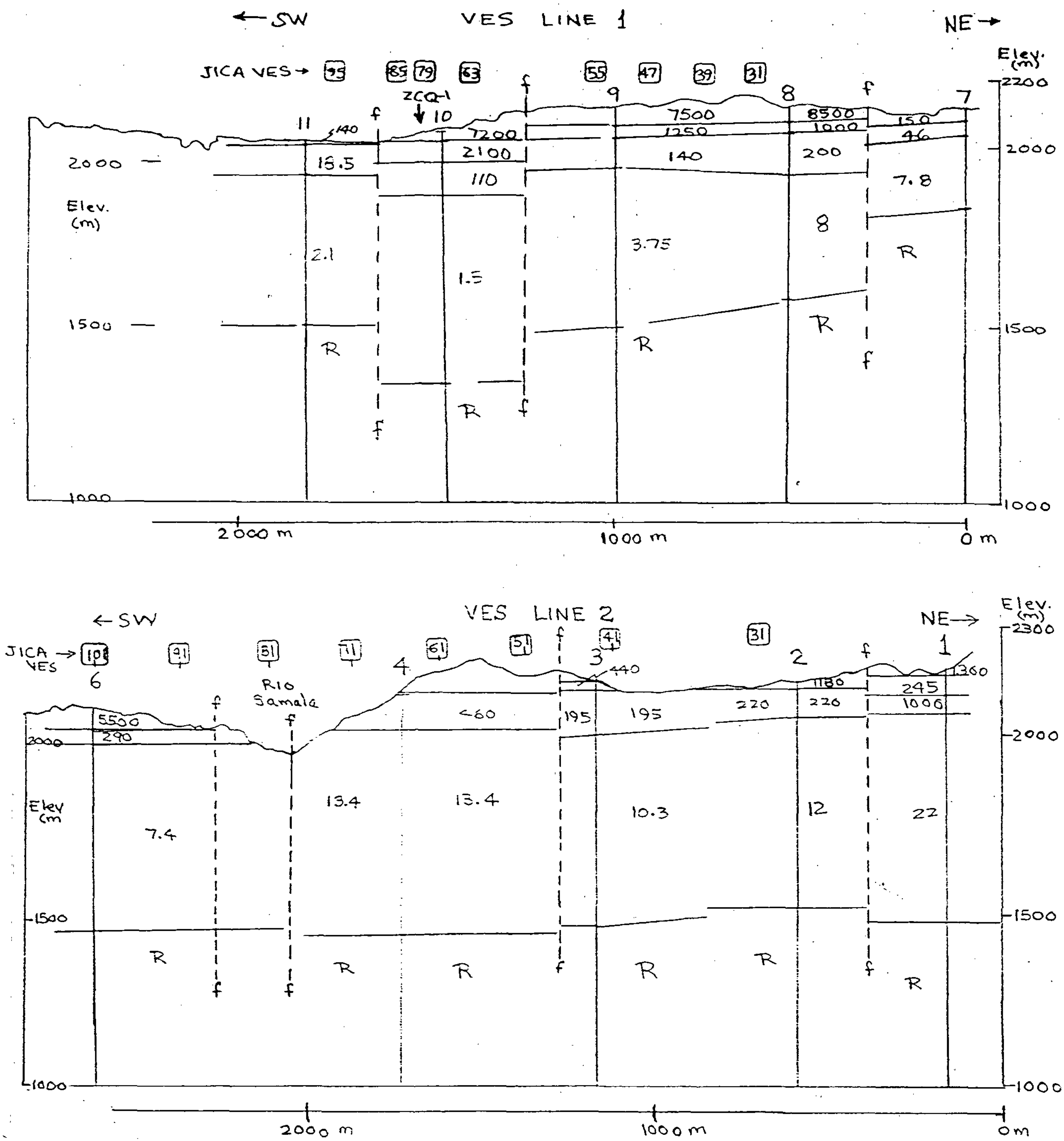


Figure 1. Location of JICA and INDE Schlumberger vertical electric soundings (VES).



Resistivity (Ω-m)
R = resistive
f = fault

note: vertical & horizontal distance scales are approximate.

Figure 2. Electrical resistivity cross sections for INDE VES Lines 1 and 2. Corresponding JICA VES sounding locations are indicated.

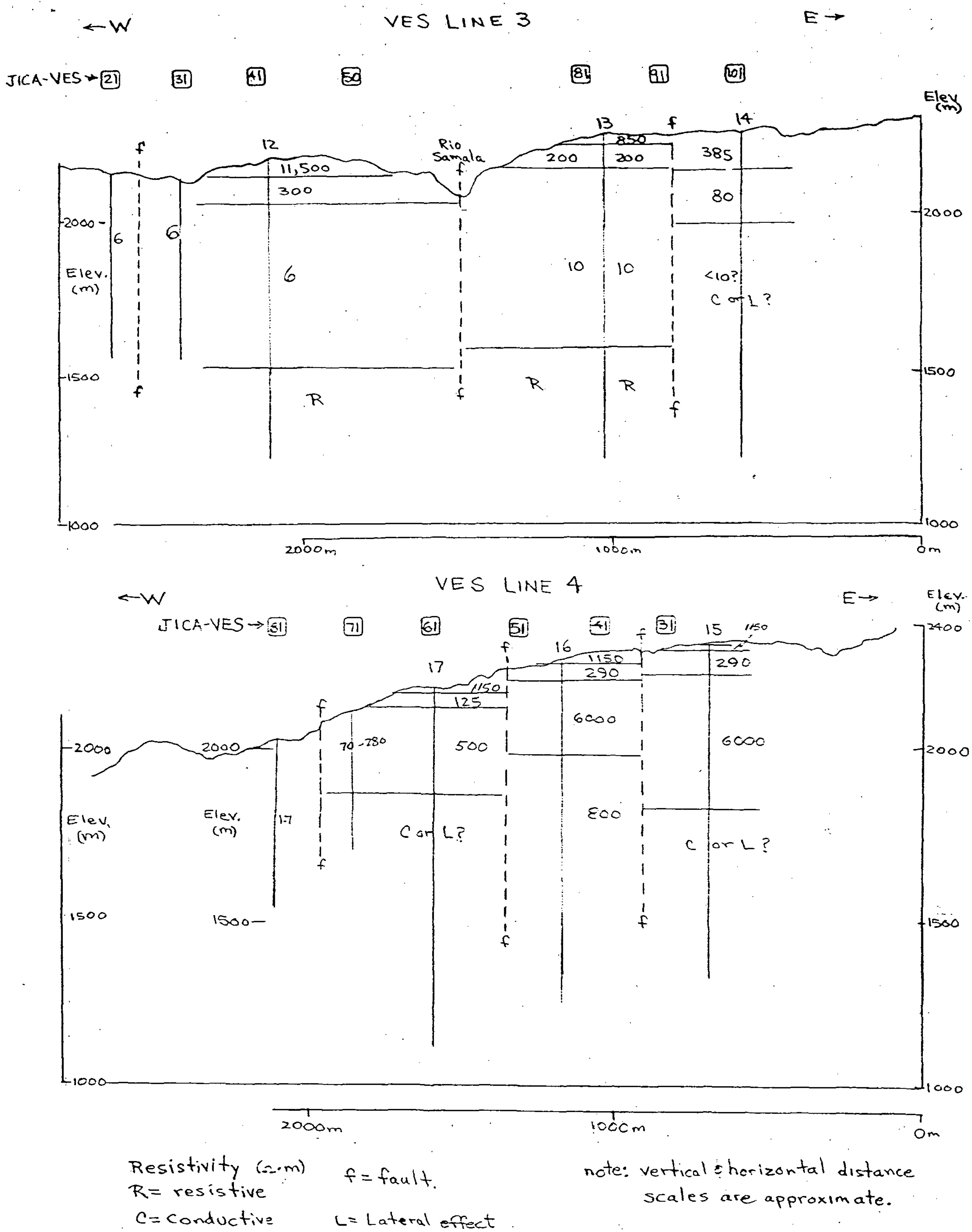
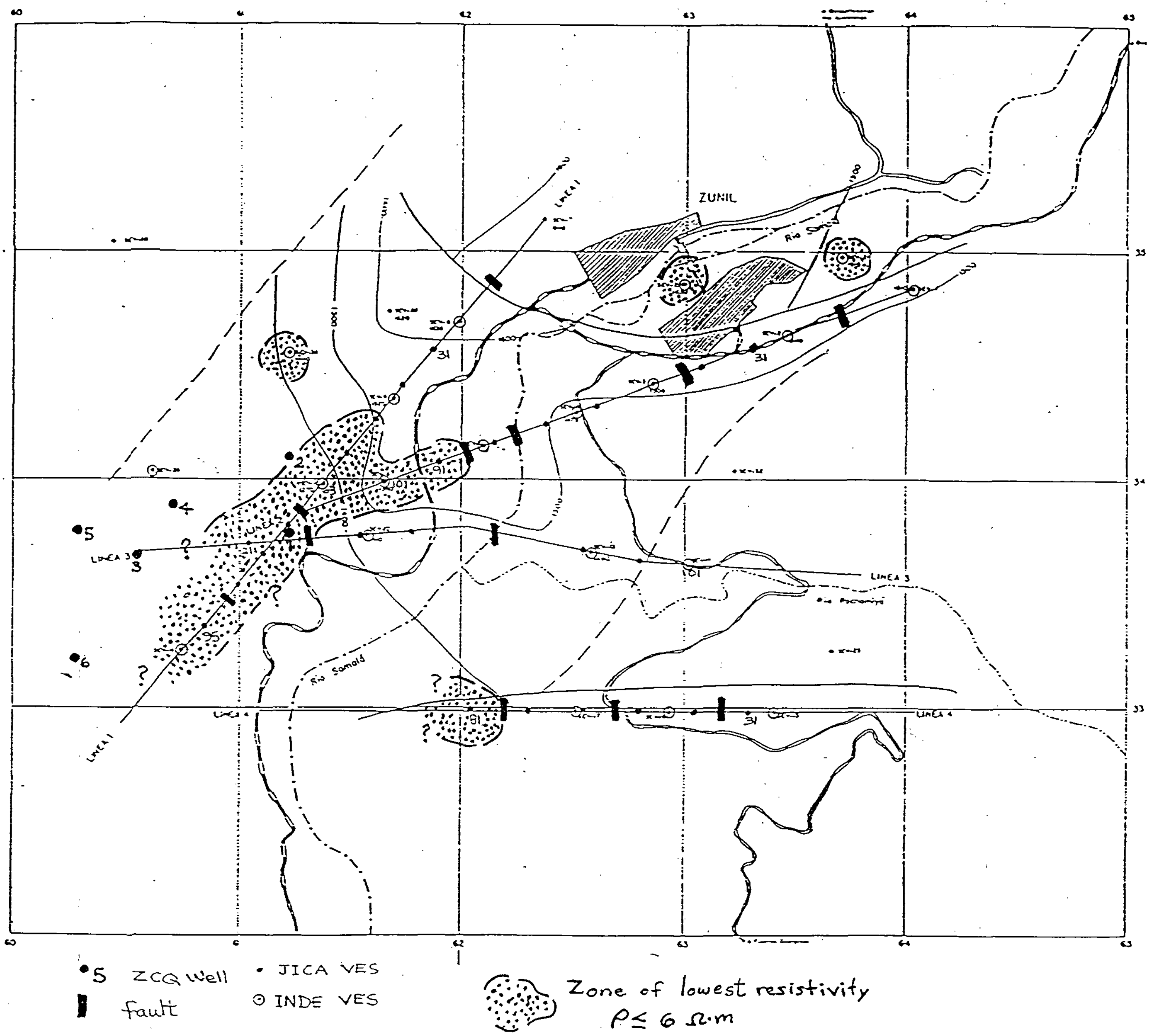


Figure 3. Electrical resistivity cross sections for INDE VES Lines 3 and 4. Corresponding JICA VES sounding locations are indicated.



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[illegible]

[illegible]

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[illegible]

[illegible]

[illegible]

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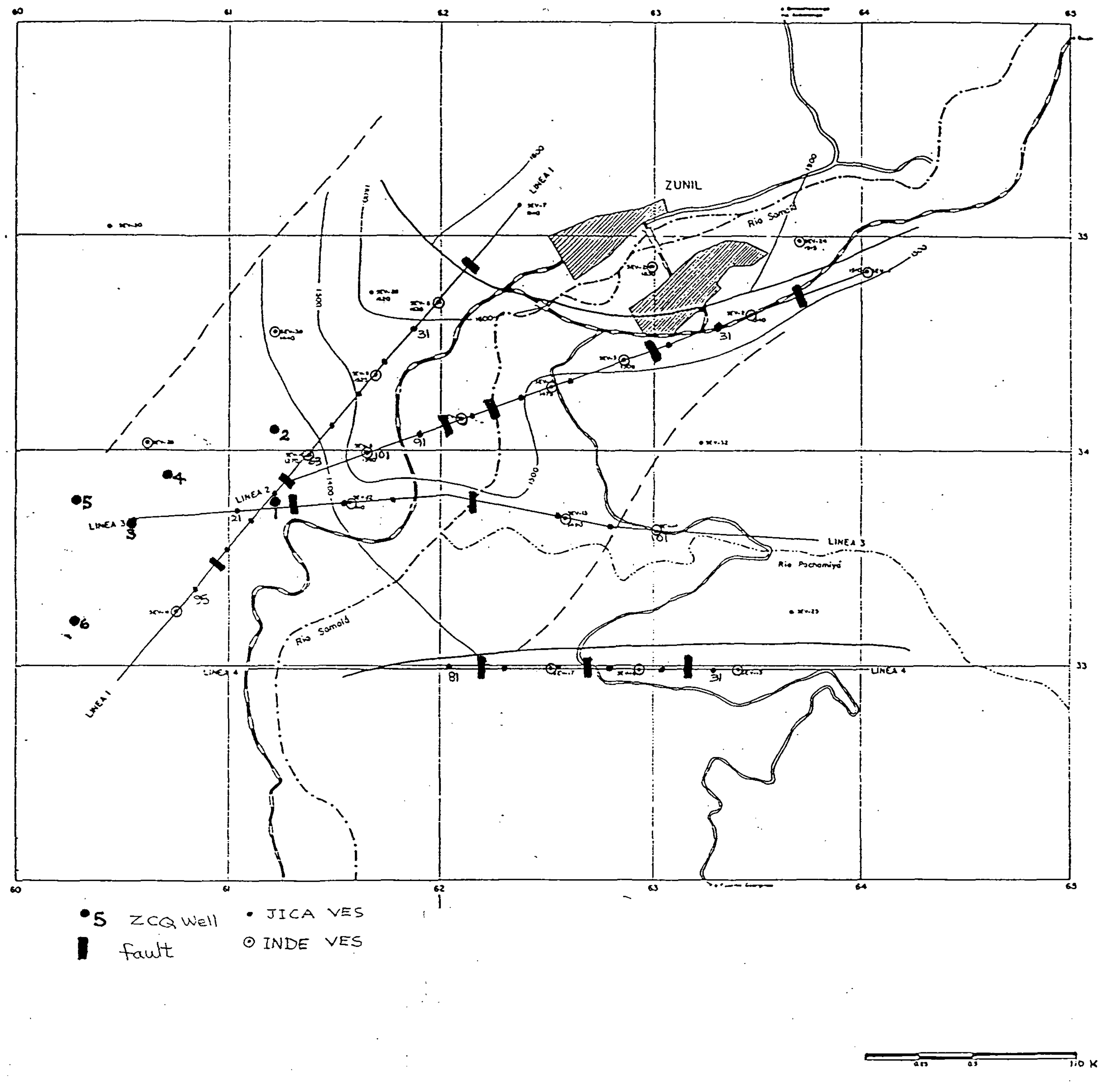

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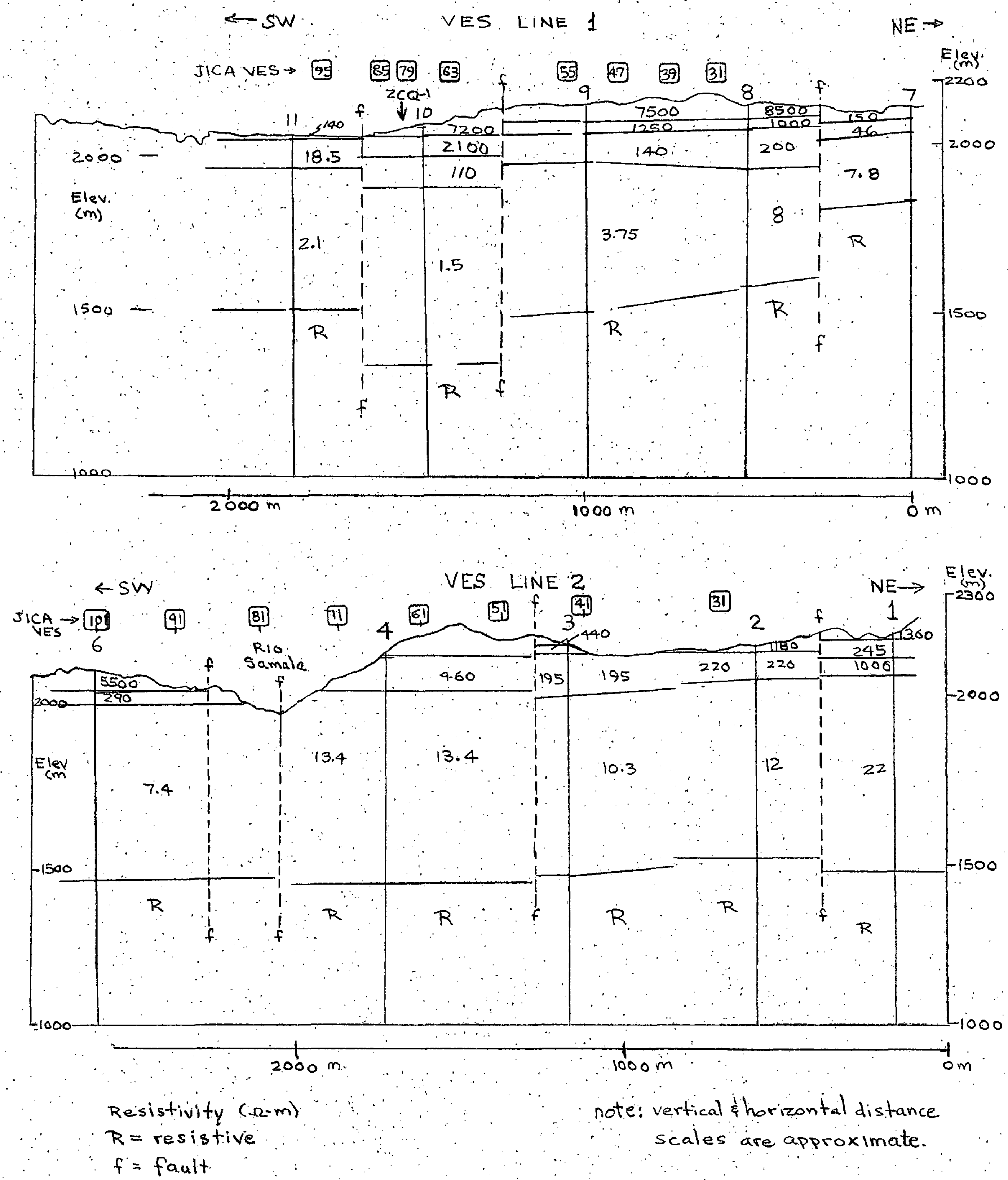

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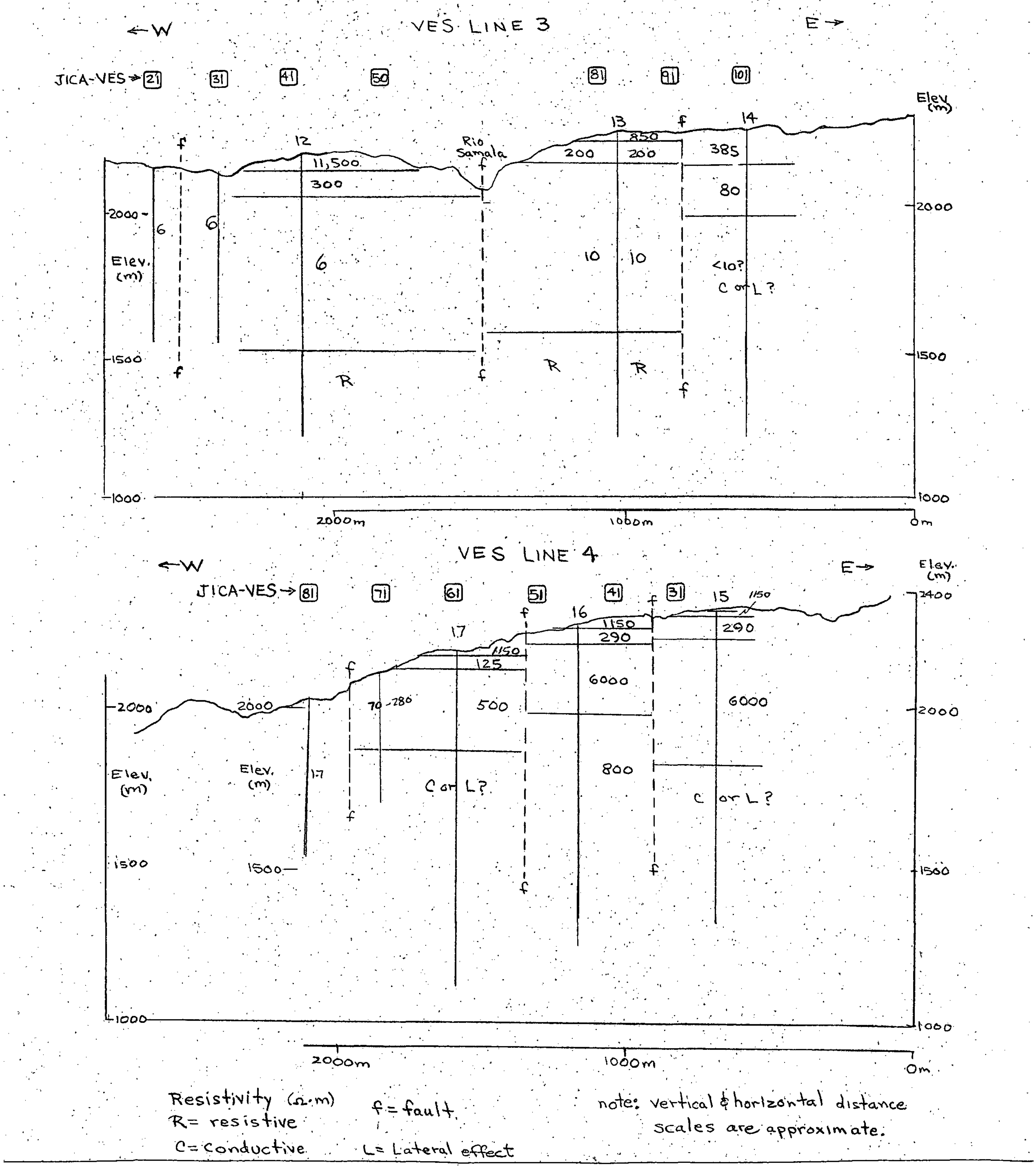
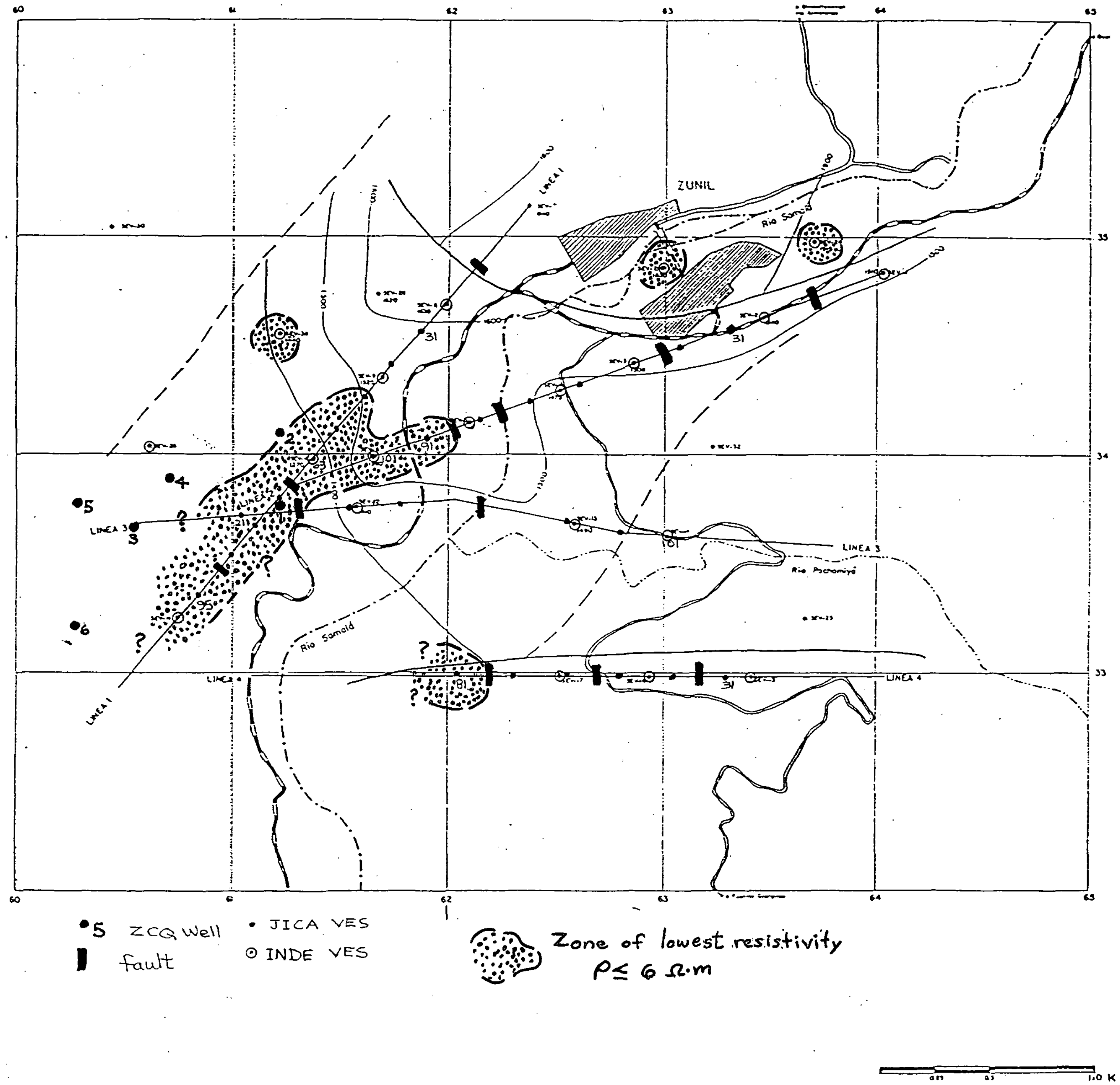


Figure 3. Electrical resistivity cross sections for INDE VES Lines 3 and 4. Corresponding JICA VES sounding locations are indicated.



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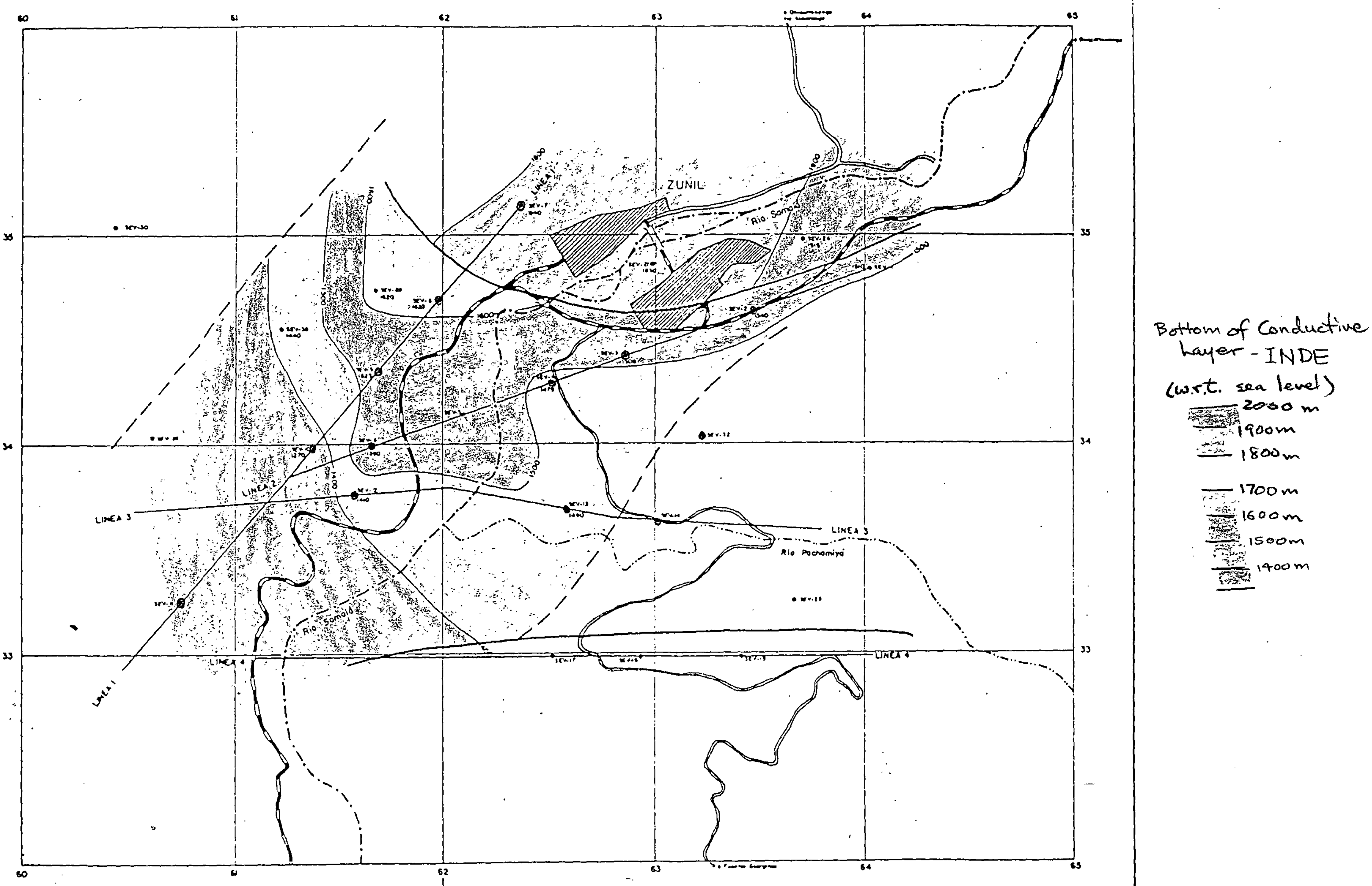
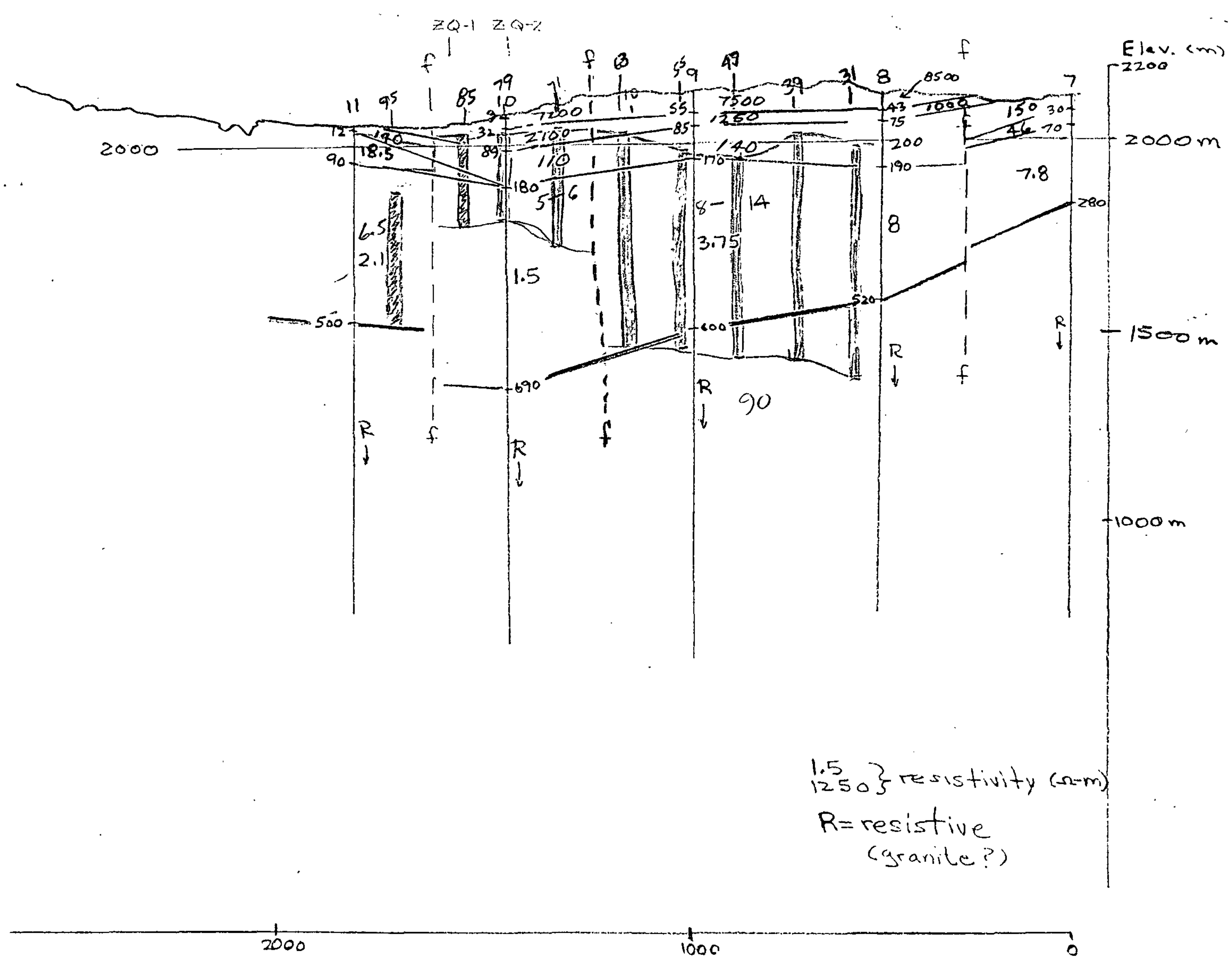
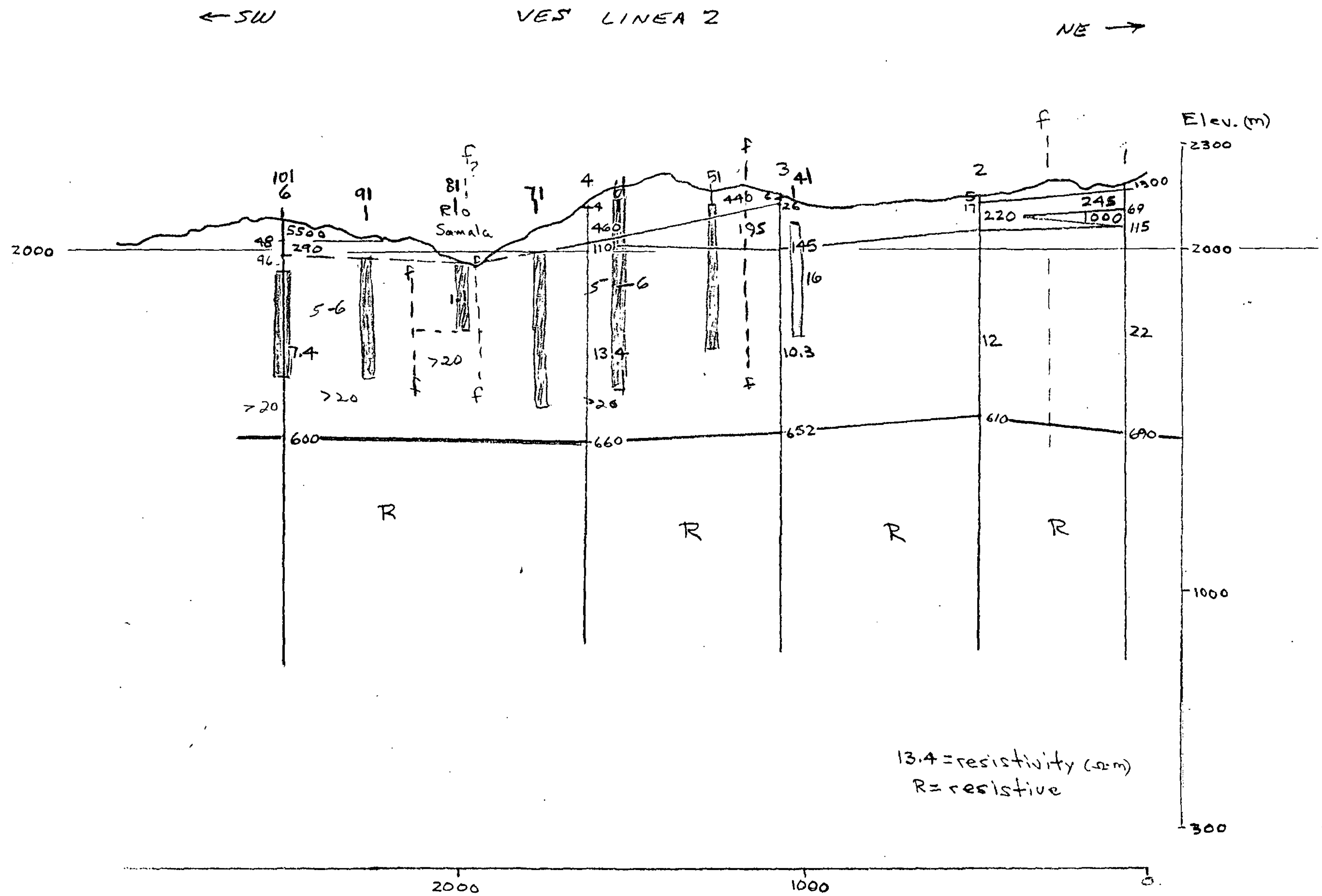
EARTH SCIENCE LABORATORY
391 CHIPETA WAY, SUITE C
SALT LAKE CITY, UTAH 84108
(801) 524-3422


ZUNIL
Rio Samala
Rio Pachamiya
LINEA 1
LINEA 2
LINEA 3
LINEA 4
1900
1800
1600
1500
1400
60
61
62
63
64
65
33
34
35
Bottom of Conductive Layer - INDE
(w.r.t. sea level)
2000 m
1900m
1800m
1700m
1600m
1500m
1400m

VES LINEA 1

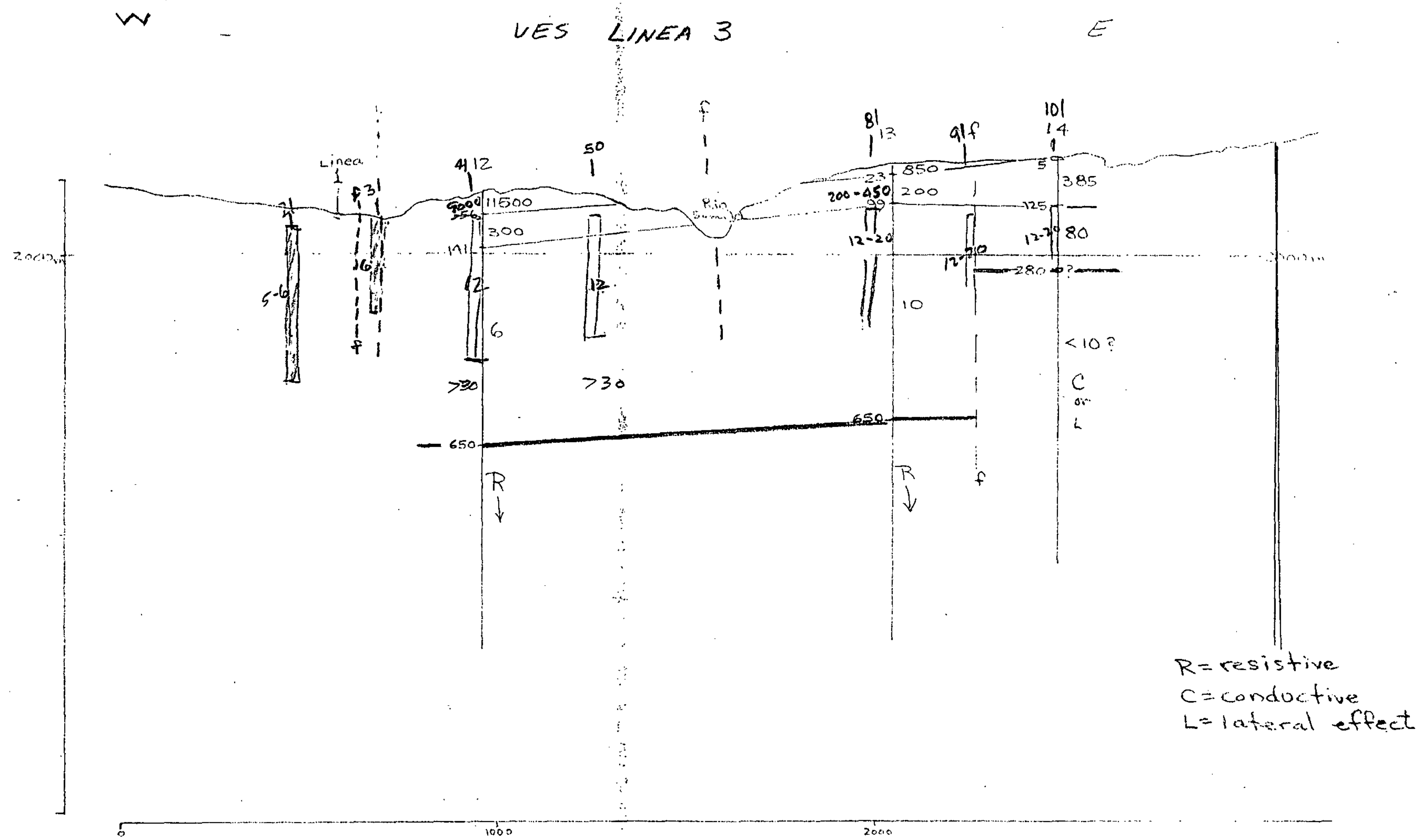


← SW
NE →
ZQ-1
ZQ-2
Elev. (m)
2200
2000 m
1500 m
1000 m
2000
f
R
1.5
1250 } resistivity (Ω-m)
R= resistive
(granite?)
2000
1000
0

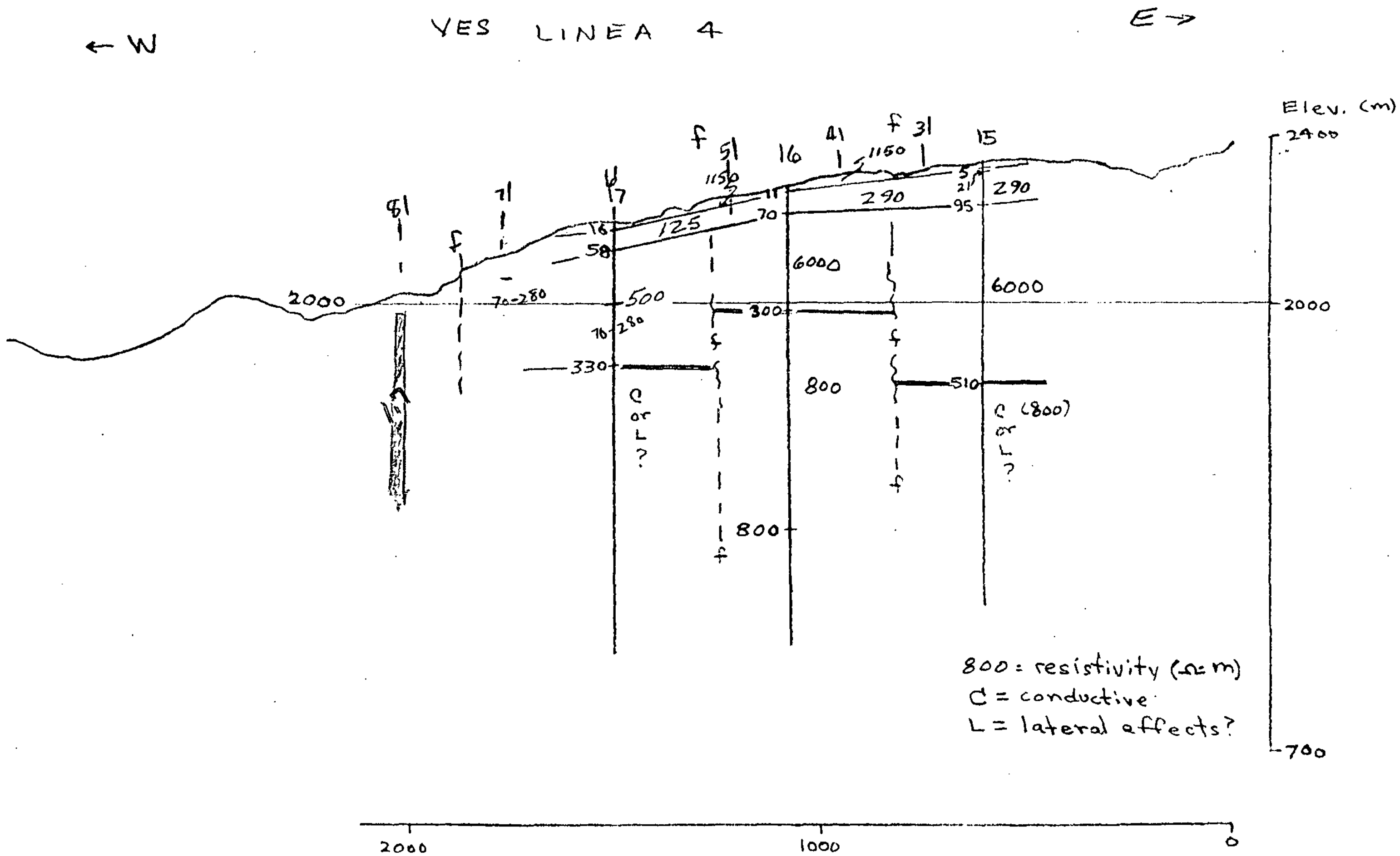


← SW
VES LINEA 2
NE →
Elev. (m)
2300
2000
1000
300
101
6
91
81
Rio
Samala
71
4
51
3
41
2
1
5500
290
48
96
5-6
7.4
>20
>20
>20
460
110
5-6
13.4
>20
446
195
26
145
16
10.3
5
17
220
245
1000
1300
69
115
12
22
600
660
652
610
690
R
R
R
R
f
f?
13.4 = resistivity (Ω·m)
R = resistive
2000
1000
0

VES LINEA 3


W
E
Linea
f
4 12
50
81 13
91 f
101 14
11500
300
850
200-450
200
385
80
280
12-20
5-6
16
12
6
>30
650
10
<10 ?
C
or
L
R
R
f
2000m
0
1000
2000
R = resistive
C = conductive
L = lateral effect

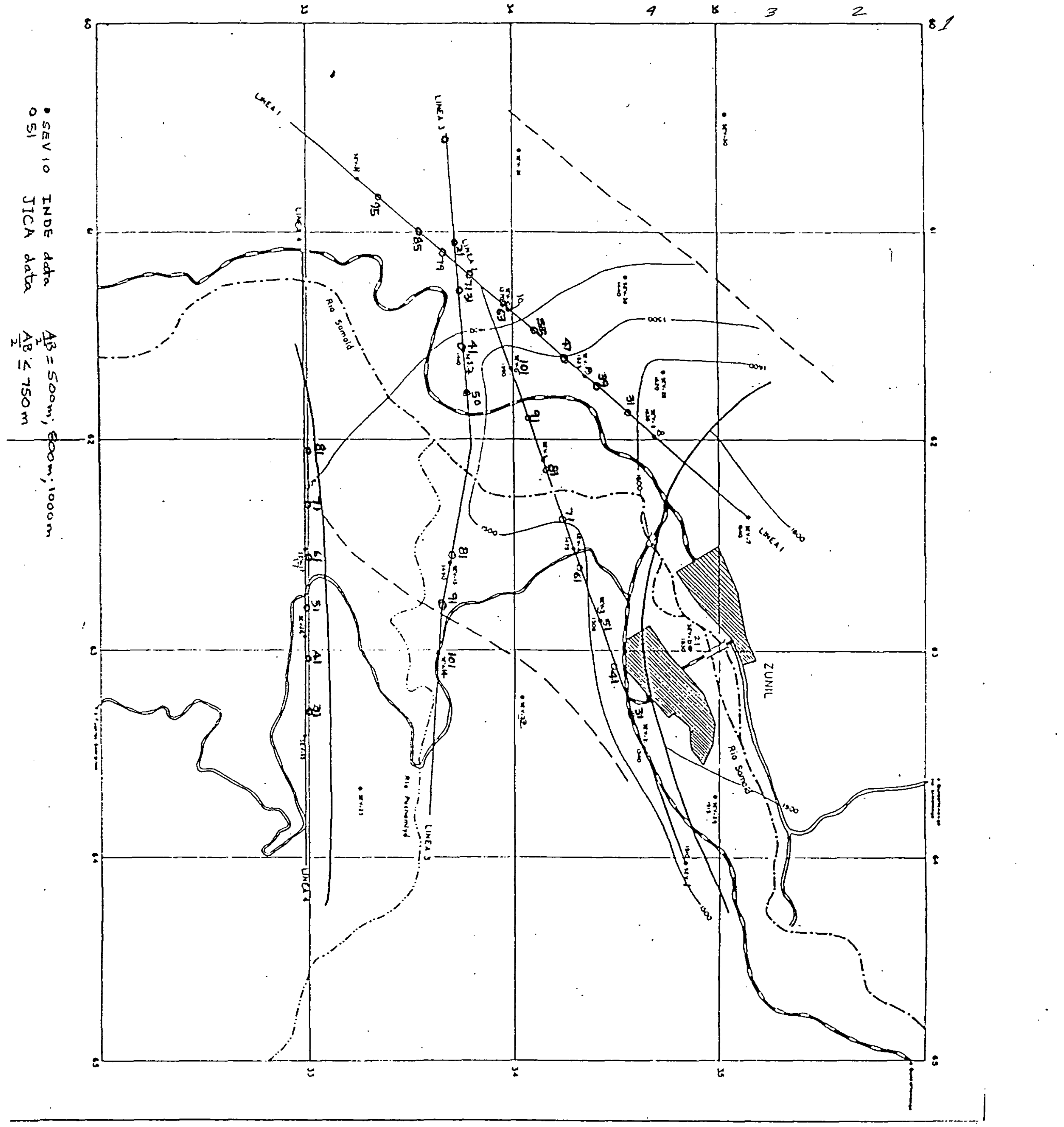
YES LINEA 4

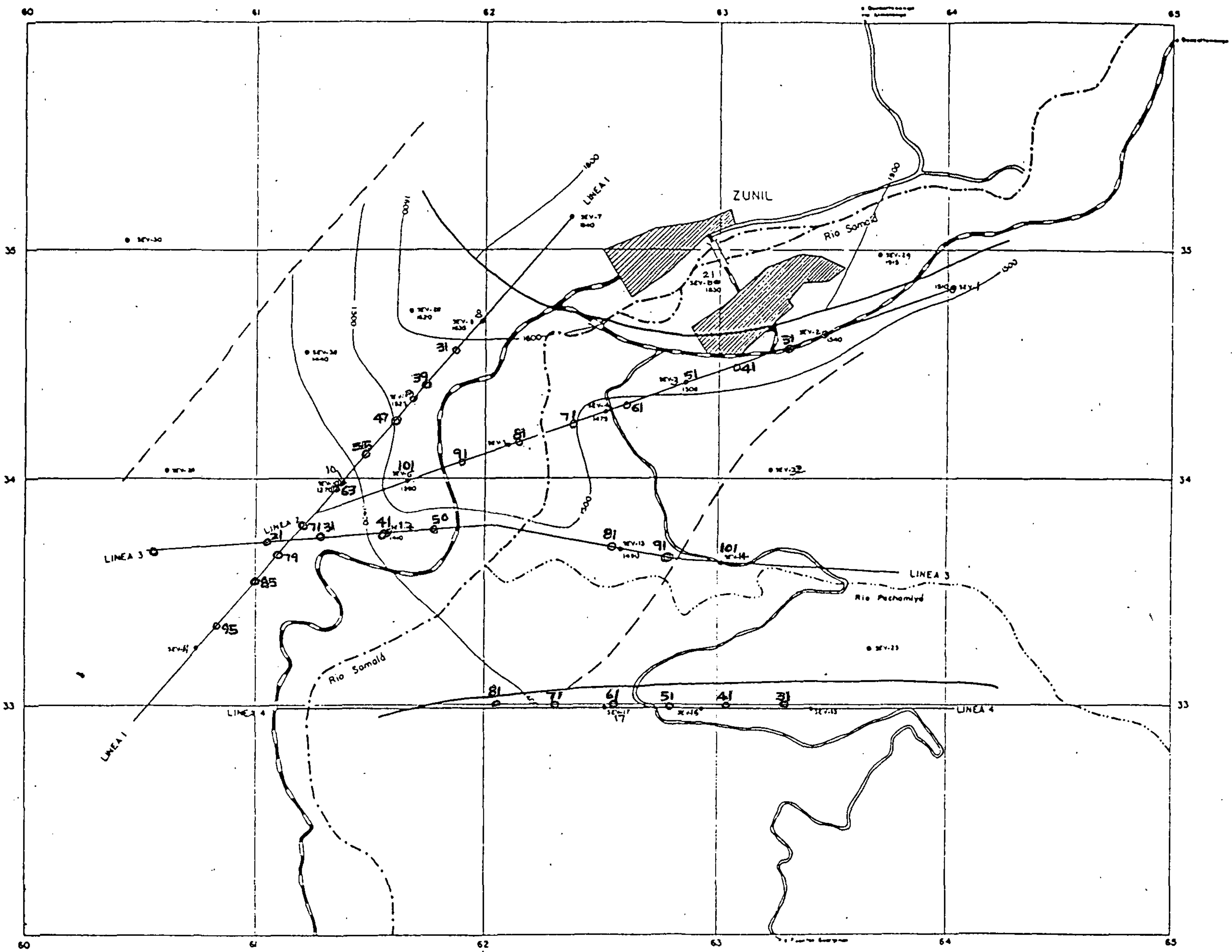


← W
E →
Elev. (m)
2400
2000
700
81
71
f
17
f
51
16
41
f
31
15
1150
1150
2000
16
58
125
11
70
290
5
21
95
290
6000
6000
70-280
500
76-280
300
330
800
510
C or L ?
C (800) or L ?
800
2000
1000
0
800 = resistivity (Ω·m)
C = conductive
L = lateral affects?

1.72 = 1.18 x 1.46

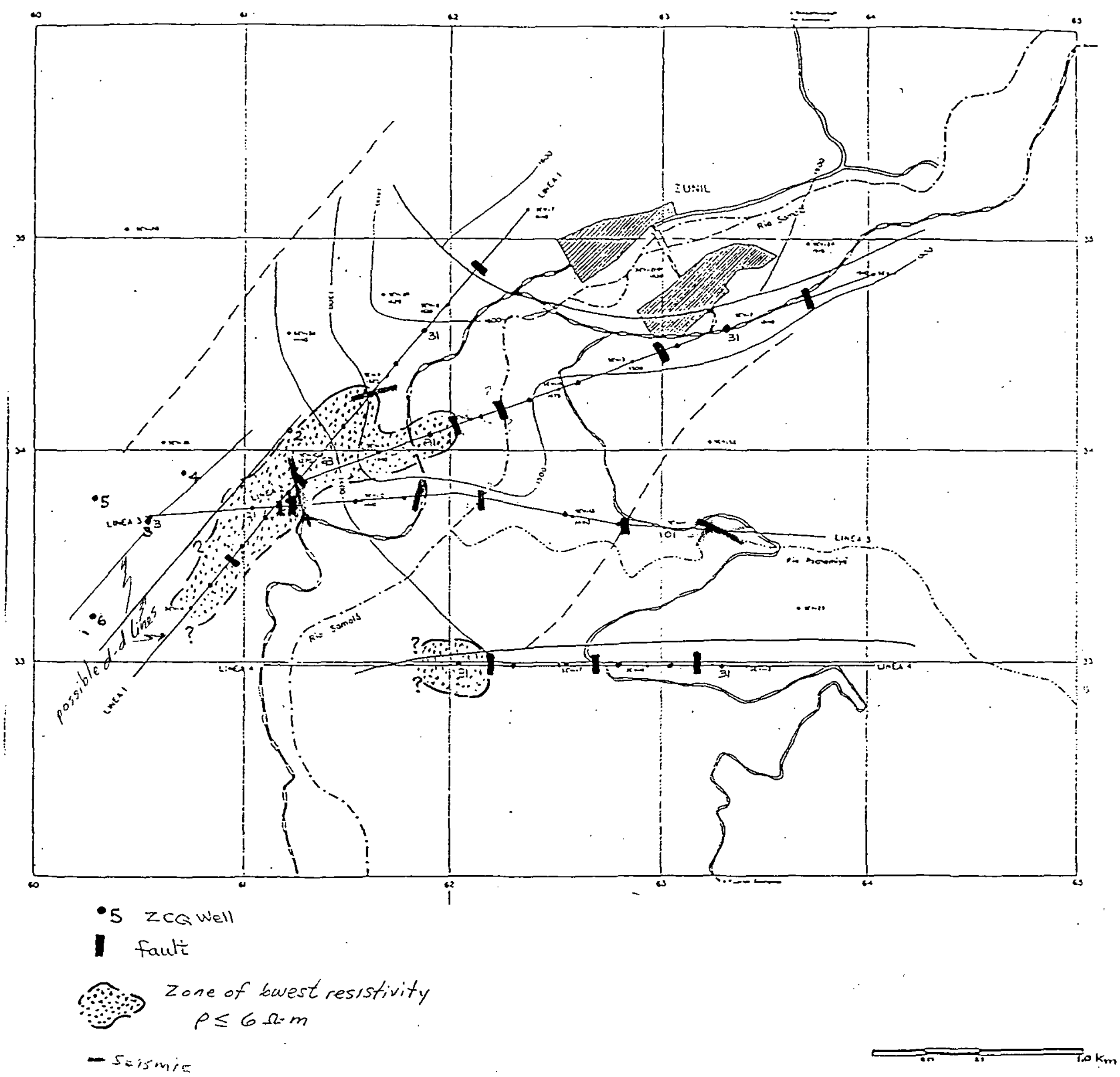
4.2 / 2.85 = 1.47 — 7.23 / 4.2 = 1.72 — 11.5 / 7.9 = 1.46 — 8.90 / 7.82 = 1.14





• SEV 10 INDE data $\frac{AB}{2}$ = 500m; 800m; 1000m
○ 51 JICA data $\frac{AB}{2} \leq$ 750m

X.80



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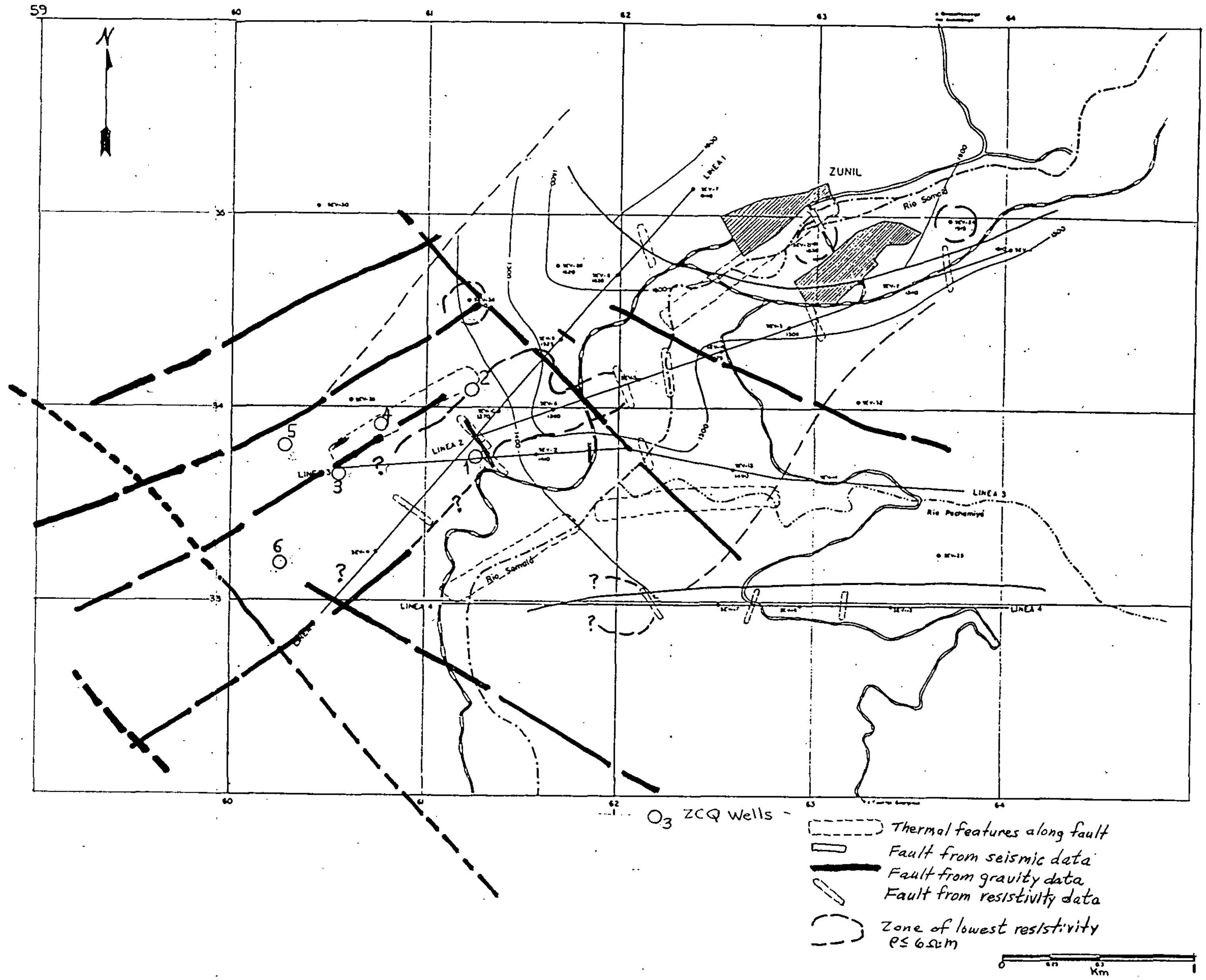
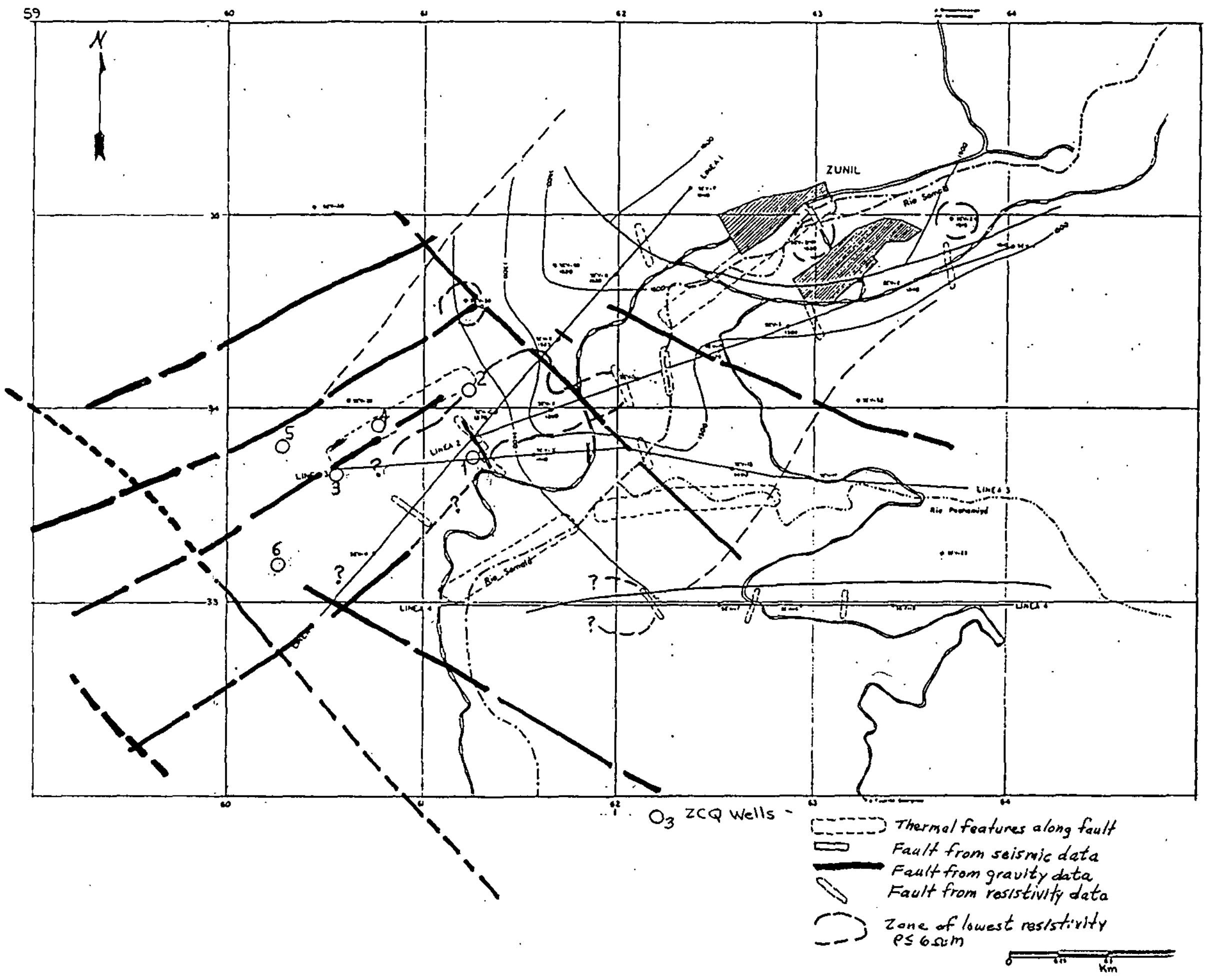
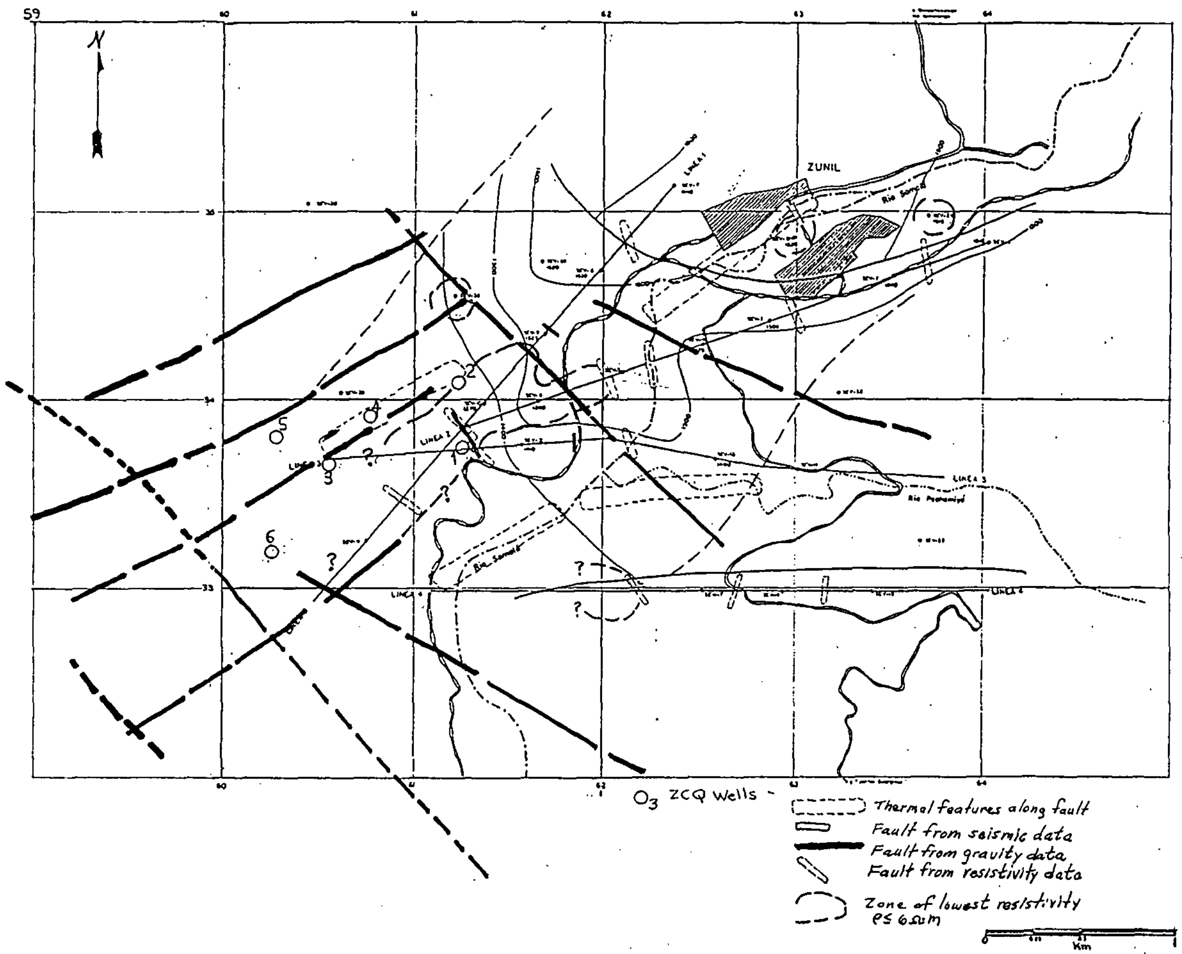
x.80


N
ZUNIL
Rio Samalá
Rio Pachamiyá
Río Samalá
LINEA 1
LINEA 2
LINEA 3
LINEA 4
1
2
3
4
5
6
59
60
61
62
63
64
35
34
33
O3 ZCQ Wells
Thermal features along fault
Fault from seismic data
Fault from gravity data
Fault from resistivity data
Zone of lowest resistivity
ρ≤ 6 Ω·m
Km

.80 x .80 = 1:40,000 6/5/89



x.80 x.78 6/5/89



59
60
61
62
63
64
35
34
33
N
ZUNIL
LINEA 3
LINEA 4
O3 ZCQ Wells
Thermal features along fault
Fault from seismic data
Fault from gravity data
Fault from resistivity data
Zone of lowest resistivity
ρ≤6Ωm
Km

EASYLINK 8832662C001 9MAY89 10:33/10:33 EST
FROM: 62822105
MORRISON-KNUDSEN CO INC
TO: 8015817880

10-87/GUA/UTAH/381

MAY 9, 1989 (this is a new copy of msg, original was canceled by WUC)

TO : JOE MOORE UURI/UTAH

FROM : LUIS MERIDA CYM/GUA

CC. : ROY MINK MKF/BSE

DEAR JOE:

YESTERDAY I HAD A MEETING WITH ING. PALMA AT INDE AND I RECEIVED A LETTER FROM INDE REQUIRING A MORE COMPLETE EXPLANATION OF THE PURPOSE OF THE STUDIES INCLUDED IN THE NEOTECTONIC AND HYDRO PROPOSALS. TALKING TO ING. PALMA HE MAKE ME A LONG EXPLANATION THAT YOU MAY SUSPECT COMES FROM MARINELI ACTITUD WHEN WE MET HIM. THIS IS ALSO IMPLIED IN HIS REPORT. ALTHOUGH THERE ARE SOME THOUGHTS ON THE EXECUTIVE SUMMARY AND INTRODUCTION CHAPTERS OF THE NEOTECTONIC AND HIDRO STUDIES PROPOSALS, I WILL APPRECIATE FROM YOU IF YOU SEND ME A MEMO EXPLAINING WHAT ARE THE MAIN PURPOSES OF THE FOLLOWING STUDIES FOR THE LOCATION OF THE NEW DEVELOPMENT WELLS

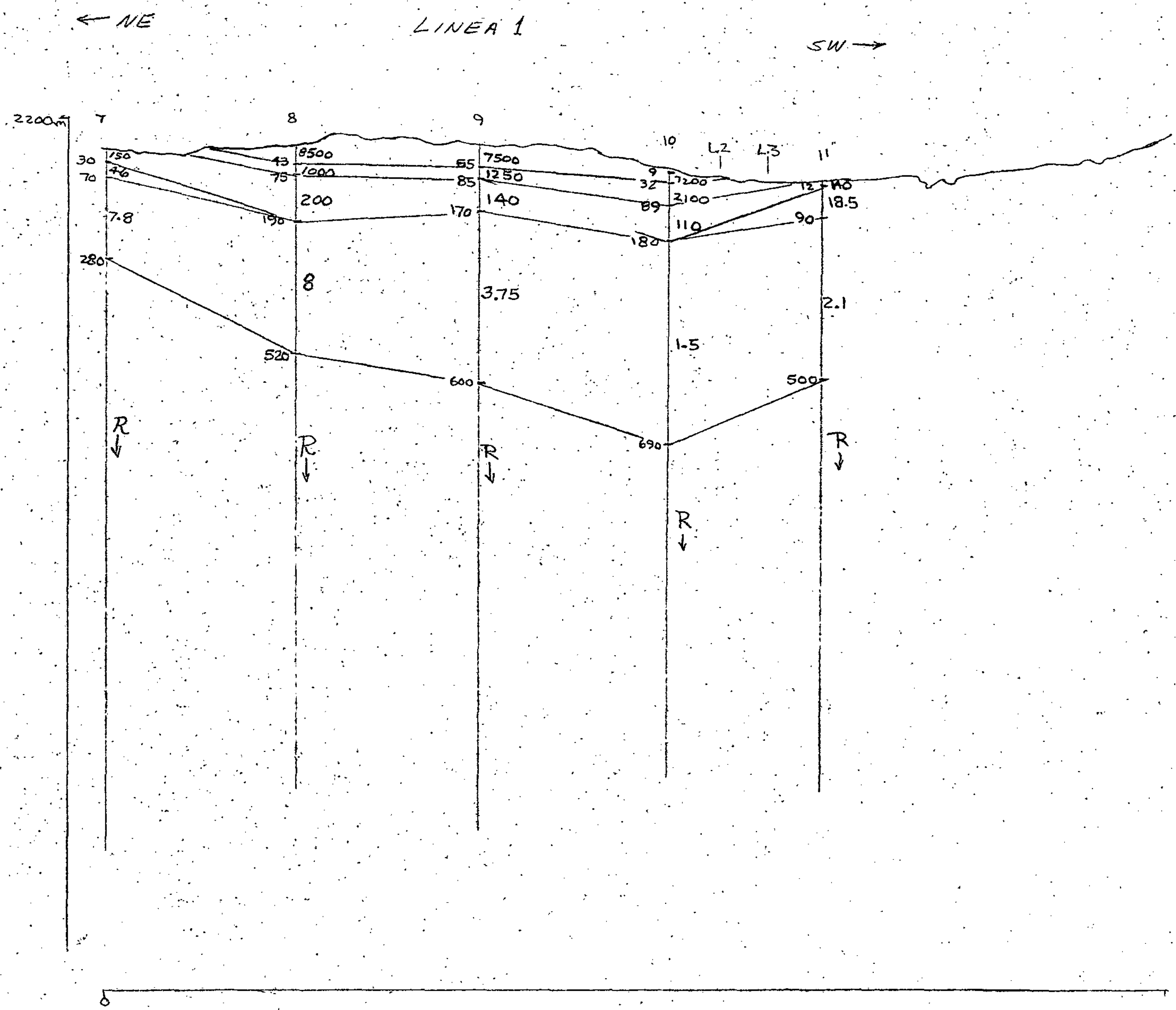
1. X-RAY STUDIES
2. FLUID INCLUSIONS
3. ISOTOPES FOR WATERS AND CORES. (FRAZER GOFF'S REQUIREMENT?)
4. GEOCHEMICAL INVESTIGATION
5. STABLE ISOTOPES
6. MERCURY SURVEY

SORRY BOTHERING YOU WITH THIS THINGS BUT I NEED TO.

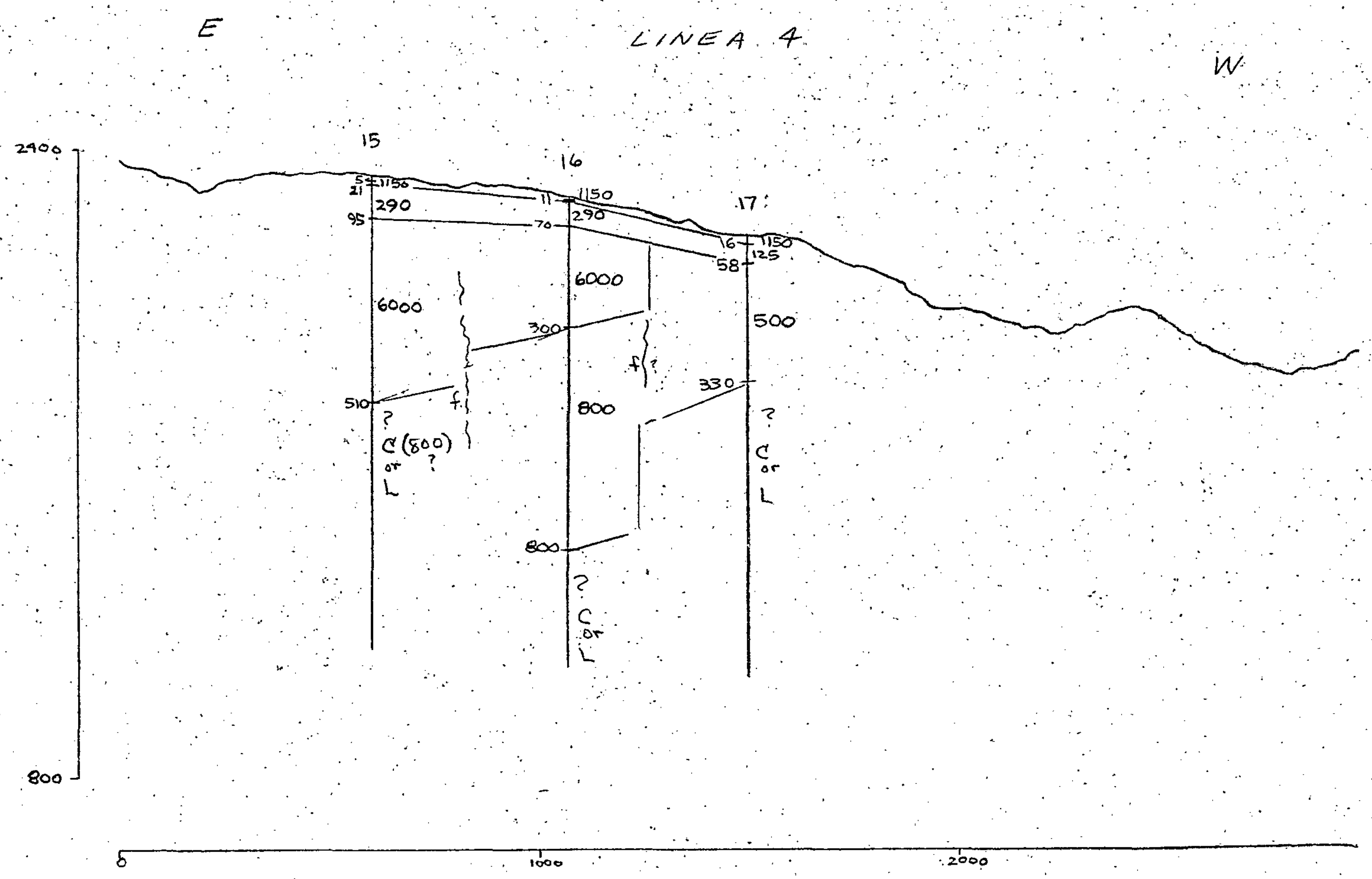
GOOD NEWS FROM Z-20; MINUTES AGO I HAVE A CALL FROM OCTAVIO TELLING ME THAT HE COLLECTED THE SAMPLES FROM Z-20 PLUS A TWIN SPRING CLOSE BY. HE MEASURED 8.5PH AND 94oC ON A 0.4 LPS; THE TWIN SPRING IS 4.5 PH, 58oC AND LOTS OF MORE WATER 1.25 LPS. I WILL BE SENDING YOU DETAILS AND THE SAMPLES; PLUS Z-17 AND THE GRANODIORITE SAMPLES.

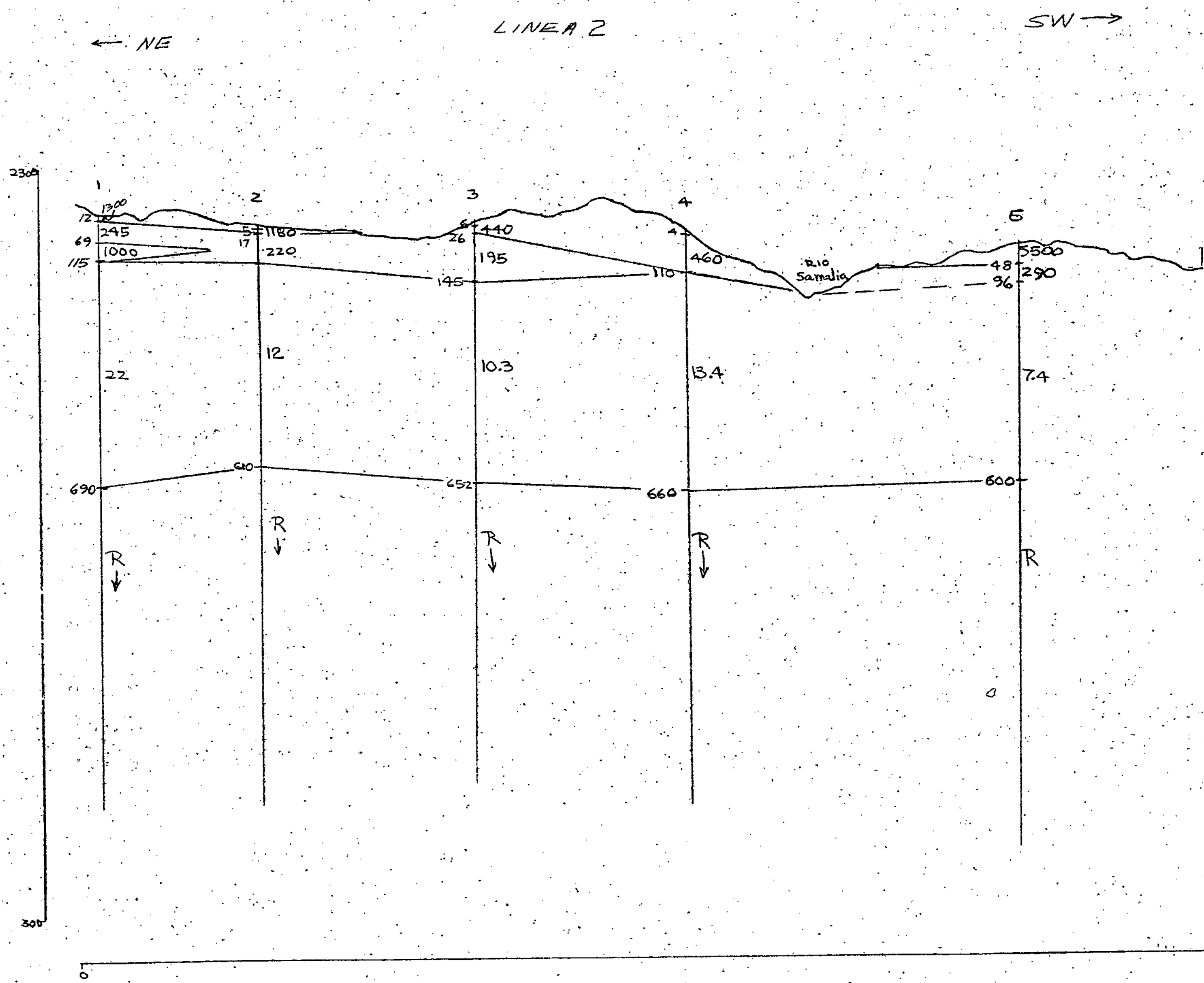
ENJOY THE WEEKEND.

MMMM

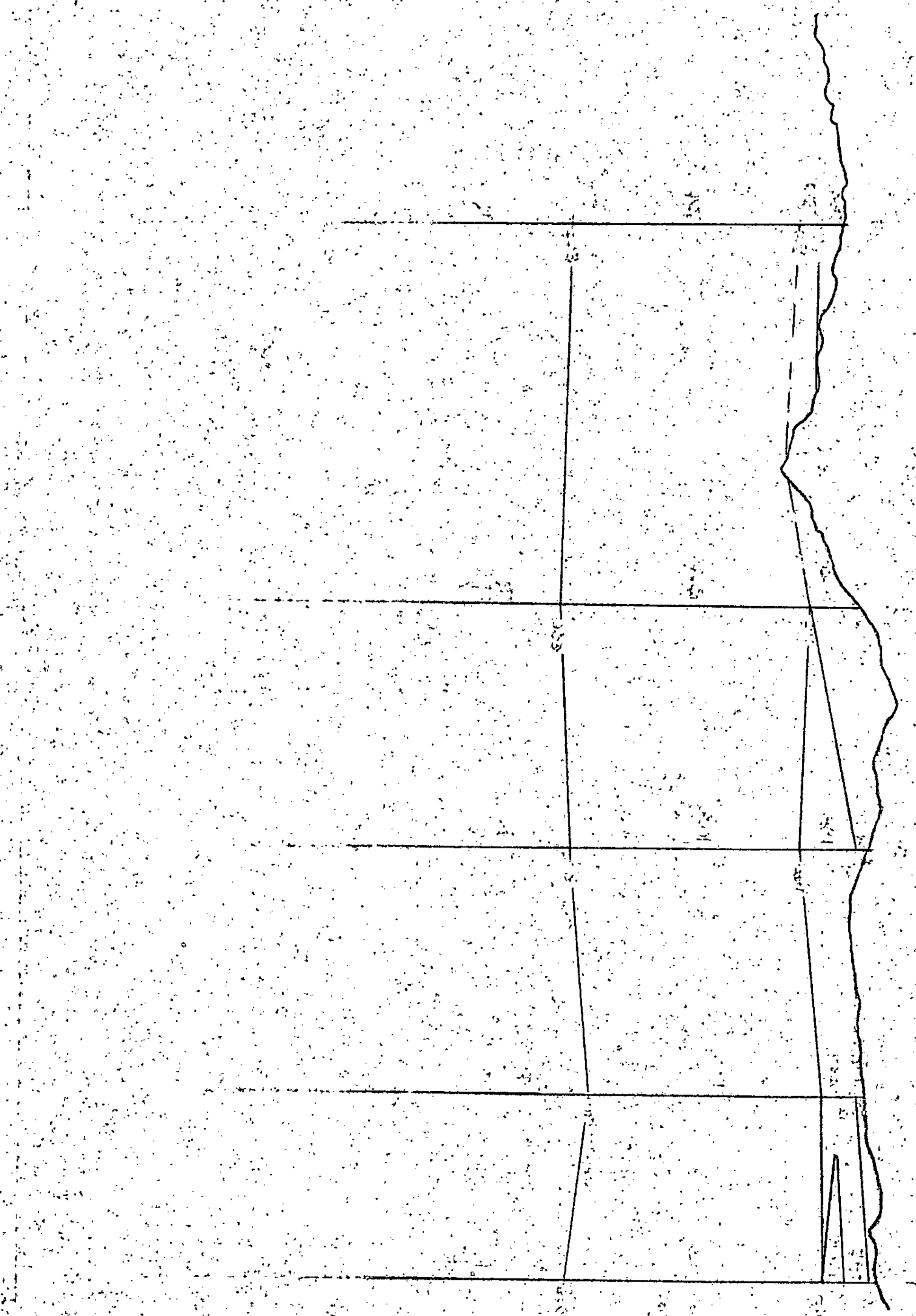


← NE
LINEA 1
SW →
2200m
7
8
9
10
L2
L3
11
R

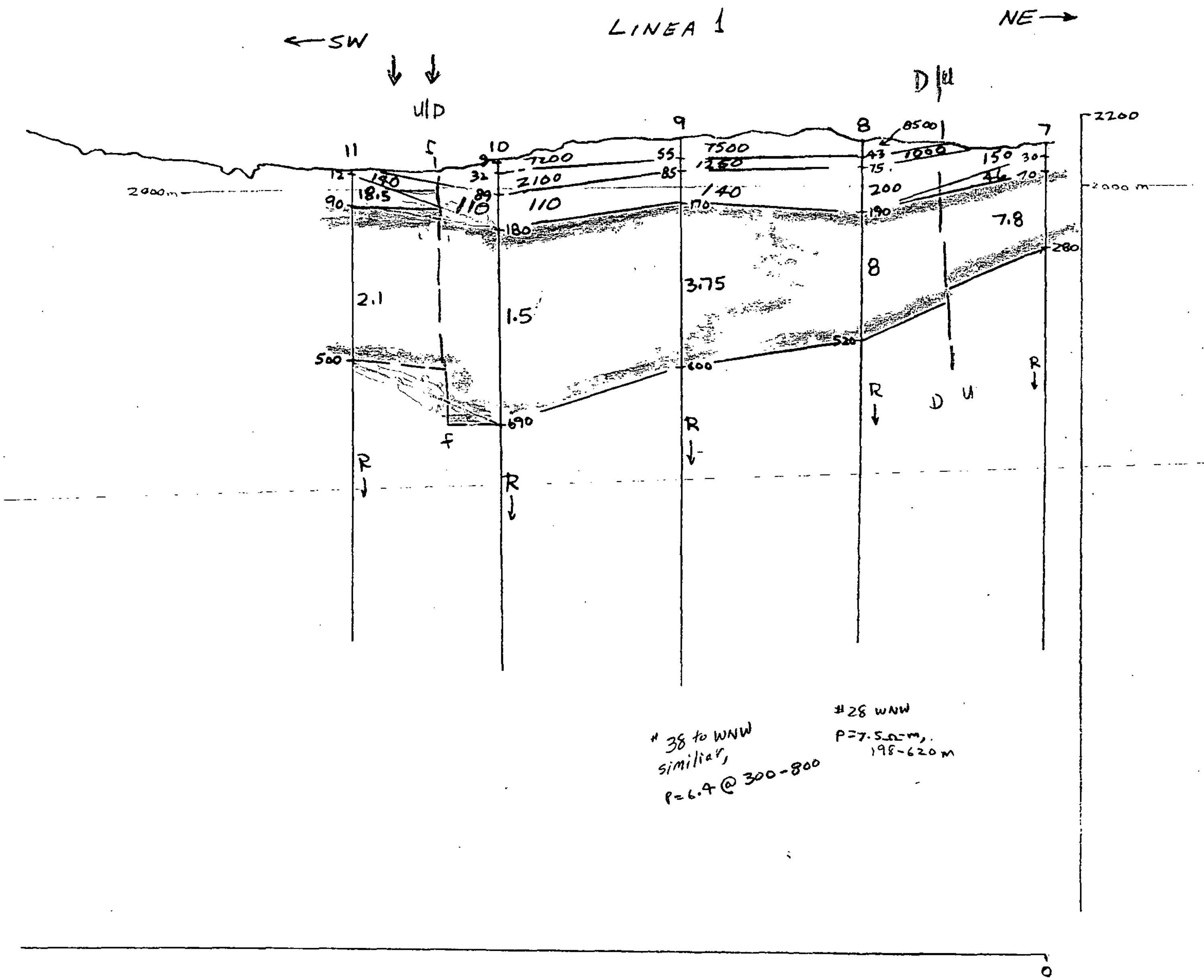

E
LINEA 4
W
15
16
17
2900
800
0
1000
2000
1150
290
95
6000
510
C (800) or L
300
800
f
6000
500
330
C or L



← NE
LINEA 2
SW →
1
2
3
4
5
Rio Samalia
1300
12
245
69
1000
115
5
1180
17
220
6
440
26
195
145
4
460
110
5500
48
290
96
22
12
10.3
13.4
7.4
690
610
652
660
600
R
2300
300
0

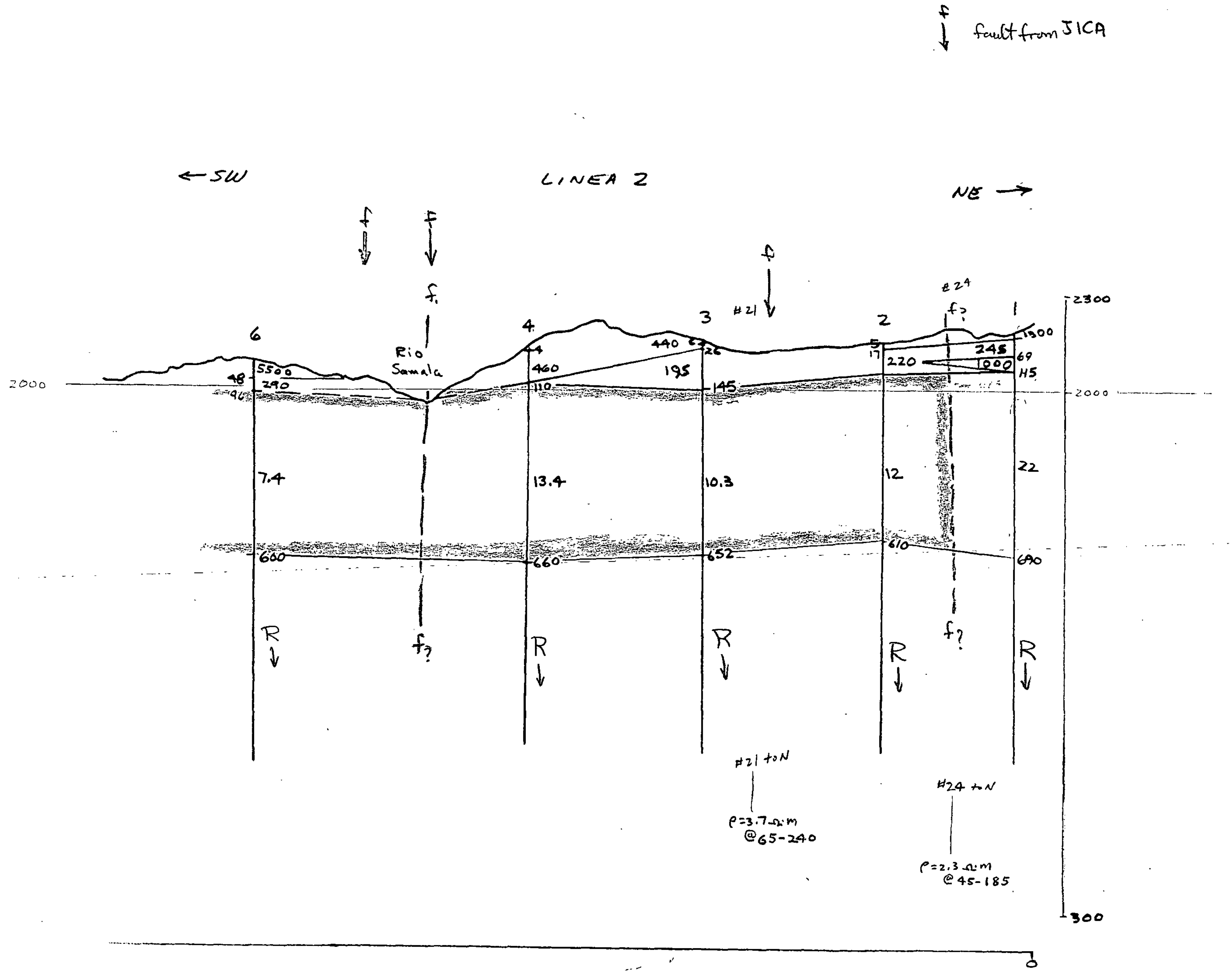


↓ fault from JICA

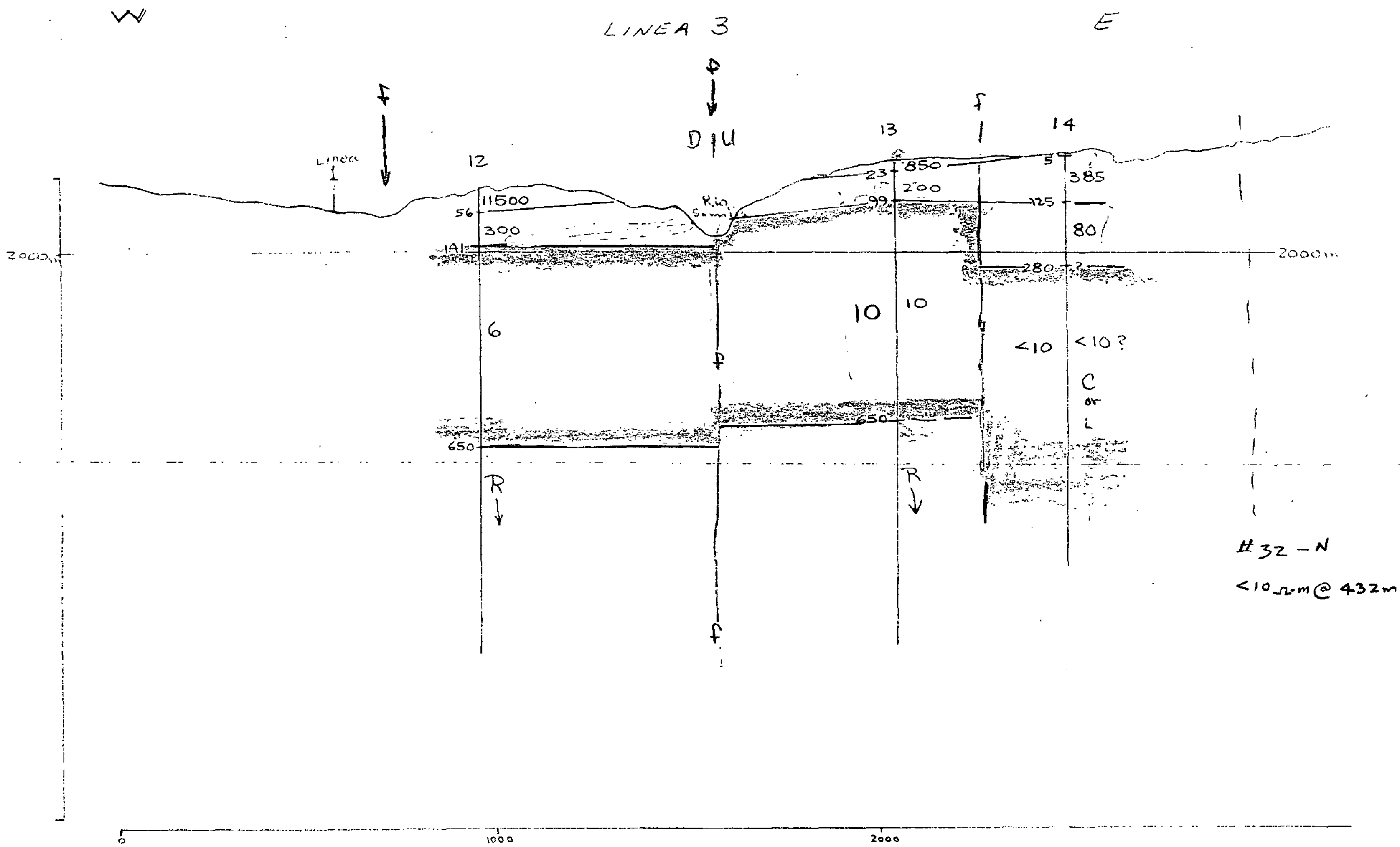


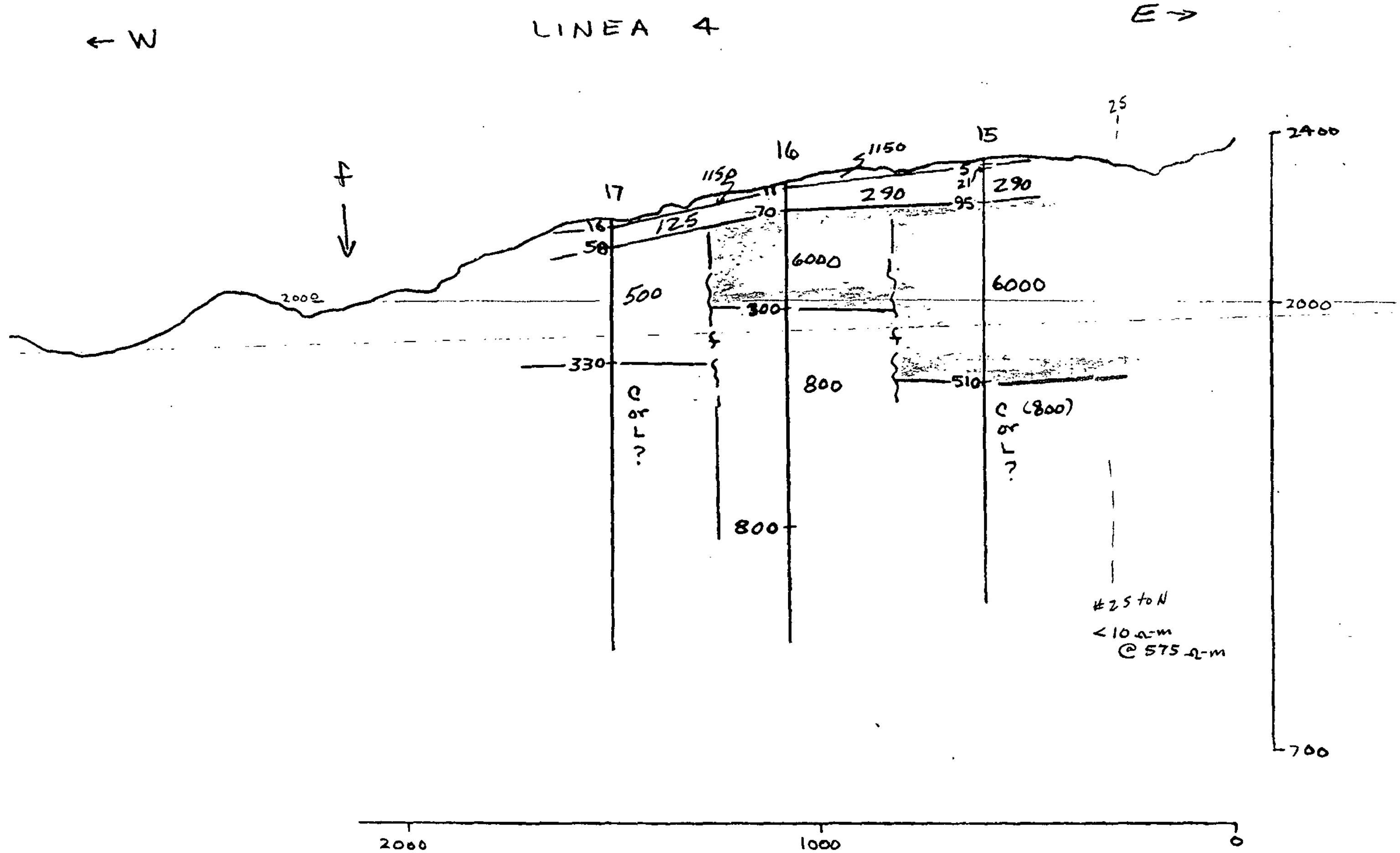
" 38 to WNW
similiar,
ρ=6.4 @ 300-800

#28 WNW
ρ=7.5 Ω-m,
198-620 m

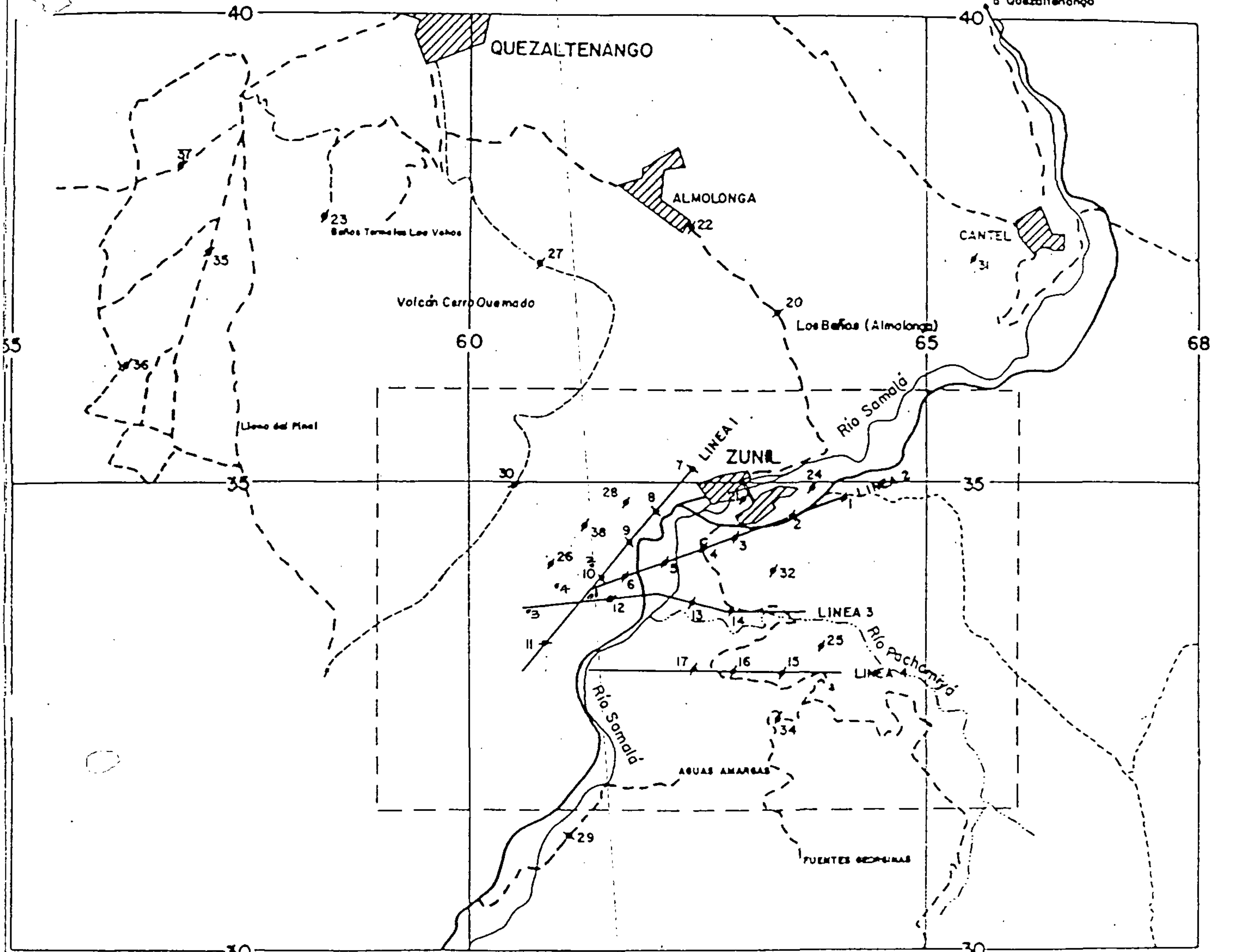


f fault from JICA
← SW
LINEA 2
NE →
f
f
f
f
f?
#21
#24
6
4
3
2
1
Rio Samala
2300
2000
2000
300
5500
48
290
96
440
460
110
195
145
26
5
17
220
245
1000
145
1300
69
7.4
13.4
10.3
12
22
600
660
652
610
690
R
R
R
R
R
f?
f?
#21 to N
ρ=3.7 Ω·m
@65-240
#24 to N
ρ=2.3 Ω·m
@45-185
0


W
LINEA 3
E
f
D | U
Linea 1
12
13
14
11500
56
300
141
2000m
6
f
650
R
850
23
200
99
385
5
125
80
280
10
10
<10
<10 ?
C
650
R
#32 - N
<10 Ω·m @ 432m
0
1000
2000



LINEA 4
← W
E →
f
2000
17
16
15
25
1150
1150
16
58
125
11
70
290
5
21
95
290
6000
6000
500
300
330
800
510
C or L ?
C (800) or L ?
800
#25 to N
<10 Ω-m
@ 575 Ω-m
2400
2000
700
2000
1000
0



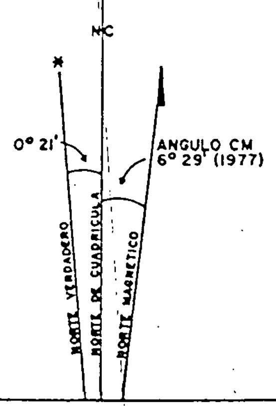
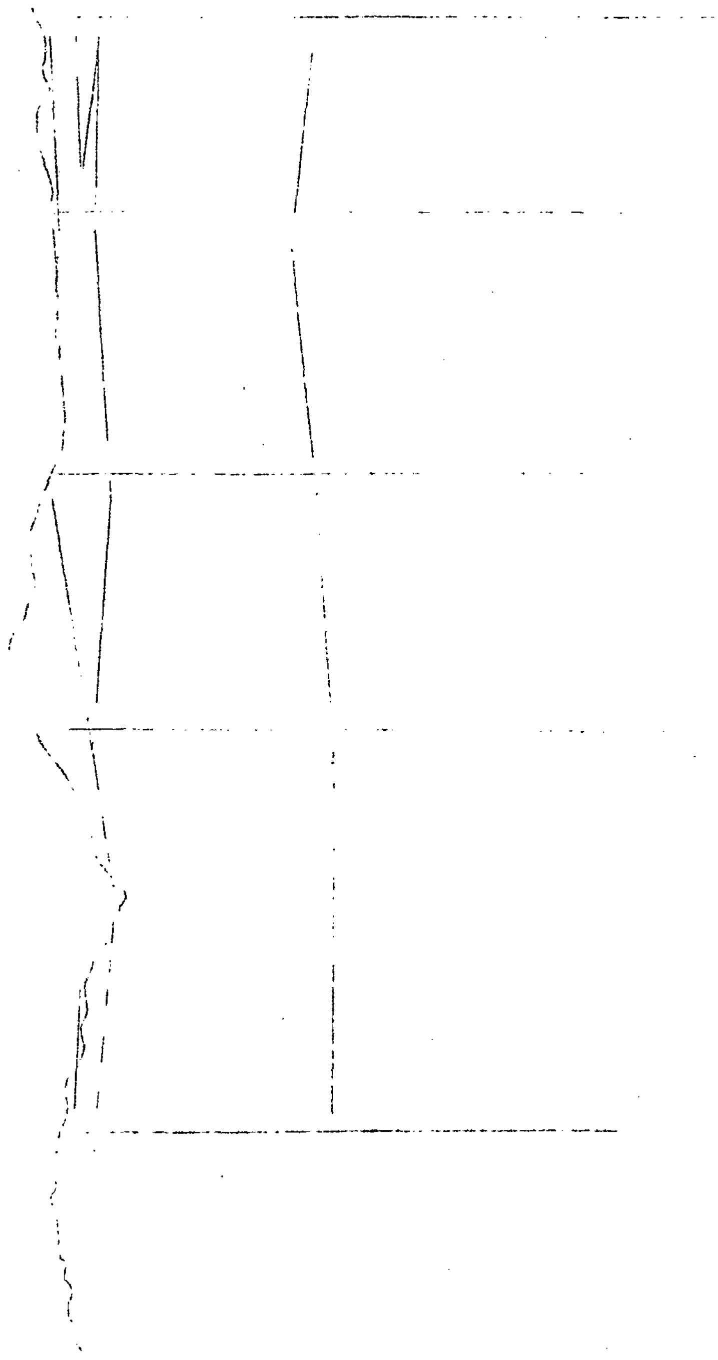


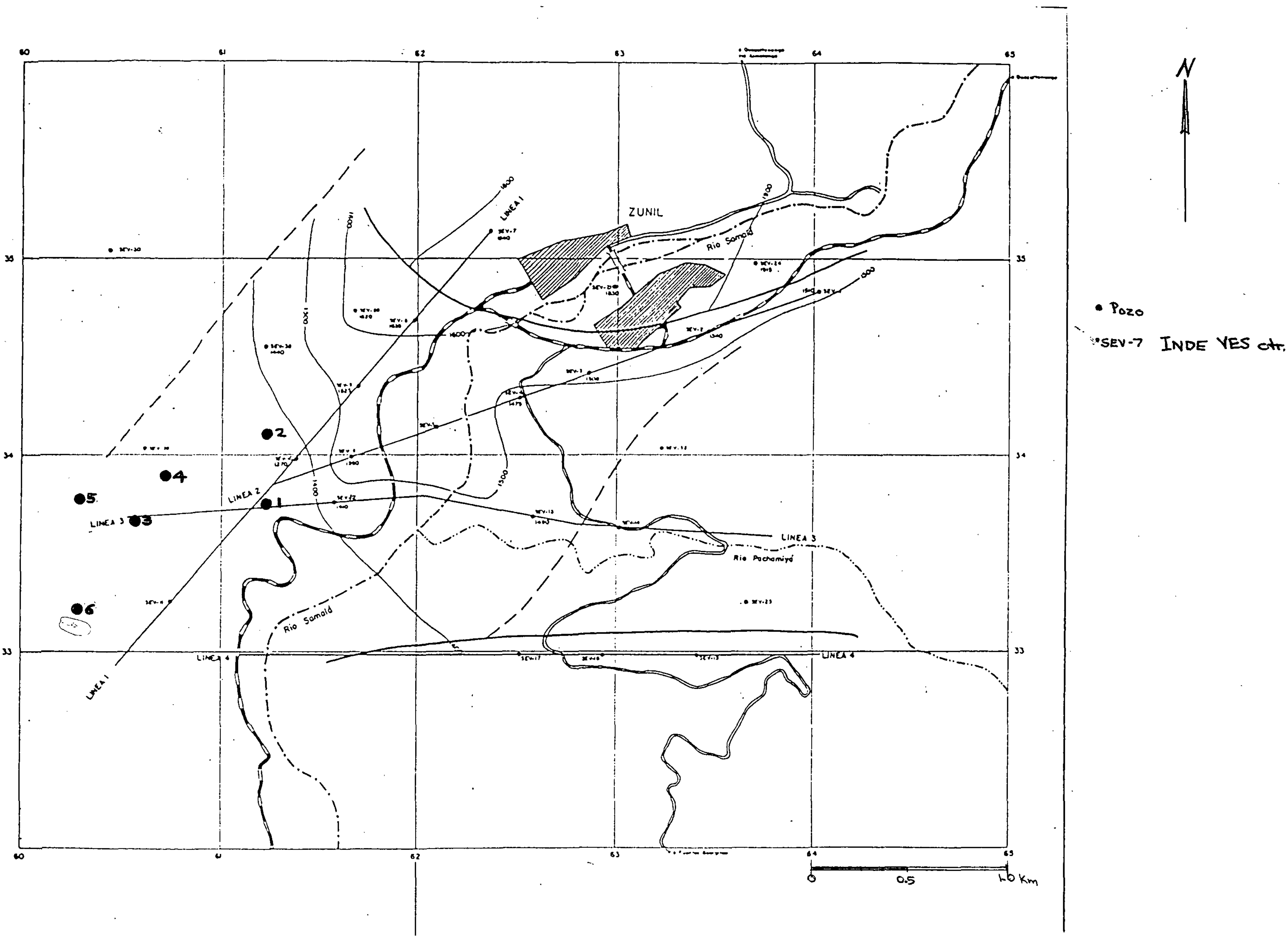
FIG. 4.1

SONDEO ELECTRICO VERTICAL (S.E.V.)
AB/2 = 2000. ARREGLO SCHLUMBERGER.

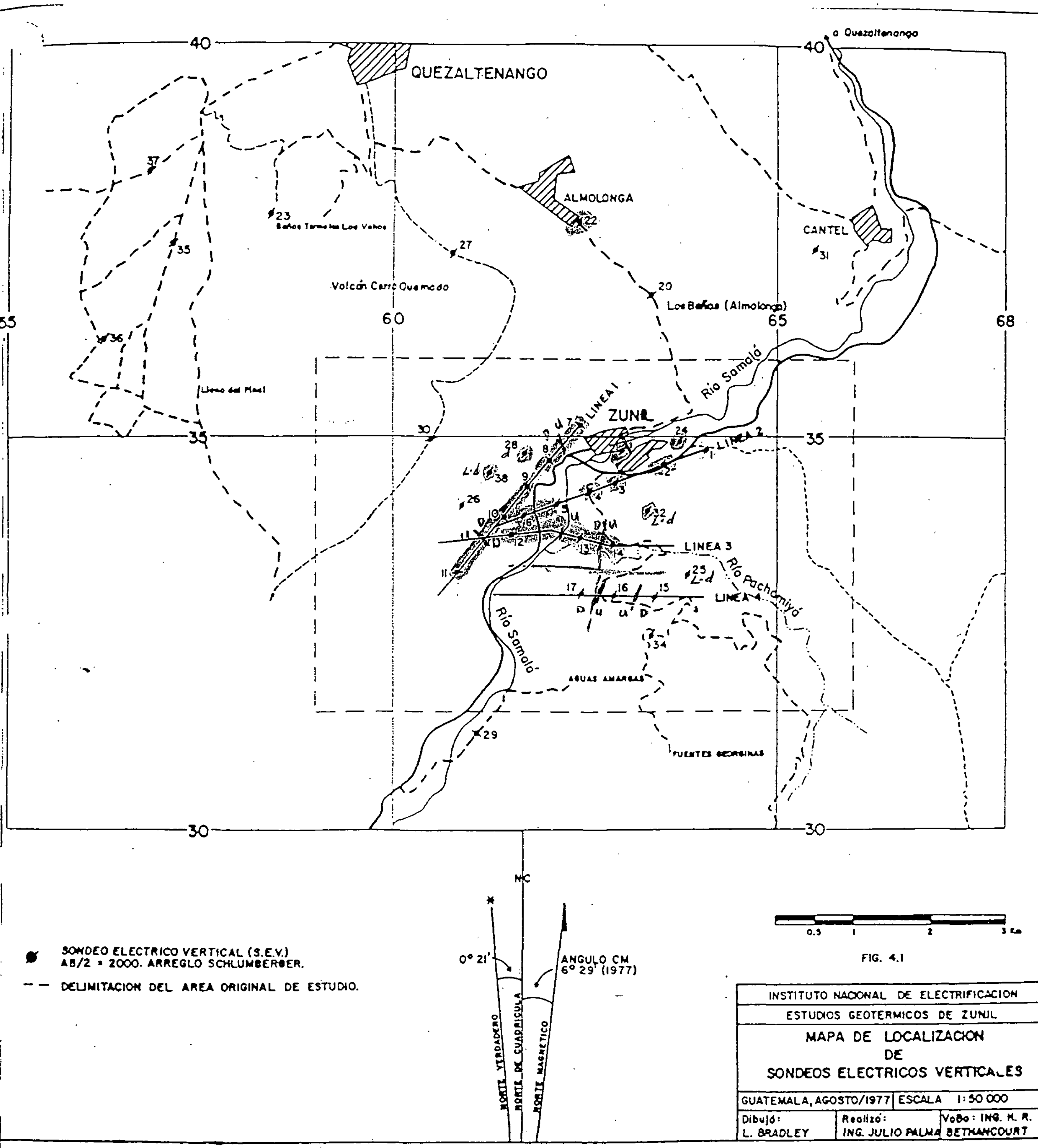
DELIMITACION DEL AREA ORIGINAL DE ESTUDIO.

INSTITUTO NACIONAL DE ELECTRIFICACION		
ESTUDIOS GEOTERMICOS DE ZUNIL		
MAPA DE LOCALIZACION DE SONDEOS ELECTRICOS VERTICALES		
GUATEMALA, AGOSTO/1977	ESCALA 1:50 000	
Dibujó: L. BRADLEY	Realizó: ING. JULIO PALMA	VoBo: ING. H. R. BETHANCOURT





ZUNIL
Rio Samala
Rio Pachamiya
LINEA 1
LINEA 2
LINEA 3
LINEA 4
1
2
3
4
5
6
60
61
62
63
64
65
33
34
35
0
0.5
1.0 Km
N
• Pozo
SEV-7 INDE VES ctr.

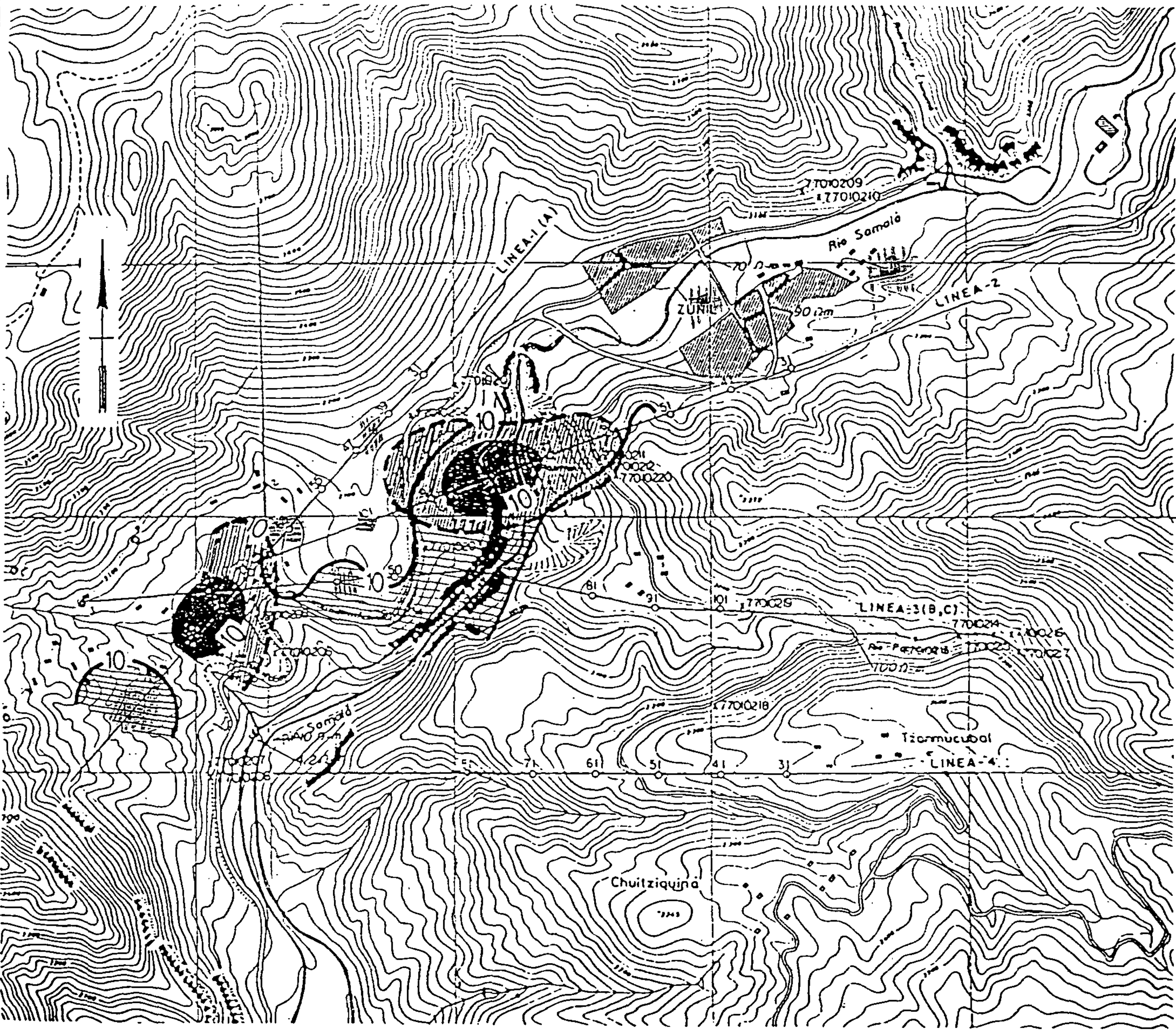


1.5 – 3.75
6 – 10.3
12 – 20
22 – 40

no data: #5
#20, #27, #23, #26
#30, #34

max depth ~ 650 m

L = lateral
d = deep



SIMBOLOGIA

 $AB/2 = 250$

 $AB/2 = 500$

 $AB/2 = 750$ JICA

Comparison with INDE VES

0 05 1Km

ESCALA GRAFICA

INFORMACION BASE: AGENCIA INTERNACIONAL DE COOPERACION DEL JAPON. (JICA).

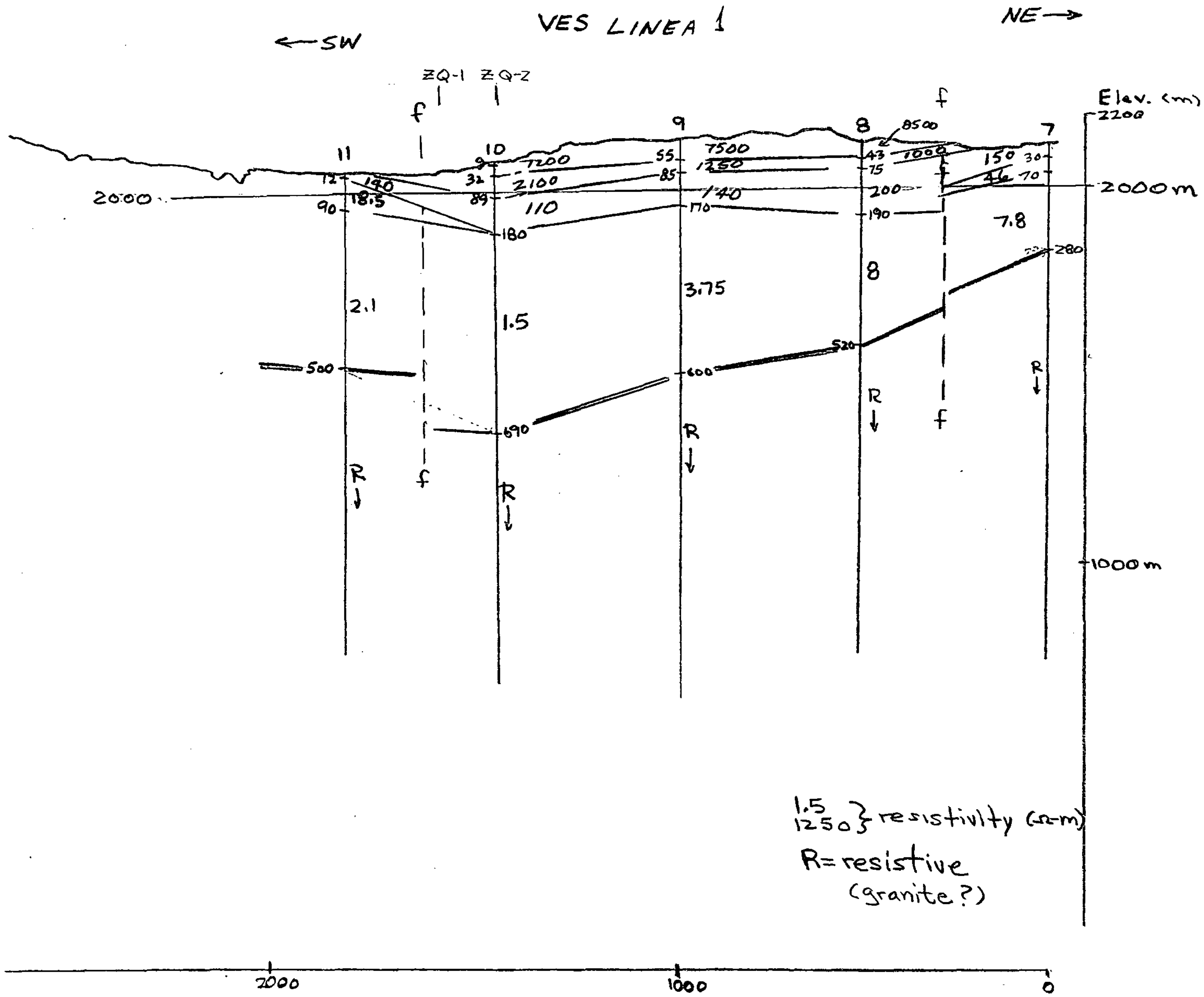
INSTITUTO NACIONAL DE ELECTRIFICACION
INDE GUATEMALA C.A.

PROYECTO GEOTERMICO ZUNIL I

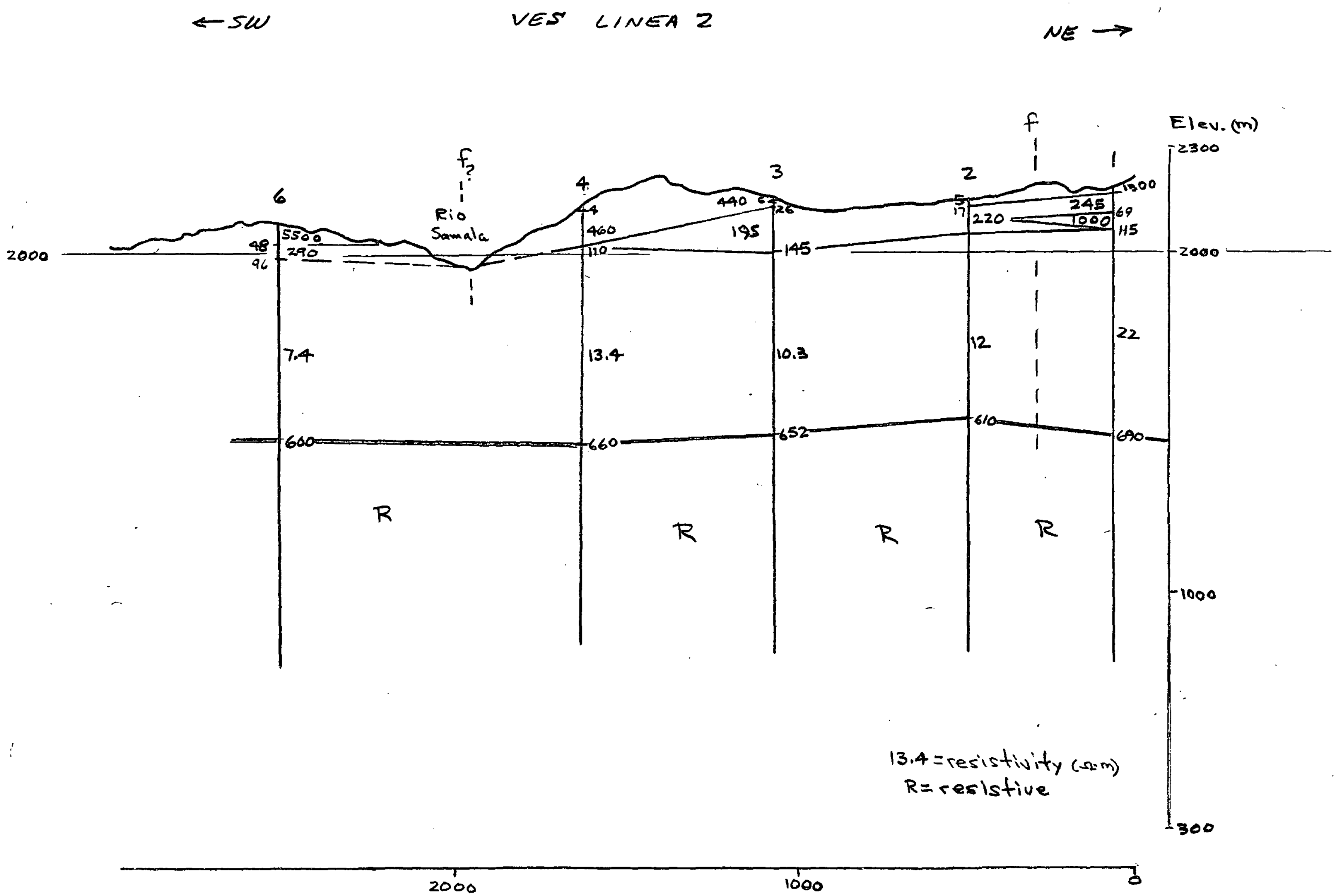
MAPA DE RESISTIVIDAD APARENTE

CyM/MKF

FIGURA: 3.3-20

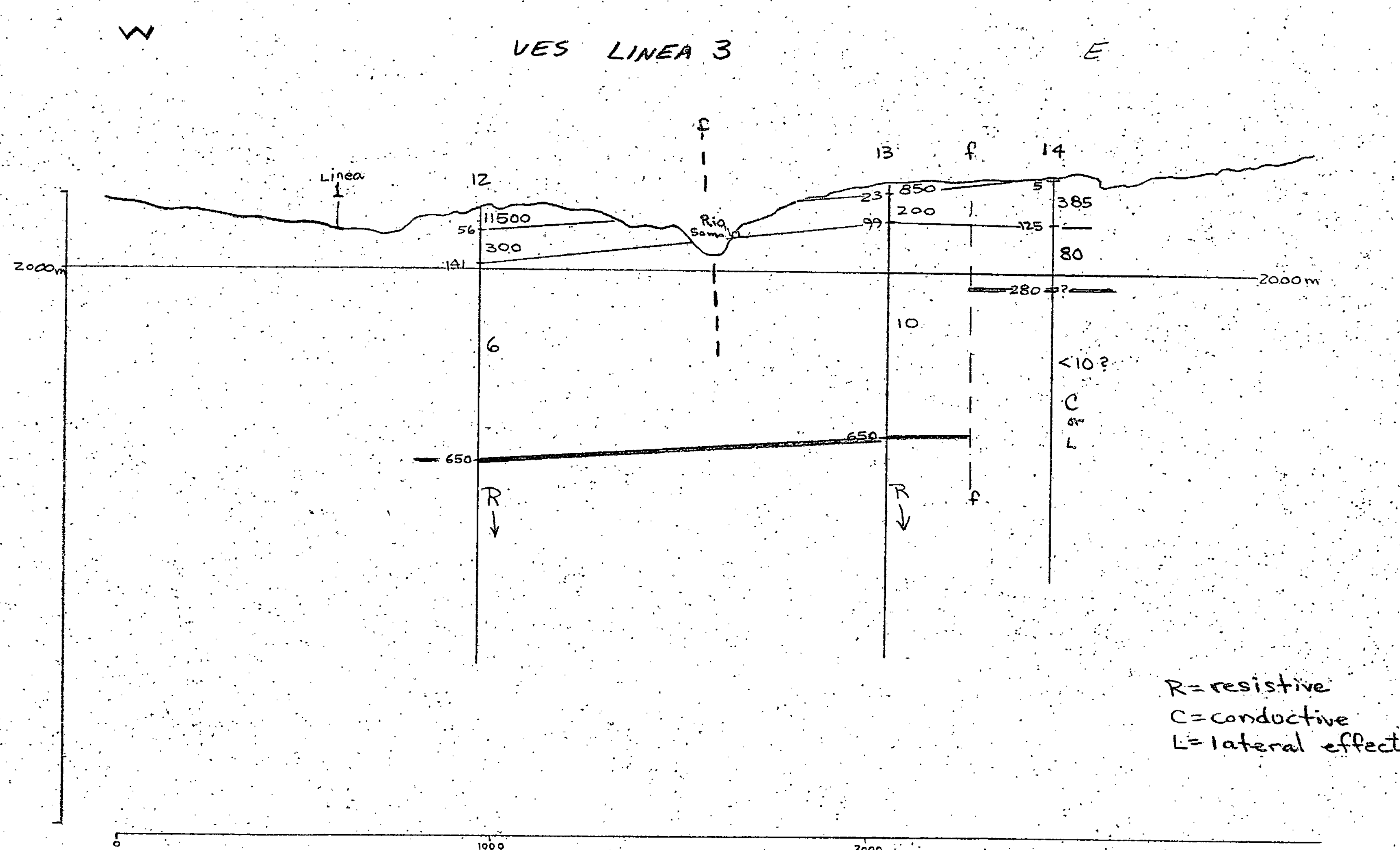


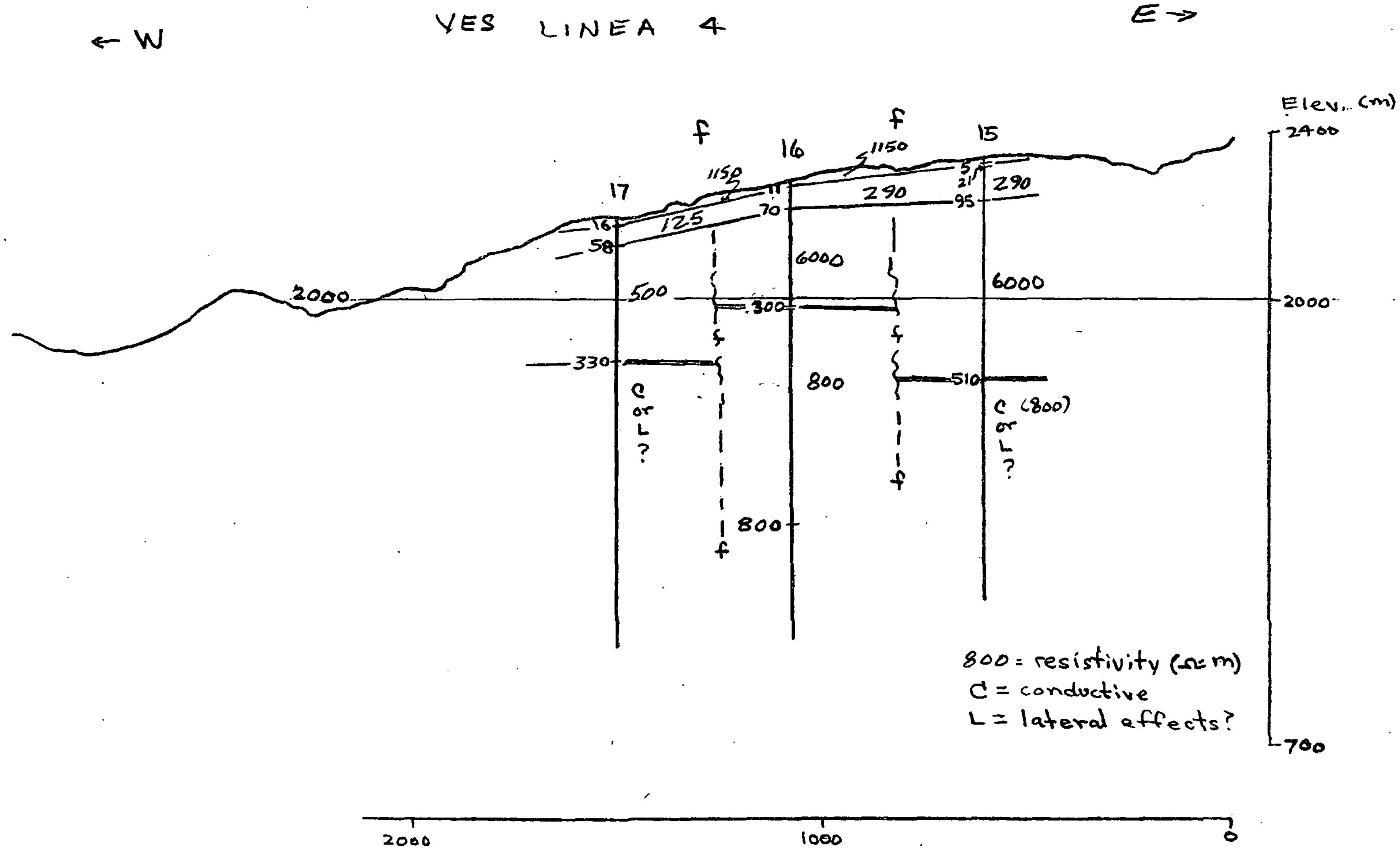
VES LINEA 1
← SW
NE →
ZQ-1
ZQ-2
Elev. (m)
2200
2000 m
1000 m
2000
1000
0
11
10
9
8
7
f
R
1.5
2.1
3.75
8
7.8
1.5 / 1250 } resistivity (Ω-m)
R= resistive (granite?)



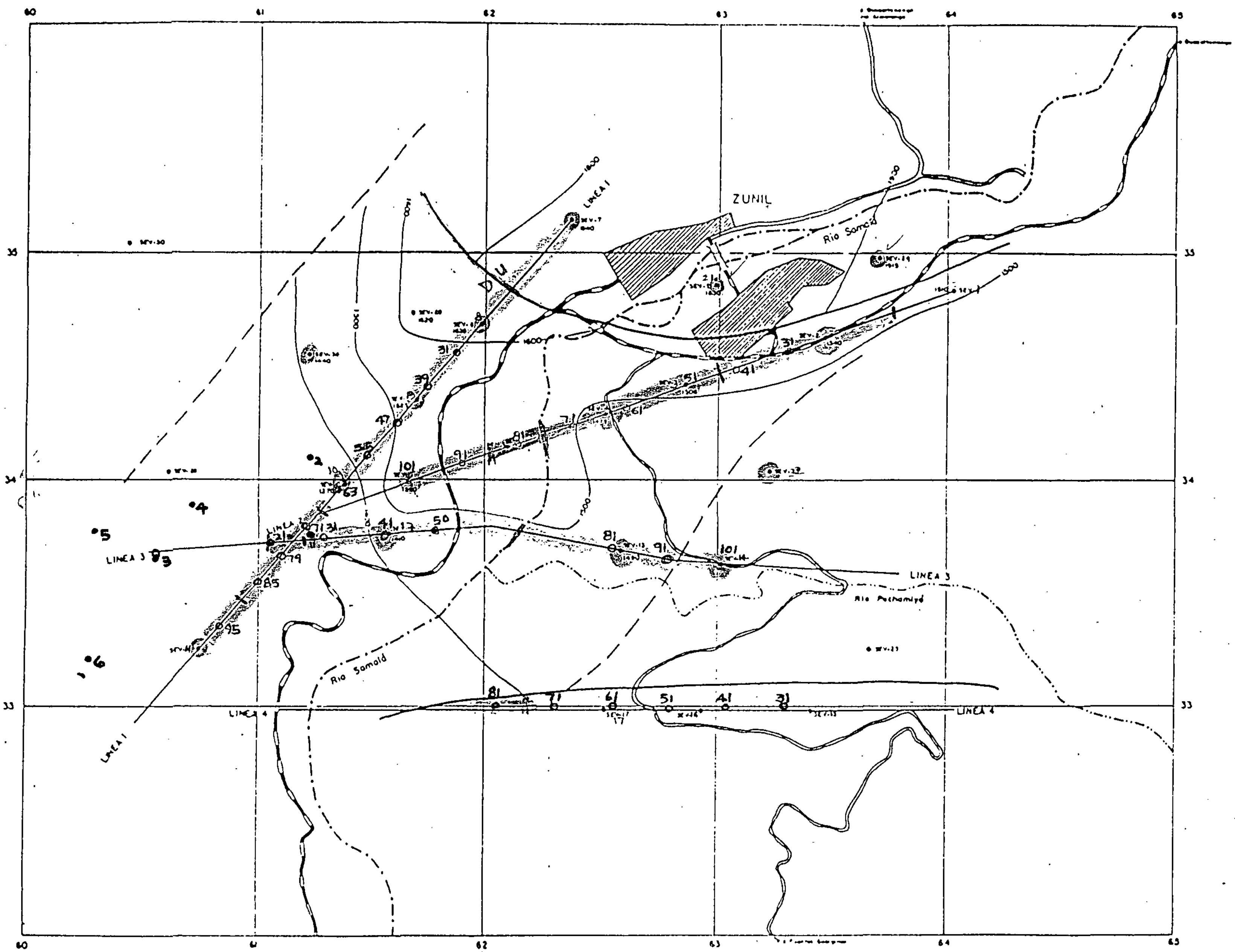
← SW
VES LINEA 2
NE →
Elev. (m)
2300
2000
1000
300
f?
f
Rio Samala
6
4
3
2
1
5500
48
290
96
460
440
26
195
110
145
245
220
1000
69
145
1300
7.4
13.4
10.3
12
22
600
660
652
610
690
R
R
R
R
2000
1000
0
13.4 = resistivity (Ω·m)
R = resistive

VES LINEA 3


W
E
f
13
f
14
Linea
1
12
850
23
5
385
11500
200
56
Rio
Sama
99
125
300
80
2000m
141
2000m
280
?
10
6
<10 ?
C
or
L
650
650
R
R
f
R=resistive
C=conductive
L=lateral effect
0
1000
2000


← W
VES LINEA 4
E →
Elev. (m)
2400
2000
700
17
16
15
f
f
1150
1150
16
58
125
11
70
290
5
21
95
290
6000
6000
500
300
330
800
510
C or L ?
C (800) or L ?
800
2000
2000
1000
0
800 = resistivity (Ω·m)
C = conductive
L = lateral effects?

Scale: 1:25,000



— falla

Intrinsic Resistivity

- 1 - 3.75 Ω·m
- 5 - 8
- 12 - 20
- 22 → 40

Lowest Res.

Line 1: VES 9 - 3.75 Ω·m
" 10 - 1.5 "
" 11 - 2.1 "

Line 2. VES 81 - 1.1 Ω·m

Line 3. VES 12 - 6 Ω·m
" 21 - 5 "

Line 4. VES 81 - 1.7 Ω·m

• SEV 10 INDE data AB/2 = 500m; 800m; 1000m

○ 51 JICA data AB/2 ≤ 750m

1:25,000

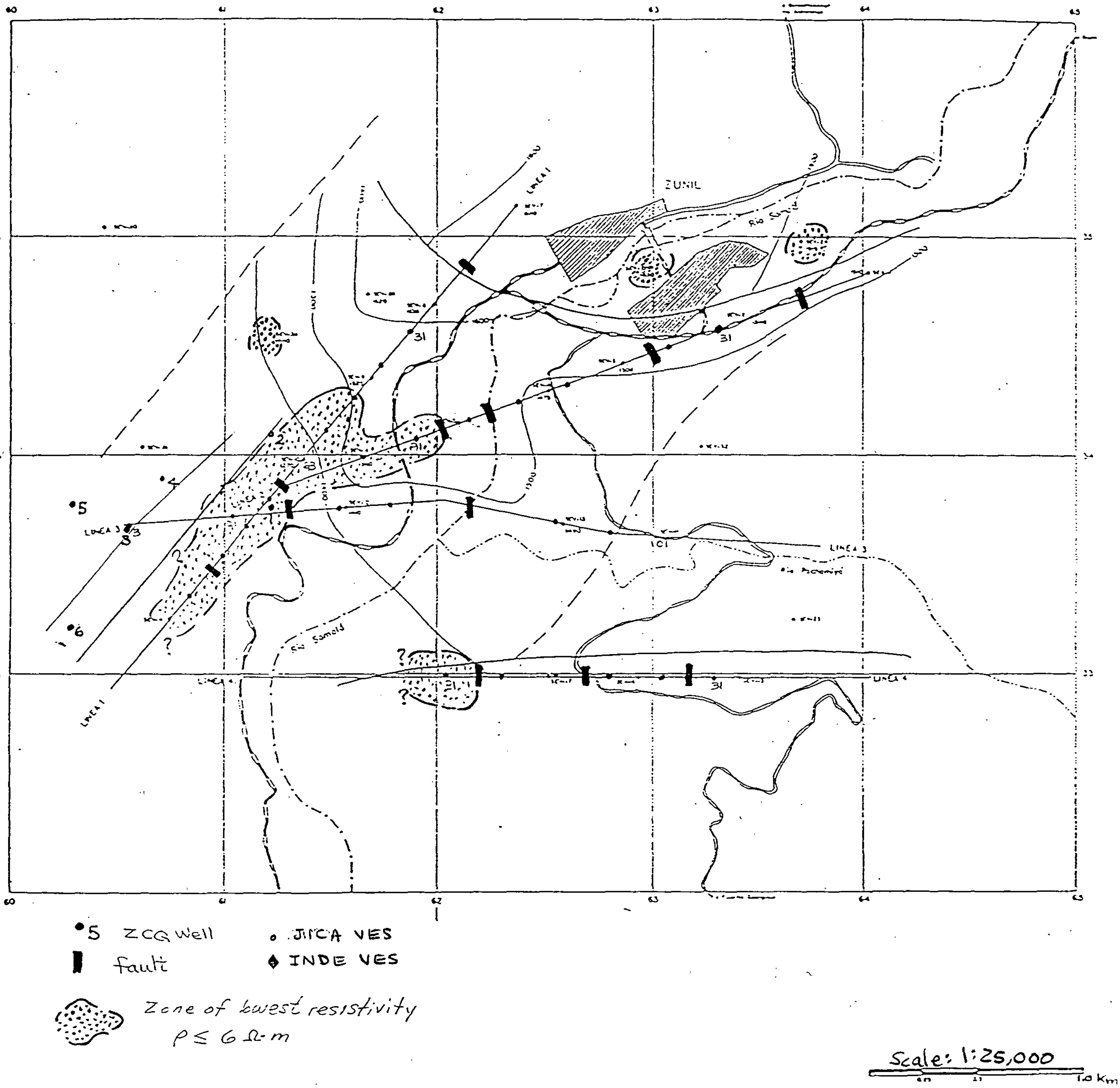
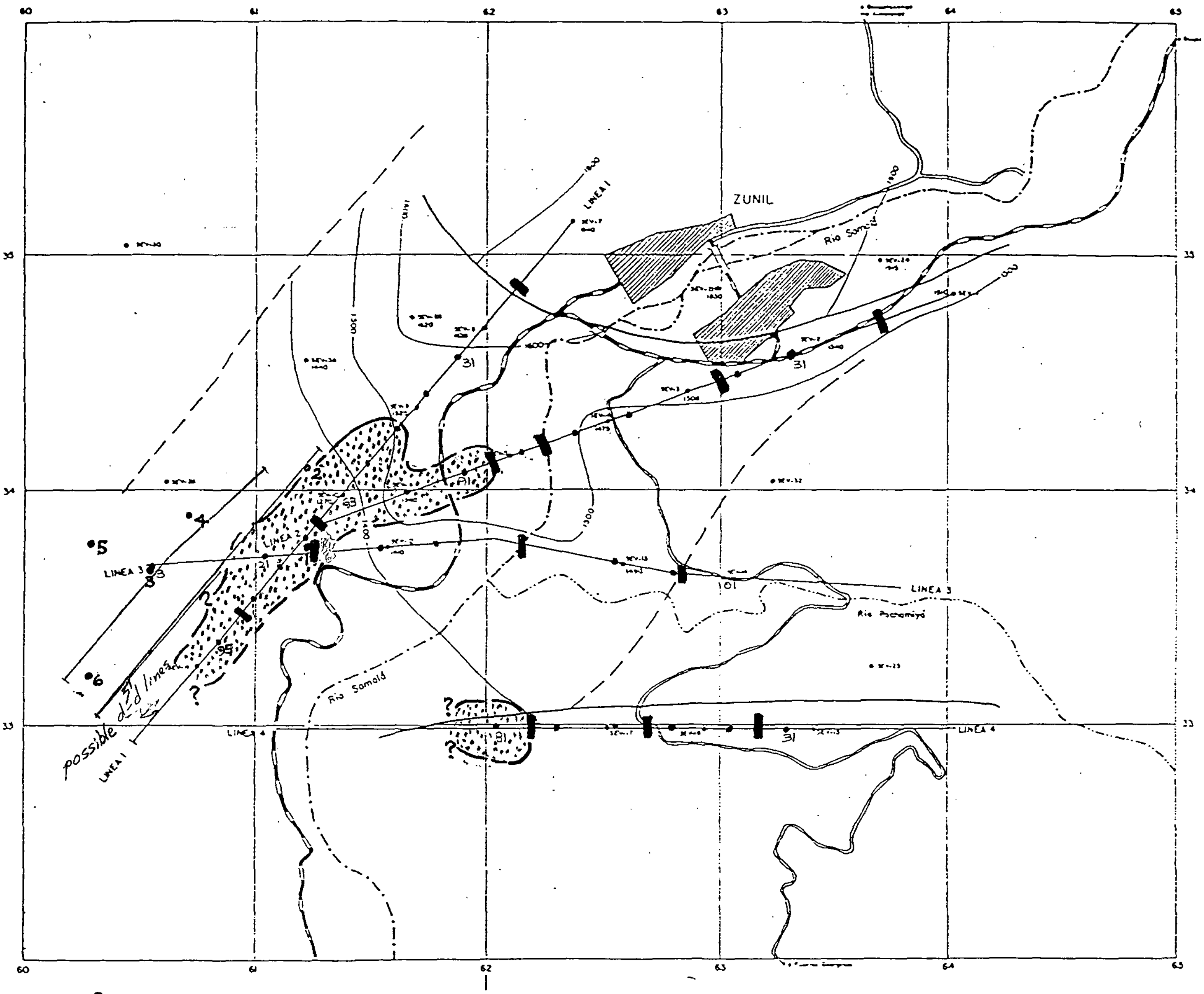


Figure 3. Summary of INDE and JICA electrical resistivity results, Zunil I area.



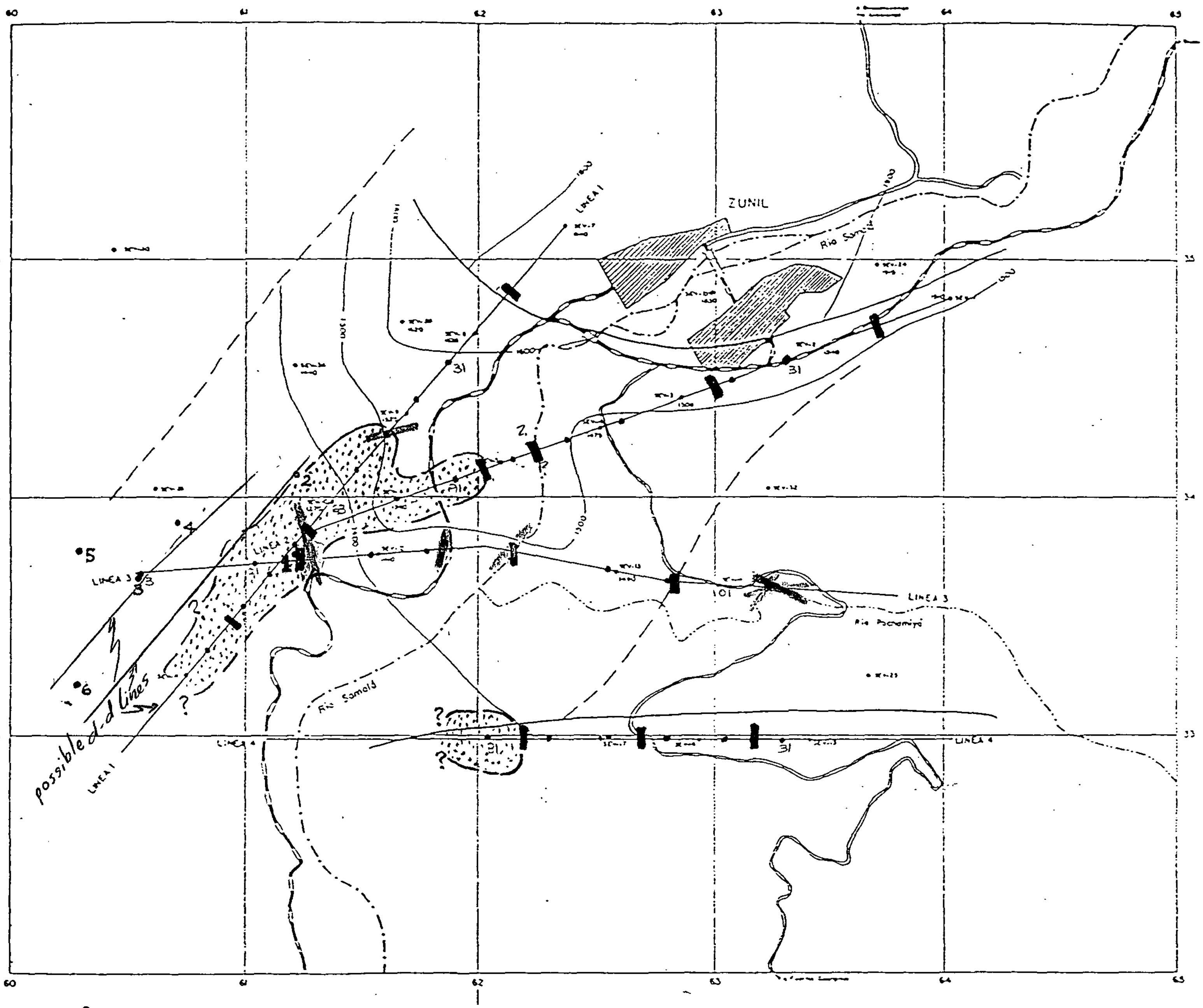
•5 ZCQ Well

fault

Zone of lowest resistivity
$\rho \leq 6\ \Omega\text{-}m$

Scale: 1:25,000

12.5/19.8 = 0.6313
(0.80x0.79)



•5 ZCQ Well

▮ fault

Zone of lowest resistivity $\rho \le 6\ \Omega\text{-m}$

— Seismic

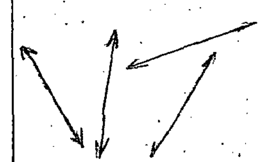
Scale: 1:25,000

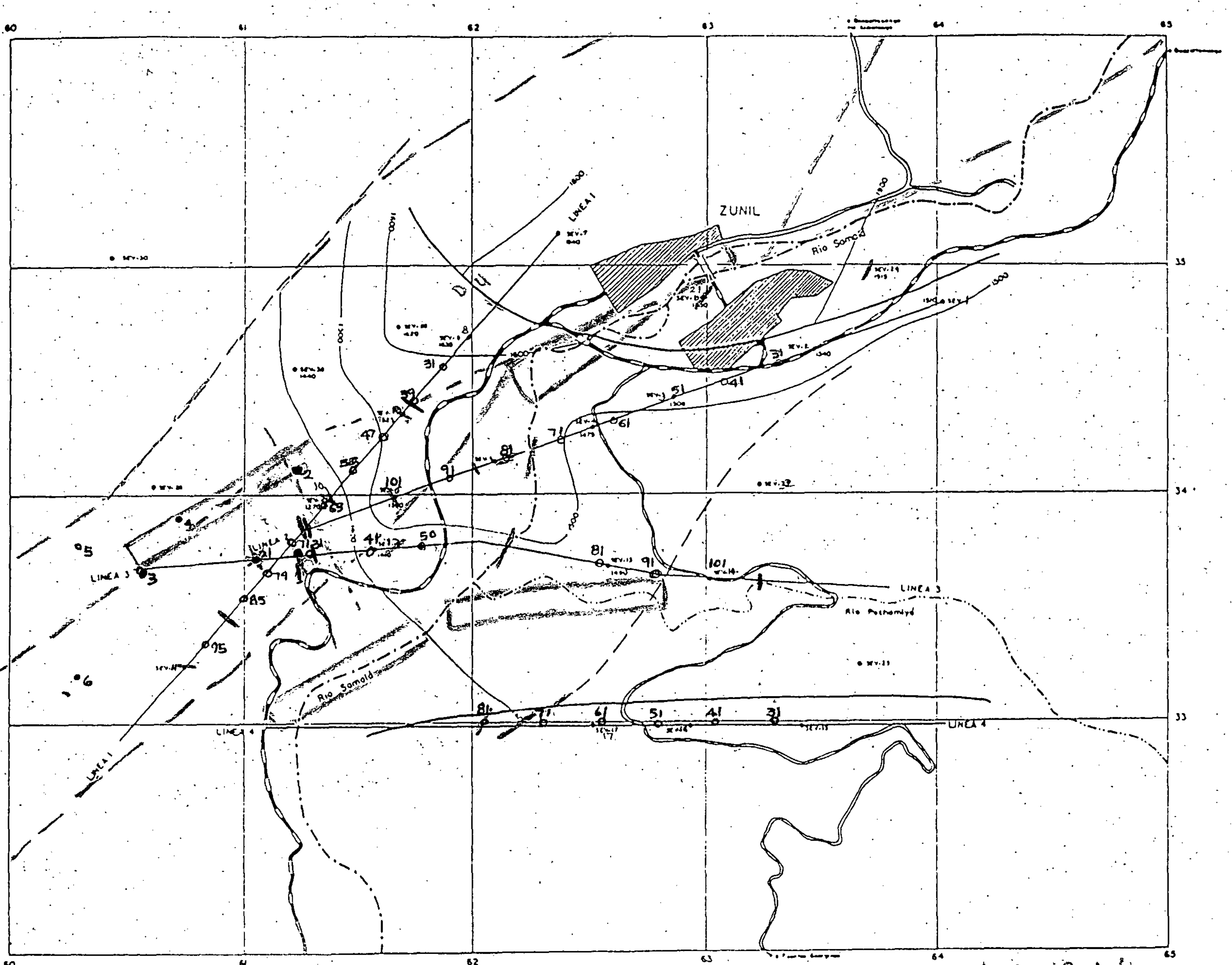
1.0 km

Figure 3. Summary of INDE and JICA electrical resistivity results, Zunil I area.

scale: 1:25,000

Probable Fault Sets





▭ Thermal Manifestations

• SEV 10 INDE data $\frac{AB}{2}$ = 500m; 800m; 1000m

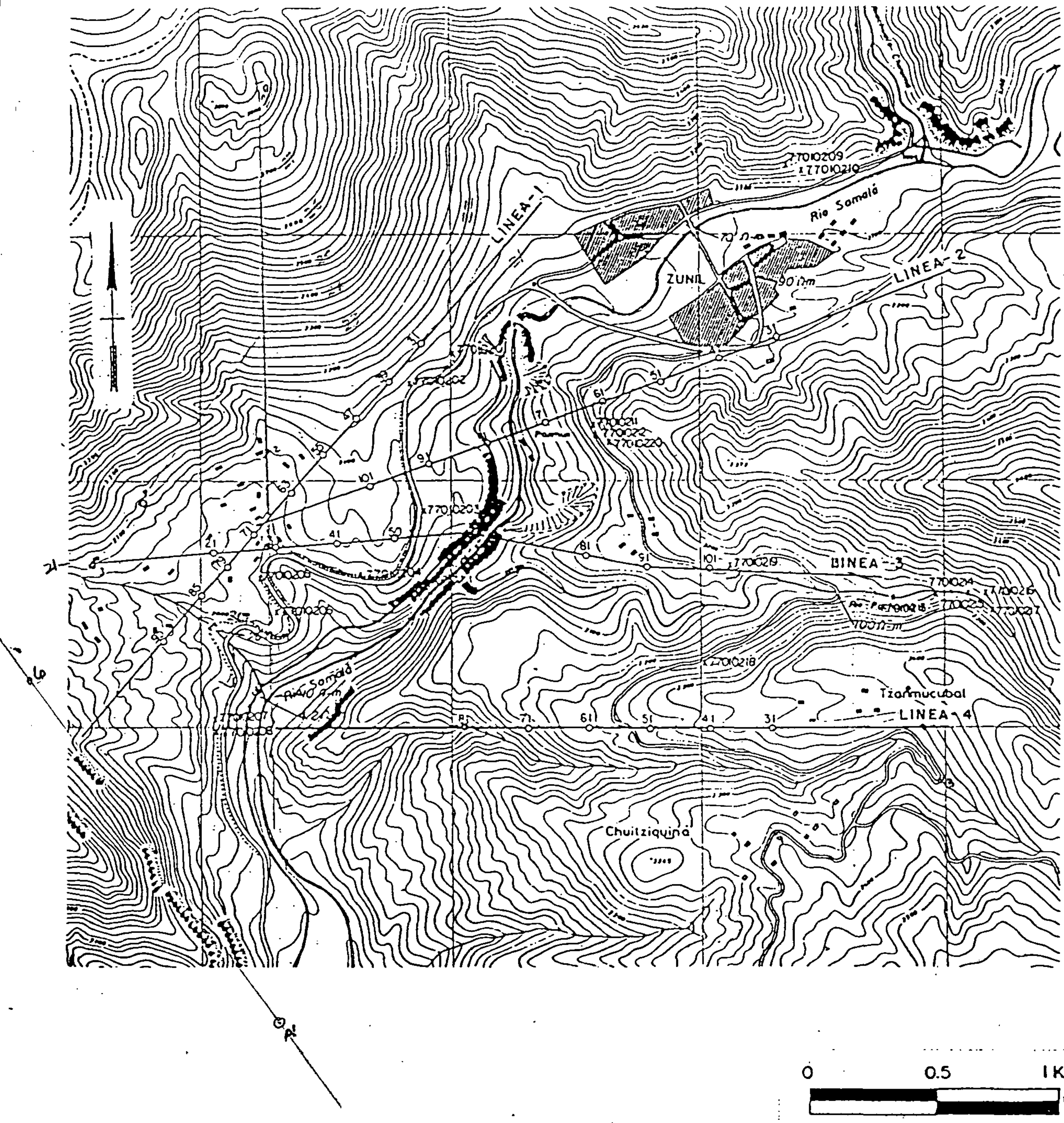
○ 51 JICA data $\frac{AB}{2} \leq$ 750m

| Gravity

| Seismic: L.1, #39, #68; L.3, #31, #110

| Resistivity

7-3 {10.3/10.3 = 1.0
7-9 {9.6/9.6 = 1.0



0 0.5 1 Km.
ESCALA GRAFICA
1:25,000

SIMBOLOGIA

—o—o—o—o— PUNTOS CENTRALES

INFORMACION BASE: PLANO INDE POR ING. J. PALMA

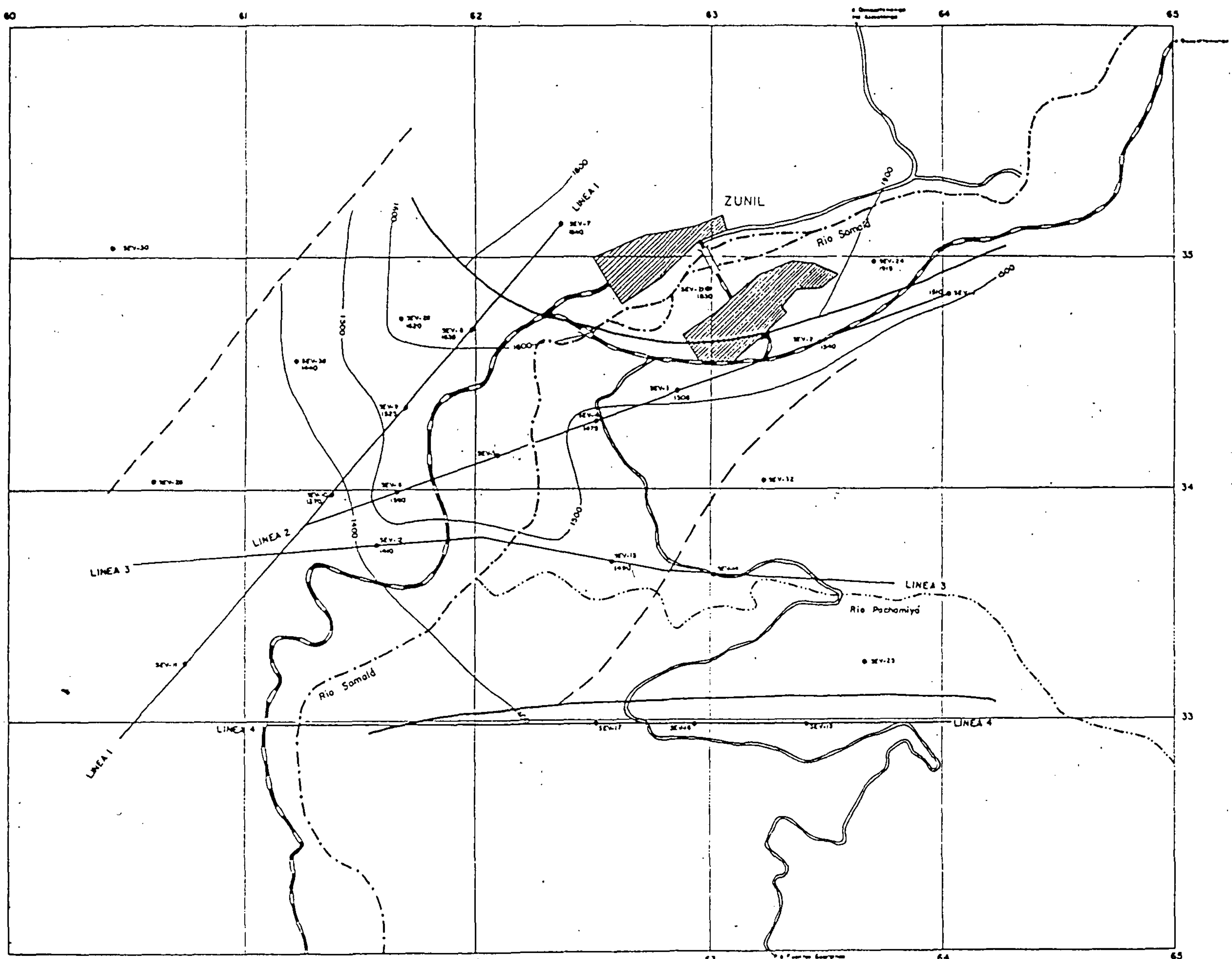
INSTITUTO NACIONAL DE ELECTRIFICACION
INDE GUATEMALA C.A.

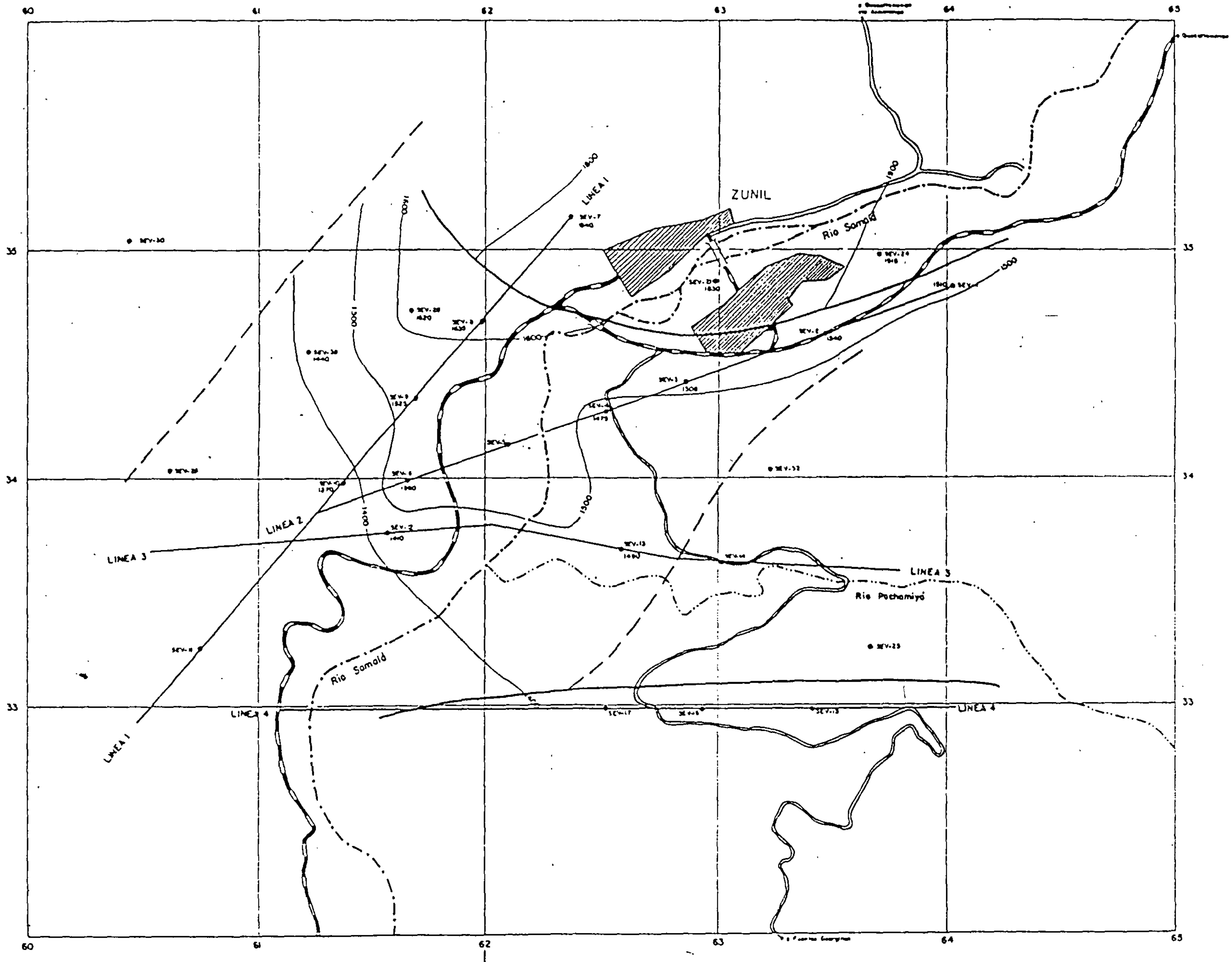
PROYECTO GEOTERMICO ZUNIL I

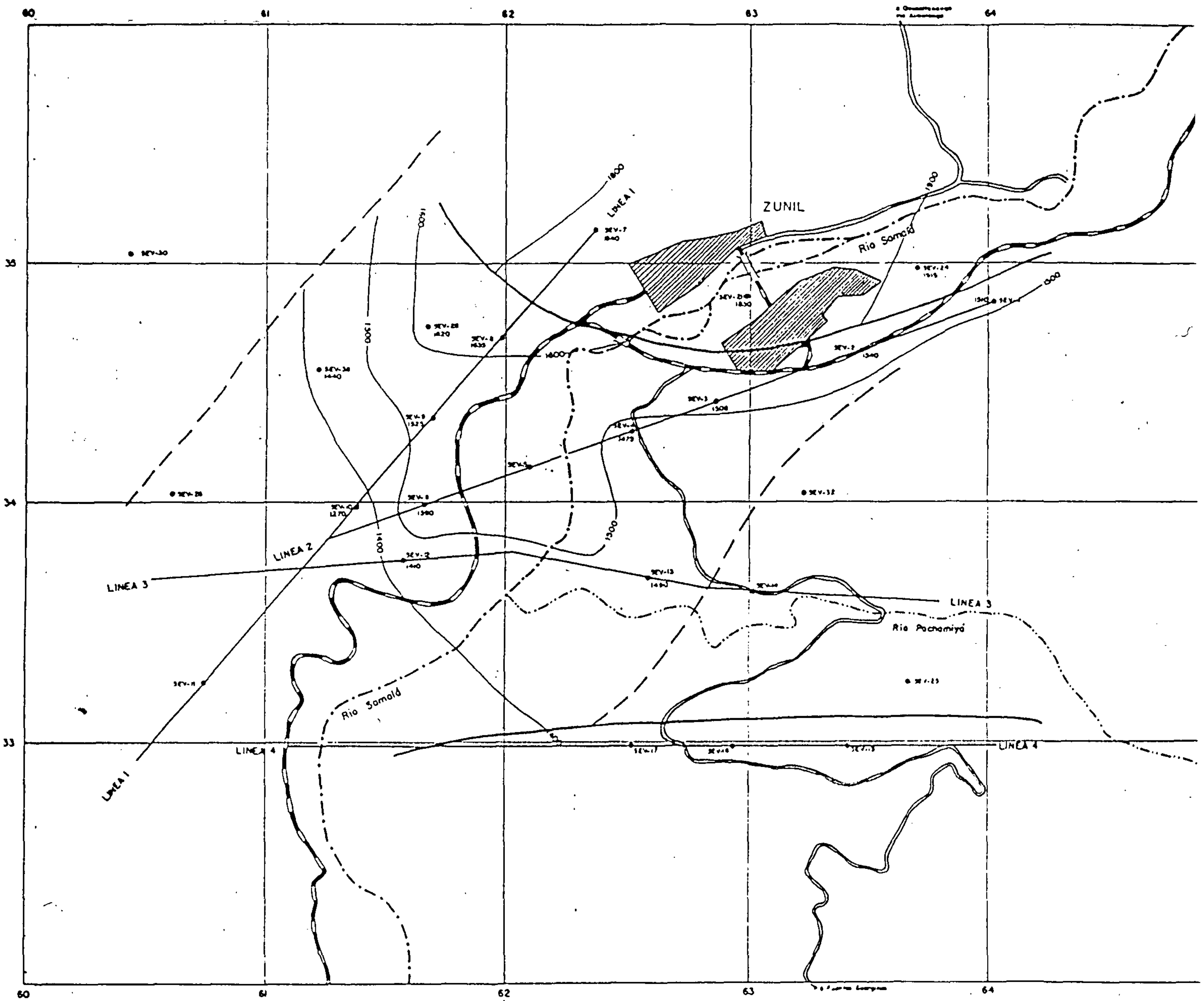
UBICACION DE LINEAS DE SONDEOS ELECTRICOS

CyM/MKF

FIGURA: 3.3-19


ZUNIL
Rio Samalá
Rio Pachamiyá
LINEA 1
LINEA 2
LINEA 3
LINEA 4
1300
1400
1500
1600
1800
60
61
62
63
64
65
33
34
35

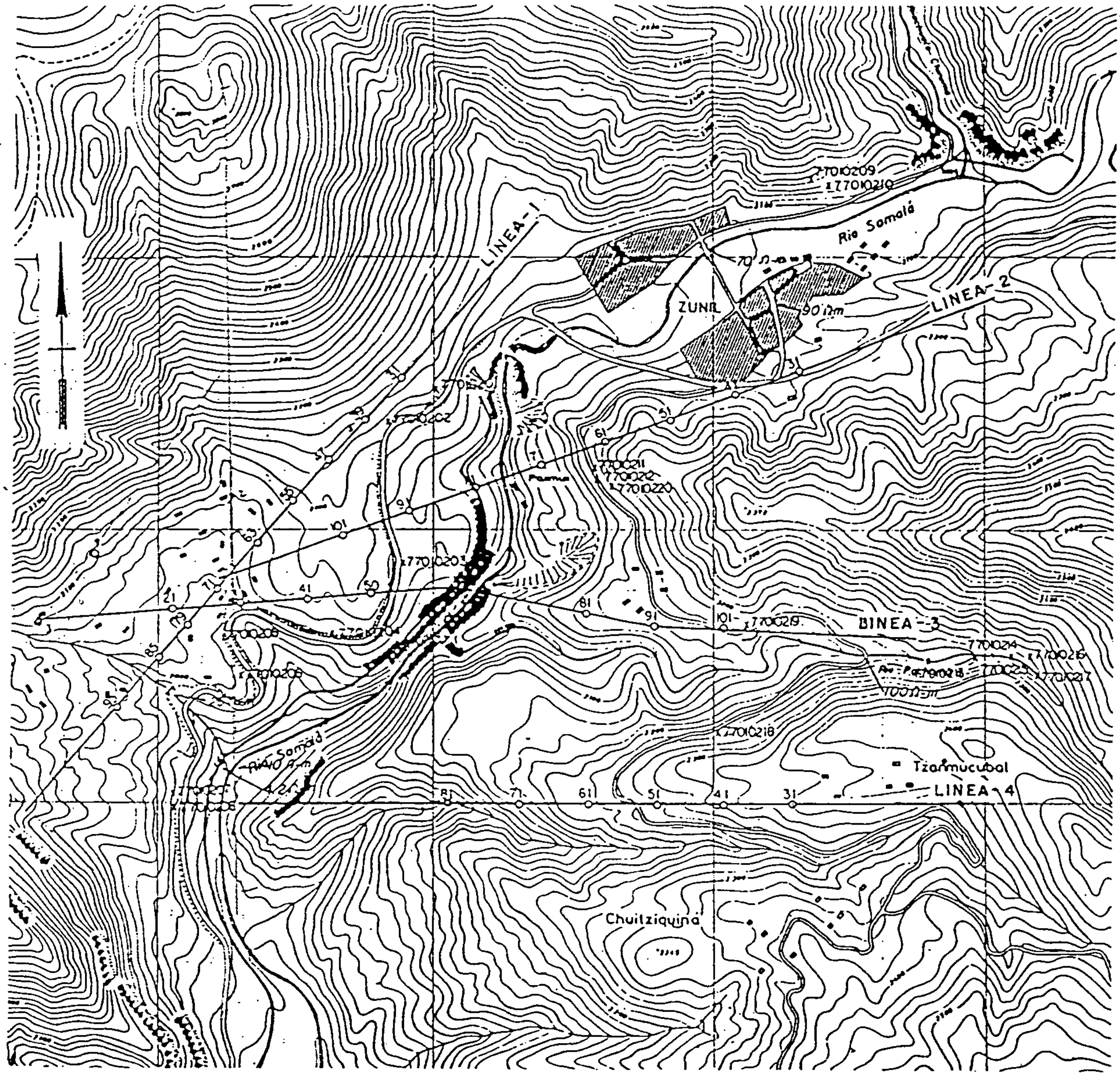

ZUNIL
Rio Samalá
Rio Pachamiyá
LINEA 1
LINEA 2
LINEA 3
LINEA 4
SEV-30
SEV-28
SEV-7
SEV-32
SEV-25
SEV-24
SEV-17
1300
1400
1500
1600
1800
1900
60
61
62
63
64
65
33
34
35



● SONDEO ELECTRICO VERTICAL (S.E.V.)
ARREGLO SCHLUMBERGER AB/2 = 2000 m

1400 —— CURVAS DE ISONIVEL DEL FONDO RESISTIVO.

3700 m. ALTURA SOBRE EL NIVEL DEL MAR
DEL FONDO RESISTIVO.



0 0.5 1 Km.

ESCALA GRAFICA

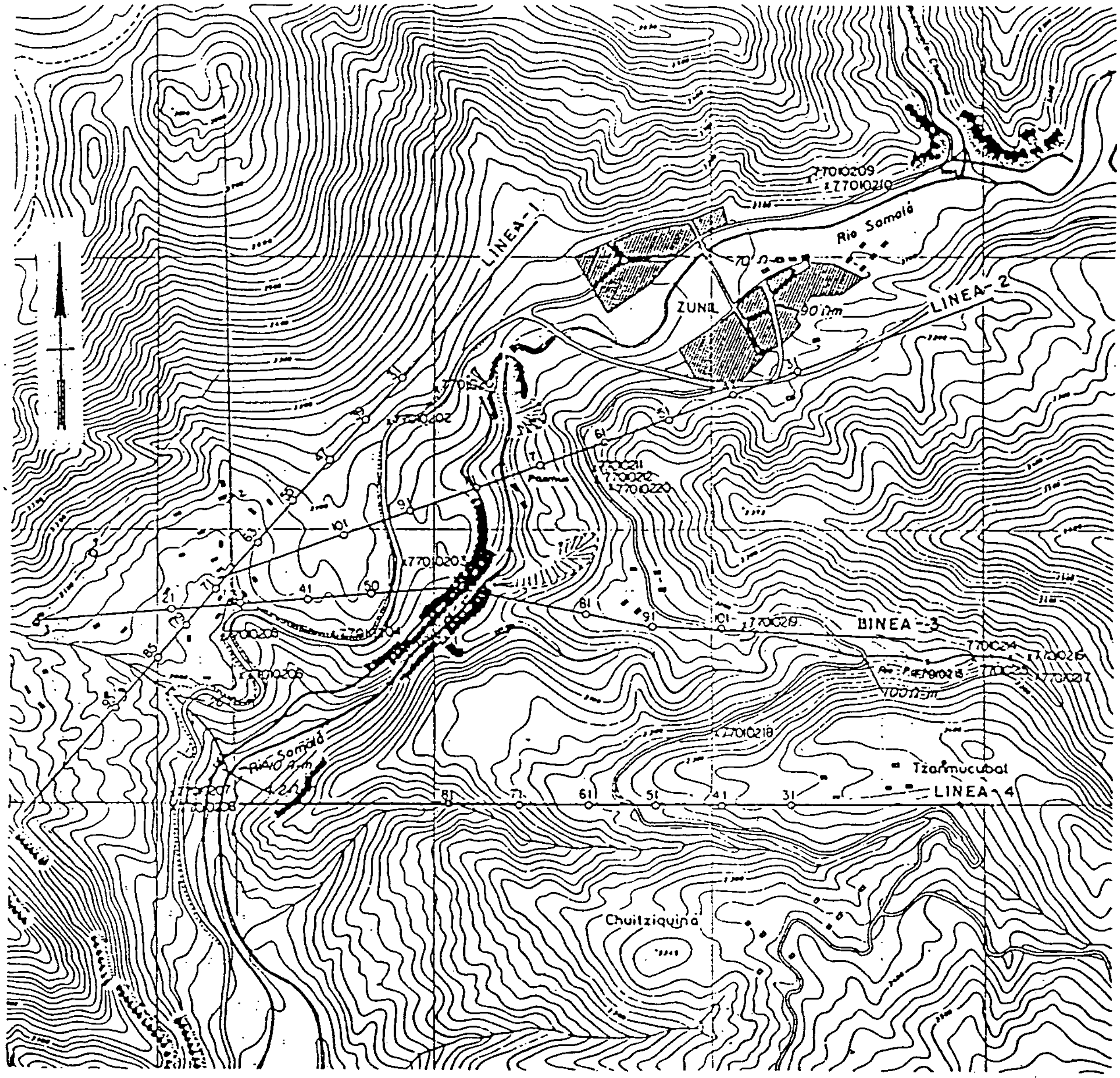
1:25,000

SIMBOLOGIA

—o—o—o—o— PUNTOS CENTRALES

INFORMACION BASE: PLANO INDE POR ING. J. PALMA

INSTITUTO NACIONAL DE ELECTRIFICACION INDE GUATEMALA C.A.	
PROYECTO GEOTERMICO ZUNIL I	
UBICACION DE LINEAS DE SONDEOS ELECTRICOS	
CyM/MKF	FIGURA: 3.3-19



0 0.5 1 Km.

ESCALA GRAFICA

SIMBOLOGIA

—o—o—o—o— PUNTOS CENTRALES

INFORMACION BASE: PLANO INDE POR ING. J. PALMA

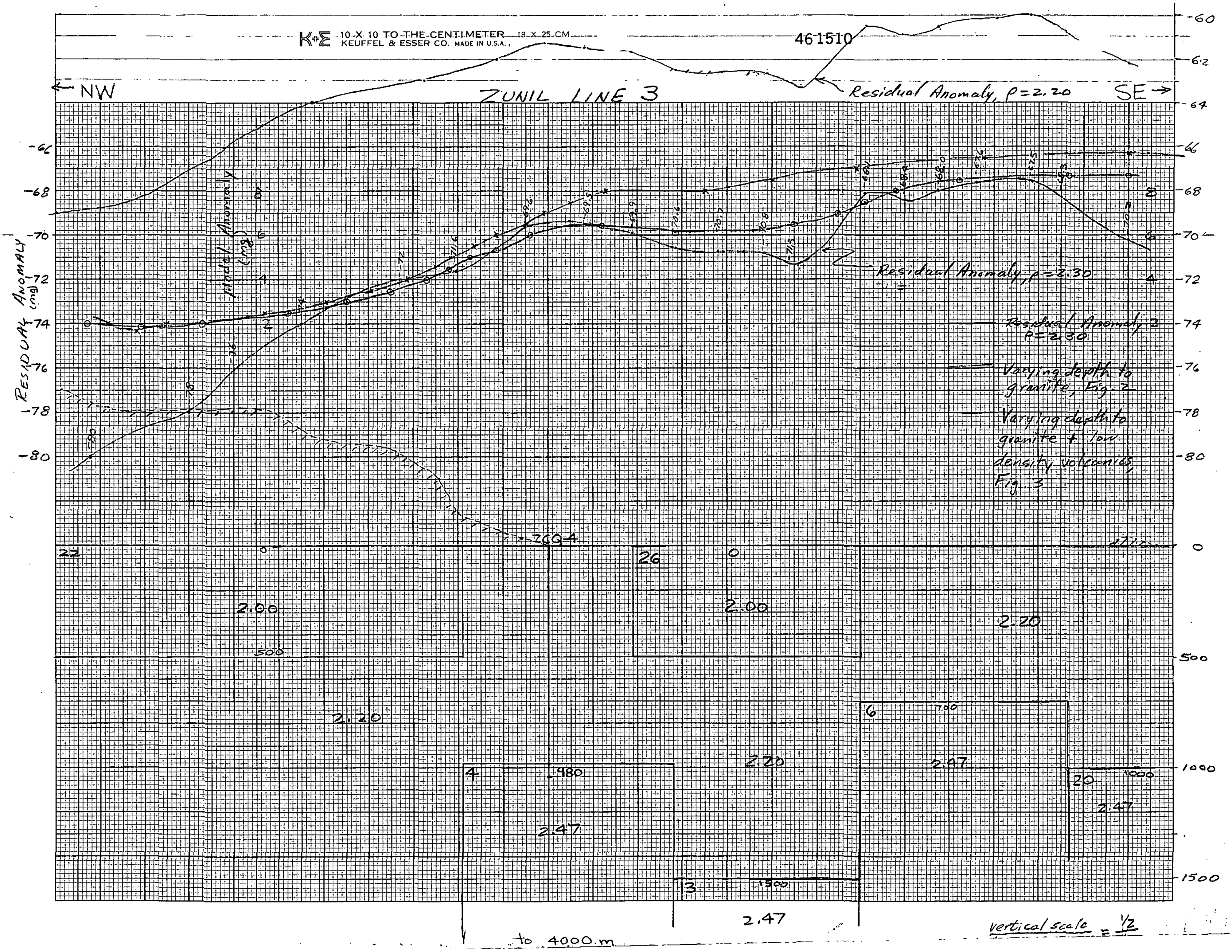
INSTITUTO NACIONAL DE ELECTRIFICACION
INDE GUATEMALA C.A.

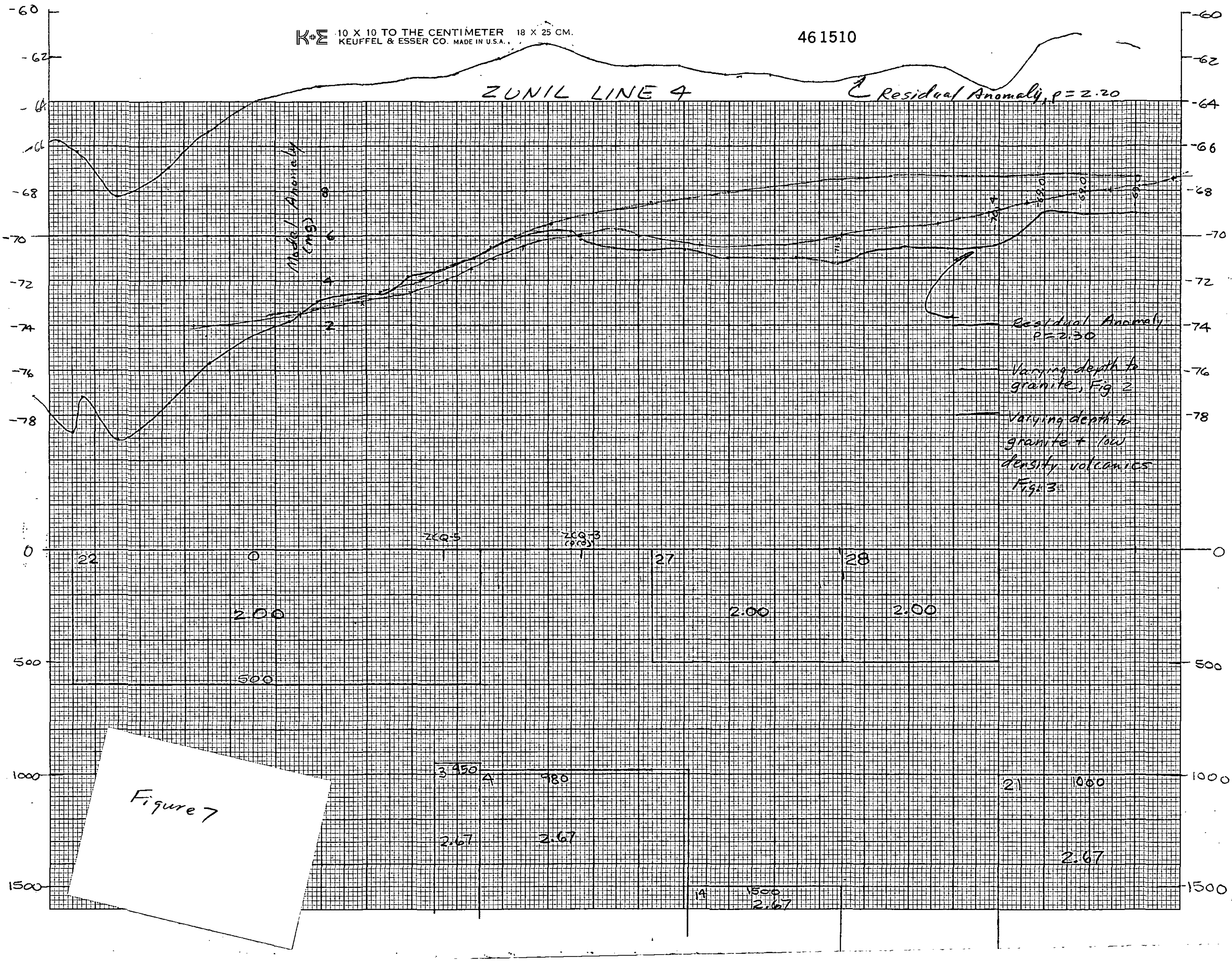
PROYECTO GEOTERMICO ZUNIL I

UBICACION DE LINEAS DE SONDEOS ELECTRICOS

CyM/MKF

FIGURA: 3.3-19

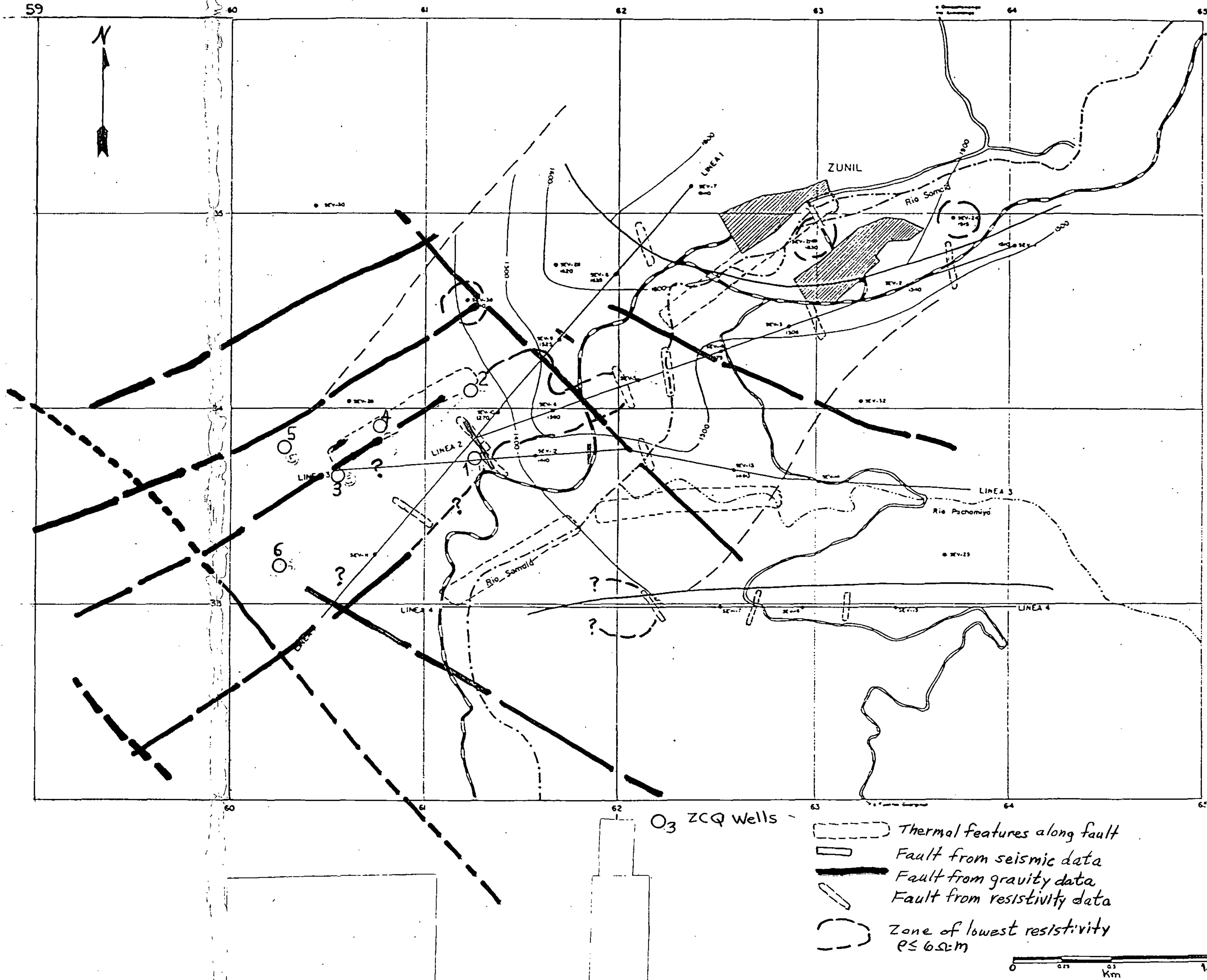

K+E 10 X 10 TO THE CENTIMETER 18 X 25 CM
KEUFFEL & ESSER CO. MADE IN U.S.A.
461510
ZUNIL LINE 3
← NW
SE →
Residual Anomaly, ρ=2.20
Residual Anomaly, ρ=2.30
RESIDUAL ANOMALY (mg)
Model Anomaly (mg)
Residual Anomaly 2 ρ=2.30
Varying depth to granite, Fig. 2
Varying depth to granite + low density volcanics, Fig. 3
ZCQ-4
2.00
2.20
2.47
500
1000
1500
to 4000 m
vertical scale = 1/2



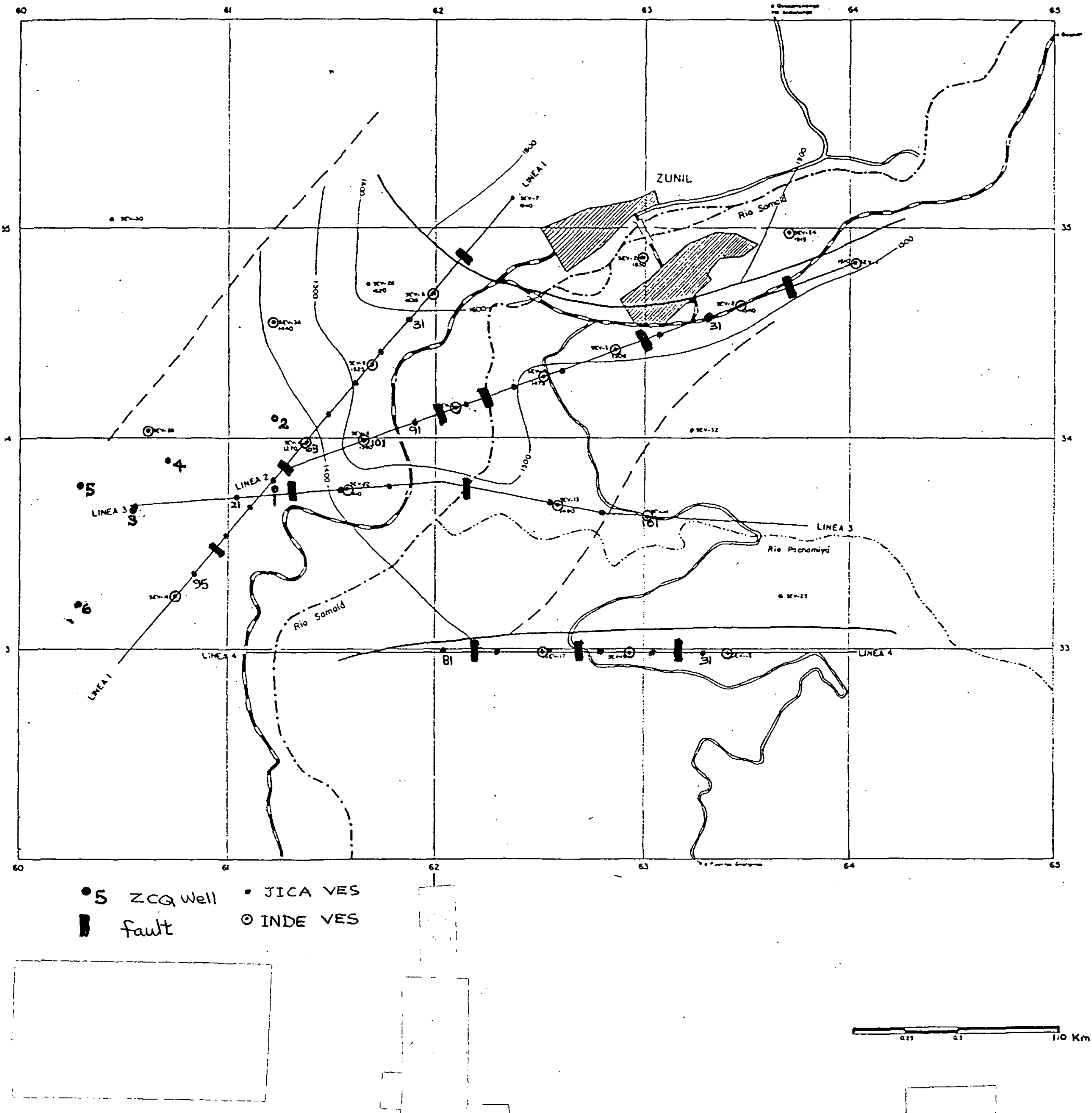
K+E 10 X 10 TO THE CENTIMETER 18 X 25 CM. KEUFFEL & ESSER CO. MADE IN U.S.A.
461510
ZUNIL LINE 4
Residual Anomaly, ρ = 2.20
Model Anomaly (mG)
Residual Anomaly ρ = 2.30
Varying depth to granite, Fig 2
Varying depth to granite + low density volcanics Fig. 3
ZCQ-5
ZCQ-3
2.00
500
2.67
1000
1500

Figure 7

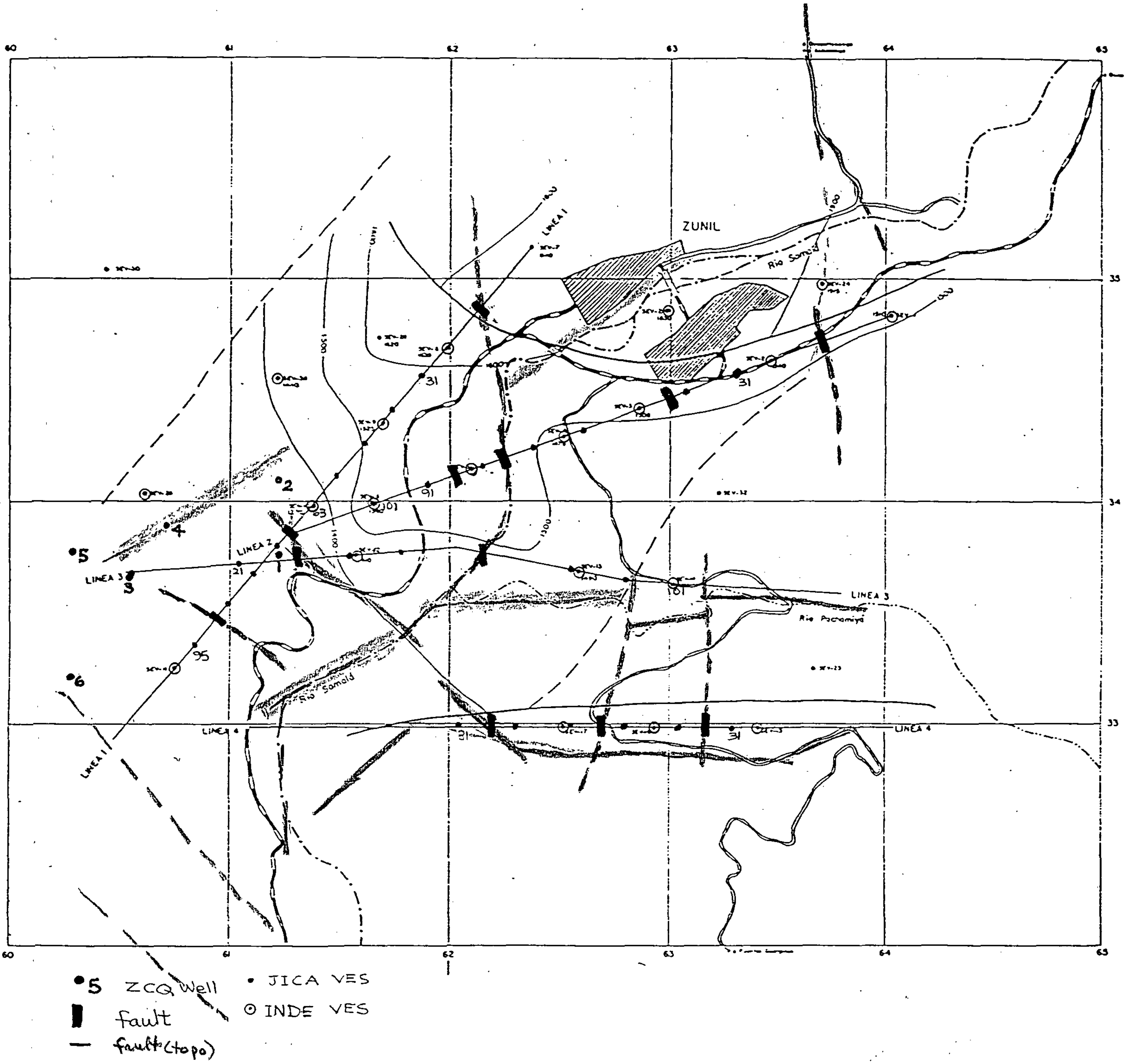
6/5/84



59
60
61
62
63
64
65
35
34
33
N
ZUNIL
Rio Samalá
Rio Pachamiyá
LINEA 1
LINEA 2
LINEA 3
LINEA 4
1
2
3
4
5
6
?
O3 ZCQ Wells
Thermal features along fault
Fault from seismic data
Fault from gravity data
Fault from resistivity data
Zone of lowest resistivity
ρ ≤ 6 Ω·m
0
1.0
Km



60
61
62
63
64
65
35
34
33
ZUNIL
Rio Samalá
Rio Pachamiya
LINEA 1
LINEA 2
LINEA 3
LINEA 4
1300
1400
1500
1600
1800
1900
•5 ZCQ Well
fault
• JICA VES
⊙ INDE VES
1.0 Km


ZUNIL
Rio Samalá
Rio Samalá
Rio Pachamiya
LINEA 1
LINEA 2
LINEA 3
LINEA 4
60
61
62
63
64
65
33
34
35
5 ZCQ Well
fault
fault (topo)
JICA VES
INDE VES

Guatemala, May 27, 1989.

Dr. Joseph Moore
UURI
Earth Science Laboratory
391 Chipeta Way, Suite C
Salt Lake City, Utah 84108-1295

Dear Joe:

Thank you very much for your letter and the copy of the report by Howard. It is a very good new to learn that through the gravity data, major structures of higher permeability could be inferred from. Besides, I am glad to confirm certain thoughts that we have already discussed. Some few problems should be solved before we proceed.

1. I can not send Howard's report to Palma because he does not know Ulrich's report. The way we are proceeding is like in an internal review. Enclosed please find a copy of the corrected paper we have here that I hope is the same you have at UURI. So, the way we should proceed is to ignore officially Ulrich's report, produce the right one and start the work with the new gravity survey. There is also a resistivity report due.

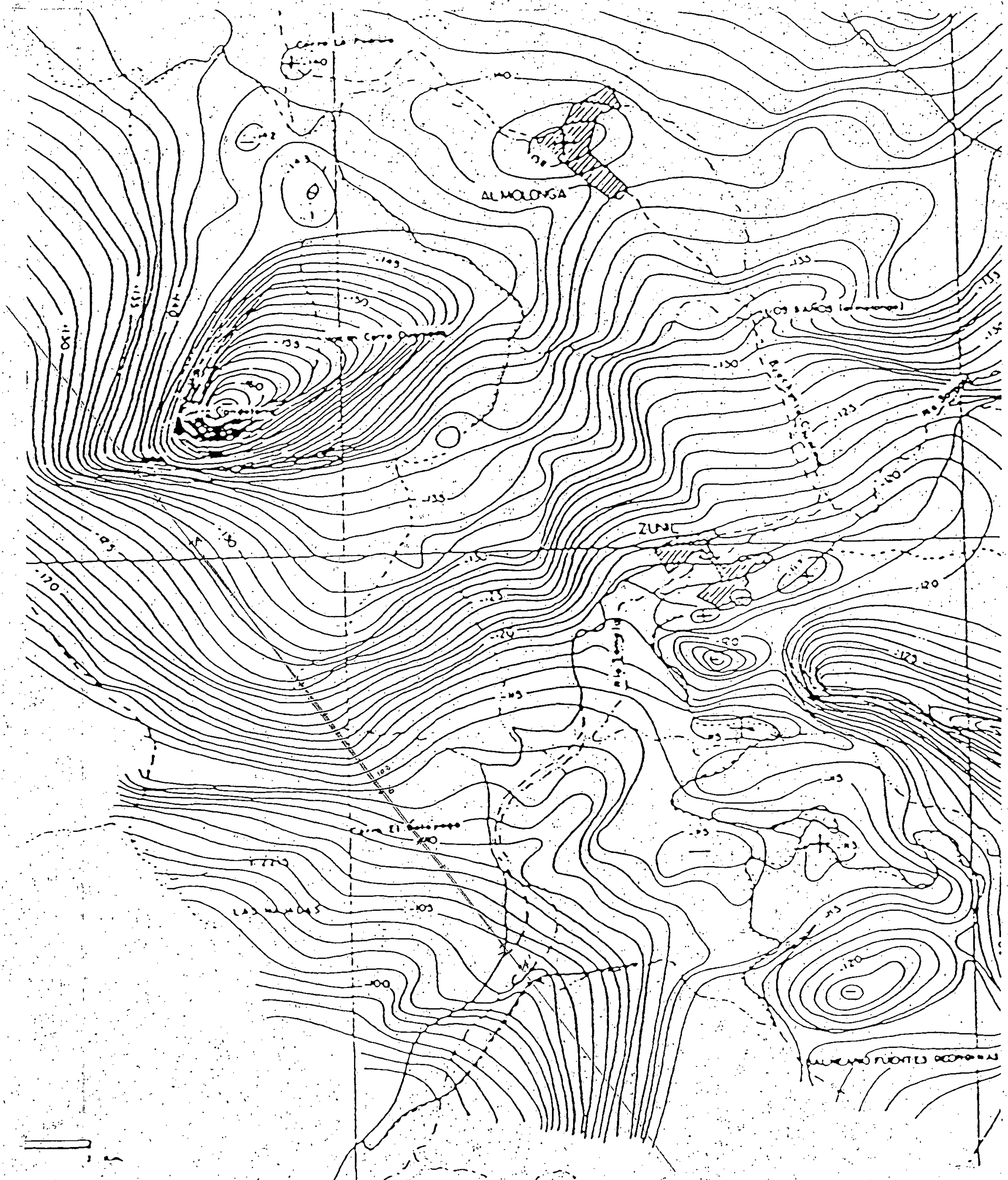
2. I think is an excellent idea to bring Howard to Guatemala. I tried to collect the plans we have here about gravity and send them to you. I came out discouraged. As you suggest, there might be things not neccesarily shown at the plans.

Albert Duprat
CGG, France

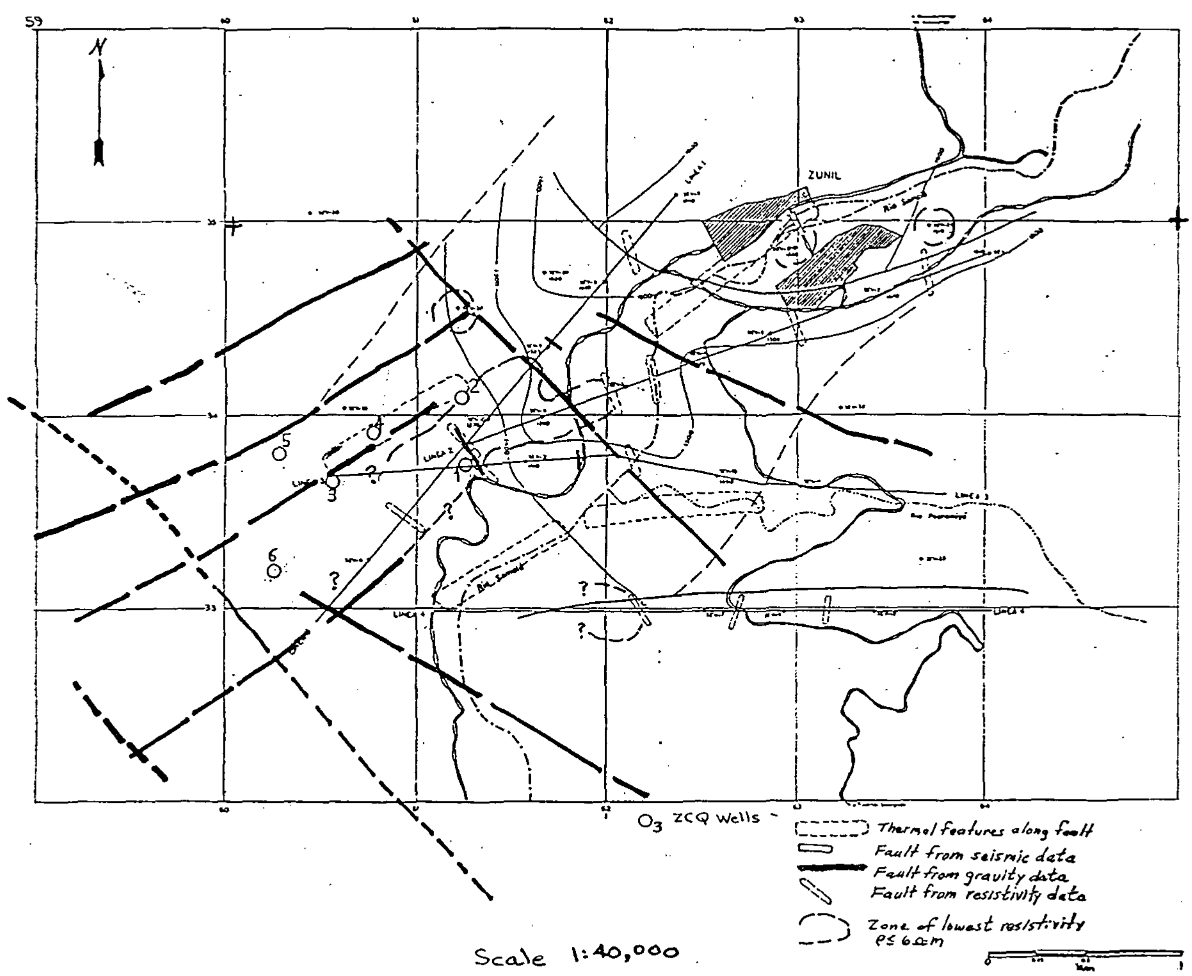
3. From Howard's information about Duprat's (the french geophysicist member of the panel) attitude at the meeting in Panama, it might be worthwhile for you to consider Mike's involment in the project, especially when we ought to present the study here for our Panel Meeting. It might come out to be a highly political meeting.

4. I am sending you also a copy of the set of nine plans that I have talked to you about, that cover the 200 Km^2 , at 1:10,000 scale. Also a photocopy of a plan made out of reductions to 1:25000 scale that can be presented in one format only (instead of nine). I like the quality of the map (not obvious in the photocopy) that comes from recent air photos, and INDE wants us to present all of our results at that scale. My problem is that here in Guatemala we can reduce by photographic process each one of the plans, but the process of putting the mine together there is no choice but manual, so there might be errors shown at the final product. I wonder if you could do that for me in the U.S. to send you my originals in transparent plastic paper.Let me know if you can. I'll appreciate your help on that and of course those are my exposure expenses.

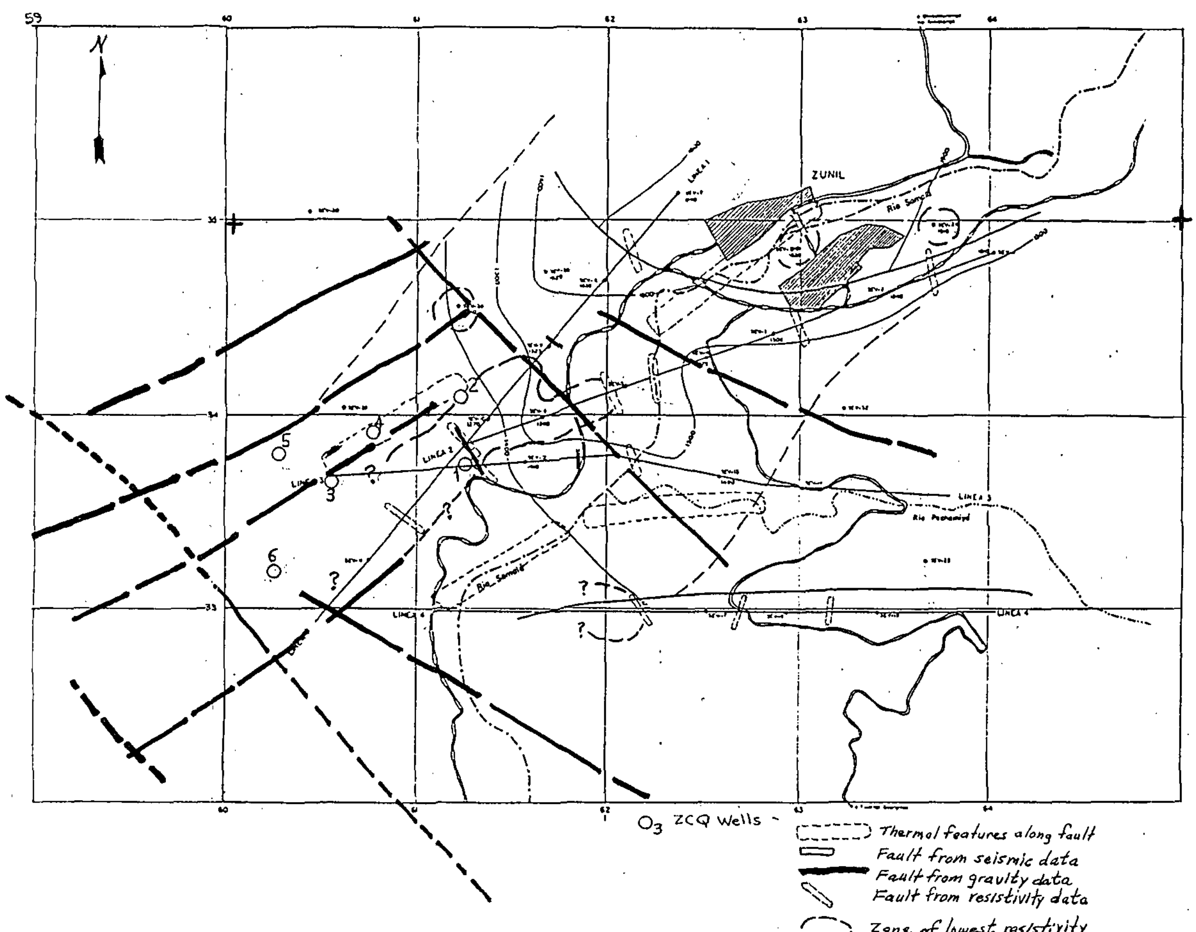
Regional Gravity @ 1:40,000 metric



Scale 1:40,000



Scale 1:40,000



Scale 1:40,000