TECHNICAL REPORT

ON

GEOTHERMAL EXPLORATION IN EBURRU GEOTHERMAL FIELD RIFT VALLEY REPUBLIC OF KENYA

MARCH, 1980

Submitted by

JICA GEOTHERMAL MISSION

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INTRODUCTION

This report is a tentative report on preliminary geothermal exploration in Eburru geothermal field, Rift Valley. The survey was carried out by JICA (Japan International Co-operation Agency) team cooperating with Ministry of Energy of Kenyan government. Because Ministry of Energy was newly created in the government structure, it did not have enough technical staff to act as a counterpart of JICA team. Therefore, Mines and Geological Department of Ministry of Environment and Natural Resources supplied its staff and equipments.

The JICA team, except the team leader, stayed in Kenya from 4th December, 1979 till 8th March, 1980 and spent about 2 weeks in the field to carry out preliminary field survey.

The JICA team consist of the following members:

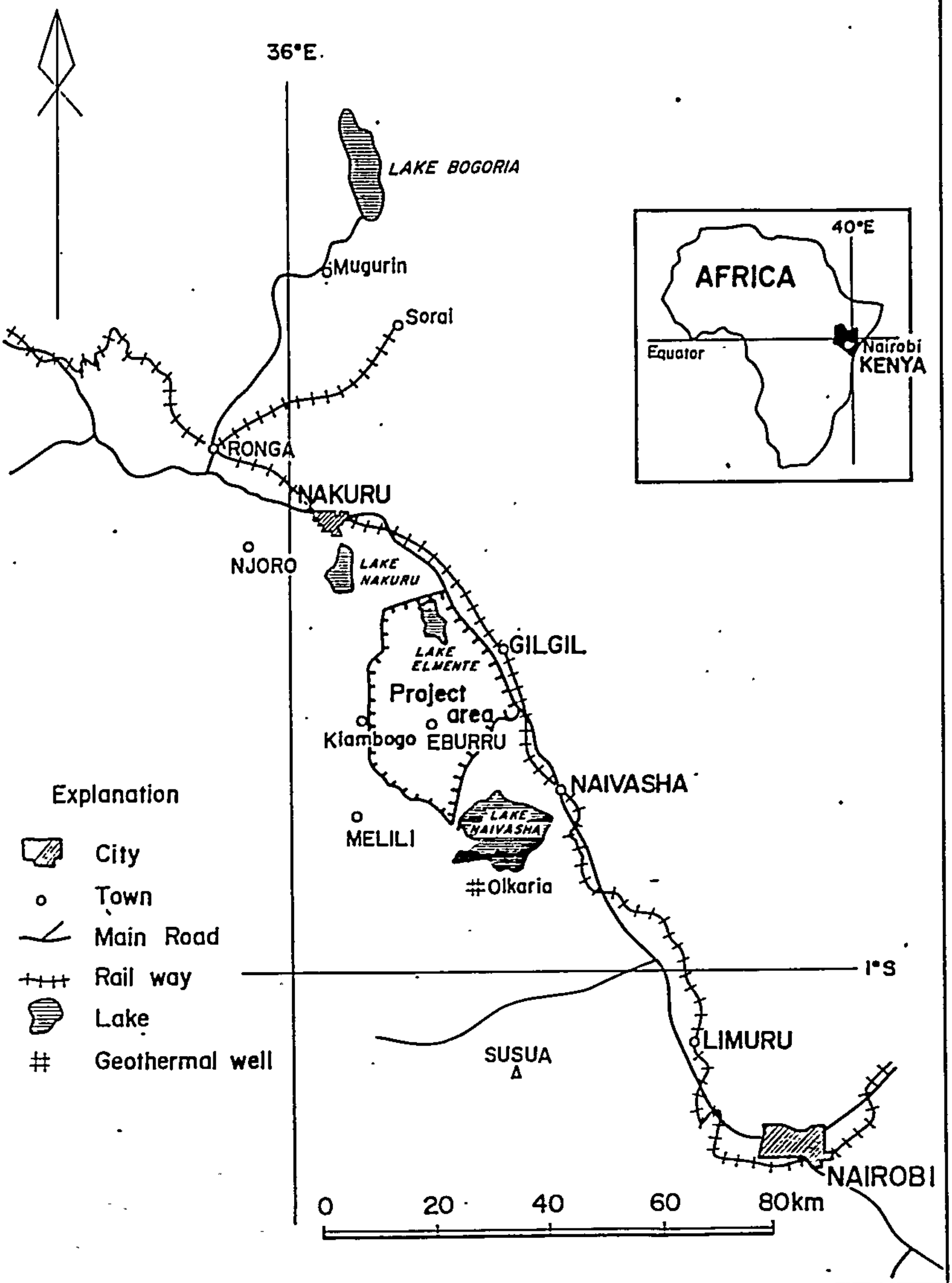
Dr. Koji Motojima	team leader geochemist/geologist
Dr. Kenzo Baba	geologist/geophysicist
Dr. Takashi Ohya	deputy team leader geophysicist
Mr. Tadao Mizuguchi	geophysicist/geologist
Mr. Kazuo Hirowatari	geochemist.

The team leader, Dr. Koji Motojima, arrived Kenya on 19th February and will stay in the country until the project ends.

The JICA team appreciates Mr. D.M. Mwiraria, Permanent Secretary, Mr. W.N. Mbote, Deputy Secretary, and Mr. W.J. Wairegi, Director of Technical Division of Ministry of Energy for their administrative and technical helps. It wishes to send appriciation to Mr. C.Y.O. Owayo, Chief Mining Engineer, Mr. P.W. Winani, Chief of Economic geology, Mr. P. Burgener Chief Chemist, and Mr. J.K. Wachira, Ag. Chief Geologist of Mines and Geological Department, Ministry of Environment and Natural Resources for their technical supports.

Fig. I-1

Location of Project Area



I RECONNAISSANCE SURVEY OF GEOTHERMAL FEATURES AT EBURRU GEOTHERMAL AREA

BY K. BABA

The field survey at Eburru geothermal area was carried out for about ten days from 25 January 1980 by JICA survey mission of 1979 FY. The present writer conducted the reconaissance geologic survey concentrated especially to the surface geothermal features there during his stay as a member of the mission. The survey was done with the cooperation of counterparts of Ministry of Environmental and Natural Resources and Ministry of Energy of Kenya Government. This is a preliminary note of the survey.

Eburru geothermal area of which Northern, Southern, Eastern, and Western boundaries are respectively about two kilometers north of old Eburru station, about three kilometers south of Eburru top (2668 meters from the sea level), about one kilometer east of the top and about three kilometers west of the top, covers about 44 square kilometers area. The distance from east to west of the area is about four kilometers and the one from north to south is about eleven kilometers.

The area is wholely covered by the volcanic products from the Lower Pleistcene to the Recent. Eburru mountain situated in the area, is a big composite volcano which has many craters and cinder cones ranged from north to south. In the same direction, there are distributed many geologic faults along which surface geothermal activities can be seen. Many surface geothermal features are distributed widely in the area and they are often associated with hydrothermally altered zones. The alteration on the surface is mainly the kaolinization

Glover (1972) showed a hundred and seventy points of warm ground by utilizing the result of the infrared survey applied in Eburru area. They are distributed widely in this area.

The surface geothermal features are generally classified into hot spring, geyser, fumarole, steaming ground, hot pool, mud pot, etc. The main geothermal features in Eburru geothermal area are the fumaroles and steaming grounds. The steaming ground is defined as the ground where the distinct fumarole can not be seen but the steam is being discharged from the underground.

The geothermal features those have the large mass-flow rate like hot spring or hot pool can be seen scarecely in this area, and this is thought to be due to the lack of the underground water especially at the shallow places. The geothermal fluid discharged from fumarole and steaming ground consists of mainly the wet steam in the saturated state.

The temperatures measured in this reconnaissance survey are shown in the table. The locality numbers used in the table are the same to ones given by Glover. Judging from this measurement, it is thought that the temperature of discharging steam is almost in the saturated one(between 90^{o}C and 95^{o}C). All of the other features than fumarole and steaming ground are in very small scale. The features at the locality No. 52-55 which is situated in the western end of the area, seem to show the most activity from the view point of heat discharge. Though there is not yet found any surface geothermal features in the Eburru forest which is situated in the western side of the site of No. 52-55, this shows the possibility that the geothermal area extends to there.

The geochemical work done by Glover as a survey on the surface geothermal feature in this area is very useful for the exploration of geothermal reservoir hereafter. Besides it, the geological work on the hydrothermally altered zones those are almost associated with the present thermal anomally will give another useful result for the exploration. Mentioning on the geological work, it should be quite interesting to apply photogeologic method for making clear the relation between the fault structures and the distribution of the surface geothermal features. Heat discharge measurement at the surface feature will also give a useful information to decide the target for the future detailed survey.

Fig. I-2

Geological Map of Kenya

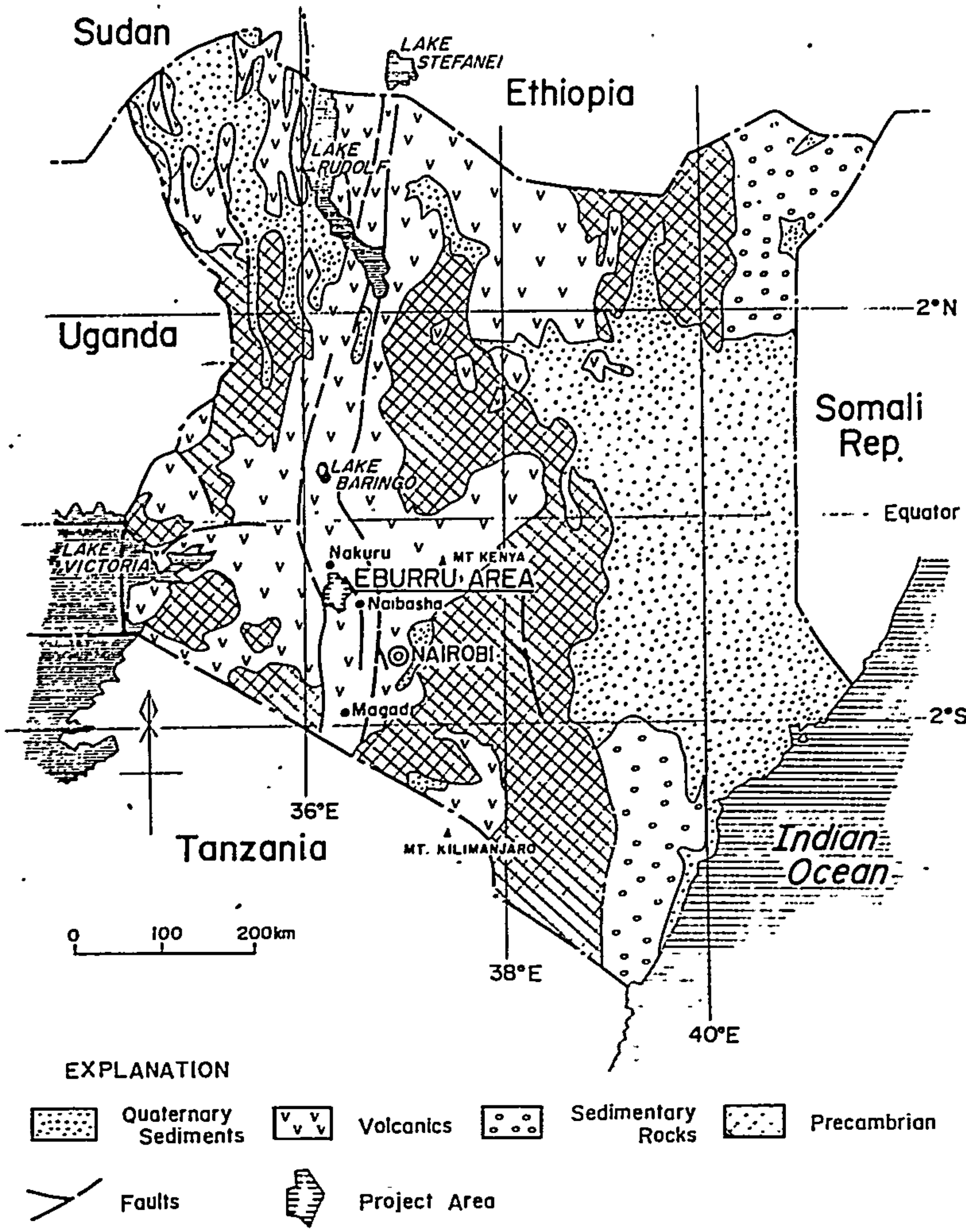


Table I-1

TEMPERATURES MEASURED AT SURFACE GEOTHERMAL FEATURES

in ^{o}C

Locality No.	Fumarole	Steaming Ground	Other features
17 (133/2/)	84.7	70.0,77.8 78.4	
38 (133/2/)		56.0	
52-55 (133/1/)	90.7	88.2	56.0 (hot pool)
60 (133/2/)		77.0	
71.72 (133/2/)	88.0		
77 (133/2/)	92.0	72.0	89.0 (mud pot)
79 (133/2/)		69.0 70.0	
80.81 (133/2/)	91.0		31.0 (hot spring well)
96 (133/2/)	86.0		

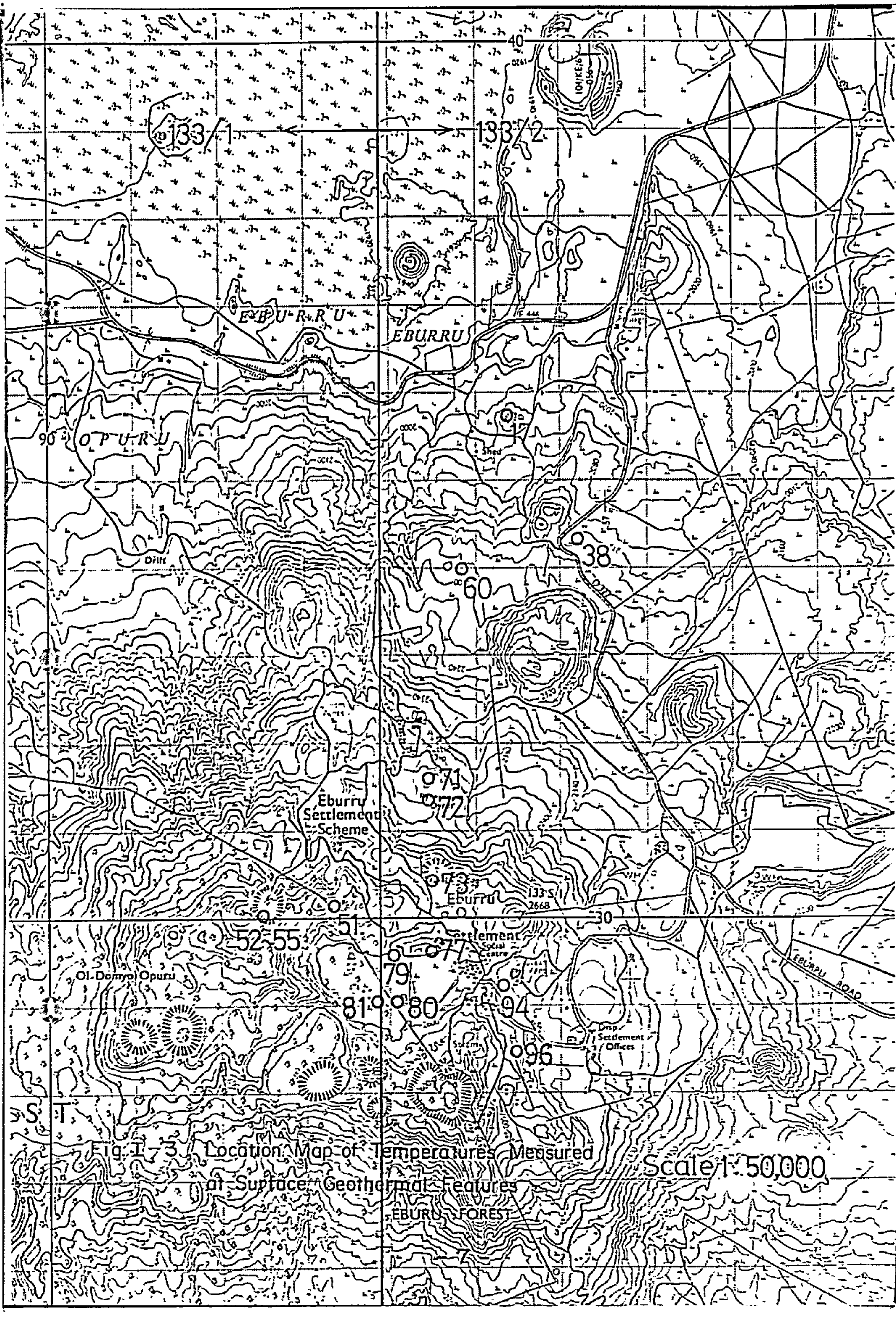


Fig. I-3 Location Map of Temperatures Measured at Surface Geothermal Features

II GEOCHEMICAL SURVEY

AT EBURRU GEOTHERMAL FIELD, ON 1980

BY KAZUO HIROWATARI.

As preliminary geochemical survey the followings were carried out in the Eburru Caldera.

1) Determination of Hg concentration in soil-air at 1m deep in the ground.

2) Determinations of CO_2 concentration in soil-air at 1m deep in the ground.

3) Measurement of temperature at 1m deep in the ground.

4) Determination of Hg concentration in soil at 1m deep in the ground (only samples were collected by JICA geothermal team and analysis were made by the chemical laboratory of Mines and Geological Department).

5) Determination of Hg, As, K, and Na concentrations in condensed water from fumaroles. (only samples were collected by JICA team and analysis were made by chemistry laboratory of Mines and Geological Department).

Field Survey.

Three traverse lines, line A(2km long), line B (1km long), and line C(1km long), were set in and around Eburru Caldera and were also used for geophysical survey. Seventy-one measuring points were set 50m intervals around the center of the caldera and 100m intervals at the peripheral of the caldera along the above mentioned traverse lines.

Eight condensed water samples were collected at fumaroles over the Eburru Geothermal area. Values of pH of collected water samples were made below 1.0 by adding concentrated nitric acid at the site where samples were collected.

Measurement and Instrumentation.

Instruments used for the geochemical survey are as follows:

Hg concentration in soil-air
Scientrex Model HGG-3 Serial No. 847000
Principle of the equipment is using atomic absoption of Hg gas at 254nm wave length.
Sensitivity 0.04 x 10^{-9}g Hg/250cc.

CO_2 concentration in soil-air
Kitagawa - CO_2 detector tubes
Principle of the detector tube is the same as gas-chrometography.

- 1m deep temperature

  Takara Model A-600 thermistor.

  Temperature range - $5^{o}C$ to $110^{o}C$

  Sensitivity $0.1^{o}C$.

Measurements were made as following procedure.

1) At the measuring point two holes (diameter approx. 20mm) were made to 1m deep by 1.2m long stick.

2) Immediately after digging holes. CO_2 concentration in soil-air was measured in one hole and Hg concentration in soil-air was measured in the other hole.

3) After those measurements, a sensor of thermistor was put into one hole at 90cm deep. Reading of temperature was taken minimum 3 minitues after its sensor being inserted.

4) Soil sample for analizing Hg, was taken from a bottom of a hole.

In order to assure that temperature at 1m deep is not affected by the atmospheric temperature variation, temperature at the surface, 33cm deep, 60cm deep, and 90cm deep were measured simultaneously.

Survey Result.

Collected data are attached to this report but because of lack of time, their detailed analysis and interpretations will be done later.

Hg concentration, CO_2 concentration, and 1m deep temperature show good agreement with geologically altered zones.

Temperature measurements at several depth show that temperature at 1m deep in the ground does not depend on diurnal temperature variation of atmosphere.

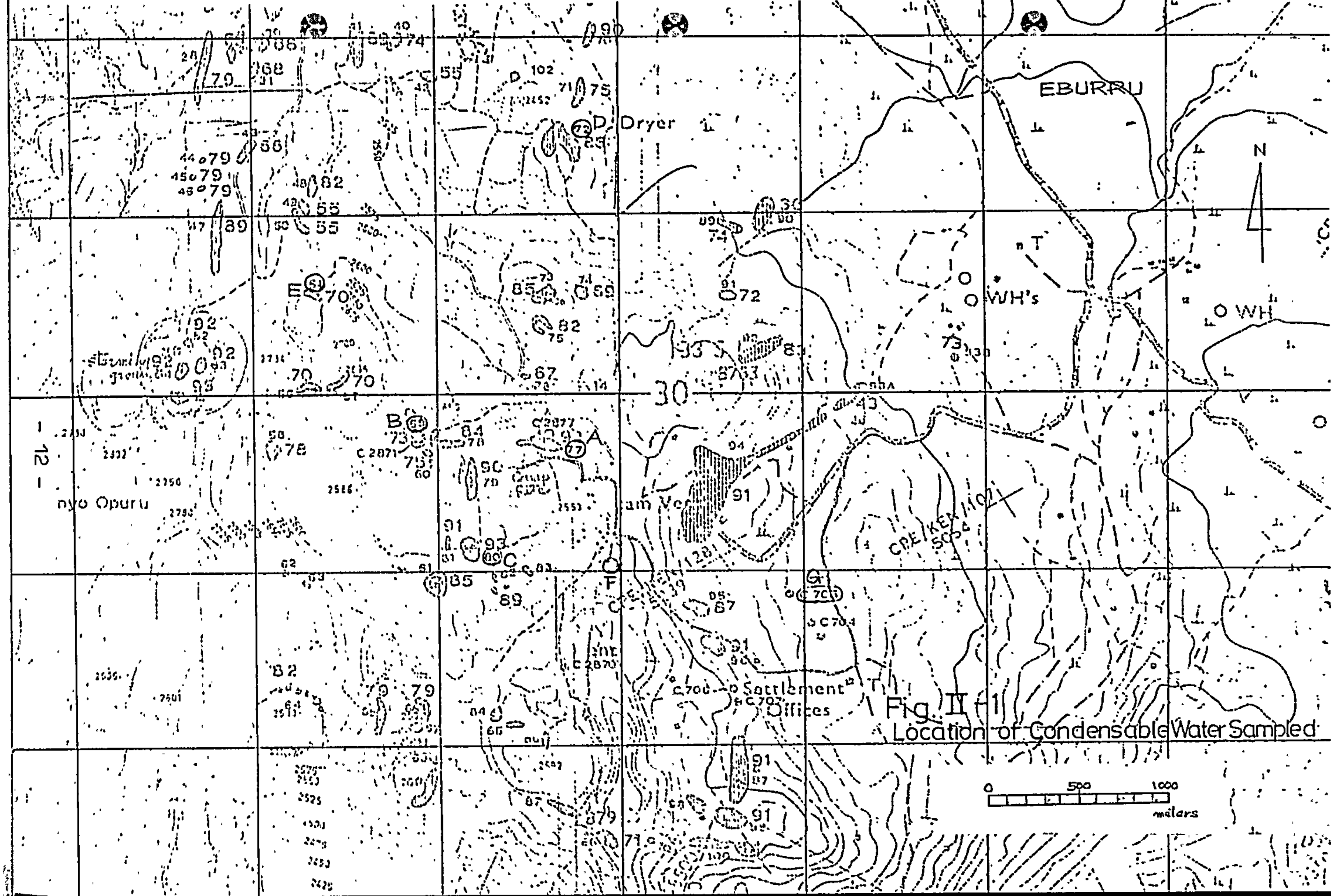


Fig. II-1
Location of Condensable Water Sampled

Fig. II-2 SKETCH OF THE POINTS OF CONDENSABLE WATER SAMPLED

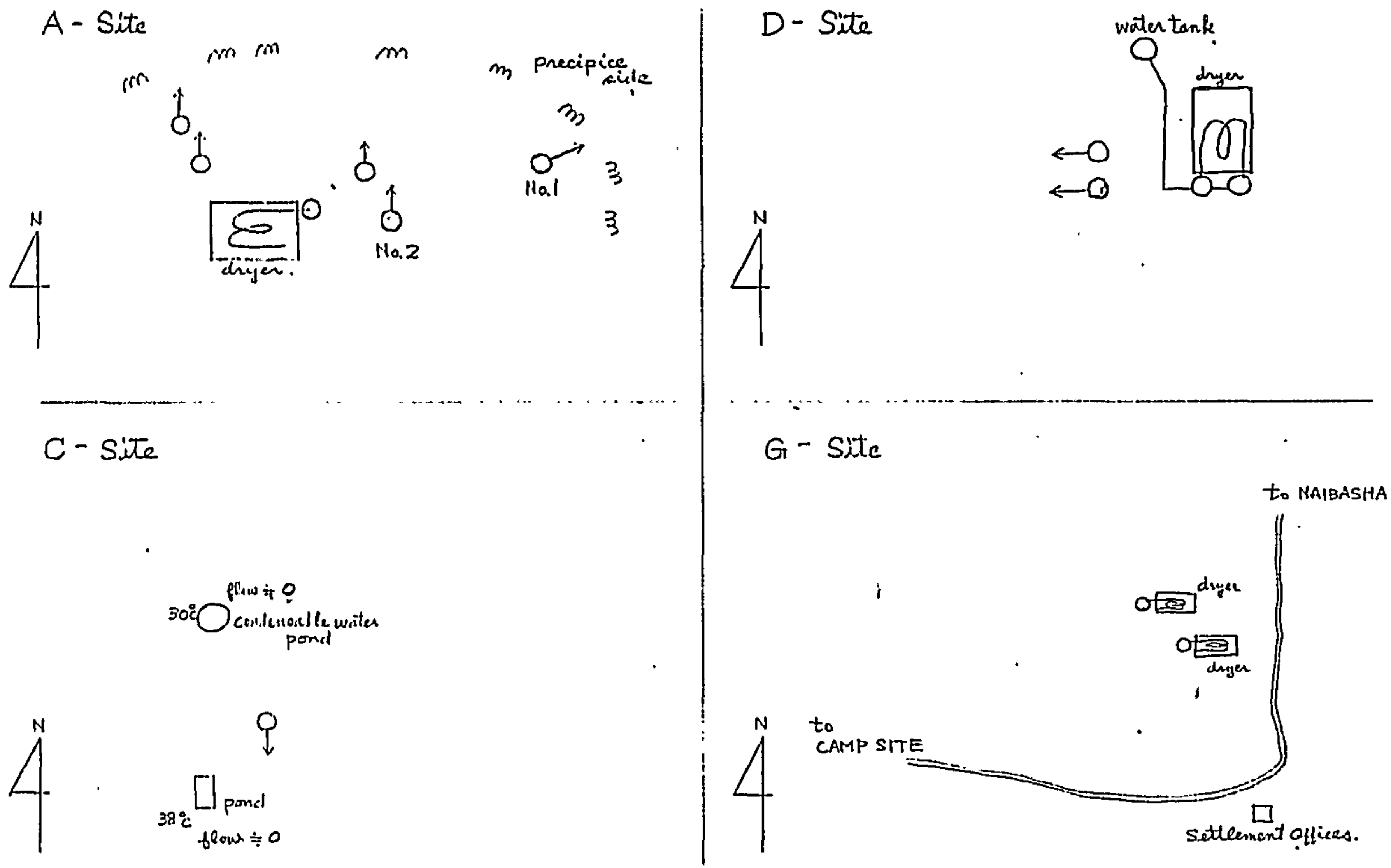
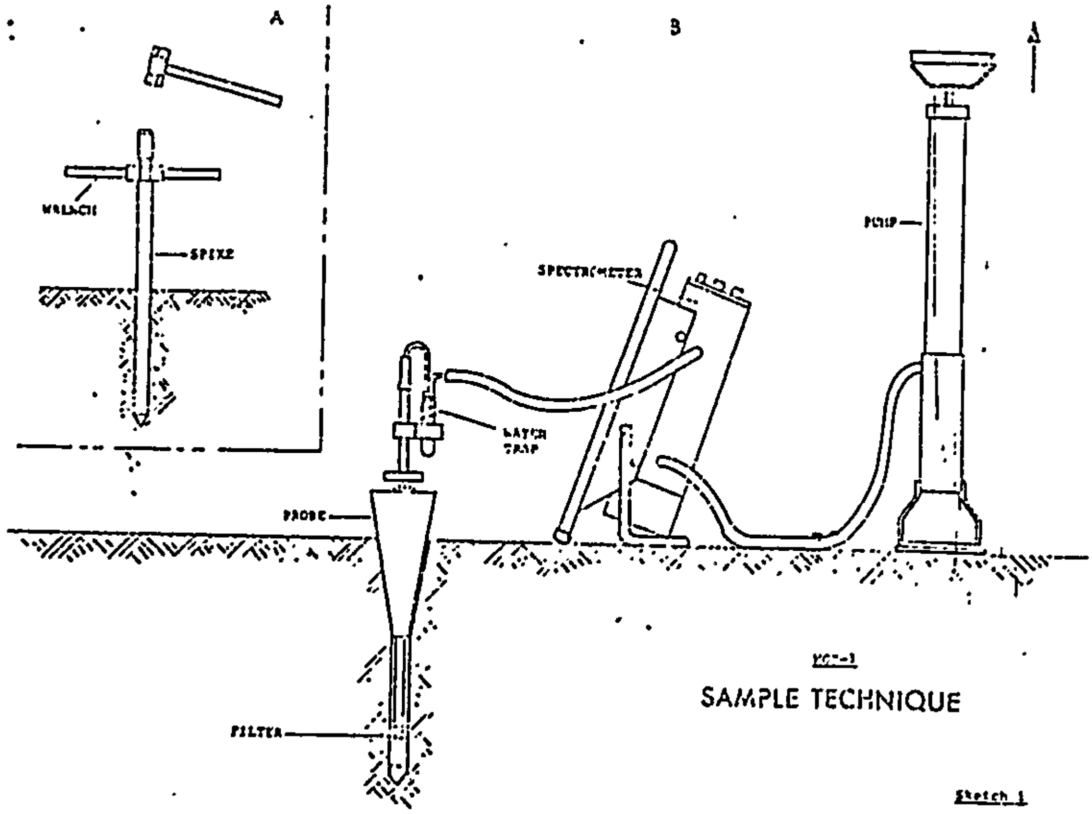


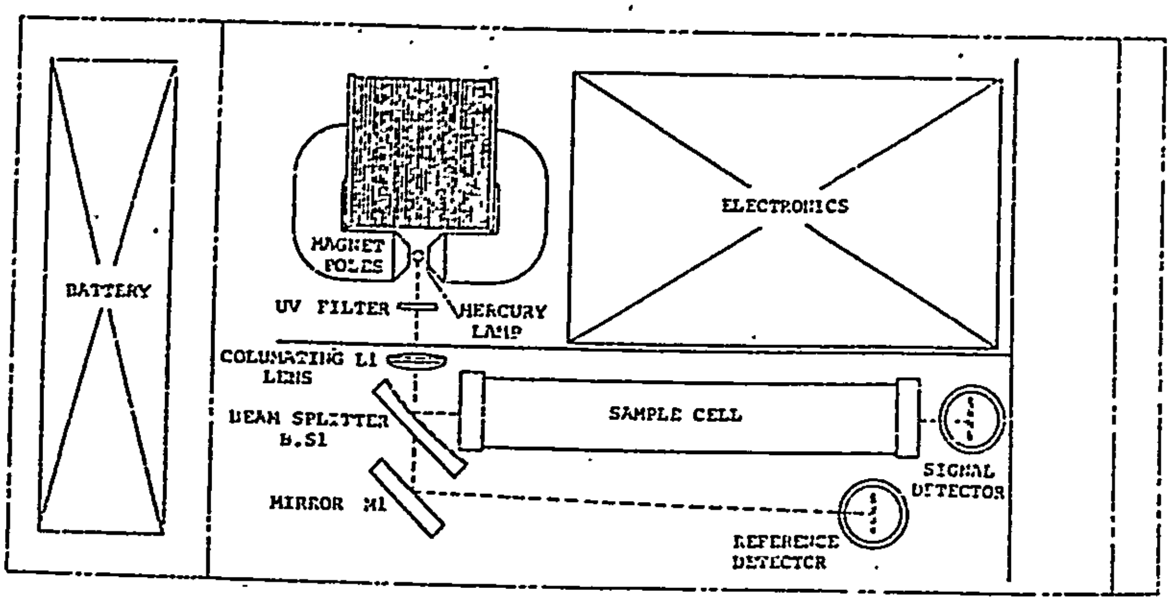
Fig.II-3

MERCURY SPECTROMETER

SCINTREX HGG-3

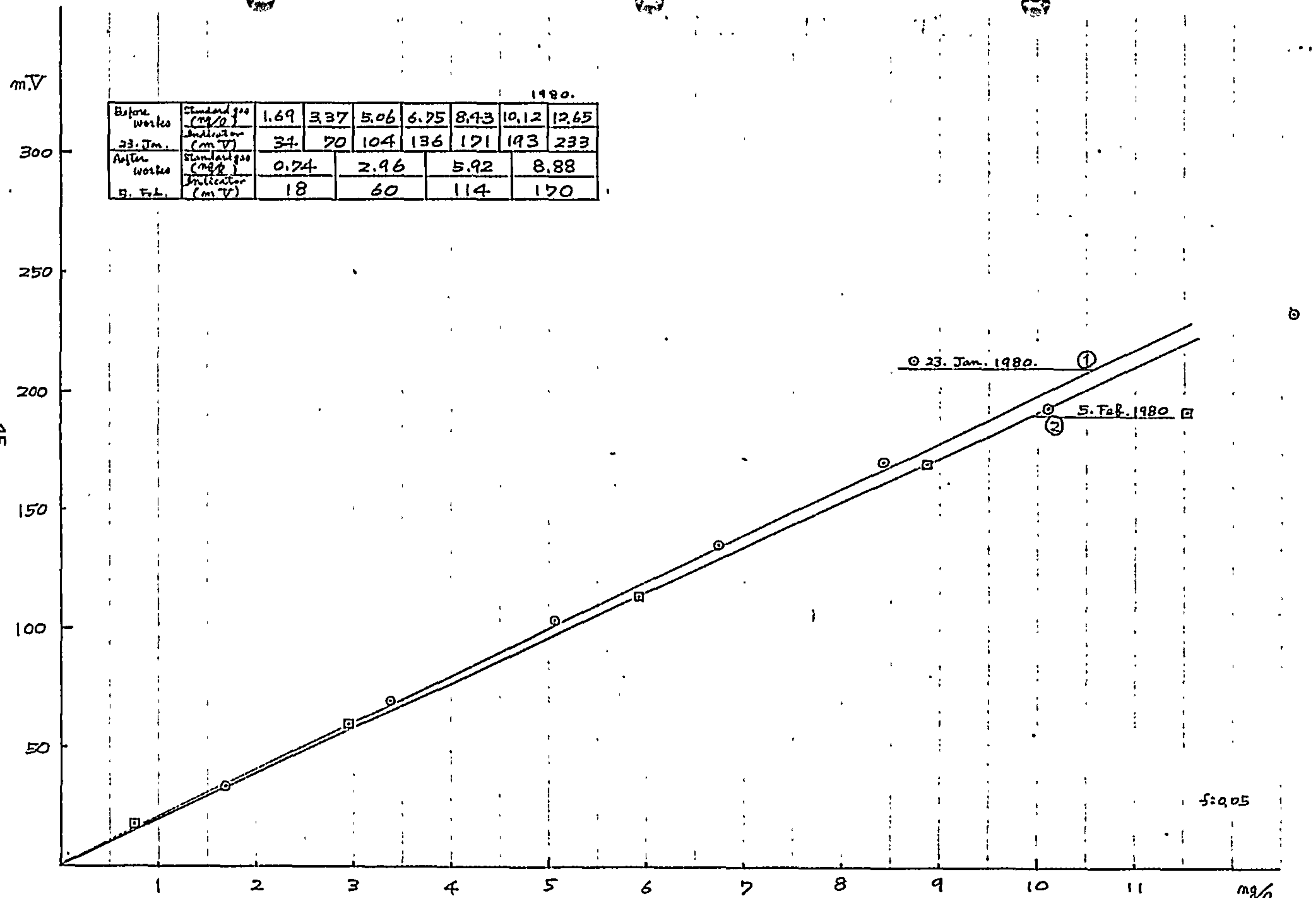


Sketch 1



HGG-3 BACKPACK SPECTROMETER

Sketch 2

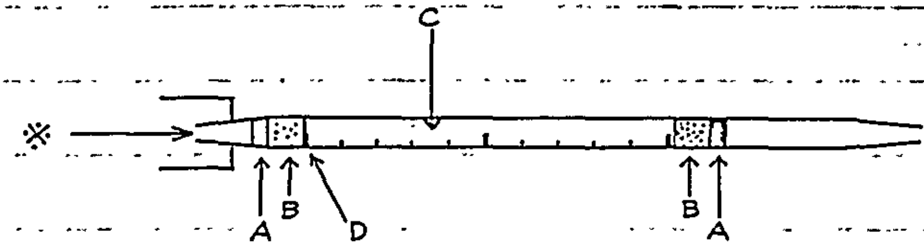


		1980.						
Before works 23. Jan.	Standard gas (mg/l)	1.69	3.37	5.06	6.75	8.43	10.12	12.65
	Indicator (mV)	34	70	104	136	171	193	233
After works 5. Feb.	Standard gas (mg/l)	0.74		2.96		5.92		8.88
	Indicator (mV)	18		60		114		170

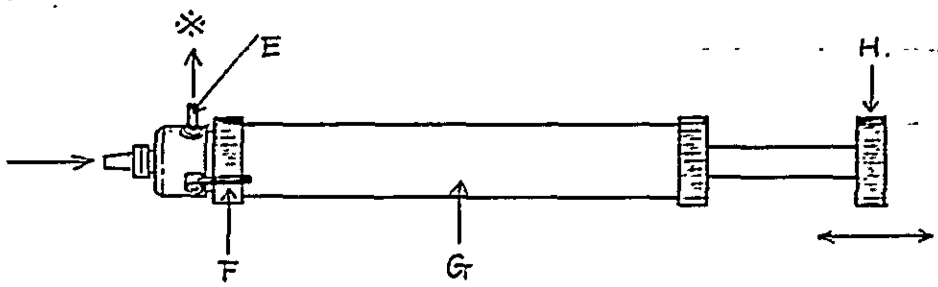
Fig. II-4 Calibration Curve of Mercury Spectrometer

Fig. II-5
CARBON DIOXIDE DETECTOR

DETECTION TUBE



GAS COLLECTOR



A stopper
B glass grains
C detection reagent
D scale
E tube conector
F three ways valve.
G cylinder
H piston nob..

Fig. II-6
TEMPERATURE VARIATIONS AT THREE DIFFERENT DEPTH IN THE GROUND AND AT THE SURFACE.

(ON 30TH, JANUARY, 1980)

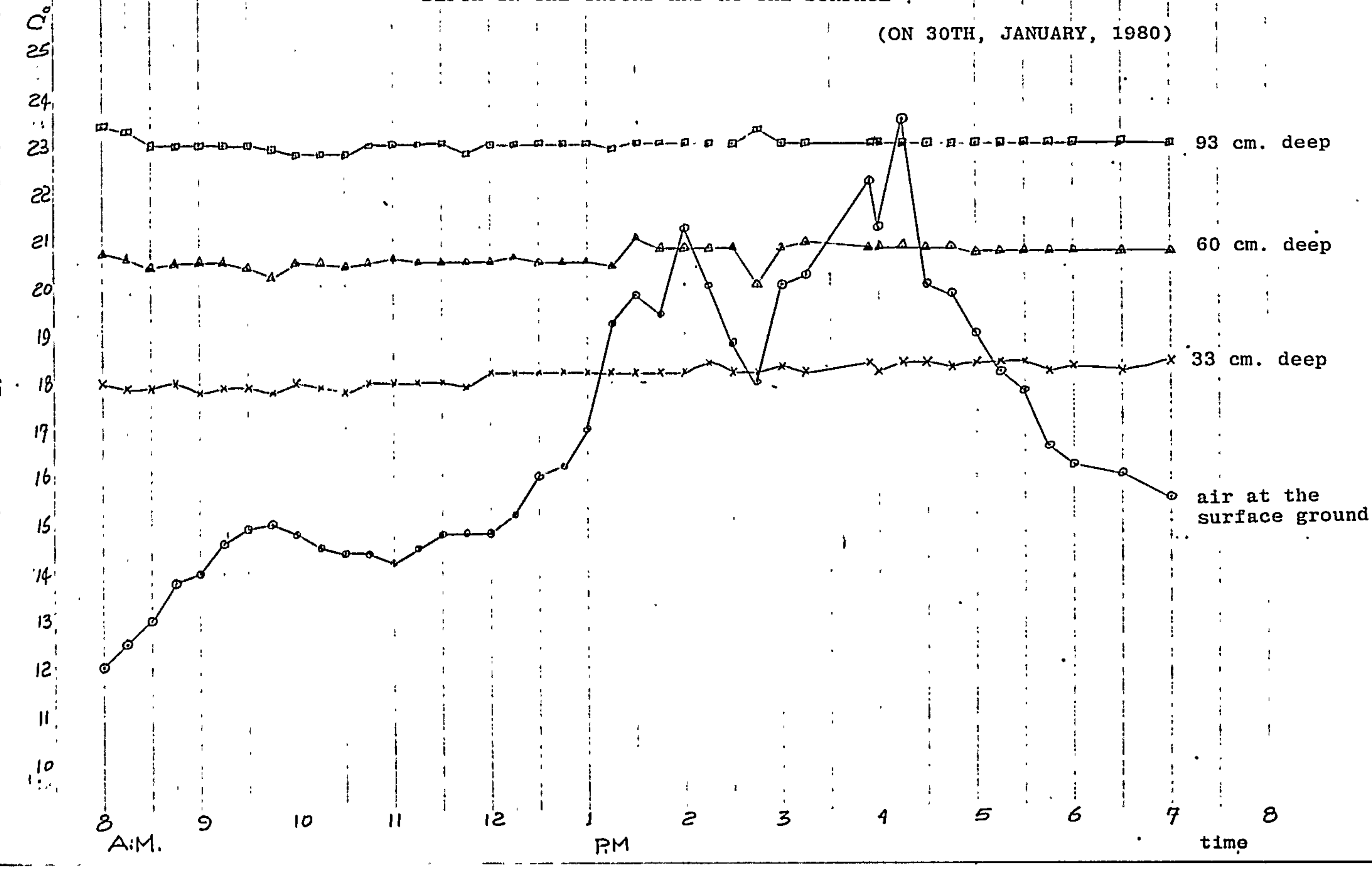


Table II-1 Geochemical Results of A-Line

EBURRU-A LINE

SAMPLE No.	IN SOIL AIR CO2 (%)	IN SOIL AIR Hg (mg/l)	IN SOIL* Hg (µg/g)	TEMP 1m depth in the ground (°C)	REMARK
A-10	0.4	N.D	2.5	34.0	↑ Eburru peak.
11	1.0	0.75	1.3	37.0	near the alteration zone
12	1.5	0.40	1.1	42.8	
13	3.0	0.25	1.9	28.0	
14	1.0	0.25	0.4	22.7	
15	0.4	N.D	0.5	17.9	
16	0.4	N.D	1.3	21.1	
16.5	0.5	0.10	0.4	19.6	
17	0.6	N.D	0.3	29.5	caldera end.
17.5	1.6	2.00	1.7	26.5	
18	2.2	0.90	0.4	27.6	
18.5	1.3	0.40	0.2	26.5	
19	0.7	0.25	0.4	25.6	
19.5	1.1	0.75	–	25.5	
20	0.5	N.D	0.8	20.8	
20.5	0.7	N.D	0.3	21.0	
21	0.7	0.15	0.9	20.2	
21.5	0.9	0.30	1.7	22.0	
22	20.0	0.75	0.8	49.0	alteration zone and hot spot.
22.5	55.0	10.50	2.0	91.0	
23	6.7	2.00	2.1	56.5	
23.5	0.8	1.05	1.1	39.4	
24	0.5	1.10	1.1	32.3	
24.5	0.9	0.20	0.9	32.6	
25	0.6	0.20	0.1	23.0	
25.5	1.3	1.15	0.3	29.6	
26	1.0	0.40	2.5	34.0	
27	0.3	N.D	0.1	21.5	
28	0.2	N.D	0.1	17.0	forest.
29	0.2	N.D	0.1	16.1	other caldera basin
30	0.5	N.D	0.9	17.0	

N.D : not detected.

※ : analyzed by Mines and Geological Department of Kenya.

Table II-2 Geochemical Results of B-Line

EBURRU-B LINE

SAMPLE N.O	IN SOIL AIR CO2 (%)	IN SOIL AIR Hg (mg/l)	IN SOIL* Hg (μg/g)	TEMP 1 m depth in the ground (°C)	REMARK
B-15	1.0	N.D	0.1	23.5	
16	0.9	N.D	0.3	23.0	
16.5	0.2	N.D	0.1	25.6	
17	0.5	0.50	0.9	27.6	
17.5	1.2	0.75	3.9	34.4	alteration and steaming ground (17.5–18.5)
18	7.5	1.75	1.8	50.0	
18.5	35.0	6.50	0.2	89.5	
19	0.6	0.25	4.4	29.0	
19.5	1.5	0.25	3.4	41.0	
20	16.6	0.75	3.1	34.4	
20.5	0.6	0.20	1.1	21.1	
21	0.7	N.D	0.9	25.0	
21.5	0.7	0.25	0.9	30.3	
22	7.0	1.25	3.8	63.0	alteration zone
22.5	1.6	0.25	5.8	30.8	
23	0.9	0.25	3.5	29.8	
23.5	0.4	N.D	0.8	25.5	
24	0.7	0.15	1.6	30.8	
24.5	1.5	0.25	1.6	32.5	
25	3.5	0.25	6.7	35.0	

Table II-3 Geochemical Results of C-Line

EBURRU-C.LINE

SAMPLE	IN SOIL AIR		IN SOIL※	TEMP	REMARK
N.O	CO_2 (%)	Hg (ng/l)	Hg (μg/g)	1 m depth in the ground (°C)	
15	0.2	N.D	0.1	17.5	
16	0.3	N.D	0.1	21.5	
16.5	0.3	N.D	0.1	21.5	
17	1.0	N.D	0.1	21.8	
17.5	0.5	0.50	0.1	18.0	
18	0.9	0.60	0.1	23.5	
18.5	0.5	0.50	0.6	22.7	
19	0.5	N.D	0.1	22.0	
19.5	0.9	N.D	0.1	21.6	
20	0.8	N.D	0.1	21.7	
20.5	0.5	N.D	0.1	19.1	
21	0.7	N.D	0.1	21.5	
21.5	1.0	0.40	0.1	27.4	
22	2.4	0.80	1.9	30.0	
22.5	1.6	0.15	1.3	29.6	
23	2.6	0.60	0.6	34.5	
23.5	2.2	0.35	0.1	30.4	
24	0.5	N.D	0.1	25.0	
24.5	0.8	N.D	0.1	28.5	
25	0.7	N.D	0.1	23.7	

Fig. II-7 Hg Concentration in Soil Air

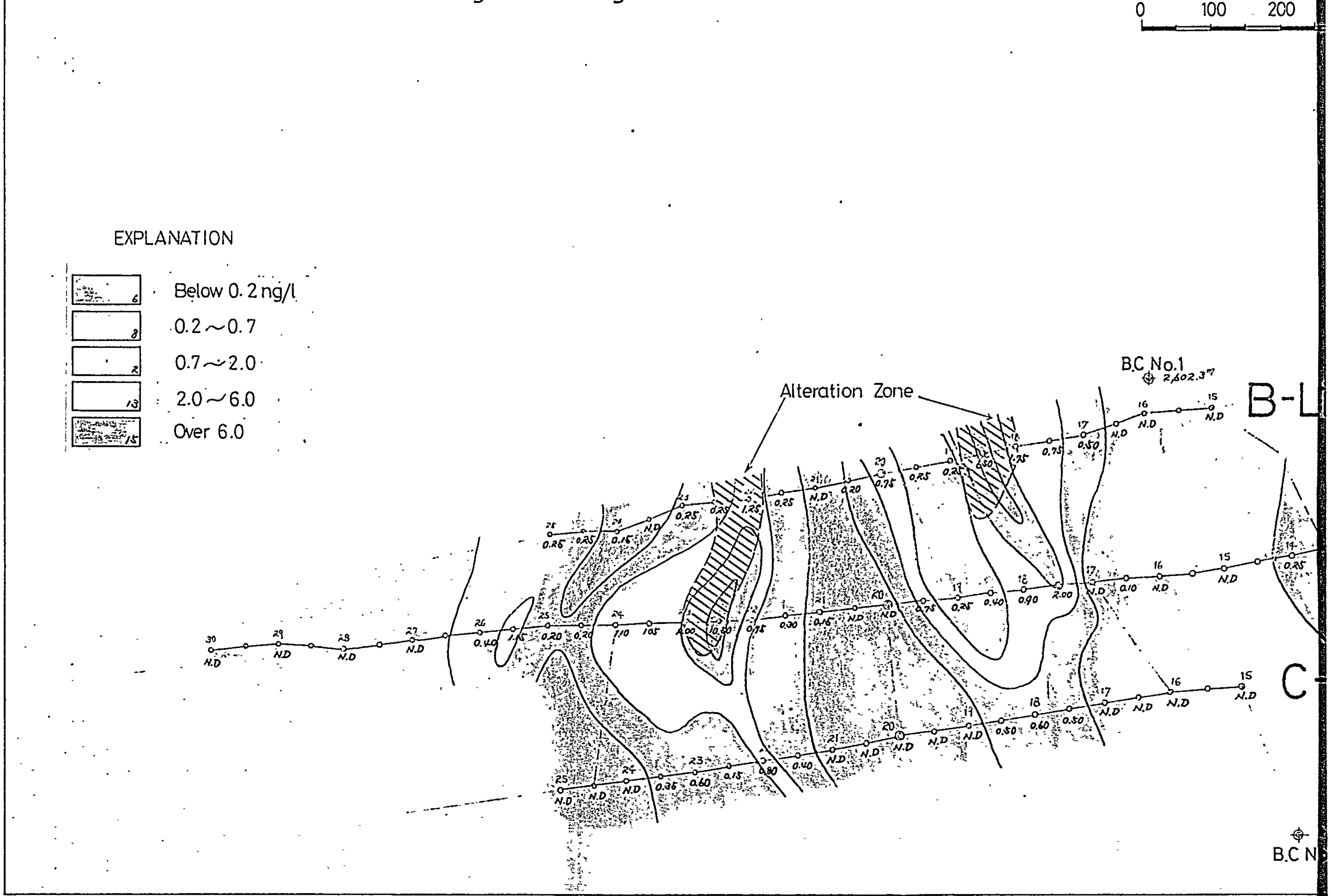


Fig. II-7 Hg Concentration in Soil Air

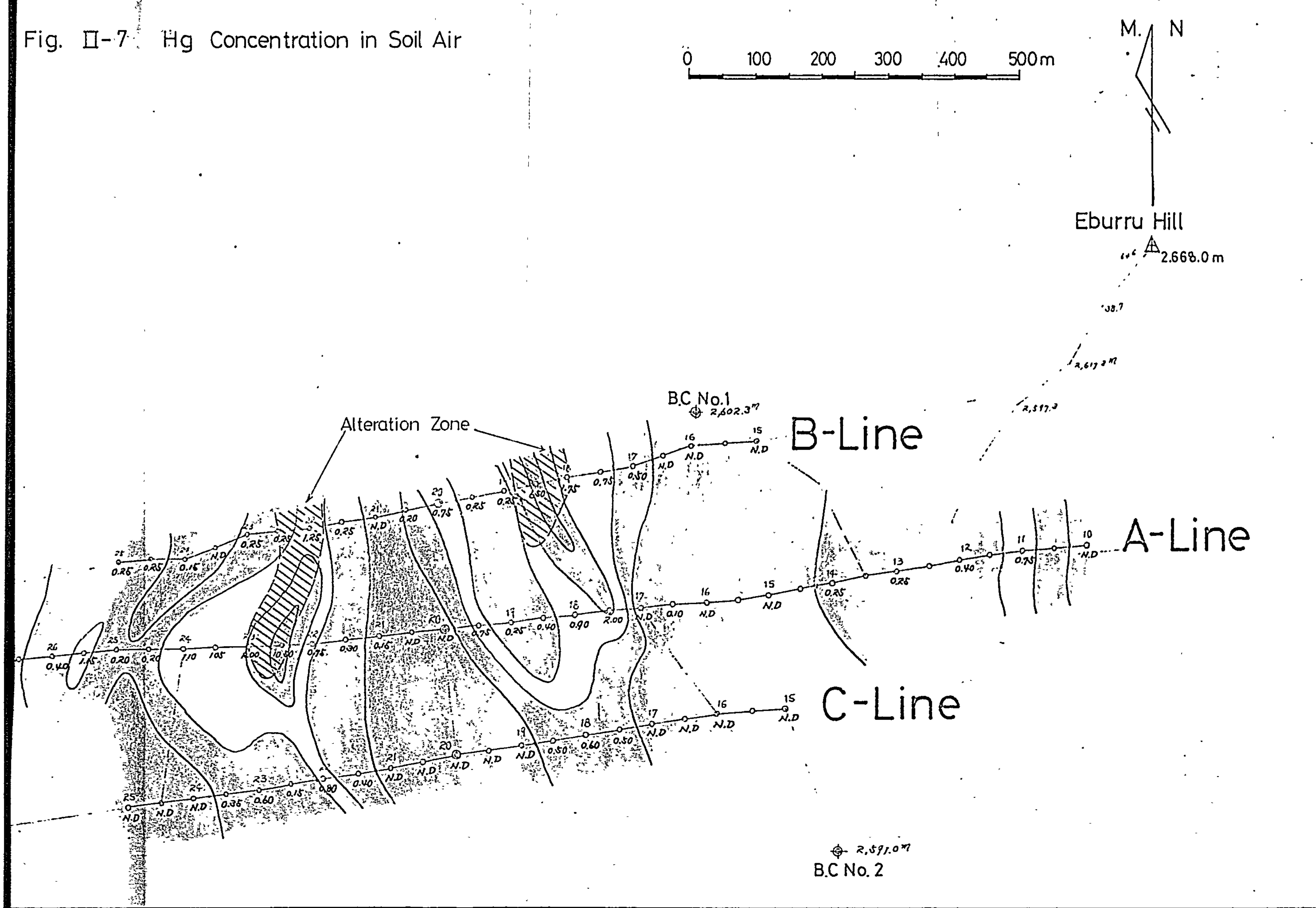


Fig. II-8 CO_2 Concentration in Soil Air

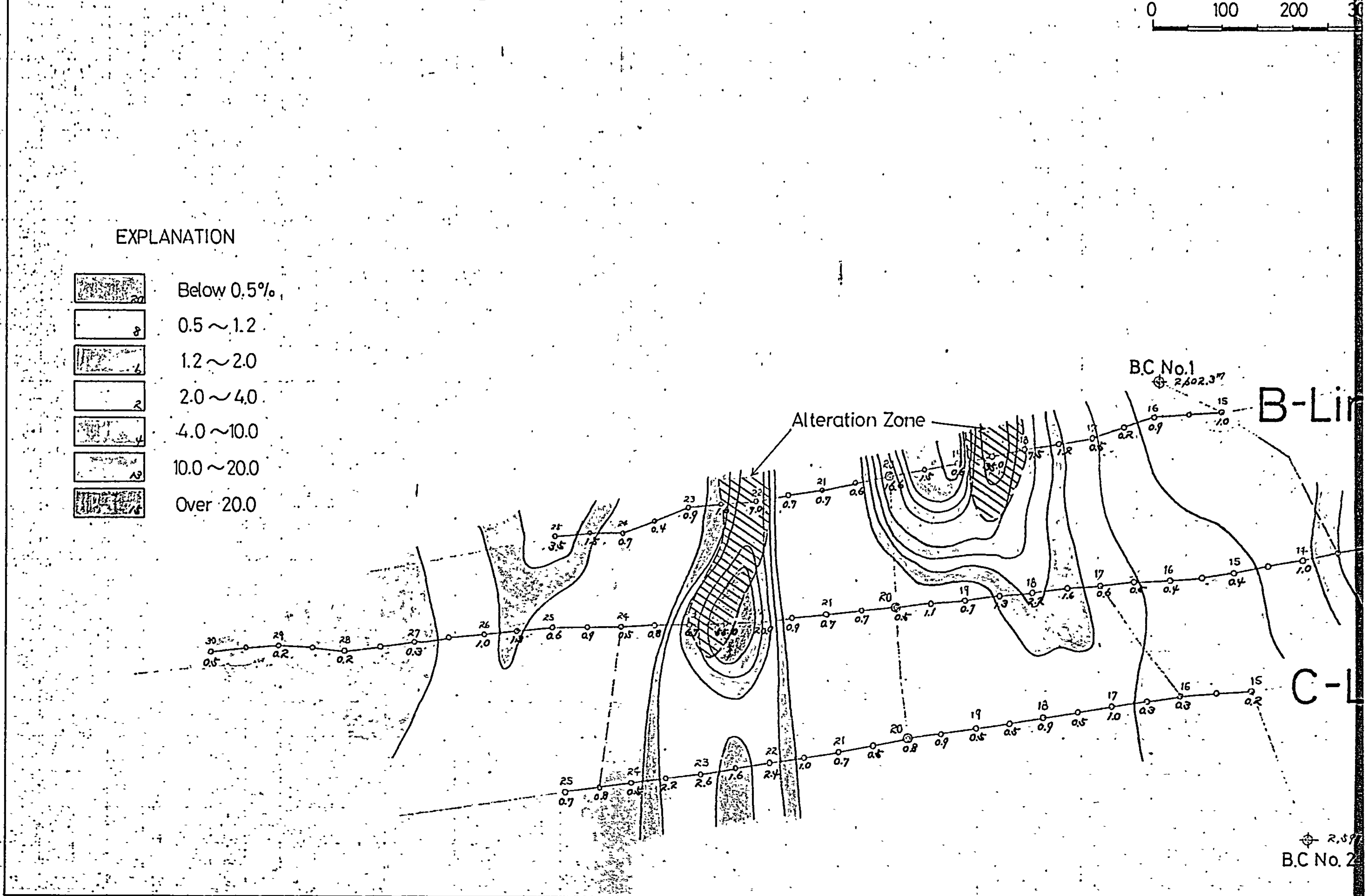


Fig. II-8 CO_2 Concentration in Soil Air

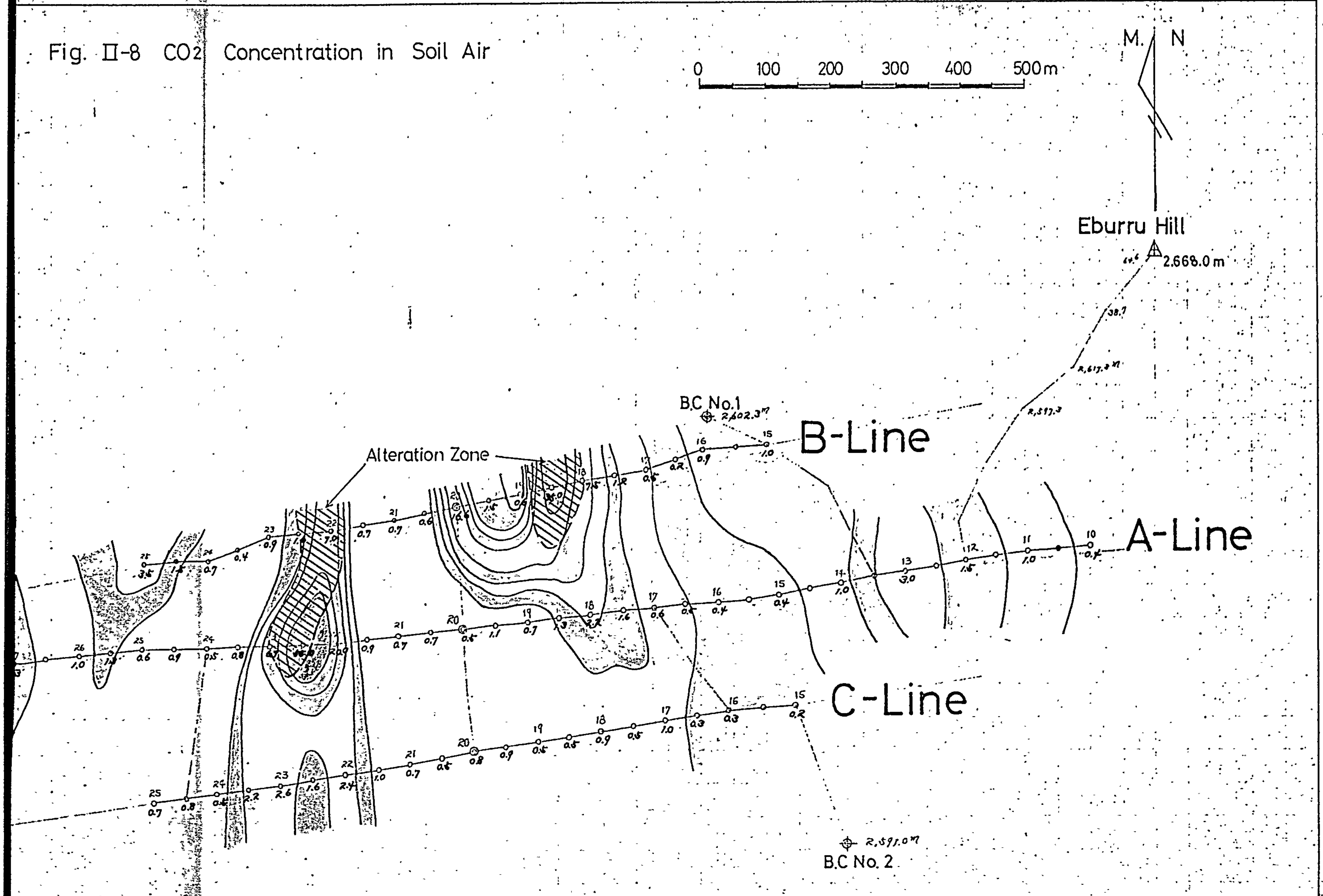


Fig. II-9 Temperature of 1m Depth in the Ground

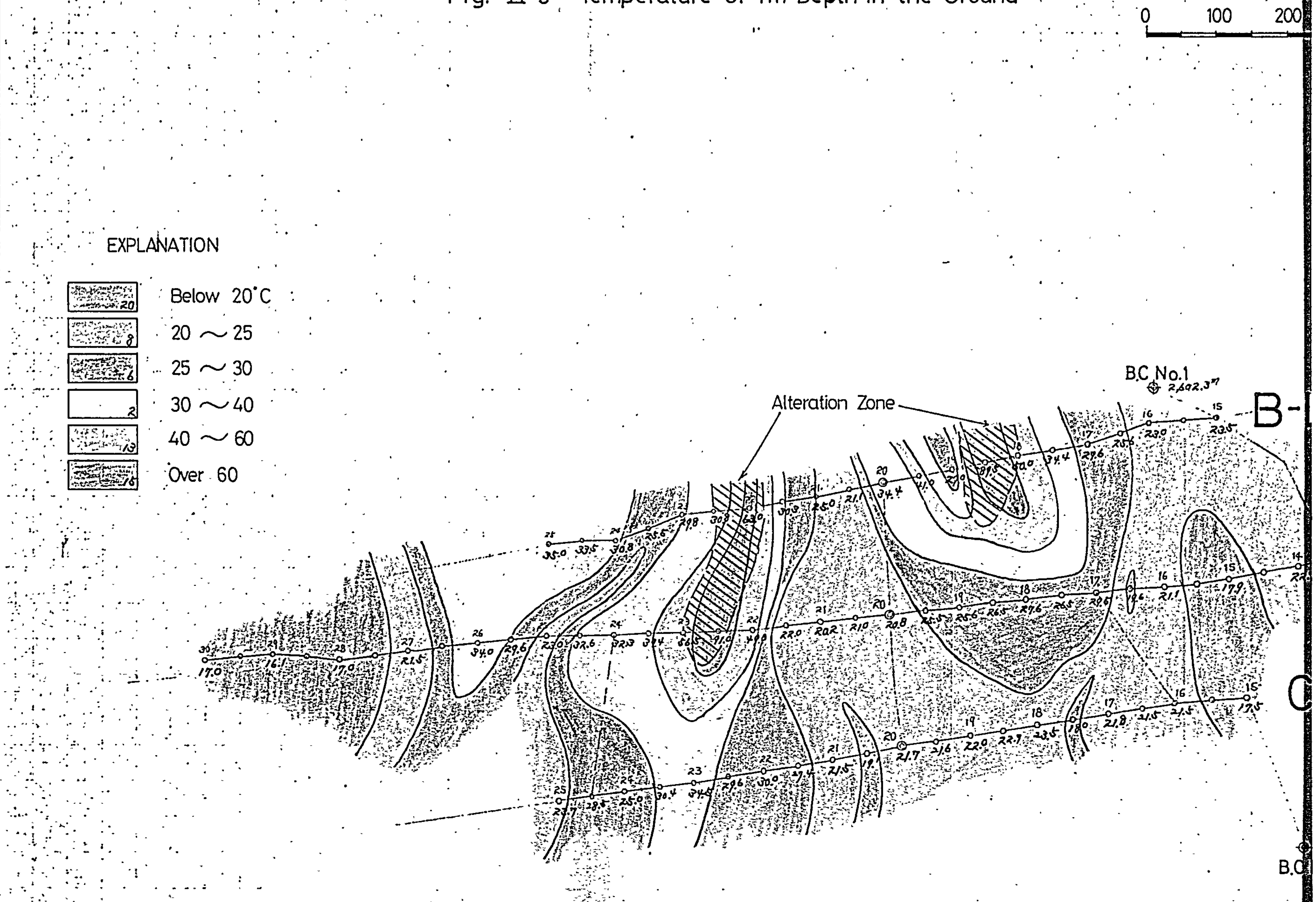


Fig. II-9 Temperature of 1m Depth in the Ground

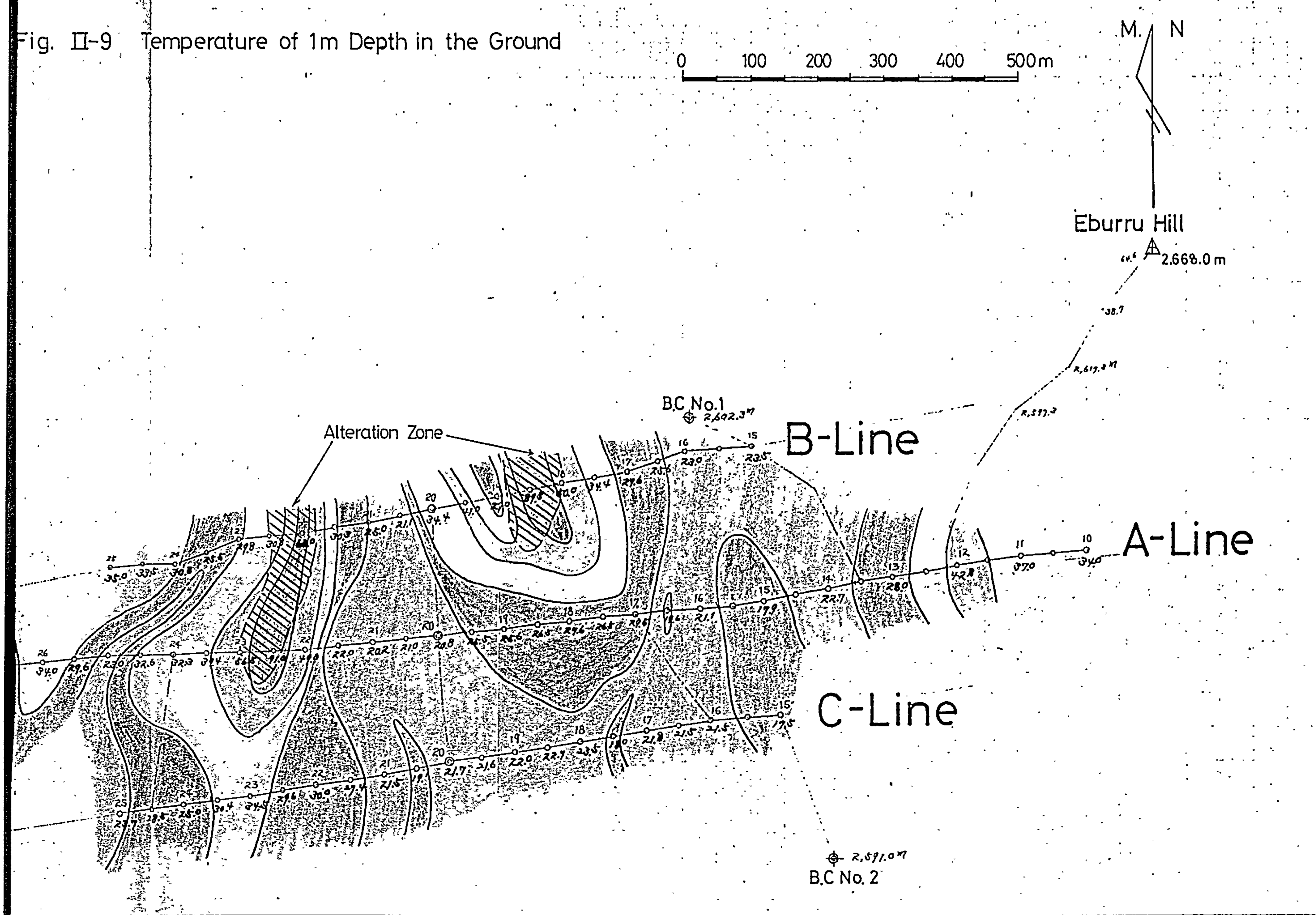


Fig. II-10 Hg Concentration in Soil

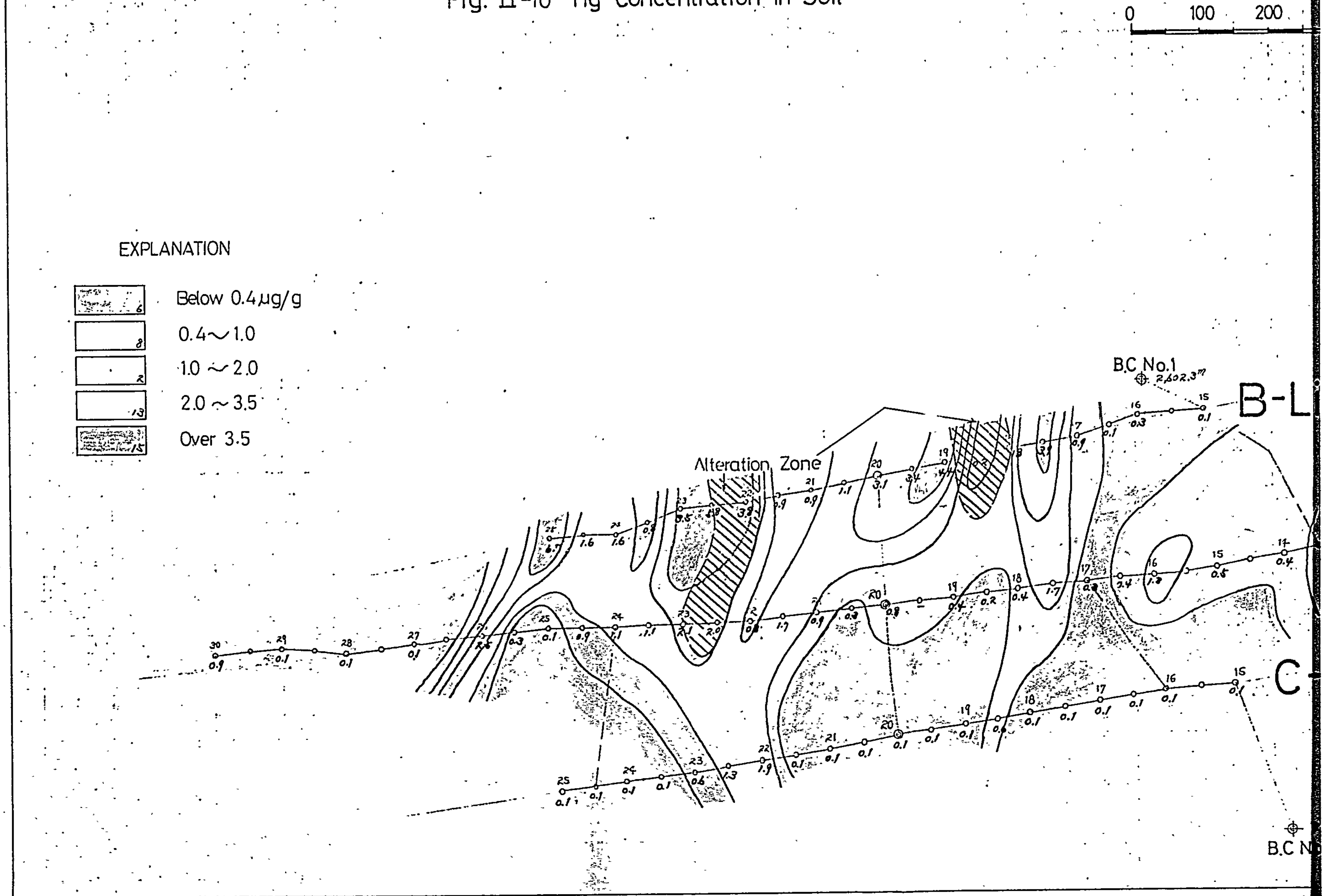
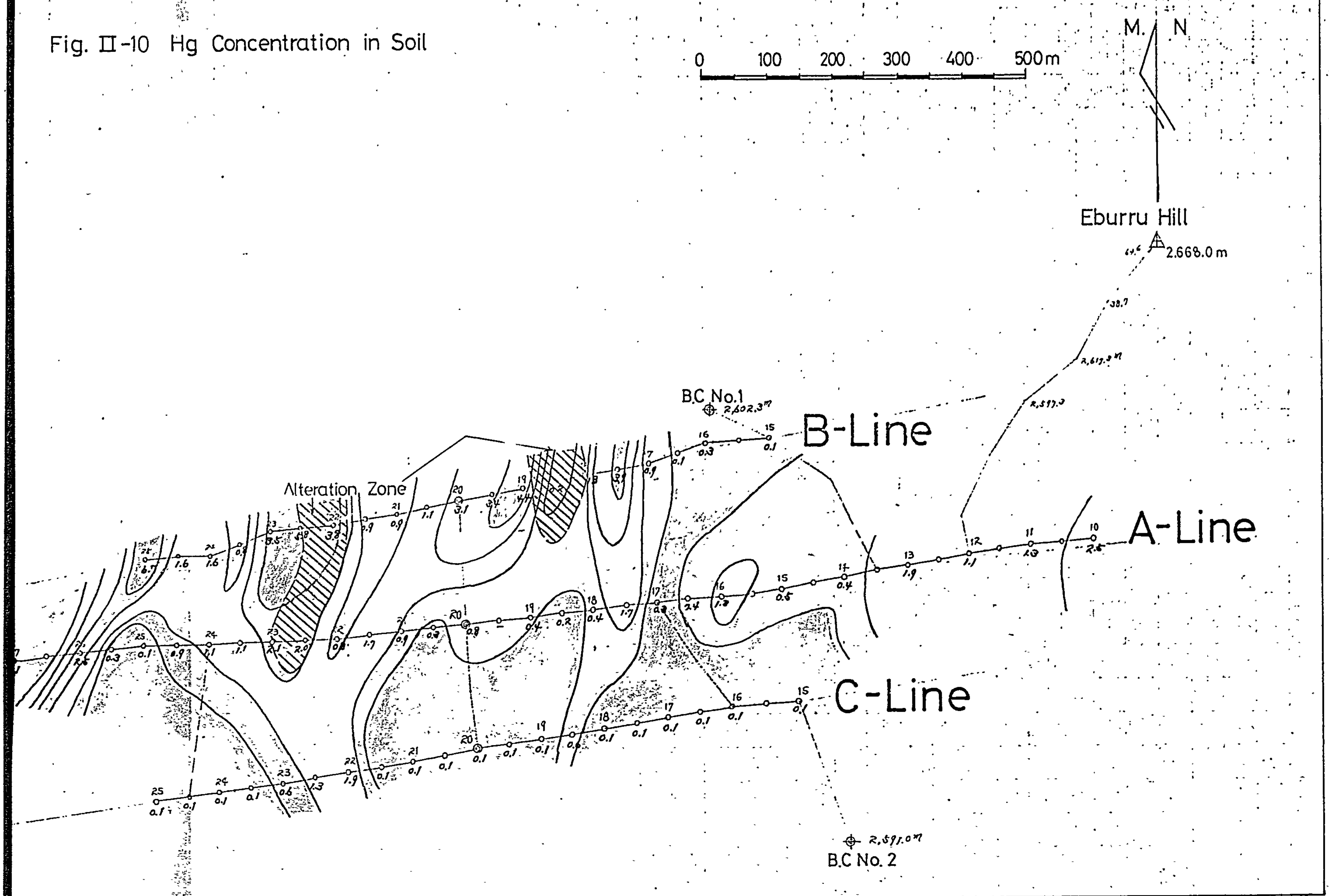
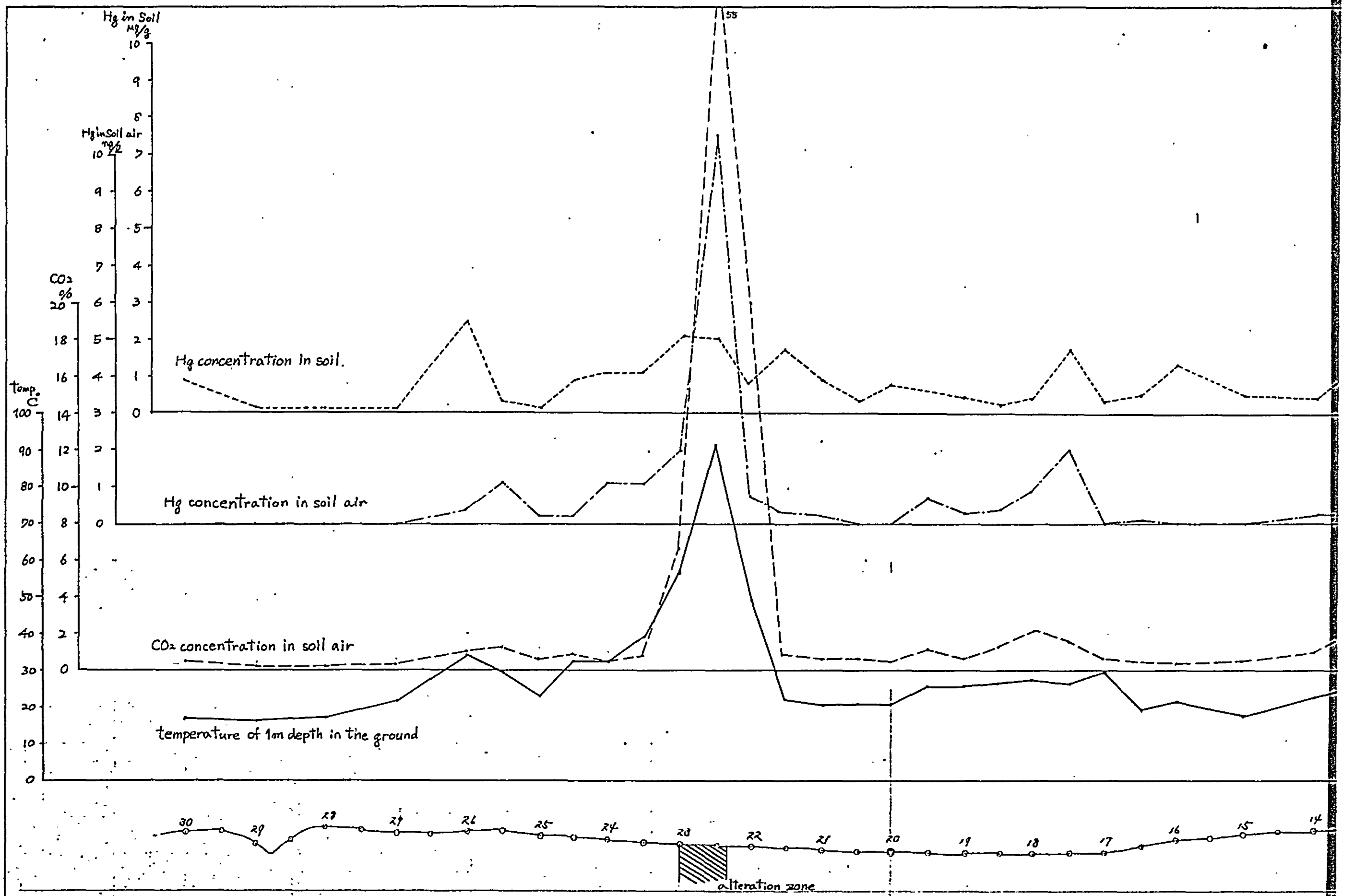


Fig. II-10 Hg Concentration in Soil





A-Line Section

Fig. II-11 Section of Geochemical Results along A-Line

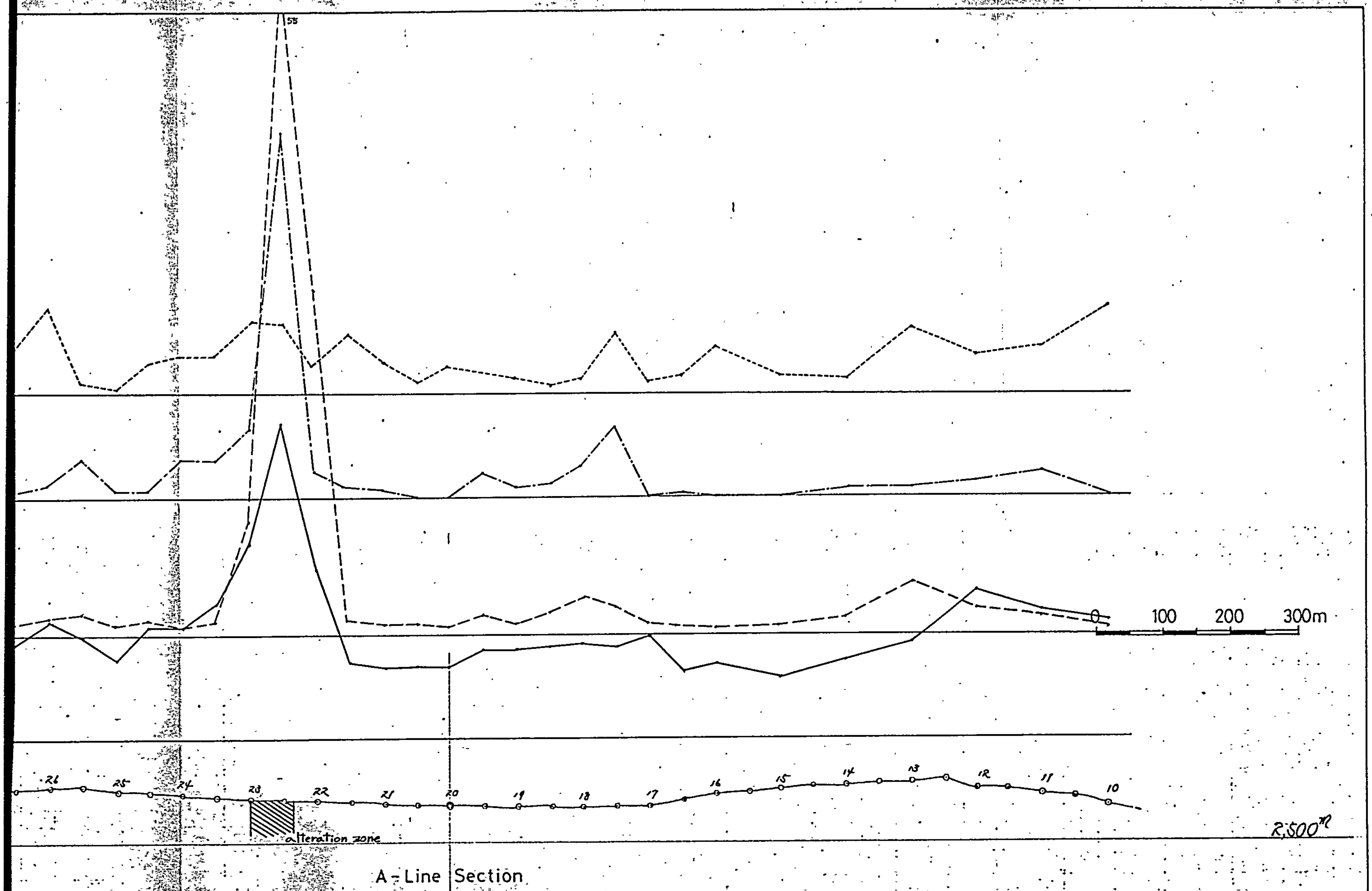


Fig. II-11 Section of Geochemical Results along A-Line

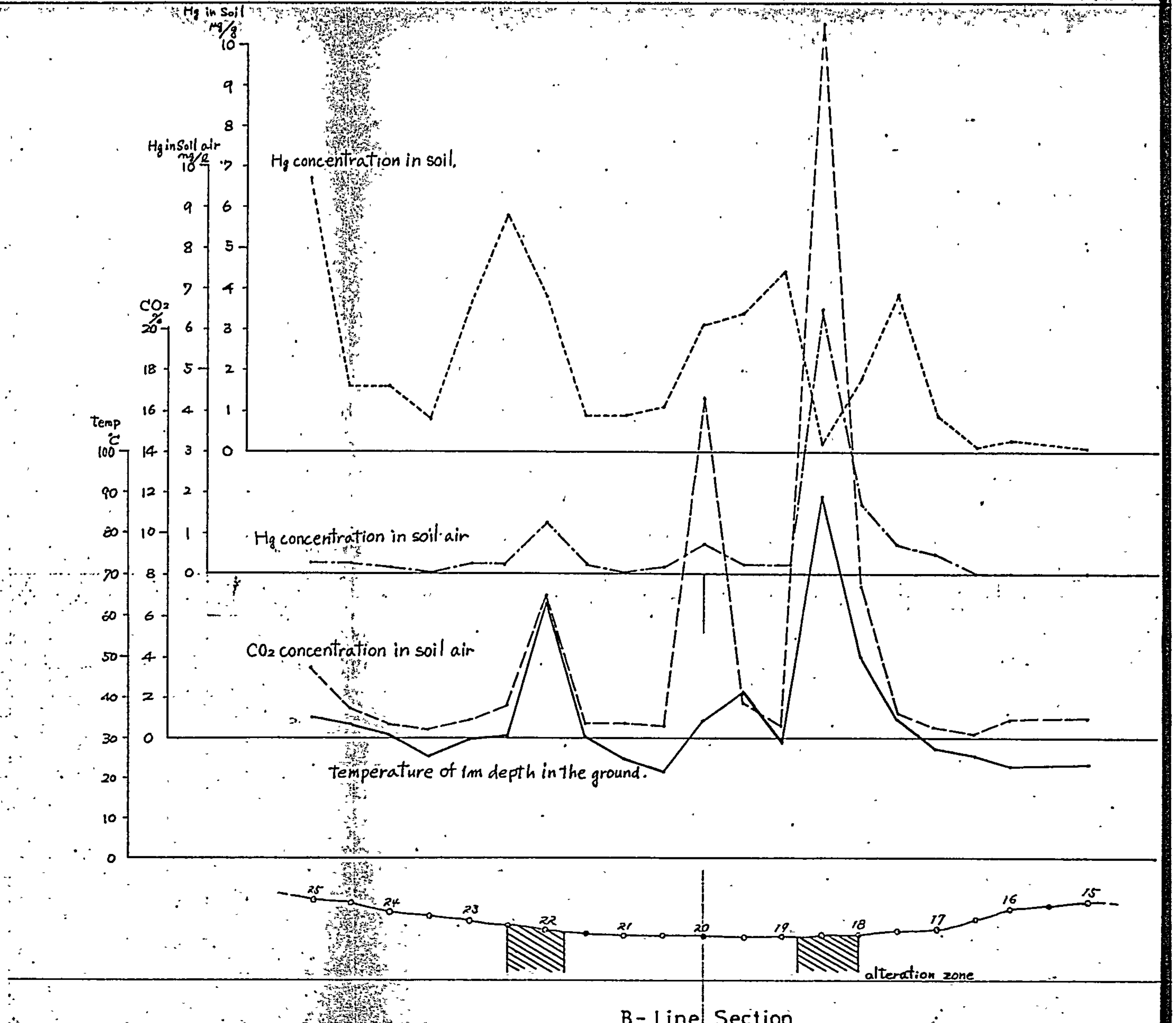


Fig. II-12 Section of Geochemical Results along B-Line

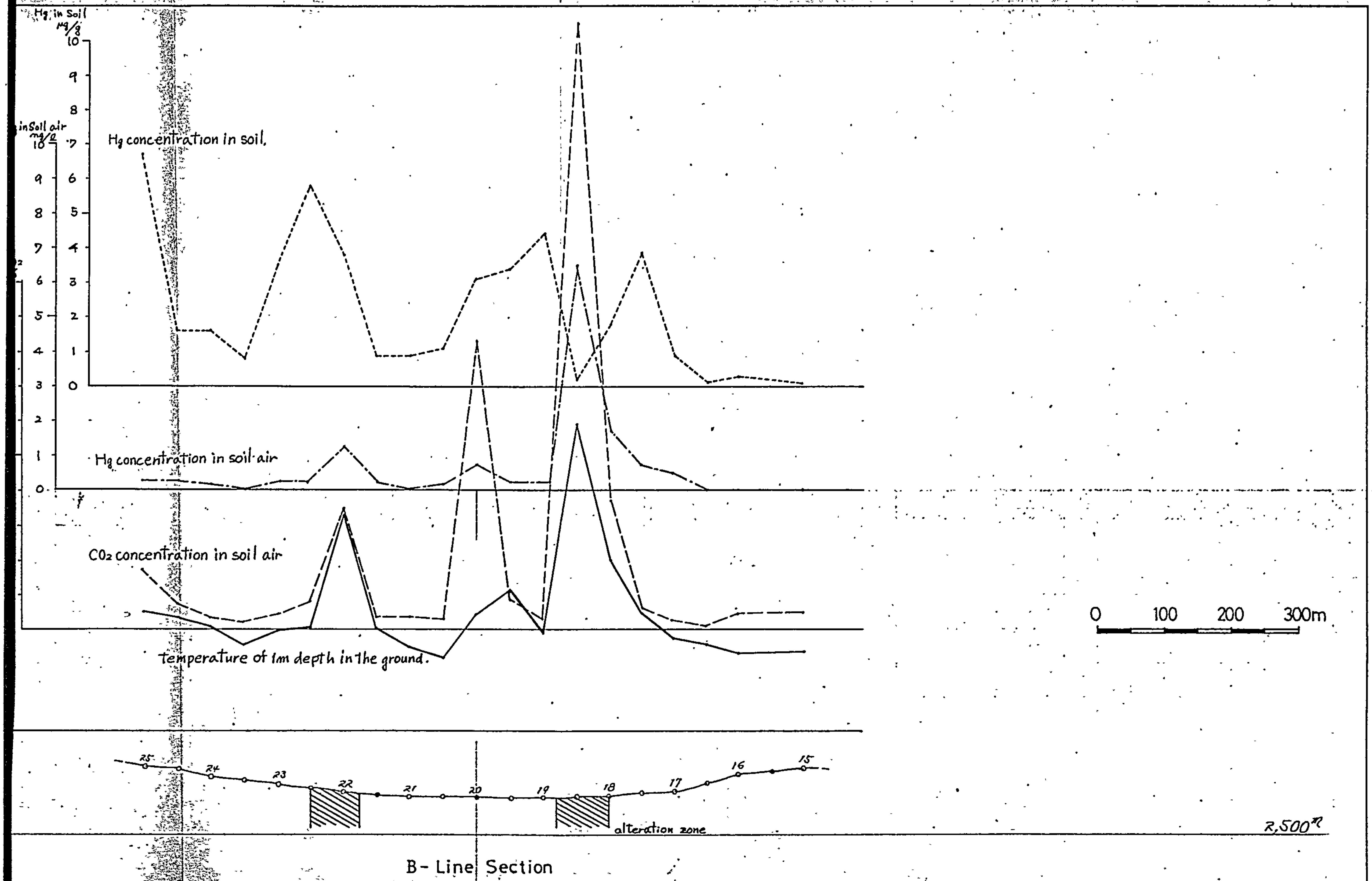


Fig. II-12 Section of Geochemical Results along B-Line

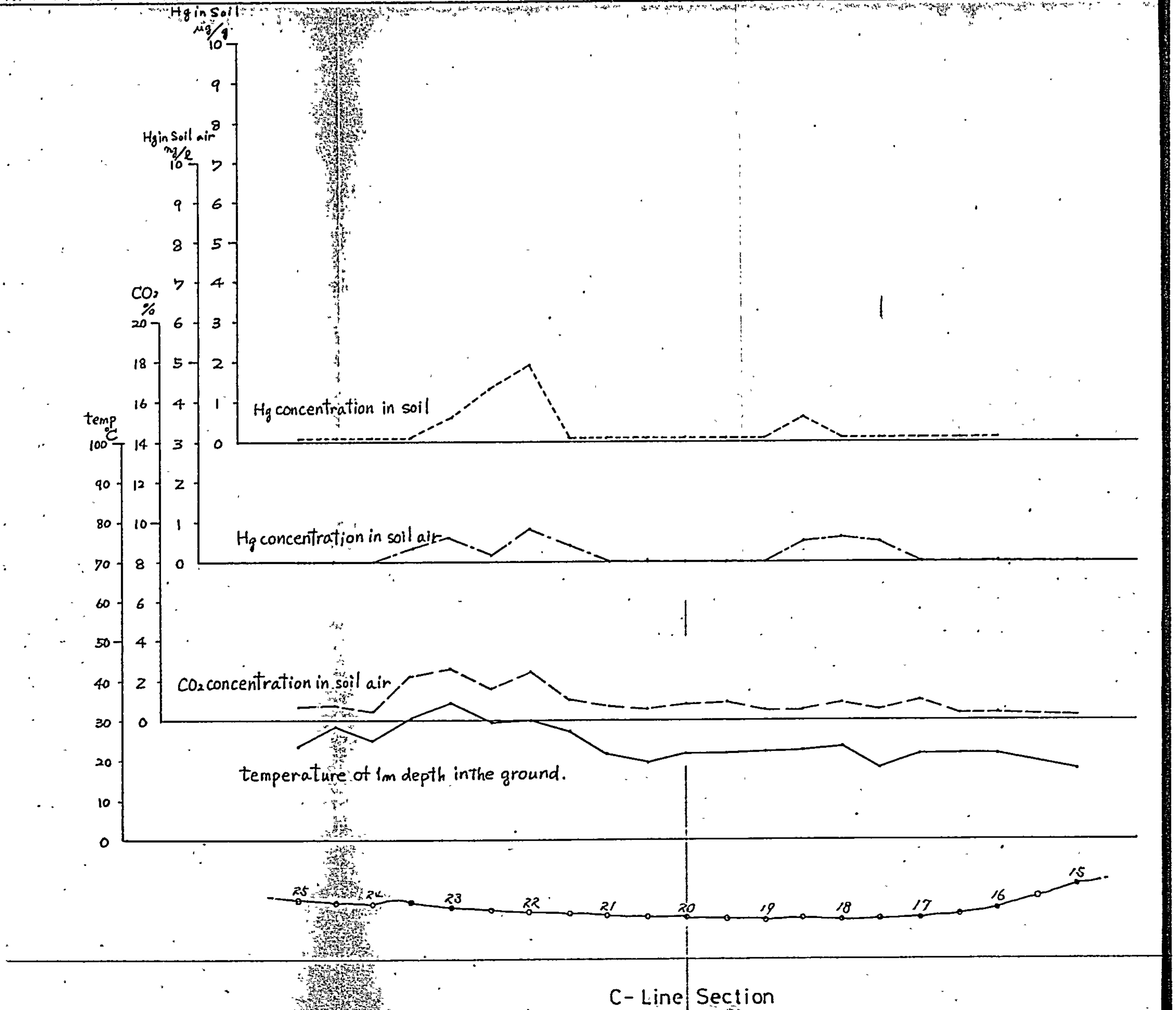
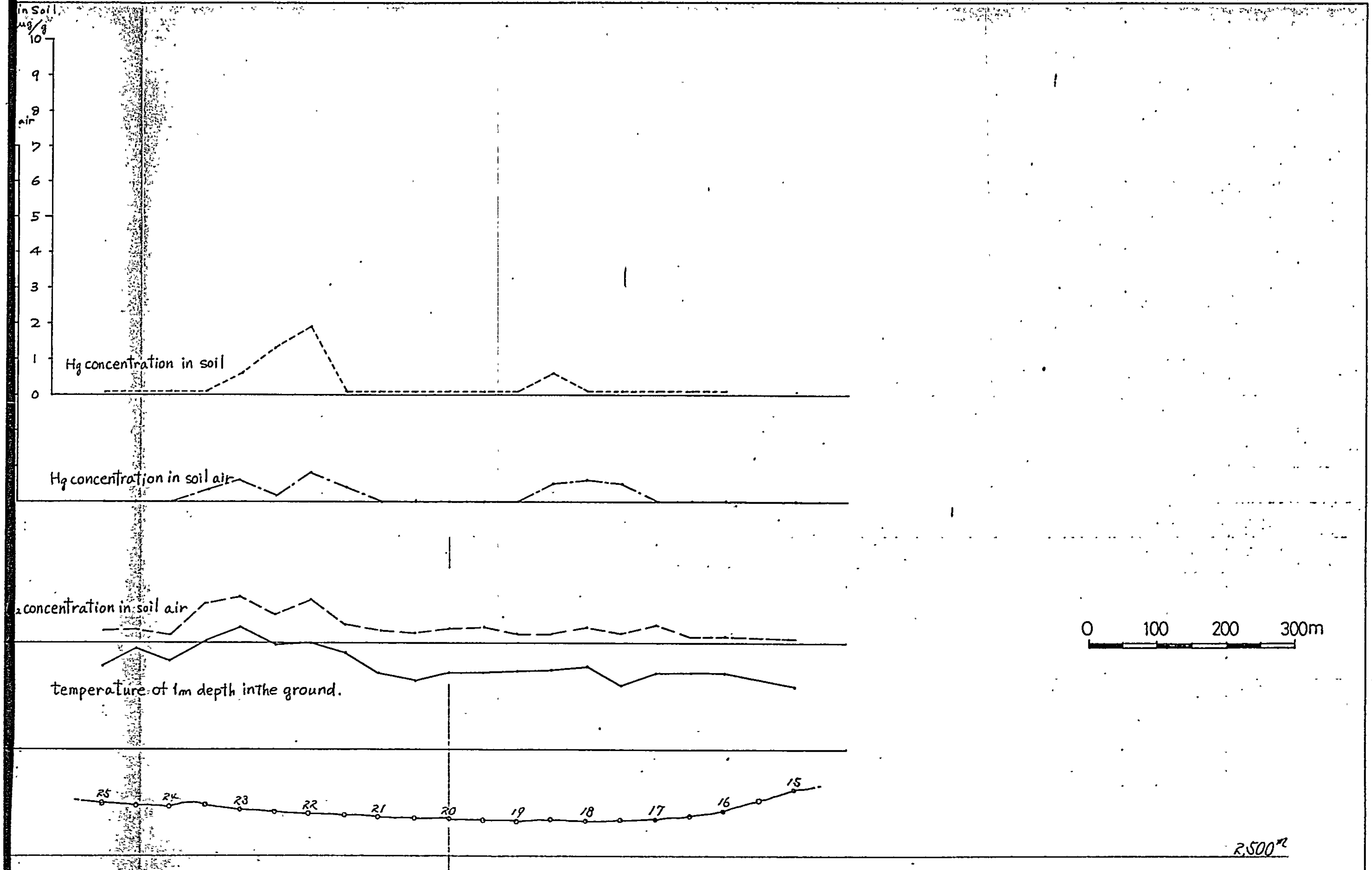


Fig. II-13 Section of Geochemical Results along C-Line



C- Line Section

Fig. II-13 Section of Geochemical Results along C-Line

GEOPHYSICAL SURVEY
AT EBURRU GEOTHERMAL FIELD, ON 1980

By TAKASHI OHYA and TADAO MIZUGUCHI

As geophysical technique, electrical soundings by using Schlumberger electrode array were carried out in the Eburru Caldera along the survey lines also used for geochemical survey.

The reasons why Schlumberger array electrical sounding is employed are:

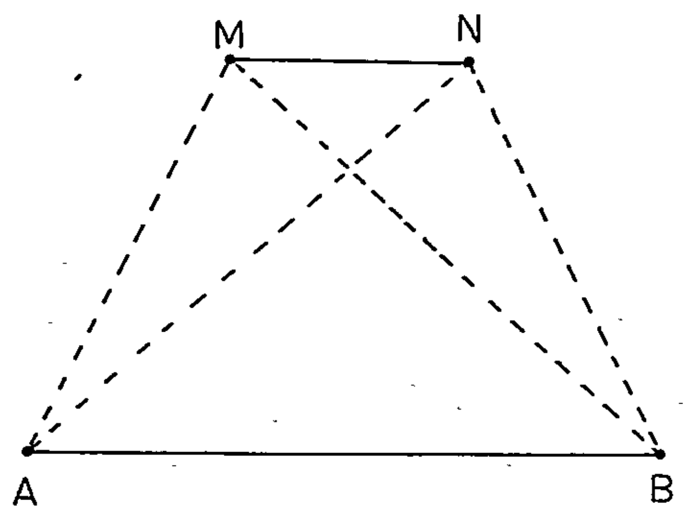
1) electrical sounding has been proved to be a very useful tool for geothermal exploration, 2) several Schlumberger array electrical soundings have done by UNDP project in the area, therefore new data can be used to interpret with UNDP data.

Seven soundings were carried out with the maximum current electrode separation of 100 meters (AB/2=500 meters). Results show fair agreement with UNDP data.

Resistivity Measurement.

The theory of d.c. resistivity survey is explained by many scientists (eg. G.V. Keller and Friscknecht, P.K. Bhattacharya and H.P. Patra). Therefore, here the technique is very briefly explained.

Consider that a current of strength I is introduced into a homogeneous isotropic ground through two electrodes A and B



The potential difference between the two potential electrodes M and N on the surface of the ground is given by:

Where ρ is the resistivity of the ground.

$$V = \frac{I\rho}{2\pi} \left\{ \left(\frac{1}{AM} - \frac{1}{BM} \right) - \left(\frac{1}{AN} - \frac{1}{BN} \right) \right\}$$

Various electrode arrangements are used for electrical explorations. The one most commonly used for resistivity sounding is Schlumberger configuration which is one of symmetrical in-line electrode configurations.

In Schlumberger electrode configuration, electrodes A, M, N, B. are set along a streight line where electrodes A and B, and M and N are set symmetrically with respect to the center point O.

An apparent resistivity ρ_a for Schlumberger configuration is as follows:

$$\rho_a = \frac{\pi}{2} \frac{\{(AB/2)^2 - (MN/2)^2\}}{MN_2} \frac{\Delta V}{I}$$

Schlumberger sounding is carried out by gradually widening between current electrodes A and B. The wider current electrodes separation is, the deeper electrical current goes into the ground. Therefore, by setting current electrodes separation gradually wider, vertical distribution of electrical resistivity in the ground can be interpreted.

Problems of electrical current flow in a horizontally stratified media can be analytically solved and albums of of apparent resistivity curves due to horizontally stratified two layer cases have been published. With standard two-layer curves and some auxiliary curves we can interpret Schlumberger resistivity curves by assuming as horizontally stratified medium

For the present project, we used the following combinations of a current electrode separation (AB) and a potential electrode separation (MN).

Three survey lines are surveyed in the Eburru Caldera. The A line is 2km along and five electrical soundings are carried out. The B line and the C line are on the north and the south side of the A line respectively and lengths of the both are 1km and one sounding each along the both lines has been carried out.

Totally seven soundings along four kilometer survey line were carried out.

The results of the survey are shown in the following figures and tables.

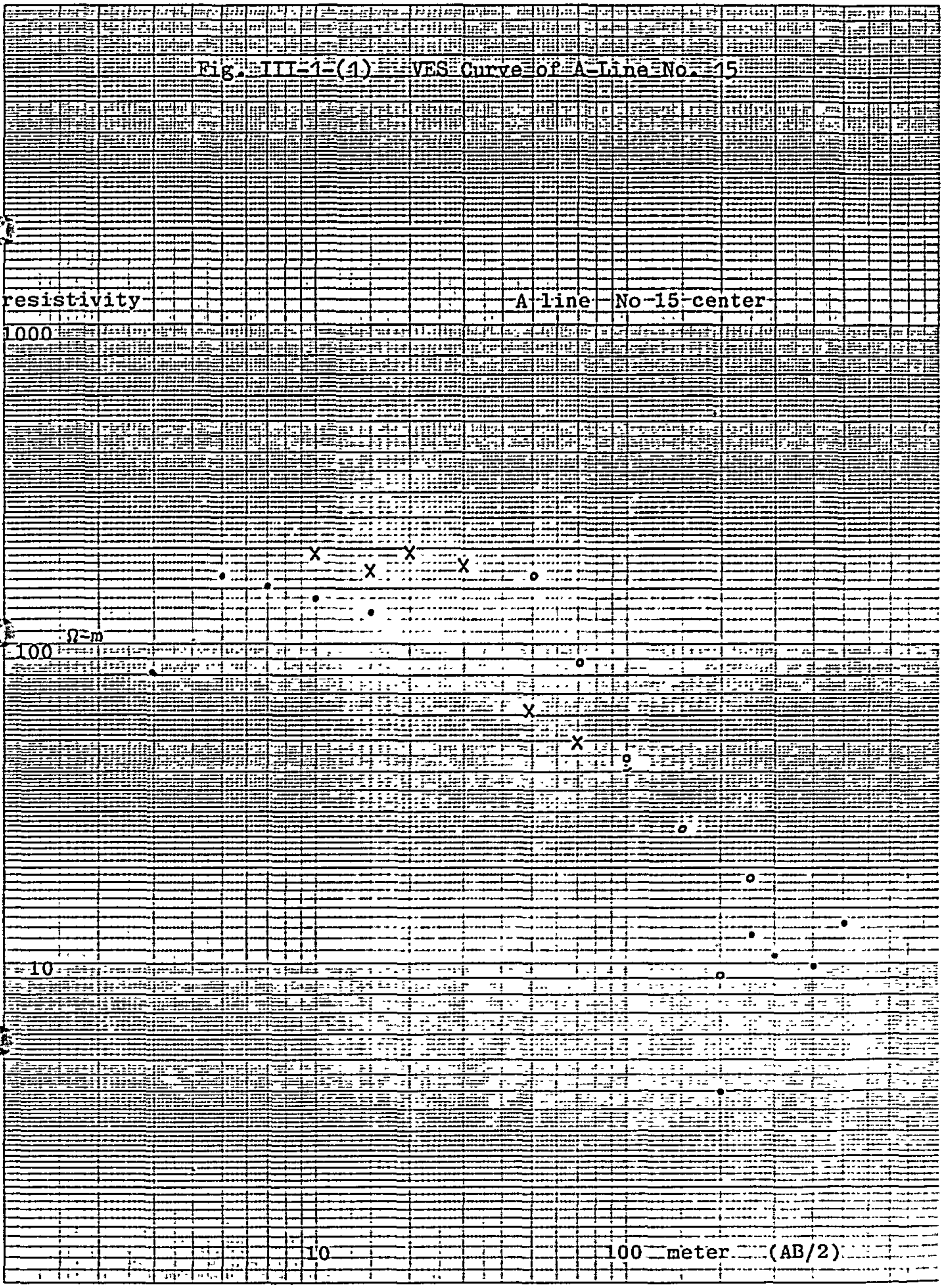


Fig. III-1-(1) VES Curve of A-Line No. 15
resistivity
A line No-15 center
1000
Ω-m
100
10
10
100 meter (AB/2)

Fig. III-1-(2) VES Curve of A-Line No. 17.5

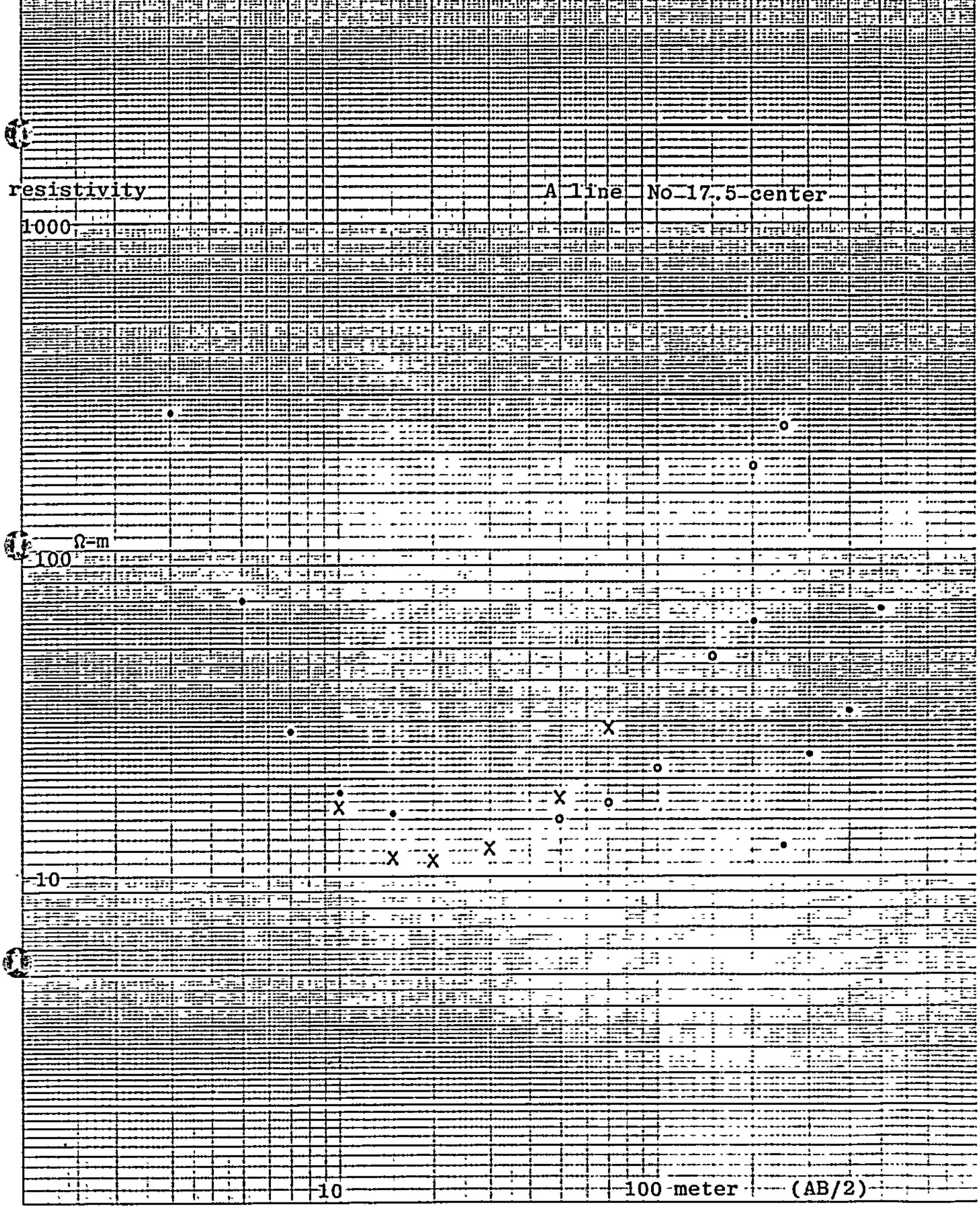
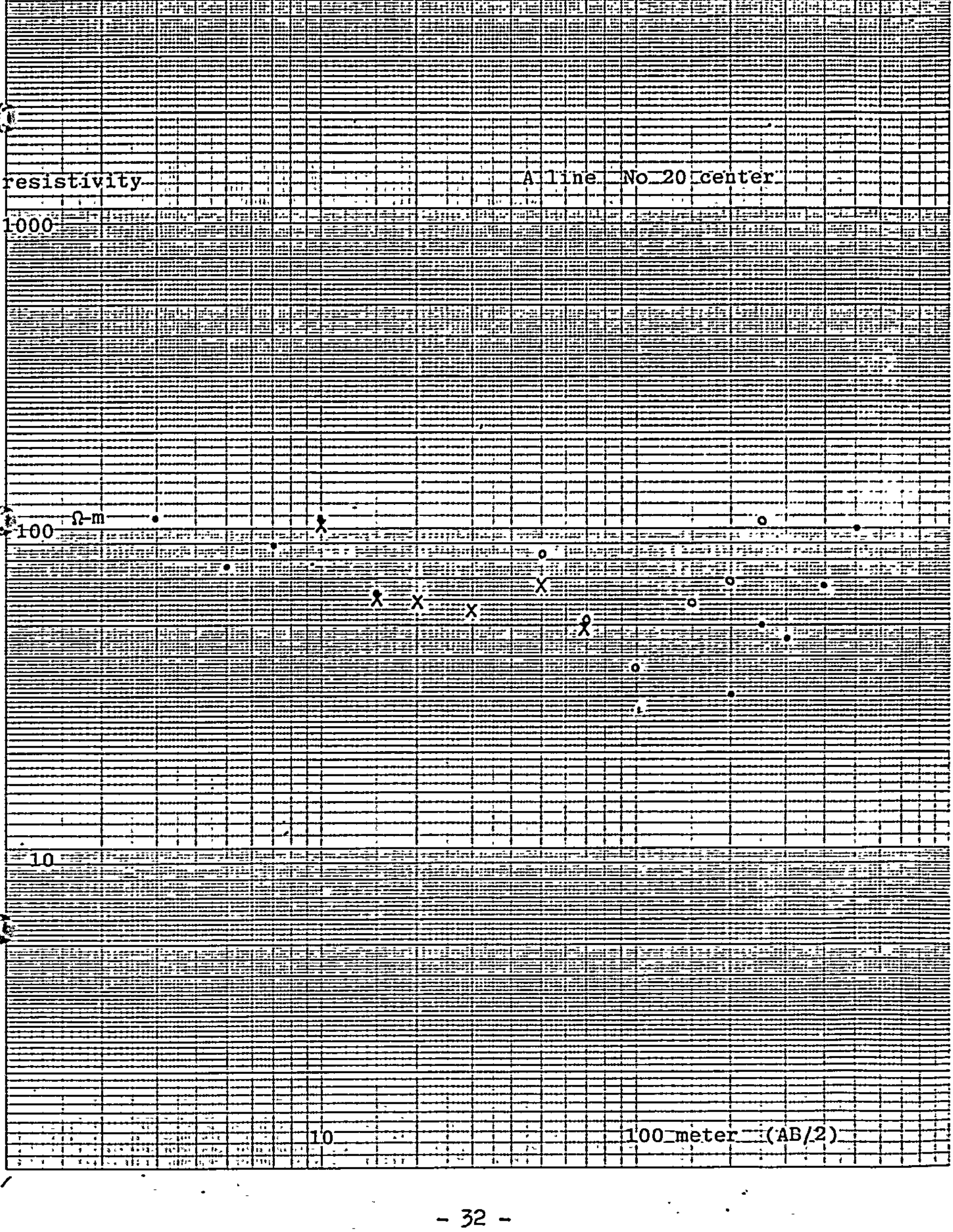


Fig. III-1-(3) VES Curve of A-Line No. 20



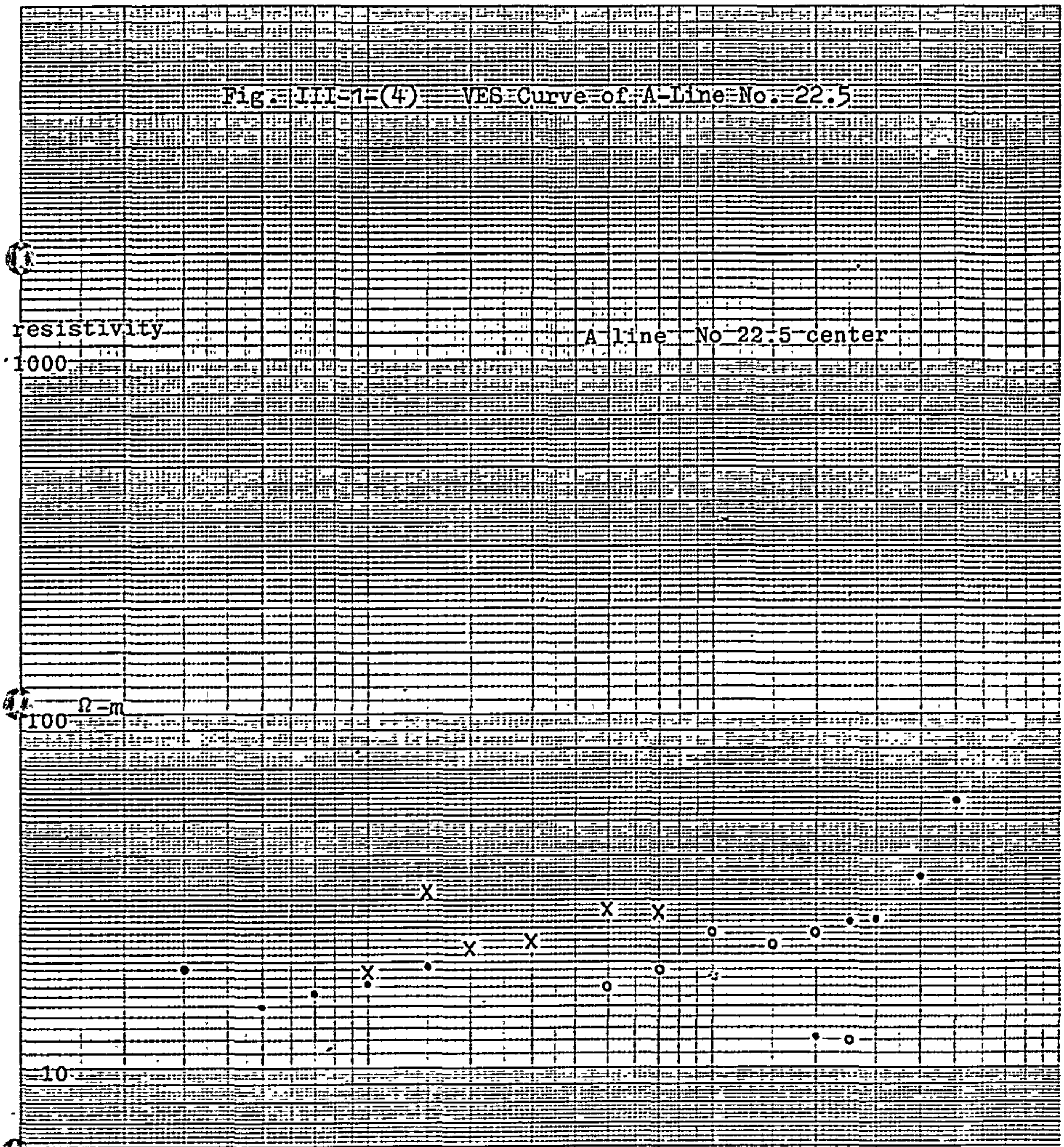


Fig. III-1-(4) VES Curve of A-Line No. 22.5

Fig. III-1-(5) VES Curve of A-Line No. 25

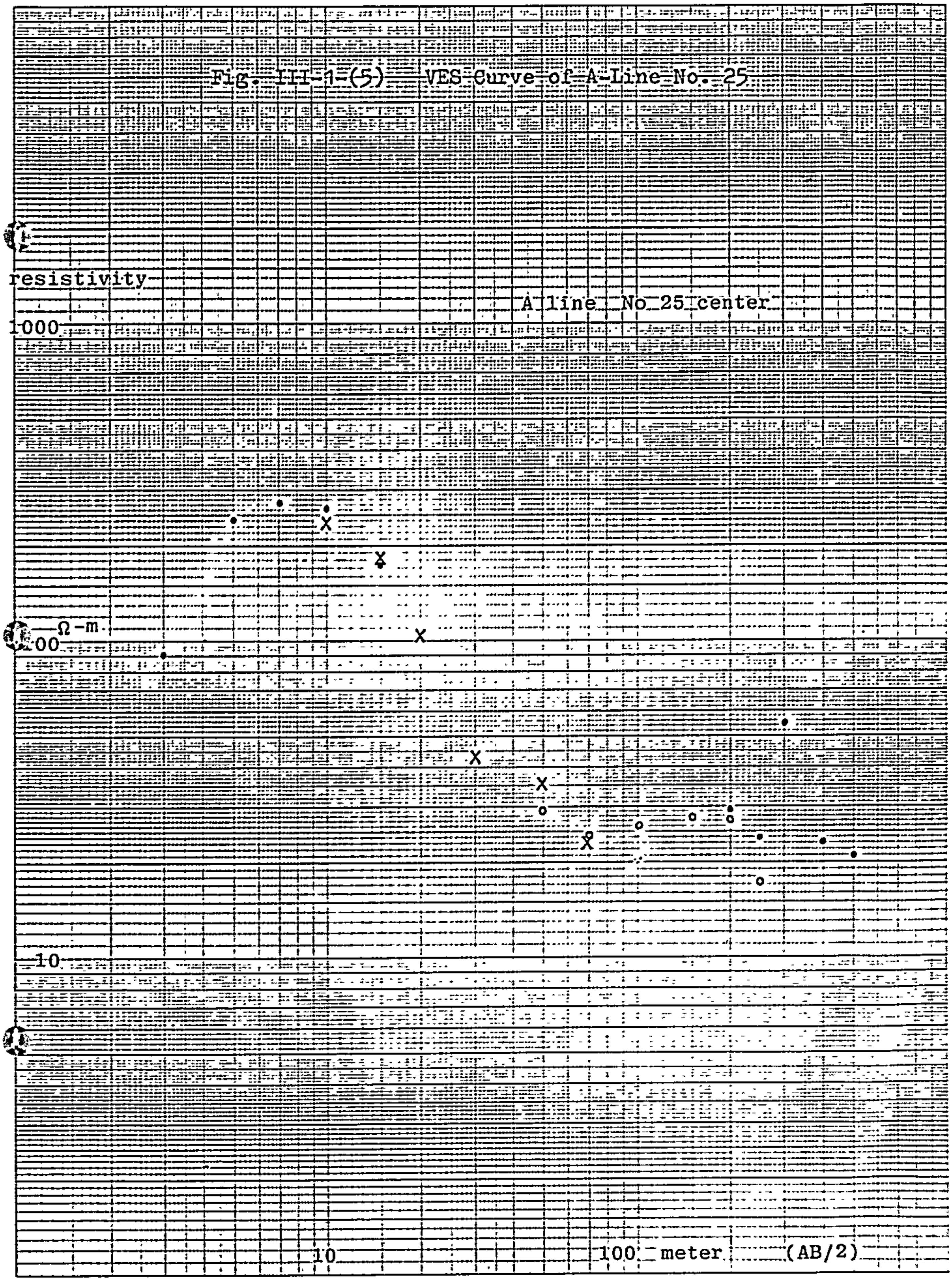
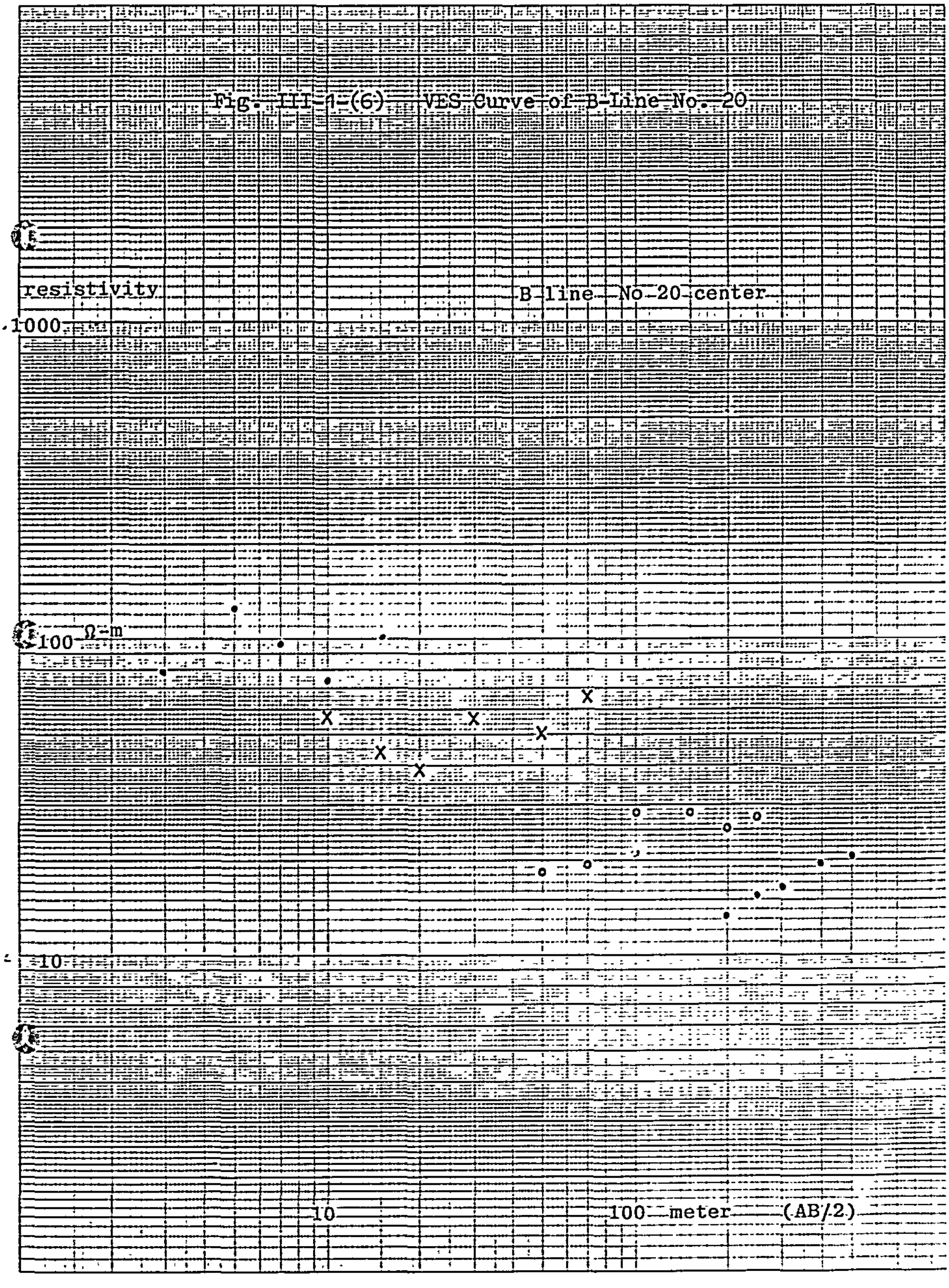


Fig. III-1-(6) VES Curve of B-Line No. 20



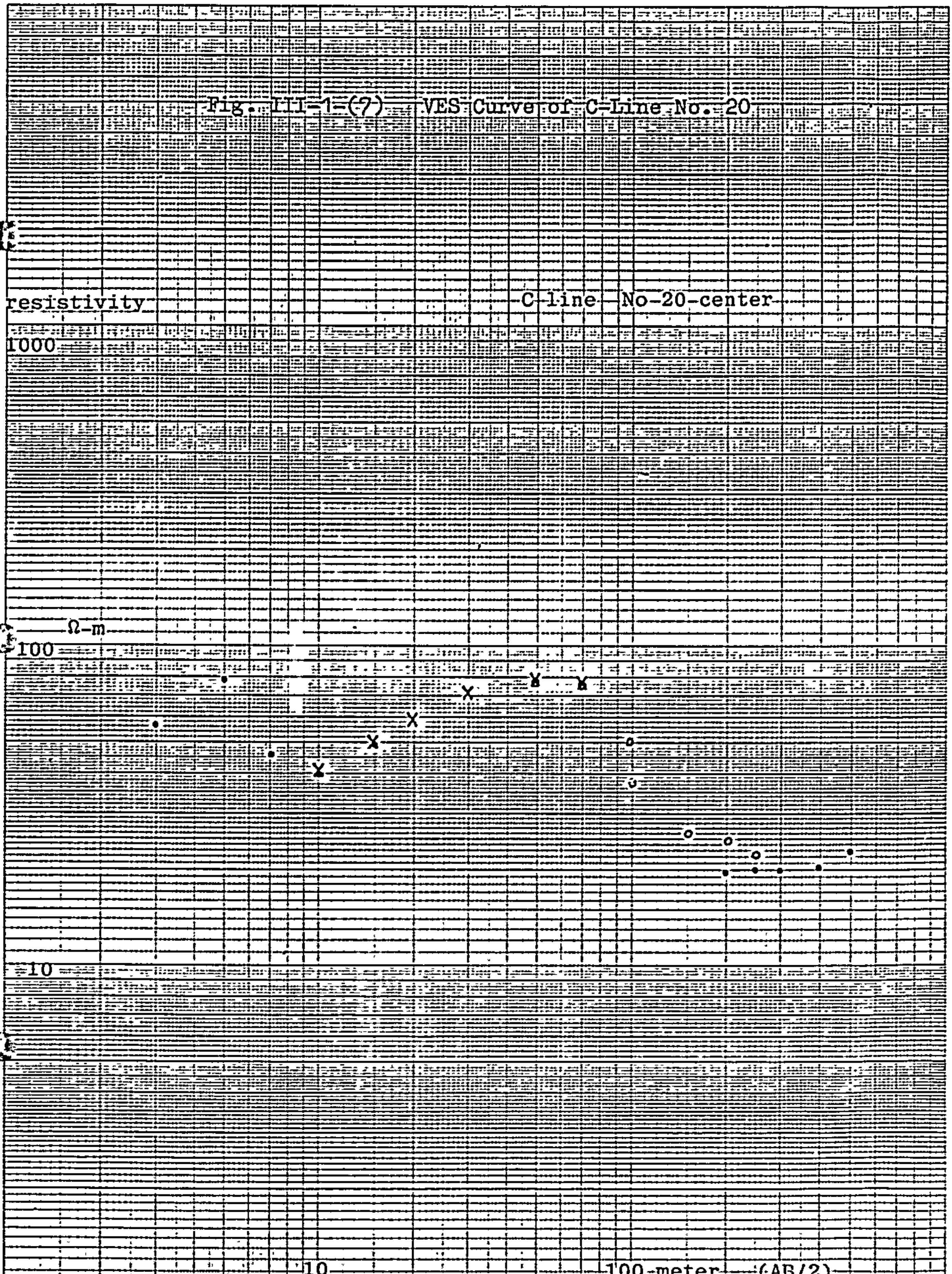


Fig. III-1-(7) VES Curve of C-Line No. 20

Fig. III-2-(1) Interpretation of VES-Curve A-Line No. 15

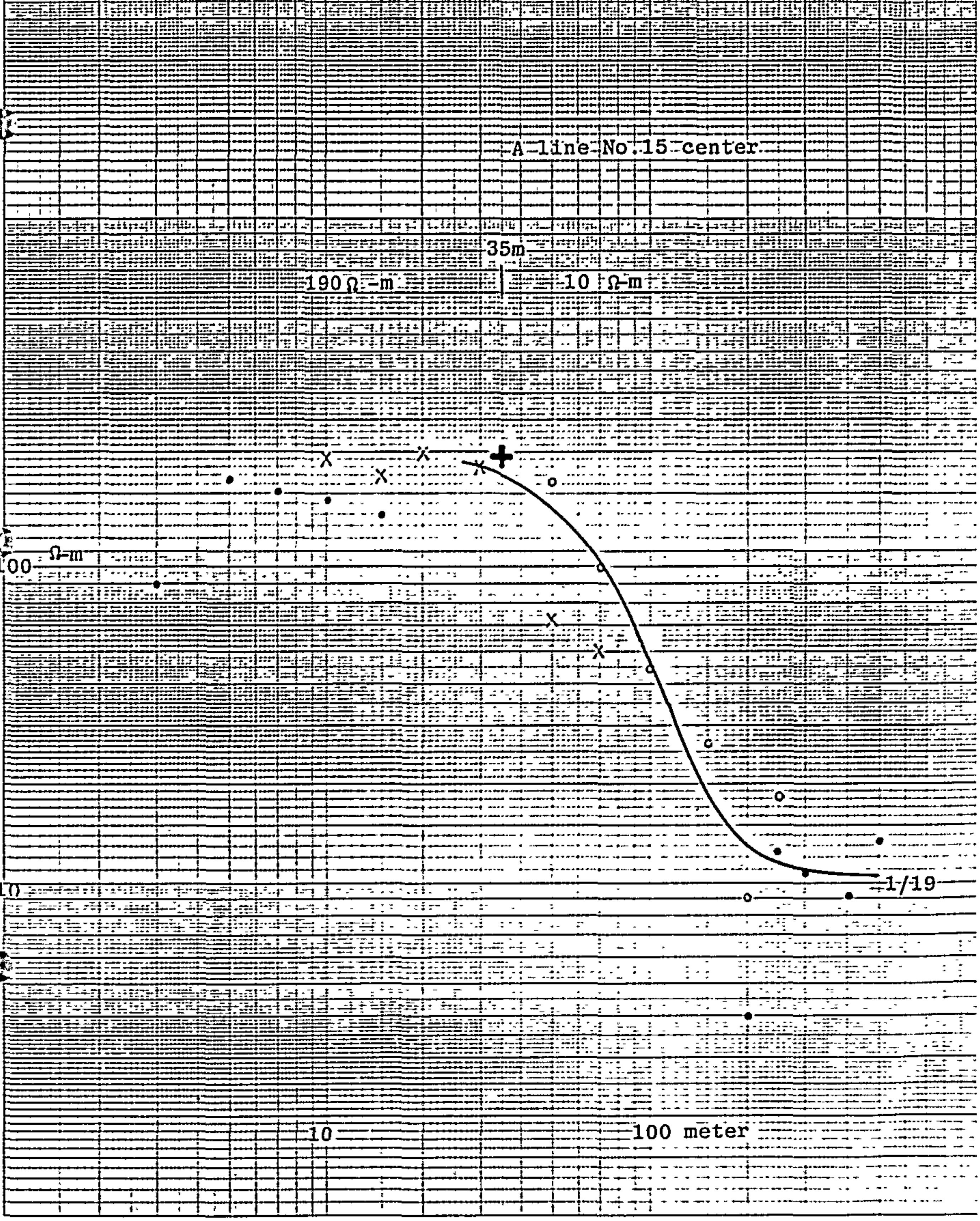


Fig. III-2-(2) Interpretation of VES Curve A-Line No. 17.5

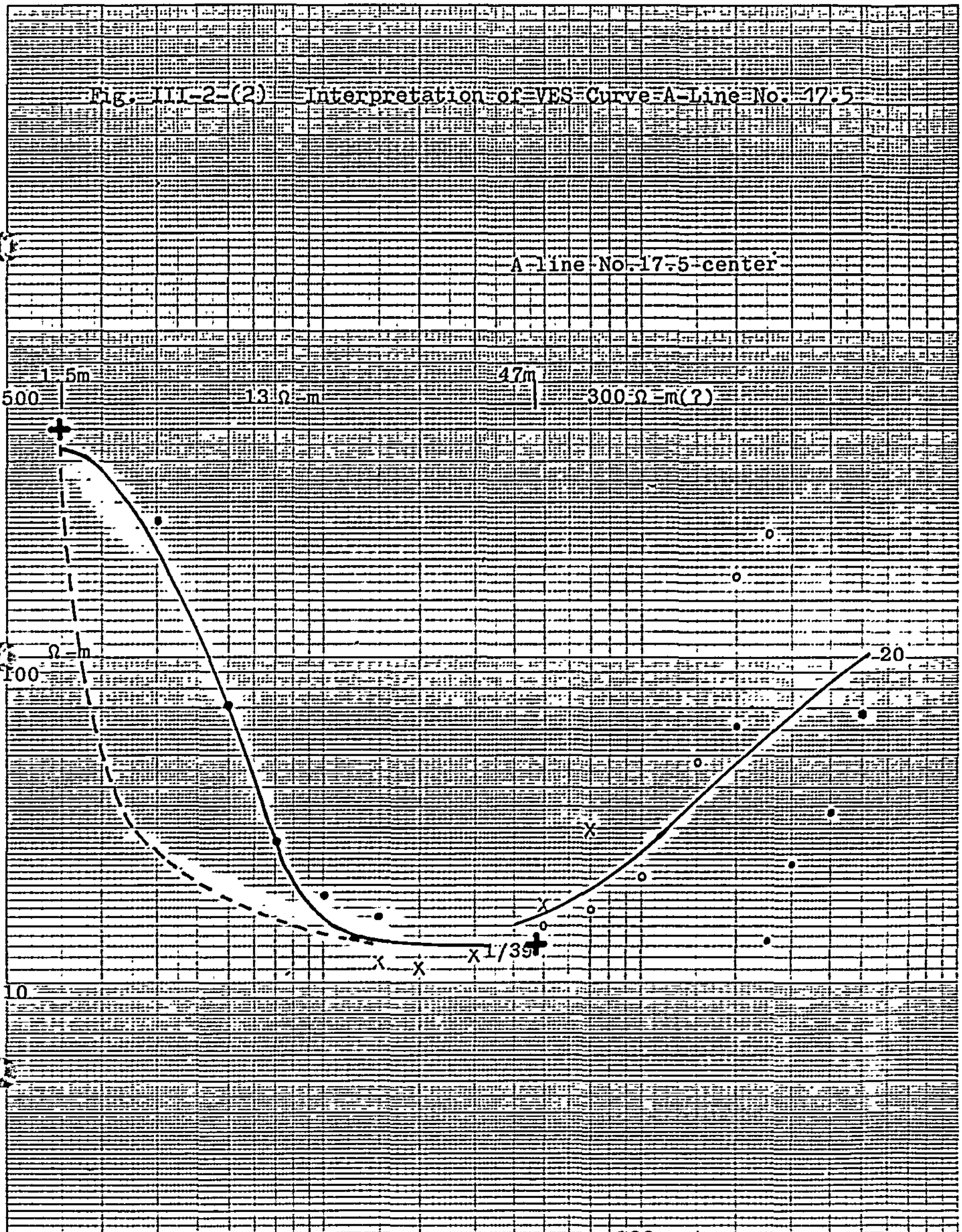


Fig. III-2-(3) Interpretation of VES Curve A-Line No. 20

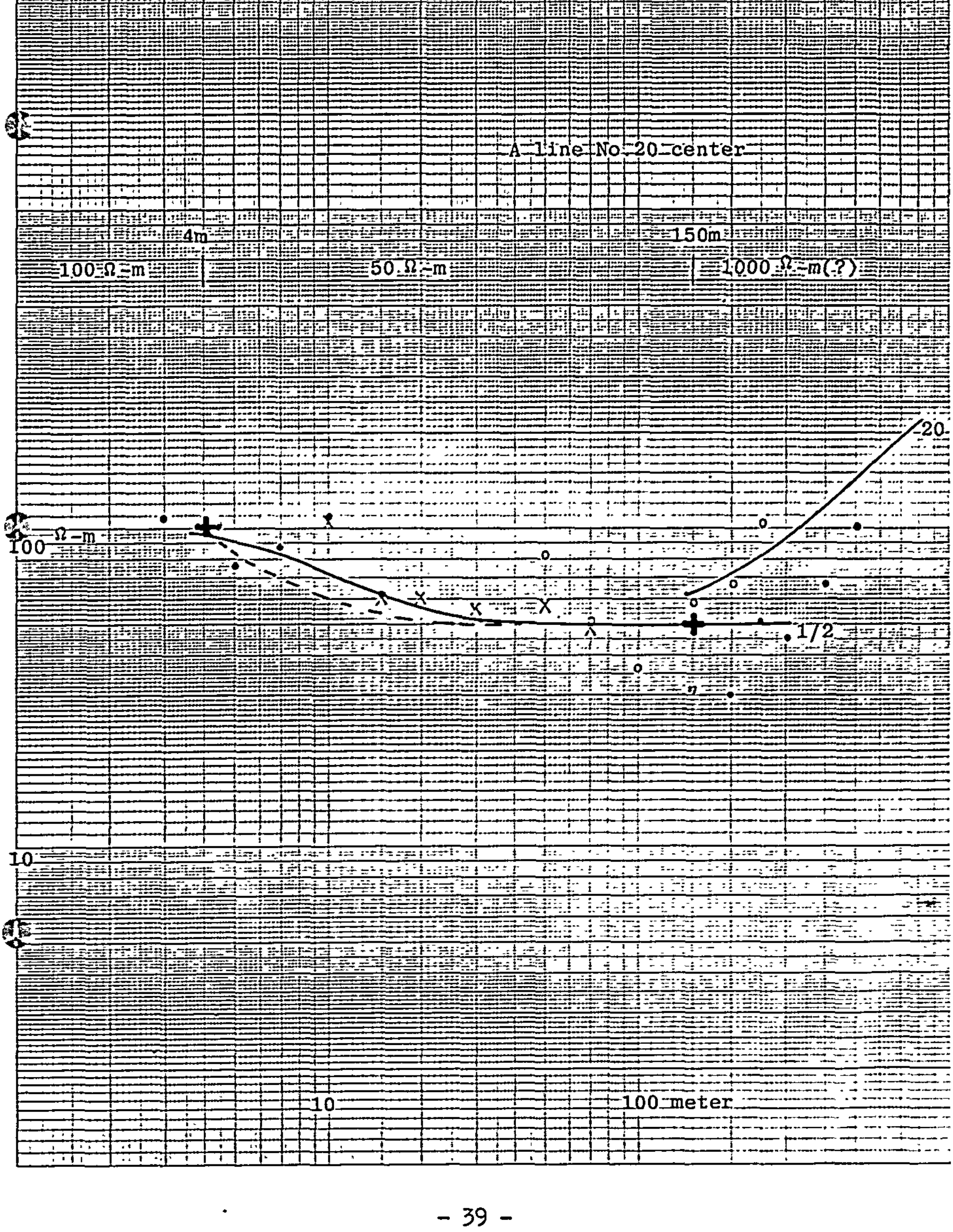


Fig. III-2-(4) Interpretation of VES Curve A-Line No. 22.5

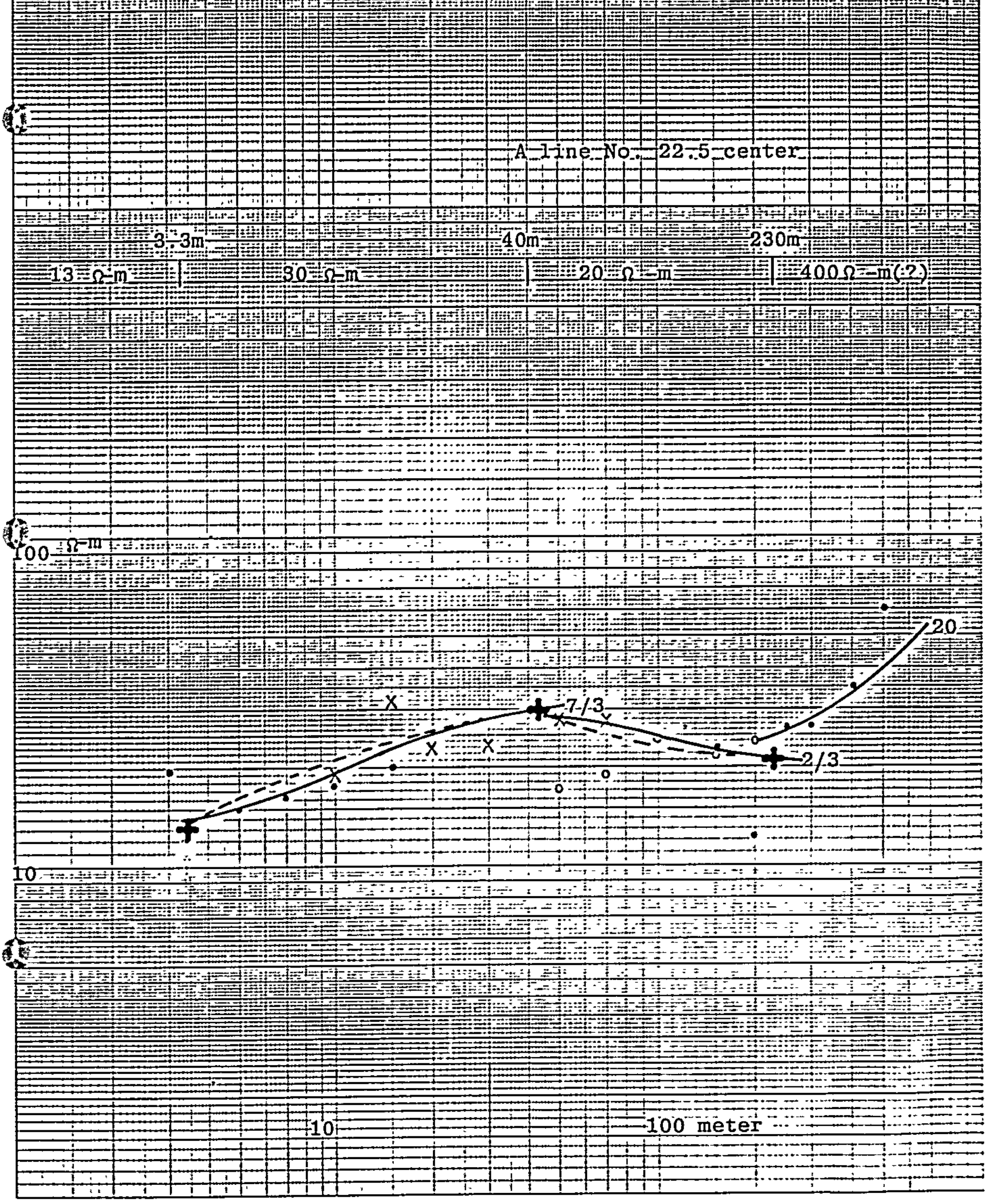


Fig. III-2-(5) Interpretation of VES Curve A-Line No. 25

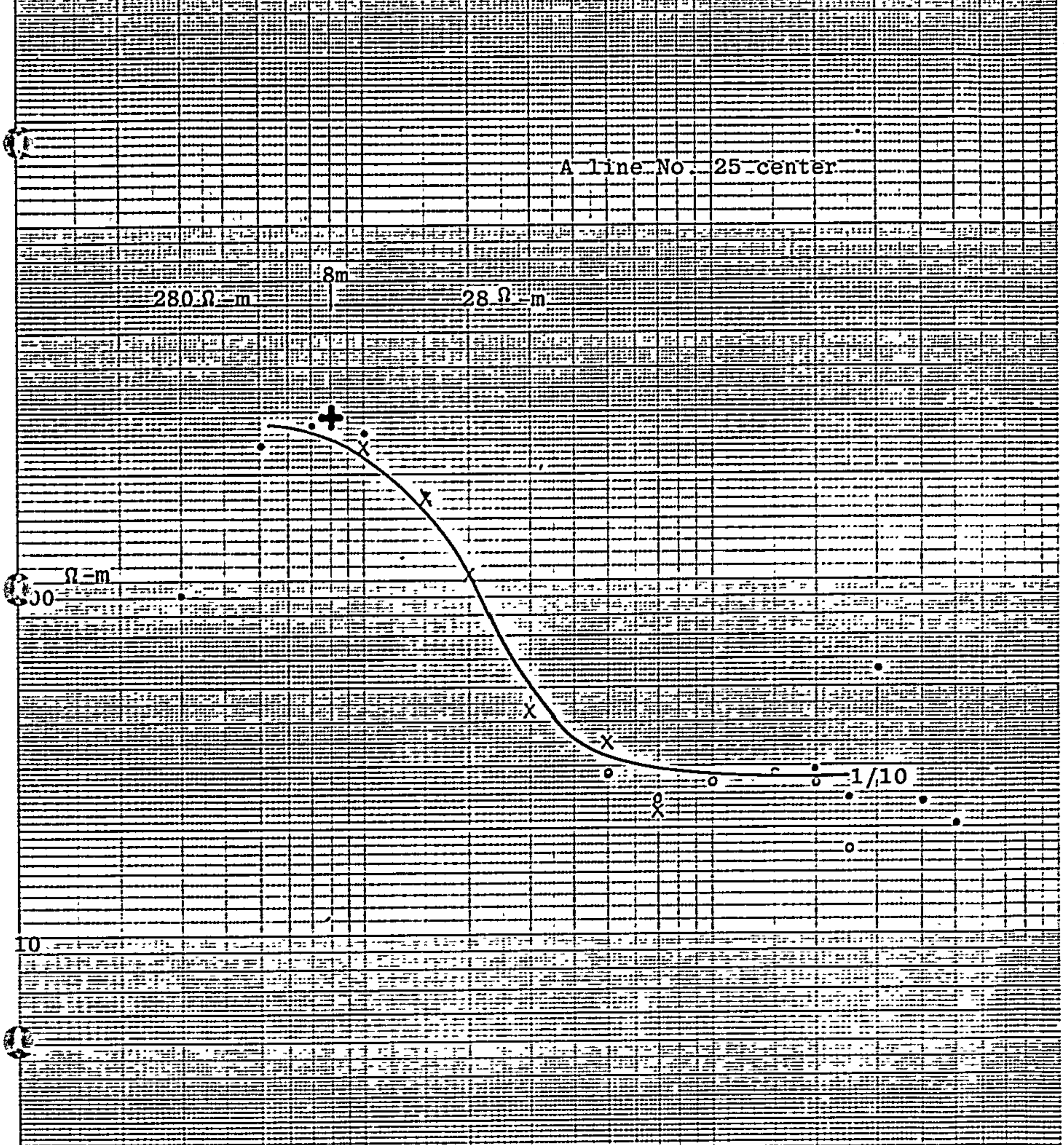


Fig. III-2-(6) Interpretation of VES Curve B-Line No. 20

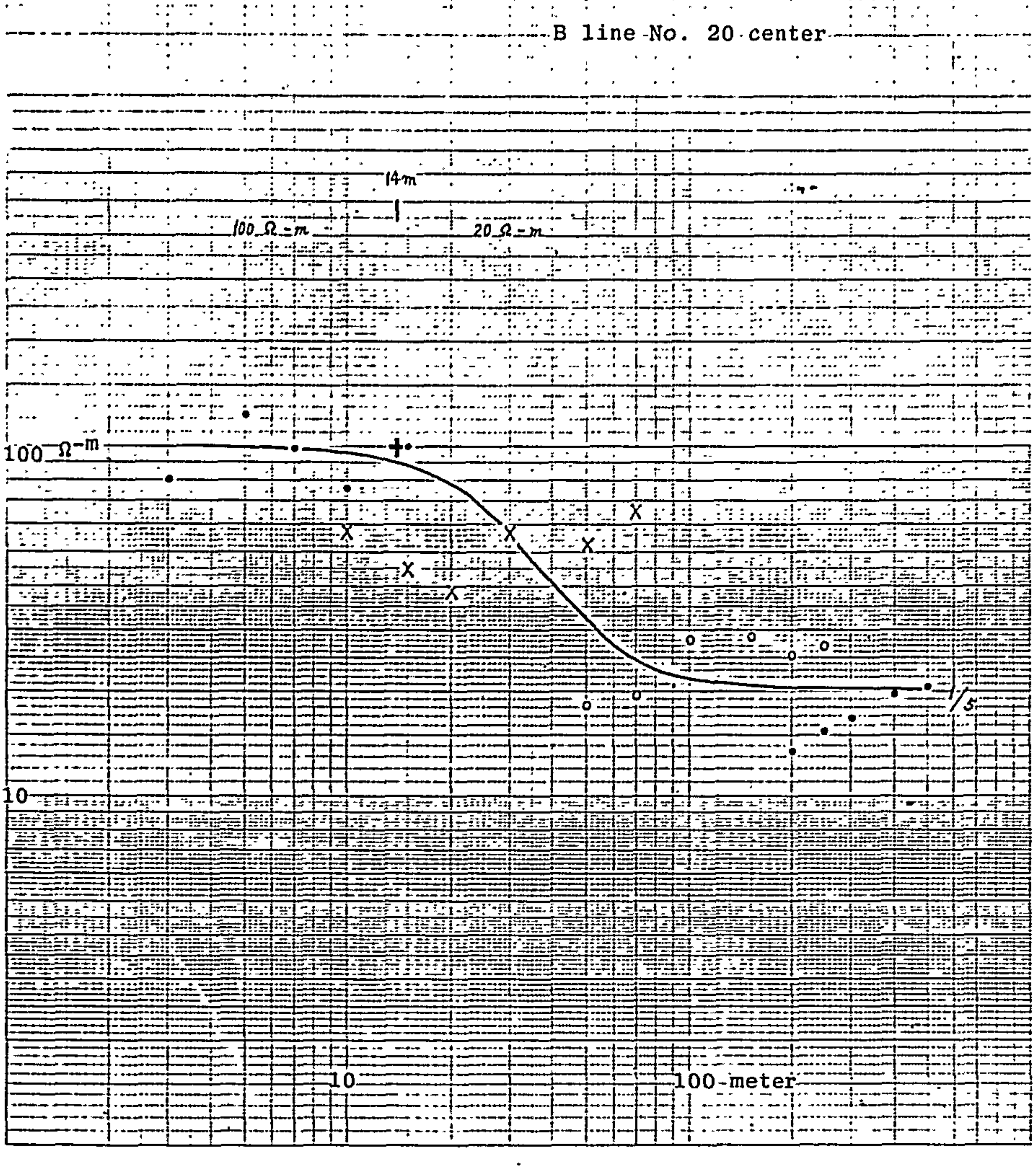
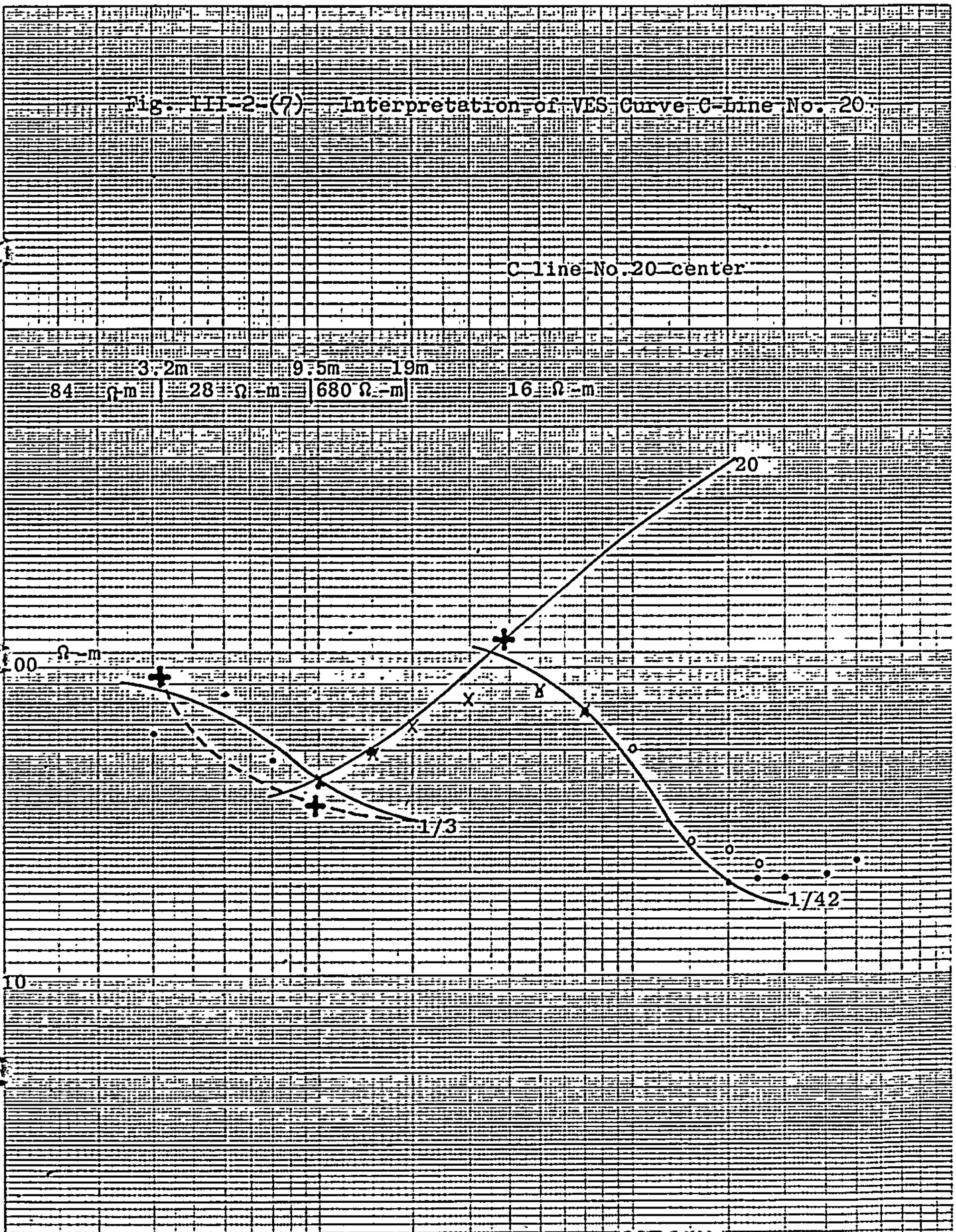


Fig. III-2-(7) Interpretation of VES Curve C-Line No. 20



A-Line Section

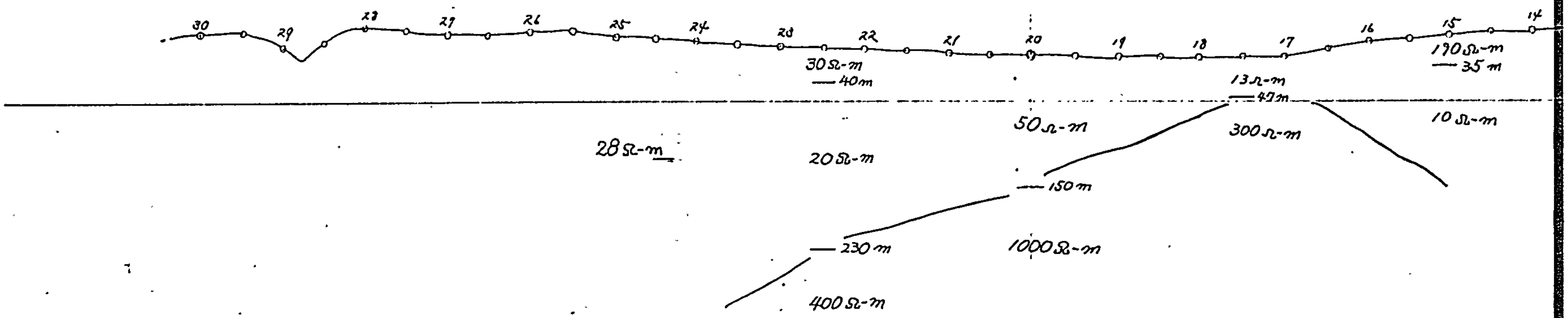


Fig. III-3 Section of Resistivity Zone along A Line

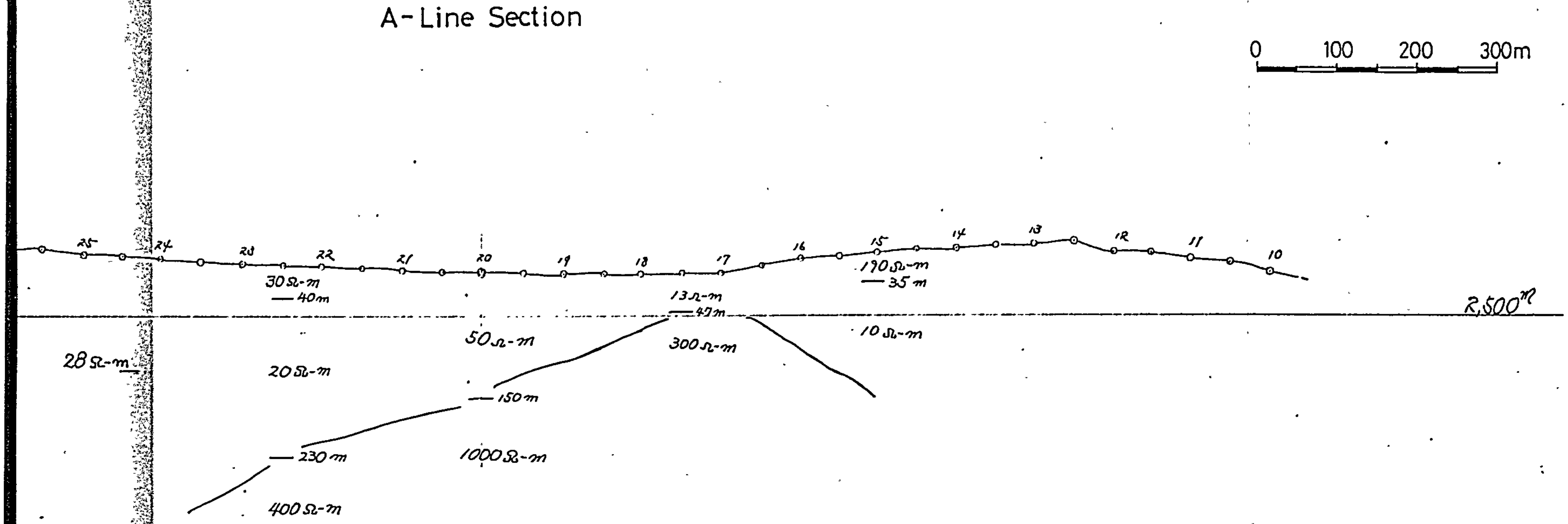


Fig. III-3 Section of Resistivity Zone along A Line

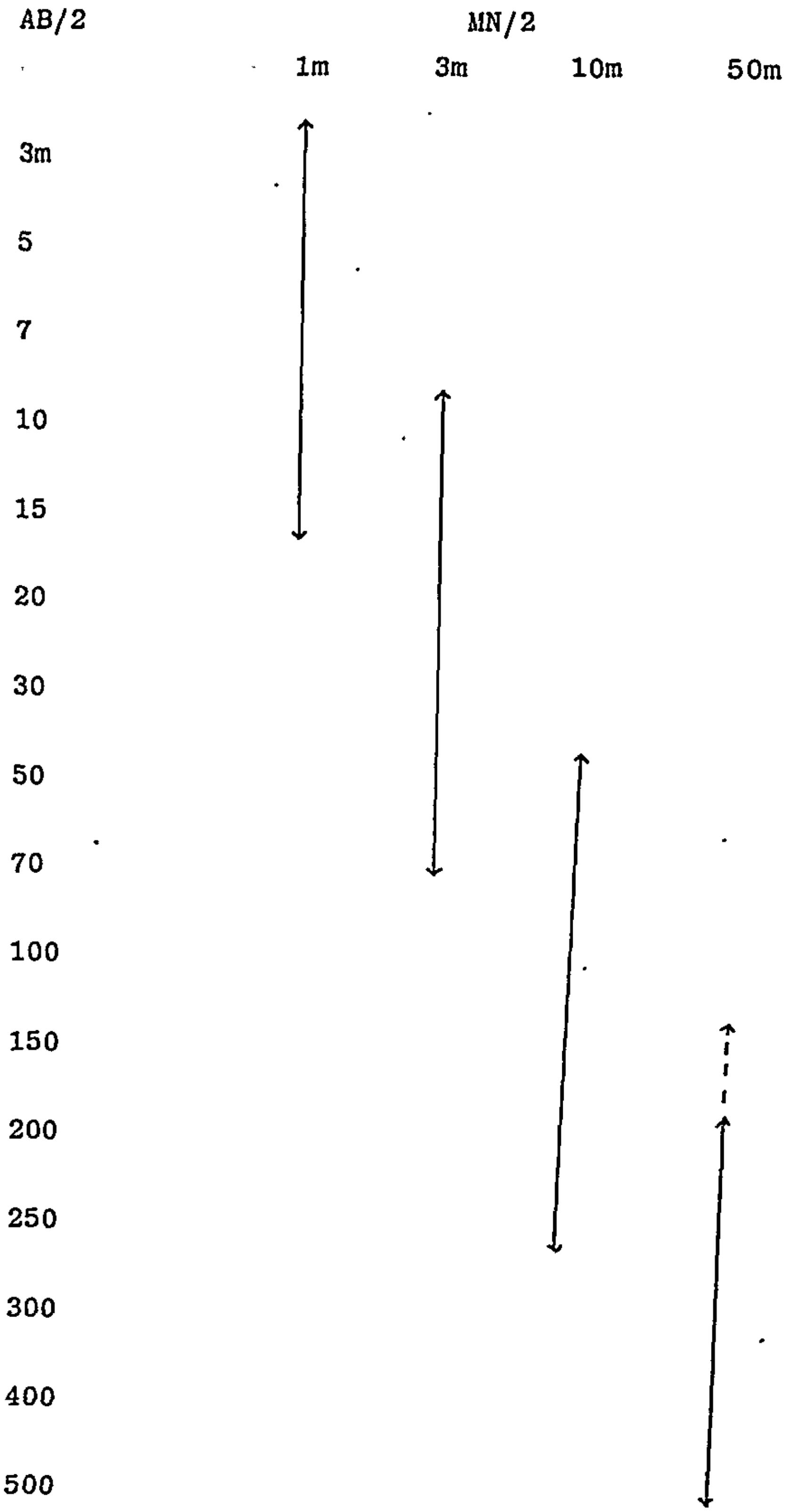


Table III-1

Combinations of Current and Potential Electrodes

A LINE NO. 15 CENTER.

AB/2	MN/2	K.	V (MV)	I (A)	RESISTIVITY (ohm-Meter)
3	1	12.56	3210	0.500	80.6
5	1	37.68	2130	0.487	165
7	1	75.36	2420	1.200	152
10	1	155.43	418	0.457	142
10	3	47.62	1870	0.467	191
15	1	351.7	335	0.920	128
15	3	113.0	1360	0.903	170
20	3	204.6	837	0.867	198
30	3	466.2	185	0.483	179
50	3	1304	17.7	0.370	62.4
50	10	376.8	163	0.370	166
70	3	2560	14.2	0.723	50.3
70	10	753.6	84.2	0.710	89.4
100	10	1555	21.6	0.750	44.8
150	10	3517	7.40	0.967	26.9
200	10	6264	1.03	0.700	9.22
200	50	1179	2.43	0.710	4.04
250	10	9797	1.40	0.733	18.7
250	50	1884	4.75	0.720	12.4
300	50	2748	2.90	0.747	10.7
400	50	4946	1.80	0.980	9.08
500	50	7772	1.60	0.937	13.3

Table III-2-(1)

Calculations of Resistivities at A-Line No. 15

A LINE NO. 17.5 CENTER

AB/2	MN/2	K	V (MV)	I (A)	RESISTIVITY (ohm - meter)
3	1	12.56	6370	0.300	267
5	1	37.68	563	0.297	71.4
7	1	75.36	173	0.470	27.7
10	1	155.43	34.0	0.283	18.7
10	3	47.62	99.7	0.287	16.5
15	1	351.7	20.0	0.443	15.9
15	3	113.0	46.0	0.443	11.7
20	3	204.6	16.7	0.290	11.3
30	3	466.2	7.33	0.277	12.3
50	3	1304	7.57	0.557	17.7
50	10	376.8	22.3	0.560	15.0
70	3	2560	3.37	0.297	29.0
70	10	753.6	6.67	0.297	16.9
100	10	1555	4.17	0.297	21.8
150	10	3517	2.73	0.197	48.6
200	10	6264	4.50	0.157	180
200	50	1178	8.33	0.163	60.2
250	10	9797	20.1	0.810	243
250	50	1884	5.43	0.807	12.7
300	50	2748	4.33	0.500	23.8
400	50	4946	3.33	0.490	33.6
500	50	7772	6.83	0.803	66.1

Table III-2-(2)

Calculations of Resistivities at A-Line No. 17.5

A LINE NO. 20 CENTER

AB/2	MV/2	K	V (MV)	I (A)	RESISTIVITY (ohm-meter)
3	1	12.56	2550	0.300	107
5	1	37.68	580	0.287	76.1
7	1	75.36	347	0.297	88.0
10	1	155.43	262	0.377	108.
10	3	47.62	853	0.390	104.
15	1	351.7	51.9	0.293	62.3
15	3	113.0	162	0.300	61.0
20	3	204.6	88	0.297	60.6
30	3	466.2	35.5	0.293	56.5
50	3	1304.	15.4	0.297	67.6
50	10	376.8	65.2	0.293	83.8
70	3	2560	5.63	0.297	48.5
70	10	753.6	20.8	0.300	52.2
100	10	1555	7.15	0.300	37.1
150	10	3517	5.00	0.297	59.2
200	10	6264	3.33	0.30	68.9
200	50	1178		0.300	30.1
250	10	9797	3.63	0.300	104
250	50	1884	8.00	0.300	50.2
300	50	2748	16.5	1.00	45.3
400	50	4946	6.67	0.500	66.0
500	50	7772	3.83	0.297	100.

Table III-2-(3)

Calculations of Resistivities at A-Line No. 20

A LINE NO. 22.5 CENTER

AB/2	MN/2	K	V (mv)	I (A)	RESISTIVITY (ohm-meter)
3	1	12.56	860	0.553	19.5
5	1	37.68	322	0.803	15.1
7	1	75.36	253	1.17	16.3
10	1	155.43	104	0.923	17.5
10	3	47.62	392	0.983	19.0
15	1	351.7	63	1.10	20.1
15	3	113.0	202	0.723	31.6
20	3	204.6	115	1.04	22.6
30	3	466.2	52.0	1.06	22.9
50	3	1304	10.9	0.503	28.3
50	10	376.8	22.8	0.497	17.3
70	3	2560	3.47	0.323	27.5
70	10	753.6	8.33	0.327	19.2
100	10	1555	4.90	0.310	24.5
150	10	3517	1.88	0.297	22.3
200	10	6264	1.17	0.298	24.6
200	50	1179	5.33	0.300	12.5
250	10	9797	0.617	0.503	12.0
250	50	1884	7.12	0.503	26.7
300	50	2748	2.87	0.297	26.6
400	50	4946	2.11	0.297	35.1
500	50	7772	2.00	0.260	59.8
150	50	628.2	10.75	0.297	22.7

Table III-2-(4)

Calculations of Resistivities at A-Line No. 22.5

A LINE NO. 25 CENTER

AB/2	MN/2	K	V (mv)	I (A)	RESISTIVITY (ohm-meter)
3	1	12.56	5530	0.757	91.8
5	1	37.68	1970	0.300	247.
7	1	75.36	1340	0.368	274.
10	1	155.43	467	0.278	261
10	3	47.62	1425	0.282	241
15	1	351.7	102	0.205	175
15	3	113.0	323	0.205	178.
20	3	204.6	223	0.425	107.
30	3	466.2	50.3	0.537	43.8
50	3	1304	14.6	0.535	35.6
50	10	376.8	41.7	0.530	29.6
70	3	2560	1.88	0.215	22.4
70	10	753.6	7.67	0.235	24.6
100	10	1555	8.83	0.505	27.2
150	10	3517	7.43	0.917	28.5
200	10	6264	2.30	0.530	27.2
200	50	1178	13.3	0.540	29.0
250	10	9797	1.05	0.590	17.4
250	50	1884	7.58	0.590	24.2
300	50	2748	7.00	0.343	56.1
400	50	4946	2.27	0.480	23.4
500	50	7772	1.13	0.417	21.1

Table III-2-(5)

Calculations of Resistivities at A-Line No. 25

B LINE NO. 20 CENTER

AB/2	MN/2	K	V (mv)	I (A)	RESISTIVITY (ohm-meter)
3	1	12.56	3200	0.503	79.9
5	1	37.68	860	0.260	125.
7	1	75.36	570	0.440	97.6
10	1	155.43	247	0.507	75.7
10	3	47.62	607	0.503	57.5
15	1	351.7	146	0.503	102.
15	3	113.0	199	0.503	44.7
20	3	204.6	194	1.01	39.3
30	3	466.2	60.0	0.503	55.6
50	3	1304	10.4	0.253	53.6
50	10	376.8	12.78	0.263	18.3
70	3	2560	11.1	0.430	66.1
70	10	753.6	11.0	0.423	19.6
100	10	1555	5.32	0.290	28.5
150	10	3517	2.46	0.300	28.8
200	10	6264	2.07	0.507	25.6
200	50	1179	5.91	0.517	13.5
250	10	9797	1.42	0.510	27.3
250	50	1884	4.20	0.513	15.4
300	50	2748	3.17	0.517	16.8
400	50	4946	2.03	0.517	19.4
500	50	7772	1.32	0.51	20.1

Table III-2-(6)

Calculations of Resistivities at B-Line No. 20

C LINE NO. 20

AB/2	MN/2	K	V (mv)	I (A)	RESISTIVITY (ohm.-meter)
3	1	12.56	3310	0.737	56.4
5	1	37.68	1370	0.690	74.8
7	1	75.36	313	0.510	46.3
10	1	155.43	127	0.503	39.2
10	3	47.62	438	0.503	41.5
15	1	351.7	70.3	0.503	49.2
15	3	113.0	219	0.503	49.2
20	3	204.6	145	0.503	59.0
30	3	466.2	78.3	0.503	72.6
50	3	1304	29.8	0.503	77.3
50	10	376.8	102.	0.503	76.4
70	3	2560	13.3	0.507	67.2
70	10	753.6	44.8	0.503	67.1
100	10	1555	16.3	0.503	50.4
150	10	3517	3.8	0.510	26.2
200	10	6264	1.22	0.310	24.7
200	50	1179	5.07	0.303	19.7
250	10	9797	1.18	0.517	22.4
250	50	1884	5.50	0.517	20.0
300	50	2748	3.72	0.510	20.0
400	50	4946	1.50	0.357	20.8
500	50	7772	1.12	0.380	22.9

Table III-2-(7)

Calculations of Resistivities at C-Line No. 20

Center Line	Station	Feature of VES Curve
A	15	$\rho_1 > \rho_2$
A	17.5	$\rho_1 > \rho_2 < \rho_3$
A	20	$\rho_1 > \rho_2 < \rho_3$
A	22.5	$\rho_1 < \rho_2$
A	25	$\rho_1 > \rho_2$
B	20	$\rho_1 > \rho_2$
C	20	$\rho_1 > \rho_2 < \rho_3 > \rho_4$

Table III-3 Classification of VES Curves

Fig. 1 Temperature Variation in Eburru Area

Table 1

Atmospheric Pressure Measurement

Location:	At Mine and Geological Department NAIROBI, KENYA
Elevation:	1,633.0 m
Date:	24, Jan., 11, Feb., 3, Mar.
Temp.:	25.0° C, 23.0° C, 26.0° C
Atmospheric Pressure:	633.0 m/mHg, 632.0 m/mHg, 630.0 m/mHg