2-4 Analysis Method

2-4-1 Data Processing

The TDIP data processing involves the determination of 3 parameters, i.e., apparent resistivity, chargeability as well as metal factor. The first 2 parameters are calculated directly by the receiver unit during data acquisition. The third one is calculated as a simple relation between the first 2 parameters. These 3 parameters are calculated as follow:

a) Apparent resistivity (ρ)

$$\rho = \pi \frac{V}{I} an(n+1)(n+2)$$

Where,
V: Received voltage in volts
a: A-spacing in meters
n: N-spacing
I: Transmitted current in Amp

b) Chargeability (M)

$$M = \frac{1}{V_p} \int V_s dt$$

Where,
Vp: Primary voltage in volts
Vs: Secondary voltage in volts

Here, the secondary voltage is calculated from 55.00 msec to 1555.00 msec.

c) Metal factor (MF)

$$MF = \frac{M}{\rho_a} \times 100$$

Where,
M: Chargeability (mV/V)
ρ: Apparent resistivity (Ωm)

2-4-2 Topographic Corrections

Since the apparent resistivity is calculated also in function of the location of the current and potential electrodes on a half-infinite plane, it is affected by topography depending on the location of the electrodes. For the case of a dipole-dipole configuration, the apparent resistivity appears to be high

beneath a hill and low beneath a valley. On the other hand, the chargeability values are less affected by topography.

For the present survey, topography corrections were carried out only in the lines 000N and 180S of Ghuzayn North, and in the lines 600N, 400N, 200N and 200S of Doqal area by using a finite element method which assumes a two dimensional half space topography.

2-4-3 Two-dimensional Analysis

For the IP data analysis and according to the standard model, the apparent resistivity distribution and the chargeability distribution are used in combination to make a quantitative analysis of the pseudo-sections and plan maps. The resultant undergound model is inferred by making use of the theoretical results given by the model. This is called in general a model simulation.

In the present survey, according to the limitations of the results of the forward modeling and to match the field results, it was used a 2-D inversion model which combines the FEM forward calculations with a non-linear square method. The inconveniences presented by the 1D analysis to make a more realistic layer analysis of the undergound structure, are best solved by the approximation made by the 2-D model.

In order to make the model calculations, the geological structure is divided into many small blocks, each of them having initially assigned their own chargeability and resistivity value. The blocks are designed so that small blocks are placed close to the surface and they increase in size as the blocks are located at deeper levels.

2-5 Electrical Measurements of Rock Samples

2-5-1 Measurement Method

Measure of the electrical properties of rock samples were carried out in order to determine the actual electrical properties of the rocks distributed on the survey area. 26 pieces of the rocks collected from the surface were formed into a cubic shape and thereafter, soaked into water for a reasonable amount of days, apparent resistivity as well as chargeability values were measured according to the IP time domain procedures.

2-5-2 Results

Results of the electrical property of rocks and ore samples measured in the laboratory are indicated in Table II-2-3. The resistivity values measured in the laboratory ranged from 0.9 to 11343 Ωm. The samples Nos. 4, 8, 21 and 23 which correspond to massive sulphide presented extremely low resistivity values of around 1 Ωm, while the samples Nos. 5, 6, 12, 13, 14, 16, 18, 25, 15 and 26 indicated intermediate values in the range of 50 to 250 Ωm. The samples Nos.1, 2, 3, 7, 9, 10, 11, 15, 17,20 and 22 indicated high resistivity values above 300 Ωm.

The chargeability values measured in the laboratory ranged bewteen 1.6 to 203 mV/V. The massive sulphide samples indicated high values between 53 and extremely high values of 203 mV/V. Also the network samples Nos. 5 and 17 showed high chargeability values of about 100mV/V. The samples Nos. 7, 10, 18 and 19 indicated comparatively high values of about 30 mV/V. The samples Nos. 1, 3, 9, 14, 15, 20 and 22 indicated intermediate chargeability values around 10 mV/V.

The samples Nos. 27 and 28 were built by placing 3 selected samples together one after another, i.e., a massive sulphide (low resistivity-high chargeability) sample was placed in the middle of other two which ranged between medium to high resistivity and low to medium chargeability. Though the influence of the massive sulphide sample can be suggested, in both integrated samples, the predominant result indicated rather relatively high resistivity and low chargeability values.

2-6 Fardah Area

2-6-1 Lines location

Eight IP lines each of 1.5 km long were located on this area along the N28°E direction. The lines 400W and 600W, located towards the west of the area, were displaced 300m southwards in order to avoid the crossing of houses built on this area. The location of the lines are indicated in Fig.II-2-4.

2-6-2 Results

Apparent resistivity, chargeability and metal factor pseudo-sections for the 8 IP lines are indicated in Figs. II-2-5, II-2-6 and II-2-7 respectively. Figs. II-2-8, II-2-9, II-2-10 and II-2-11 show the resistivity, chargeability and metal factor maps for n=1 to n=4.

According to the above mentioned results, it can be inferred that the apparent resistivity values range from 3 to 288 Ωm, but showing in general relatively low values of less than 50 Ωm. To the NE of the gossanized zone, it can be seen a zone of low resistivity extended along the NW-SE direction. This low resistivity zone presents a width of about 250m below 10 Ωm and displaced towards northeast at depth.

Table II-2-3 Resistivity and chargeability of core samples

No.	Area	Borehole No.	Sampling Depth(m)	Resis. (Ω-m)	Charge. (mV/V)	Rock Name	Remarks
1	GG	G2	76.10	654.7	13.1	Pw(V1-1)	Py diss(sl)
2	GG	G2	170.30	454.3	5.1	Pw(V1-1)	Py diss, Py-Qz net, Sili(sl)
3	GG	G3	80.00	817.8	15.2	Ml(V1-2)	Py-Cp diss(sl), Sili(sl)
4	GG	G3	140.30	1.1	53.3	Ms	Massive Sulphide
5	GG	G4	83.50	105.3	135.9	Pw(V1-2)	Sph-Cp net, Py diss(in), Sili(sl)
6	GG	G4	212.00	79.1	6.6	Pw(V1-2)	Py diss(sl), Py str
7	GG	G5	86.10	1000.0	34.6	Pw(V1-2)	Py diss, Py vein
8	GG	G5	165.40	0.9	177.6	Ms	Massive Sulphide
9	GG	G5	238.30	693.1	11.3	BaDy	Py diss, Sili(sl)
10	GG	G6	164.80	626.4	27.0	Ml(V1-2)	Py diss(sl), Cp-Epi-Cal vein
11	GG	G7	28.10	930.5	5.1	Calc(Q)	
12	GG	G7	194.00	57.2	1.6	Ml(V1-2)	Py diss(sl)
13	GG	G7	252.90	70.1	2.1	Pw(V1-2)	Py diss(sl)
14	GG	G8	115.60	225.6	12.0	Ml(V1-2)	Py diss(sl), Cp-Py-Cal vein
15	GG	G9	52.70	489.0	16.3	Pw(V1-2)	Py diss
16	GG	G10	50.00	124.1	3.1	GaDy	
17	GG	G11	163.90	1134.0	104.1	Js	Hm, Py, Cp
18	GG	G12	64.00	248.7	31.5	Pw(V1-2)	Py diss, Py-Chl vein
19	GG	G13	167.80	81.2	32.1	Pw(V1-1)	Py diss(in), Py-Qz net, Sili(in)
20	GG	G14	80.00	423.0	11.4	BaDy	Py diss(sl), Py fine net
21	GG	G14	150.00	1.8	202.9	Ms	Massive Sulphide
22	GG	G15	52.50	327.0	14.6	Pw(V1-2)	Py diss, Sili
23	GG	G15	207.55	1.2	149.6	Ms	Massive Sulphide
24	GG	G16	45.25	253.5	3.7	Ml(V1-2)	Py diss(sl)
25	DA	D1	31.20	147.7	6.7	Cata	Brecciated
26	DA	D4	37.50	221.9	7.6	Ml(V1-2)	Py diss(sl), Py-Cal vein
27		14+23+7		261.4	33.0		
28		14+23+2		126.8	9.2		

Notes

GG :Ghuzayn Gossan
DA :Daris

Resis. :Resistivity
Charge. :Chargeability

Pw Pillow lava(basalt)
Ml :Massive lava(basalt)
MS :Massive sulphide
Js :Jaspar
BaDy :Basalt~doleritic lava
GaDy :Gabbroic lava
Calc :Calcreto
Cata :Cataclastic volcanic rock

V1-1 :Lower Extrusives 1
V1-2 :Lower Extrusives 2
Q :Quaternary

Py :Pyrite
Cp :Calcopyrite
Sph :Sphalerite
Epi :Epidote
Cal :Calcite
Hm :Hematite
Chl :Chlorite
Qz :Quartz

diss :dissemination
net :network
vein :veinlets
(sl) :slight
(in) :intense
Sili :Silicified

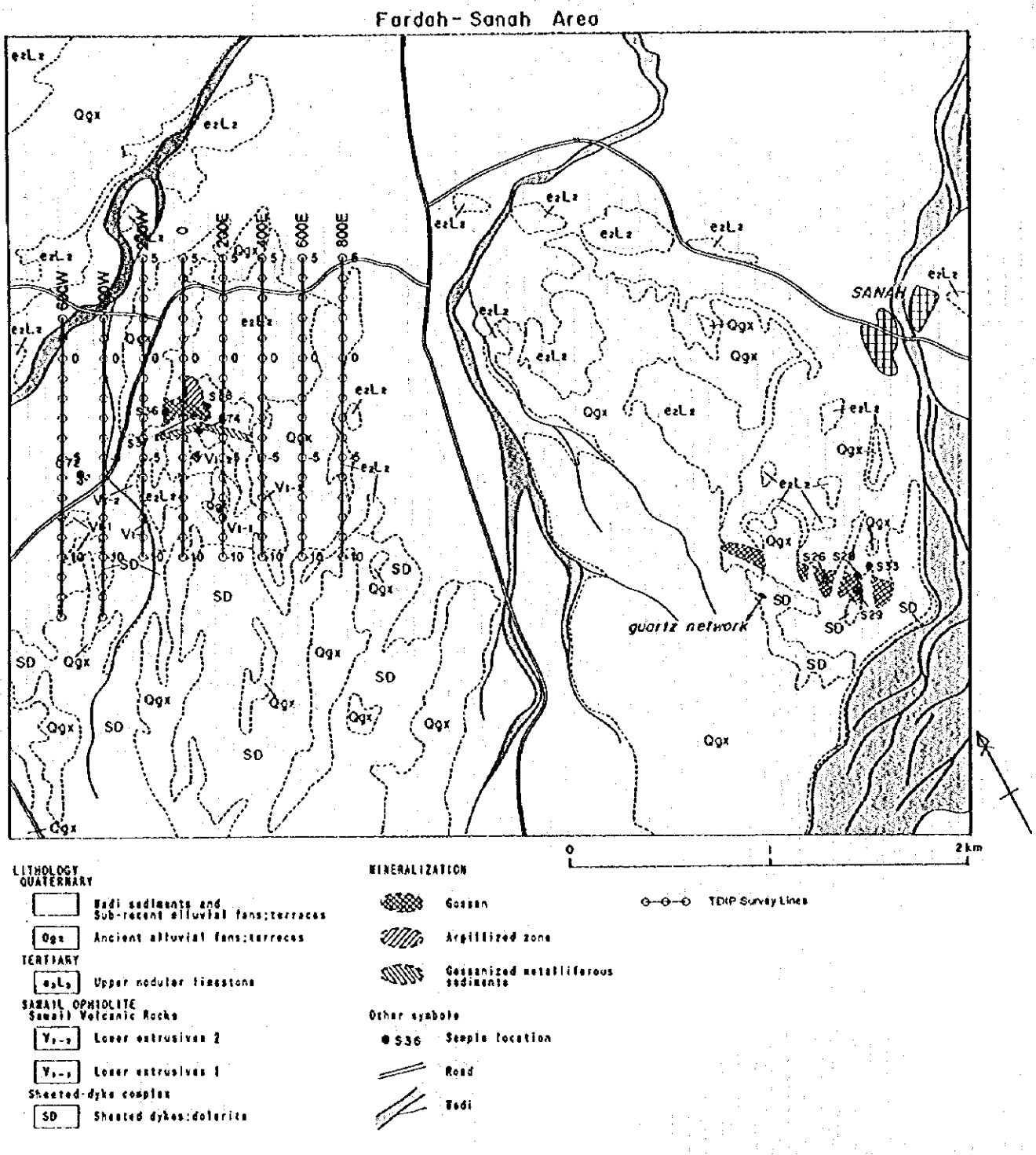


Fig.II-2-4 IP line locations in Fardah area

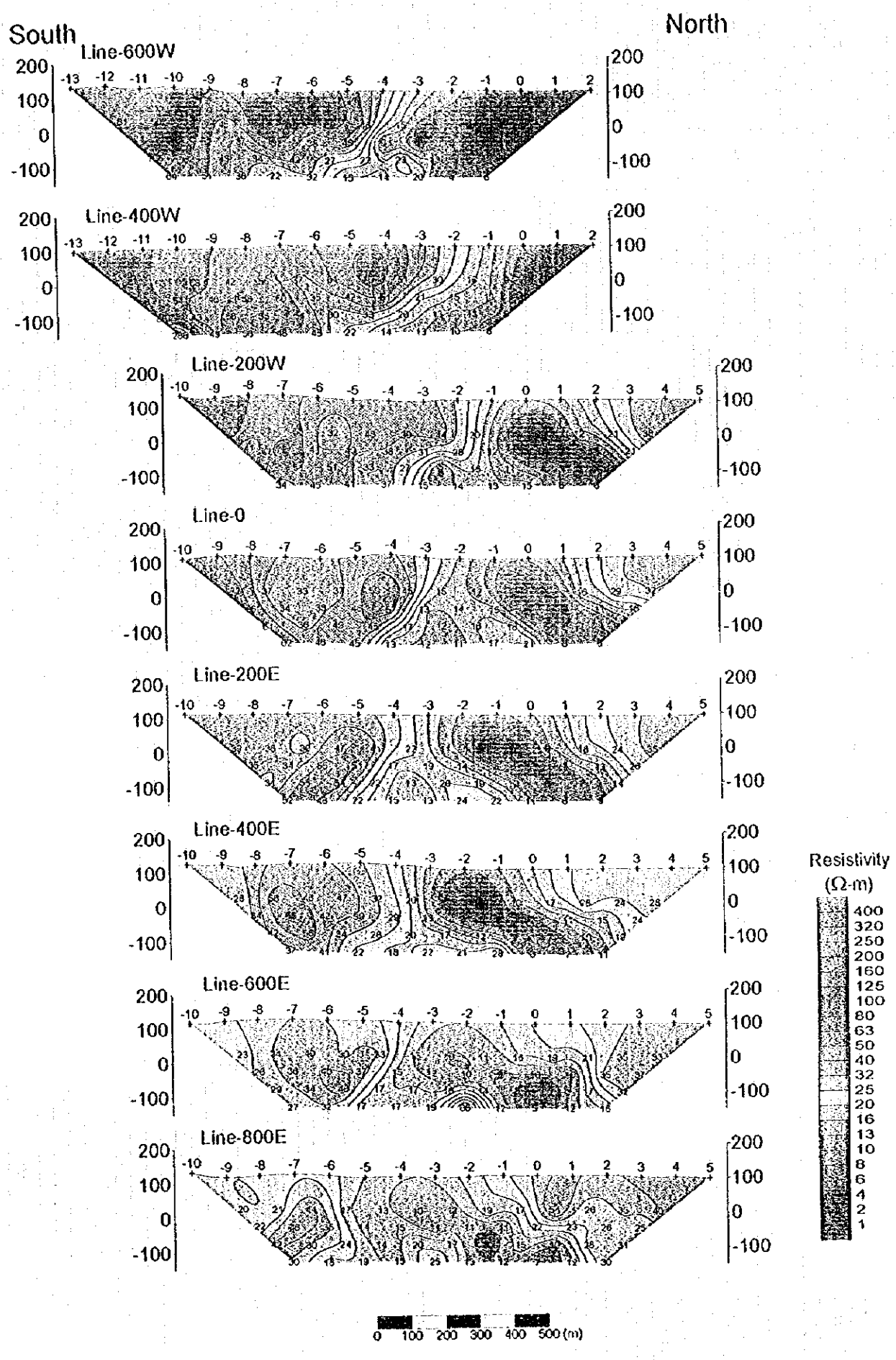
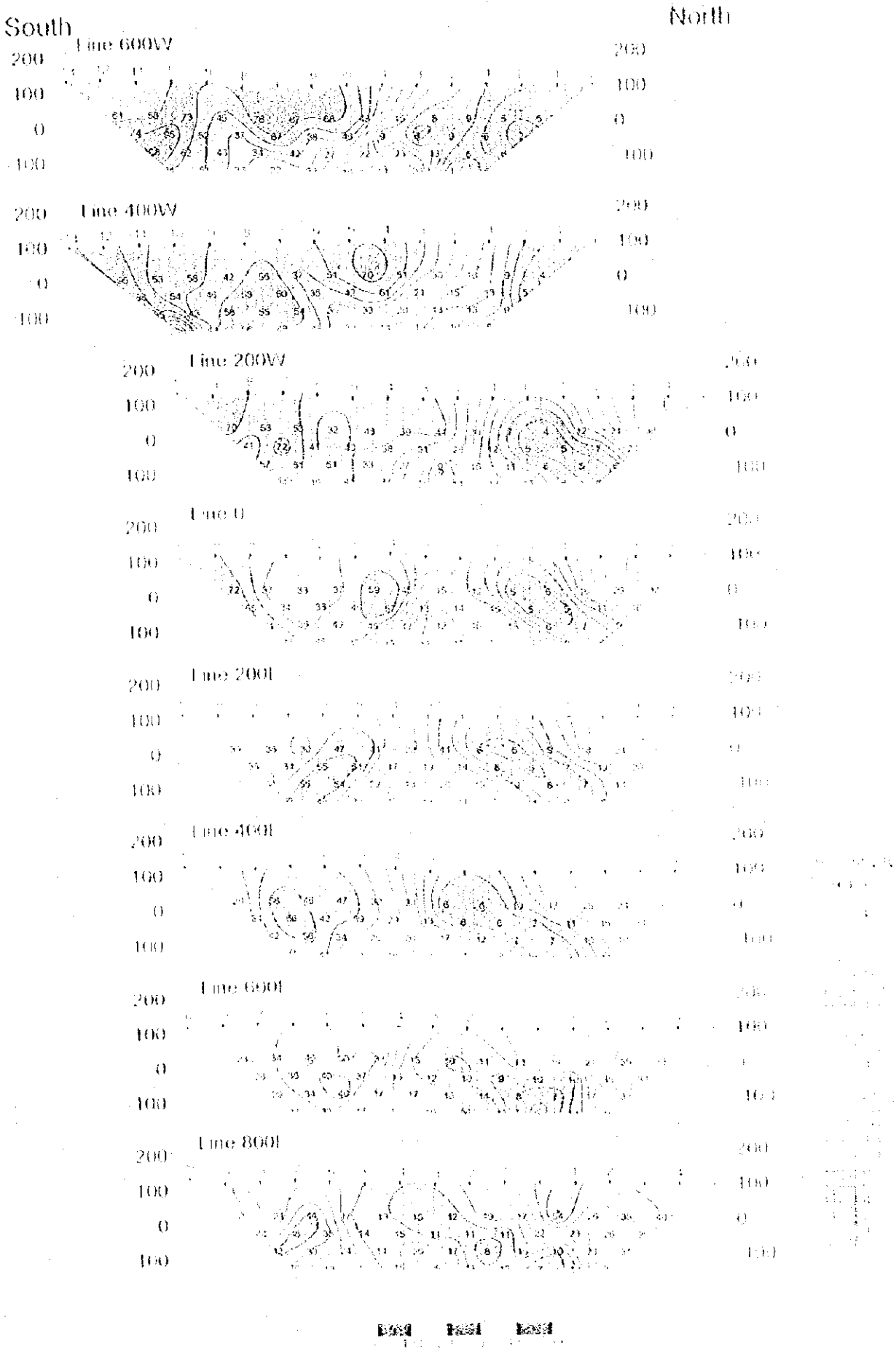


Fig.II-2-5 Apparent resistivity pseudo-sections in Pardah area


South
North
Line 600W
Line 400W
Line 200W
Line 0
Line 200E
Line 400E
Line 600E
Line 800E
200
100
0
100

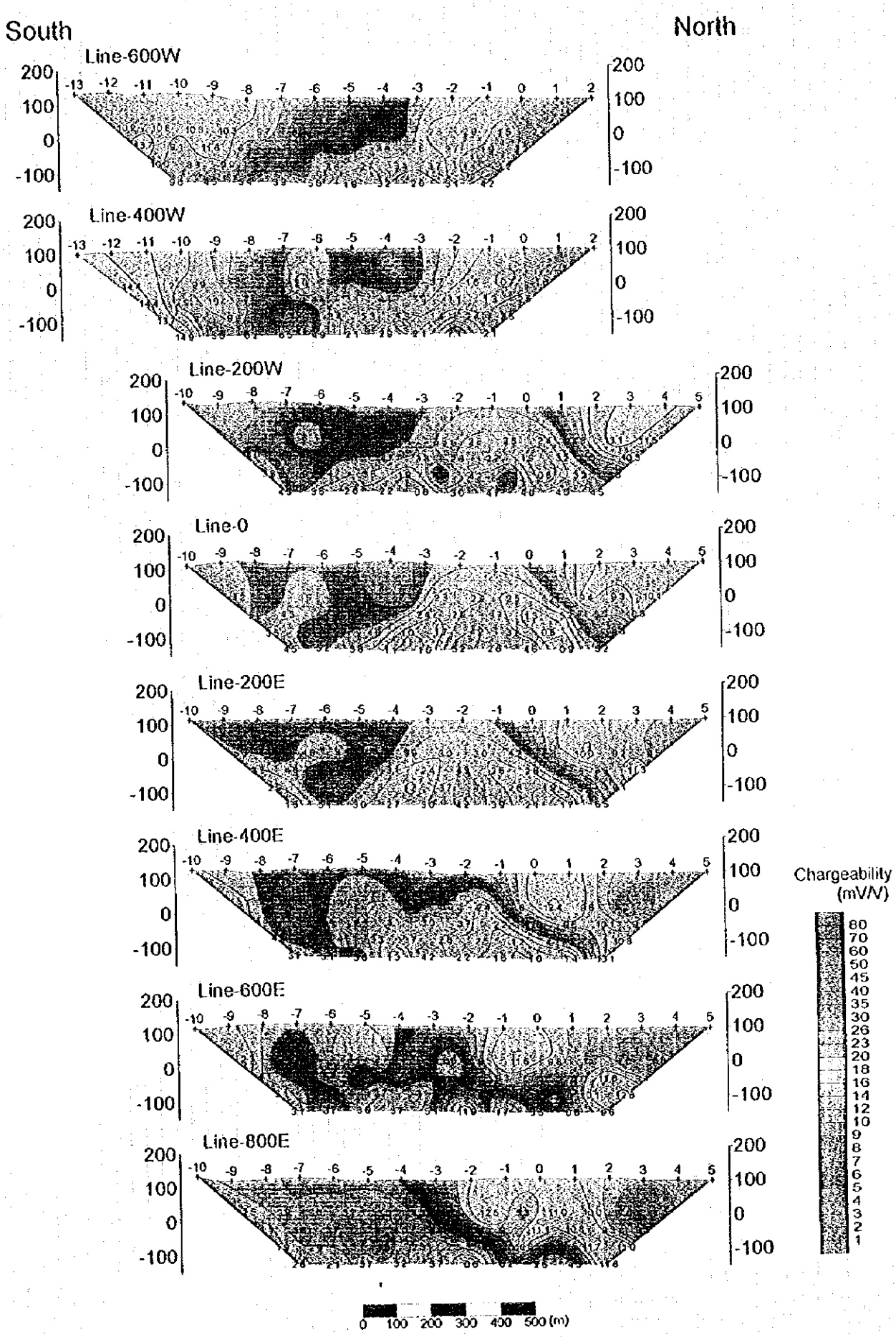
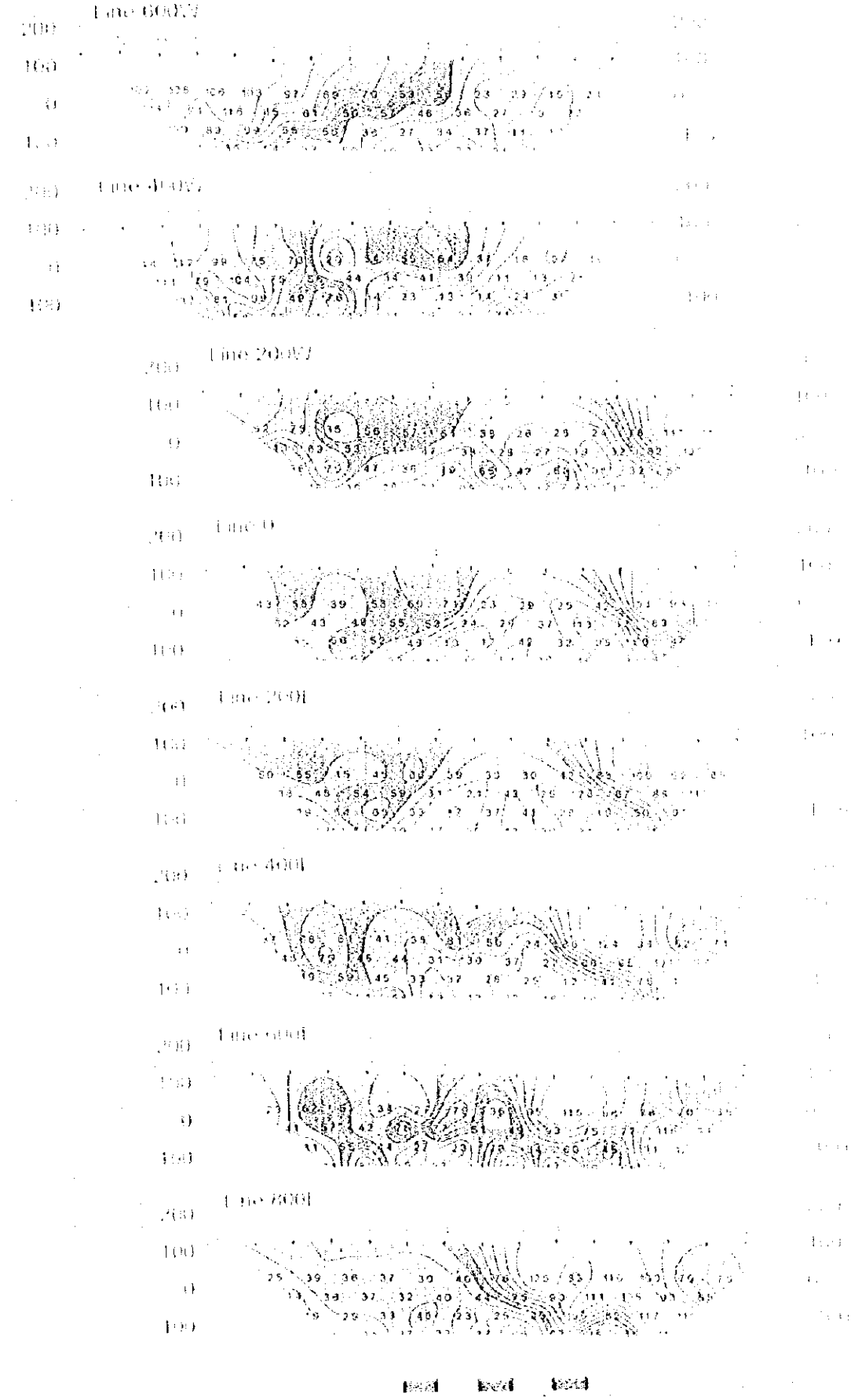


Fig.II-2-6 Chargeability pseudo-sections in Fardah area

South North


Line 6000
Line 4000
Line 2000
Line 0
Line -2000
Line -4000
Line -6000
Line -8000

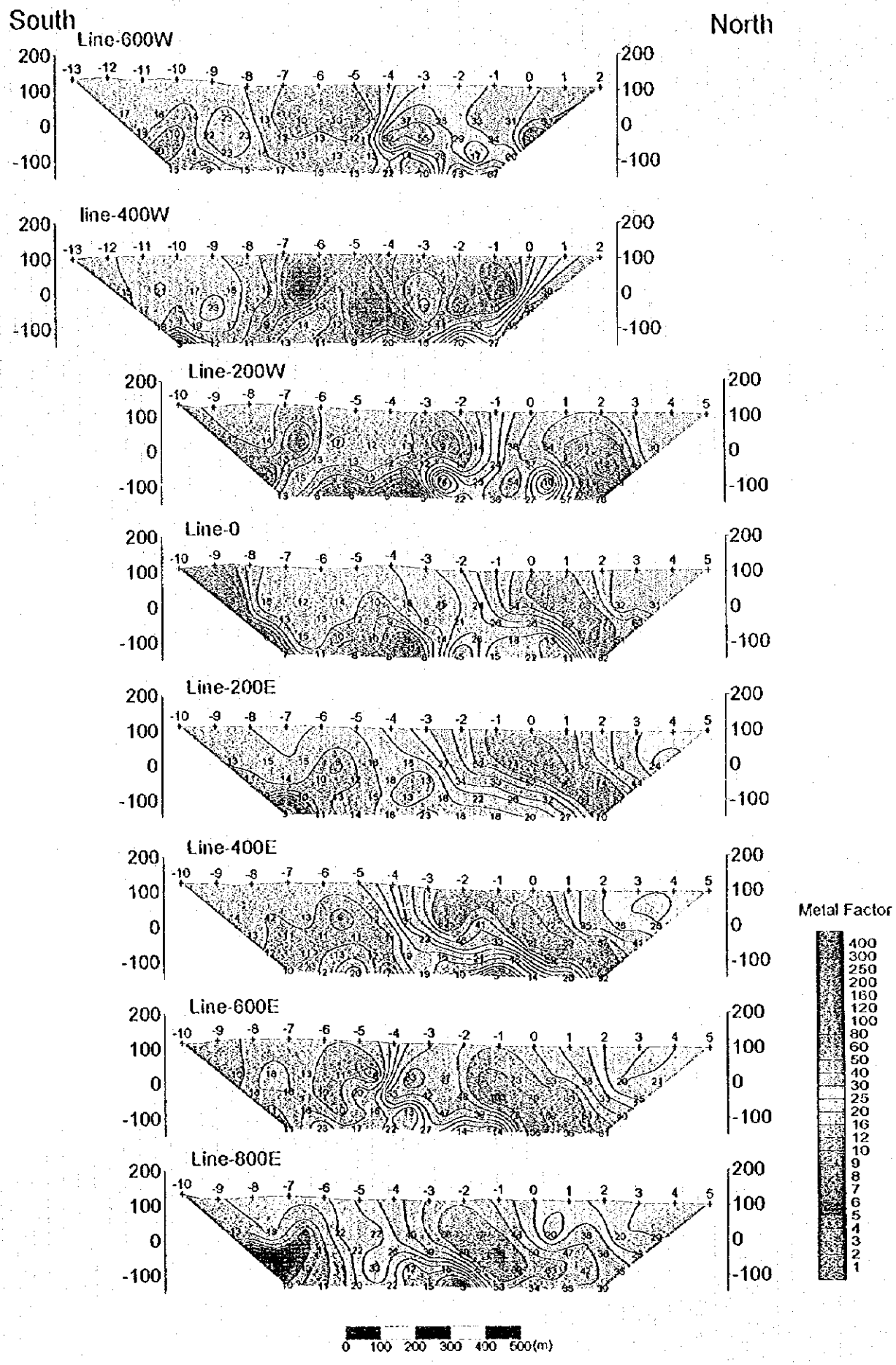


Fig.II-2-7 Metal factor pseudo-sections in Pardah area

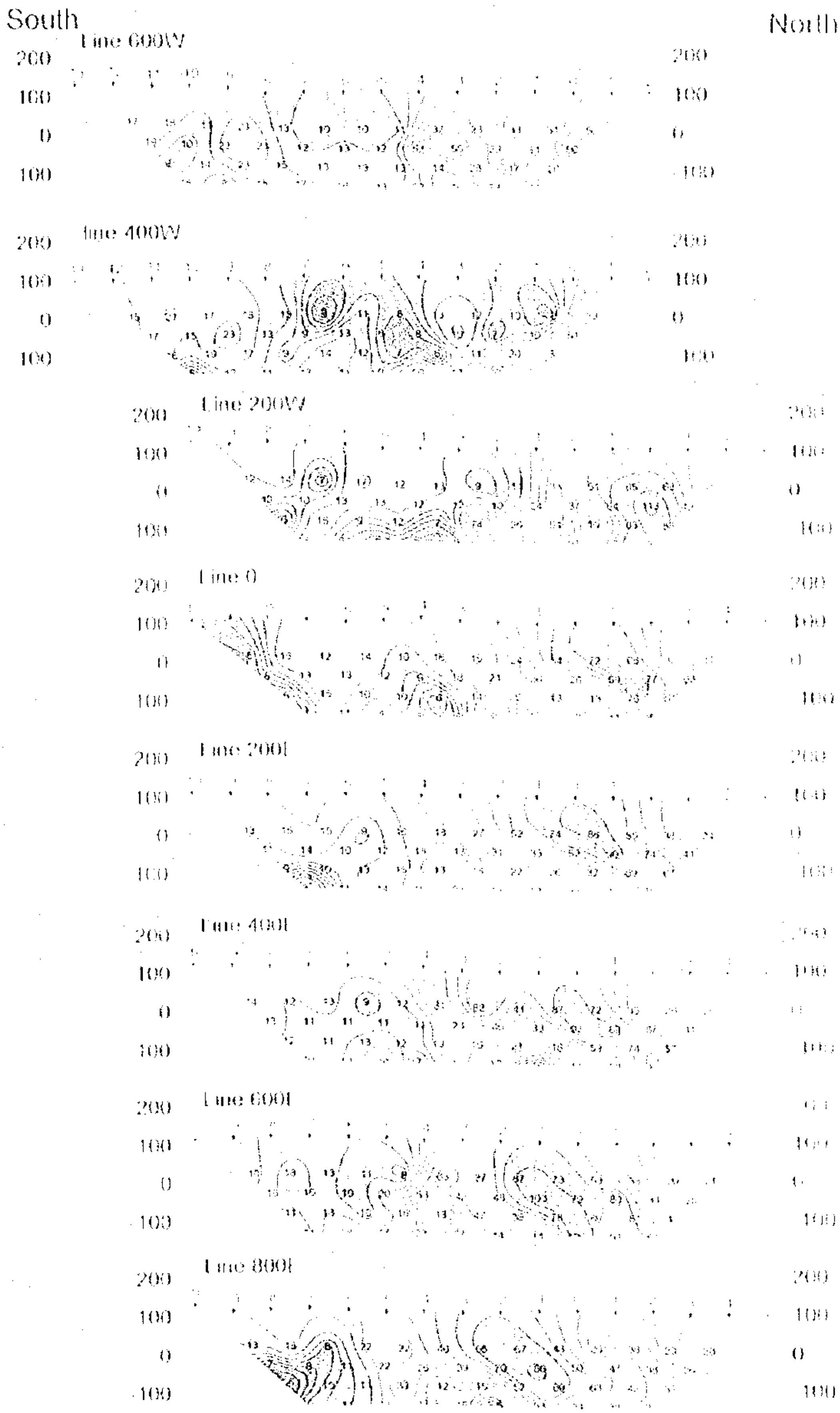


Fig. II.2.[illegible] Metal factor pseudosections [illegible]

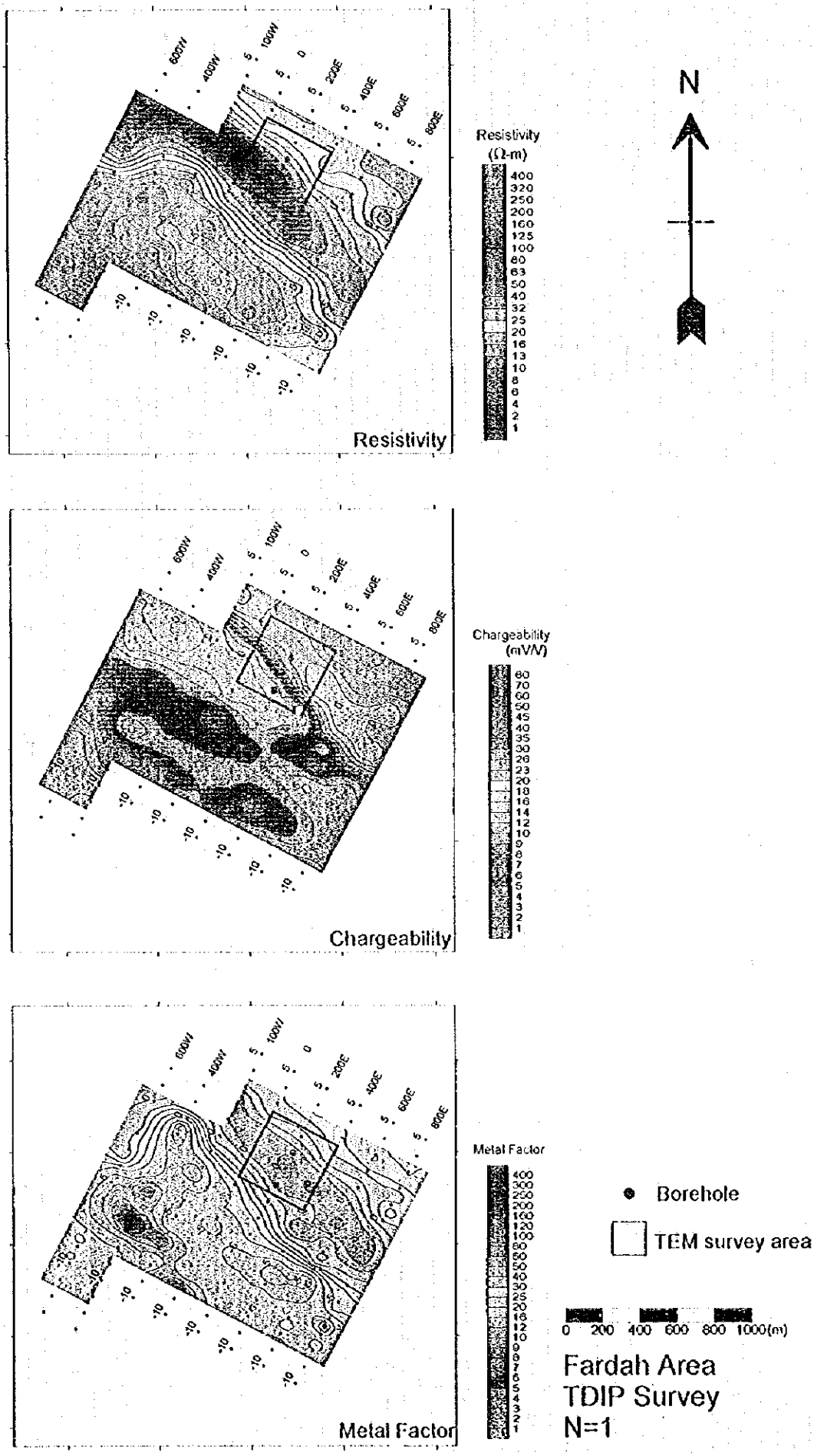
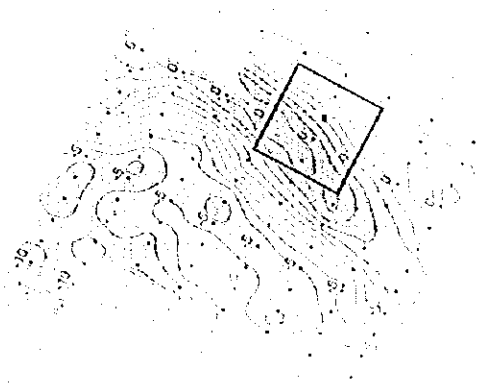
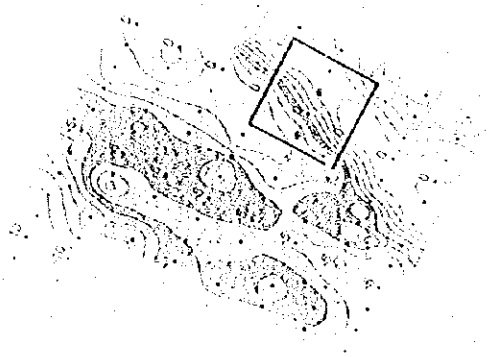


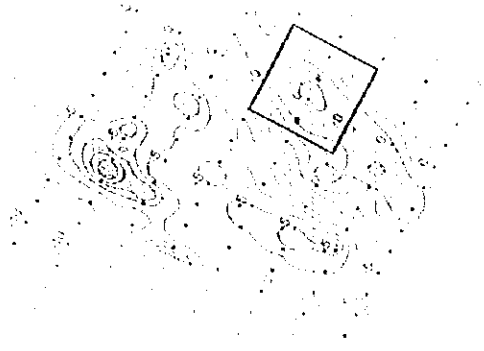
Fig.II-2-8 IP plane map of n=1 in Fardah area



Resistivity



Chargeability



Metal Factor

N

Fardah Area
IDIP Survey
N 1

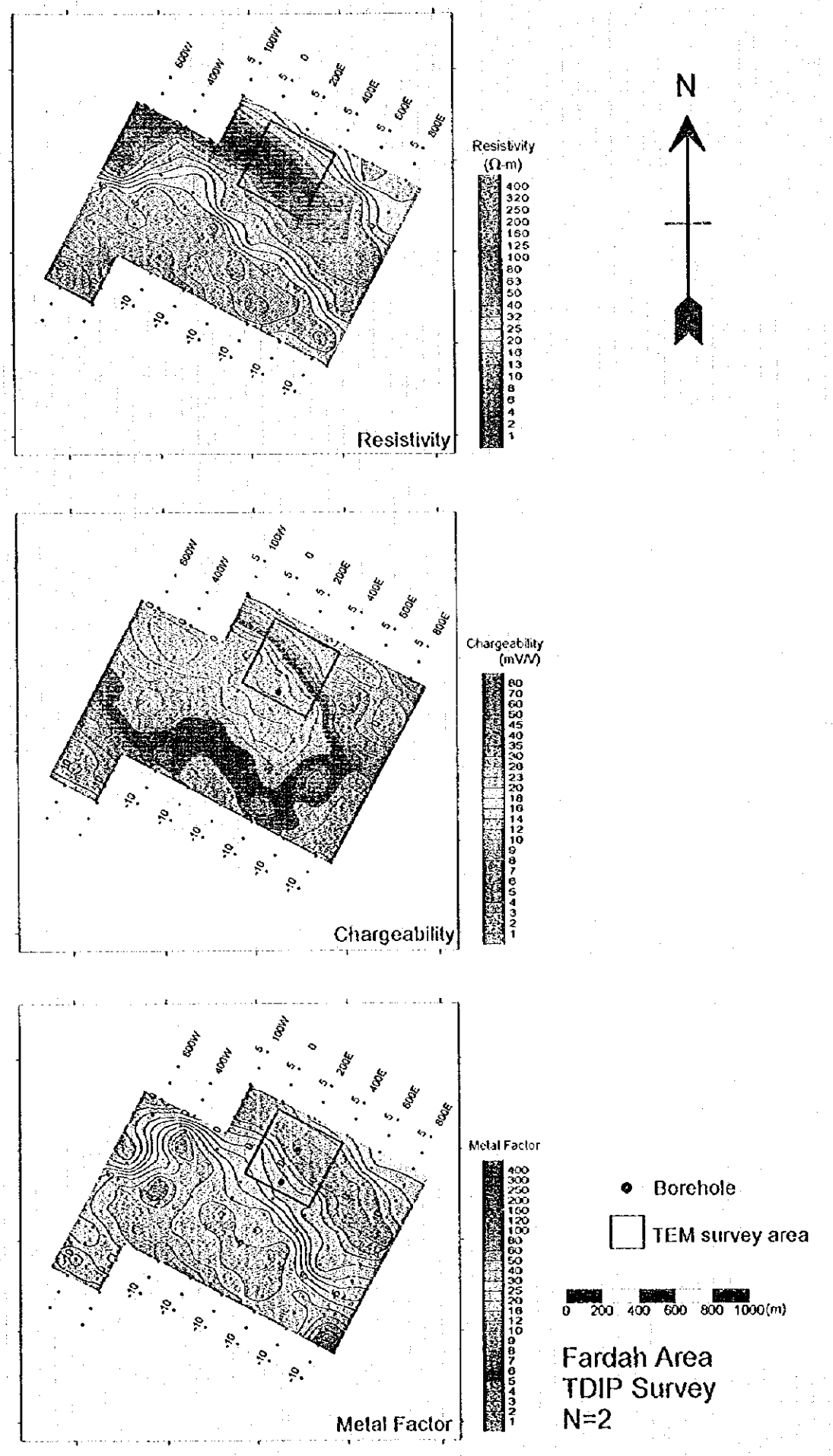
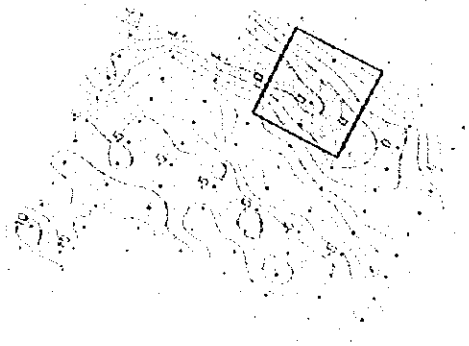
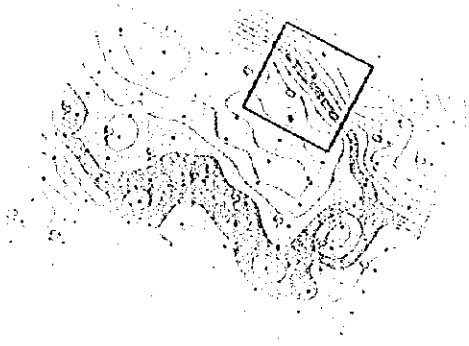


Fig.II-2-9 IP plane map of n=2 in Farda area



Resistivity



Chargeability

Metal Factor

Pardah Area
IDIP Survey
N 2

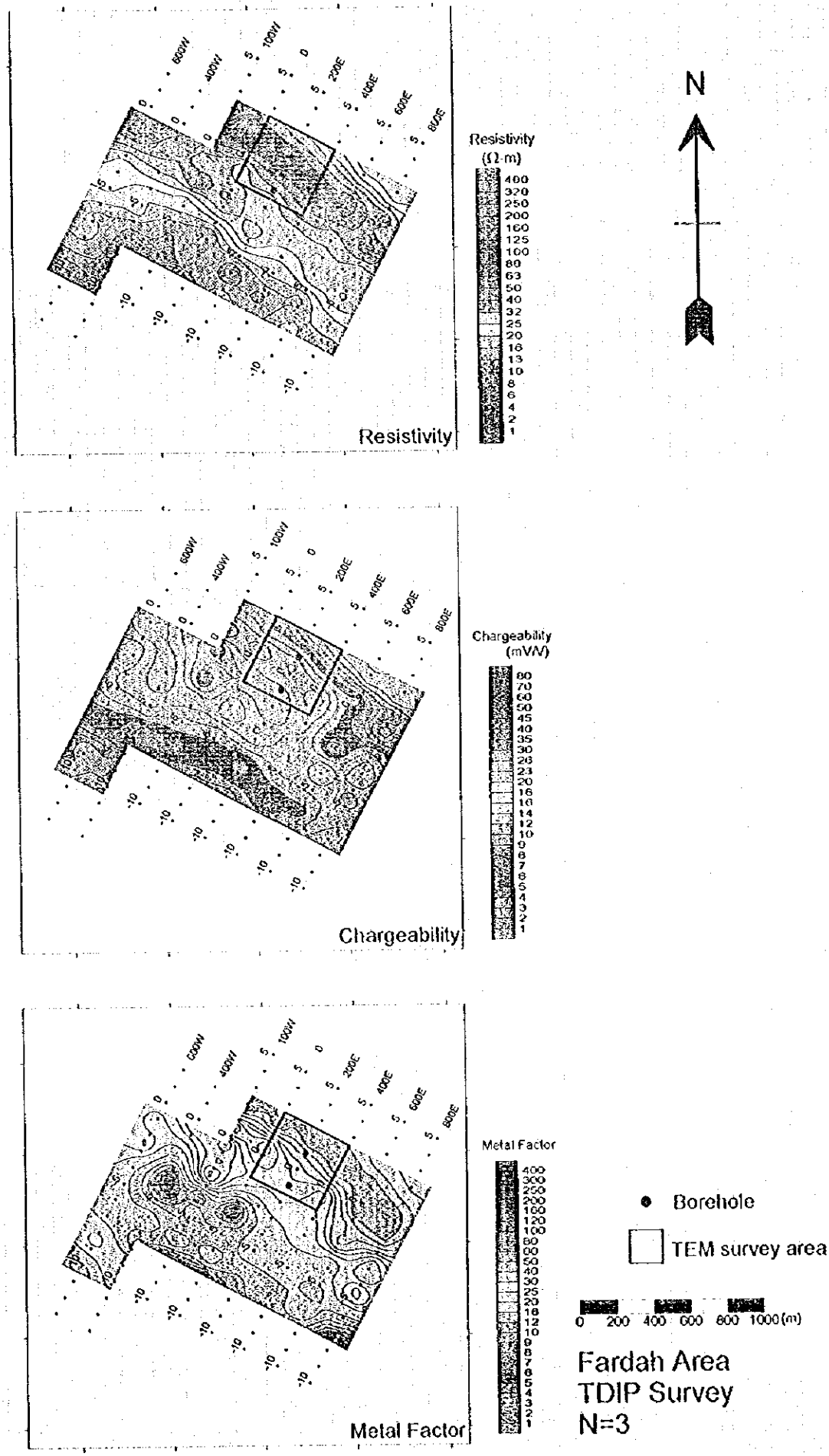
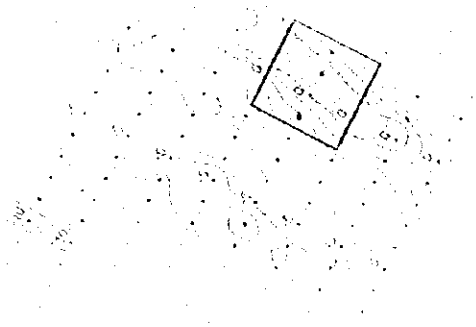
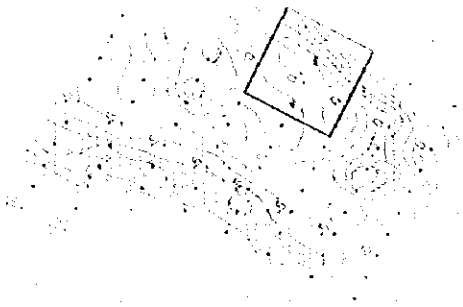
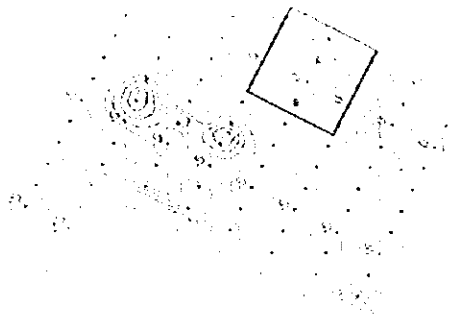


Fig.II-2-10 IP plane map of n=3 in Farda area







Landslide Area
IP Survey
N-S

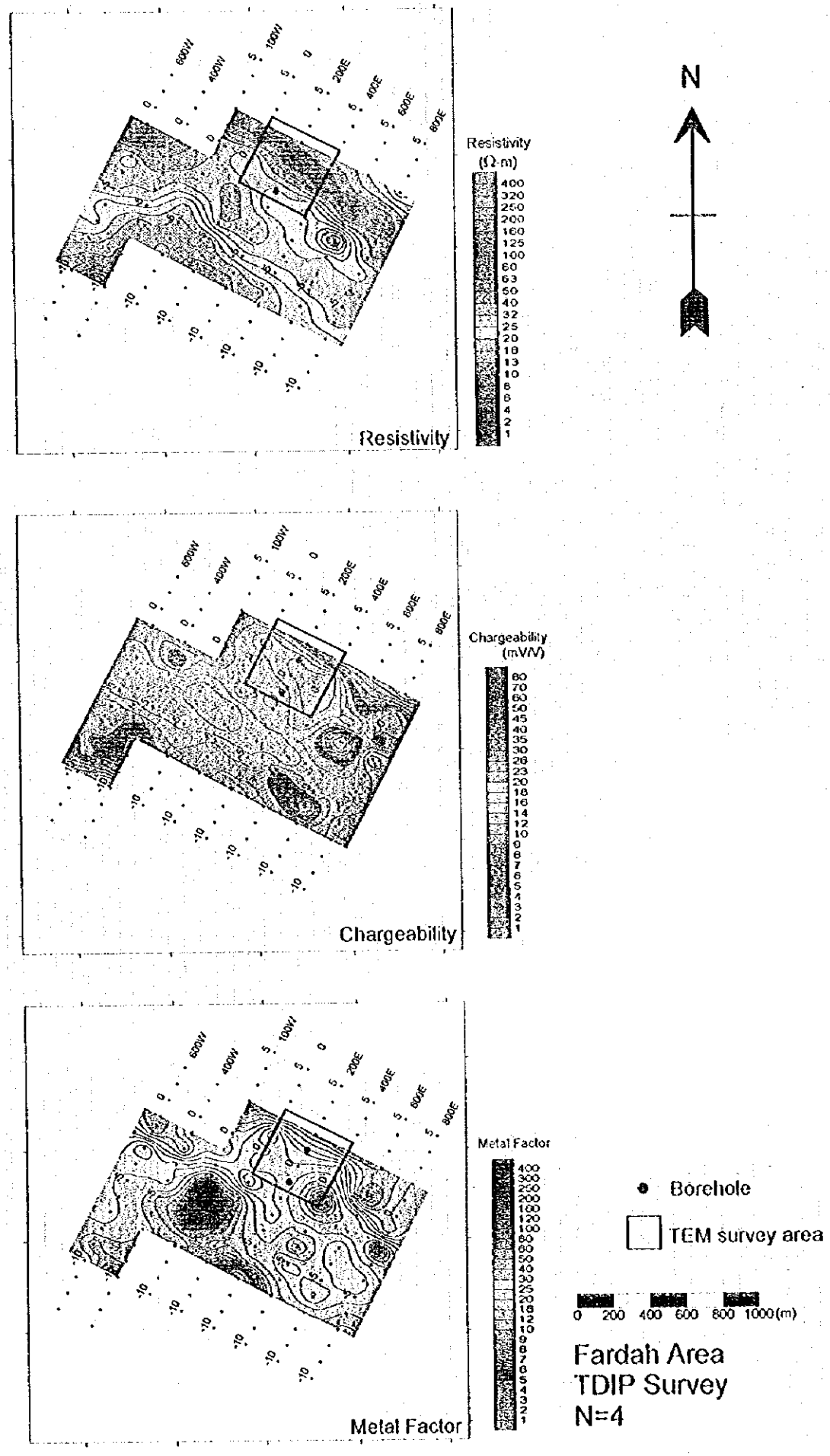


Fig.II-2-11 IP plane map of n=4 in Farda area

Chargeability values of about 10mV/V are seen as medium chargeability zones distributed in the same way as the zone of low resistivity values previously mentioned but displaced toward the north. This chargeability zone of medium values is also seen displaced towards the NE in such a way that for n=4 this chargeability zone looks like is out of the range of the area under study. In the SW corner of the area under study, medium values chargeablity distributions are seen with values above 10mV/V.
In relation to the metal factor, the zone of low resistivity and the zone of medium chargeabilty values with values higher than 60 are seen also extended in a similar way as a low resistivity zone along the NW-SE direction.

2-6-3 2-D Analysis

For this area, the line 200E was selected for 2 dimensional analysis purposes. Fig. II-2-12 shows the results of 2-D analysis.

The resistivity section shows a distribution centered around station No -1 with values less than 10 Ωm and a width of about 200m. This distribution seems oriented about 60° inclined towards the north.
By observing the chargeability section, it is possible to delineate from station No. 1 and northwards, a shallow medium chargeability distribution of above 9 mV/V.

The metal factor section shows around the Station No. 0, a shallow distribution of above 60. This distribution trends northwards and presents similar patterns as the resistivity distribution mentioned above.

2-7 Sanah Area

2-7-1 Lines location

Within the area under study, seven IP lines of 1.5 km each were located along N28°E. To the north of the area, the line 400E were displaced 100m towards the south to avoid houses located in the north margin. The location of the lines are indicated in Fig. II-2-13.

2-7-2 Results

The apparent resistivity, chargeability and metal factor pseudo-sections are indicated in Figs. II-2-14, II-2-15 and II-2-16, respectively. Figs. II-2-17, II-2-18, II-2-19 and II-2-20 show the resistivity, chargeability and metal factor maps for n=1 to n=4, respectively.
The apparent resistivity and chargeability distibutions found in this area present very similar patterns



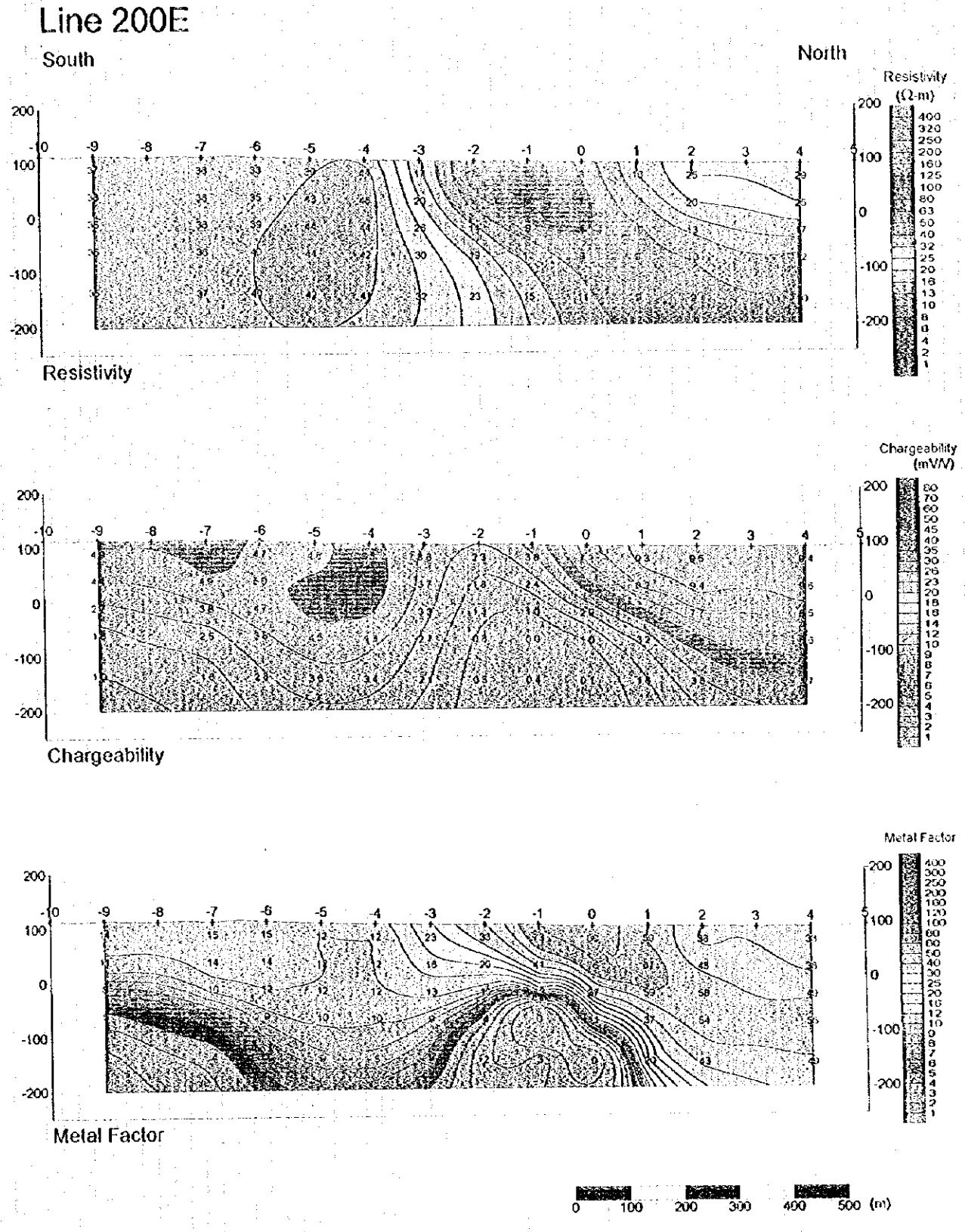
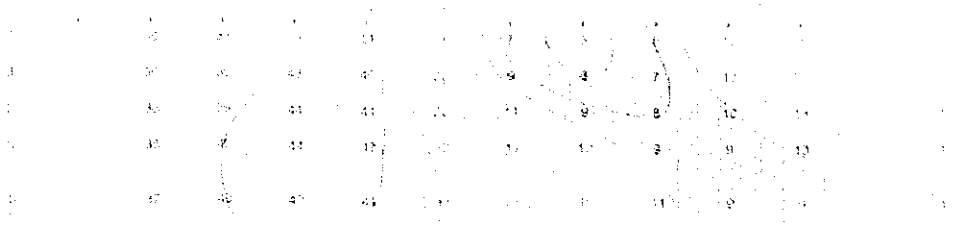
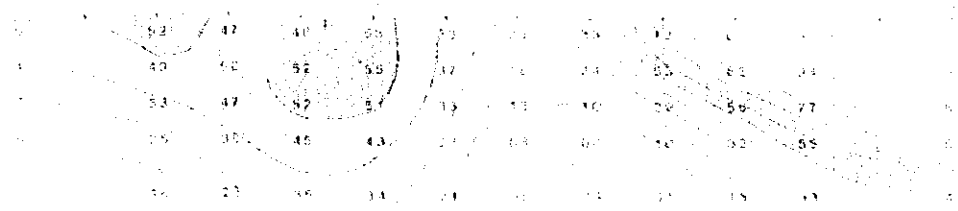
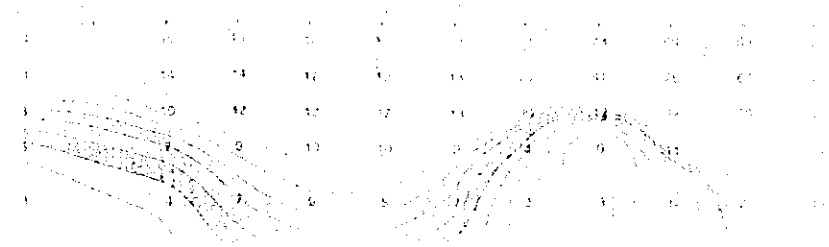


Fig.II-2-12 Results of model simulation on Line 200E in Pardah area

Line 2008







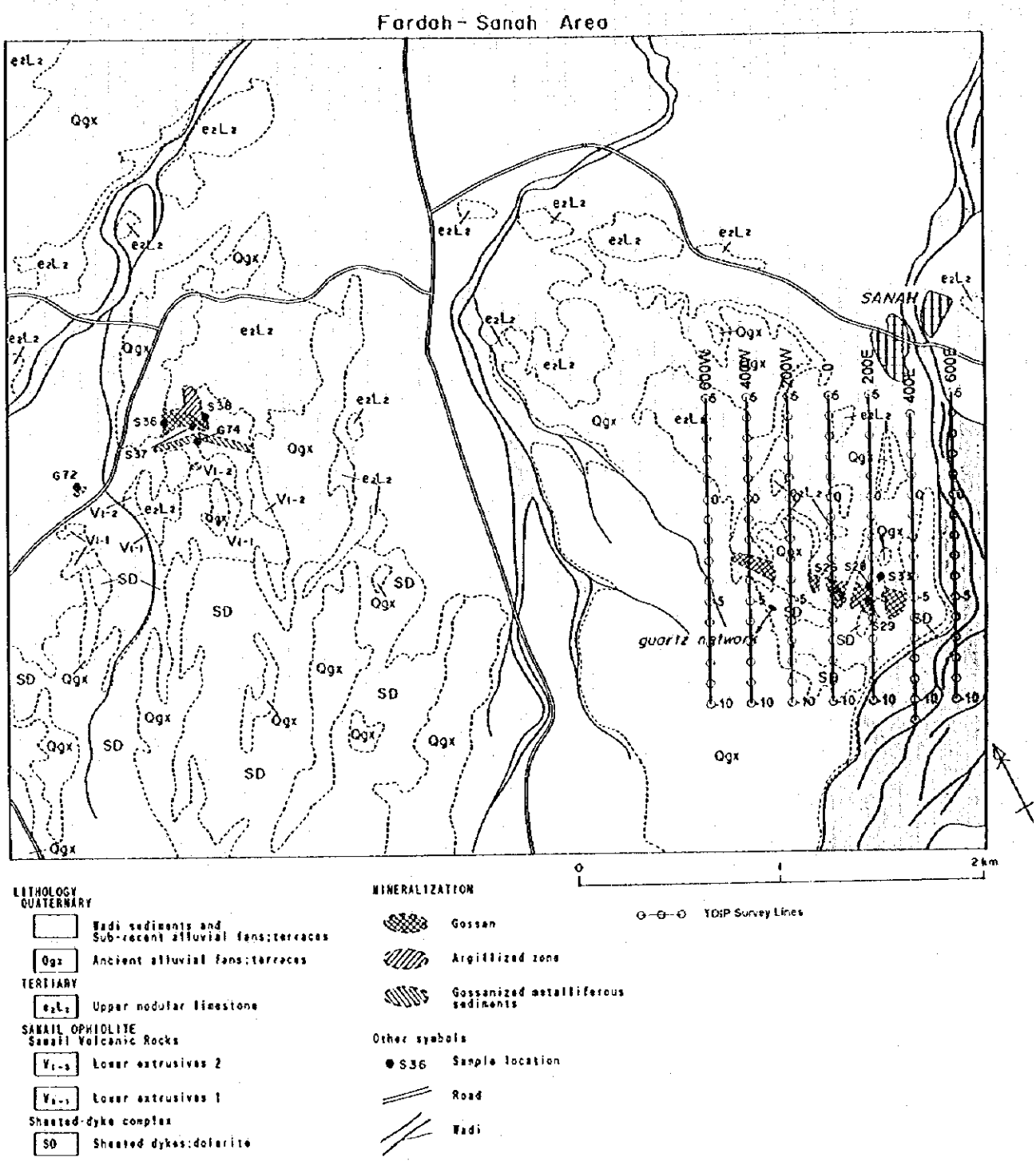


Fig.II-2-13 IP line locations in Sanah area

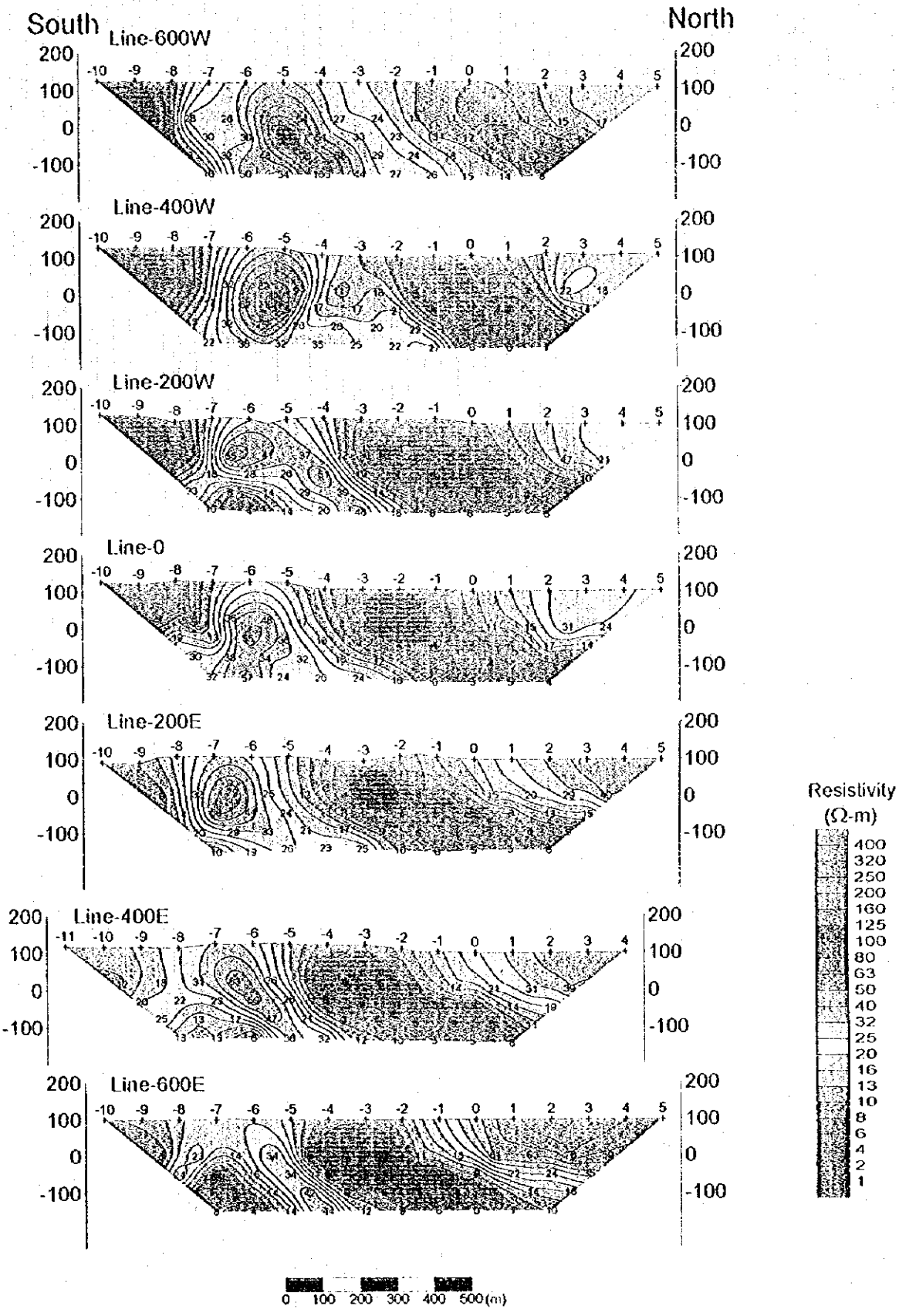
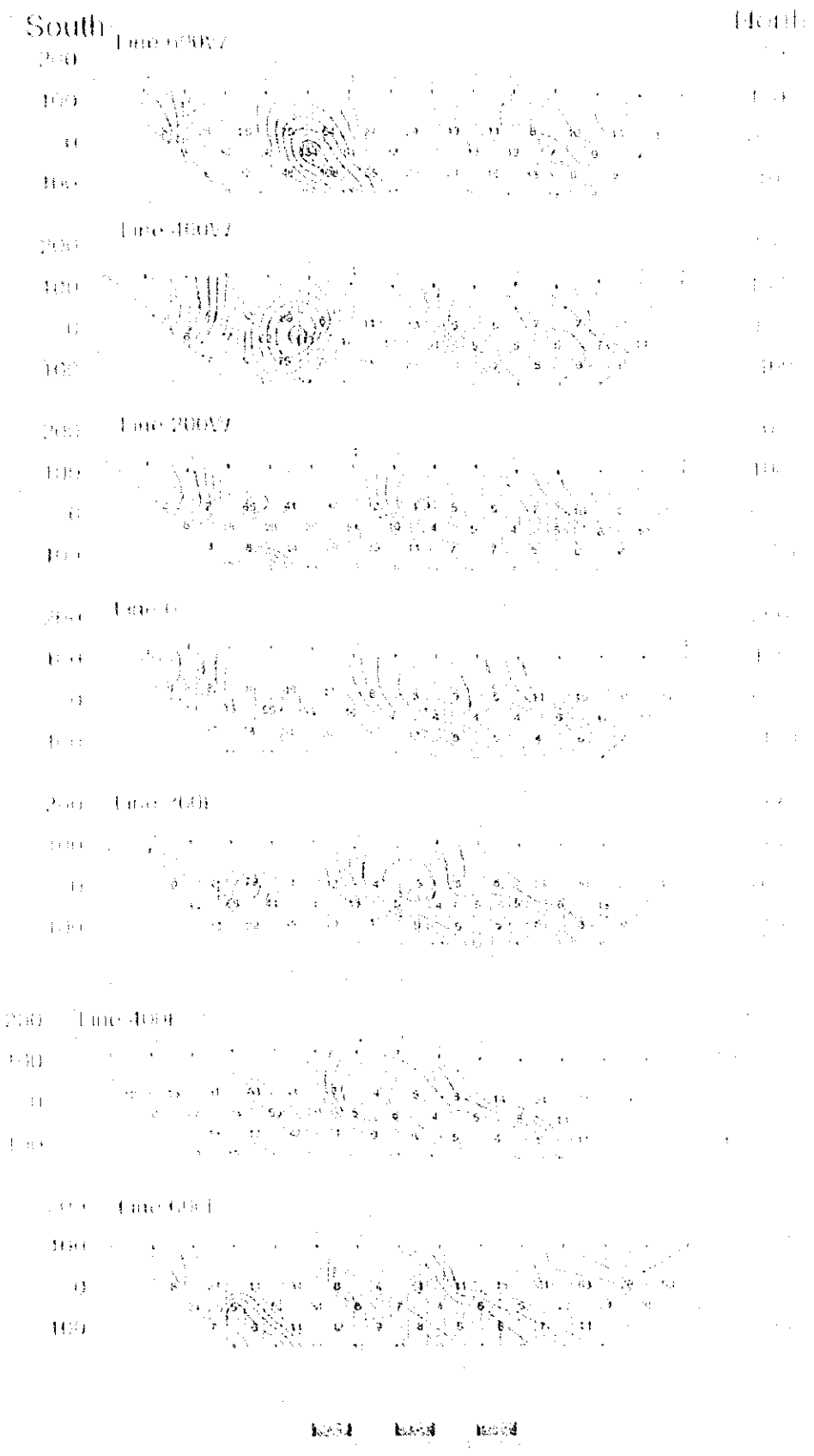


Fig.II-2-14 Apparent resistivity pseudo-sections in Sanah area


South
North
Line 500kV
Line 400kV
Line 230kV
Line G
Line 66kV
Line 400kV
Line 66kV

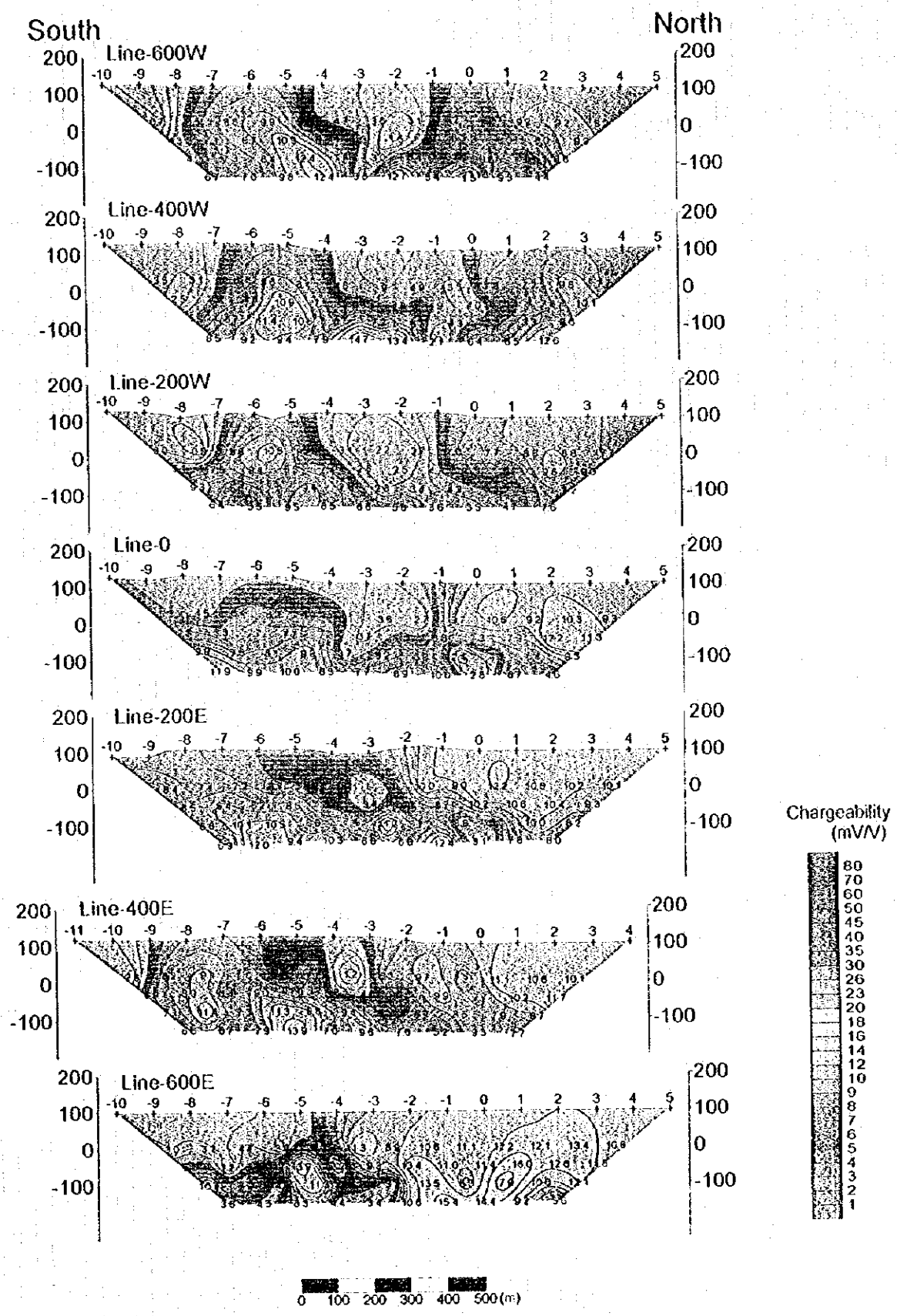
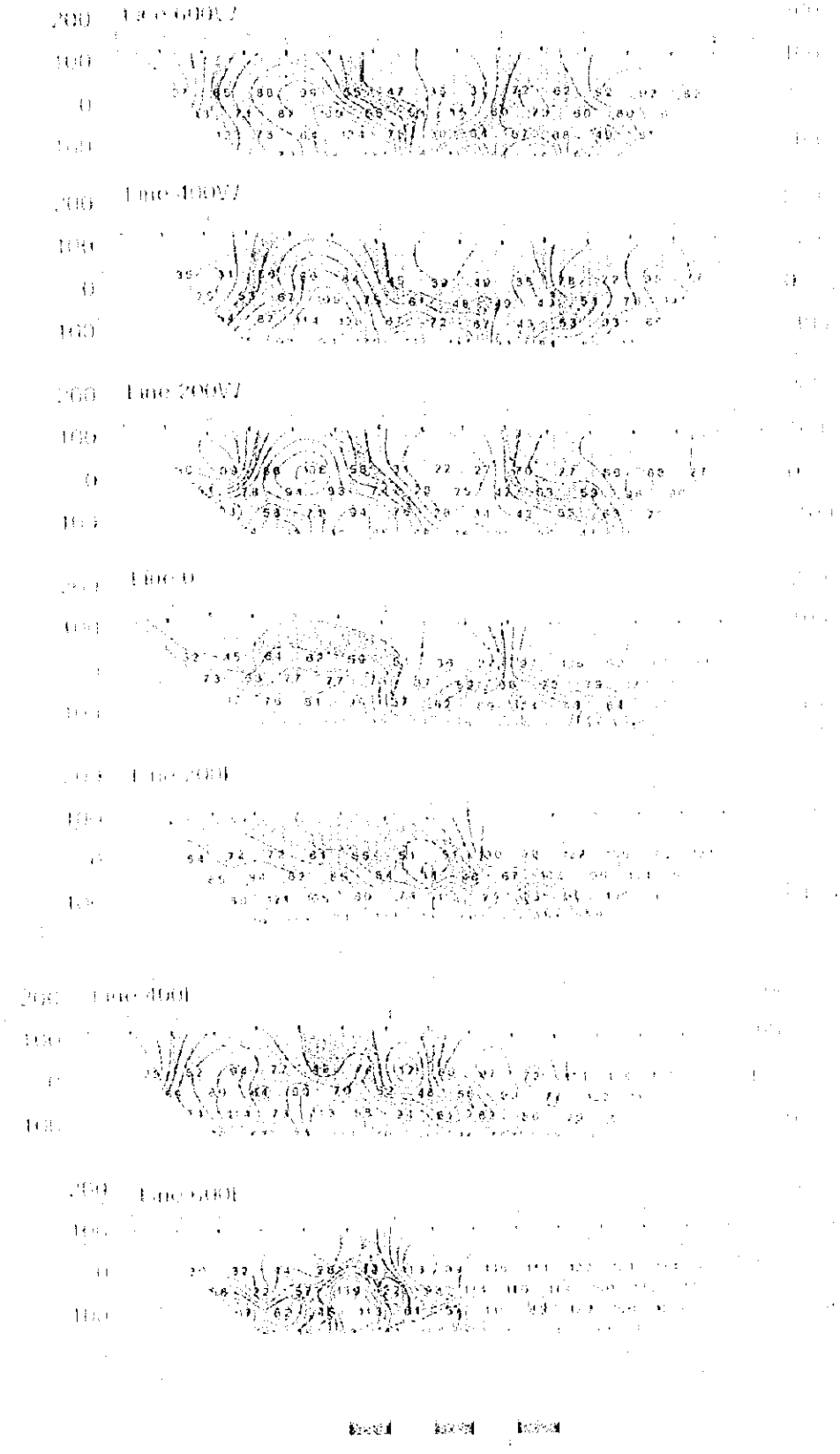


Fig.II-2-15 Chargeability pseudo-sections in Sanah area

South

North



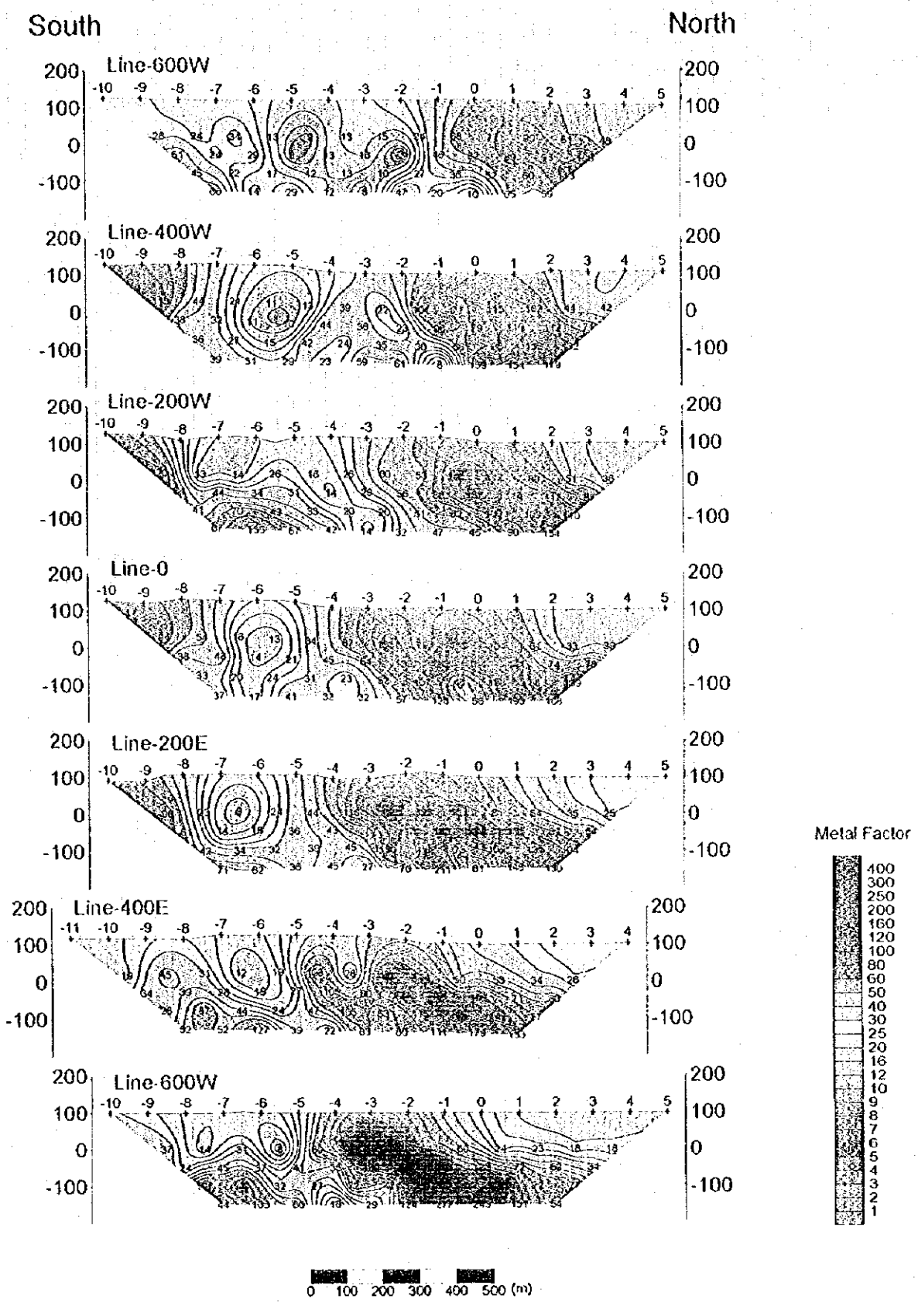
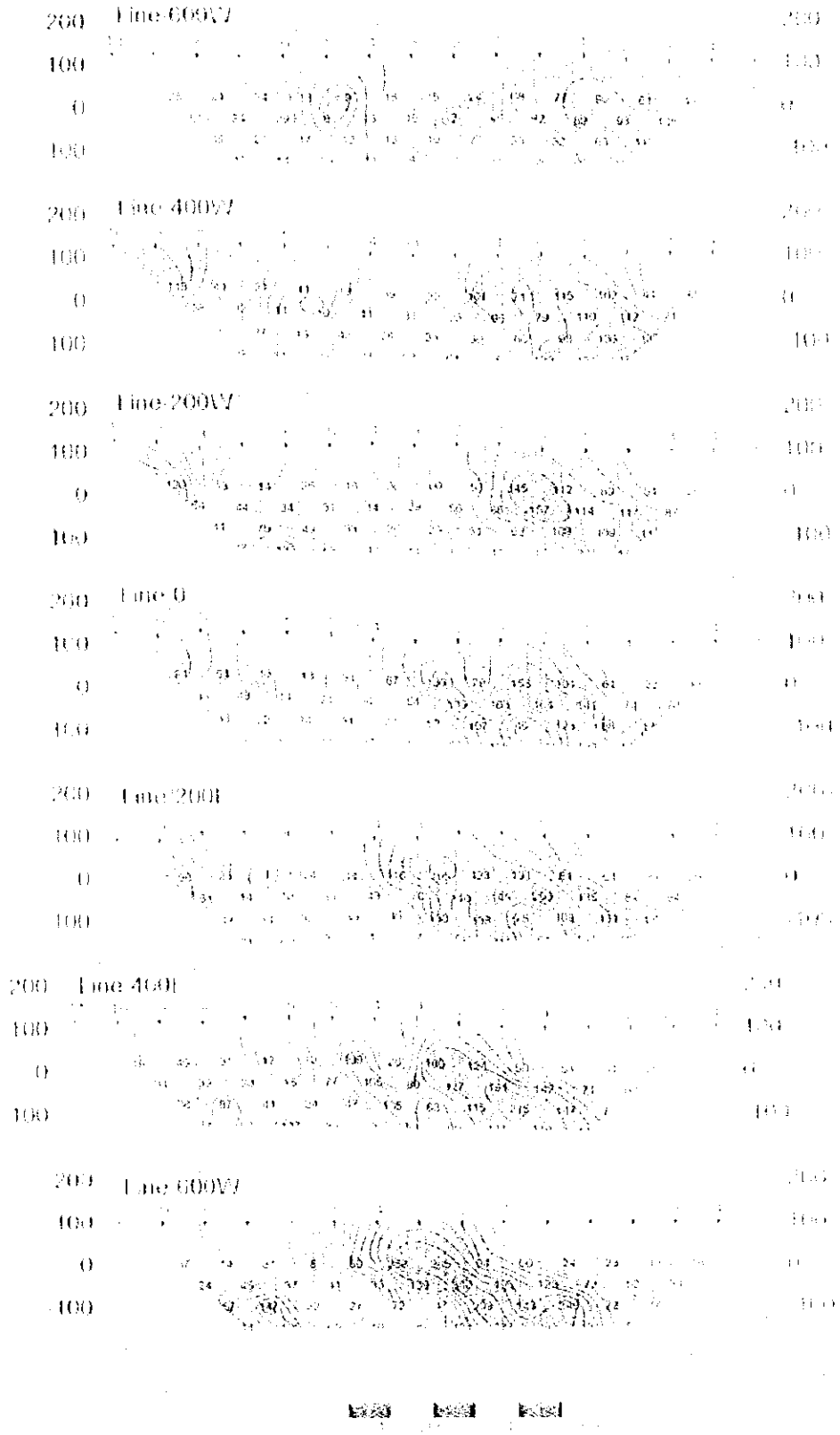


Fig.II-2-16 Metal factor pseudo-sections in Sanah area


South
North
Line 600V
Line 400V
Line 200V
Line 0
Line 200I
Line 400I
Line 600V

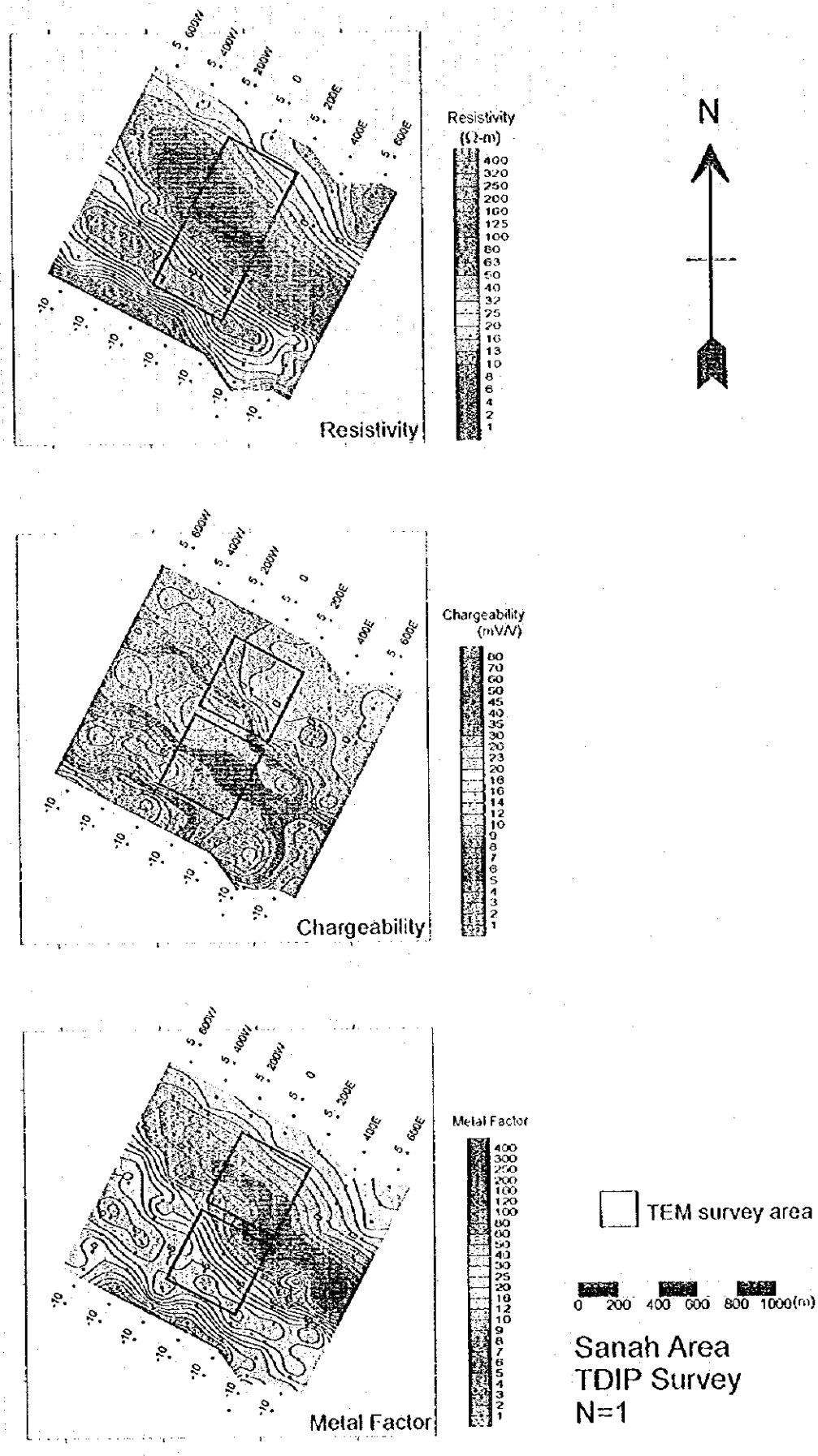
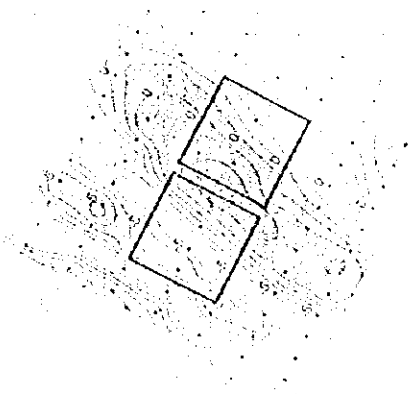
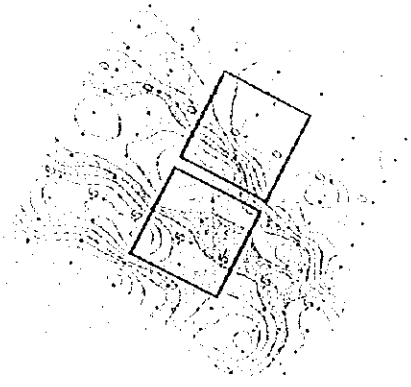
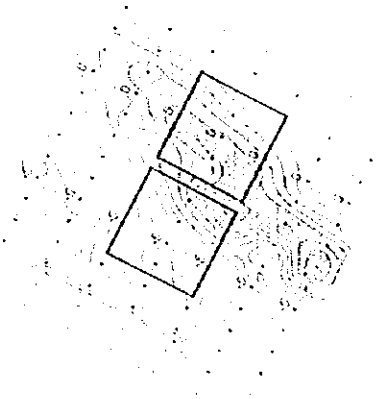


Fig.II-2-17 IP plane map of n=1 in Sanah area







Sanah Area
IDIP Survey
N-1

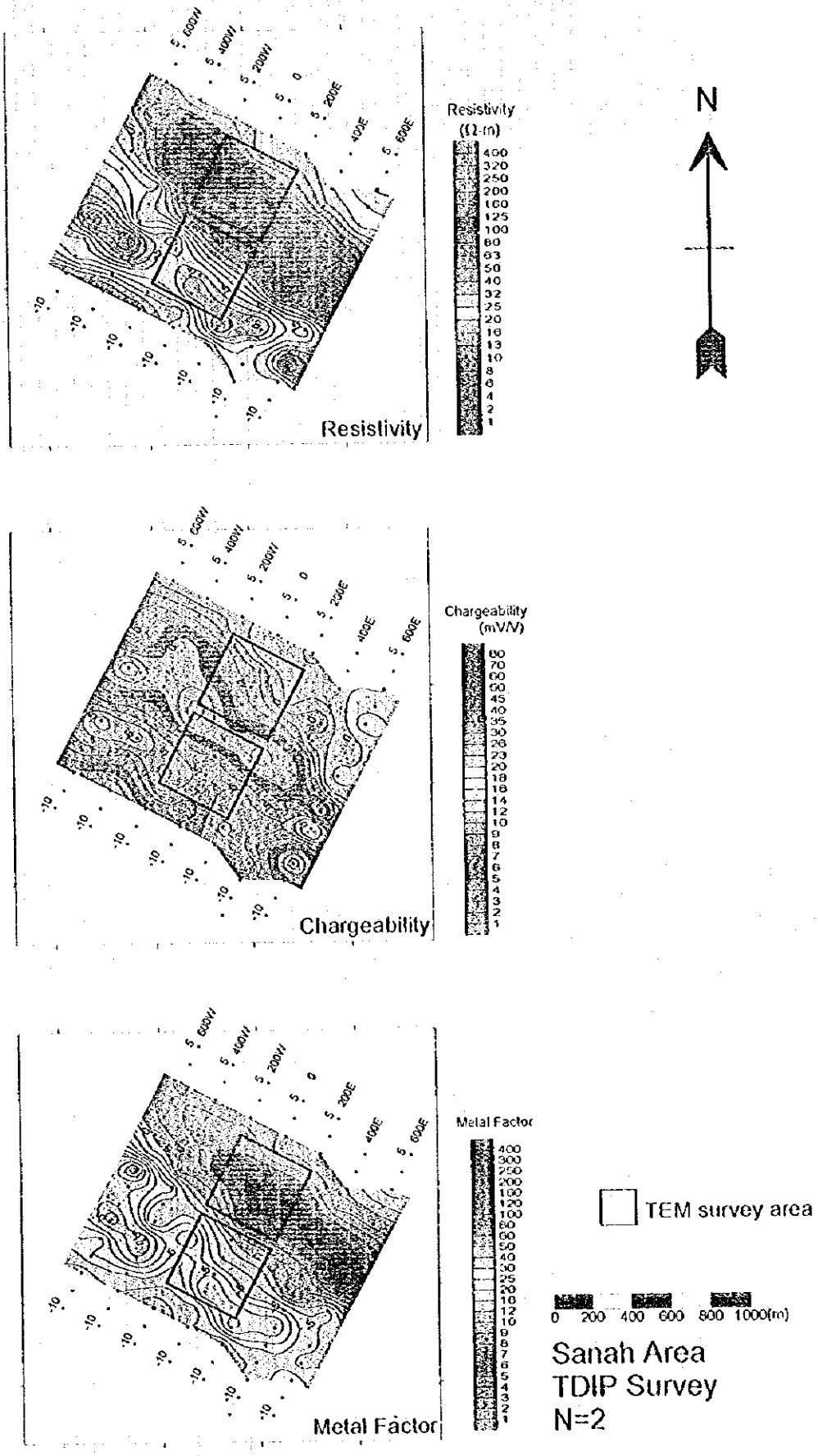
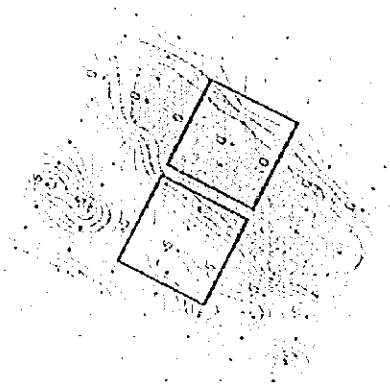
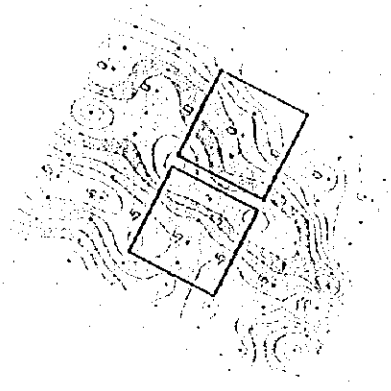


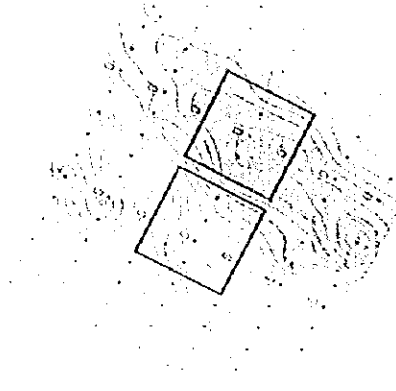
Fig.II-2-18 IP plane map of n=2 in Sanah area



Resistivity



Chargeability



Metal Factor

N

Sanah Area
TDIP Survey
N 2

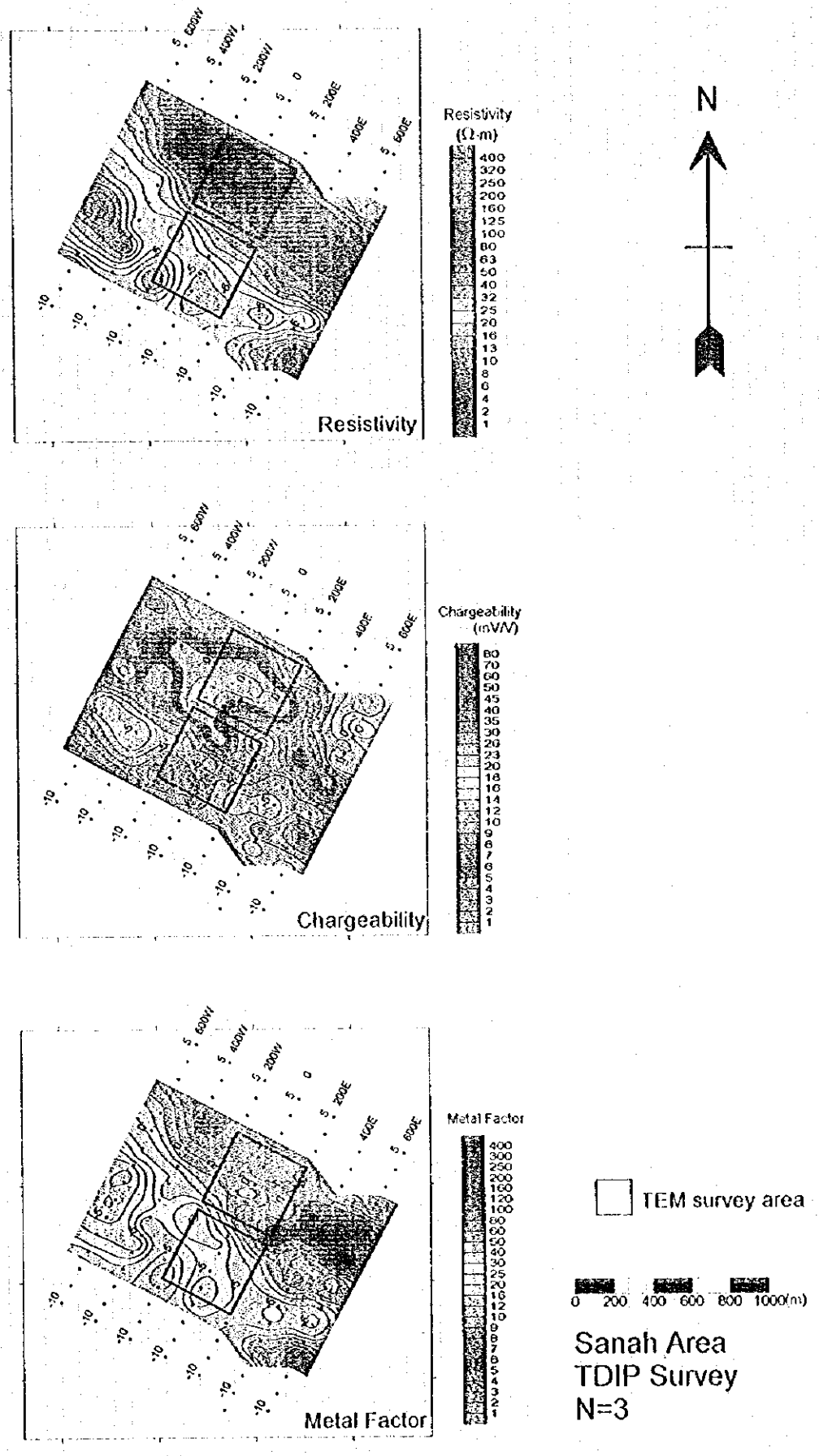
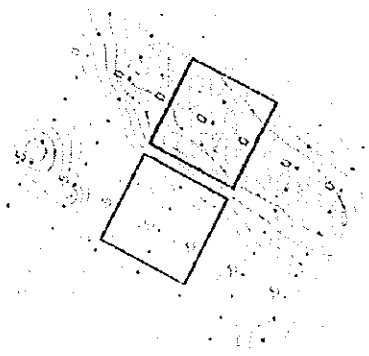
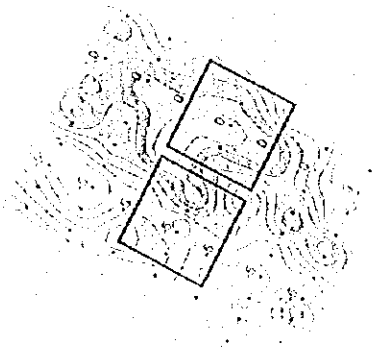
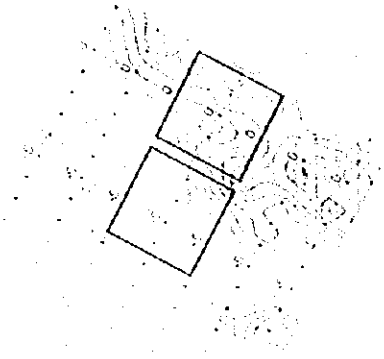


Fig.II-2-19 IP plane map of n=3 in Sanah area







Sanah Area
IDIP Survey
N 3

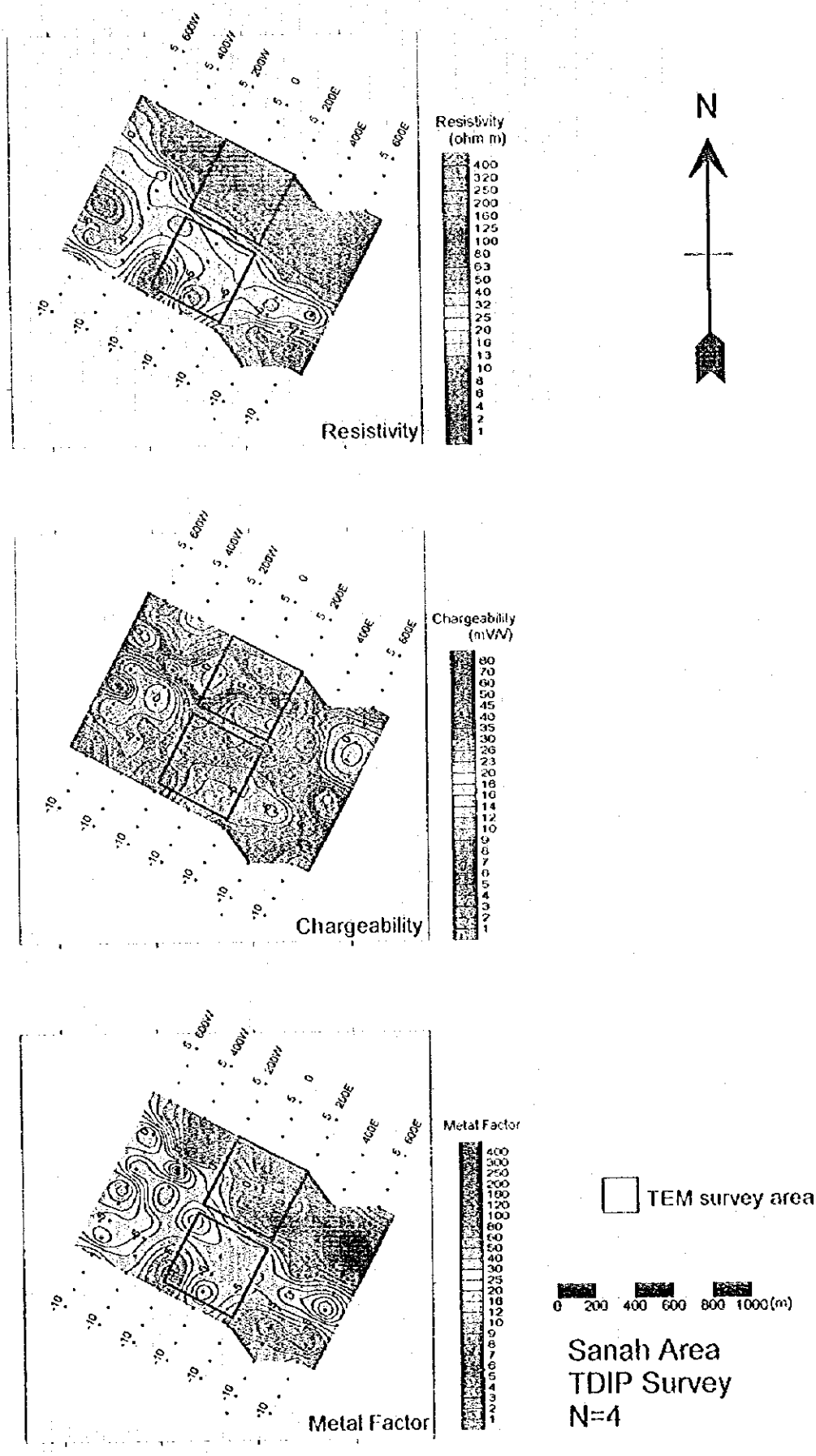
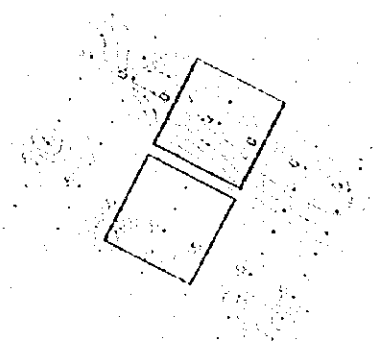
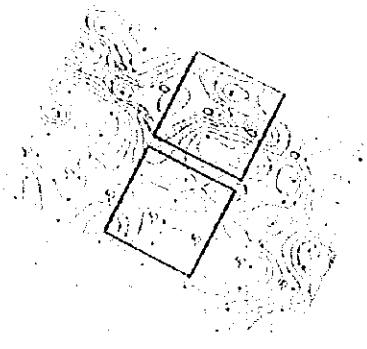
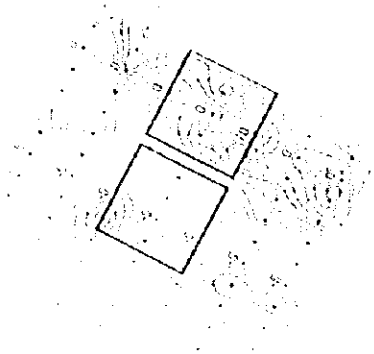


Fig.II-2-20 IP plane map of n=4 in Sanah area







N

Samah Area
TDIP Survey
N-4

as the ones found in Fardah area.

In relation to the apparent resistivity, the results show values between 3 to 134 Ωm, however, it is observed that more than 90% of the results show in general values of less than 50 Ωm. To the north side of the gossanized area, which is distributed along NW-SE, it is seen a low resistivity zone of about 300m distributed also along NW-SE. This low resistivity distribution is seen at shallow depth of line No.0 with station No. -2 as the center and displaced at depth towards NE. This low resistivity distribution runs parallel to another low resistivity distributed in the south part of the area where resistivities of less than 10 Ωm were confirmed in some places.

In relation to the chargeability, it can be seen in general low values, however, a somewhat medium chargeability zone of about 10 mV/V is seen adjacent to the north of the above mentioned low resistivity zone along the NW-SE direction.

Metal factor values above 100 can be also seen about 150m to the north of he low resistivity distribution and nearly similar to the chargeability distribution pattern.

2-7-3 2-D analysis

The data obtained from the line No 0 were interpreted by a 2 dimesional analysis. The results of simulation are indicated in the Fig. II-2-21.

According to the results, a low resistivity distribution of less than 10 Ωm and a width of about 200m is seen dipping northwards from the surroundings of station No. -2.

According to the chargeability results, two medium chargeability distributions of more than 9 mV/V are seen, one of them is distributed above a depth of less than 100m of station No. 0 extended towards the north and, another is seen below a depth of about 100m of station No. -2 extended southwards.

The metal factor section shows a distribution of above 100 at shallow depth around station No. 0. and dipping northwards in the same way as the low resistivity distribution mentioned above.

2-8 Ghuzayn Village North Area

2-8-1 Lines Location

On this area, two lines were set along the direction N27°E and a third line perpendicular to the above two lines. As indicated in the Fig. II-2-22, the line 000N has a length of 1.5km, the line 180S has a length of 1.4 km and the line 000E has a length of 800m.

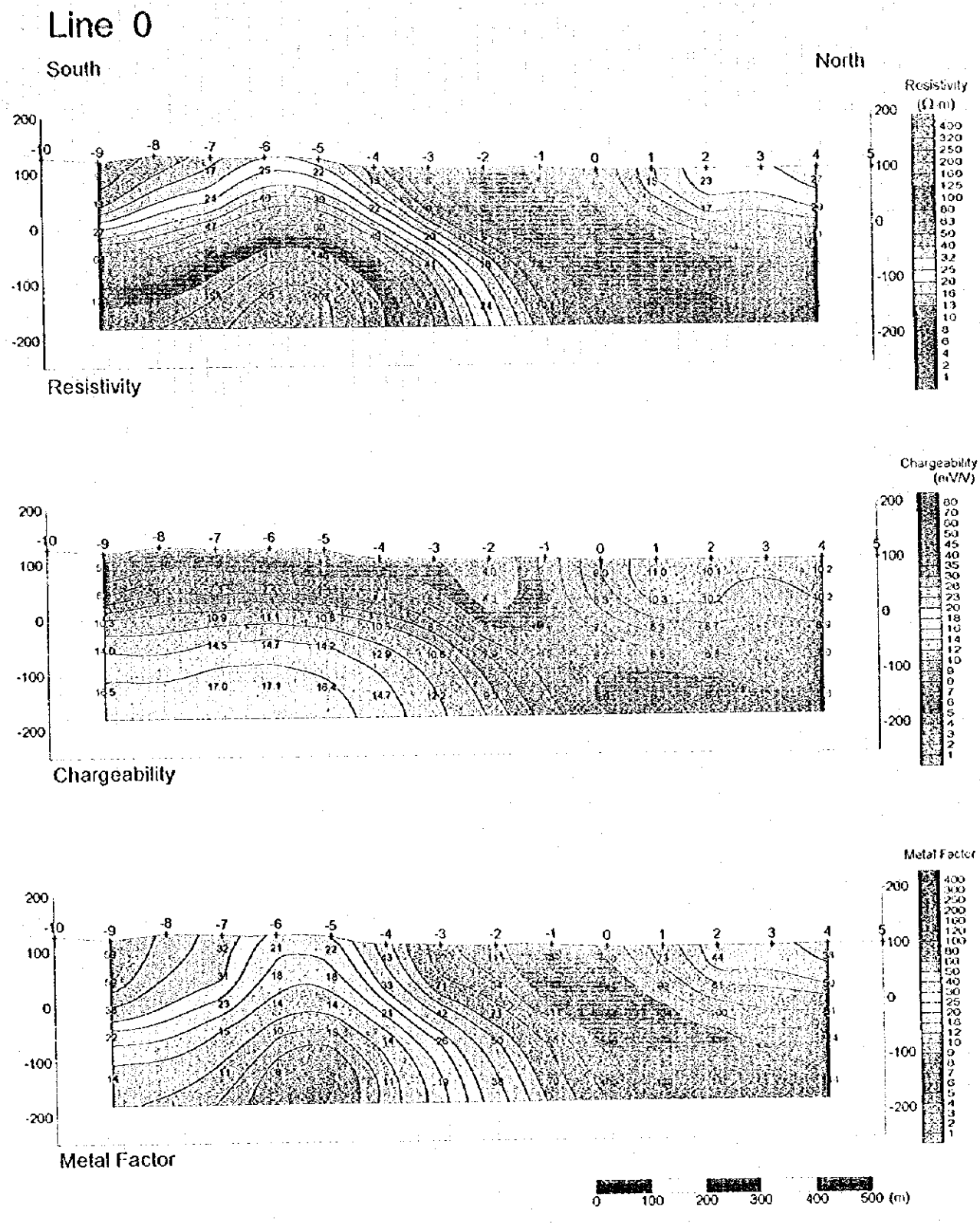
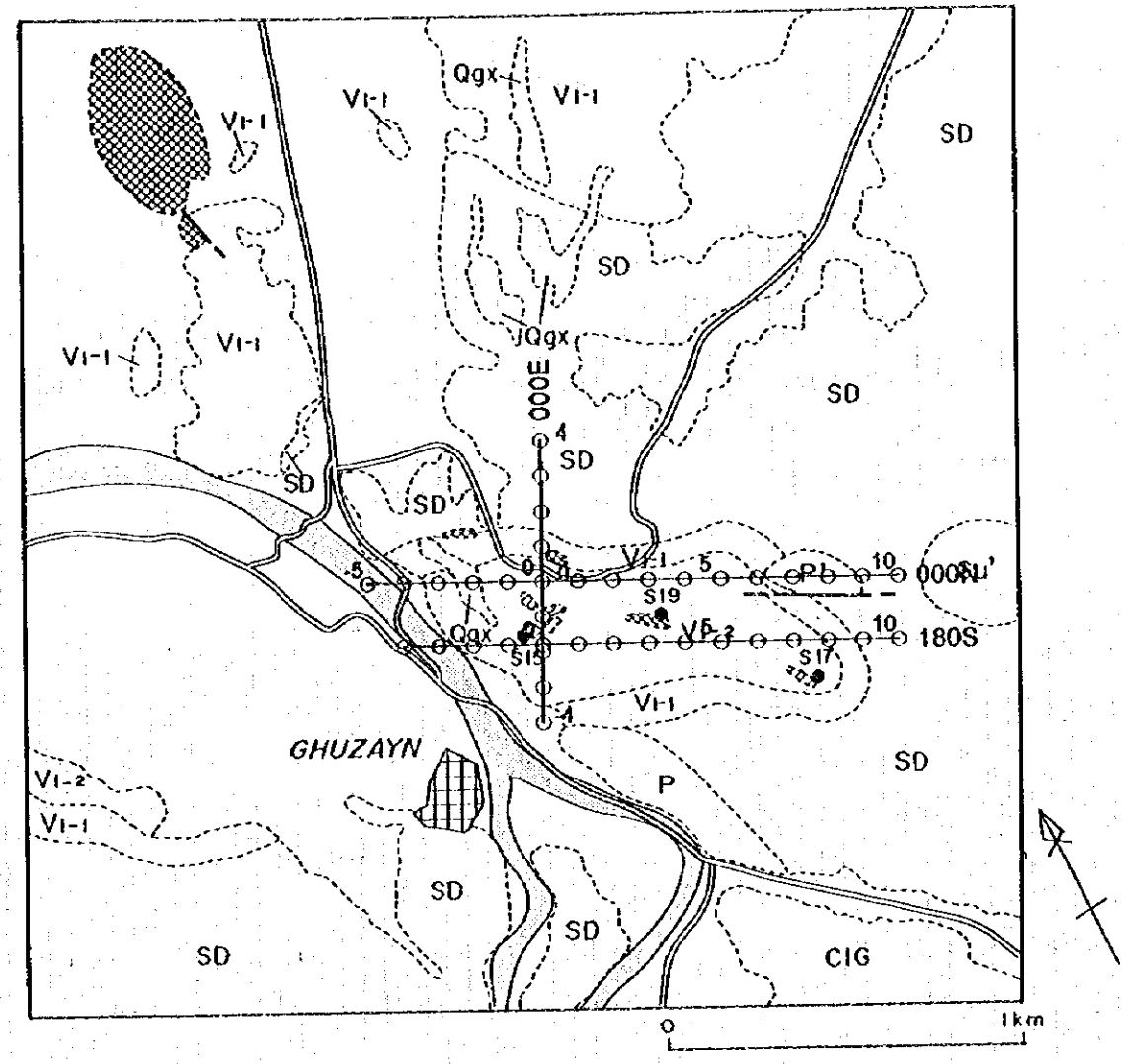


Fig.II-2-21 Results of model simulation on Line 0001 in Sanah area



LITHOLOGY
QUATERNARY

- Wadi sediments and Sub-recent alluvial fans;terraces
- Qgx — Ancient alluvial fans;terraces

SAMAIL OPHIOLITE
Samail Volcanic Rocks

- V_{t-2} — Lower extrusives 2
- V_{t-1} — Lower extrusives 1

Sheeted-dyke complex

- SD — Sheeted dykes;dolerite

Cumulate Sequence

- CIG — Cumulate layered gabbro

Intrusives

- Gu' — Uralitic Gabbro
- P' — Peridotite

MINERALIZATION

- Gossan
- Silicified or argillized zone

Other symbols

- ● S15 — Sample location
- Ghuzayn village
- Road
- Wadi
- TDIP Survey Lines

Fig.II-2-22 IP line locations in Ghuzayn north area

2-8-2 Results

The apparent resistivity, chargeability and metal factor pseudo-sections are indicated in the Figs. II-2-23, II-2-24 and II-2-25, respectively. The Figs. II-2-26, II-2-27, II-2-28 and II-2-29 show the resistivity, chargeability and metal factor maps for n=1 to n=4, respectively.

Although the measured apparent resistivity values range from 50 to 1440 Ωm, most of the values are within 100 to 250 Ωm, which indicates that in general, the area presents rather high apparent resistivity values. Only a relatively low resistivity distribution is seen on the line 000N but limited to the area surrounding the station No. -2.

In relation to chargeability and at shallow depth (n=1), it is seen medium chargeability values in the extension north of the line 000E as well as in the intersection of this line with the line 180S towards the station No.-2 of the last mentioned line. At higher depths (n=2 to 4), the north part of the line 000E as well of the east part of line 000N, indicate relatively high chargeability values above 10 mV/V.

Metal factor values above 10 are seen on the line 000N at the shallow depths (n=1,2) of the surroundings of the station No. -1.

2-8-3 2-D Analysis

Fig. II-2-30 presents the calculated simulation results on line 000N. The calculations showed in all the depth, resistivity values of several hundreds Ωm in the east part of this line but decreasing towards 100 Ωm as it is approaching the surface. On station No. -2 and close to the surface, values around 50 Ωm are seen.

The simulation of chargeability shows in general, relatively high values, and specially the east part indicates values above 30 mV/V below 100m depth. Below station No. 1, chargeability values are seen also to be increasing towards depth.

Relatively medium metal factor values of above 10 are seen only at shallow depths below stations Nos. -1, -2 and surroundings.

2-9 Doqal Area

2-9-1 Line Locations

A total of 7 IP lines were set on the survey area. The lines were oriented along the EW direction and with a length of 1.5 km. The locations of the IP survey lines are indicated in Fig. II-2-31.

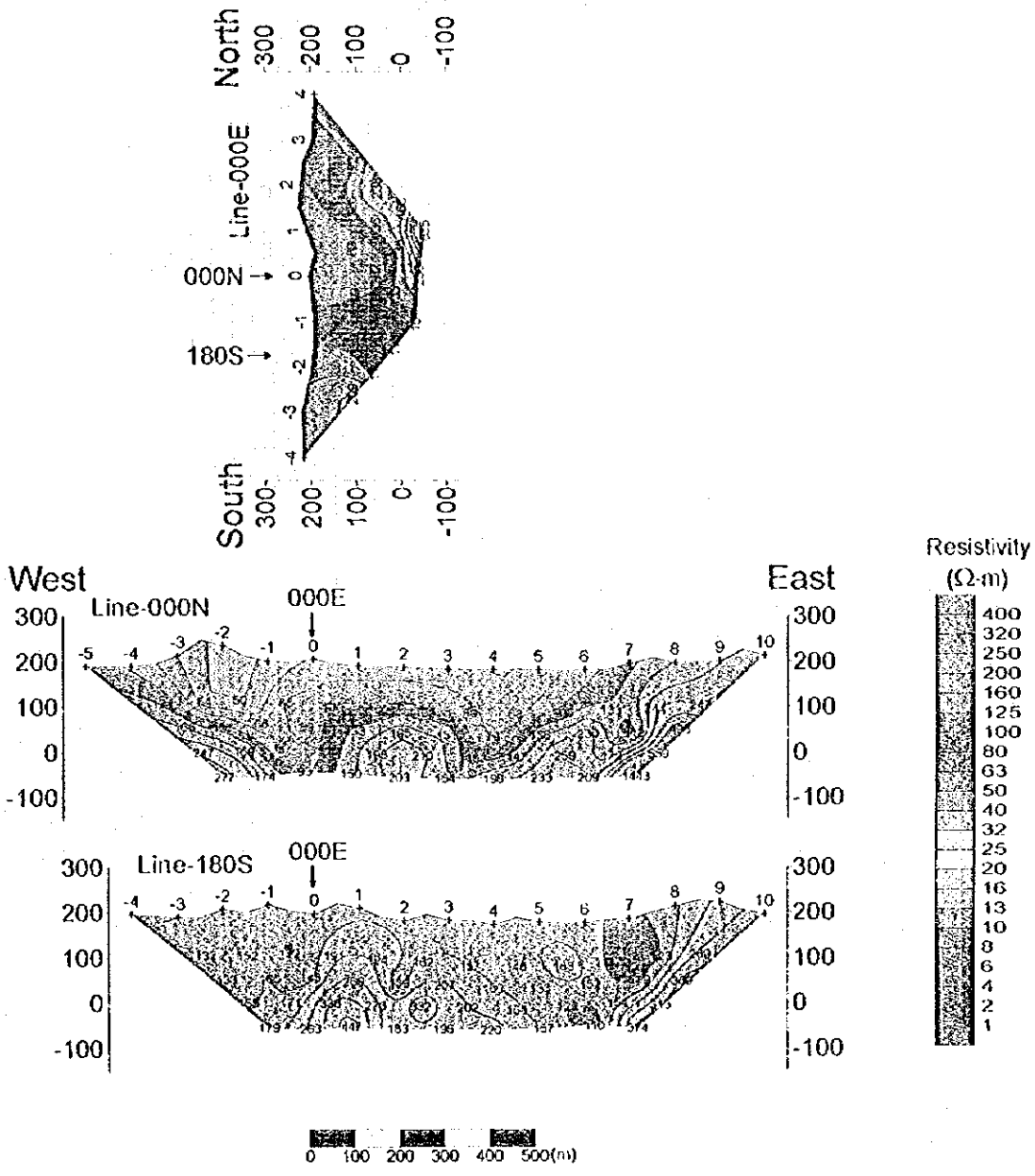


Fig.II-2-23 Apparent resistivity pseudo-sections in Ghuzayn north area

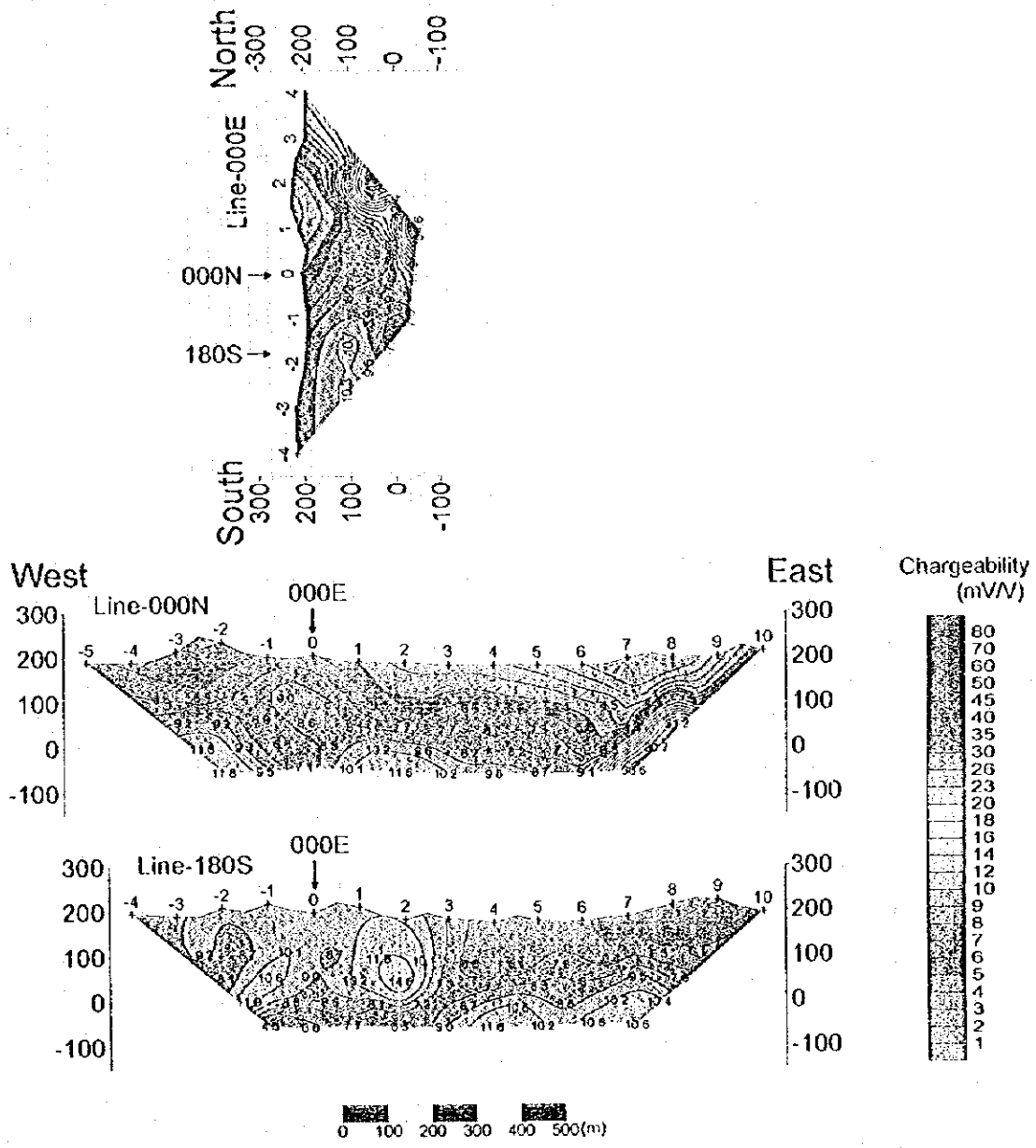
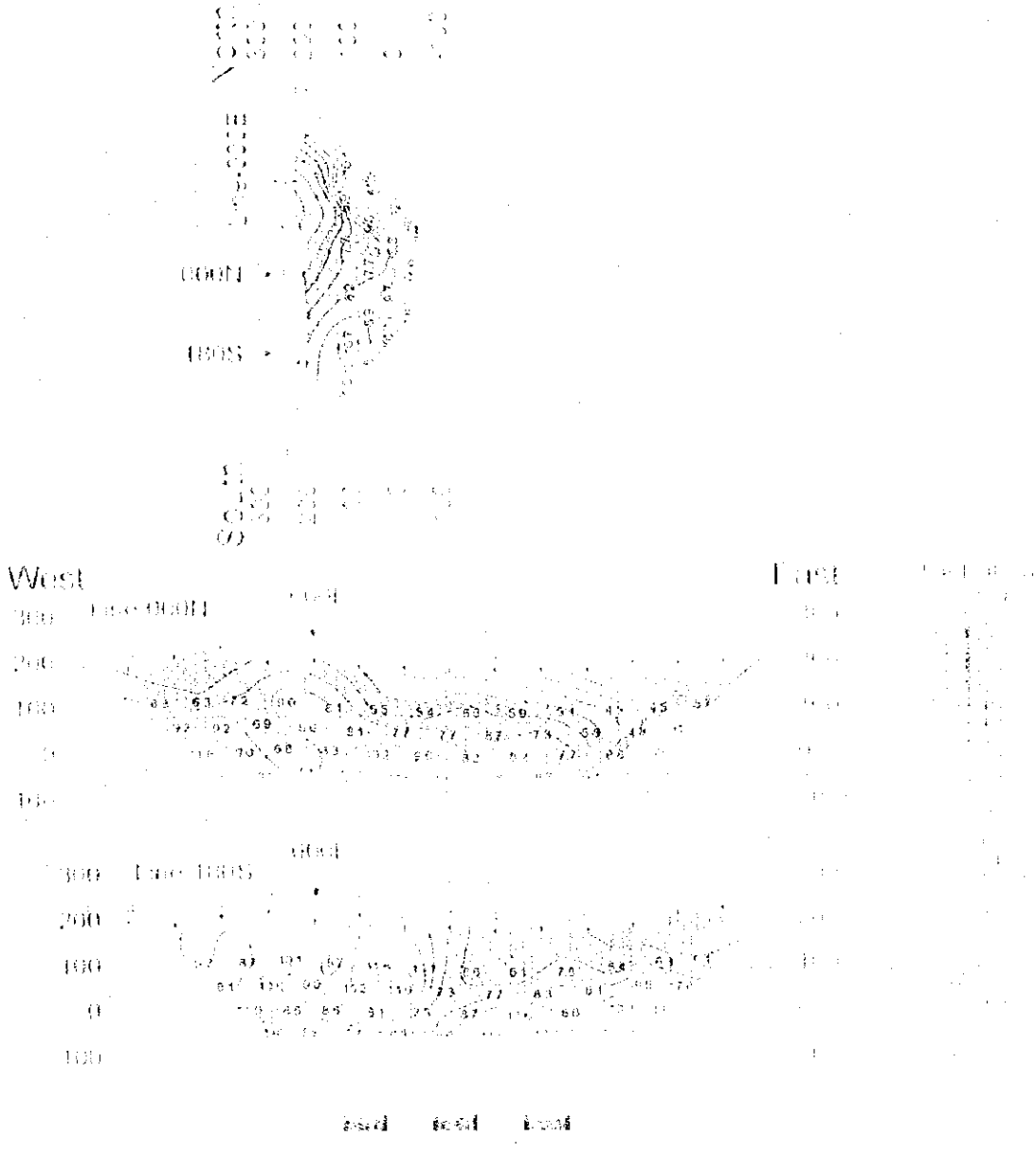


Fig.II-2-24 Chargeability pseudo-sections in Ghuzayn north area


West
East

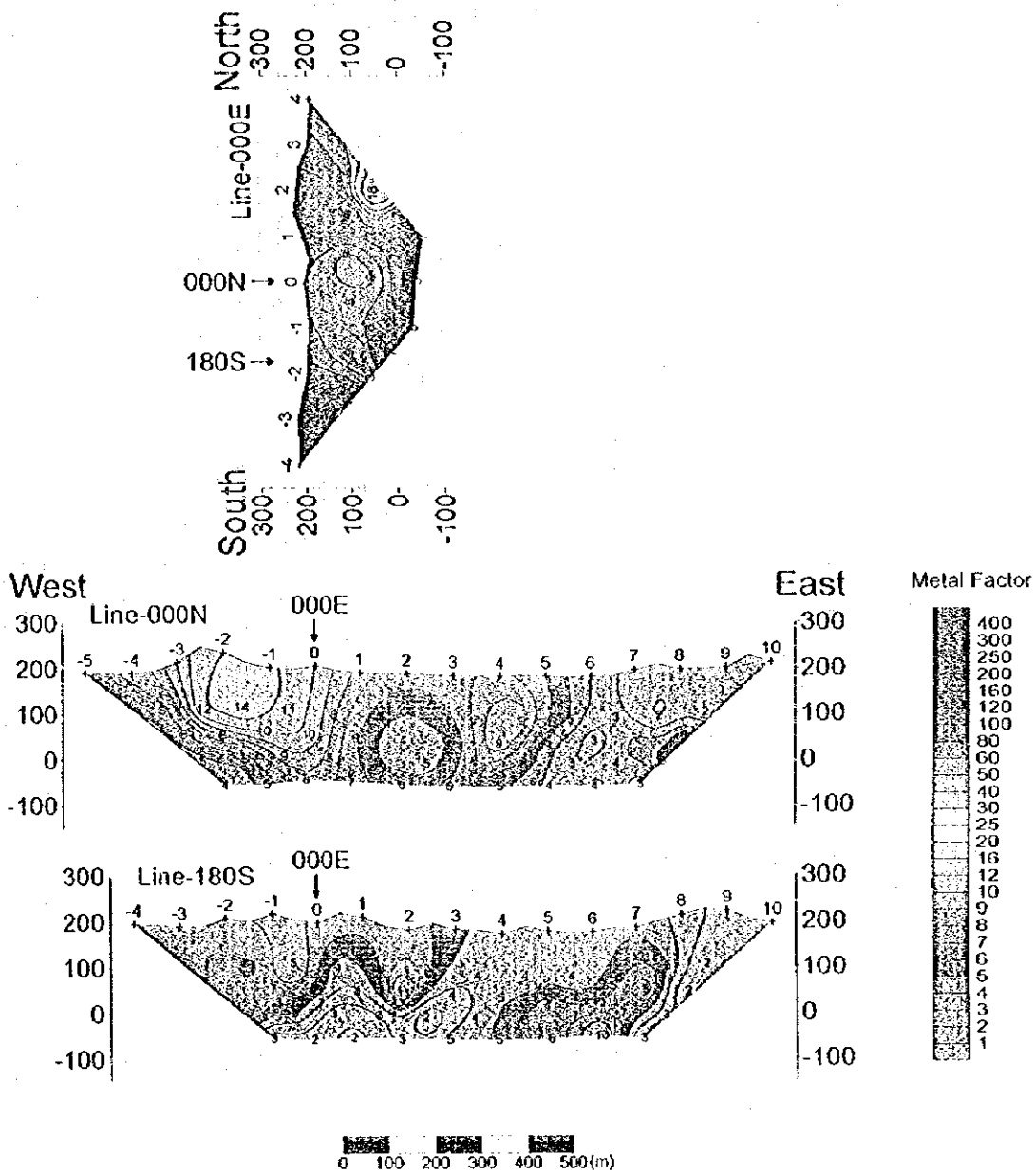
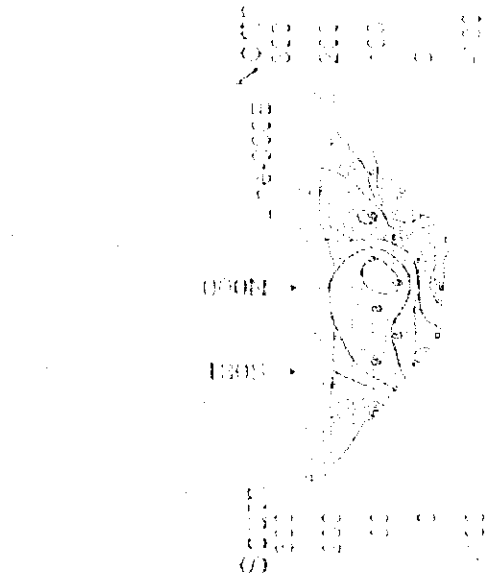
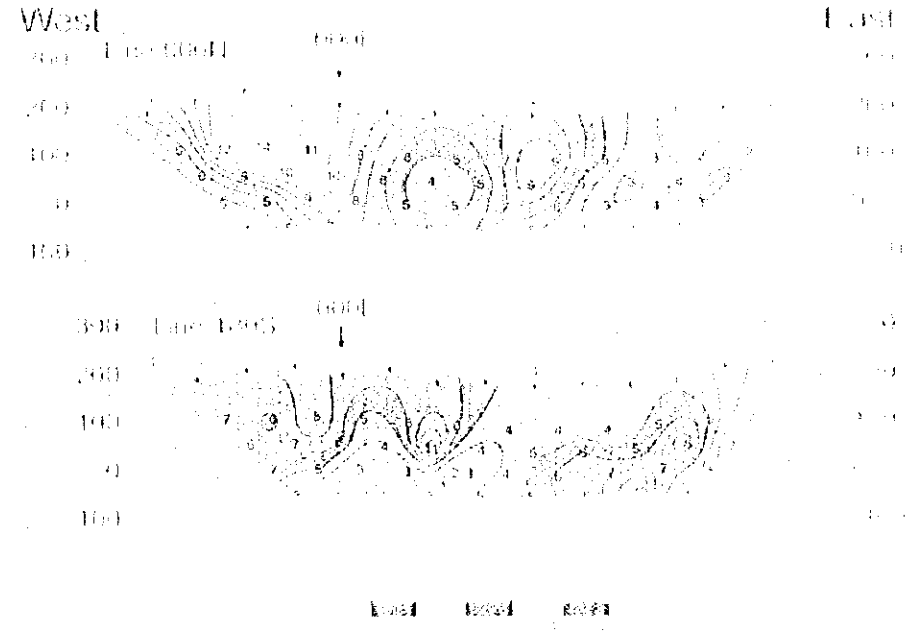


Fig.II-2-25 Metal factor pseudo-sections in Ghuzayn north area




West
East

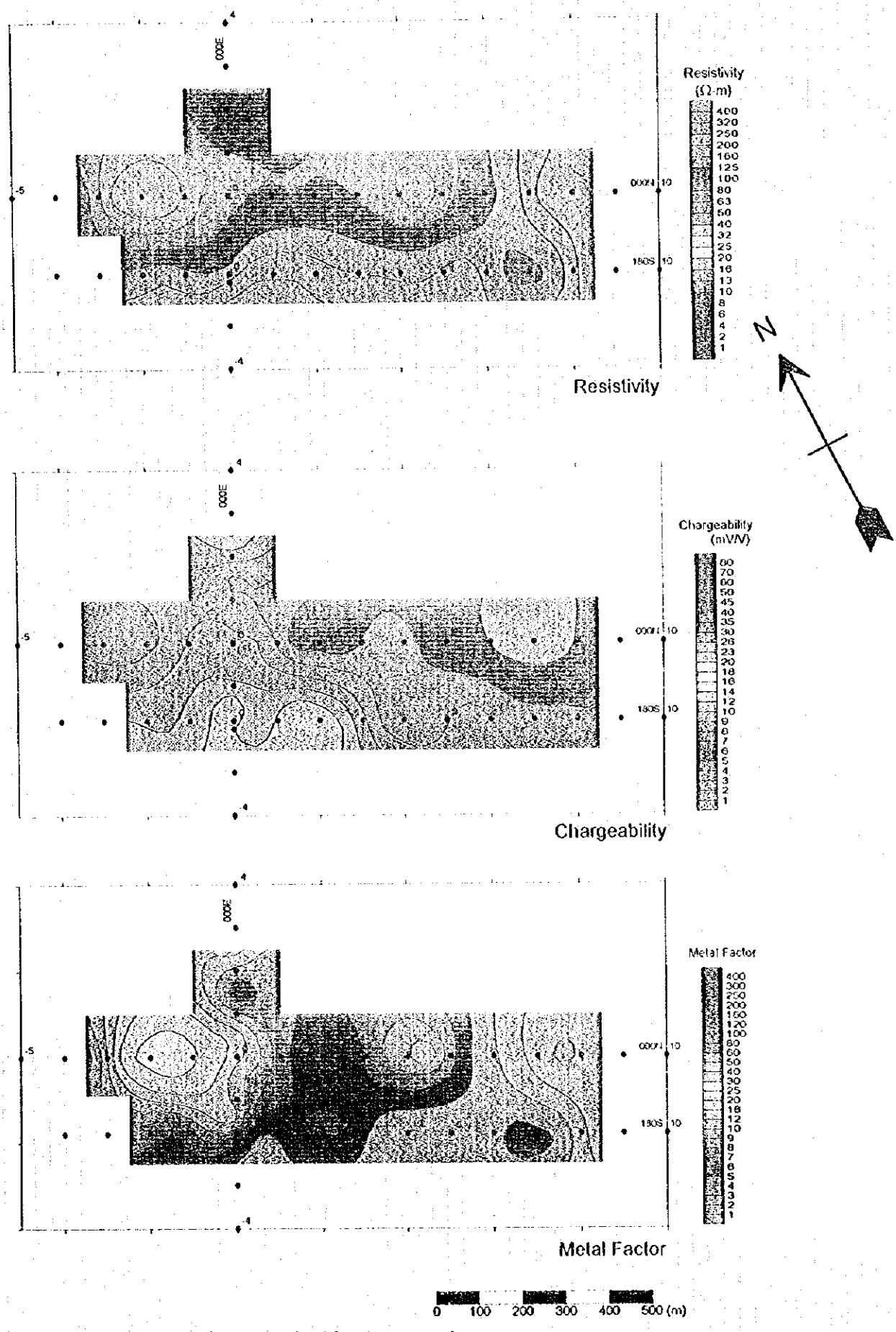
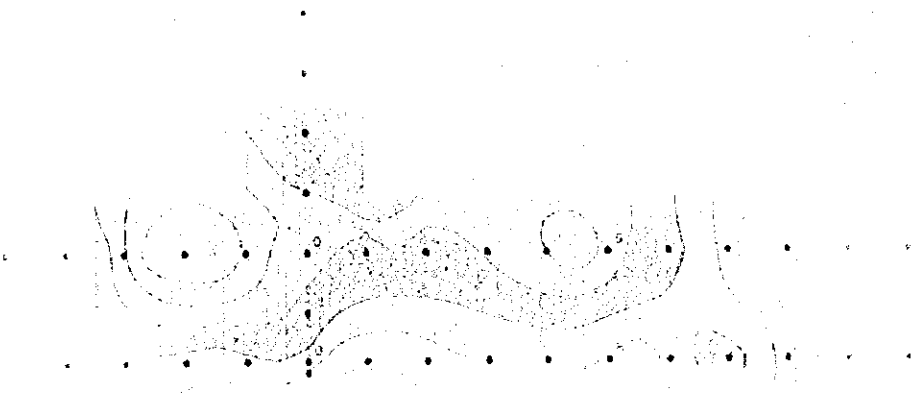
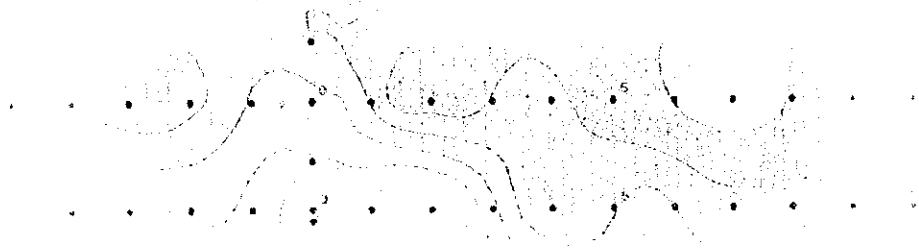
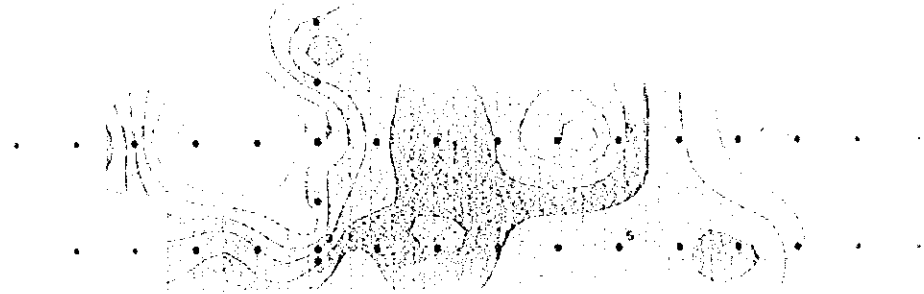


Fig.II-2-26 IP plane map of n=1 in Ghuzayn north area

Ghuzayn North Area TDIP Survey N=1







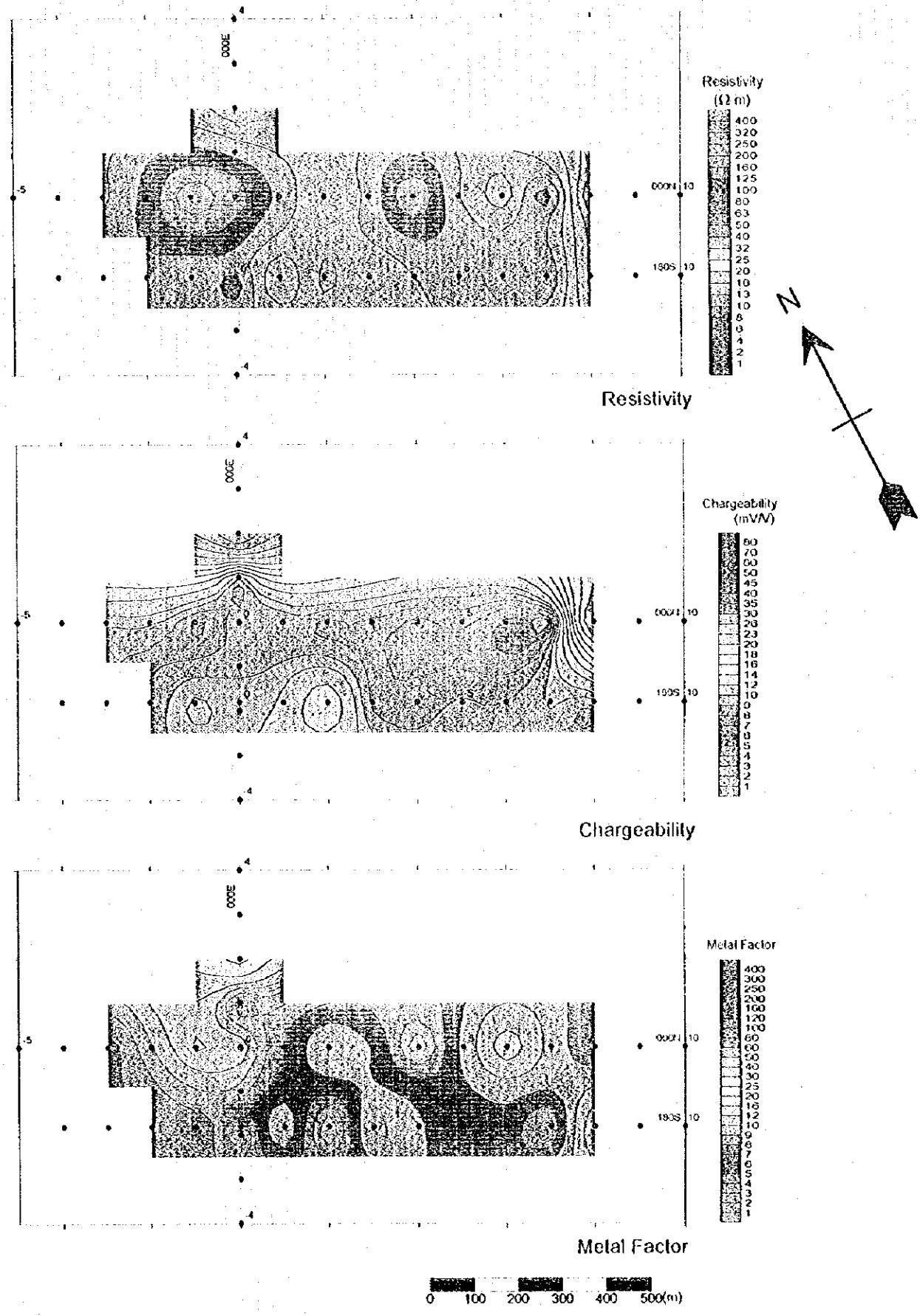
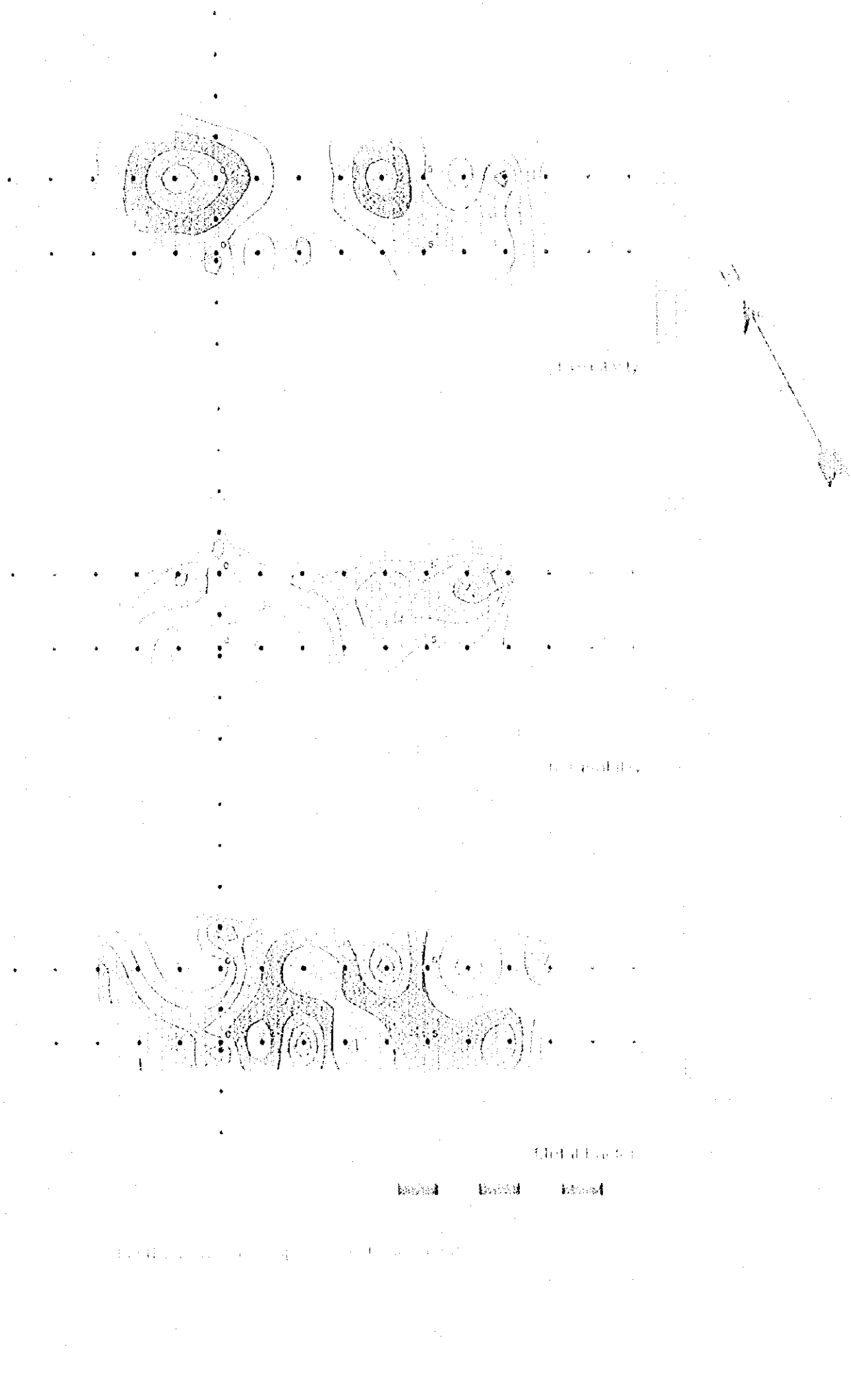


Fig.II-2-27 IP plane map of n=2 in Ghuzayn north area



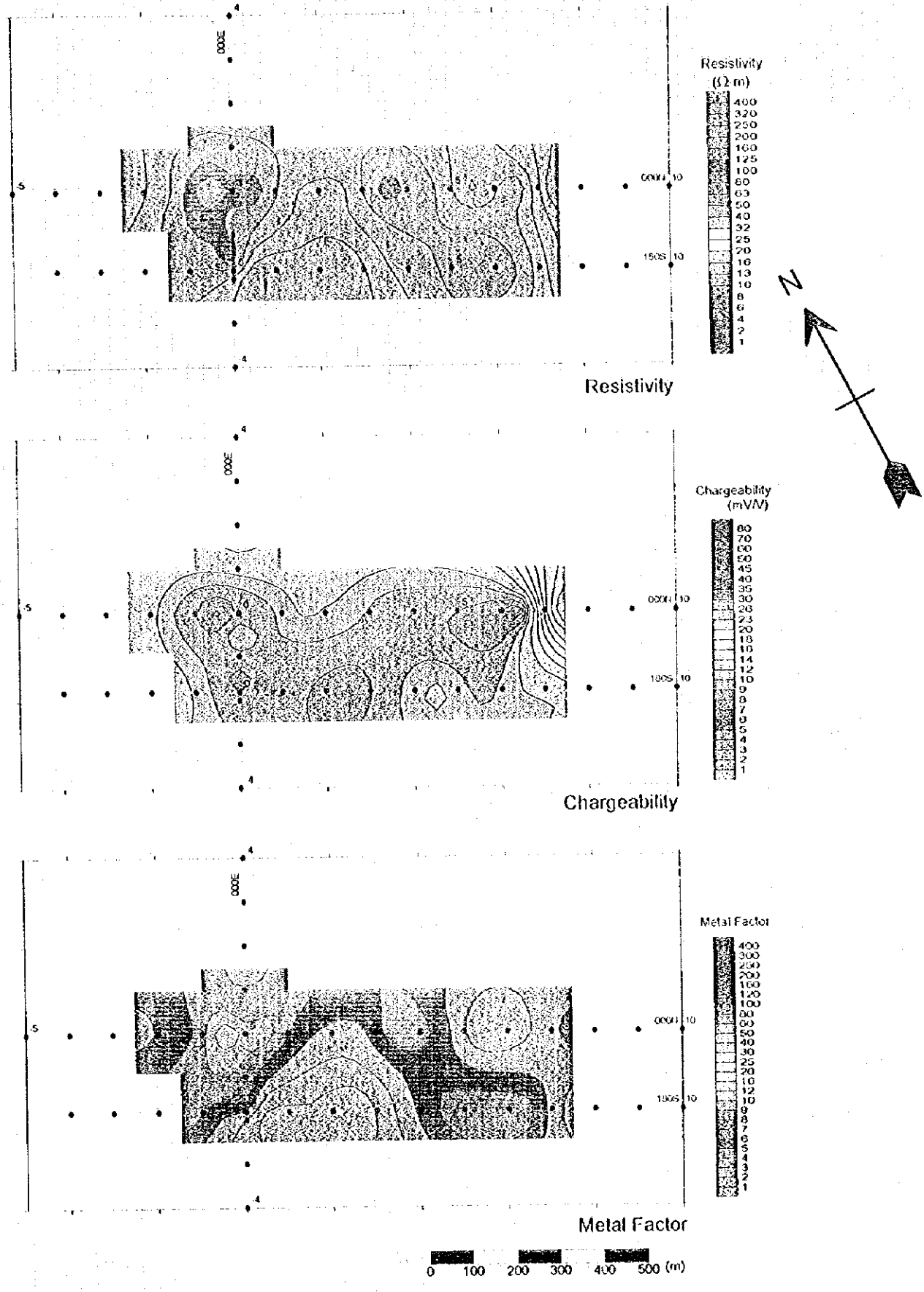
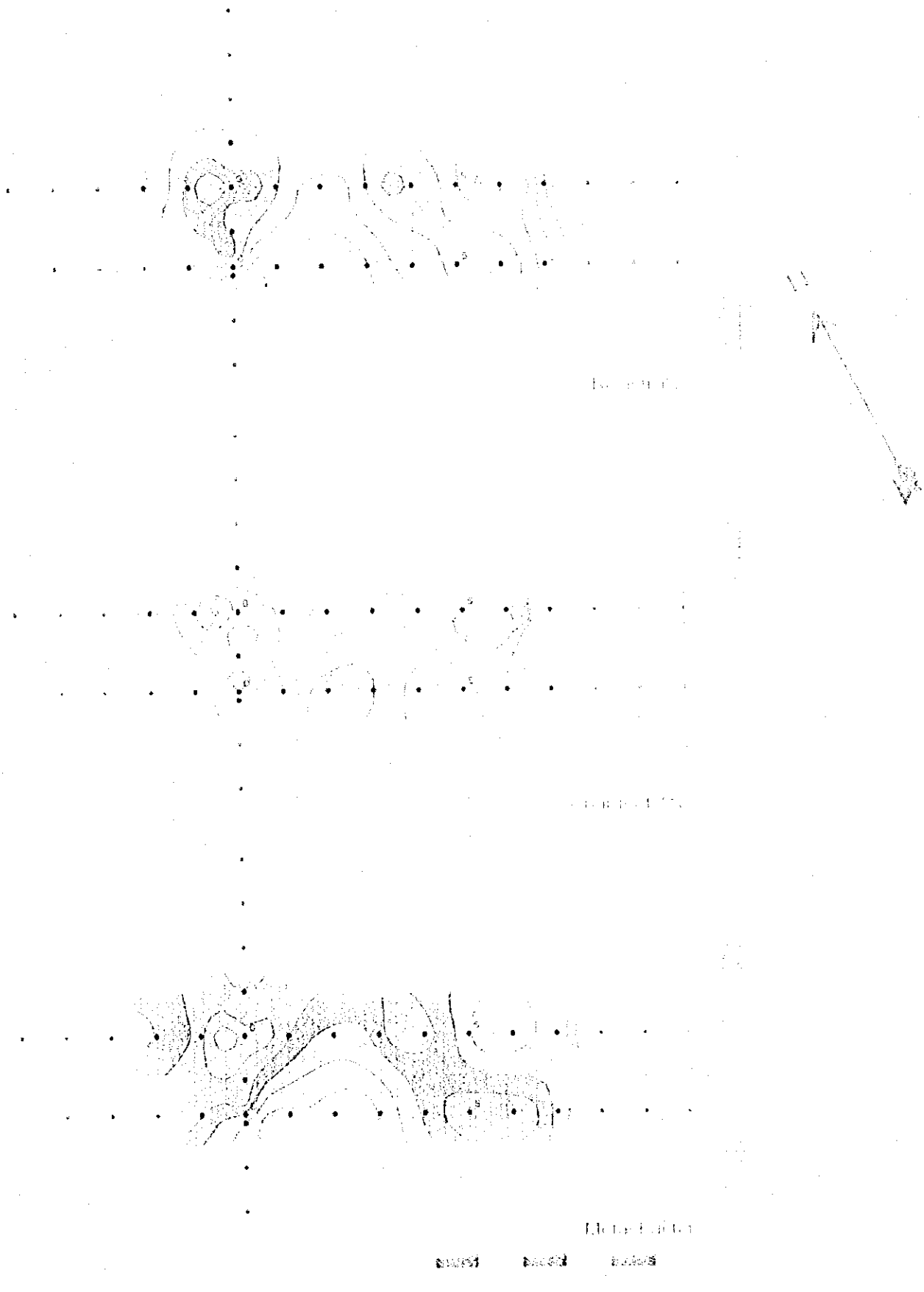


Fig.II-2-28 IP plane map of n=3 in Ghuzayn north area



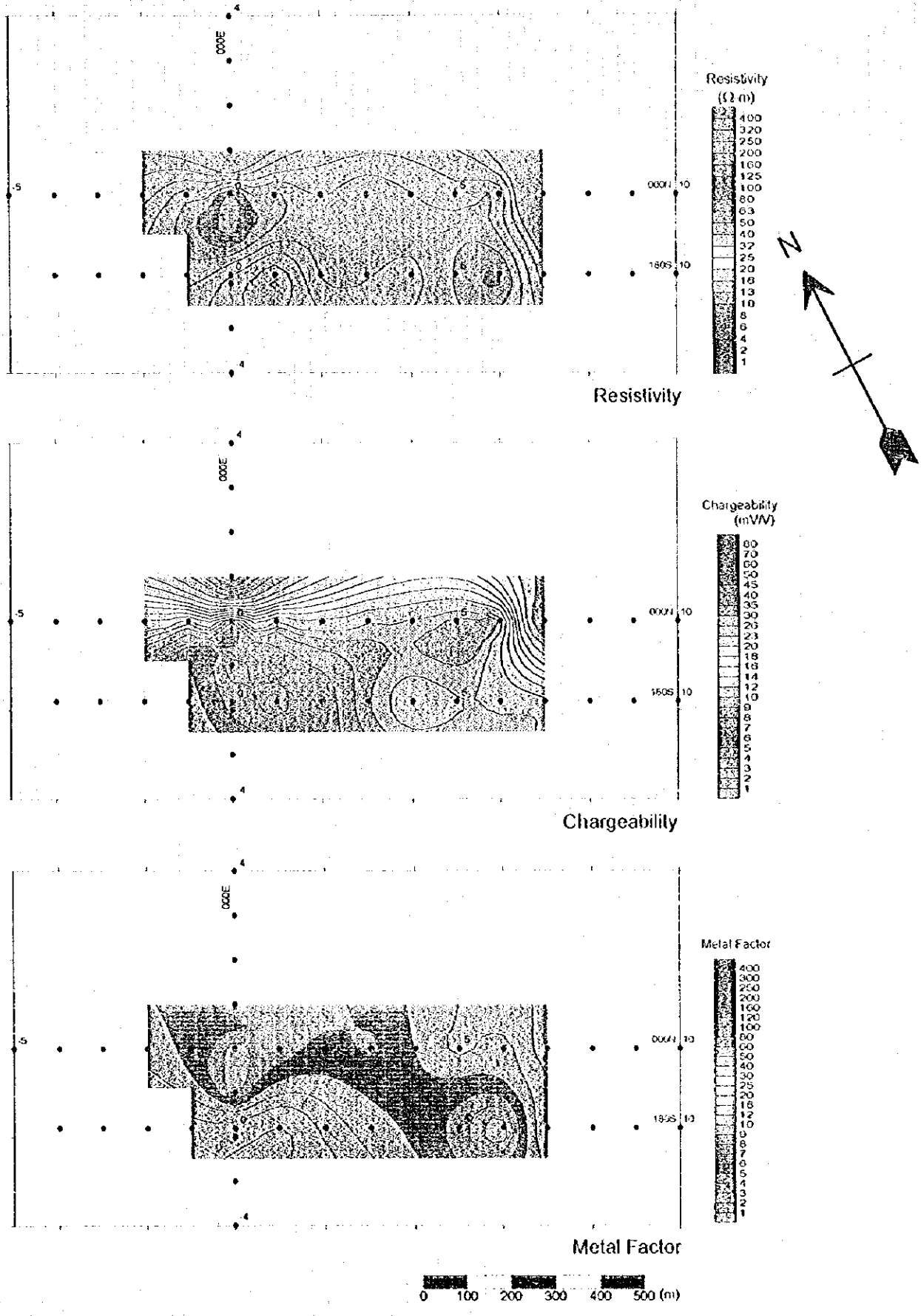


Fig.II-2-29 IP plane map of n=4 in Ghuzayn north area

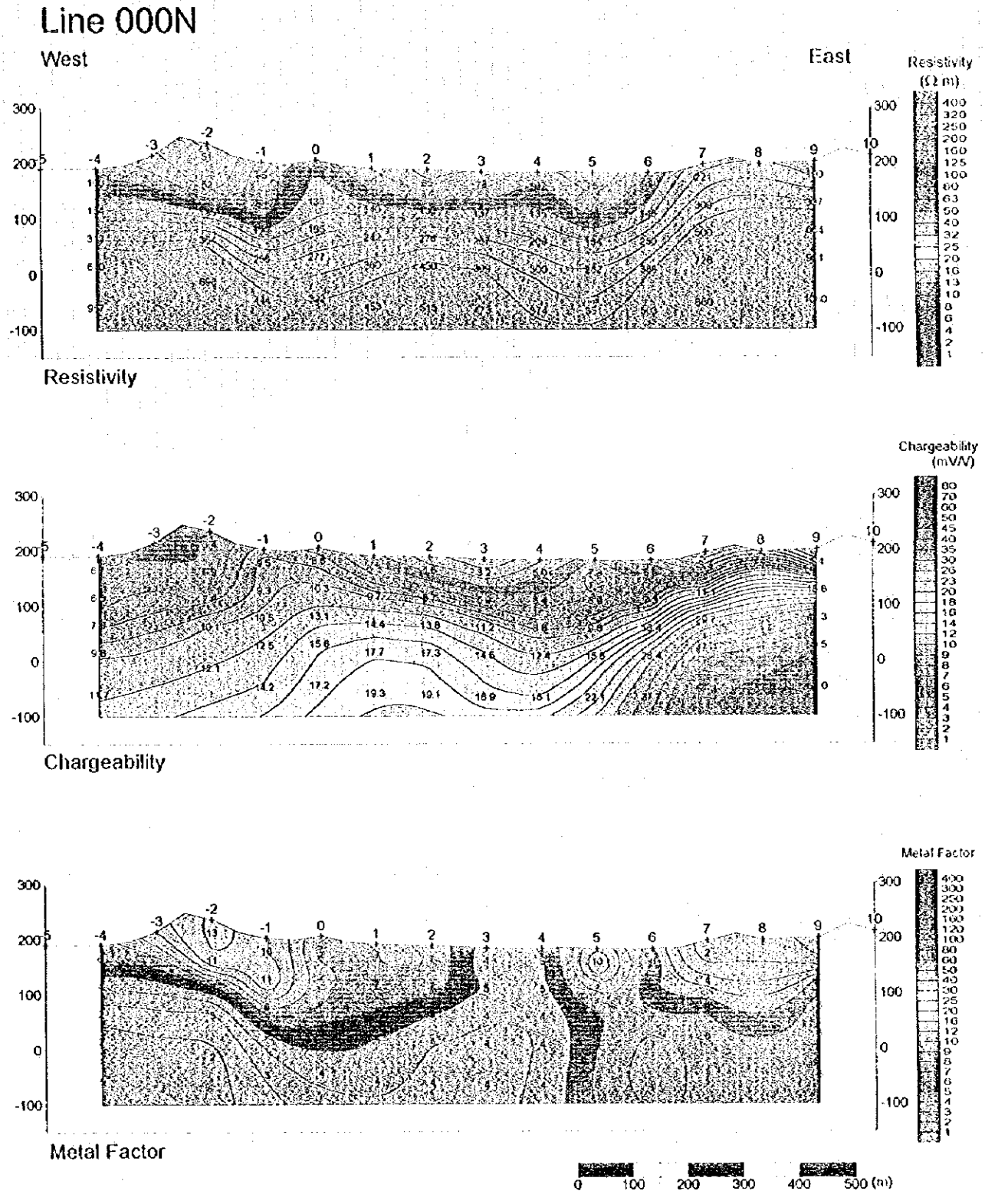
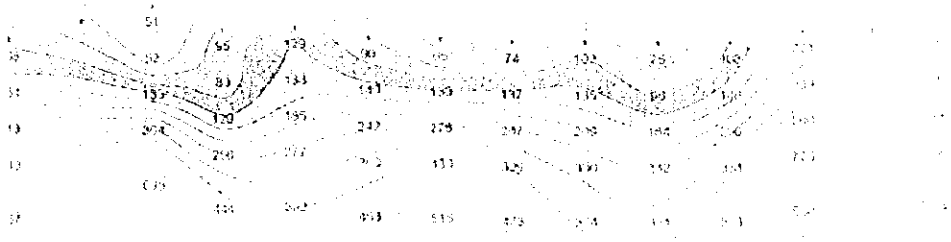
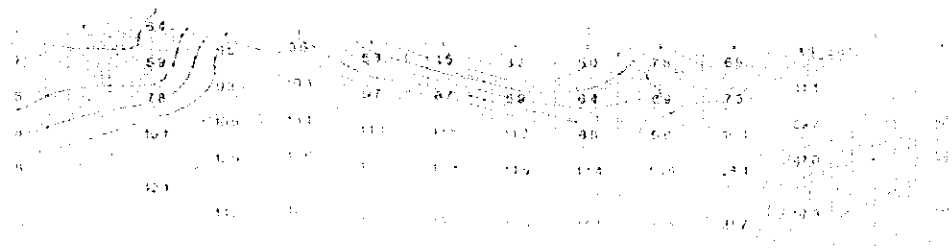
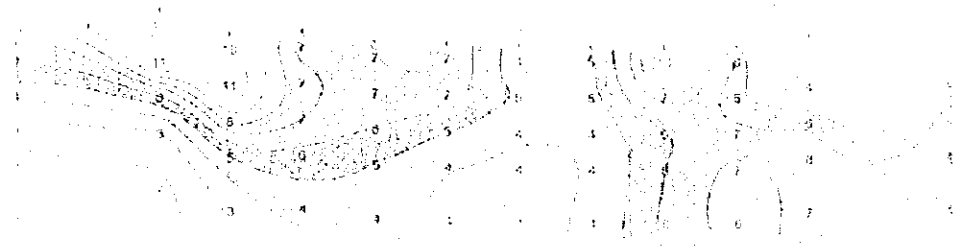


Fig.II-2-30 Results of model simulation on Line 000N in Ghurayn North area

Line 0000N







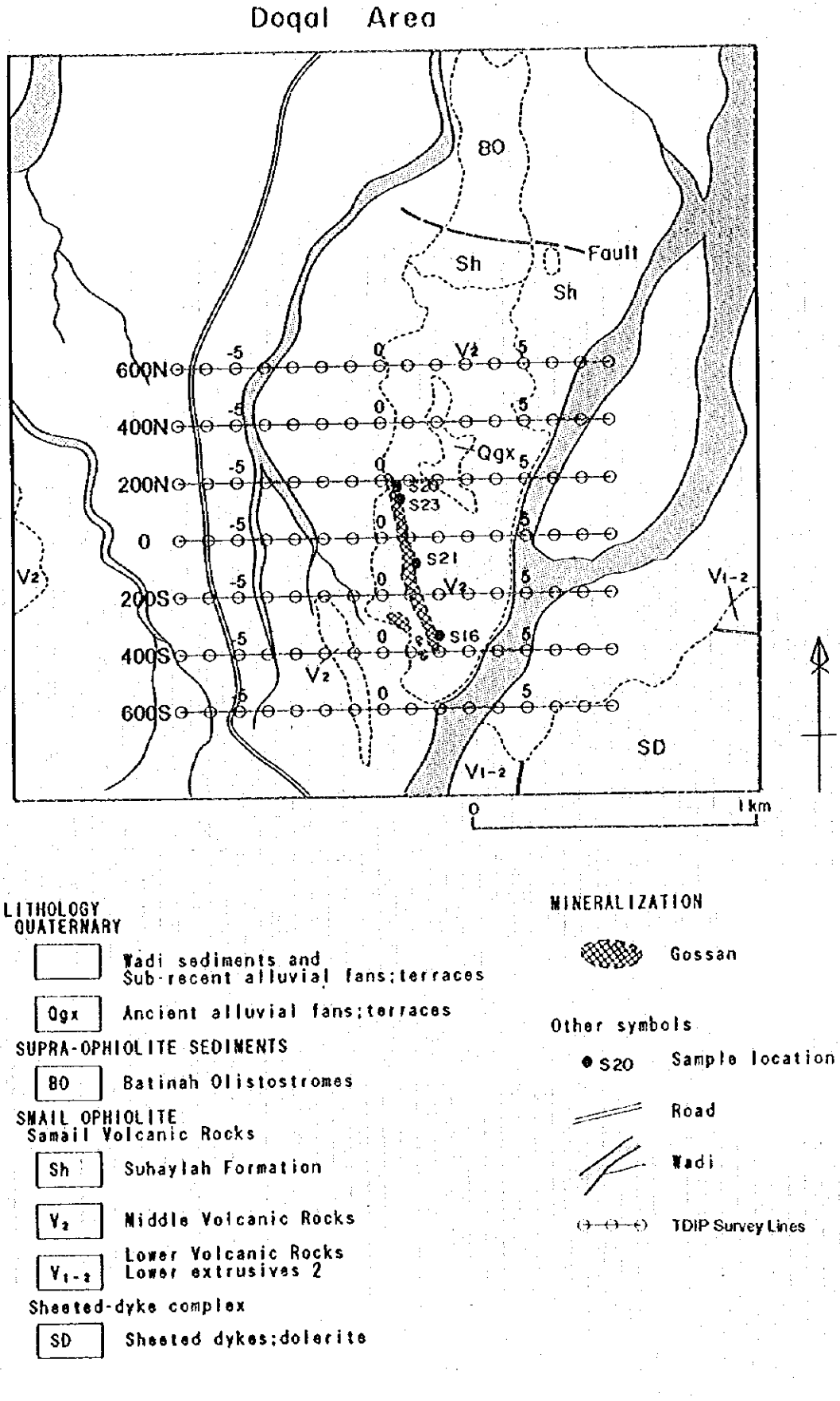


Fig.II-2-31 IP line locations in Doqal area

2-9-2 Results

Apparent resistivity, chargeability and metal factor pseudo-sections are indicated in Figs. II-2-32, II-2-33 and II-2-34, respectively. Figs. II-2-35, II-2-36, II-2-37 and II-2-38 show the resistivity, chargeability and metal factor maps for n=1 to n=4, respectively.

The apparent resistivity values range from 3 to 330 Ωm, distributed so that in general, low values are seen in the north part while increasing to higher values towards the south. Within this general tendency, partially relatively low resistivity distributions extend from the north along NS direction, one of them, can be seen in the central part of the survey area from the station No. 0 of the line 200N to the station No. 0 of the line 200S. Another distribution is seen extended from station No. 5 of the line 200N to the station No. -5 of the line 400S. The low resistivity distribution in the central part seems to coincide quite well with the NS direction of the gossanized mineralized zone. The low resistivity tendency located in the west part, coincides on the surface with the Wadi that elongates along NS direction.

In relation to the chargeability distribution ,a comparatively high chargeability distribution of above 15 mV/V, is seen extended from the central part of the area towards the south. As same as in the case of the low resistivity distribution above mentioned, this high chargeability distribution coincides well with the gossanized zone, which at shallow depth (n=1) reaches a maximum of about 25.5 mV/V around the stations 0 corresponding to the lines 200N and 000. At greater depth (n=4), however, the high chargeability distribution seems to be splitted in two, one centered around the stations -1 of the lines 200N and 000 and the other around the station 1 of the line 200S. At shallow depths, it can also be added that the high chargeability distribution is seen at the northwest part of the area as a medium chargeability distribution of about 10 mV/V.

Regarding the metal factor, a distribution of above 15 seen in the central part which extends towards the north west part of the area becoming even wider. Within this distribution, prominent values can be seen around the station 0 of the lines 000N and 200N. Prominent values are also seen at shallow depths around the station -4 on the line 400N, and at greater depths, prominent values of more than 30 are seen around the stations -3 on the lines 000N and 200N.

2-9-3 2-D Analysis

The lines 400N, 200N, 0 and 200S underwent two dimensional analysis to match an assumed geo-electrical structure with the results obtained in the field. Simulation results of the above mentioned lines are indicated in Figs. II-2-39 to II-2-42.

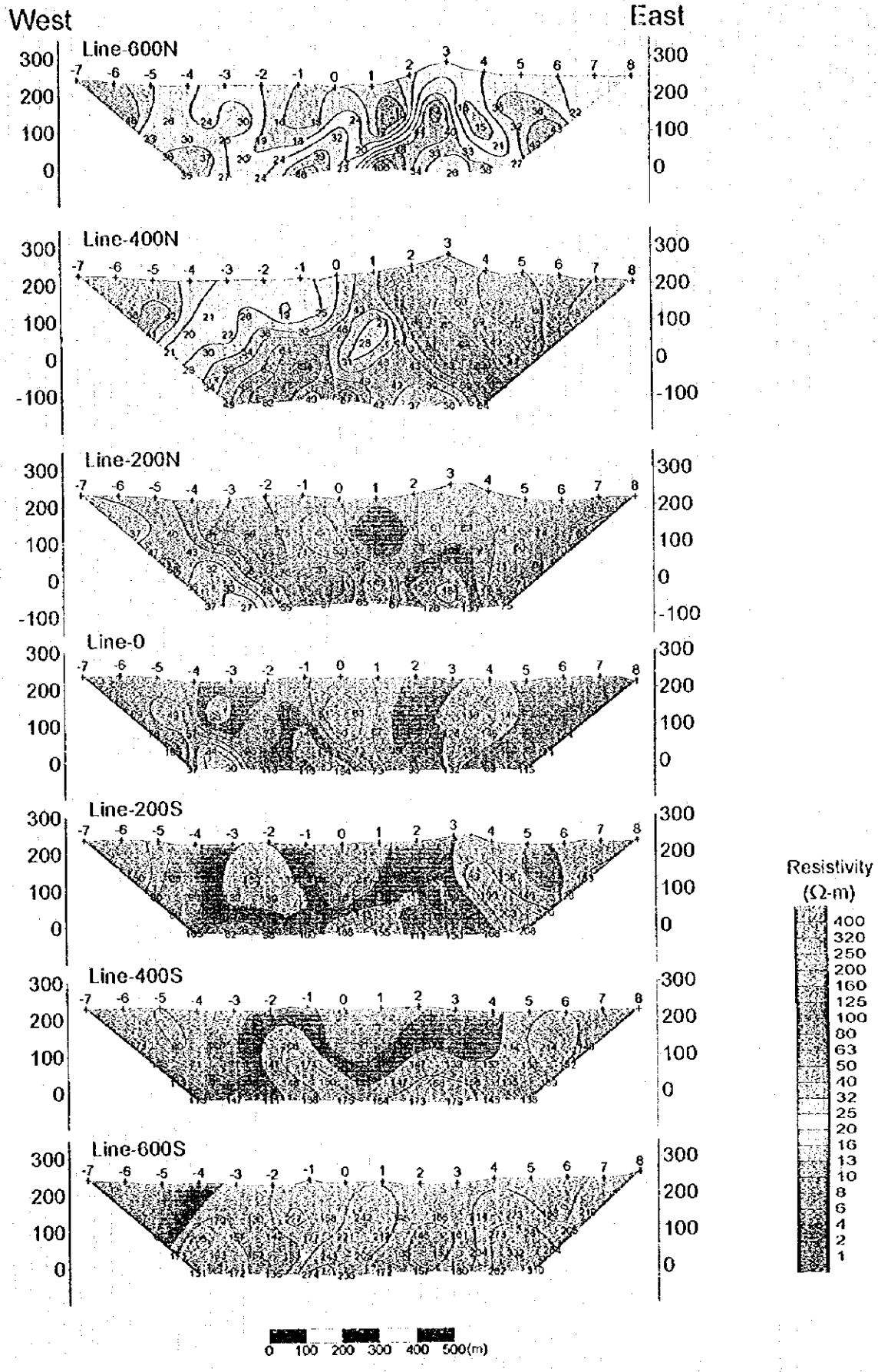
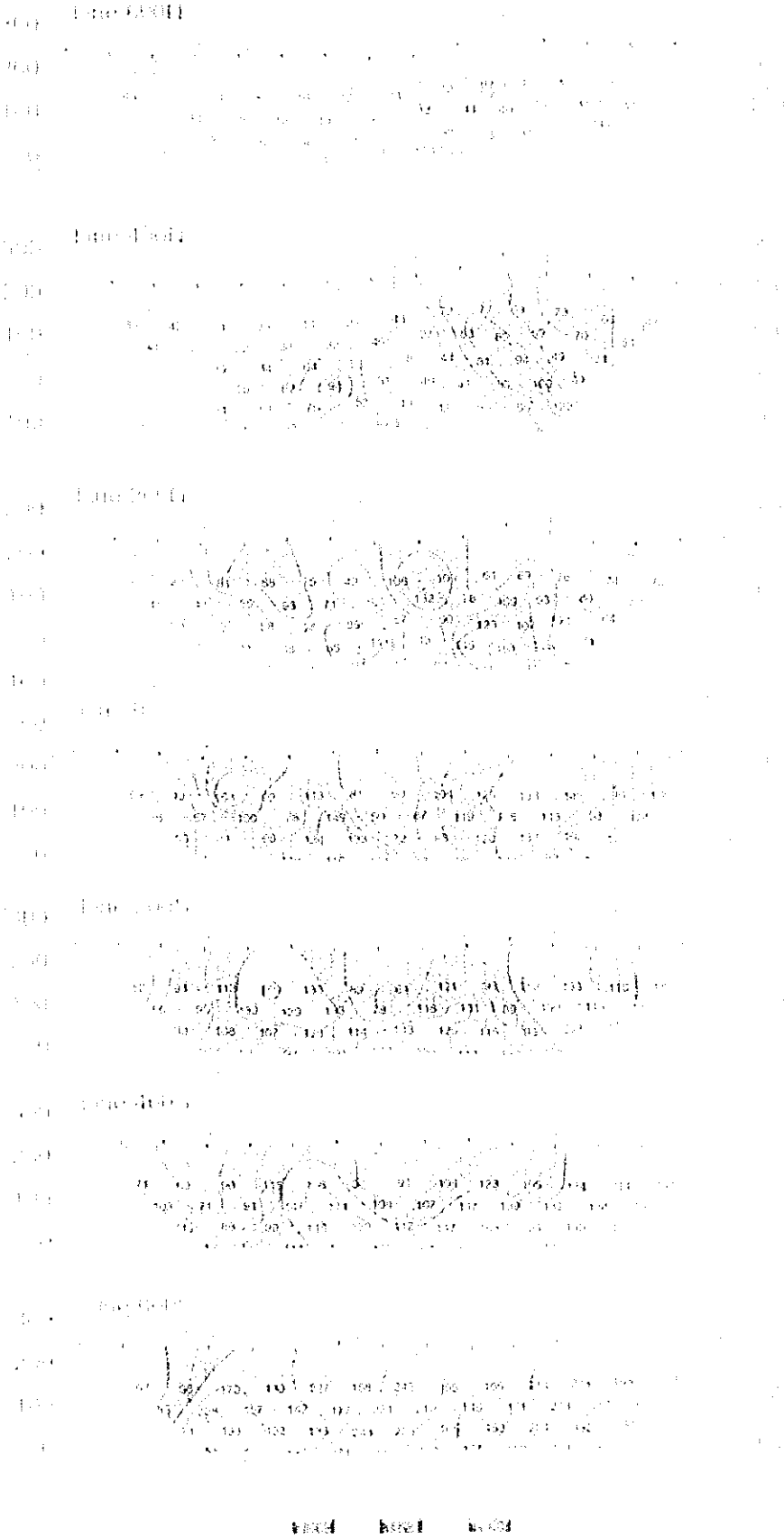


Fig.II-2-32 Apparent resistivity pseudo-sections in Doqal area



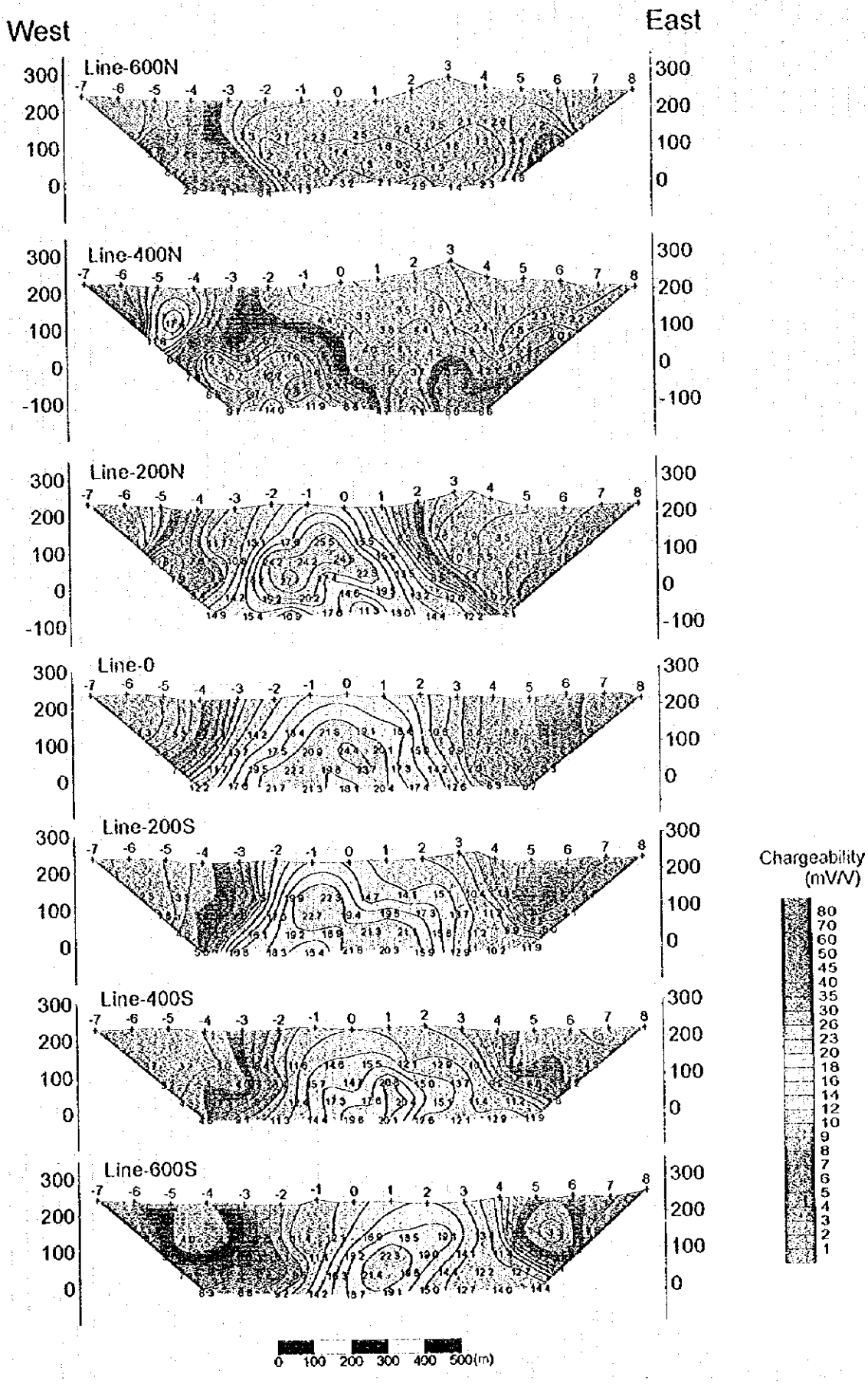
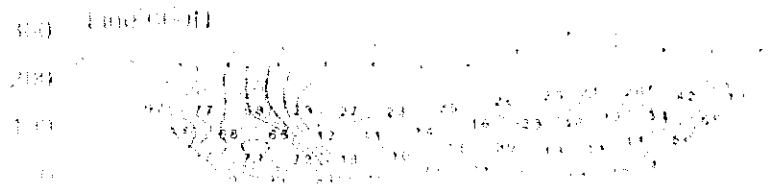
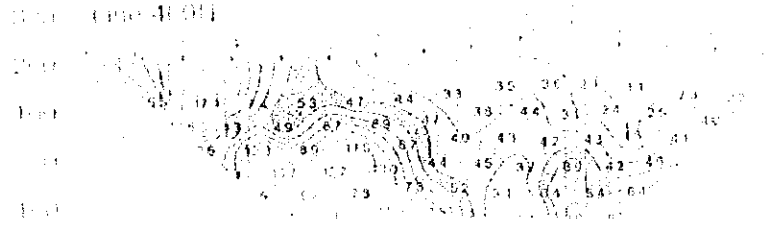
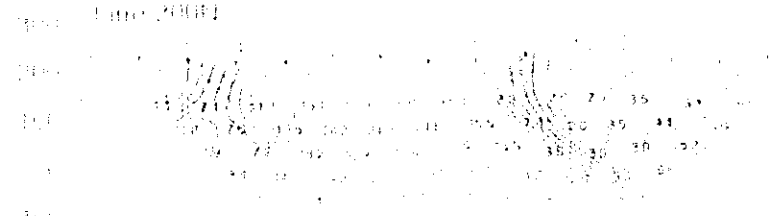


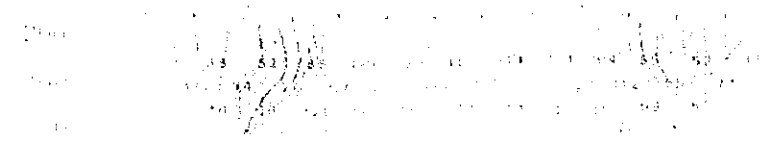
Fig.II-2-33 Chargeability pseudo-sections in Doqal area

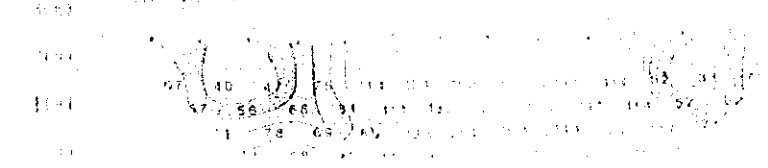
West











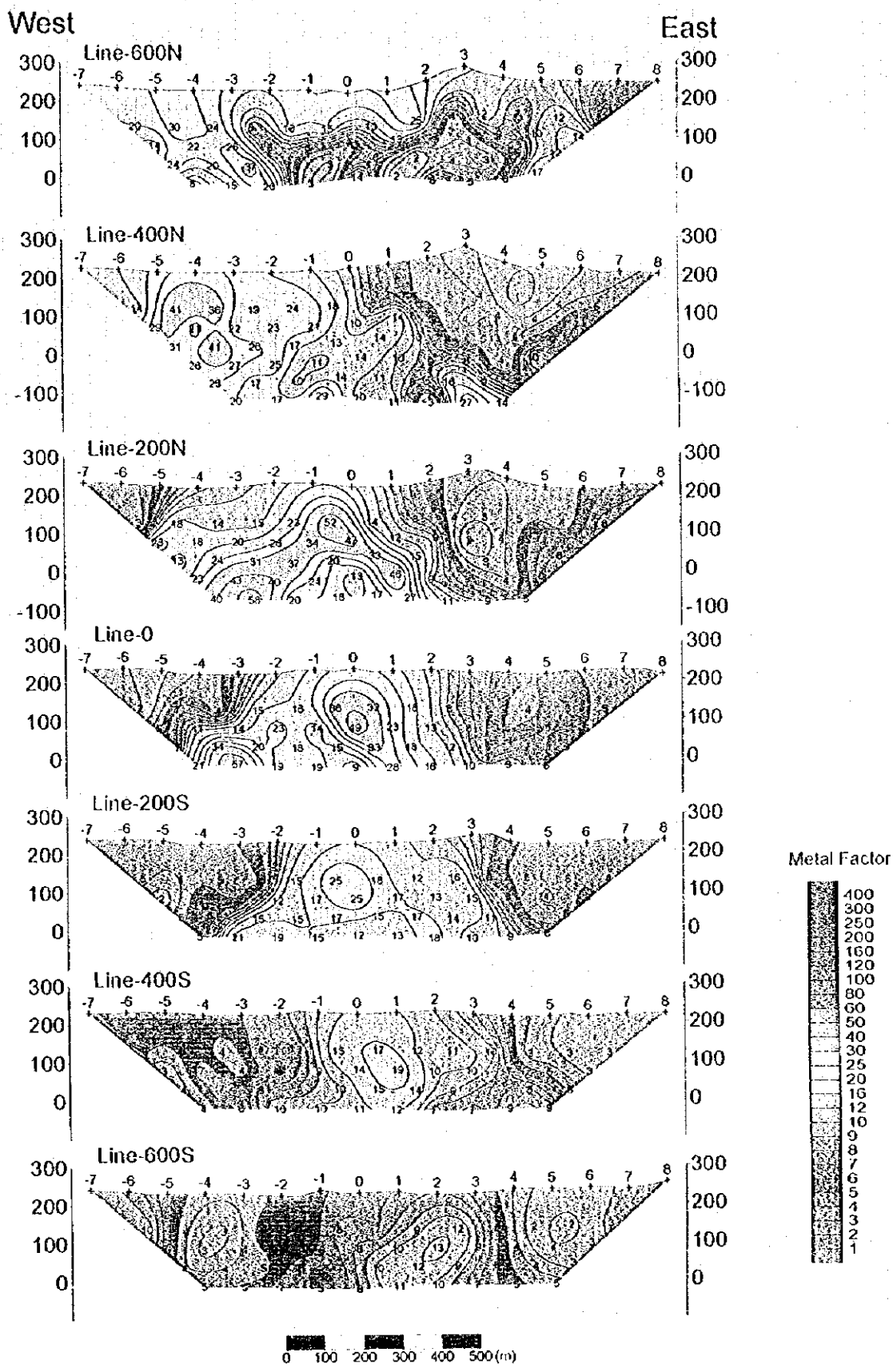
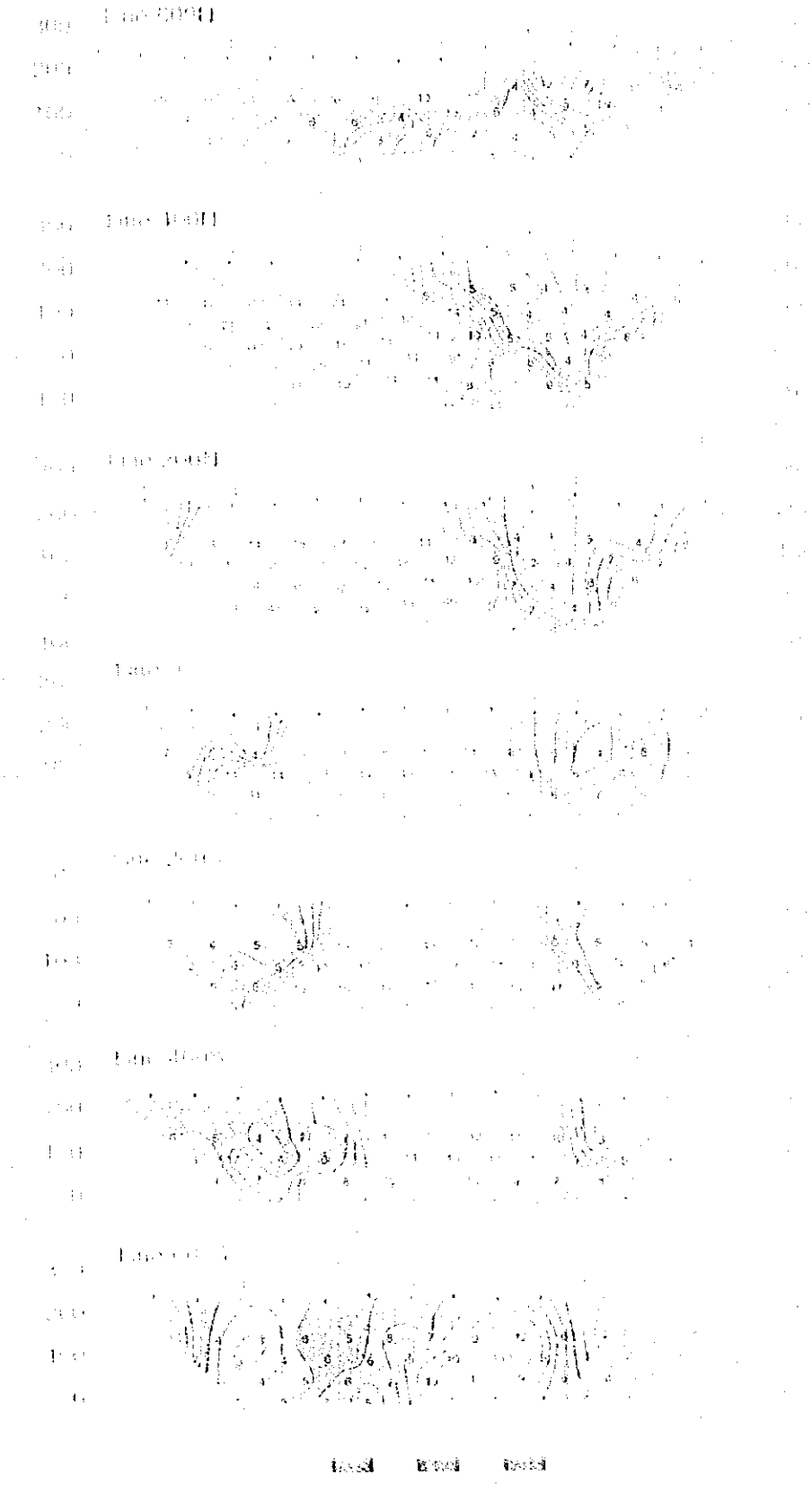


Fig.II-2-34 Metal factor pseudo-sections in Doqal area


West
East

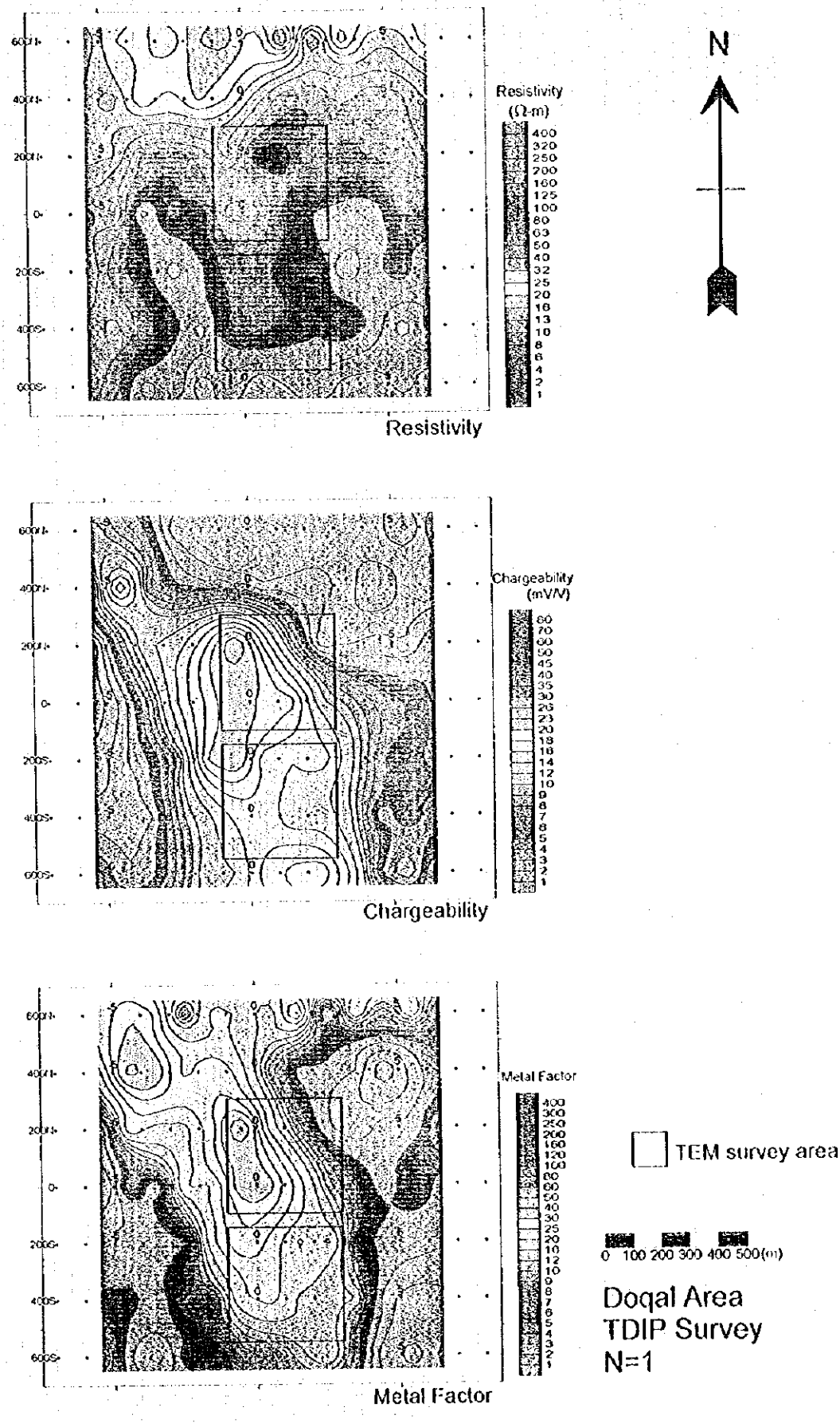
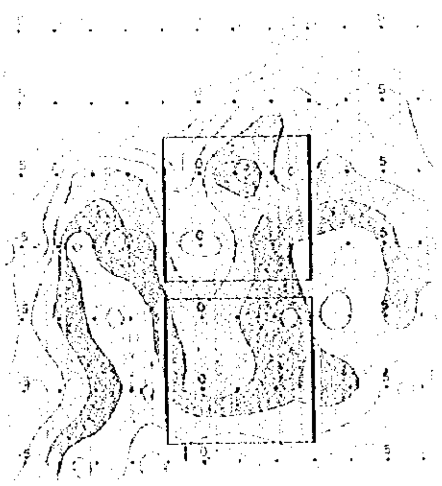
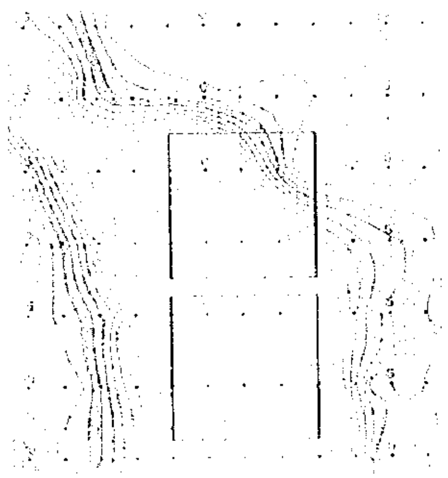
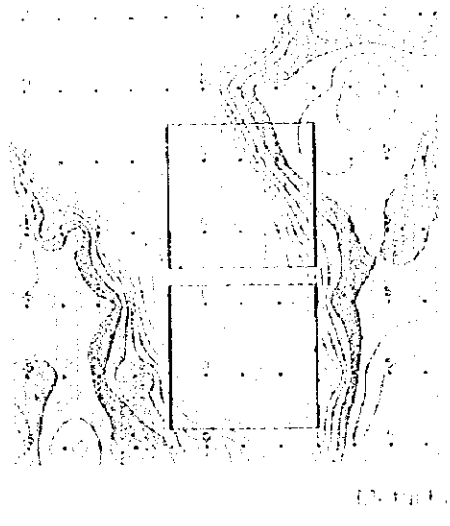


Fig.II-2-35 IP plane map of n=1 in Doqal area



Resistivity





Doqal Area
TDIP Survey
N-1

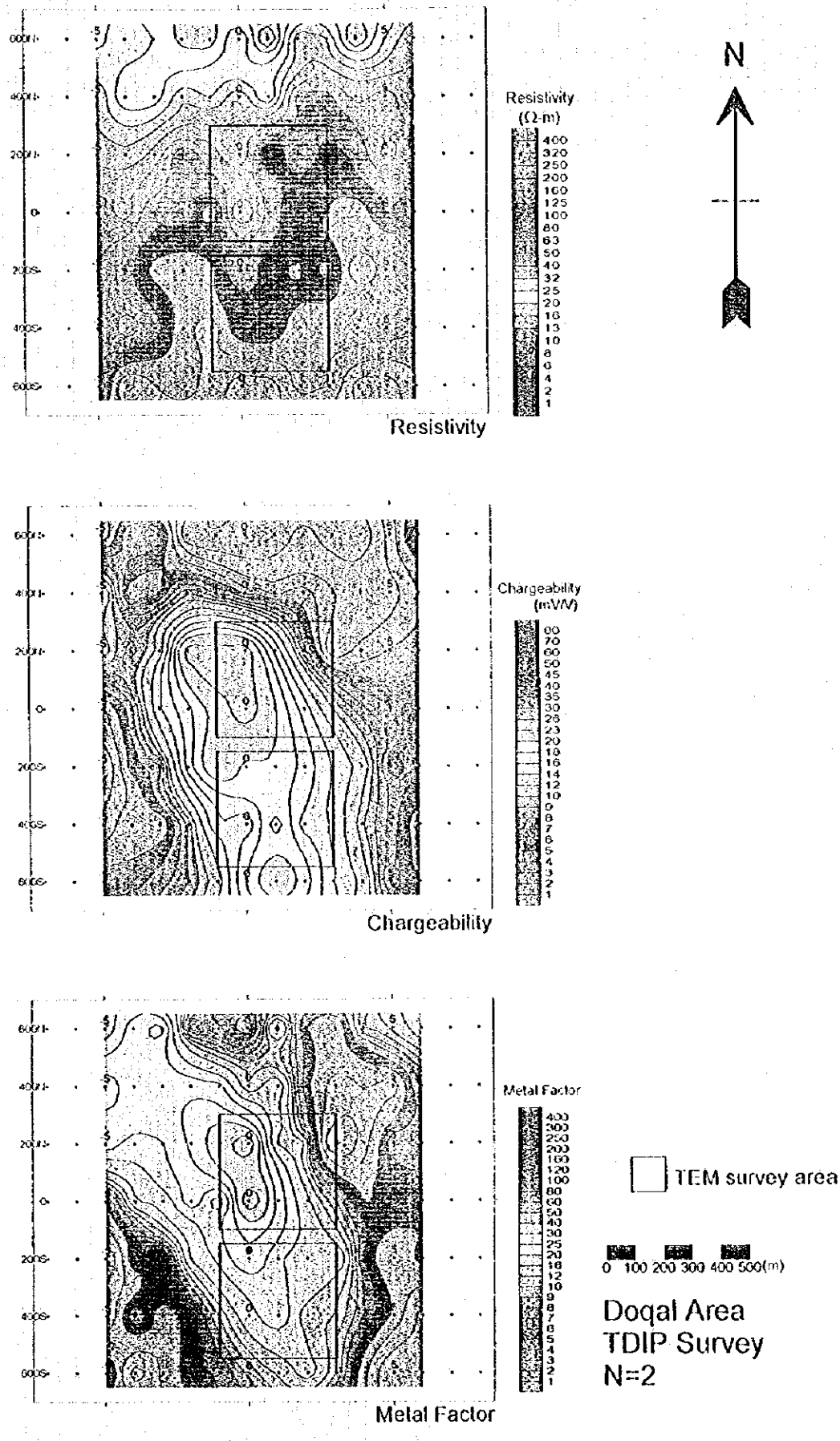
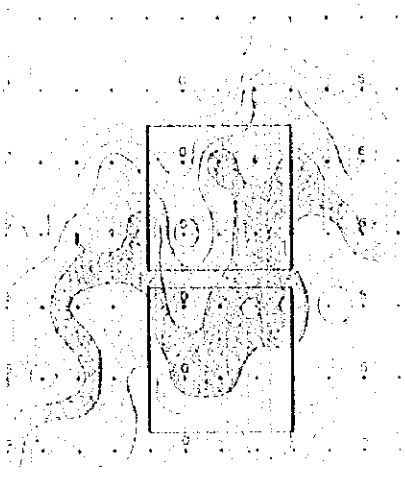
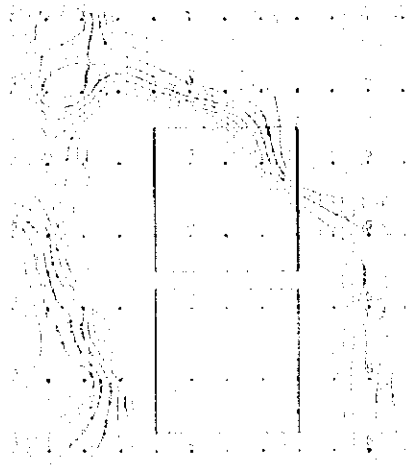
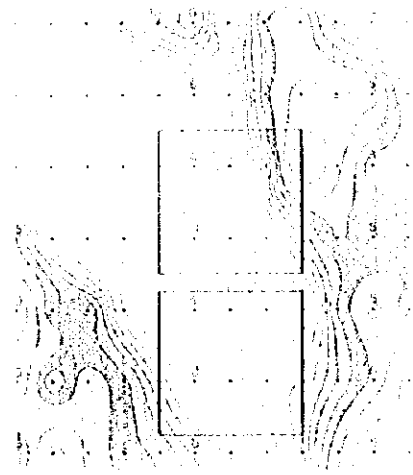


Fig.II-2-36 IP plane map of n=2 in Doqal area







Depth Area
HDR Survey

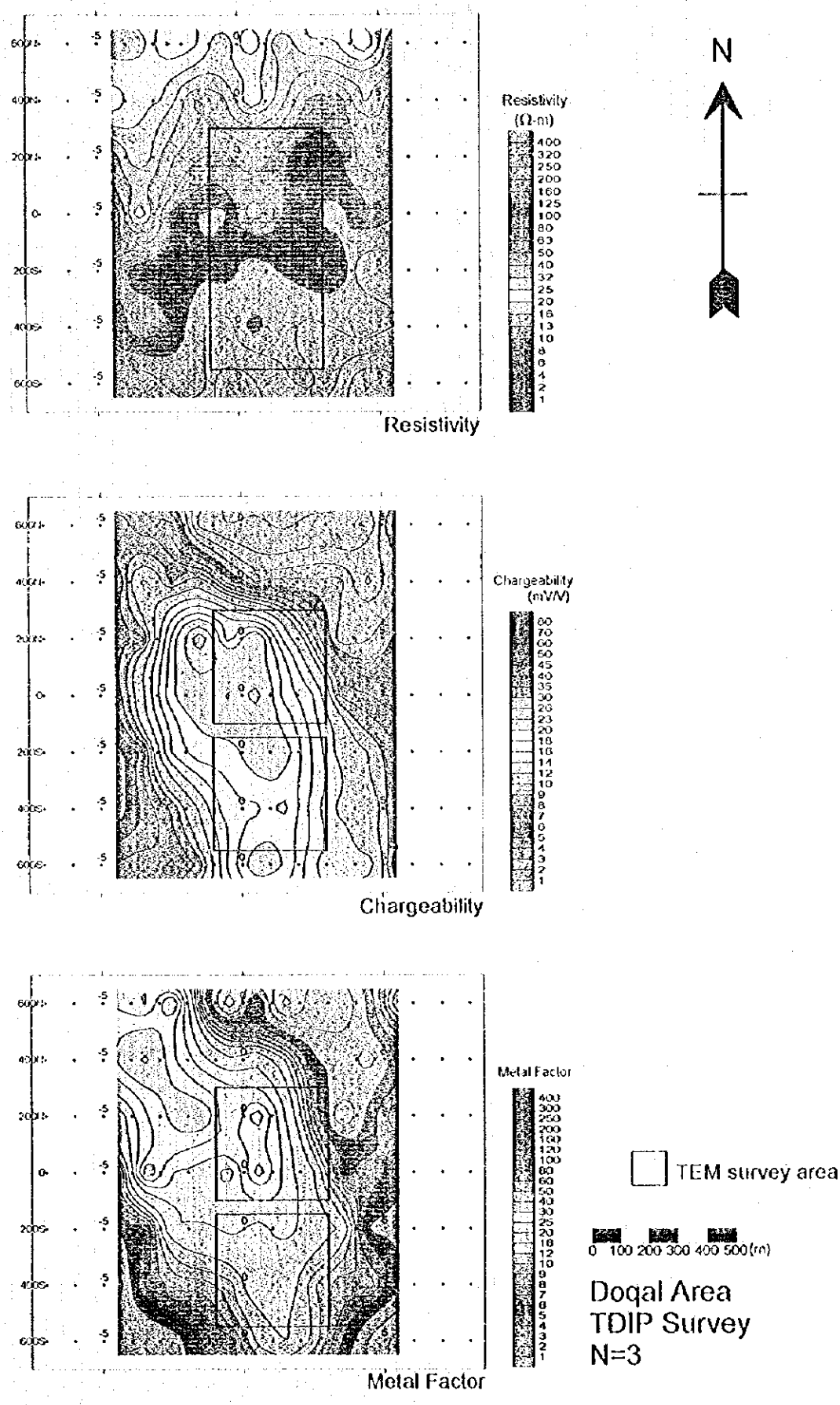
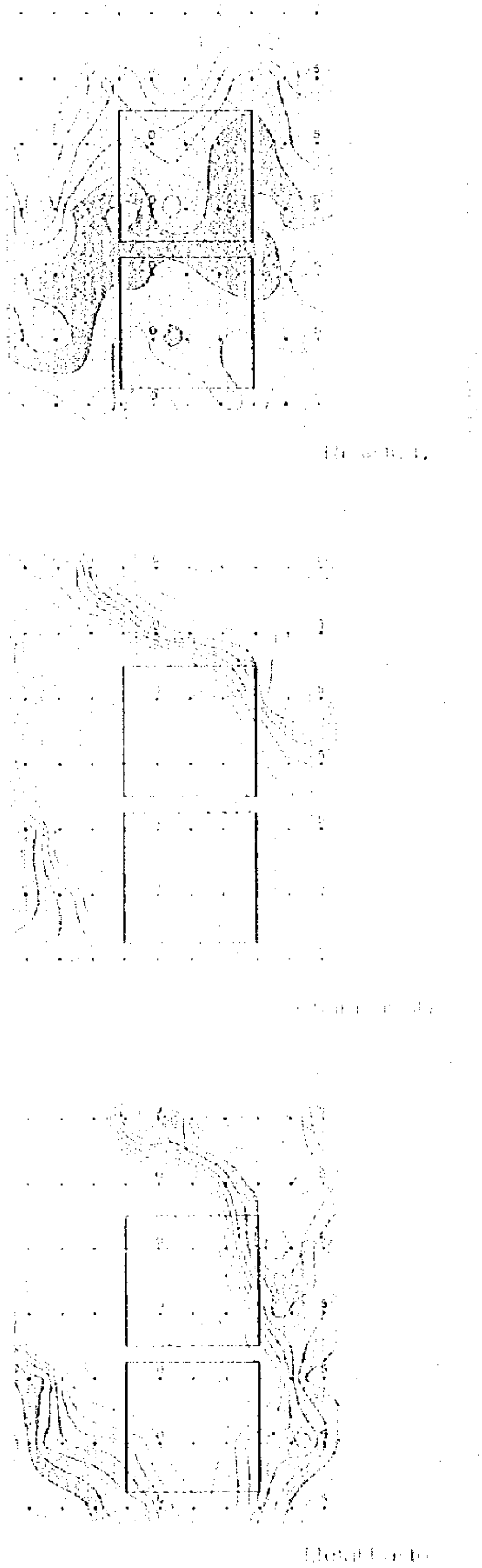


Fig.II-2-37 IP plane map of n=3 in Doqal area



Doqal Area
HDIP Survey