3) IP Anomaly Type 3

This type of IP anomaly is located in and around the zones:

No.7 to 9, No.10 to 13 from the shallow to the depths of Line-D1,
South of No.14 in the shallow, No.4 to 5, No.6 to 8 from the medium to the depths,
No.9 to 11, No.13 to 15 in the medium of Line-E,
No.2 to 5, No.7 to 8, and the south of No.10 in the medium of Line-F,
No.4 to 6, No.8 to 9, and No.11 to 12 in the shallow of Line-G.

Sources of the IP anomaly is also distributed in the mountainous area of the survey area.

(3) Simulation analysis

The strong IP anomaly, mentioned above, which indicated a promising mineralization of copper was considered important for the simulation analysis. The results of the two dimensional model simulation for the IP anomalies are shown in Fig. II-2-13.

Distribution of strong IP anomaly bodies was already described in the previous item No.2. These IP anomaly bodies continue to extend to the north-eastward in central part of the survey area. IP anomaly type 1 with resistivity low and chargeability high, is seen in the flat area of a southwestern part of the survey area except the southern part of the survey area. IP anomaly type 2 with resistivity medium and chargeability high, and IP anomaly type 3 with resistivity high and chargeability high are distributed in the mountainous area of a northeastern part of the survey area.

2-4 Discussion (Fig. II-2-14)

Geological survey conducted in the area shows that serpentinized peridotite consisting mainly harzburgite predominantly occur in the area with minor lens of dunite and small intrusive bodies of gabbro. The alteration and mineralization found in the area is not intense. It occurs only in restricted area surrounding intrusive bodies of gabbro in where relatively intense alteration zone with strong serpentinization accompanied by weak pyrite dissemination and clay minerals such as chlorite and montmorillonite was found. No clear evidence of the mineralization and alteration that reflecting Cu, Ag and Ni anomalies that extracted during the Supra-regional survey was found.

The IP anomalies obtained by the survey, on the other hand, coincide very well with distribution of Cu anomalies of the Supra-regional survey. While, no clear indication of IP effect, corresponding to alteration and week pyrite dissemination found by geological survey was obtained.

Relatively intense IP anomaly obtained in the southwestern part of the area correspond to the location of sulfide mineralization with chalcopyrite found by the previous survey. This may implies an occurrence of considerable amount of sulfide underneath the surface. The most intensive anomalies were obtained over the area from southwestern part to northeastern (northern part of Line B north, Line D middle, Line E north, Line F south and Line G middle). No clear alteration and mineralization were found by geological survey over this area, however, these clear anomalies suggests an existence of possible sulfide veins or dissemination underneath the surface of the area.

The intense anomalies covering the distribution of geochemical anomalies suggest a further detailed survey to be conducted in the area to clarify IP anomaly source.

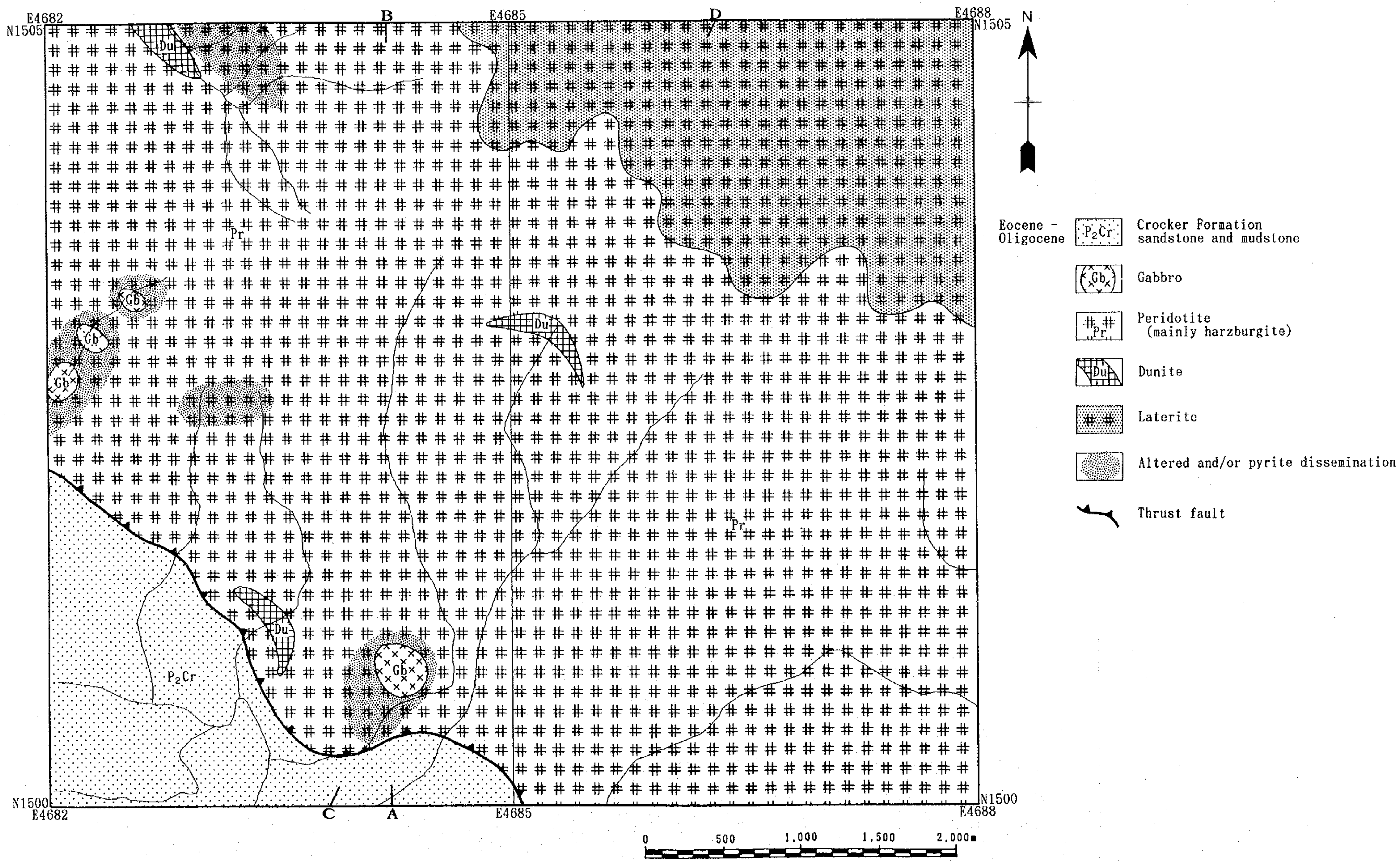

Fig. II-2-1 Geological map and cross sections of Pinanduan Sub-area (1)

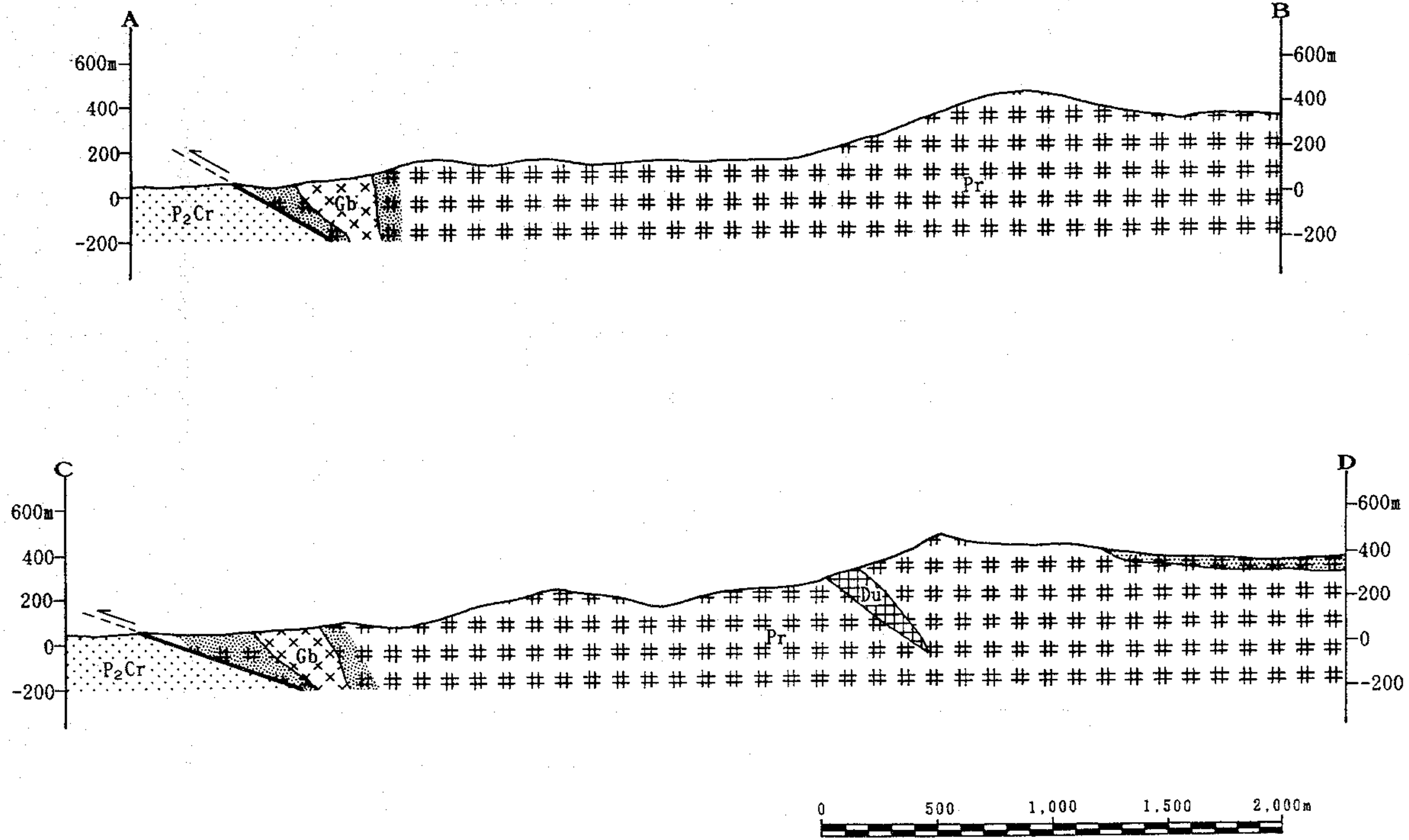

Fig. Ⅱ-2-1 Geological map and cross sections of Pinanduan Sub-area (2)

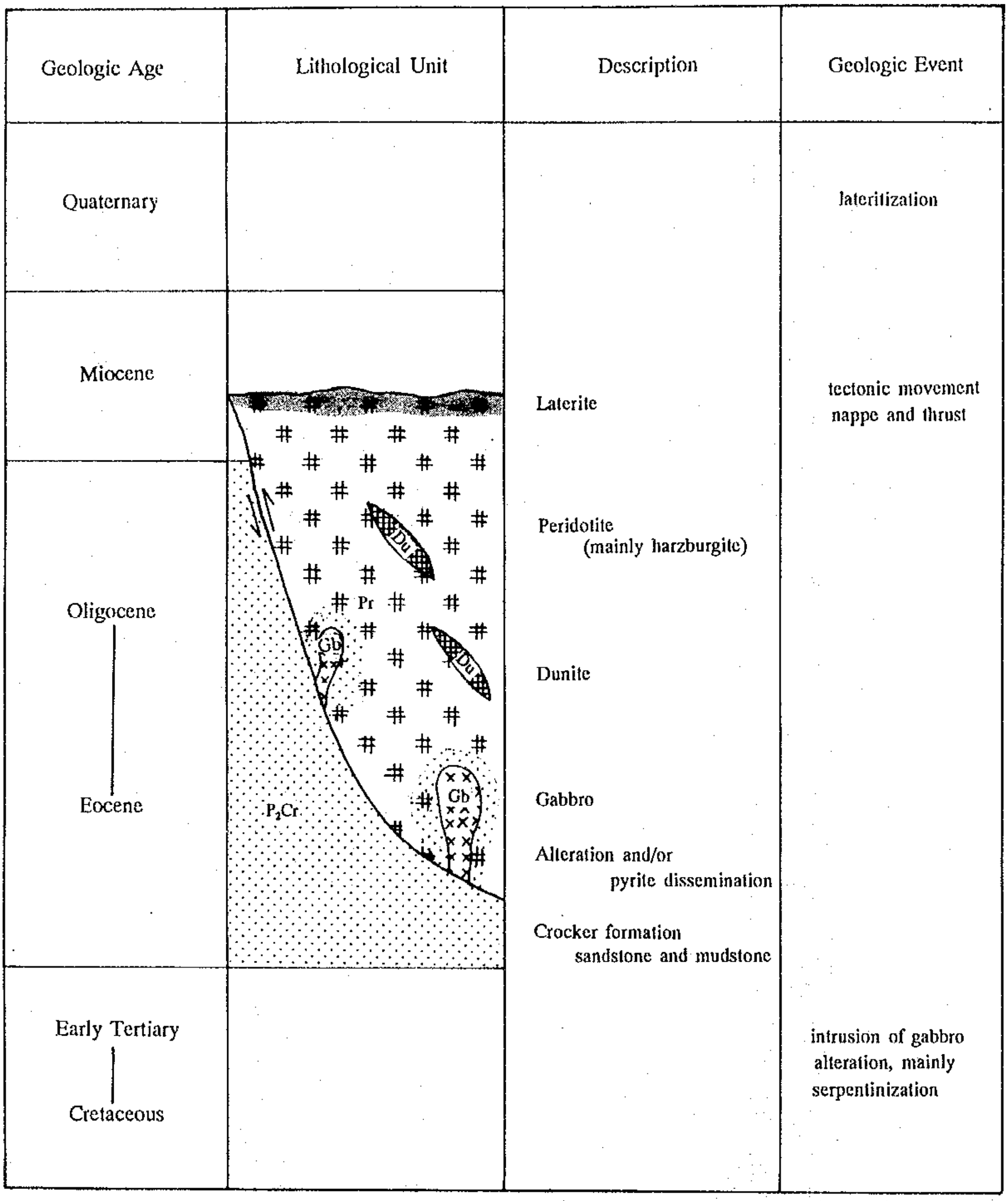

Fig. II-2-2 **Schematic lithological succession of Pinanduan Sub-area**

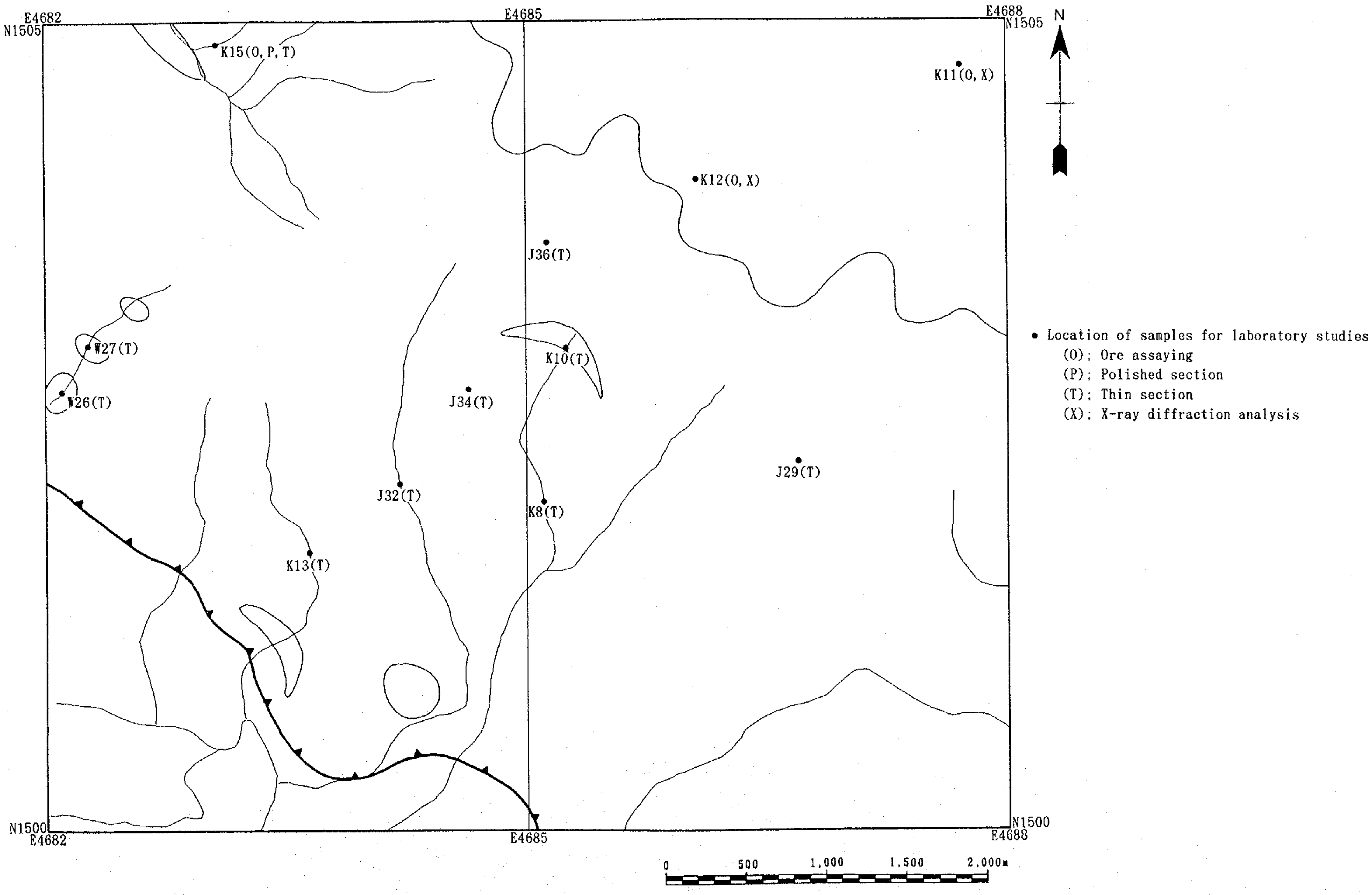

Fig. II-2-3 Location of mineral showings and laboratory work samples in Pinanduan Sub-area

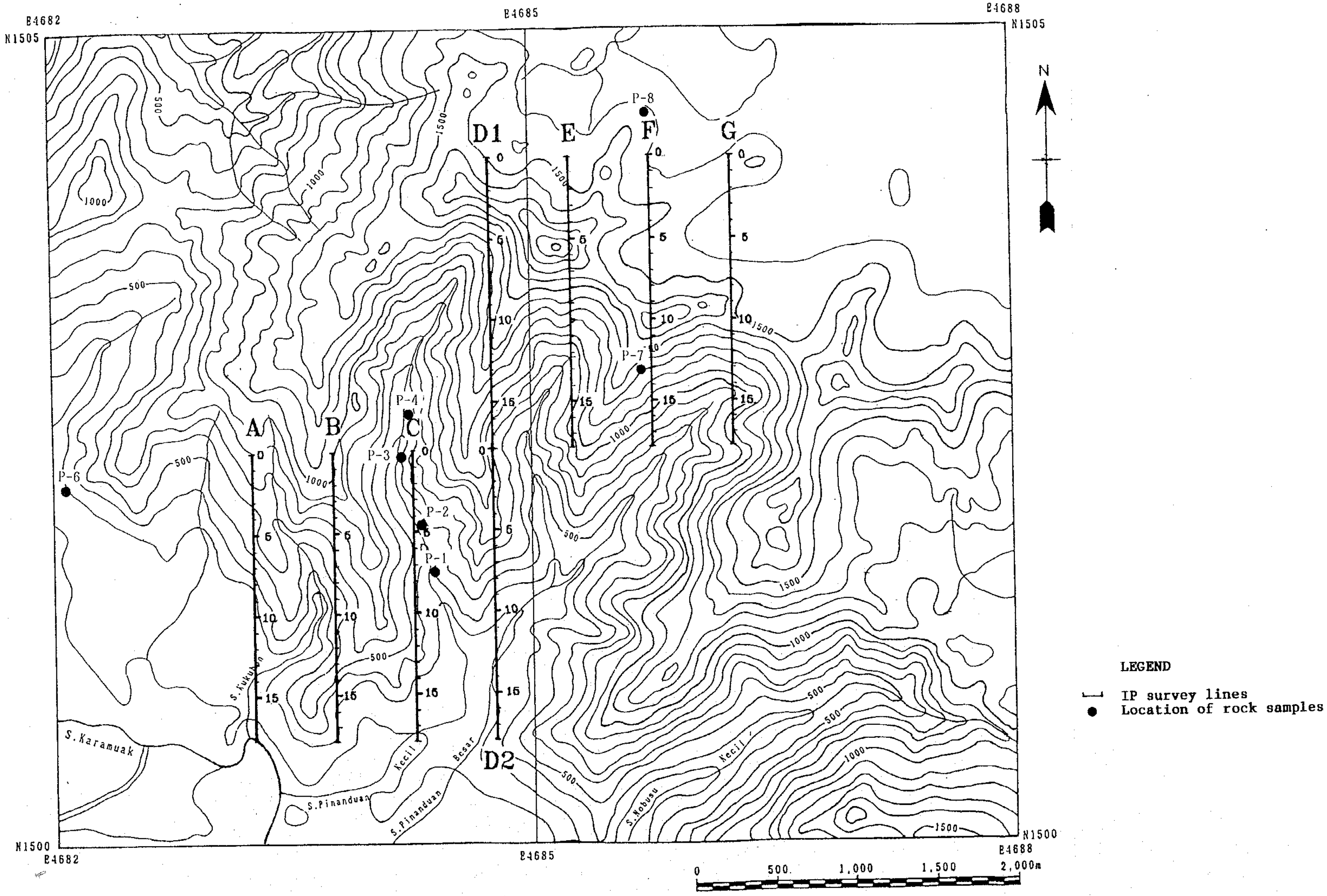

Fig. II-2-4 Location of survey lines and rock samples

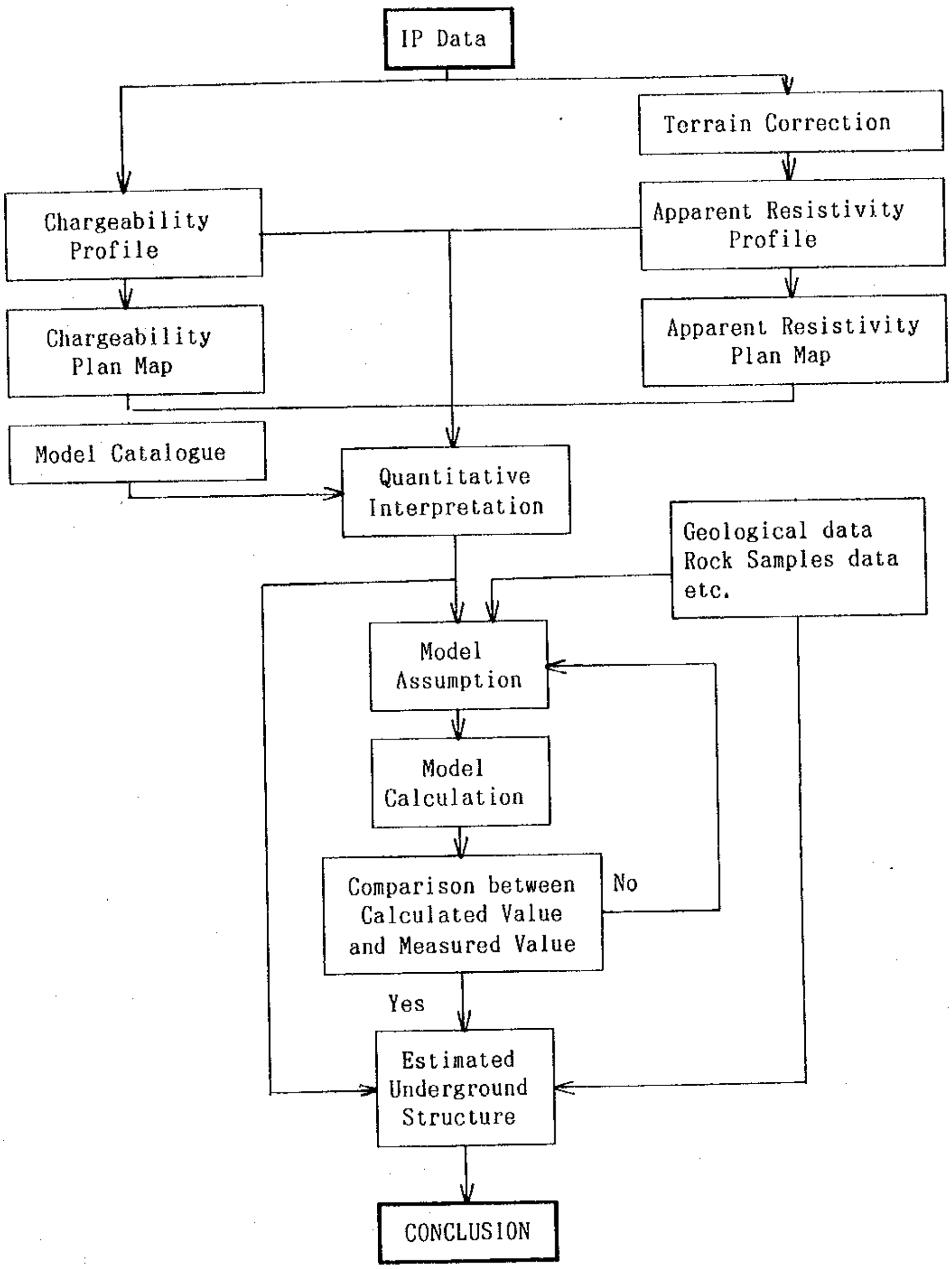

Fig. II-2-8 Flow chart of IP data analysis

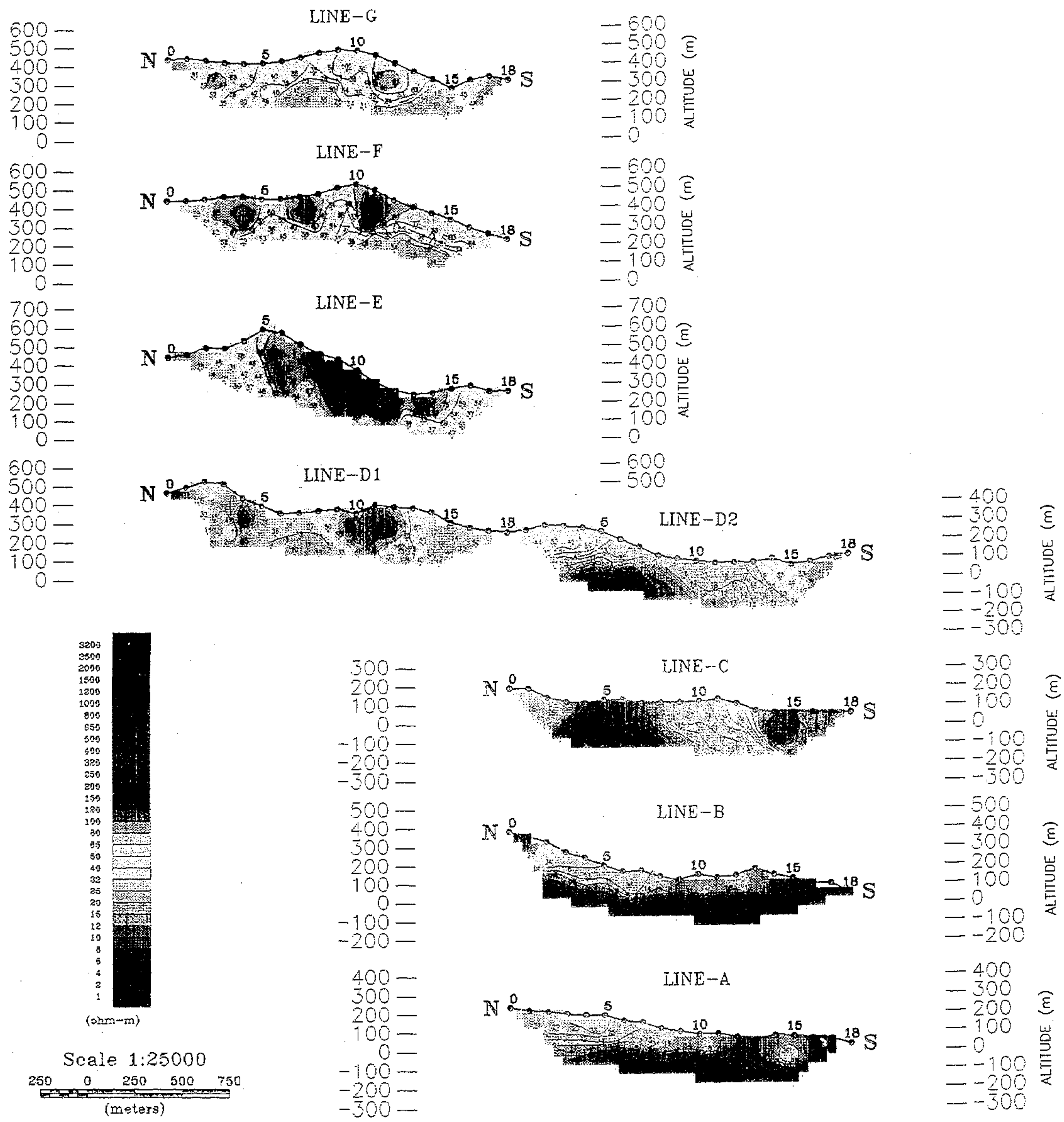

Fig. II-2-9 Pseudo-section of apparent resistivity

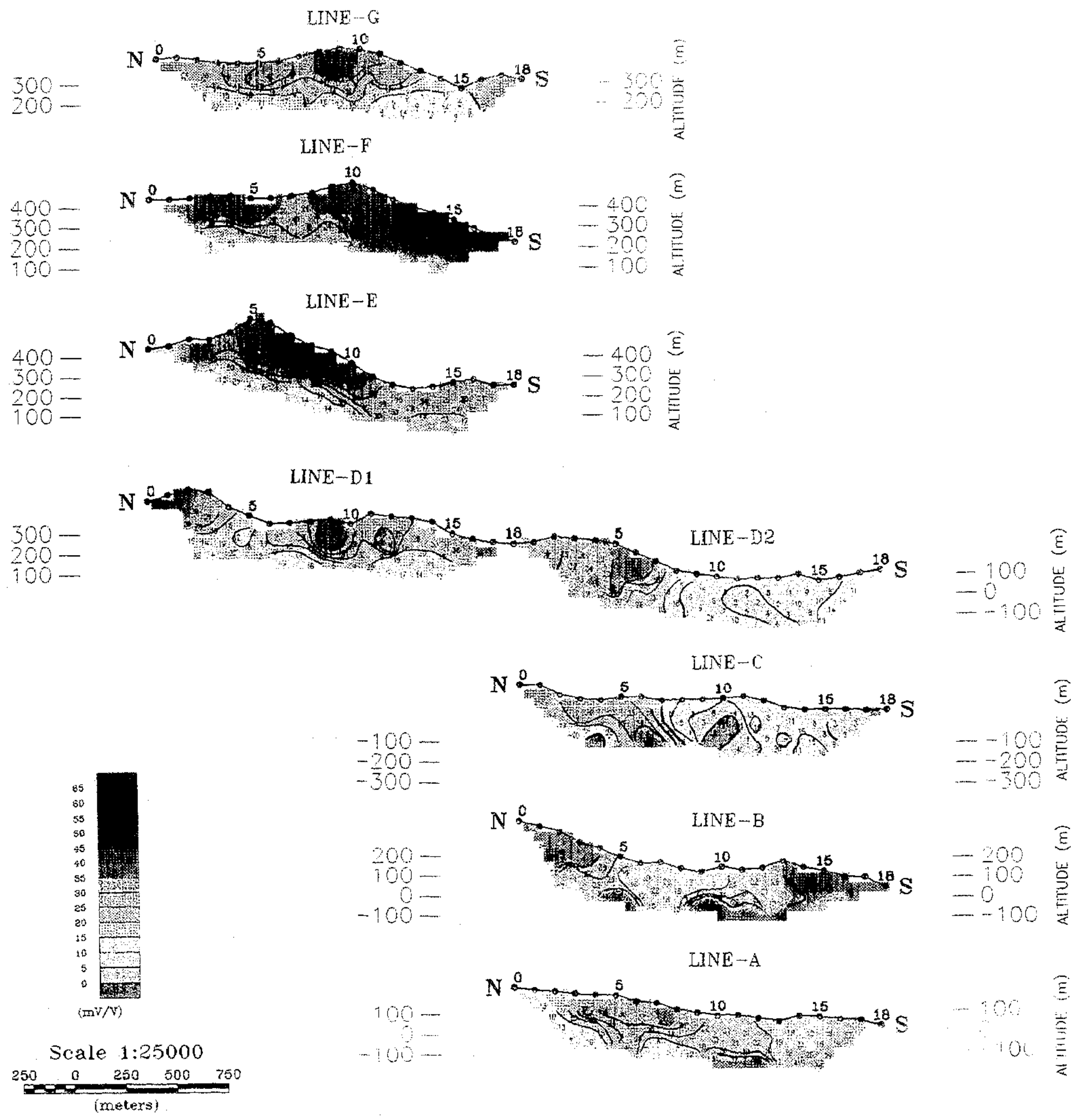

Fig. II-2-10 Pseudo-section of chargeability

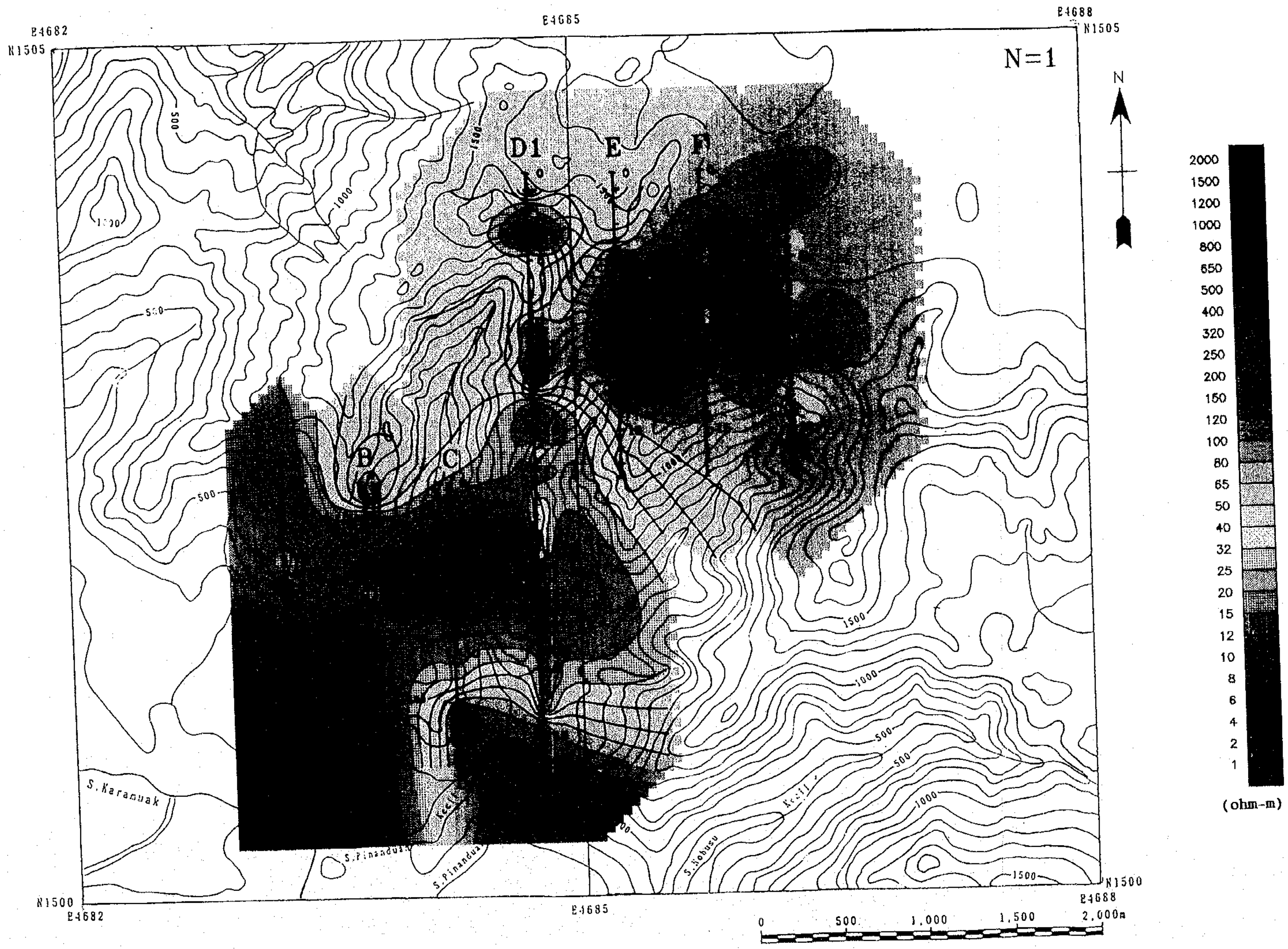

Fig. Ⅱ-2-11 Plan map of apparent resistivity (n=1)

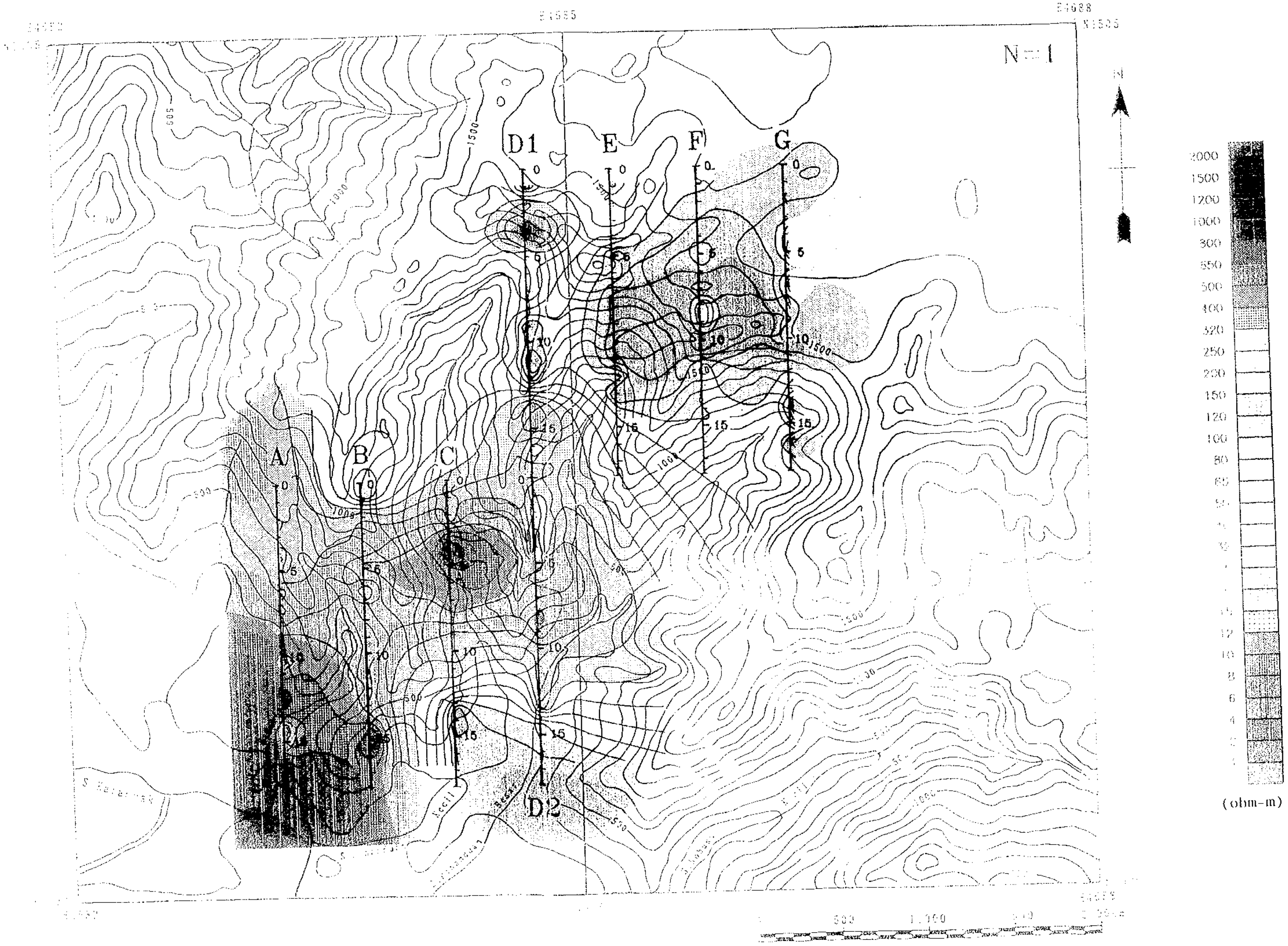

Fig. II-2-11 Plan map of apparent resistivity (n=1)

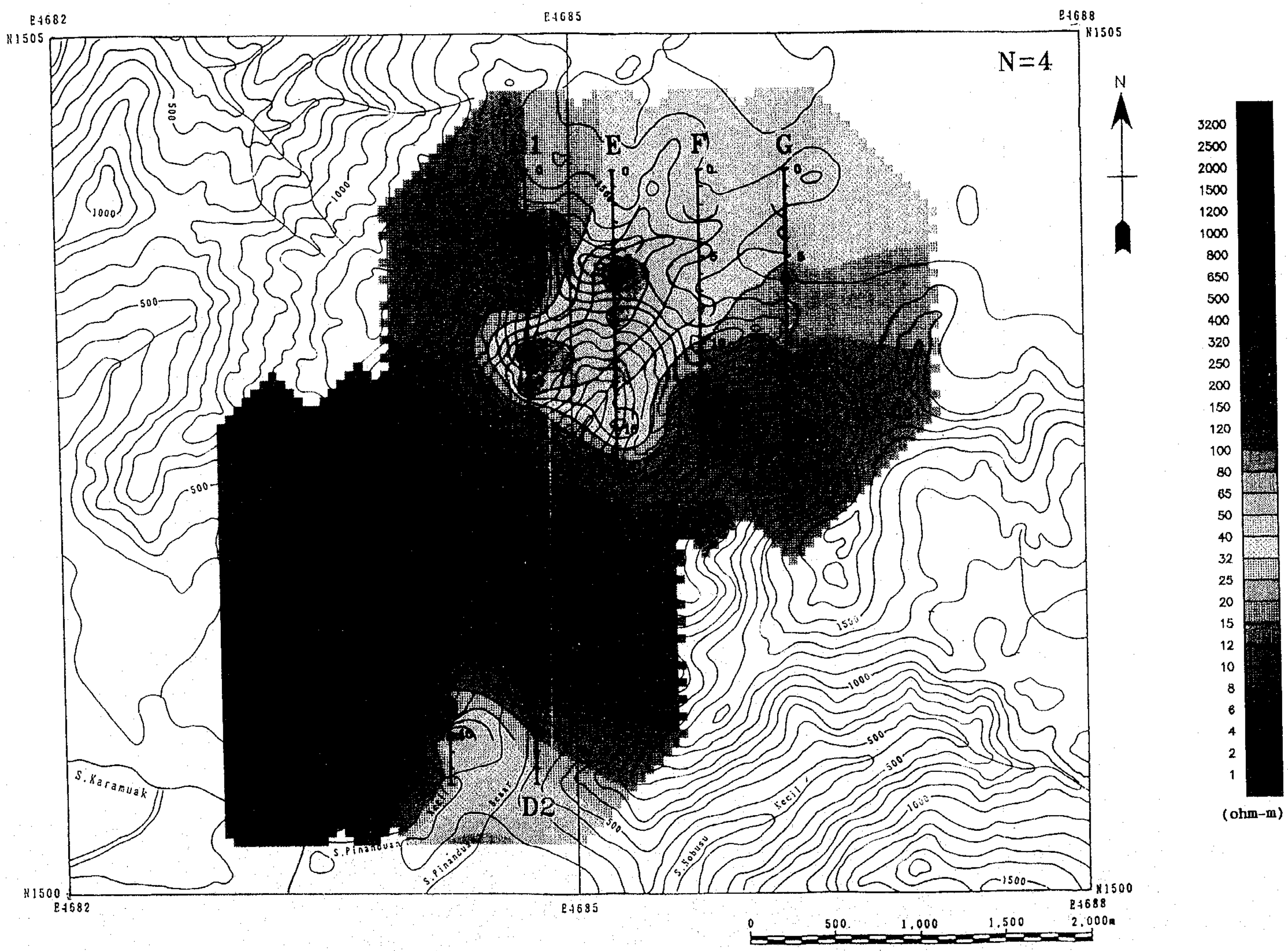

Fig. II-2-11 Plan map of apparent resistivity (n=4)

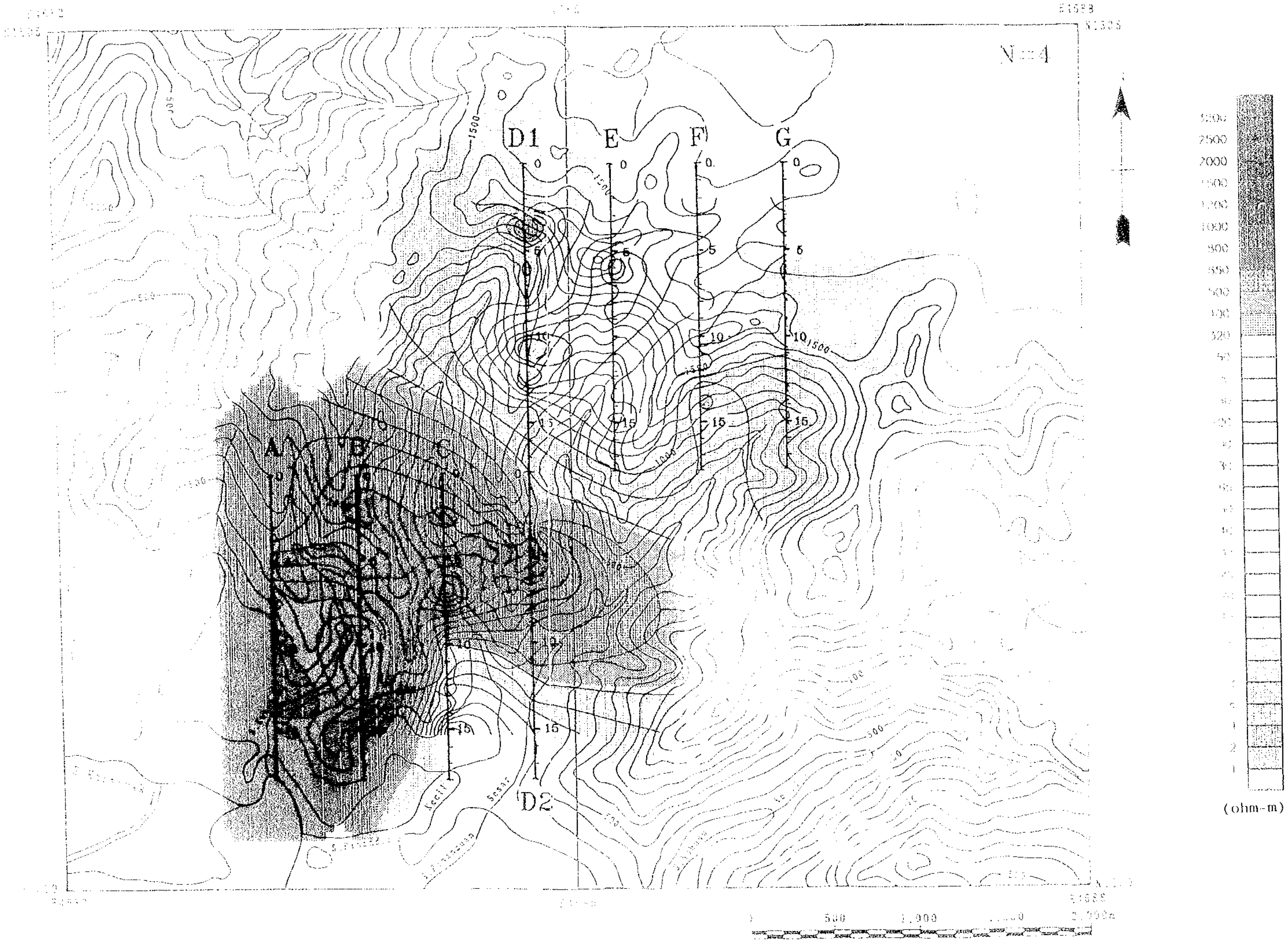

Fig. II-2-11 Plan map of apparent resistivity (n=4)

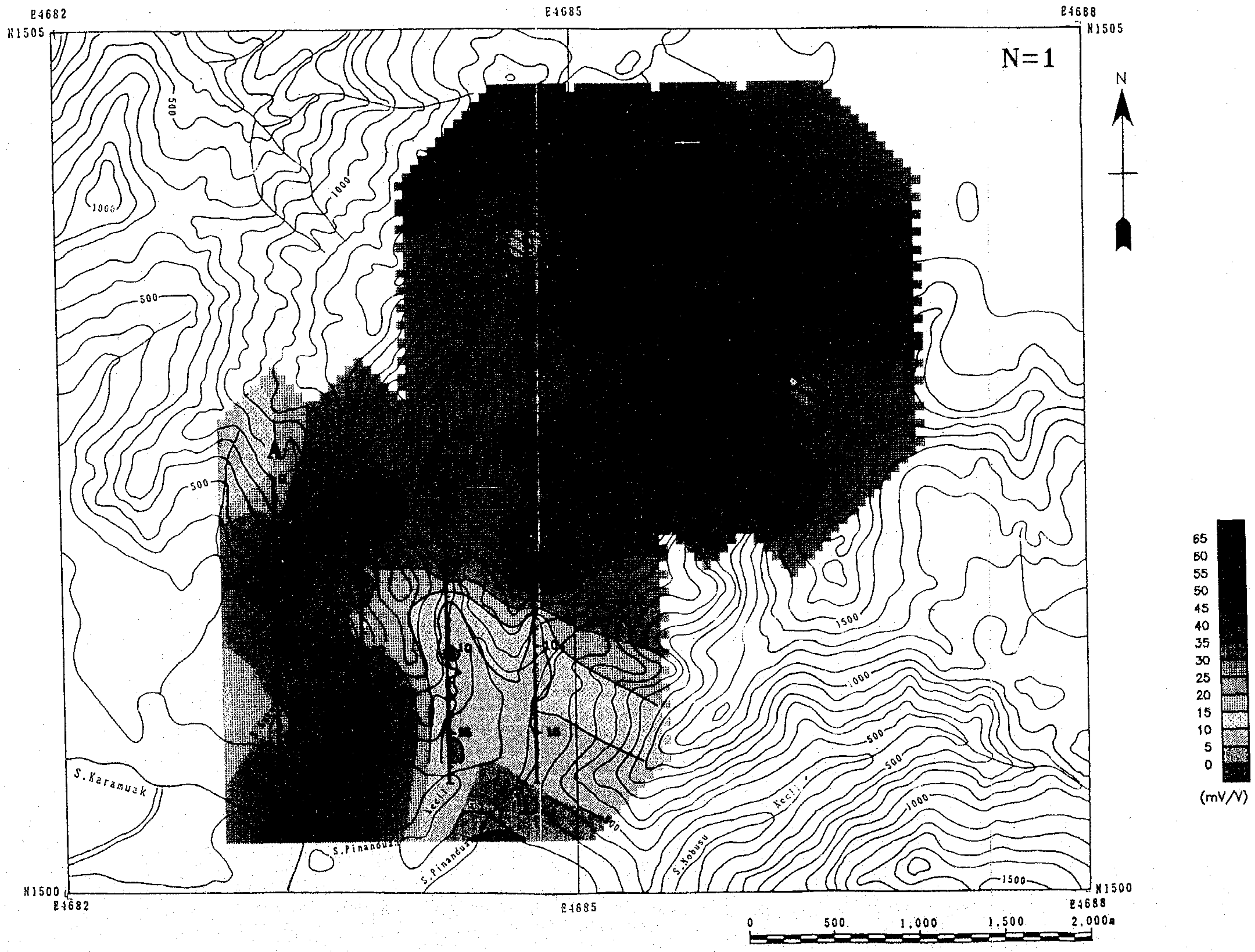

Fig. II-2-12 Plan map of chargeability (n=1)

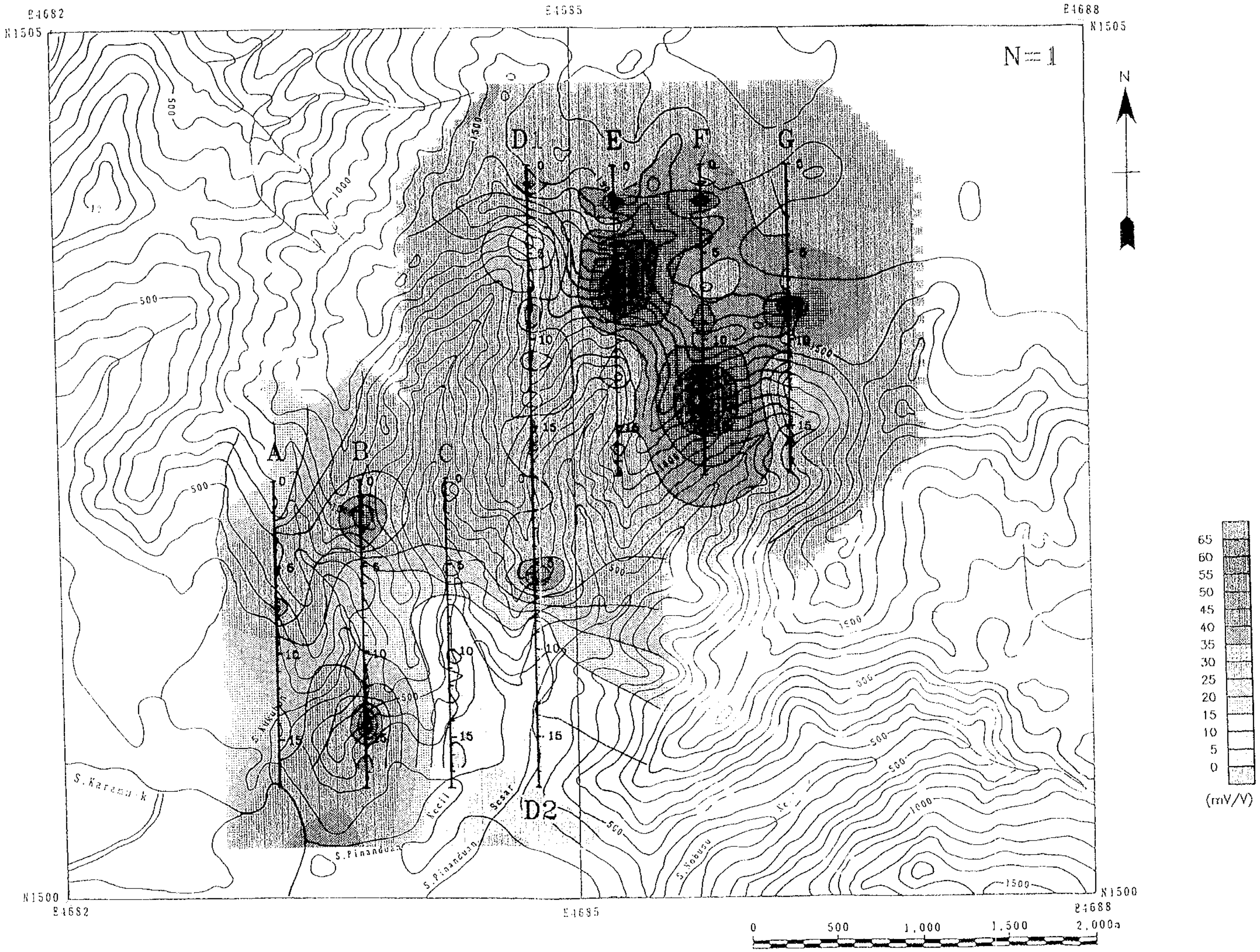

Fig. II-2-12 Plan map of chargeability (n=1)

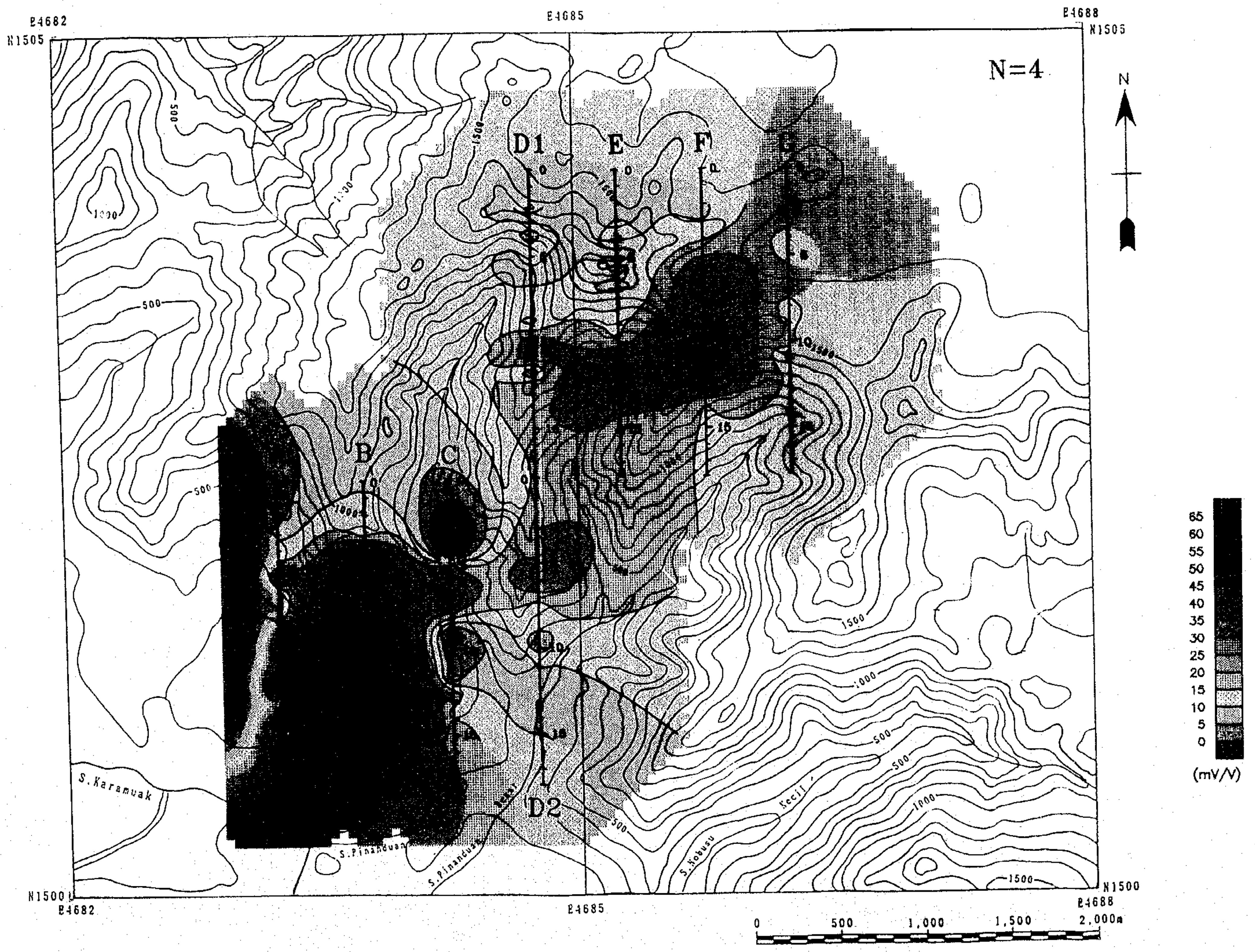

Fig. II-2-12 Plan map of chargeability (n=4)

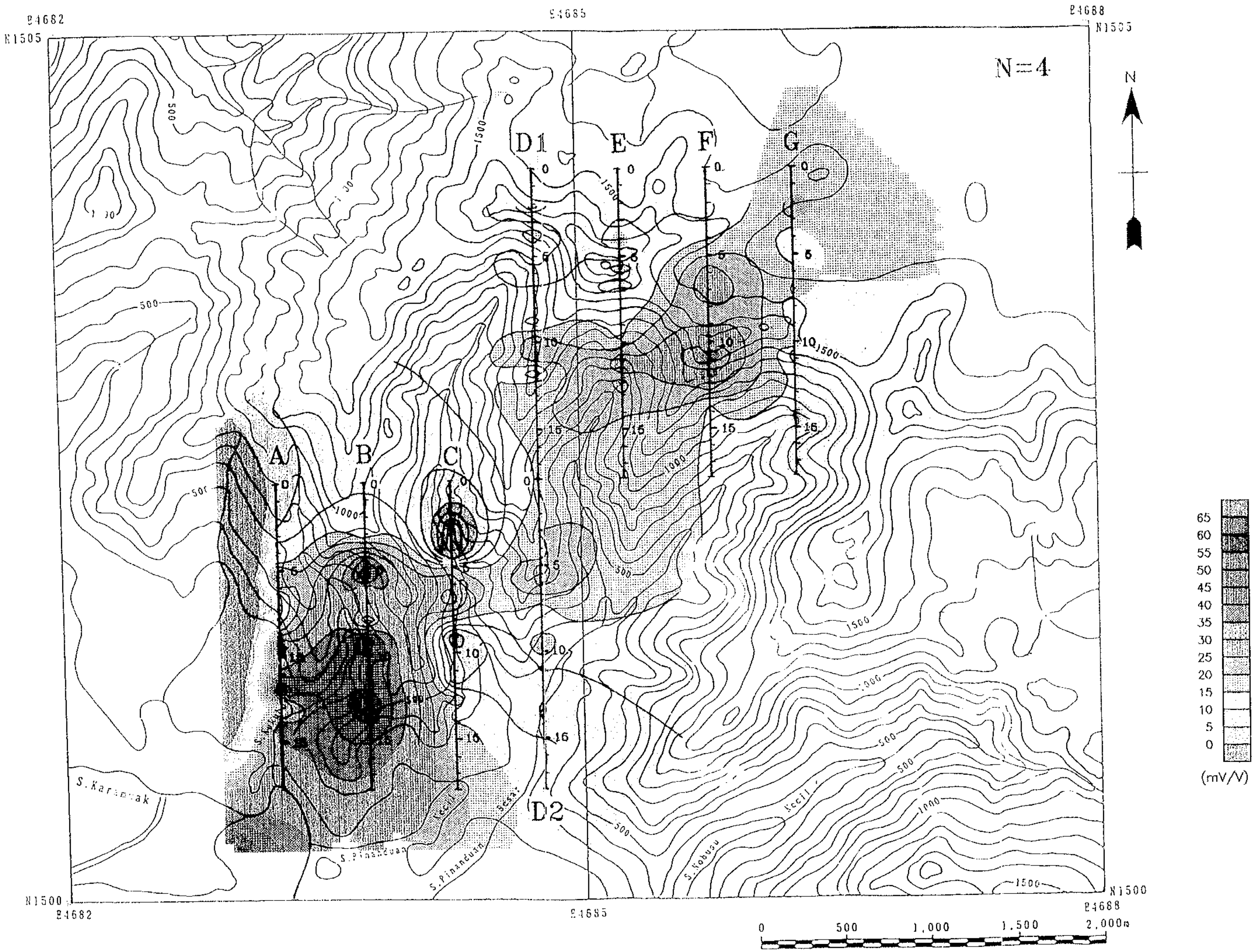

Fig. Ⅱ-2-12 Plan map of chargeability (n = 4)

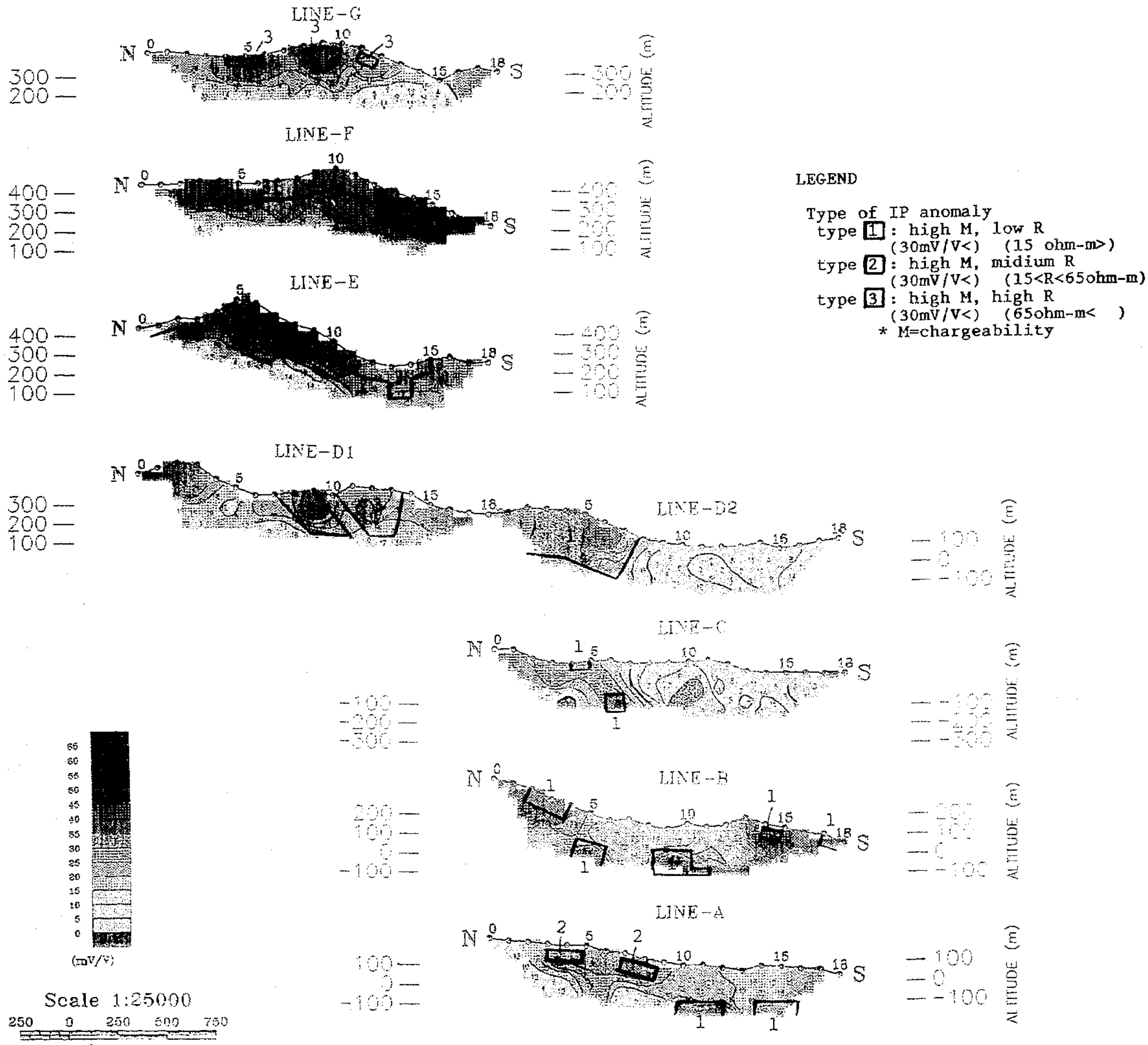

Fig. II-2-13 Results of model simulation

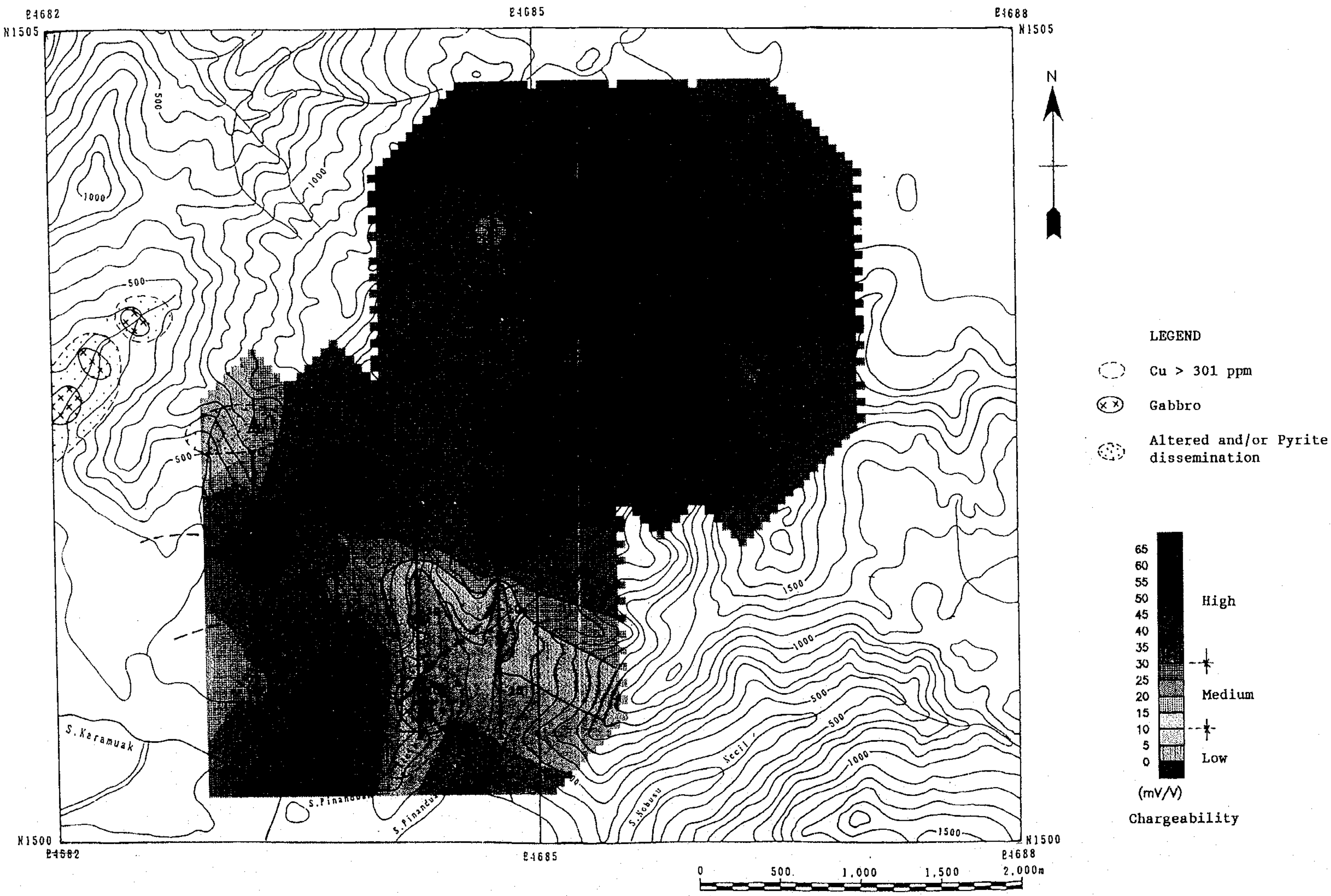

Fig. II -2-14 Compilation of survey results in Pinanduan Sub-area

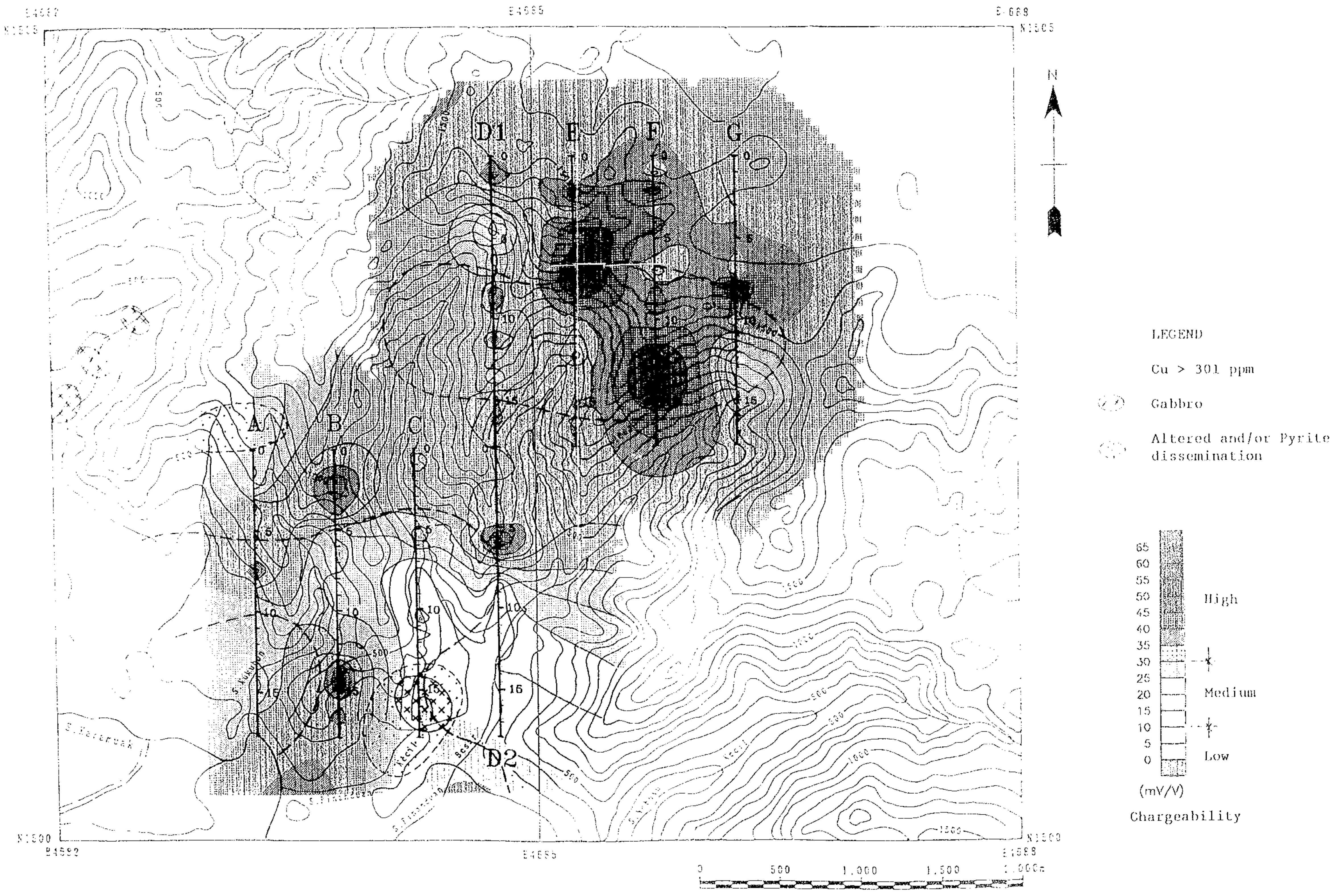

Fig. II-2-14 Compilation of survey results in Pinanduan Sub-area

Table II-2-1 Descriptions of thin sections of Pinanduan Sub-area

Ser. No.	Sample No.	Coordinates N	Coordinates E	Rock Name	Texture	Primary minerals: Plagioclase	Clinopyroxene	Orthopyroxene	Olivine		Secondary minerals: Quartz	Sericite	Chrolite	Epidote	Prehnite	Serpentinite	Tremolite	Hornblende	Montmorillonite	Accessory mine.: Opaque minerals	Hematite	Picolite			Remarks
1	J29	4686.70	1502.28	Harzburgite	mesh structure		·	○	○							◎		·		+	·				serpentinized harzburgite
2	J32	4684.22	1502.14	Harzburgite	mesh structure											◎	·			+		·			pyroxene remains only as pseudomorph, serpentinized harzburgite
3	J34	4684.65	1502.72	Harzburgite	mesh structure											◎					·	·			pyroxene remains only as pseudomorph, serpentinized harzburgite
4	J36	4685.15	1503.63	Harzburgite	mesh structure											◎				+	+	·			pyroxene remains only as pseudomorph, serpentinized harzburgite
5	K 8	4685.12	1502.03	Harzburgite	mesh structure		·	+	·							◎						·			serpentinized harzburgite
6	K10	4685.26	1502.98	Dunite	mesh structure											◎				+	+	·			serpentinized dunite
7	K13	4683.65	1501.72	Harzburgite	mesh structure											◎			+	+	·	·			totally serpentinized harzburgite, pyroxene pseudomorph remains
8	K15	4683.09	1504.85	Harzburgite	mesh structure											◎				+	·	·			totally serpentinized harzburgite, pyroxene pseudomorph remains
9	W26	4682.11	1502.71	Gabbro	hypidiomorphic granular	◎	◎				·	+	+			+	○			·					coarse clinopyroxene gabbro
10	W27	4682.28	1503.00	Gabbro	hypidiomorphic granular	◎	◎				·	·	+		+	+	+			·					

◎: abundant ○: common +: a little ·: rare

Table Ⅱ-2-2 Descriptions of polished sections of Pinanduan Sub-area

Ser. No.	Sample No.	Coordinates		Descriptions	Ore minerals															Remarks
		N	E		Chalcopyrite	Bornite	Chalcocite	Covellite	Sphalerite	Galena	Arsenopyrite	Pyrite	Colloform Pyrite	Native Gold	Acanthite-Argentite	Magnetite	Hematite	Goethite	Gangue minerals	
1	K15	4683.09	1504.85	peridotite with py. dissm.								·							◎	

◎: abundant ○: common +: a little ·: rare q : Quartz

Table Ⅱ-2-3 Results of X-ray diffraction analyses in Pinanduan Sub-area

Ser. No.	Sample No.	Coordinates		Description	Identified Minerals												Remarks
		N	E		Se/Mo mixed layer	Kaolinite	Chlorite	Sericite	Quartz	Plagioclase	K-feldspar	Amphibole	Pyrite	Goethite	Chalcopyrite	Arsenopyrite	
1	K11	4687.73	1504.72	limonitic gossan										+			
2	K12	4686.08	1504.01	limonitic gossan										○			

◎: abundant ○: common +: a little ・: rare

Table Ⅱ-2-4 Assay results of Pinanduan Sub-area

Ser. No.	Sample No.	Coordinates		Descriptions	Assay results							Remarks and sampling width (m)
		N	E		Au (g/t)	Ag (g/t)	Cu (ppm)	Pb ppm)	Zn (ppm)	Mo (ppm)	S (%)	
1	K11	4687.73	1504.72	limonitic gossan	<0.1	<0.1	19	10	88	<1	0.07	grab sample
2	K12	4686.08	1504.01	limonitic gossan	<0.1	<0.1	32	10	113	<1	0.08	grab sample
3	K15	4683.09	1504.85	serpti. peridotite with py. dissm.	<0.1	<0.1	5	<1	31	<1	0.91	grab sample

Table Ⅱ-2-7 Resistivity and chargeability of rock samples

Sample No	Resis. (ohm-m)	Charge. (mV/V)	Rock Name	Alt./Mineral	Remarks
P-1	205.0	5.8	Peri.	Chloritized	
P-2	2400.0	51.7	Peri.	Serpentinized	
P-3	10000.0	19.7	Peri.	Serpentinized	
P-4	404.0	7.5	Peri.	Serpentinized	
P-6	8360.0	37.3	Peri.	Serpentinized	
P-7	6400.0	3.5	Alt.Peri.	Serpentinized	
P-8	2070.0	19.3	Lat.Peri.	Oxidized	Goethite rich

Resis : Resistivity Charge : Chargeability Alt : Alteration
Peri : Peridotite Lat : Latelite

Chapter 3 S. Imbak Sub-area

3-1 Introduction

The S. Imbak Sub-area, 98 Km^2 (NW 14 km × EW 7 km), is located in the south end of the Central Sabah area. The area is separated into two parts by the south end line of Labuk area of the Supra-Regional Survey. The northern part (S. Imbak Sub-area North), NS 4 km × EW 7 km, is a southern part of the Area T of Supra- Regional Survey, where soil geochemical survey was conducted in 1993, while, the southern part (S. Imbak Sub-area South, Gunong Kuli), NS 10 km × EW 7 km, is located immediate south of the Supra-Regional Survey area. A geological survey (semi-detail) and geophysical survey was conducted in S. Imbak Sub-area North and soil geochemical survey was conducted in the S. Imbak South.

3-1-1 Survey area

(1) S. Imbak Sub-area North

The drainage system of the S. Imbak Sub-area North is belong to southern tributaries of S. Imbak except southeastern part of the area in where streams flow to Sungai Kuamut.

In the northern and western parts of the area topography is relatively gentle with altitude of 300 m to 400 m and toward south it becomes drastically steep and ragged mountainous topography reaching more than 900 m at the south end of the area. The entire area of the S. Imbak North is covered by primary jungle and no trace of human activities such as cultivation and logging is found in the area. The access to the area is poor only by a small trail. The base camp was established along the logging road at the closest point to the area, then a trail of approximately 6 km long was constructed along ridge for transportation of geophysical equipment and various supplies. The geological survey and geophysical survey were conducted establishing advanced camp in side area.

(2) S. Imbak Sub-area South (Gunong Kuli)

The S. Imbak Sub-area South is located immediate south of the S. Imbak Sub-area North separated by steep ridge of more than 900 m high and no previous geological work has been done in the area. The area belongs to drainage system of Sungai Kuli, which is a tributary of Sungai Kuamut and flows from the western part to southern part of the area.

The topography of the area is very steep and ragged except southeastern part of the area along Sungai Kuli. The area is mainly consisting of a ridge running in the middle of the area trending in NNW-SSE direction and slopes of both sides of the ridge. The altitude of the ridge is more or less 1,000 m and the maximum height reaches to approximately 1,500 m in the northern part of the area. Gunong kuli is located along this ridge in the central part of the area.

The entire area is covered by primary jungle and there is no trace of human activity in the area. The access to the area is very poor, only a few trail are found in the area. The geochemical survey was conducted by fly camp and it takes three days to reach the northwestern corner of the area.

3-1-2 Background

The S. Imbak Sub-area, which had been lacking previous geological information, has been considered to be an area of monotonaous Tertiary sedimentary rocks. The stream sediments with high concentrations of Au and Hg (maximum Au 6.530 ppb, Hg 24,735 ppb) obtained at near the mouth of southern tributary of S. Imbak leaded to the subsequent semi-detail soil geochemical survey in the Area T covering the catchment area of the tributary during the Supra-regional Survey. By the soil geochemical survey of the Area T, various evidences of an existence of Au and Ag mineralization were found in the southern part of the area, such as intrusions of diorite porphyry at 8 location, silicification/pyrite dissemination in sedimentary rocks surrounding the intrusions, Au, Cu, Hg, S and Zn anomalies of soil geochemical survey and occurrences of high Au, Ag (maximum Au 18.4 g/t, Ag 931.4 g/t) in thin quartz veins and float along the main stream. These evidences strongly support the high potentiality of the Au and Ag mineralization in the Area T and a possibility of the mineralization to continue further south from the Area T.

For further investigating and evaluating the Au and Ag mineralization, the S. Imbak Sub-area was established including southern part of Area T (S. Imbak Sub-area North) and south extension of the Area T (S. Imbak Sub-area South, Gunong Kuli).

3-1-3 Survey amount

For purpose of investigation and evaluation of Au, Ag mineralization in the southern part of the Area T, geological survey (semi-detail) and geophysical survey was conducted in the S. Imbak Sub-area North(28 km^2). The survey consists of a semi-detail geological survey of 52 km long traverse and IP geophysical survey of 21 km (10 lines). In addition to these, 201 rock samples were collected during the geological survey to investigate the geochemical halo related to the mineralization.

To trace the mineralization of the S. Imbak Sub-area North further to the south , a soil geochemical survey was conducted in the S. Imbak Sub-area South (Gunong Kuli). A total of 283 soil samples were collected in the area of 70 km^2.

3-2 Geological survey (S. Imbak Sub-area North)

A geological survey (semi-detail) was conducted in the S. Imbak Sub-area North.

3-2-1 Survey method

(1) Geological survey

A geological survey (semi-detail) was conducted along drainage system using 1 : 5,000 scale map produced from enlargement of 1 : 50,000 topographic sheet. Other than streams, wherever outcrop is expected, ridges and slopes of mountainous and geophysical survey lines were traversed. Typical rock and ore samples were collected for thin section and polished section. Ore assaying of 7 elements (Au, Ag, Cu, Mo, Pb, Zn and S) and X-ray diffraction analysis were done, respectively, for mineralized and alteration samples. For determination of intrusive age of the intrusive rocks, dating by K-Ar method was conducted.

(2) Rock geochemical survey

A total of 201 rock samples were collected during the geological survey for geochemical investigation. At each outcrop, the sample representing the whole outcrop was taken and description was done on sample sheet. After crushing and splitting they were sent for chemical analysis for 15 elements (Ag, As, Au, Ca, Cu, Hg, K, Na, Mg, Pb, Rb, S, Sb, Sr, Zn).

The analytical results of the geochemical samples were input in computer and statistical data treatment, single element and multi-element analyses were conducted. For the single element analyses, statistic figures such as maximum, minimum, mean values and standard deviation for each element were calculated. A half value of the detection limit was used for the sample showing value less than the detection limit. The mean values calculated are geometric means. The correlation matrix among the elements were also calculated.

The drainage system of the survey area was input in the computer using digitizer and distribution maps of each element were prepared. Exploratory Data Analysis (EDA) method was applied to delineate the threshold value (anomalous value) for each element.

As the multi element analyses, factor analysis was utilized in this survey. The factor analysis is a method to delineate the factor (group of elements) controlling the chemical character of a group of the samples.

The data analyses and interpretation were conducted based on the geological information.

Among the 201 rock samples of geochemical survey, 51 samples were selected for X-ray diffraction analysis.

3-2-2 Geology

The S. Imbak Sub-area North is mainly overlain by the Tanjong formation (NT_2j) of early to middle Miocene. In addition to this, many intrusive bodies of diorite porphyry(I_1) occur in southern part of the area and silicification/pyrite dissemination zone of sedimentary rocks occurs in the central south of the area. Geologic map together with cross sections are given in Plate II-3-1 and Fig. II-3-1 and schematic lithological succession is shown Fig. II-3-2. The sample location of laboratory studies and location of mineralization are given in Fig. II-3-3 . The results of laboratory studies are given on Table II-3-1 (thin section), Table II-3-2 (polished section), Table II-3-3 (X-ray diffraction analysis) and Table II-3-4 (ore assaying). The results of K-Ar dating of the diorite porphyry are given in Table II-3-5.

The Tanjong formation consisting of mudstone, sandstone and intercalation of both mudstone and sandstone occurs predominantly in the area. Based on a ratio of sandstone and mudstone, the Tanjong formation was divided into two horizons, mudstone dominant horizon (lower) and sandstone dominant horizon (upper).

The lower mudstone dominant horizon occurs topographically lower, relatively flat region of the northern and eastern parts of the area. Dark gray to black, slightly soft mudstone dominantly occurs with occasional intercalation of gray to dark gray sandstone layers of 1 m to 50 cm wide. In the eastern part of the area, amount of sandstone slightly increases.

The upper sandstone dominant horizon occurs in the topographically higher, ragged mountain slopes in the southern and western parts of the area. Gray to dark gray, fine sandstone predominantly occurs intercalated by thin dark gray layers of mudstone. The thickness of each layer of mudstone and sandstone varies a few meter to a few 10 cm. In the central south area, because of silicification, a discrimination of sandstone and mudstone is difficult, however, microscopic observation suggests that fine, hard sandstone dominantly occurs in the area forming water falls and ragged slopes.

The mudstone in thin section shows they consists of mainly quartz of 0.02mm to 0.03 mm with occational association of plagioclase fragments. The matrix is filled by fine quartz and accessary minerals such as zircon and tourmaline. Sericite is most common alteration minerals covering over detrital grains. Kaolinite and chlorite, also, occur as alteration minerals. When alteration increase, commonly observed at the vicinity of intrusion of diorite porphyry, amount of sericite and secondary quartz increase.

The sandstone is well sorted, 0.1 mm to 0.3 mmm grain size, arkose sandstone consisting of mainly of quartz with subordinate plagioclase, K-feldspar, rock fragments. When alteration increases, network of sericite occurs with secondary quartz.

The strike and dip of the Tanjong formation is consistent over the area of mountain slop i the southern to western parts of the area. It strikes in NW-SE and dips toward SW at 20° to 40° . While on the flat area dip and strike of sandstone and mudstone is not consistent. The major scale faults was not identified in the area.

The diorite porphyry is a gray porphyritic rock with plagioclase and hornblende phenocrysts of a few mm across. The intrusions occur central south part to eastern part of the area, and they are concordant to sub-concordant to the sedimentary rocks. The size of intrusion varies from few meters to few 100 meters wide and the size of intrusion increases toward east. They are affected by different degree of alteration and their appearances vary from gray color rock with clear porphyritic texture to a totally argillized, white color rock consisting of quartz and sericite. The argillized diorite porphyry commonly occur as small scale intrusion in the central south area. Microscopic observation of the less altered rock shows clear porphyritic texture with plagioclase and hornblende phenocrysts. In addition to them, biotite and clinopyroxene phenocrysts occasionally appear. The altered rock is totally replaced by alteration minerals such as quartz, sericite, calcite, chlorite and the original texture is completely extinguished.

The results of K-Ar dating of 4 diorite porphyry suggest their age of intrusion to be early Pliocene, ranging from 7.25±0.18 (Ma) to 7.82±0.20 (Ma).

3-2-3 Mineralization

The main mineralization and alteration of the area occur within the zone of silicification/pyrite dissemination in the central south part of the area where many intrusive bodies of diorite porphyry occur. In the zone silicification, rarely argillization, and pyrite (arsenopyrite) dissemination with thin pyrite veinlet along fracture occur to the sandstone and mudstone of the Tanjong formation. Furthermore, quartz-sulfides (pyrite, arsenopyrite) veins and lenses of 10 cm to 25 cm occur commonly cutting the sedimentary structure.

The main mineral showings are summarized below and Table II-3-6. Fig. II-3-4 shows sketch of main mineral showings.

IM-1(Sketch 1) : Strongly argillized diorite porphyry occurs associated with remnant of unaltered part for approximately 40 m along the stream. A weak pyrite dissemination is the only mineralization observed in the argillized diorite porphyry. X-ray diffraction analysis shows mainly quartz, sericite/kaolinite mixed layer and chlorite with minor association of Kaolinite and sericite. Assaying dose not show any encouraging results.

IM-2 : Many large, 1 m to few m across, boulders with rusty surface occur in the restricted area of approximately 50 m along stream. They are argillized and silicified sandstone with pyrite dissemination. Assay results show Au ranging from 0.7 g/t to 5.2 g/t.

IM-3(Sketch 2) : Quartz-sulfides (pyrite, arsenopyrire) veins of 1 cm to 20 cm are scattered on the steep ragged slop of approximately 150 m high. The country rock is silicified mudstone and quartz-sulfide veins occur cutting bedding of mudstone, trending in N-S with steep dip toward west. The largest one found in this showing is 15 cm wide and 2 m long. Microscopic observation shows that sulfides are mainly pyrite and arsenopytite with minor association of chalcopyrite and sphalerite.
Covelline and galena rarely appear. Assay results of quartz-sulfides veins shows Au grades of commonly range from 7.0 g/t to 9.5 g/t with the maximum of 24.6 g/t and Ag grade of from 22 g/t to 196 g/t. Cu, Pb and Zn are generally low.

IM-4(Sketch 3) : This mineral showing was found along Line F of geophysical survey line. Two quartz-sulfides (pyrite and arsenopyrite) veins, one on the bottom of the small stream and the other on side wall of the same stream occur concordantly to the bedding of silicified and weakly pyrite disseminated mudstone. The one on the bottom of the stream is 12 cm wide and densely packed by sulfides with poor quartz. The other one is 10 cm wide and strongly oxidized. Microscopic observation shows pyrite and arsenopyrite with minor association of sphalerite, chalcopyrite and covelline. Native gold of few 10 μ was found surrounded by arsenopyrite in two samples (M31, M37) (Fig. II-3-5) and argentite was found in two samples (M-31, M-36). Assay results shows Au ranging from 7 g/t to 72 g/t and Ag ranging from 17 g/t and 67 g/t with minor concentration of Cu, Pb, and Zn. The country rock, silicified mudstone, shows Au 0.3 g/t.

IM-5 : Quartz-sulfides (pyrite, sphalerite) lens of 25 cm × 2 m occur in silicified and pyrite disseminated mudstone. The lens, unlike others, is rich in base metal (Zn 8.9 %, Pb 2.0 %, Cu 0.1 %), Ag (105 g/t) and poor in Au (0.4 g/t).

Other than above there are minor quartz-sulfide veins with Au and Ag in the zone of silicification/pyrite dissemination.

The mineralization and alteration of the S. Imbak Sub-area North is characterized by silicification and pyrite dissemination of the sedimentary rock closely associated by intrusion of diorite porphyry. Quartz sulfide veins with high Au and Ag occur in the zone and they are classified in three types; Au≧Ag type (IM-4), Ag>Au type (IM-3), rich in Pb, Zn, Ag type (IM-5). Although weak Au and Ag mineralization observed in the sedimentary rock at the contact zone with quartz-sulfide veins and diorite porphyry, no major disseminated mineralization in sedimentary rock has not been found.

3-2-4 Rock geochemical survey and alteration

(1) Sampling

In addition to geological survey a rock geochemical survey was conducted in S. Imbak Sub-area North. Locations of collected samples and their list are, respectively, shown in Fig. II-3-6 and Appendix 2.

(2) Statistical data treatment

Analytical results are shown in Appendix 3. These analytical results were input to a computer and statistical figures were obtained. The results of these are given in Table II-3-7. Among 201 sample for geochemical survey, 17 samples are diorite porphyry and lest of them are sandstone and mudstone. The mudstone and sandstone shows similar chemical character, however there is some chemical differences between two and diorite porphyry. The diorite porphyry shows following chemical characters compared with sandstone and mudstone.

Clearly high in diorite porphyry: Ca, Sr
Slightly high in diorite porphyry: Cu, Mg, Na
Low in diorite porphyry: As

Compared with argillized diorite porphyry with fresh diorite porphyry, the latter shows higher As, K and lower Ca, Na.

Ag, As, Au, Hg and S show high maximum values of Ag 17.37 ppm, As 13,675 ppm, Au 6,920 ppb, Hg 2,290 ppb and S 11.15 %.

In order to clarify relationships between the elements, correlation coefficients were also calculated. The results show following pairs of elements to be comparatively good (correlation coefficient: more than 0.500) correlations.

Ag-Au-As, Ca-Mg-Na-Sr, K-Rb, Mg-Zn

Good correlations between the elements such as Ag, As and Au are probably reflecting the chemical nature of mineralization in the area. Ca, Mg, Na, Sr are high in diorite porphyry.

(3) Single element analysis

Distribution maps of each element were prepared (Appendix 4) using the values obtained by EDA method. Distributions of each element are summarized as follows;

Ag: Anomalies are distributed over area of silicified/pyrite dissemination zone and the area north of the zone is covered by high value zone. The samples of high value occur in the northwestern part of the area.

As: Similar to Ag distribution, high value and anomalous zones occur over the area of silicified/pyrite dissemination zone in central south of the area and the area north of the zone is, also, covered by high value zone.

Au: Overlapping the Ag and As distributions, anomaly and high value zone occur over the silisified/pyrite dissemination zone. Almost all samples corrected outside of silicified/pyrite dissemination zone show concentration below detection limit.

Ca: All samples with anomalous value are diorite porphyry. Many samples of in the silicified/pyrite dissemination show concentration below background value.

Cu: Distribution of samples with anomalous value and high value is restricted in the zone of silicified/pyrite dissemination and diorite porphyry of eastern part of the area.

Hg: Sample of high value is scattered over the area and no characteristic distribution is observed.

K: Samples of high value occur in and around the silicified/pyrite dissemination zone and in diorite porphyry of the eastern part of the area.

Mg: Diorite porphyry and some of the sedimentary rock outside of the silicified/pyrite dissemination zone show high value. Samples in silicified/pyrite dissemination zone show concentration below background value.

Na: Similar to Mg distribution, diorite porphyry shows high concentration and depleted in zone of silicified/pyrite dissemination.

Pb: Anomalous zones only occur in the zone of silicified/pyrite dissemination.

Rb: No clear distribution tendency observed, however, samples of silicified/pyrite dissemination tend to show high value.

S: High value zone occur at the center of silicified/pyrite dissemination zone trending in N-S. Other this high value zones occur in the western part of the area.

Sb: Samples of high value is scattered over the area and no clear distribution tendency is observed.

Sr: Diorite porphyry shows high concentration.

Zn: Samples of anomalous value are distributed in the silicified/pyrite dissemination zone. High value zone occur in mudstone in the northern part of the area.

Distributions of anomalous zone and high value zone of the elements possibly related to the mineralization of the area are shown in Fig. II-3-7. Anomalies and high value zones of As, Au, Cu and S occur closely associated in the silicified/pyrite dissemination zone. Anomalous zones of Ag, Cu and Au, also, occur immediate north of the silicified/pyrite dissemination zone.

The samples of silicified/pytrite dissemination are depleted in Ca, Mg and Na, because of alteration.

(4) Multi element analysis

Factor analysis was conducted as a multi element analysis in this survey. The results of factor analysis are given in Table Ⅱ-3-8. Following relationships between elements and factors were extracted by the factor analysis.

Factor 1 : -Ag, -As, -Au, Ca, Mg, Na, Sr
Factor 2 : -Cu, -Hg, -Mg, -S, -Zn
Factor 3 : K, Rb
Factor 4 : -Ag, -Au
Factor 5 : -Pb, -Zn
Factor 6 : Hg

Considering the relations between factors and related elements and distributions of each element, Factor 1, Factor 2 and Factor 3 are related to mineralization and alteration of the area. Distribution map of these factor scores was prepared allocating three different colors for each factor (Fig. Ⅱ-3-8). Three factors are shown by following colors.

Factor 1 : red   Factor 2 : blue   Factor 5: yellow

Distribution tendencies of these factors are summarized as below;

Factor 1: Samples of high factor score are distributed over the zone of silicified/pyrite dissemination and extended further north to the outside of the zone.

Factor 2: High factor score zone overlaps Factor 1 zone, distributed in the zone of silicified/pyrite dissemination with an elongated shape in N-S trend.

Factor 3: Distribution of high factor score occurs at the eastern edge of silicified/pyrite dissemination where Pb, Zn mineralization of mineral showing IM-5 occurs.

The factor analysis suggests that mineralization and alteration of the S. Imbak Sub-area are characterized by Factor 1. Ag, As and Au are considered to be indicators of mineralization and Ca, Mg, Na and Sr with negative relation with former three elements are indicator of the alteration. Consequently, zone of high Factor 1 factor score is considered to be the area of high potential for mineralization. Distribution of high Factor 5 factor score in the eastern edge of silicified/pyrite dissemination zone support the Pb-Zn mineralization exist in the area in addition to Ag and au mineralization.

(5) Alteration

To understand the characteristic feature of the alteration related to the mineralization of the area, X-ray diffraction analysis was conducted for 18 samples collected from mineral showing and alteration zone and, together with these, for 51 randomly selected samples from the rock geochemical survey X-ray diffraction analysis was conducted to consider alteration halo related to the mineralization.

The alteration of mineral assemblages of quartz-sericite-Se/Mo(sericite/montmorillonite)-kaolinite-sericite. Altered sandstone and mudstone has common mineral assemblage of quartz and sericite associated by chlorite, kaolinite and Se/Mo. A negative relation is observed between plagioclse and sericite. A sample of abundant plagioclase has a small amount of sericite and a sericite rich samples amount of plagioclase is rare or absent. Therefore, amount of sericite can be used as a indicator of alteration.

Based on the above, alteration mineral assemblages are considered for 51 samples. Base on three key minerals characterizing the alteration of the area, Se/Mo, chlorite and appearance of sericite more than trace amount, results of X-ray diffraction analysis were shown on Fig. II-3-9. As shown in the figure, three zones of alteration minerals are identified in a concentric distribution surrounding the silicified/pyrite dissemination zone at the center. Se/Mo occurs in the outer margin, mainly northwestern part of the area and chlorite occur in the middle, near the out margin of silicified-pyrite dissemination zone. The samples with sericite more than trace amount occur only in side the sericite/pyrite dissemination zone. The three zones considered to be indicator of the intensity of alteration. The alteration increases toward the silicified/pyrite dissemination zone.

The existence of argillized diorite porphyry in the outside of silicified/pyrite dissemination zone and no strong argillization found at the vicinity of argillized diorite porphyry suggest that argillization of diorite porphyry is a different episode of alteration from alteration of sedimentary rocks.

3-3 Geophysical survey (S.Imbak Sub-area North)

3-3-1 Survey method

(1) Purpose

The purpose of the survey is to clarify the relation with the existing mineralization and the geochemical anomalies in the survey area. An investigation of the electrical structure of the survey area was carried out by clarifying the distribution of IP anomalies in the survey area by means of an IP method.

The measurements were also done by using the time domain IP method adopting dipole-dipole electrode configuration with a separation factor "n" from 1 to 4. Based upon the geological structure, 8 survey lines of 2.0 km each and another 2 lines of 2.5 km each in length were set along a N-S direction with a 300m line spacings. The numbering of IP survey stations were set from 0 to 20 or 25 with 100m spacing from the north to the south. Survey specifications are shown in Table II-3-9. Location of survey lines and rock samples are illustrated in Fig. II-3-10.

Table Ⅱ-3-9 Survey specifications

Method	Specifications
Measuring	Time domain
Configuration	Dipole-dipole
n-spread	n = 1 to 4
Survey lines	10 lines
Total amount	21.0 line-km
Line spacings	300 m
IP measurement of rock samples	
	Chargeability & resistivity 14 pcs

(2) Method of IP measurement

The time domain IP method was also used in the survey area as same as the in Pinanduan Sub-area.

(3) IP measurement of rock samples

IP measurement of rock samples were carried out in order to determine the actual electrical properties of rocks distributed on the survey area. The 14 rock samples collected from the surface were measured using the same type of receiver of Scintrex Ltd.(IPR-12) as in field survey.

(4) Survey equipment used

Survey equipments used for the IP survey are the same as the equipments in the Pinanduan Sub-area.

3-3-2 Method of analysis

Analysis method is the same as the procedure used for IP data analysis and interpretation in the Pinanduan Sub-area.

3-3-3 Survey results

(1) Results of rock sample measurements

Resistivity and chargeability were measured for 14 rock samples collected in this area. The location of rock samples collected are shown in Fig. Ⅱ-3-10 , and the corresponding measurement results are indicated in Table Ⅱ-3-10. Collected rock samples consist of mudstone(5 samples), sandstone(4 sample), diorite porphyry(4 samples) and ores(2 samples).

Resistivity of rock samples ranges from 3 to 4,040 ohm-m. Rock sample of I-3 and I-7 are the ores which contain small grains of native gold in arsenopyrite. These samples indicate a low resistivity.

Rock samples of I-9, I-13, I-15 which contain a many micro-fractures, indicate a medium resistivity values. The others show a high resistivity. Chargeability values, which are generally indicative of sulfide contents, range from 1.7 to 124.2 mV/V. The ores and rock samples with much pyrite, such as I-3, I-7 and I-1 show the highest chargeability values of 49, 124.4, and 31.9 mV/V. The others indicate a low chargeability values of less than 15 mV/V.

(2) Distribution of apparent resistivity and chargeability (Fig. II -3-11 to Fig. II -3-14)

In this survey area, apparent resistivity values were detected in the range from 1 to 1,000 ohm-m and chargeability values in range from -40 to 77 mV/V.
Based on this, apparent resistivity and chargeability values were also classified into three group as followings.

Classification of apparent resistivity and chargeability values

Class	Apparent resistivity(AR) (ohm-m)	Chargeability(M) (mV/V)
High	65 < AR	30 < M
Medium	15 < AR < 65	10 < M < 30
Low	AR < 15	M < 10

Distribution of apparent resistivity is a medium to low in the northern part of the area consisting of mudstone, especially low values less than 5 ohm-m at depth in the area. High chargeability zone with over 30 mV/V extends to the north-eastward in the central part of the survey area. Highest chargeability values with over 40 mV/V are detected at shallower part in a southern half of the Line-F. These high chargeability values suggest a strong mineralization. In the survey area, the following types of IP anomalies are seen.

Classification of IP anomaly type

Type	Item	Alteration/Mineralization
Type 1	Resistivity Low Chargeability High	Strong alteration and much Sulfidation Dissemination type
Type 2	Resistivity Medium Chargeability High	Medium alteration and much Sulfidation Dissemination and/or vein combination type
Type 3	Resistivity High Chargeability High	Weak alteration and much Vein type

1) IP Anomaly Type 1

This type of IP anomaly is located in and around the zones:

No.16 to 17 in the shallow of Line-D,

No.15 to 17 in the shallow,No.16 to 17 in the medium of Line-E,

No.10 to 11 in the medium, and No.11 to 12 from the shallow to the depths of Line-F.

Sources of the IP anomaly is mainly distributed in the mountainous area in the central-southern part of the survey area.

2) IP Anomaly Type 2

This type of IP anomaly is located in and around the zones:

No.12 to 13 from the shallow to the depths of Line-D,

No.12 to 14 from the medium to the depths of Line-E.

Sources of the IP anomaly is also mainly distributed in the mountainous area the same as the distribution of IP Anomaly Type 1.

3) IP Anomaly Type 3

This type of IP anomaly is not located in the survey area.

(3) Simulation analysis

The strong IP anomaly, mentioned above, which probably indicates a strong sulfide mineralization , was considered important for the simulation analysis. The results of the two dimensional model simulation for the IP anomalies are shown in Fig.II-3-15.

Distribution of strong IP anomaly bodies was previously described in section (2). These IP anomaly bodies continue to extend to the southward in central-southern part of the survey area. IP anomaly type 1, with resistivity low and chargeability high, is seen in the mountainous area in the southern part of the survey area, mainly the south half of Line-D and Line-F. IP anomaly type 2 with resistivity medium and chargeability high is distributed in the southern part of the survey area, mainly the south half of Line-D and Line-E.

3-4 Soil geochemical survey (S. Imbak Sub-area South, Gunong Kuli)

A soil geochemical survey was conducted in the S. Imbak Sub-area South to trace the mineralization of S. Imbak Sub-area North toward south.

3-4-1 Survey method

(1) Sampling and sample preparation

Soil was used as the sample media. A geologic survey including sampling of laboratory studies was simultaneously carried out along the sampling routes of the geochemical survey. The soil samples were collected at the upper part of B horizon and a density of soil sample is 4 samples/km2.

During the sampling each sampling site was described on the sampling list. The amount of sample collected at each sampling site is more than 1 kg for soil samples. After drying up soil sample, -80 fraction was prepared, then it was split into two portions, one for chemical analyses and the other for spare sample stored at the Geological Survey of Malaysia, Sabah office. The samples were sent to the laboratories in Japan and Canada for chemical analyses of 21 elements(As, Au, Ba, Co, Cr, Cu, Hg, K, Mg, Mn, Mo, Na, Ni, Pb, S, Sb, Sr, Ti. U. W, Zn).

The sampling work was conducted by fly camp.

(2) Statistical data treatment

The analytical results of the geochemical samples were input in computer and statistical data treatment, single element and multi element analyses were conducted. For the single element analyses, statistic figures such as maximum, minimum, mean values and standard deviation for each element were calculated. A half value of the detection limit was used for the sample showing value less than the detection limit. The mean values calculated are geometric means. The correlation matrix among the elements were also calculated. Based on this calculation, distribution map of each element was drawn by computer. The drainage system of the survey areas were input in the computer using digitizer and distribution maps of each element were prepared. Exploratory Data Analysis (EDA) method was applied to delineate the threshold value (anomalous value) for each element.

As the multi element analyses, factor analysis was utilized in this survey. The factor analysis is a method to delineate the factor (group of elements) controlling the chemical nature of a group of samples.

The data analyses and interpretation were made using geological information of the survey area.

3-4-2 Geology and Mineralization

(1) Geology

The area is overlain by the Tangoing formation (N_2Tj) of early to middle Miocene and it is intruded by numerous intrusive bodies of diorite porphyry(I_1). Silicification and pyrite dissemination of the Tangoing formation are observed in the area of diorite porphyry intrusion. Geologic map together with cross sections are given in Fig. II-3-16 and sample location of laboratory studies is given in Fig. II-3-17. The results of laboratory studies are given on Table II-3-11 (thin section), Table II-3-12 (polished section), Table II-3-13

(X-ray diffraction analysis) and Table II-3-14 (ore assaying).
Dating by K-Ar method was conducted for three samples of diorite porphyry and the results are given on Table II-3-15.

The Tangoing formation consisting of mudstone, sandstone and intercalation of both mudstone and sandstone occurs predominantly in the area. Sandstone tend to dominate on the steep slope of both side of the ridge and almost only sandstone occurs near the ridge. Whole, on the lower flat area in the southeastern and southwestern parts of the area mudstone commonly occurs. Dark gray to black, slightly soft mudstone occurs with occasional intercalation of gray to dark gray sandstone layers. Fine to medium size sandstone is gray to dark gray color and shows massive appearance. The mudstone shows similar appearance to the mudstone of the S. Imbak Sub-area North, however, sandstone is slightly different. Quartz arenite is dominant sandstone of the area.

The strike and dip of the Tangoing formation is consistent over the area and similar to the S. Imbak area. It strikes in NW-SE to N-S and dips toward SW at 20° to 40° .

Despite the existing information of the area, which shows only Tertiary sedimentary rocks in the area, numerous intrusions of the diorite porphyry along the ridge were found by this survey.

The diorite porphyry is a gray porphyritic rock with plagioclase and hornblende phenocrysts of a few mm across. The intrusions occur along the steep slop of both side of ridge and most dominant on the western slop in the central part of the area. The size of intrusion varies from few meters to few 100 meters wide. They are affected by different degree of alteration and their appearances vary from gray color rock with clear porphyritic texture to light gray rock with obscured porphyritic texture.

Microscopic observation of the less altered rock shows clear porphyritic texture with plagioclase and hornblende phenocrysts. In addition to them, biotite and clinopyroxene phenocrysts occasionally appear. The altered rock is totally replaced by alteration minerals such as quartz, sericite, calcite, chlorite and only trace of original texture preserved by pseudomorphs of plagioclase and hornblende phenocryst.

The results of K-Ar dating of 3 diorite porphyry samples suggest their age of intrusion to be late Miocene to early Pliocene, ranging from 7.27±0.18 (Ma) to 10.5±0.27 (Ma).

(2) Mineralization

The mineralization in the area is silicification and pyrite dissemination of sedimentary rocks and diorite porphyry. The intensive of occurrences of this are found in on the western slope of ridge in the northwestern part of the area and central part of the area. These silicification and pyrite dissemination occur commonly in the sedimentary rock at the vicinity of diorite porphyry intrusion. The diorite porphyry with a weak dissemination of chalcopyrite was observed in the silicification/pyrite dissemination zone of the central part of the area. Polished section shows a mineral assemblages of pyrite, sphalerite, chalcopyrite and, in addition to them, a small grain of native gold was observed surrounded by chalcopyrite.

Assay results of the silicified/pyrite disseminated sandstone in the northwestern part of the area shows some trace of Au and Ag mineralization (Au 0.2 g/t, Ag more or less 1.0 g/t). Chalcopyrite disseminated diorite porphyry with small native gold grain shows Au 0.9 g/t, Ag 1.9 g/t and Cu 0.64 %.

3-4-3 Survey result

(1) Sampling

A soil geochemical survey was conducted in S. Imbak Sub-area South (Gunong Kuli). Locations of collected samples and their list are, respectively, shown in Fig. II-3-18 and Appendix 5. After drying up these samples, -80 mesh fractions were prepared for chemical analyses.

(2) Statistical data treatment

Analytical results are shown in Appendix 6. These analytical results were input to a computer and statistical figures were obtained. The results of these are given in Table II-3-16.
The statistical figures of the S. Imbak Sub-area South show following tendencies comparing with those of other areas with similar geological environment.

Element indicating higher value:	As, Hg, Cu
Element indicating lower value:	Co, Mg, Mn

As, Au, Cu, Hg show high maximum values of As 724 ppm, Au 234 ppb, Cu 1,999 % and Hg 1,755. If compared with the statistical figures of the area with those of Area T of the supra-regional survey, As, Au, Cu, Hg are higher and Pb, S are lower in the S. Imbak Sub-area North.

Correlation coefficients show good correlations between the elements such as As, Au and Pb and this probably reflects the chemical nature of the mineralization that occurs in the area.

(3) Single element analysis

Based on the results of statistical data treatment, the threshold values were determined using EDA method. Distribution maps of each element were prepared (Appendix 7) using the values obtained by EDA method. Distributions of each element are summarized as follows;

As: High value zone occur along the ridge and silicified/pyrite dissemination zone in the northwestern part of the area is covered by high value zone.

Au: Anomaly and high value zones, clearly, cover the silicified/pyrite dissemination zone of northwestern part and central part of the area.

Ba: Anomaly occur in northeastern, northwestern and southeastern parts of the area.

Co: Anomaly and high value samples occur along the ridge at relatively higher elevation.

Cr: Anomaly and high value samples are distributed along the both side of ridge. Cr concentration is low in the silicified/pyrite dissemination zone.

Cu: High value samples are scattered over the both side of ridge at relatively low elevation. The silicified /pyrite dissemination zone of the central area is covered by high value zone.

Hg: Anomaly zones clearly occur over the silicified/pyrite dissemination zones of northwestern and central part of the area.

K: High concentration samples are scattered over the area of lower elevation.

Mg: Samples of high concentration occur over the western flank of the ridge.

Mn: High value samples are distributed over the area of silicified/pyrite dissemination zone in the central part of the area.

Mo: Many samples (87.3 %) show concentration below detection limit. The samples with Mo value more than detection limit occur over the area of silicification/pyrite dissemination.

Na: Anomaly and high value samples occur both side of the ridge at relatively lower elevation. Na concentration is very low in the silicified/pyrite dissemination zone.

Ni: Ni shows similar distribution pattern to Cr, being distributed over the area of lower elevation on the both side of ridge.

Pb: High value zones are distributed covering the silicified/pyrite dissemination zone of northwestern and central parts of the area.

S: High value zones, clearly, occur covering the silicified/pyrite dissemination zone of northwestern and central part of the area.

Sb: High value samples occur over the silicified/pyrite dissemination zone.

Sr: Distribution of high value samples is restricted only in the area of lower elevation.

Ti: Similar to the distribution of Sr, high value samples are scattered over the area of lower elevation on both side of ridge.

U: Anomaly and high value samples occur over the silicified/pyrite dissemination zone in the central part of the area.

W: Many samples (84.8%) show concentration below detection limit, however, samples of with concentration more than detection limit occur over the silicified/ pyrite dissemination zone in the northwestern part of the area.

Zn: High value zone clearly cover the silicified/pyrite dissemination zone.

Considering the distribution map and geologic environment of the area, five elements were selected for the anomaly map given in Fig. II-3-19. The silicified/ pyrite dissemination zone in the northwestern part of the area is cover by anomaly and high value zones of As, Hg, S , while, silicified/pyrite dissemination zone in the central part of the area is covered by anomalies and high value zones of Au, Cu, Hg and S.

(4) Multi element analysis

Factor analysis was conducted as a multi element analysis in this survey. The results of factor analysis are given in Table II-3-17. Following relationships between elements and factors were extracted by the factor analysis.

Factor 1 : -Co, -Mg, -Mn, -Na, -Ni, -Zn
Factor 2 : -Au, -Cu, -Sb, -W
Factor 3 : -Ba, -K, -Mg, -Na,-Sr
Factor 4 : Cr, Ni, Ti
Factor 5 : -Cu, -Pb, -U
Factor 6 : As, Au, Hg, S

Considering the relations between factors and related elements and distributions of each element, Factor 2 and Factor 6 can be related to the mineralization of the S. Imbak Sub-area South. Factor 3 reflects chemical nature of unaltered sedimentary rocks and diorite porphyry. Including these three factors, a distribution map of factor scores was prepared allocating three different colors for each factor (Fig. II-3-20). Three factors are shown by following colors.

Factor 2 : blue Factor 3 : yellow Factor 6 : red

Distribution tendencies of these factors are summarized as below;

Factor 1: High factor score zones extensively occur over the northern part of the area including silicified/pyrite dissemination zone of the northwestern part of the area. Some small high factor zone are scattered in the area of silicified/pyrite dissemination zone in the central part of the area.

Factor 2: Samples of high factor scores are scattered over area of lower elevation in the western part of the area and the area of diorite porphyry.

Factor 6: High factor score zone occurs covering over the silicified/pyrite disseminated zone in the central part of the area. Small high factor score zones occur in the silicified/pyrite dissemination zone in the northwestern part of the area.

The factor analysis suggests that the mineralization in the S. Imbak Sub-area South is characterized by Factor 2 and Factor 6. The silicified/pyrite dissemination zones in the northwest and south west show slightly different chemical character. The former is characterized by Factor 2 and the latter is characterized by Factor 6. The areas covered by high factor score of these factors are considered to be high potential areas for mineralization.

3-5 Discussion

3-5-1 Geological survey and geophysical survey (S.Imbak Sub-area North) (Fig. II-3-21)

The S. Imbak Sub-area North is overlain by the Tanjong formation of early to middle Miocene and numerous concordant intrusion of diorite porphyry occur in the Tanjong formation. The main mineralization and alteration occur within approximately, 2 km × 2 km wide, zone of silicified/pyrite (arsenopyrite) dissemination in the central south part of the area where many intrusive bodies of diorite porphyry occur. Au and Ag bearing quartz-sulfides (pyrite, arsenopyrite) veins and lens of 10 cm to 25 cm wide occur, sporadically, in the silicified/pyrite dissemination zone. Assay results of them show Au ranging from 8 g/t to 72 g/t and Ag ranging from 30 g/t to 196 g/t. The mineral assemblages of them are pyrite, arsenopyrite, chalcopyrite and two samples show small grains of native gold surrounded by arsenopyrite.

Rock geochemical survey in the area shows that the silicification/pyrite dissemination zone are covered by overlapping anomalies and high value zones of Ag, As, Cu, S. High factor score zone of Factor 1 (Ag -