No. 23

REPORT
ON
THE COOPERATIVE MINERAL EXPLORATION
IN
THE CENTRAL SABAH AREA
MALAYSIA

(PHASE I)

MARCH 1995

JAPAN INTERNATIONAL COOPERATION AGENCY
METAL MINING AGENCY OF JAPAN

REPORT
ON
THE COOPERATIVE MINERAL EXPLORATION
IN
THE CENTRAL SABAH AREA
MALAYSIA

(PHASE I)

MARCH 1995

JAPAN INTERNATIONAL COOPERATION AGENCY
METAL MINING AGENCY OF JAPAN

PREFACE

In response to the request of the Government of Malaysia, the Japanese Government agreed to conduct a Mineral Exploration Project in the Sabah area and entrusted the project to the Japan International Cooperation Agency (JICA) and the Metal Mining Agency of Japan (MMAJ).

The JICA and MMAJ sent to Malaysia a survey team headed by Mr. Masatsugu Okazaki from October 20, 1994 to January 10, 1995.

The team exchanged views with the officials concerned of the Government of Malaysia and conducted a field survey in the central Sabah area. After the team returned to Japan, further studies were made and present report has been prepared. This report includes the survey results of a semi-detailed geological and geochemical surveys and geophysical survey in Phase I.

We hope that this report will serve for the development of the mineral resources and contribute to the promotion of friendly relations between Japan and Malaysia.

We wish to express our deep appreciation to the officials concerned of the Government of Malaysia for their close cooperation extended to the team.

March, 1995

Kimio Fujita
President
Japan International Cooperation Agency

Takashi Ishikawa
President
Metal Mining Agency of Japan

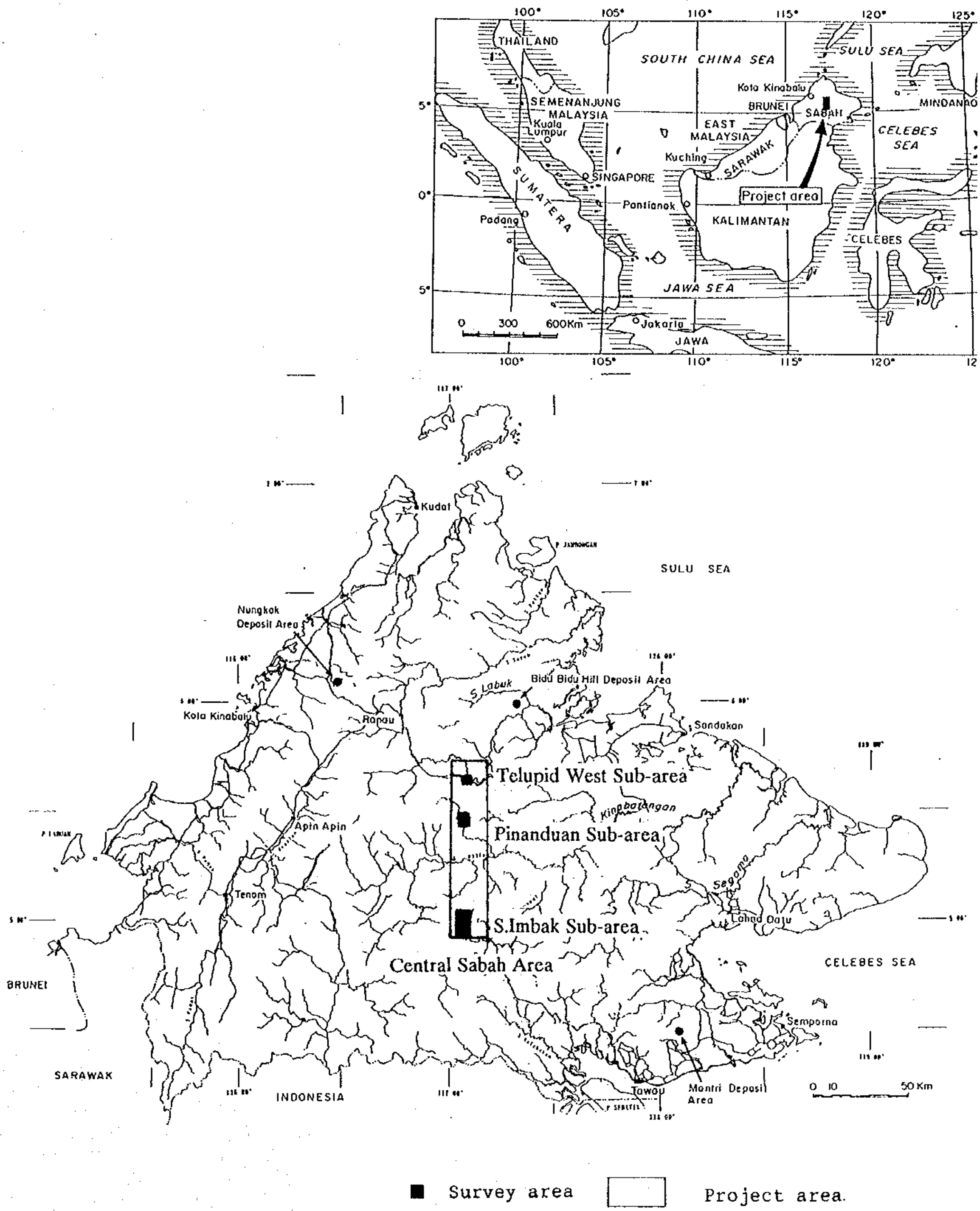


Fig. 1 Location map of the project area

ABSTRACT

The Government of Malaysia and the Government of Japan agreed a three-year mineral exploration project, starting from 1994, in the central Sabah area. The Scope of Work for this project was signed by both governments on 1st September 1994. The objective of this project is to explore and to assess the mineral potential of the survey area. This report includes the survey results of the first year (Phase Ⅰ).

Semi-detail geological, geochemical survey including pitting and auguring and geophysical survey were conducted in three sub-areas, Telupid West, Pinanduan and S. Imbak Sub-areas of the Central Sabah area.

(1) Terupid West Sub-area

The laterite soil of the Telupid West shows similar vertical profile and chemical characters to the laterite soil of the typical Ni laterite deposit elsewhere in the world. The typical laterite soil succession of the Telupid West consists of laterite soil, laterite soil with weathered peridotite fragments and saprolite.

A very wide range of Ni grade, ranging from less than 100 ppm to more than 2 %, was obtained from the laterite soil and saprolite of the Telupid West. Although vertical chemical variation exists at each site, it is considerably small compared with a large lateral variation. This, in addition to shallow development of laterite soil especially around central hill, may suggest the laterite soil of the Telupid West to be premature.

Although relatively high grade soil (more than Ni 0.8 %) occur along and around crest of the central hill, the thicknesses are restricted in 2 m to 3 m. While, thickness of the laterite soil reaches more than 5 m in flat area, but Ni grade is very poor. The limited lateral and vertical distribution of relatively high Ni, only along and around the crest of the central hill implies that ore reserve is not enough for further exploration and exploitation of Ni laterite of the Telupid West.

(2) Pinanduan Sub-area

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 were 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 to northeastern part (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 suggest 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.

(3) S. Imbak Sub-are

1) S. Imbak Sub-area North

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.

The mineralization in the area is characterized by Au - Ag type related to intrusion of diorite porphyry. Considering from the geological environment, mineral assemblages of ore minerals and alteration minerals, this mineralization is not an epithermal type. However, type of silver minerals occurring in the area and relatively high Ag compared to Au suggest temperature of mineralization to be relatively low. One of the possibility is that this area is located at the outer margin of a porphyry copper type mineralization. The intrusion age of the diorite porphyry is contemporaneous to the intrusive rocks of Mamut mine, which is Au rich porphyry copper type mine.

The distribution of IP anomalies obtain by the survey correspond well with distribution of silicified/pyrite dissemination zone in the central south of the area and anomaly seems to extend further south. The strongest anomaly is located from south end of Line D to central south of Line F in the silicified/pyrite dissemination zone. The Au anomaly of rock geochemical survey in the southern part of the area correspond to the medium to strong chargeability anomaly with more than 20mV/V. The strong chargeability anomaly with 30mV/V at the central south of Line F correspond to the location where Cu and S anomalies overlap. Consequently, there is strong indication of an existence of sulfide in the area surrounding central south of Line F.

The potentiality of sulfide mineralization is high and further detail survey in the area is awaited.

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

Numerous intrusive bodies of diorite porphyry were found along both slopes of the ridge that runs in the center of the area. Dating shows their age of intrusion to be early Pliocene. The silicified/pyrite dissemination zones occur in the sedimentary rock along the slopes of the ridge, closely associated with intrusion of diorite porphyry. The most intensive silicified/pyrite dissemination zone occur in the northwestern part of the area and the central part of the area. The one in the central part of the area shows a chalcopyrite dissemination in the diorite porphyry, in addition to pyrite dissemination of the sedimentary rocks. The polished section of this shows a small grain of native gold surrounded by chalcopyrite. The southern extension of the mineralization that occurs in the S. Imbak Sub-area North was confirmed along the ridge of Gunong Kuli in S. Imbak Sub-area South.

Geochemical survey shows distributions of overlapping Au, Cu, Hg, S anomalies and high value zones over the areas of silicified/pyrite dissemination zones northwestern and central parts of the area. These areas are also covered by high factor score zone of, respectively, Factor 2 and Factor 6. These areas of high factor score have high potentiality for the mineralization.

CONTENT

Preface
Location map of the project area
Abstract
Contents

Part I General

Chapter 1 Introduction 1
1-1 Background and objectives 1
1-2 Coverage and outline of Phase I survey 1
1-3 Member of the project 1
1-4 Survey period 3

Chapter 2 Geography of the survey area 7
2-1 Location and access 7
2-2 Topography and drainage system 7
2-3 Climate and vegetation 8

Chapter 3 Geology and economic geology of Sabah, Malaysia 11
3-1 General geology 11
3-2 Mineralization and mining activities 11

Chapter 4 Survey results 16
4-1 Telupid West Sub-area 16
4-2 Pinanduan Sub-area 16
4-3 S. Imbak Sub-area 17

Chapter 5 Conclusions and recommendations 19
5-1 Conclusions 19
5-2 Recommendations 21

Part II Survey Results

Chapter 1 Telupid West Sub-are 29
1-1 Introduction 29
1-1-1 Survey Area 29
1-1-2 Background 29

1-1-3 Survey method and amount of work 29
1-2 Survey results 30
1-2-1 Augering 30
1-2-2 Pitting 31
1-2-3 Analytical result of soil samples 31
1-3 Discussion 32

Chapter 2 Pinanduan Sub-area 39
2-1 Introduction 39
2-1-1 Survey area 39
2-1-2 Background 39
2-1-3 Survey amount 39
2-2 Geological survey 40
2-2-1 Survey method 40
2-2-2 Geology 40
2-2-3 Mineralization 40
2-3 Geophysical survey 41
2-3-1 Survey method 41
2-3-2 Method of analysis 44
2-3-3 survey results 44
2-4 Discussion 47

Chapter 3 S. Imbak Sub-area 81
3-1 Introduction 81
3-1-1 Survey area 81
3-1-2 Background 82
3-1-3 Survey amount 82
3-2 Geological survey (S. Imbak Sub-area North) 82
3-2-1 Survey method 82
3-2-2 Geology 83
3-2-3 Mineralization 84
3-2-4 Rock geochemical survey and alteration 86
3-3 Geophysical Survey 89
3-3-1 Survey method 89
3-3-2 Method of analysis 90
3-3-3 Survey results 90
3-4 Soil geochemical survey (S. Imbal Sub-area South, Gunong Kuli) 93
3-4-1 Survey method 93
3-4-2 Geology and Mineralization 93
3-4-3 Survey result 95

3-5 Discussion 97
3-5-1 Geological survey and geophysical survey (S.Imbak Sub-area north) 97
3-5-2 Soil geochemical survey (S. Imbak Sub-area South, Gunong Kuli) 98

Part Ⅲ Conclusions and recommendations

Chapter 1 Conclusions 165

Chapter 2 Recommendations for the future 167

Reference
Lists of figures, tables, plates and appendices
Appendices

Part I General

Chapter 1 Introduction

1-1 Background and objectives

In accordance wgith the Scope of Work signed between the Government of Malaysia and the Government of Japan on 1st September 1994, the mineral exploration was carried out in the Central Sabah area in the state of Sabah, Malaysia. Based on the results of the Supra-regional survey in central Sabah conducted during a period of 1989 to 1993, the Central Sabah Area (Fig. 1) was selected as an area of the highest mineral potential in Sabah. This project is three years project starting from 1994 and this report includes the survey results of Phase Ⅰ.

The objectives of the project is to explor and to assess the mineral potential of the survey area. The survey of the Phase Ⅰ includes hand auger and pit survey in the Telupid West Sud-area, semi-detail geological and geophysical survey in both of the Pinanduan and S. Imbak Sub-areas and semi-detail, soil geochemical survey in the south of the S. Imbak Sub-area (Gunong Kuli).

1-2 Coverage and outline of Phase Ⅰ survey

The Central Sabah Area with a rectugular shape (NS 90 km × EW 20 km) extending south from Telupid, is located in the central part of the Sabah and in the southern part of the Labuk Area of the Supra-regional survey (Fig. 1). The surveys of the Phase Ⅰ were conducted in the three sub-areas of Telupid West, Pinanduan and S. Imbak. The amount and content of the work for Phase Ⅰ survey are Table Ⅰ-1 and Table Ⅰ-2.

For understanding of Ni concentration in lateritic soil that covers the Telupid West Sub-areqa hand augering and pitting were conducted. In the Pinanduan and S. Imbak Sub-areas, semi-detail geological survey and gephysical survey (IP method) were conducted for understanding of the nature and geologic environment of mineralization of the areas. A soil geochemical survey was conducted in the southern part of the S. Imbak Sub-area (Gunong Kuli area), which is imeadiate south of the semi-detail geological survey and geophysical survey area of S. Imbak, for a porpose of tracening geochemical anormalies such as Au and As found during the Supra-regional survey further south.

The field work was conducted establishing base camp at two locations, along the logging road at the nearest point to the S. Imbak Sub-area and within the area of Pinanduan Sub-area.

1-3 Member of the project

The members of the project are as followings:

(1) Project planning and negotiation

Japanese Counterpart

Shingoro Tsuchiya	Metal Mining Agency of Japan
Yoich Iida	Ministry of International Trade and Industry
Yoshiaki Igarashi	Matal Mining Agency of Japan
Tetsuo Suzuki	Manila office, Metal Mining Agency of Japan

Malaysian Counterpart

Fateh Chad	Director General	Geological Survey of Malaysia
Lim Peng Siong	Director	Geological Survey of Malaysia
Chu Ling Heng	Head of Corporate Unit	Geological Survey of Malaysia
Pola Singh	Senior Assistant Director	Economic Planning Unit
Suhaimi		Economic Planning Unit
Mohamed Nor Aziz		Ministry of Primary Industries
P. Loganathan	Secretary	Geological Survey of Malaysia

(2) Inspection of field work

Eishi Endo	Metal Mining Agency of Japan
Naoki Sato	Matal Mining Agency of Japan
Tetsuo Suzuki	Manila office, Matal Mining Agency of Japan

(2) Field survey

Japanese Counterpart

Masatsugu Okazaki	Team leader	Bishimetal Exploration Co., Ltd.
	Geol. and Geochem. Survey	Bishimetal Exploration Co., Ltd.
Makoto Kawamura	Geol. and Geochem. Survey	Bishimetal Exploration Co., Ltd.
Masatane Kato	Geophysical Survey	Bishimetal Exploration Co., Ltd.
Kohei Sugawara	Geophysical Survey	Bishimetal Exploration Co., Ltd.
Takayuki Yokoyama	Geophysical Survey	Bishimetal Exploration Co., Ltd.

Malaysian Counterpart

Alexander Yan	Deputy Director	Geological Survey of Malaysia
Joanes Muda	Geologist	Geological Survey Of Malaysia
Wong Vui Chunug	Geologist	Geological Survey of Malaysia
Dzazali b. Hi Ayub	Geophysicist	Geological Survey of Malaysia
Salleh Adanan	Assistant	Geological Survey of Malaysia
Japili Samin	Assistant	Geological survey of Malaysia

1-4 Survey period

The field work and compilation work were conducted in Malaysia during the period shown below.

Geological and Geochemical surveys including augering and pitting.

Field Work	October 10, 1994	to	December 31, 1994
Compilation Work	January 1, 1995	to	January 7, 1995

Geophysical Survey

Field Work	October 10, 1994	to	December 21, 1994
Compilation Work	December 22, 1994	to	December 28, 1994

Table I-1 Summary of work amounts

Survey Method	Work Amount	
(1)Geological Survey (semi-detail)		
1)Pinanduan Sub-area	Survey Area	30 km^2
	Survey Route	52 km
2)S. Imbak Sub-area	Survey Area	28 km^2
	Survey Rout	52 km
	Rock Samples for Geochemical Survey	201 samples
(2)Geochemical Survey		
1) Telupid West Sub-area	Survey Area	16 km^2
	Pit	5 sites
	Hand auger	72 sites
	Soil samples	292 samples
2) S. Imbak Sub-area (Gunong Kuli Sub-area)	Survey Area	70 km^2
	Soil samples	283 samples
(3)Geophysical Survey (IP method)		
1) Pinanduan Sub-area	Total line length	14.4 km
	Number of lines	8 lines
	Number of measurement	462 times
2) S. Imbak Sub-area	Total line length	21.0 km
	Number of lines	10 lines
	Number of measurement	700 times

Table I -2 Work amounts of laboratory studies

Laboratory Studies	Geological Survey	Geochemical Survey	Total
1) Thin section	27 samples	24 samples	51 samples
2) Polished sectoion	20 samples	7 samples	27 samples
3) X-ray diffraction analysis	71 samples	11 samples	82 samples
4) Dating (K-Ar method)	4 samples	3 samples	7 samples
5) Chemical analysis			
a)Rock (15 elements: Au, Ag, Cu, Pb, Zn, Sb, As, Hg, K, Na, Sr, Rb, Ca, Mg, S)	201 samples		201 samples
b)Soil-1 (5 elements: Al, Co, Fe, Cr, Ni)	292 samples	292 samples	292 samples
c)Soil-2 (21 elements: As, Au, Ba, Co, Cr, Cu, Hg, K, Mg, Mn, Mo, Na, Ni, Pb, S, Sb, Sr, Ti, U, W, Zn)		283 samples	283 samples
d)Ore Assay (7 elements:Ag, Au, Cu, Mo, Pb, S, Zn)	61 samples	20 samples	81 samples
3. Geophysical survey			
1) Resistivity measurement			20 samples
2) Porlarizability measurement			20 samples

Chapter 2 Geography of survey area

2-1 Location and access

Malaysia, a principal member of ASEAN countries, consists of Western Malaysia occupying the Malay Peninsular and East Malaysia occupying the northernand the southwestern parts of the Borneo island. The total population of West and East Malaysia is 18.0 millions. The area of the whole country is approximately 330,000 km^2.

The East Malaysia comprises the State of Sabah and State of Sarawak. The State of Sabah, occupying area of 73,700 km^2 in the northeastern part of the Borneo island, has population of approximately 1.393 millions. It is facing Kalimantan of Indonesia on the south, Sarawak on the southeast and surrounded by the sea such as South China, Sulu and Celebes on the west, north and east.

The state capital is Kota Kinabalu on the west coast of Sabah. Direct flights from various cities, including outside of the country (Singapore, Hong Kong, Taiwan, Phillipines, Japan) and domestic (Kuala Lumpure, Tawau, Sandakan) connecting the Kota kinabalu International Airport make the easy access to the state of Sabah. The pricipal roads of shealded run connecting major cities such as Kota Kinabalu-Telupid-Sandakan and Sandakan-Lahad Datu-Tawau.

The Central Sabah area, occupying 1,800 km^2(NS 90 km, EW 20 km), extends southward from Telupid in the center of Sabah (Fig I -1). The major road connecting Kota Kinabalu and Sandakan runs northern part of the area, however, other than this, existing roads in the area are the one that goes toward southeast from Telupid connecting small villages and the other one is timber road go south from Telupid along the project area. The latter one is recently connected to the timber road that goes up northward from Tawau. The Telupid West Sub-area and Pinanduan Sub-area are accessible by vehicle, while the there is no road within the area of the S. Imbak Sub-area.

2-2 Topography and drainage system

The state of Sabah is occupied by three characteristic topographic features. Steep, ragged mountains trending in north northeast dominate in the western part of Sabah along the coast. Highland occupies the eastern area and volcanic mountains are found in the southern part. Flat plain is along rivers and their lower tributary. Mt. Kinabalu which is the highest mountain in the southeast Asia, rise up to 13,455 ft in westernend of the Kinabalu area which is occupied by steep topography. Highland dominates in the Labuk and Segama areas. Swamps are found at the lowerpart of main rivers where they are extremely meandered. Highland dominates in the Semporna area except the young volcanics region with volcanic topography.

The main drainage systems in Sabah are Sungai Pegalan, Sungai Sugut, Sungai Labuk, Sungai Kinabatangan, Sungai Segama, Sungai Tingkayu, SungaiKalumpang, Sungai Kalabakan etc. Among these river systems, Sungai Pegalan flowsinto the South China Sea, Sungai Kalumpang and Kinabatangan flows down to the Celebes Sea and other river systems into the Sulu Sea in the east. These riversystems generally form deep valley at the upper stream and extremely meandered down stream. The river also forms swamp area at the mouth of the river.

2-3 Climate and vegetation

The survey area is situated in the tropical monsoon region. From February to July, it is dry to little rain season, from August to January is the rainy season. Precipitation in the dry season is 100 - 250 mm in a month and in the rainy seasonis 200 - 450 mm in a month. Temperature is 22 C to 33 C throughout the year.

The maximum and minimum temperature and monthly rainfall for each month in Kota Kinabalu at the west coast, Sandakan at the east coast and Tawau at the south coast are shown in Table I-3. As shown in this table, east coast has more rainfall than the west coast.

Vegitation in the survey area mainly consists of primary and secondary jungles except the area under plantation. The project area is mostly situated in the secondary jungle.

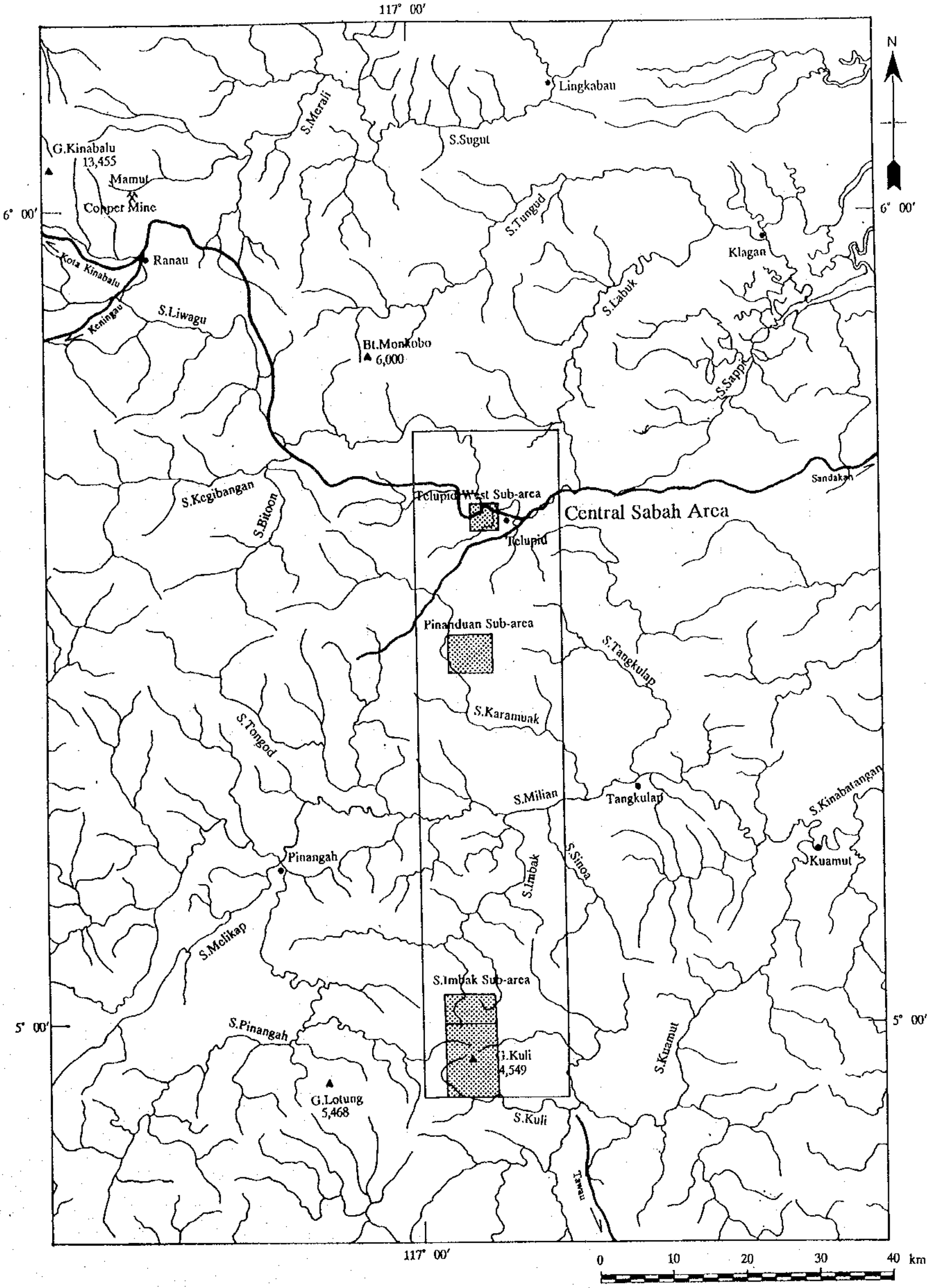


Fig. I -1 Location of the Central Sabah Area

Table I -3 Statistics of temperature and rainfall

Month	Kota Kinabalu			Sandakan			Tawau		
	Temperature(℃)		Rainfall	Temperature(℃)		Rainfall	Temperature(℃)		Rainfall
	Max.	Min.	(mm)	Max.	Min.	(mm)	Max.	Min.	(mm)
January	30.5	22.4	95.1	29.7	24.2	398.2	31.4	22.2	161.4
February	31.6	22.5	61.6	30.5	23.6	229.9	31.9	22.3	132.4
March	31.8	22.8	47.1	31.0	23.8	120.0	32.4	22.6	107.7
April	32.5	23.4	137.5	32.2	23.8	87.5	32.6	22.8	101.3
May	32.5	23.9	287.9	32.5	24.3	110.8	32.8	23.5	113.6
June	31.7	23.3	248.7	32.8	23.6	209.3	32.3	23.0	185.5
July	31.6	23.0	257.2	32.4	23.5	214.5	31.6	22.7	226.3
August	31.7	23.3	263.4	32.9	23.5	183.6	31.3	22.6	217.7
September	31.8	23.2	315.8	32.3	23.5	241.2	31.7	22.5	196.9
October	32.0	23.5	292.9	31.8	23.6	271.9	31.9	22.8	188.1
November	31.4	23.2	314.6	31.2	24.0	324.8	32.4	23.1	174.0
December	31.3	22.7	149.7	29.8	24.4	453.0	32.4	22.4	135.3

Temperature: 1989 and 1990 Rainfall: average of last 10 years(1981 - 1990)

Chapter 3 Geology and economic geology of Sabah, Malaysia

3-1 General geology

The survey area occupies a wide area, streching from the northwest to the southeast corner of the State of Sabah. Known mineral showings are found mostly inthis region. The State of Sabah is underlain by crystalline rocks (Cb), sedimentary rocks accompanied by spilite eruption (K, KP), sedimentary rocks characterized by flysch sediments(P1, P2, P3 and P4) and other sedimentary rocks (N1, N2, N3, N4 and N5). Cb is pre-Triassic rock and forms a basement in this area. K and KP were deposited in the age from Cretaceous to Eocene, during the earlier time of the Northwestern Borneo geocyncline. P1, P2, P3 and P4 were deposited in Eocene through middle Miocene. N1, N2, N3, N4 and N5 were deposited during early Miocene through Pleistocene. Orogenic movement is begun in middle Miocene through Pliocene.

Cretaceous ultra-basic intrusives, syn- and post-orogenic plutonic intrusives and extrusive rocks such as dacite, andesite and basalt of Pliocene to Holocene age are the result of the igneous activities during this period.

Geological map (Y.E. Heng, 1985) of the State of Sabah including the survey area is shown in Fig.I-2. This map tells that crystalline rocks such as schistsand gneisses, which form the basement, and sedimentary rocks are mainly distributedin the Segama area. Sedimentary rocks accompanied by spilite effusion occupied widearea both in the Labuk and Segama areas. Ultra-basic rocks are found in the Kinabalu, Labuk and Segama areas, and closely relates with the sedimentary rocks associated with spilite. Plutonic intrusions such as adamellite and granodiorite are typically found in the Kinabalu area. Volcanic rocks such as dacite, andesite and basalt are found mainly in the Semporna area. This volcanic belt extends northeast toward the southern part of the Philippine.

3-2 Mineralization and mining activities

Principal metallic ore deposits in the survey area comprise porphyry copper deposit closely related with plutonic rocks, Cyprus-type massive sulfide deposit related to spilite extrusion and hydrothermal gold-silver deposits closely relatedwith volcanic rocks. Chromium or platinum deposits are related to the ultra-basicrocks, lateritic aluminum and nickel deposits and manganese deposits in sedimentaryrocks are also found. The distribution map of the main metallic ore deposits andmineral showings in the project area (after K.M. Leong, 1976) are shown in Fig. I-3.

The Mamut mine is the only active mine in the Sabh. The Mamut depositis porphyry copper type, located to the north of Ranau in the Kinabalu area. Thisore deposit was discovered by a geochemical survey conducted by the United Nations Development Program (UNDP). The Overseas Mineral Resources Development Co., Ltd.,Japan, obtained the exploration right on the Mamut area through international tender in 1968, and carried out further exploration work from 1968 to 1972, and began development work in 1973. The mine has been operating since May, 1975. The current production of crude ore is 20 thousand tons per day with the grade of 0.47% Cu. Staffs and workers of the Mamut Copper Mining Sdn. Bhd. are about 1,300.

The Bidu Bidu Hill ore deposit is in the latest stage of the exploration work and the development will be made in the near future. This ore deposit is a Cyprus-type massive sulfide deposit emplaced in spilitic extrusive rocks. Exploration work for this ore deposit is being carried out by Leadstar Sdn. Bhd. Ore reserves of 3,600 thousand tons with 3.6 % Cu, 1 - 2 g/t Au and 8-15 g/t Ag have been confirmed by drilling work (approximately 40,000 m) for this deposit.

Exploration work for gold-silver deposits occured in volcanic rocks in the Semporna area is being carried out by Zamia Sdn. Bhd. The area surveyed by this company covers a wide area from the west of Semporna to northern Tawau. The survey consists of mainly soil geochemical survey and trenching. A few drill holes have been completed for the Mantri area recently.

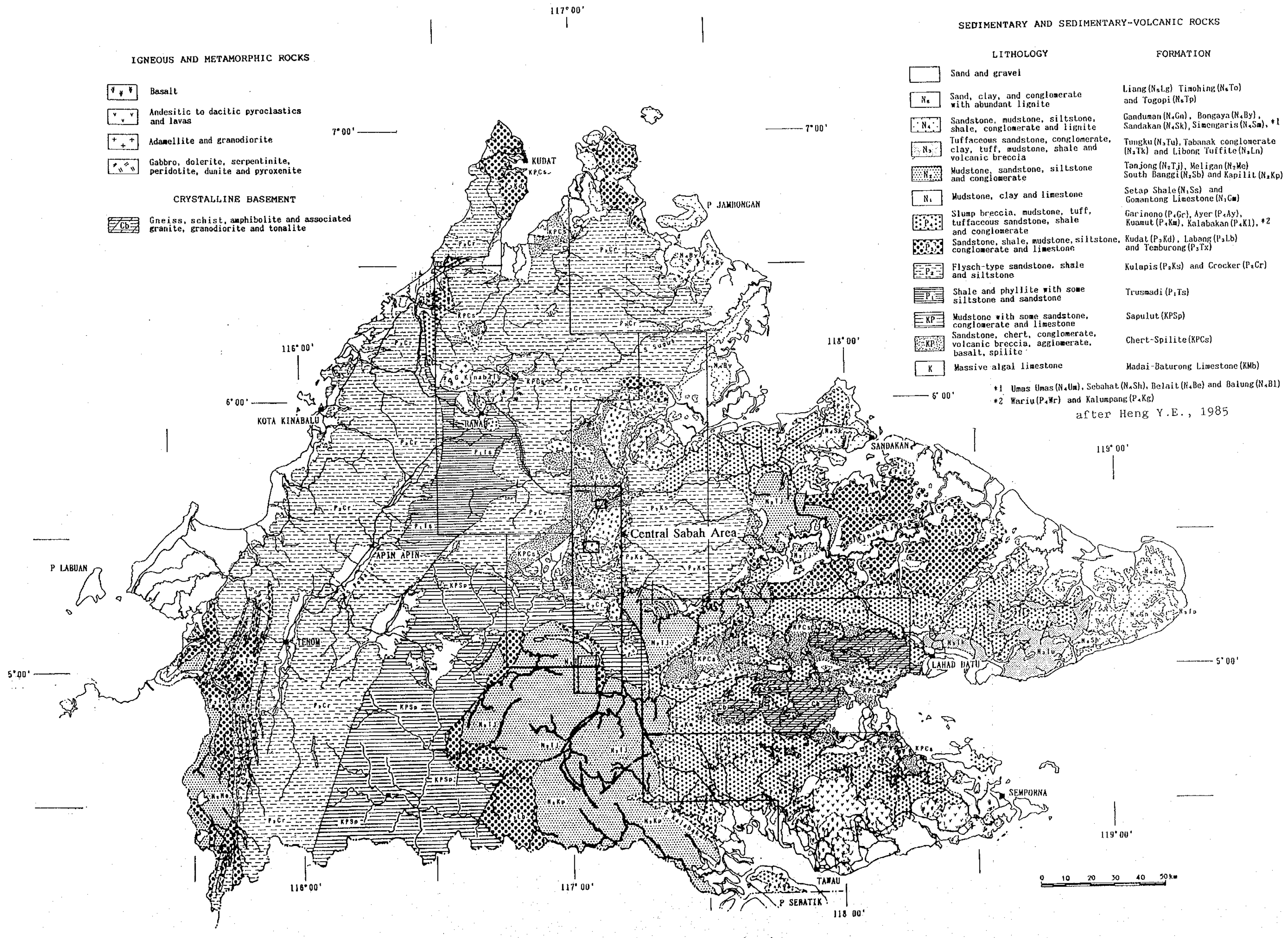


Fig. I-2 Geologic map of Sabah, Malaysia

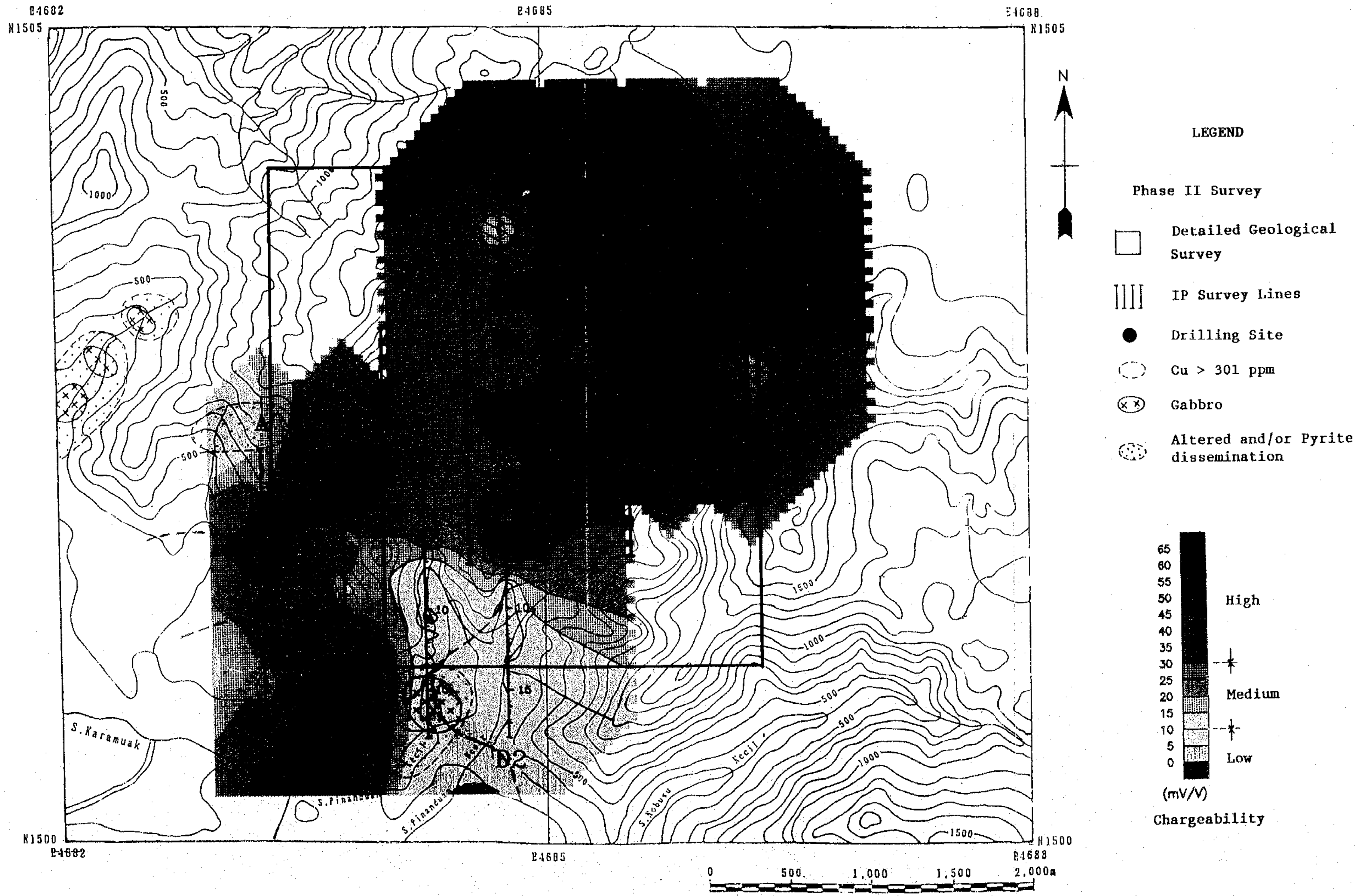


Fig. I-4 Recommendation for future work in Pinanduan Sub-area

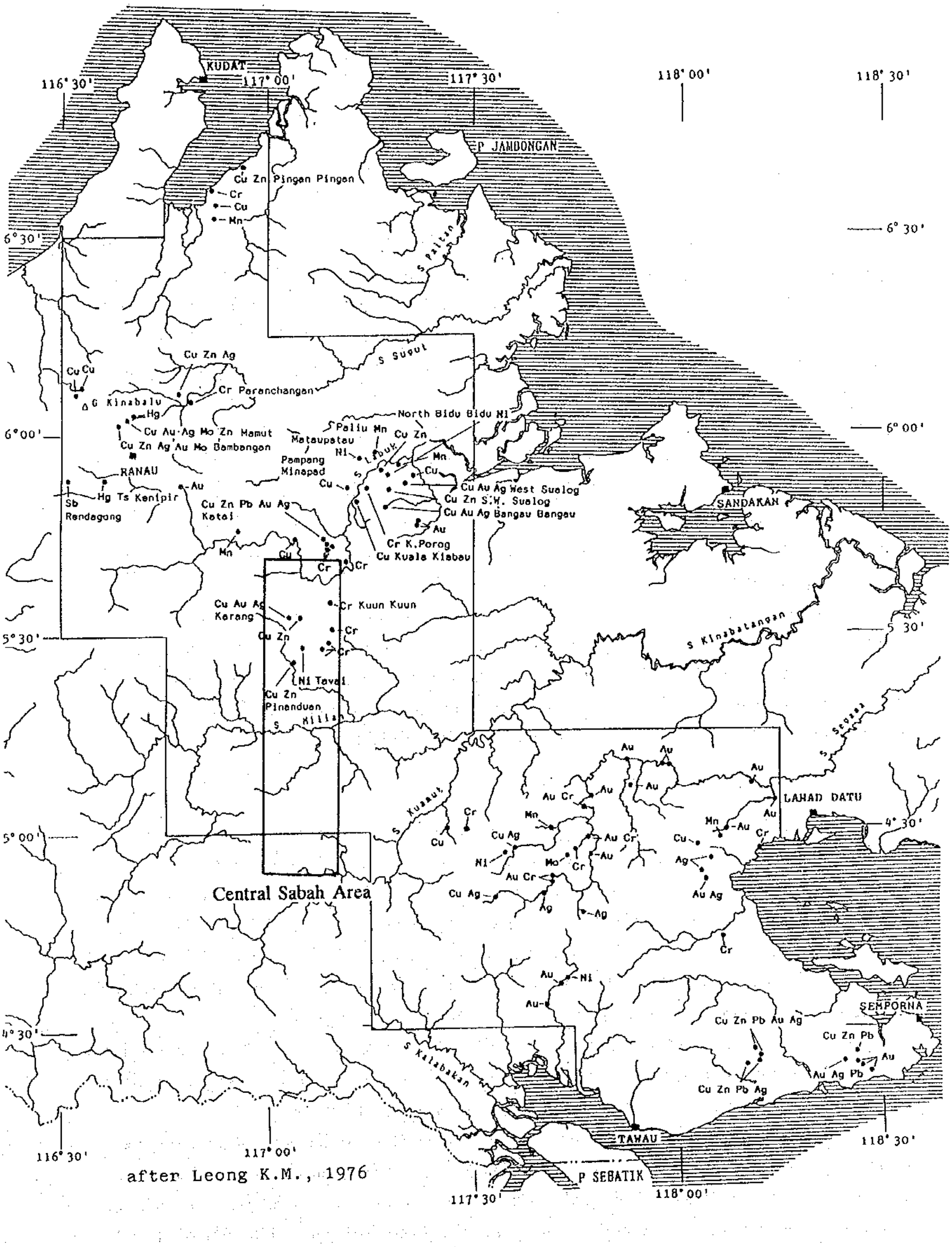


Fig. I -3 Distribution of mineral occurrences in the project area

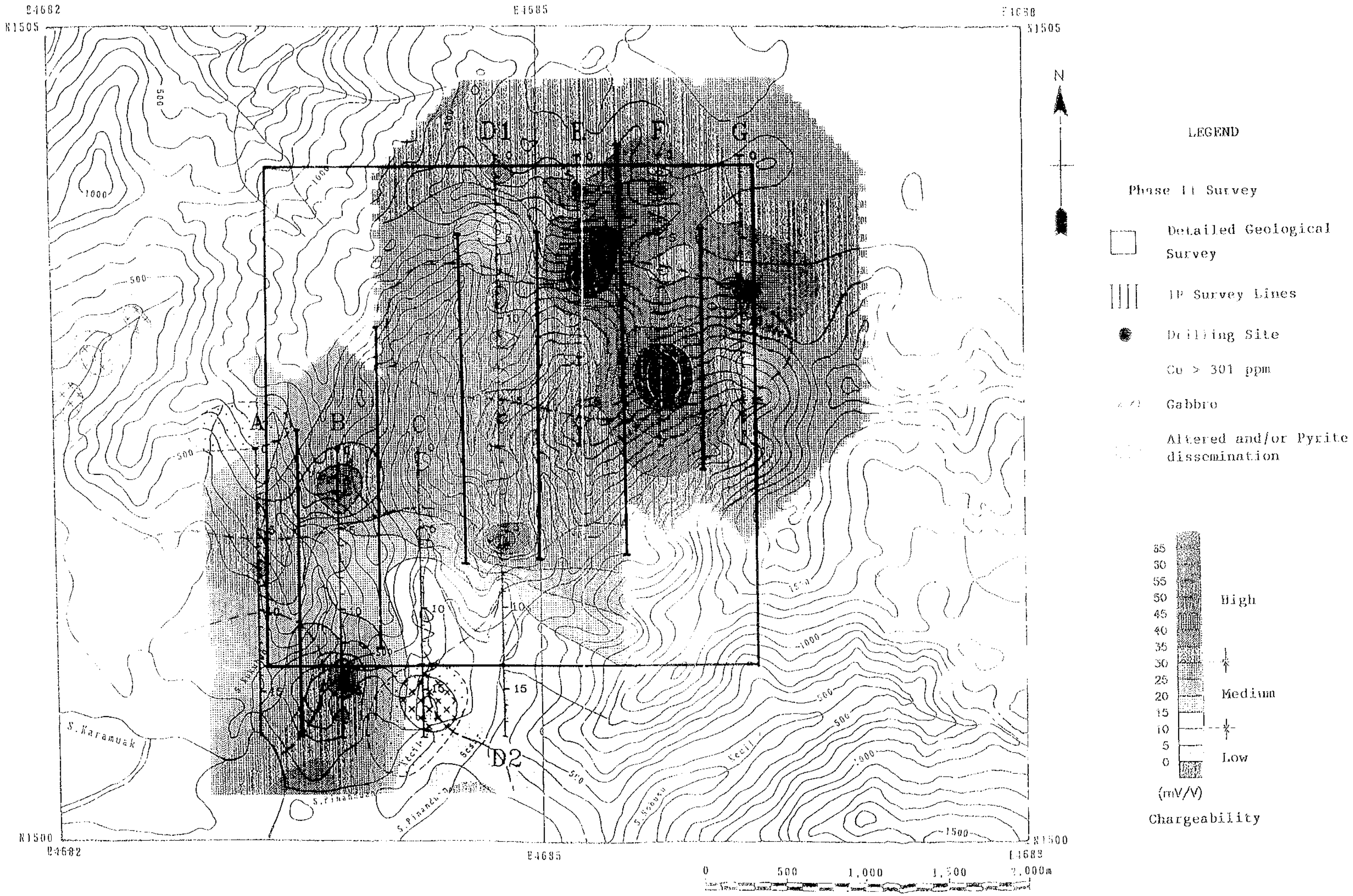


Fig. I -4 Recommendation for future work in Pinanduan Sub-area

Chapter 4 Survey results

4-1 Telupid West Sub-area

The laterite soil of the Telupid West shows similar vertical profile and chemical character to the laterite soil of the typical Ni laterite deposit elsewhere in the world. The typical laterite soil succsession of the Telupid West consits of laterite soil, laterite soil with weathered peridotite fragments and saprolite. Al consistenly dcreases towaord depth, while, Co, Cr, Fe increase in accordance with depth and reaching to the maximum value at the bottom of laterite soil with rock fragments before reaching to saprolite. Ni consistently increases with increase of depth and reaching its maximum at the bottom of saprolite imeadeatly above peridotite bedrock.

A very wide range of Ni grade, ranging from less than 100 ppm to more than 2 %, was obtained from the laterite soil and saprolite of the Telupid West. Although vertical chemical variation exists at each site, it is considerably small compared with a large lateral variation. This in addition to shallow development of laterite soil especially around central hill may suggest the laterite soil of the Telupid West to be prematured.

Although relatively high grade soil (more than Ni 0.8 %) occur along and around crest of the central hill, the thicknesses are restricted in 2 m to 3 m. While, thickness of the laterite soil reaches more than 5 m in flat area, but Ni grade in very poor. The limited lateral and vertical distribution of relatively high Ni, only along and ariund the crest of the central hill implies that ore reserve is not enough for further exploration and exploitation of Ni laterite of the Telupid West.

4-2 Pinanduan Sub-area

Geological survey conducted in the area shows that serpentinized peridotite, consisting mainly of harzburgite, predominantly occur in the area with minor lens of dunite and small intrusive bodies of gabbro. The alteratiogn and mineralization found in the area is not intence. It occurs only in restricted area surrounding intrusive bodies of gabbro where relatively intence alteration zone with strong serpentinization occur accompanied by weak pyrite dissemination, and clay minerals such as chlorite and montmorillonite wre also found. No clear evidence of the mineralization and alteration that refrecting 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, coinside 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 obtaine.

Relatively intence 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 to northeastern part (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 intence anomalies covering the distribution of geochemical anomalies suggest a further detailed survey to be conducted in the area to clarify IP anomaly source.

4-3 S. Imbak Sub-area

(1) S.Imbak Sub-area North

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 approximetly, 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, calcopyrite 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 - As - Au), also, occurs over the area of the silicification/pyrite dissemination zone.

X-ray diffraction analysis shows three zones (SE/Mo, chlorite, sericite) of alteration minerals occur in a concentric distribution surrounding the silicified/pyrite dissemination zone.

From the above the mineralization in the area is characterized by Au - Ag type related to intrusion of diorite porphyry. Considering from the geological environment, mineralassemblages of ore minerals and alteration minerals, this mineralization is not an epithermal type. However, type of silver minerals 1occurring in the area and relatively high Ag compared to Au suggest temperature of mineralization to be relatively low. One of the possibility is that this area is located at the outer margin of a porphyry copper type mineralization. The intrusion age of the diorite porphyry is contemporaneous to the intrusive rock of Mamut mine, which is Au rich pophyry copper type mine.

The distribution of IP anomalies obtain by the survey correspond well with distribution of silicified/pyrite dissemination zone in the central south of the area and anomaly seems to extend further south. The stroogest anomaly is located from south end of Line D to central south of Line F in the silicified/pyrite dissemination zone. The Au anomaly of rock geochemical survey in the southern part of the area correspond to the medium to strong chargeability anomaly with more than 20mV/V. The storong chargeability anomaly with 30mV/V at the central south of Line F correspond to the location where Cu and S anomalies overlap. Concequently, there is storng indication of an existence of sulfide in the area surrounding central south of Line F.

The potentiality of sulfide mineralization is very high and furhter detail survey in the area is awaited.

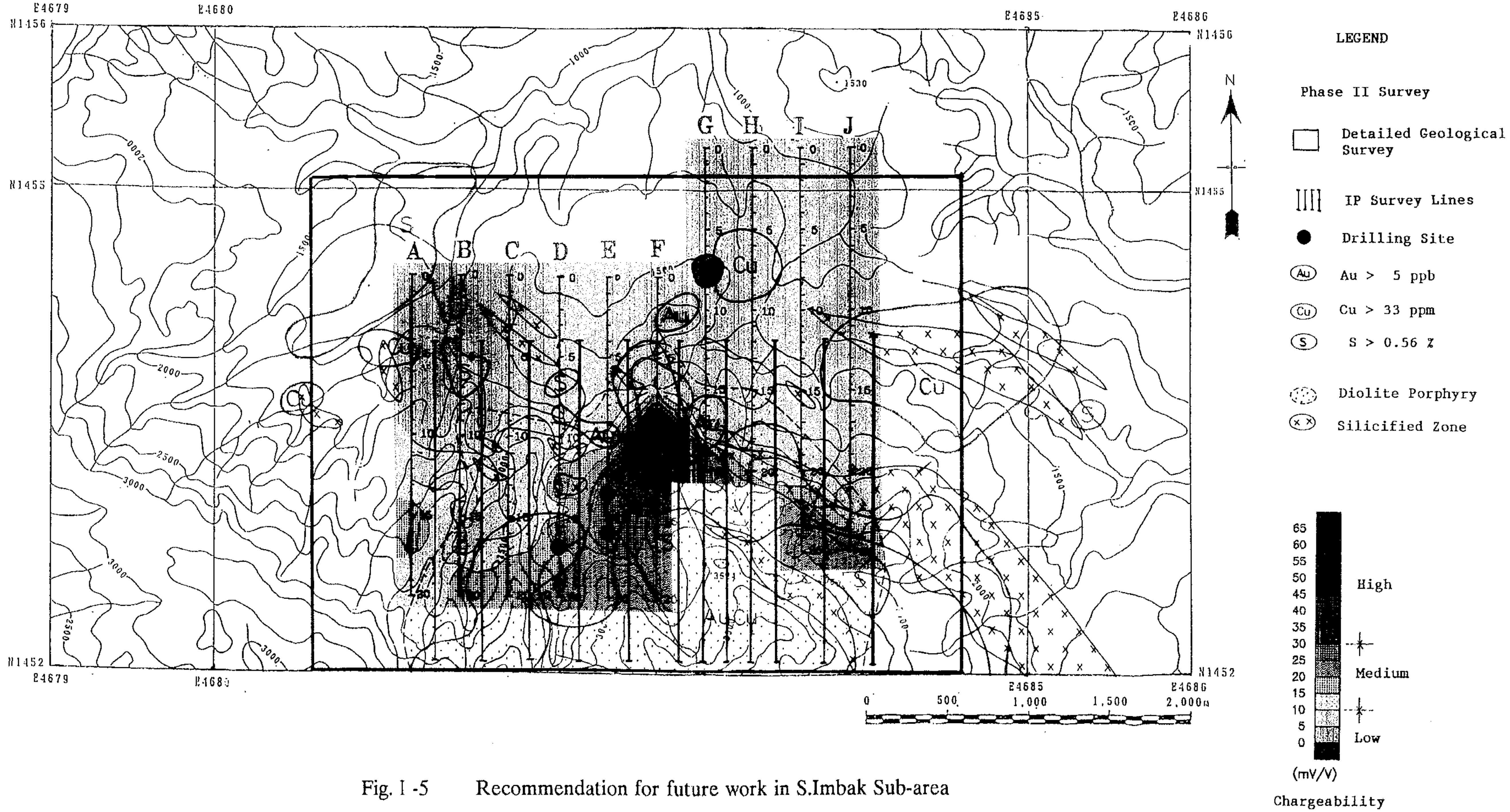


Fig. I -5 Recommendation for future work in S.Imbak Sub-area

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

Numerous intrusive bodies of diorite porphyry were found along both slopes of the ridge that runs in the center of the area. Dating shows their age of intrusion to be early Pliocene. The silicified/pyrite dissemination zones occur in the sedimentary rock along the slopes of the ridge, closely associated by intrusion of diorite porphyry. The most intensive silicified/pyrite dissemination zone occur in the northwestern part of the area and the central part of the area. The one in the central part of the area shows a chalcopyrite dissemination in the diorite porphyry, in addition to pyrite dissemination of the sedimentary rocks. The sample of this shows a small grain of native gold surrounded by chalcopyrite. The southern extension of the mineralization that occurs in the S. Imbak Sub-area was confirmed along the ridge of Gunong Kuli.

Geochemical survey shows distributions of overlapping Au, Cu, Hg, S anomalies and high value zones over the areas of silicified/pyrite dissemination zones northwestern and central parts of the area. These areas are also covered by high factor score zone of, respectively, Factor 2 and Factor 6. These area of high factor score have high potentiality of the mineralization.

Chapter 5 Conclusions and recommendations

5-1 Conclusions

(1) Terupid West Sub-area

The laterite soil of the Telupid West shows similar vertical profile and chemical character to the laterite soil of the typical Ni laterite deposit elsewhere in the world. The typical laterite soil succsession of the Telupid West consists of laterite soil, laterite soil with weathered peridotite fragments and saprolite. A very wide range of Ni grade, ranging from less than 100 ppm to more than 2 %, was obtained from the laterite soil and saprolite of the Telupid West. Although vertical chemical variation exists at each site, it is considerably small compared with a large lateral variation. This, in addition to shallow development of laterite soil especially around central hill, may suggest the laterite soil of the Telupid West to be prematured.

Although relatively high grade soil (more than Ni 0.8 %) occur along and around crest of the central hill, the thicknesses are restricted in 2 m to 3 m. While, thickness of the laterite soil reaches more than 5 m in flat area, but Ni grade is very poor. The limited lateral and vertical distribution of relatively high Ni, only along and around the crest of the central hill implies that ore reserve is not enough for furhter exploration and exploitation of Ni laterite of the Telupid West.

(2) Pinanduan Sub-area

The alteration and mineralization found in the area is not intence. It occurs only in restricted area surrounding intrusive bodies of gabbro in where relatively intence alteration zone with strong serpentinization occur accumpanied by weak pyrite dissemination and clay minerals such as chlorite and montmorillonite was found. No clear evidence of the mineralization and alteration that refrecting 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, coinside 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 obtaine.

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

(3) S. Imbak Sub-are

1) S. Imbak Sub-area North

The main mineralization and alteration occur within approximetly, 2 km × 2 km wide, zone of silicified/pyritc (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, calcopyrite and two samples show small grains of native gold surrounded by arsenopyrite.

The mineralization in the area is characterized by Au - Ag type related to intrusion of diorite porphyry. Considering from the geological environment, mineral assemblages of ore minerals and alteration minerals, this mineralization is not an epithermal type. However, type of silver minerals occurring in the area and relatively high Ag compared to Au suggest temperature of mineralization to be relatively low. One of the possibility is that this area is located at the outer margin of a porphyry copper type mineralization. The intrusion age of the diorite porphyry is contemporaneous to the intrusive rocks of Mamut mine, which is Au rich pophyry copper type mine.

The distribution of IP anomalies obtain by the survey correspond well with distribution of silicified/pyrite dissemination zone in the central south of the area and anomaly seems to extend further south. The strongest anomaly is located from south end of Line D to central south of Line F in the silicified/pyrite dissemination zone. The Au anomaly of rock geochemical survey in the southern part of the area correspond to the medium to strong chargeability anomaly with more than 20mV/V. The strong chargeability anomaly with 30mV/V at the central south of Line F correspond to the location where Cu and S anomalies overlap. Consequently, there is storng indication of an existence of sulfide in the area surrounding central south of Line F.

The potentiality of sulfide mineralization is high and further detail survey in the area is awaited.

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

Numerous intrusive bodies of diorite porphyry were found along both slopes of the ridge that runs in the center of the area. Dating shows their age of intrusion to be early Pliocene. The silicified/pyrite dissemination zones occur in the sedimentary rock along the slopes of the ridge, closely associated with intrusion of diorite porphyry. The most intensive silicified/pyrite dissemination zone occur in the northwestern part of the area and the central part of the area. The one in the central part of the area shows a chalcopyrite dissemination in the diorite porphyry, in addition to pyrite dissemination of the sedimentary rocks. The polished section of this shows a small grain of native gold surrounded by chalcopyrite. The southern extension of the mineralization that occurs in the S. Imbak Sub-area was confirmed along the ridge of Gunong Kuli.

Geochemical survey shows distributions of overlapping Au, Cu, Hg, S anomalies and high value zones over the areas of silicified/pyrite dissemination zones northwestern and central parts of the area. These areas are also covered by high factor score zone of, respectively, Factor 2 and Factor 6. These area of high factor score have high potentiality for the mineralization.

5-2 Recommendations

(1) Telupid West Sub-area

Although relatively high grade soil occurs along and around crest of the central hill, the thicknesses are restricted in 2 m to 3 m. While, thickness of the laterite soil reaches more than 5 m in flat area, but Ni grade in very poor. The limited lateral and vertical distribution of relatively high Ni, only along and around the crest of the central hill implies that ore reserve is not enough for further exploration and exploitation of Ni laterite of the Telupid West.

(2) Pinanduan Sub-area

To the IP anomalies at the upper stream of S. Pinanduan, a detail geological survey (3km × 3km) including rock geochemical survey to clarify the IP anomaly source and IP geophysical survey to trace detail diststribution of anomaly are recommneded (Fig. 1-4).

(3) S. Imbak Sub-area North

Detailed survey including belows in the silicified/pyrite dissemination zone in central south part of the area are recommended for the evaluation of sulfide mineralization underneath the area (Fig. 1-5).

1) preparation of accurate topographic map over the area of silicified/pyrite dissemination

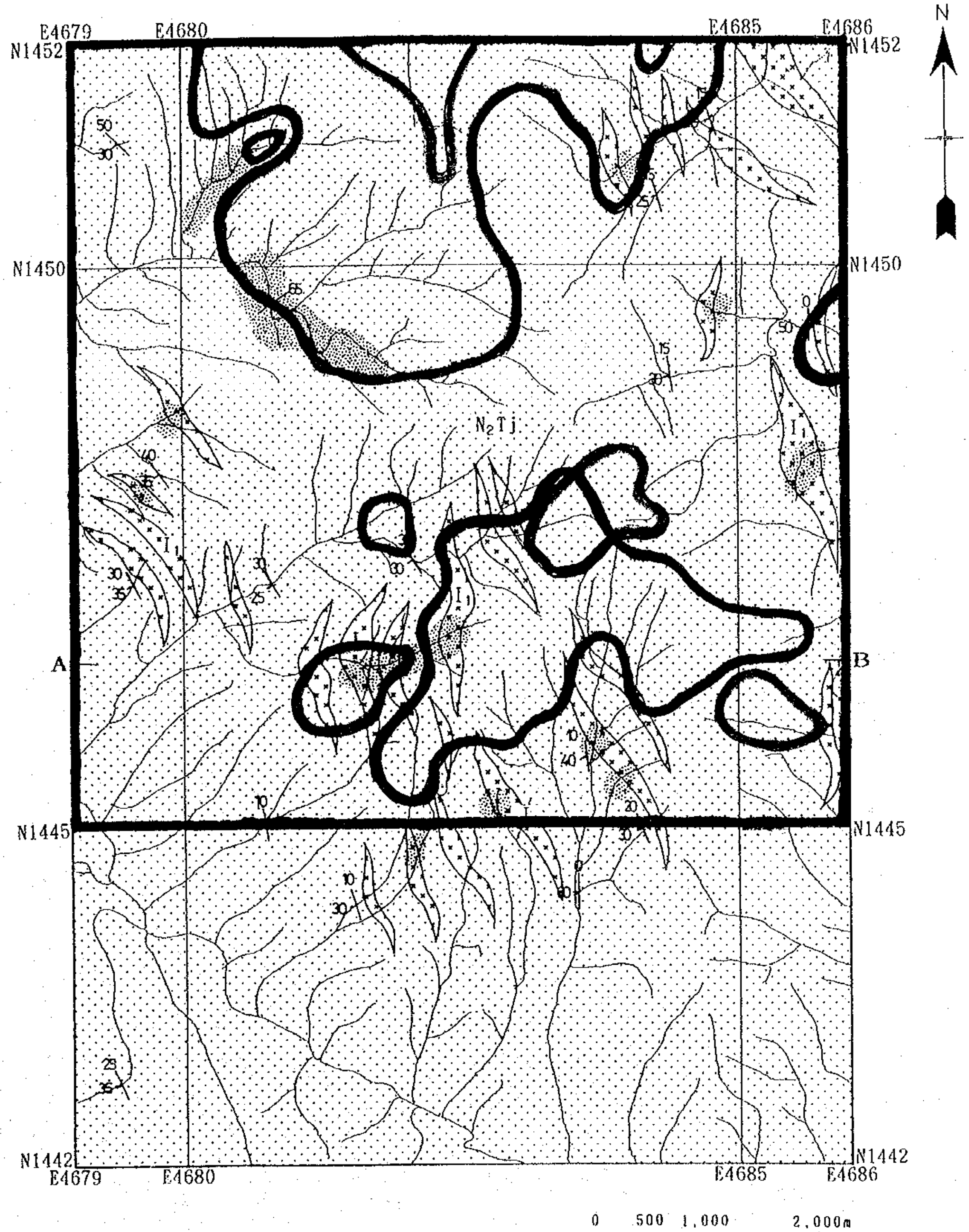
2) detail geological survey (4 km × 3km)

3) IP geophysical survey

4) drilling to IP and geochemical anomalies

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

Semi-detail geological survey and rock geochemical survey are recommended to northen part of the area (7 km × 7km) (Fig. 1-6).



Zone of Factor 2 high factor scores

Zone of Factor 6 high factor scores

Area of recommendation for further work

Fig. I -6 Recommendation for future work in S. Imbak Sub-area (Gunong Kuli Sub-area)

Part II Survey Result

Chapter 1 Telupid West Sub-area

1-1 Introduction

1-1-1 Survey area

The Telupid West Sub-area, 16 km^2 (EW 4km × NS 4 km), is located in northern part of the Central Sabah Area, just west of the town of Telupid. The area is easily accessible by the main road connecting Ranau and Sandakan, which pass through the northern part of the area. The Sungai Labuk, one of the main stream in Sabah, flow toward east in northern part of the area and several small tributaries of the Sungai Labuk is drainage system of the area. The topography of the area is generally gentle with a flat plain and small hill except in the southern part of the area where 500 m high ridge runs in WSW - ENE trend. Auguring and pitting were conducted covering and around the NE-SW trending hill with altitudes of 150 m to 300 m in the central part of the area. The southern part of the area is covered by secondary jungle and the flat area is use for oil palm plantation.

1-1-2 Background

Many, large and small, bodies of ultramafic rock are scattered over the Sabah. Although lateritic soil has been known to occur surrounding these ultramafic rocks, no economical nickel laterite deposit has, so far, been found in Sabah. The hand auger survey covering an area of 21 km^2 in Telupid area (Area N), conducted during Phase IV (1993) of the Supra-regional survey, found a zone of relatively high nickel latelite (more than Ni 0.6 %, maximum 1.45 %) covering the hill located west of Telupid. Therefore, the area was considered to be high potential for nickel laterite deposit and Telupid West Sub-area covering the hill of Ni high were selected for further consideration.

1-1-3 Survey method and amount of work

For understanding the nature of Ni high laterite soil found during the Supra-regional survey, hand augering at 72 sites and pitting, 1 m × 1 m size, at 5 site were conducted at approximately 200 m grid on and around the hill, west of Telupid. The target depth for both auger and pit was 4 m. Since Ni is known to enrich at zone of weathered ultramafic rock (saprolite) which occur between laterite soil and bedrock of ultramafic rock, a priority was given to reach saprolite zone despite the target depth of 4 m.

At each auger site description of soil was conducted at each site to produce columnar section and a soil sample of 1 m long was collected for each meter. At each pit site soil was described in detail to produce sketch and a soil sample for 50 cm was collected for each 50 cm. For each sample approximately 1 kg soil was collected and a total of 293 samples were collected from both auger and pit for chemical analysis. After drying, -80 mesh fraction was sent for chemical analysis.

Chemical analyses were conducted for following 5 elements.

Element	Detection limit	Element	Detection limit
Al	0.01 %	Co	1 ppm
Fe	0.01 %	Cr	2 ppm
Ni	1 ppm		

Nickel laterite deposit is a residual soil produced by weathering of ultramafic rock. Olivin which dominant constituent mineral of ultramafic rock, commonly contains 0.3 % to 0.4 % of Ni, while in nickel laterite soil, Ni grade of as much as more than 2 % is obtained by the enrichment of Ni thorough weathering. A characteristic soil profile is observed in the soil of typical nickel laterite deposit(eg. Guilbert and Park, 1986). It consists of iron oxides crust on the top, laterite soil, saprolite (weathered ultramafic rock) and, then, bedrock of serpentinized ultramafic rock at the bottom. The zone of most Ni enriched is saprolite in which occasionally garnierite (Ni serpentine) occur.

1-2 Survey results

The geology of the area consists of serpentinized peridotite, chert and basalt. The serpentinized peridotite occupies the hill in the center of the area and the mountain in south of the area, while flat area is occupied by chert and basalt. The hill in the center of the area is covered by reddish brown laterite soil and flat area is covered by yellow brown soil.

Locations of hand auger and pit in shown in Fig. II -1-1.

1-2-1 Augering

Hand auger survey was conducted at 72 site and 266 soil samples were collected. Profiles of soil sections and analytical results are given in Appendix 1.

The succession of soil in the Telupid West Sub-area consists of humic soil at the upper most horizon, laterite soil, laterite soil with weathered peridotite fragment, saprolite (weathered peridotite), peridotite bedrock. Compared to a typical horizon of nickel laterite soil, the soil profile of the Telupid West Sub-area lacks iron oxides crust at the top.

Dark brown thin layer, 0.05 to 0.10 m , of humic soil is found only in a restricted area at both flanks of hill in the central part of the area. The humic soil was excluded from sampling for chemical analysis.

Laterite soil of the area has thickness of 1.5 m to more than 5.0 m. In the northern part of the central hill, where highest Ni values were obtained by the previous survey, development of laterite is generally poor and hard bedrock or boulder rich horizon was encountered at the depth of more or less 2.0 m. While both flanks of the central hill, thickness of laterite is 2 m to 4 m and it becomes more than 5 m thick in the flat area. Two types of laterite soil is identified, laterite soil consisting of only soil and laterite soil with rock fragments. The latter composed of soil with weathered peridotite fragments of pebble size and, generally, occurs beneath the former. The laterite soil with rock fragment changes to saprolite at the bottom without clear boundaries. The typical color of laterite soil is reddish to orange brown in the central hill and bark brown to dark gray in the flat area.

Saprolite is weathered ultramafic rock composed of clayey soil or sandy soil with texture of peridotite being preserved. Saprolite occur mainly on flanks of the central hill for a thickens of less than 1 m to more than 3 m. Reddish brown and orange brown are the dominant colors of saprolite.

1-2-2 Pitting

Pitting was conducted at 5 locations where the highest Ni contents were obtained by the previous survey. Descriptions and analytical results are given in Fig. II-1-2.

In the northern part of the central hill, bedrock occurs at shallow depth, 2.60 m and 1.60 m, respectively, for PT1 and PT2. Both of the pits show similar soil profile composed of only laterite soil and laterite soil with rock fragments and they lack saprolite between laterite soil and bedrock.

The three pits (PT3, PT4 and PT5) in the central part of the central hill show similar soil profile, consisting of laterite soil with thickness of approximately 2.5 m and 1 m to 2 m thick saprolite. The green clay mineral occurs along the fracture of saprolite was identified as chlorite by X-ray diffraction analysis (Table II-1-1).

The pit survey suggest that distribution of soil in the northern part of the central hill is poor with thickness of more or less 2 m and laterite soil directly faces bedrock without appearance of saprolite. While, in the central part of the central hill, saprolite occurs beneath the laterite soil of approximately 2.5 m thick, however, its thickness is 1 m to 2 m.

1-2-3 Analytical result of soil sample

Analytical result of 292 soil samples collected from auger and pit sites area, respectively shown in Appendix 1 and Fig. II-1-1.

The results are summarized as follows:

Al: It ranges from 0.49 % to 16.06 % and commonly between a range of 1.0 % to 10.0. Al decrease with increase of depth and shows negative correlations with Co, Fe, Cr, Ni.

Co: It ranges from 7 ppm to 2,932 ppm and commonly a few 100 ppm. Ni shows positive correlation with Ni, however, it shows the maximum value at the bottom of laterite soil and it reduces the concentration further deeper than this.

Fe: It ranges from 2.69 % to 59.03 % and commonly between a range of 10.0 % to 40.0 %. Fe shows similar chemical variation with Co, increasing its concentration toward the bottom of laterite soil and in saprolite it decrease with increasing depth.

Cr: It ranges from 81 ppm to 15,354 ppm (1.54 %) and commonly observed value are between a range of 1,000 ppm to 10,000 ppm (1.0 %). It shows similar chemical variation, increasing it concentration with Ni until bottom of laterite soil and decrease in saprolite.

Ni: It ranges from 71 ppm at the minimum to 21,971 ppm (2.20 %) at the maximum and commonly fall in a range of a few 1100 ppm to 10,000 ppm. The highest values are obtained in laterite soil with peridotite fragment and saprolite. It tends to decrease its concentration at the depth close to peridotite bedrock.

The analytical results show a very wide range of Ni concentration, however, variation of Ni concentration among samples collected at the same site of the different horizon is small. Despite a wide range of lateral variation in Ni concentration, a vertical variation in Ni concentration is small. In addition to this, relatively shallow bedrock horizon may suggest the laterite soil of the Telupid West Sub-area to be relatively premature.

The comparison of colors of laterite soil and saprolite with Ni concentration shows soils of reddish brown and orange color, which occur on the top and along the both flanks of the central hill tend to contain higher Ni concentration than ones with yellow brown and light brown color.

Because of a small vertical variation between samples collected at different depths of the same auger or pit sites, Ni grade for each pit and auger site was calculated by averaging the Ni grade of all samples collected from the same site. This values was considered as the Ni grade of each auger and pit site. Distribution of Ni grade of the Telupid West Sub-area is shown by classifying this average value into 4 ranks by Ni 1.2 %, Ni 0.8 % and Ni 0.5 % (Fig. II-1-3). Frequency and depth of auger and pit for each rank of Ni grade is shown below:

	Number of site	Average depth
Ni ≧ 1.2 %	14 (18.1 %)	2.8 m
1.2 % > Ni ≧ 0.8 %	21 (27.3 %)	3.1 m
0.8 % > Ni ≧ 0.5 %	9 (11.7 %)	3.7 m
0.5 % > Ni	33 (42.9 %)	4.0 m
Total	77 (100 %)	

The highest grade soil, Ni grade more than 1.2 %, occurs along the top and on slop of central hill and intermediate grade soil (Ni 0.5 % to Ni 1.2 %) occurs on both flanks of the central hill surrounding the distribution of the highest grade. While, Ni poor soil occurs on flat area. At the location of highest ore with average depth of 2.8 m, generally, thickness of laterite soil and saprolite is thin, especially in northern part of the central hill where the highest laterite soil occurs only for 2 m to 3 m deep before reaching to hard, peridotite bedrock. While, on the flat plain laterite soil occurs to the depth more than 5 m, however, Ni concentration is very poor.

1-3 Discussion

The laterite soil of the Telupid West shows similar vertical profile and chemical character to the laterite soil of the typical Ni laterite deposit elsewhere in the world. The typical laterite soil succession of the Telupid West consist of laterite soil, laterite soil with weathered peridotite fragments and saprolite. Al consistently decreases toward depth, while, Co, Cr, Fe increase in accordance with depth and reaching to the maximum value at the bottom of laterite soil with rock fragments before reaching to saprolite. Ni consistently increases with increase of depth and reaching its maximum at the bottom of saprolite immediately above peridotite bedrock.

A very wide range of Ni grade, ranging from less than 100 ppm to more than 2 %, was obtained from the laterite soil and saprolite of the Telupid West. Although vertical chemical variation exists at each site, it is considerably small compared with a large lateral variation. This in addition to shallow development of laterite soil especially around central hill may suggest the laterite soil of the Telupid West to be premature.

Although relatively high grade soil (more than Ni 0.8 %) occur along and around crest of the central hill, the thicknesses are restricted in 2 m to 3 m. While, thickness of the laterite soil reaches more than 5 m in flat area, but Ni grade in very poor. The limited lateral and vertical distribution of relatively high Ni, only along and around the crest of the central hill implies that ore reserve is not enough for further exploration and exploitation of Ni laterite of the Telupid West.

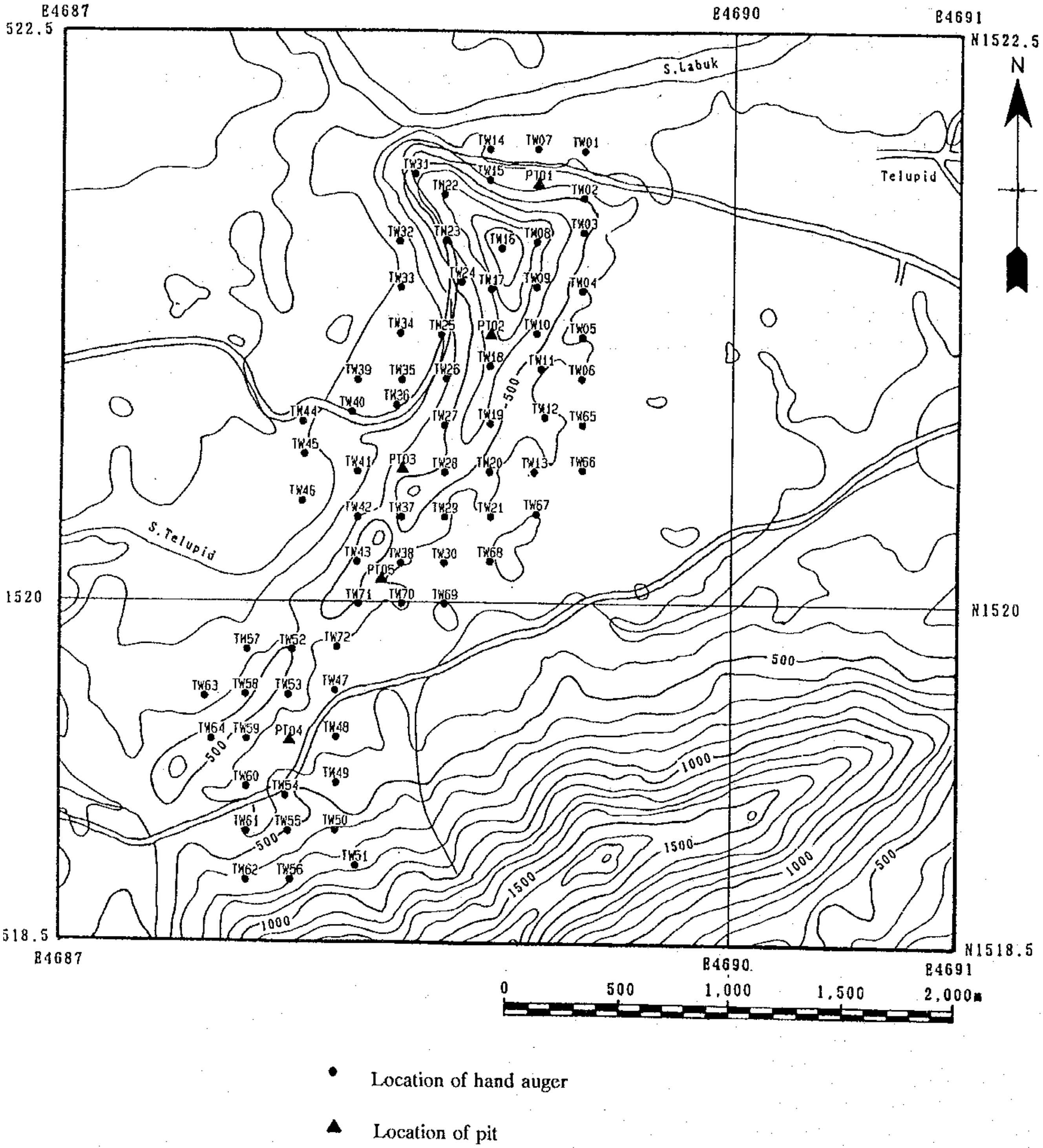
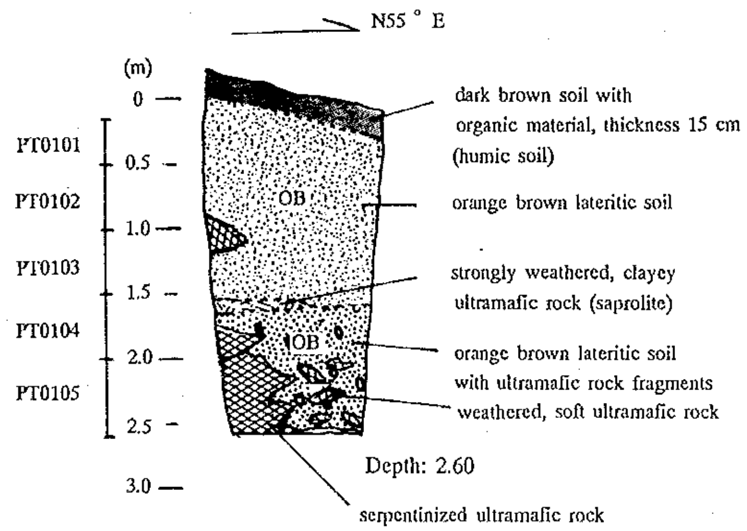


Fig. II-1-1 Location map of hand auger and pit sites in Telupid West Sub-area

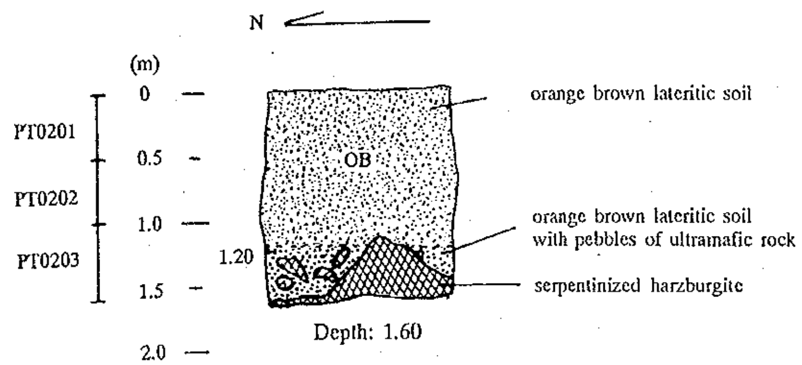
PT1



Coordinates: E4689.12, N1521.83		Vegitation: secondary forest			Slop: moderate	
Sample No.	Depth(m)	Analytical Results				
		Al(%)	Co(ppm)	Fe(%)	Cr(ppm)	Ni(ppm)
PT0101	0.15 - 0.50	2.72	729	53.51	6,498	11,424
PT0102	0.50 - 1.00	2.19	808	51.20	6,634	13,460
PT0103	1.00 - 1.50	1.85	728	46.52	5,862	12,386
PT0104	1.50 - 2.00	0.93	614	36.36	4,471	12,197
PT0105	2.00 - 2.60	1.15	329	21.70	3,946	9,744

Ave. 11,842

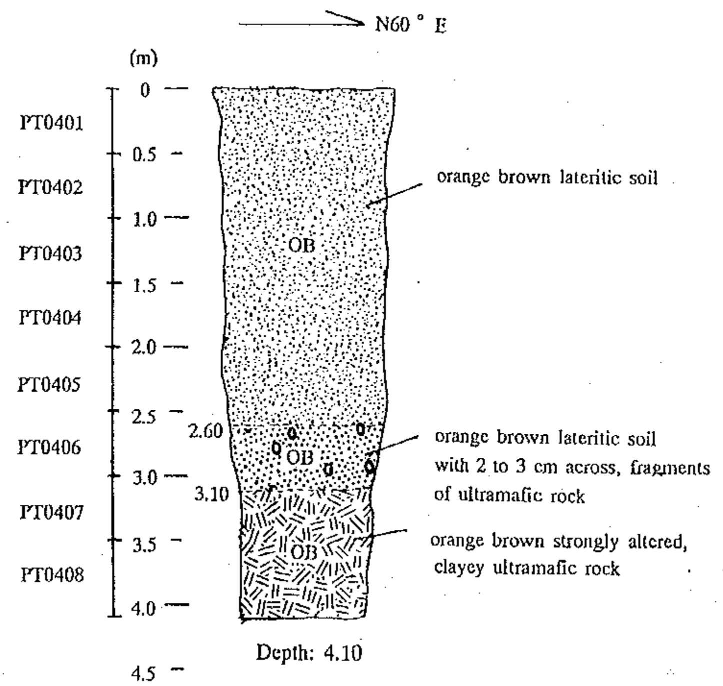
PT2



Coordinates: E4688.91, N1521.17		Vegitation: secondary forest			Slop: steep	
Sample No.	Depth(m)	Analytical Results				
		Al(%)	Co(ppm)	Fe(%)	Cr(ppm)	Ni(ppm)
PT0201	0.00 - 0.50	3.48	576	43.96	9,150	7,686
PT0202	0.50 - 1.00	3.74	687	46.87	11,643	11,037
PT0203	1.00 - 1.60	3.10	675	42.26	11,697	14,564

Ave. 11,096

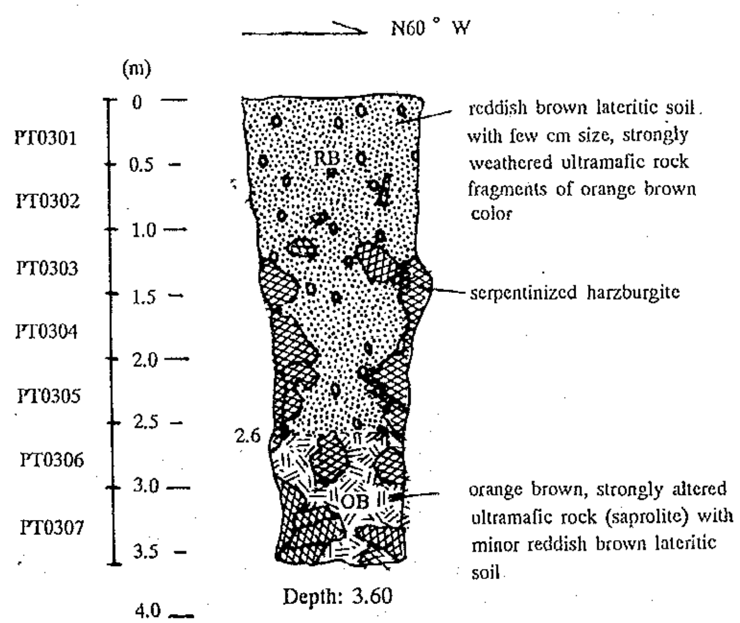
PT3



Coordinates: E4688.02, N1519.38		Vegitation: plantation of oil palm			Slop: flat	
Sample No.	Depth(m)	Analytical Results				
		Al(%)	Co(ppm)	Fe(%)	Cr(ppm)	Ni(ppm)
PT0401	0.00 - 0.50	10.34	198	32.91	6,995	2,687
PT0402	0.50 ~ 1.00	8.70	258	33.00	7,229	3,111
PT0403	1.00 - 1.50	8.80	279	34.52	8,841	3,532
PT0404	1.50 - 2.00	8.72	356	40.01	10,795	4,239
PT0405	2.00 - 2.50	8.95	266	37.64	12,771	3,771
PT0406	2.50 - 3.00	10.80	167	30.38	7,875	2,936
PT0407	3.00 - 3.50	11.68	413	23.42	7,153	2,332
PT0408	3.50 - 4.10	12.63	869	18.04	7,653	2,113

Ave. 3,090

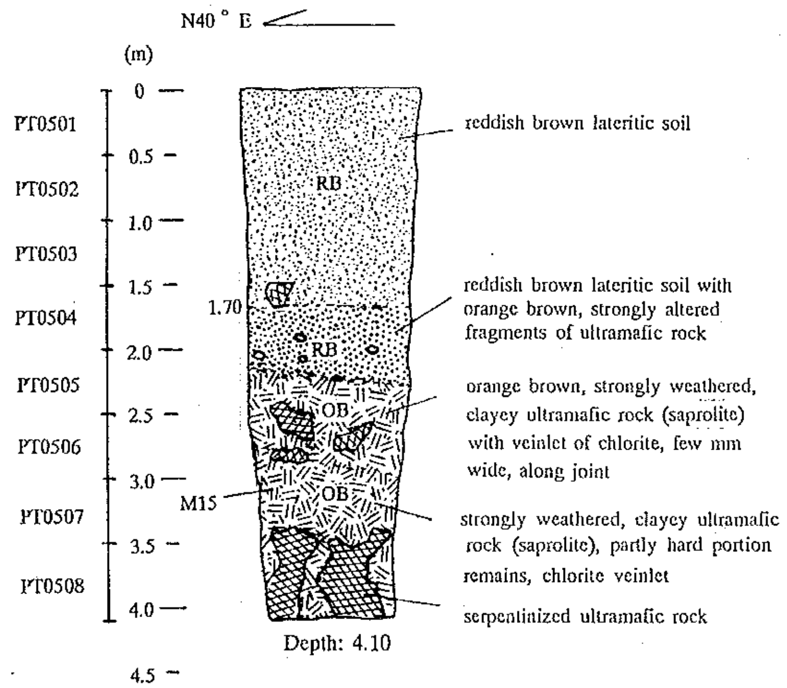
PT4



Coordinates: E4688.51, N1520.58		Vegitation: plantation of oil palm			Slop: steep	
Sample No.	Depth(m)	Analytical Results				
		Al(%)	Co(ppm)	Fe(%)	Cr(ppm)	Ni(ppm)
PT0301	0.00 - 0.50	2.68	534	57.52	8,813	9,971
PT0302	0.50 - 1.00	2.31	1,187	59.03	8,484	12,483
PT0303	1.00 - 1.50	1.81	1,214	57.42	6,204	17,230
PT0304	1.50 - 2.00	1.21	1,018	55.23	5,896	21,971
PT0305	2.00 - 2.50	10.38	1,080	56.27	6,092	19,351
PT0306	2.50 - 3.00	0.59	130	32.20	6,519	3,032
PT0307	3.00 - 3.60	10.34	575	29.77	5,464	7,431

Ave. 13,067

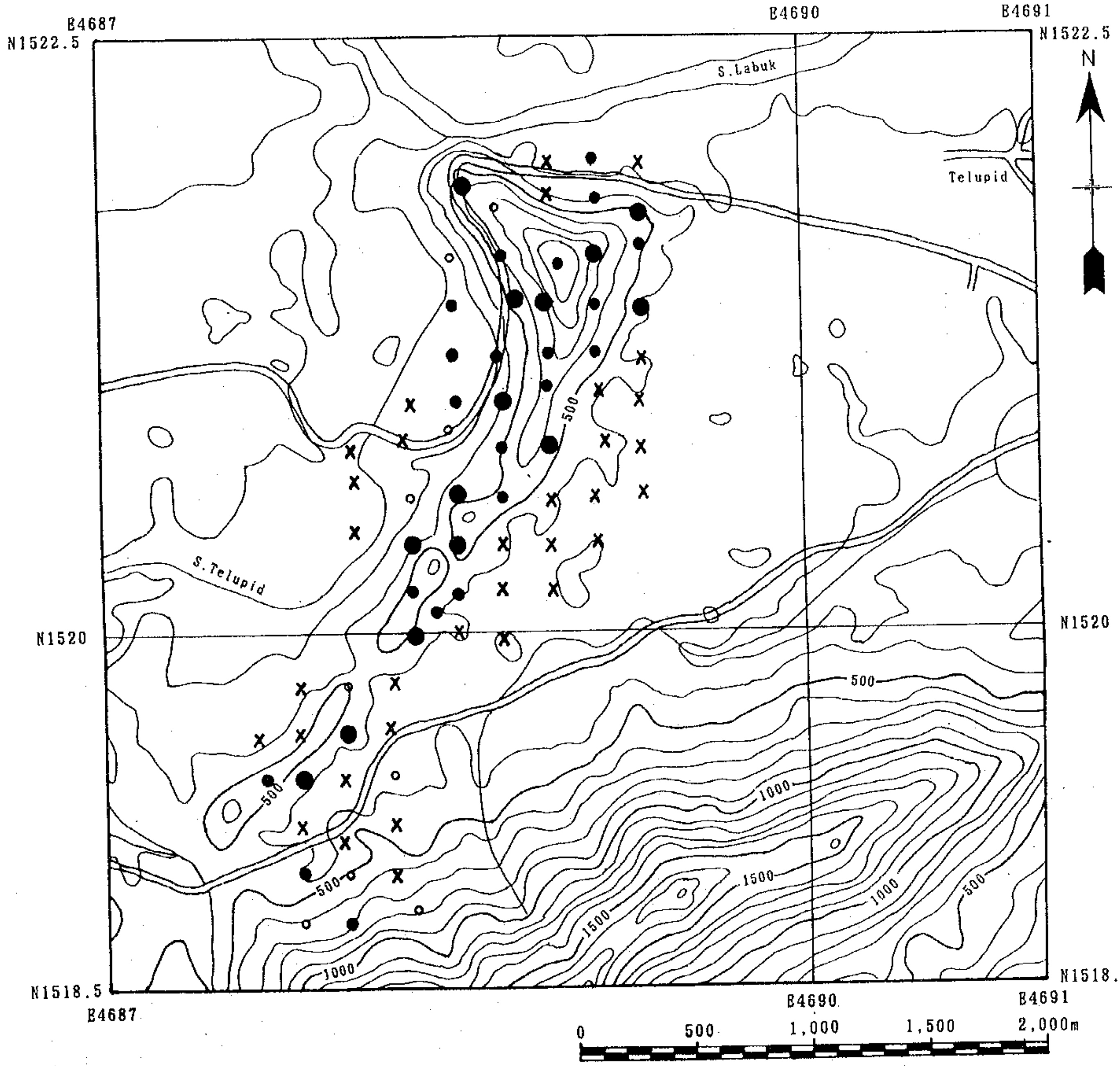
PT5



Coordinates: E4688.42, N1520.10		Vegitation: plantation of oil palm			Slop: moderate	
Sample No.	Depth(m)	Analytical Results				
		Al(%)	Co(ppm)	Fe(%)	Cr(ppm)	Ni(ppm)
PT0501	0.00 - 0.50	3.11	519	34.46	6,124	6,356
PT0502	0.50 - 1.00	3.02	361	32.09	6,840	4,807
PT0503	1.00 - 1.50	4.93	803	53.26	8,828	8,355
PT0504	1.50 - 2.00	4.01	1,064	51.31	10,604	11,829
PT0505	2.00 - 2.50	3.84	791	41.24	6,260	14,974
PT0506	2.50 - 3.00	3.35	463	23.25	5,149	18,668
PT0507	3.00 - 3.50	1.52	465	19.73	3,637	18,846
PT0508	3.50 - 4.10	2.55	231	10.51	1,932	4,080

Ave. 10,989

Fig. II-1-2 Sketch and analytical results of Pit



● Ni ≧ 1.2 %

• 1.2% > Ni ≧ 0.8 %

○ 0.8 % > Ni ≧ 0.5 %

x 0.5 % > Ni

Fig. II-1-3 Distribution of Ni in Telupid West Sub-area

Table Ⅱ-1-1 Result of X-ray diffraction analysis in the Telupid West 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	Hematite	Chalcopyrite	Arsenopyrite	
1	M15	4688.42	1520.10	green mica veinlet in peridotite			○										

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

Chapter 2 Pinanduan Sub-area

2-1 Introduction

2-1-1 Survey area

The Pinanduan area, 30 km^2 (EW 6 km × NS 5 km), is located in the northern part of the Central Sabah area, 15 km south of Telupid. The Sungai Karamuak flows southeastern edge of area and small tributaries of Sungai Karamuak, such as Sungai Kukubon, Sungai Pinanduan Kecil and Besar, Sungai Nobusu Kecil, flow north to south in the area.

The southwestern part of the area, along Sungai Karamuak is occupied by flat area with altitude of 60 m to 100 m. A flat topography also occurs on the top of mountain at altitude of approximatly 500 m. The area is called as Tavai Plateau and it extends further east from the Pinanduan Sub-area. The area between the plateau and flat low land along the Sungai Karamuak is occupied by relatively steep mountainous slop facing southwest. The vegetation of the area is secondary jungle with dense small tree and bush which makes difficult for traversing the area and line cutting for geophysical survey. The area can be reached by 45 minute drive from Telupid along logging road. Geological and geophysical survey were conducted establishing base camp within the area.

2-1-2 Background

During the early 1960s, exploration work conducted in the area for an evaluation of copper and iron mineralization (Lewis, 1964). The results of hand auguring, trenching and drilling of this project showed uncommercial zones of sulfide mineralization with copper in peridotite at vicinity of small gabbro intrusion and more than a million tonnes of limonitic clay containing 0.7 % copper as secondary oxides on the surface. Other than this, Fe and Ni exploration conducted on the Tavai Plateau conformed 76 million tons of lateritic soil with Fe 41 % over the plateau.

The soil and stream sediments geochemical survey conducted during the Supra-regional survey (1993) over the area of 42 km^2 (Area Q) extracted Cu, Au and Ni anomaly over the area of Sungai Pinanduan. The Pinanduan Sub-area was established over the area of these anomalies for an evaluation of Cu, Au and Ni mineralization of the area.

2-1-3 Survey amount

Geological survey (semi-detail) and geophysical survey (IP method) were conducted to investigate the geochemical anomalies of Cu, Au and Ni found during the Supra-regional survey investigate the potentiality of of sulfide mineralization in the area. A geological survey was conducted along 52 km route in the area of 30 km^2 and geophysical survey was conducted along 8 lines with a total length of 14.4 km.

2-2 Geological survey

2-2-1 Survey method

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 slops of mountainous and geophysical survey lines were traversed. Typical rock and ore samples were collected for thin section and polished section. Ore assaying and X-ray diffraction analysis was done,respectively, for mineralized and alteration samples.

2-2-2 Geology

Peridotite (Pr), mainly consisting of harzburgite, predominantly occur in the Pinanduan Sub-area with dunite (Du) and small intrusive bodies of gabbro (Gb). Other than this, Crocker formation (P_2Cr) of Eocene to Oligocene is found only in a restricted area. Geologic map together with cross sections are given in Plate Ⅱ-2-1 and Fig. Ⅱ-2-2 and schematic lithological succession is shown Fig.Ⅱ-2-2. The sample location of laboratory studies is given in Fig.Ⅱ-2-3 . The results of laboratory studies are given on Table Ⅱ-2-1 (thin section), Table Ⅱ-2-2 (polished section), Table Ⅱ-2-3 (X-ray diffraction analysis) and Table Ⅱ-2-4 (ore assaying).

The peridotite with lenses of dunite is believed to be dismembered ophiolite of Cretaceous to early Tertially age and it thrust up onto the Crocker formation in the southwestern part of the area. The Pinanduan Sub-area is overlain mainly by dark green to black, serpentinized peridotite and common occurrences of orhtopyroxene of a few mm across in the peridotite indicate the peridotite to be harzburgite. Intensity of serpentinization of the peridotite varies place to place. At location of weak serpentinization, olivine is still preserved and occasionally peridotite shows layered structure. A few hundred meter wide lenses of dunite occurs in harzburgite. The flat plain of plateau is occupied by lateritic soil and gossan produced by weathering and oxidation of peridotite. Microscopic observation of less serpentinized peridotite shows olivin crystals in the mesh structure of serpentine. Unaltered pyroxenes of 1 mm to 2 mm across, mainly orthpyroxen with minor clinopyroxene, are found in serpentinite. In serpentinized harzburgite, only pseudomorph of pyroxene, totally replaced by serpentine, is remains.

The gabbro occurs as intrusive bodies of a few 100 m across in southern part of the area. The one at immediate west of Sugai Pinanduan Kecil is slightly epidotized, fine grained gabbro. While, the others in the western part of the area are medium to large grained gabbro consisting of clinopyroxene and plagioclase. Because of no activities of basic plutonic bodies found in the surrounding area of Tertialy sediments, the gabbro is considered to be member of ophiolite and intrusion of gabbro might had occurred before the emplacement of dismembered ophiolite.

2-2-3 Mineralization

Alteration and mineralization found in the area is relatively intense alteration of gabbro with weak pyrite dissemination surrounding intrusion of gabbro bodies and lateritic soil and gossan widespread on the Tavai Plateau.

The peridotite that occurs at the vicinity of gabbro intrusion shows relatively intense serpentinization accompanied by alteration minerals such as montmorillonite and chlorite. Weak pyrite dissemination occasionally occur to the peridotite at the vicinity of gabbro intrusion. Microscopic observation of the peridotite with pyrite dissemination only shows pyrite as ore mineral. Any encouraging results was not obtained from assay result. The drilling conducted during early 1960s at the vicinity of gabbro intrusion just west of Sungai Pinanduan Kecil revealed sulfides veins of 15 cm to 60 cm wide, consisting of mainly pyrrohtite with chalcopyrite and sphalerite. The assay result showed Cu 0.53 %, Ni 0.06 % and Zn 0.15 % for approximately 1.5 m. The location of the mineralization is currently covered by heavy bush and only epidotized gabbro was found at the site.

The Tavai Plateau was occupied by widespread gossan with iron oxides pisolite and iron rich gossan. The X-ray diffraction analysis of gossan showed goethite is the main constituent mineral and assaying did not show any encouraging results.

2-3 Geophysical survey

2-3-1 Survey method

(1) Purpose

The purpose of the survey is to clarify the relation with the existing mineralization and the geochemical anomalies extracted during the Supra-regional survey in the survey area. An investigation of the electrical structure of the survey area was carried out by clarifing the distribution of IP anomalies in the survey area by means of an IP (Induced Polarization) method.

The measurements were 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 1.8 km each in length were set along a N-S direction with a 500m line spacings. The numbering of IP survey stations were set from 0 to 18 with 100m spacing from the north to the south. Survey specifications are shown in Table Ⅱ-2-5. Location of survey lines and rock samples are illustrated in Fig. Ⅱ-2-4.

Table Ⅱ-2-5 Survey specifications

Method	Specifications
Measuring	Time domain
Configuration	Dipole-dipole
n-spread	n = 1 to 4
Survey lines	8 lines
Total amount	14.4 line-km
Line spacings	500 m

IP measurement of rock samples

Chargeability & resistivity 7 pcs

2. Method of IP measurement

The time domain IP method was used using battery-driven portable equipments (receiver IPR-12 and transmitter) manufactured by Scintrex Ltd. The transmitter has a maximum output of 1500 volts in 10 steps and a maximum current of 10 amps. The receiver connected to another pair of electrodes. The signal (Vp) observed during the on-time of transmitter is used together with the current and electrode geometry to obtain the resistivity (unit in ohm-m). The signal received (Vs) by the receiver during off-time of transmitter will fall instantaneously to zero unless there is polarizable material like sulfides present. In the presence of such material there will be a slow decay of received potential with time as shown in Fig. II-2-5. Standard pulse duration was 2 seconds, 11 chargeability values (unit in mV/V) were sampled on the decay curve (Fig. II-2-6). The most convenient array was found to be dipole - dipole array illustrated in Fig. II-2-7.

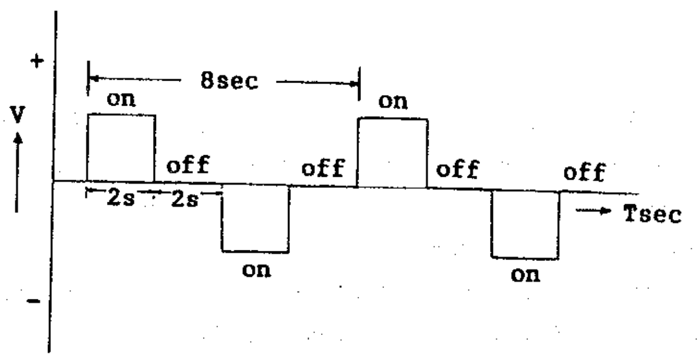


Fig. II-2-5 Wave form produced by the transmitter

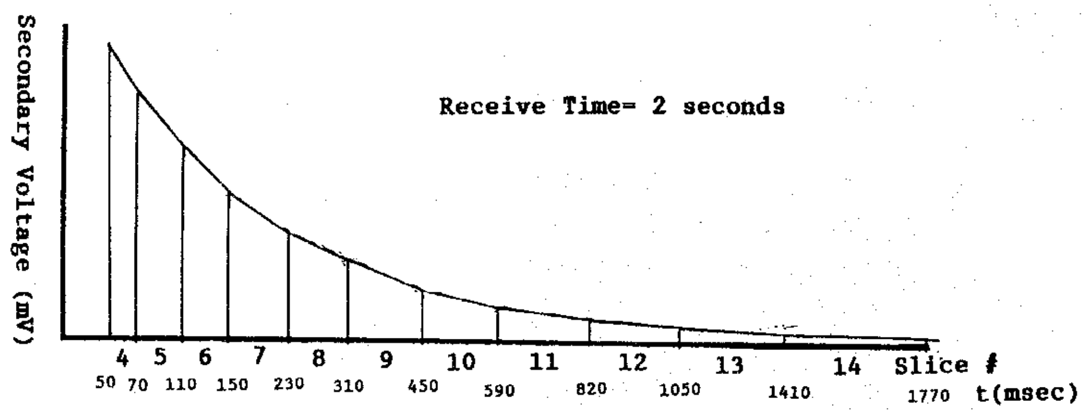


Fig. II-2-6 Sampling interval of the IP receiver

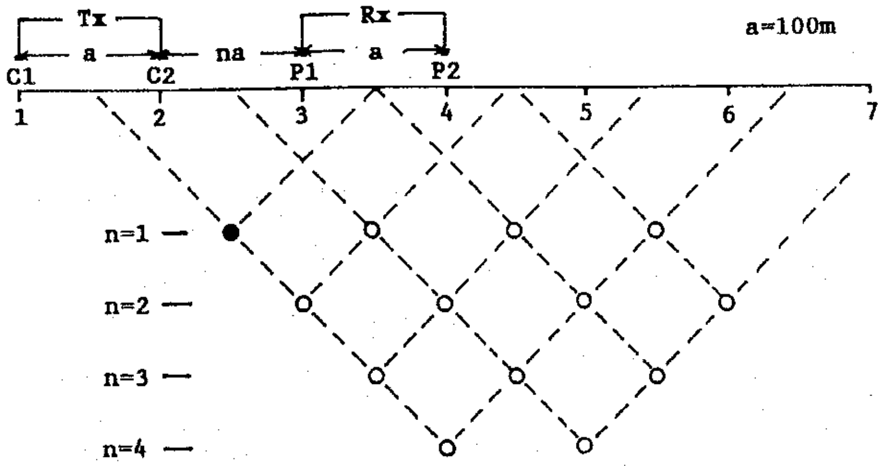


Fig. II-2-7 Dipole-dipole array and plotting procedure

3. Electrical measurement of rock samples

Electrical measurement of rock samples were carried out in order to determine the actual electrical properties of rocks distributed on the survey area. The rocks collected from the surface were formed into a cubic shape. Their measurements were carried out in water saturated condition after the rocks were soaked in water during 2 days. The receiver used for rock samples is the same type of receiver (Scintrex Ltd. IPR-12) as in the field survey.

4. Survey equipment used

The equipments used for the IP survey, manufactured by Scintrex Ltd. in Canada, are shown in Table II-2-6.

Table II-2-6 Survey Equipment

Equipment	Model	Specification	Quantity
IP transmitter (Scintrex)	TSQ-3	2.0 A, 1500V	1
Engine generator (Briggs & stratton)		5 HP	1
IP receiver (Scintrex)	IPR-12	8ch, 14windows Input range: 50uV to 14V	2

2-3-2 **Method of Analysis**

Fig. II-2-8 shows the procedure used for IP data analysis and interpretation.

(1) Terrain correction

Since the geometrical factor K is calculated as a function of the location of current and potential electrodes on half-infinite plane, a is affected by the topography depending upon the location of electrodes, even if the terrain is homogeneous. For example, for the case of a dipole-dipole configuration, a appears to be high beneath a hill and low beneath a valley. On the other hand, chargeability is less affected by topography because it is rather proportional to the ratio of the primary and secondary voltage of a decay curve.

Since the topography of the survey area is comparatively steep and rugged, the correction was performed for all survey lines by means of a finite element method assuming a two dimensional half space topography. The pseudo-sections and plan maps were drawn using the terrain corrected values.

(2) Simulation analysis

For the analysis and interpretation of IP data, two methods are mainly used: one qualitative and another qualitative.

The qualitative method correlates the anomaly patterns of the profiles and the maps in reference to precomputed standard anomaly patterns derived from various simple electrical structural models of the subsurface. The quantitative method compares the observed data with theoretical data calculated from the simulated electrical structure.

These two methods were combined to obtain a best results. Pseudo-sections were modeled by using the meshes of the model which assumed resistivity and chargeability values on the basis of geology, standard models and IP properties of rock samples. The theoretical values were calculated by a numerical analysis using the two-dimensional finite element techniques.

Further comparisons between the calculated values and observed data permitted to change the various parameters of the model in order to approach efficiently the observed values. By the iterative procedure and guided by existing geological information of the area, it was possible to obtain the most reasonable model of the underground electric structure.

Simulation analysis were mostly carried out for the strong IP anomaly on the lines, to clarify the lateral and vertical extension of the mineralization zone.

2-3-3 **Survey results**

(1) Results of rock sample measurements

Resistivity and chargeability were measured for 7 rock samples collected in this area. The location of rock samples collected are shown in Fig. II-2-4 , and the corresponding measurement results are indicated in Table II-2-7. Collected rock samples are consist of serpentinized peridotite.

Resistivity of rock samples ranges from 205 to 10000 ohm-m. Rock sample of P-1 has a low resistivity due to be strong chloritization. Chargeability values, which are generally indicative of sulfide contents, range from 3.5 to 51.7 mV/V. Two rock samples of P-2 and P-6, indicate strong chargeability values over 30 mV/V and high resistivity without pyritization and chloritization etc. Others indicate a weak chargeability less than 10 mV/V and middle to high resistivity values.

2. Distribution of apparent resistivity and chargeability (Fig. II -2-9 to Fig. II -2-12)

In this survey area, apparent resistivity values were detected in the range from 1 to 366 ohm-m and chargeability values in range from -28 to 62 mV/V.

On this basis and in this report, apparent resistivity and chargeability values were classified of 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 low in the north-eastern part of the area from surface to depth, 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. The 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.10 to 12 and No.14 to 16 in the depths of Line-A,
No.2 to 4, No.14 to 15, a south of No.17 in the shallows,
No.4 to 5, and No.9 to 12 in the depths of Line-B,
No.4 to 5 at shallow, and No.6 in the depths of Line-C,
No.2 to 7 from the shallow to the depths part of Line-D2.

Sources of the IP anomaly is mainly distributed in the flat area of the south-western part of the survey area.

2) IP Anomaly Type 2

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

No.3 to 5, No.7 to 9 in the shallow of Line-A,
No.1 to 3 in the shallow of Line-D2,
No.2 to 3 in the medium of Line-E,
No.5 to 7 and No.8 to 10 in the medium of Line-F.

Sources of the IP anomaly is mainly distributed in the mountainous area of the north-eastern part of the survey area except Line-A.