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

(CONSOLIDATED REPORT)

MARCH 1997

JAPAN INTERNATIONAL COOPERATION AGENCY

METAL MINING AGENCY OF JAPAN

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PREFACE

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

Based on the results of the Supra-regional survey in Sabah area conducted during a period of 1989 to 1993, the Central Sabah Area was selected as an area of the highest mineral potential in Sabah.

The JICA and MMAJ sent survey team to Malaysia during the period from 1994 to 1996.

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 the reports were prepared. This report includes all the survey results of the project.

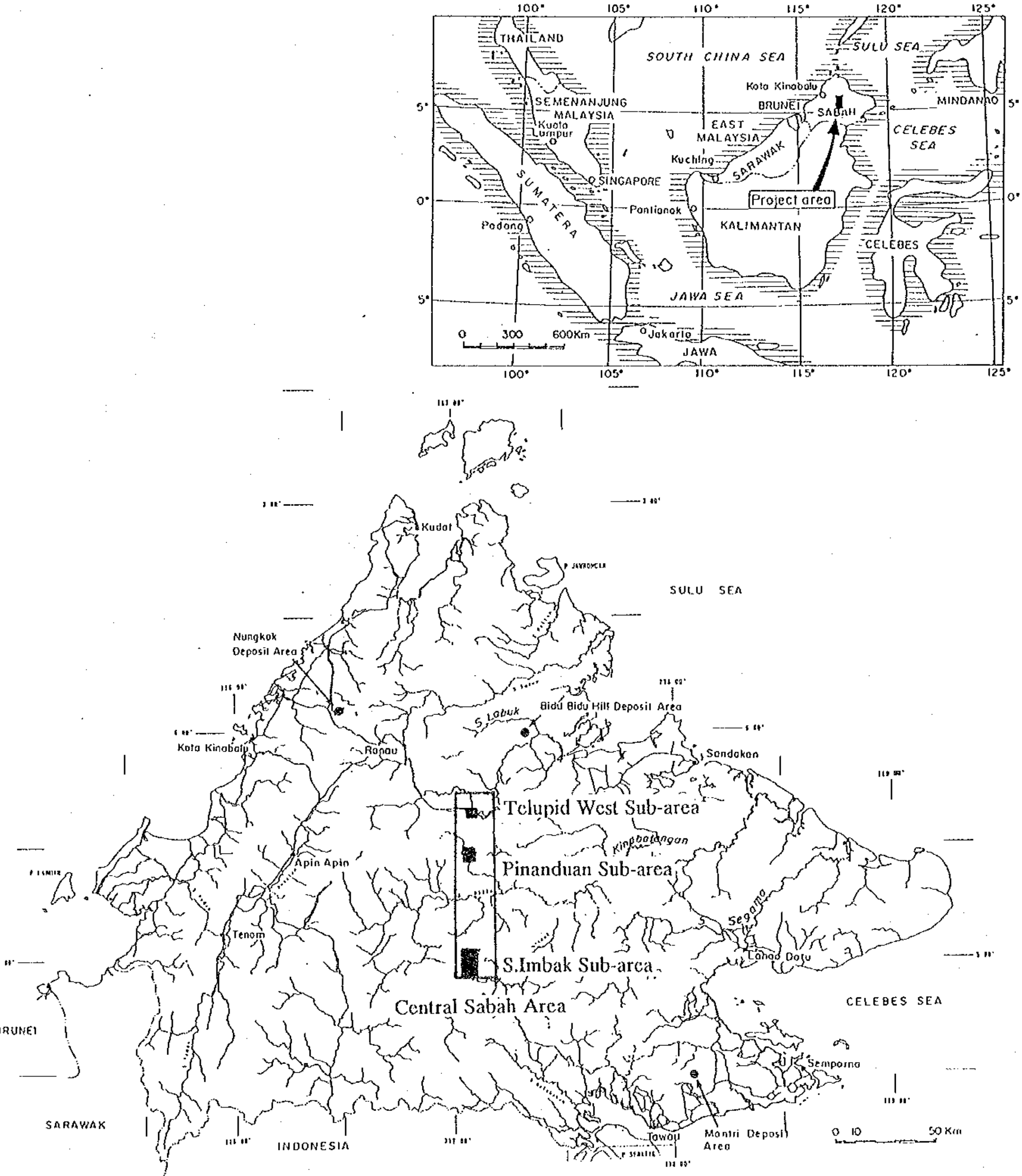
We hope that this report will serve for the development of the mineral resources and contribute to the promotion of friendly relations between Japan and Malaysia.

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, 1997.

Kimio Fujita
President
Japan International Cooperation Agency

Shozaburo Kiyotaki
President
Metal Mining Agency of Japan



Project area.

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 three years .

The Central Sabah project was conducted in three Sub–areas of Telupid West, Pinanduan and S. Imbak (North and South)

1. Telupid West Sub-area

The laterite soil of the Telupid West sub-area, consisting of lateritic soil and saprolite, shows similar vertical profile and chemical characters to the laterite soil of typical Ni laterite deposits elsewhere in the world. A wide range of Ni grade, ranging from less than 100 ppm to more than 2 %, was obtained from the laterite soil and saprolite in the Telupid West Sub-area. 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 the central hill, may suggest the laterite soil of the Telupid West Sub-area to be premature.

Although relatively high grade soil (more than Ni 0.8 %) occur along and around crest of the central hill, the limited lateral and vertical distribution of high Ni soil, implies that ore reserve is not enough for further exploration and exploitation of Ni laterite in the Telupid West Sub-area.

2 Pinanduan Sub-area

The geological survey shows that the mineralization of the area occurs only in the restricted area around bodies of gabbro where relatively strong serpentinization accompanied by weak pyrite dissemination. No clear evidence of the mineralization and alteration, that reflect Cu, Ag and Ni anomalies detected 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.

Relatively intense IP anomaly obtained in the southwestern part of the area correspond to the location of the Cu-bearing sulfide mineralization found by the previous survey. This may implies an occurrence of considerable amount of sulfide underneath the surface. The most intensive IP anomalies were obtained over the area from southwestern to northeastern part of the area. No clear alteration and mineralization were found by the 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 that further detailed survey is recommended in the area to further determine the source of IP anomaly.

3. S. Imbak Sub-area North

The mineralization of the area, closely associated with the intrusion of the diorite porphyry, occurs in the silicification/pyrite dissemination zone in the center to southern part of the area. It occurs as : (i) quartz sulfides veins in the sedimentary rocks and (ii) network veins of sphalerite and dissemination of sulfides in the diorite porphyry.

The quartz-sulfides (pyrite, arsenopyrite, sphalerite, galena, chalcopyrite) veins of few cm to 25 cm wide sporadically occur in the sedimentary rocks within silicification/pyrite dissemination zone. These quartz-sulfides veins are Au-Ag vein and Pb-Zn veins. The former occurs in a zone of higher alteration corresponding to phyllic zone in the west of the silicification/pyrite dissemination zone, while the latter tends to occur in the eastern part of the silicification/pyrite dissemination zone.

Among the seven drill holes conducted in the project, the most prominent mineralization was found at MJSI-4 where sphalerite-(chalcopyrite) network veins and patches with Zn grade ranging from 0.40 % to 1.00 % occur in the diorite porphyry for 15 m . This Zn mineralization zone includes 3 m long Ag rich (Ag 37.2 g/t to 90.5 g/t) zone.

The geological information, mineral assemblage of ore minerals, filling temperature of fluid inclusion suggest that the most possible geological environment of mineralization in the S. Imbak Sub-area is that of similar to outer margin of the porphyry copper mineralization.

The results of geophysical survey revealed that the strong anomalous zone coincided with the silicification pyrite dissemination zone. The distribution of these strong anomalies, similar to the anomalies of typical porphyry copper mineralization, form the shape of letter "C" which open ended to the east. The drilling survey conducted in the PhaseII at the target of very strong IP anomalies and in the Phase III in the east part of the area with Type 2 and Type 3 IP anomalies resulted in intersecting a minor mineralization. The area at the center of "C" shape anomalies is recommended as target for the future exploration.

4 S. Imbak Sub-area South

The mineralization of the area, closely associated with the intrusion of the diorite porphyry, occurs in the silicification/pyrite dissemination zone in the center of the north part (SA), the center part (SB) and the east part (SC) of the area.

The mineralization zone SA is believed to be the southern extension of the silicification/pyrite dissemination zone of S. Imbak Sub-area North (NA) and characterized by Ag and Cu enriched quartz-sulfides veins. The west part of the zone is covered by Au, As and Cu high value zones of the rock geochemical survey and alteration is slightly intensive than the surrounding area. The mineralization zone SB is characterized by dissemination of pyrite and chalcopyrite in the diorite porphyry and the sedimentary rocks and it is covered by anomalies of Au, Cu and S. The Cu grade is slightly low, however, it shows a similar mineralization to porphyry copper type. Distinguished mineralization and clear geochemical anomaly were not found in the mineralization zone SC. The alteration zoning and fluid inclusion temperature suggest a similar environment to the phyllic zone of porphyry copper type mineralization for the mineralization zones (SA) and (SB).

The survey results suggest that the most potential areas for mineralization in the S. Imbak Sub-area South are the western part of the mineralization zones (SA) and the mineralization zone (SB), and further detail survey should be conducted in future.

CONTENT

Part I General

Part II Survey Results

Part I General

Chapter 1 Introduction

1-1 Background and objectives

In accordance with the Scope of Work signed between the Government of Malaysia and the Government of Japan on 1st of September 1994, the mineral exploration project was started in the Central Sabah area in the state of Sabah, Malaysia. Based on the results of the Supra-regional survey in Sabah area 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 a three year project starting from 1994 and this is a consolidated report including the summary of all of the results of the project through Phase Ⅰ to Ⅲ.

The objectives of the project are to explore and assess the mineral potential of the Central Sabah area for the future development of mineral resources of the area. Work was conducted in three sub-areas in Central Sabah, namely, Telupid West, Pinanduan and S. Imbak Sub-areas. The surveys including geologic, geochemical, geophysical and drilling surveys were conducted in the three sub-areas. The targets of mineralization in each sub-area are:

Telupid West Sub-area :	Ni
Pinanduan Sub-area:	Cu
S. Imbak Sub-area:	Au, Cu .

1-2 Coverage and outline of the project

The Central Sabah Area, with a rectangular shape (NS 90 km × EW 20 km) extending southward 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. Ⅰ-1).

The exploration work done in the three sub-areas of Telupid West, Pinanduan and S. Imbak through Phase Ⅰ to Ⅲ is summarized in Fig. Ⅰ-2 and Fig. Ⅰ-3.

In the Phase Ⅰ survey, hand auger and pit surveys were conducted in the Telupid West Sub-area, covering an area of 16 km^2 for evaluation of Ni laterite, and in the Pinanduan Sub-area (30 km^2) semi-detail geological survey and geophysical survey were conducted for evaluation of Cu mineralization. The S. Imbak Sub-area (98km^2) was sub-divided into two parts, S. Imbak Sub-area North and S. Imbak Sub-area South. Semi-detail geological survey and geophysical survey were conducted in the S. Imbak Sub-area North (28 km^2) and soil geochemical survey was conducted in the S. Imbak Sub-area South (70 km^2).

In the Phase Ⅱ survey, no further work was continued in the Telupid West and Pinanduan Sub-areas. However, in the S. Imbak Sub-area, based on the results of the Phase Ⅰ survey, the Phase Ⅱ survey was conducted in the smaller areas of higher potential in both of the S. Imbak Sub-area North

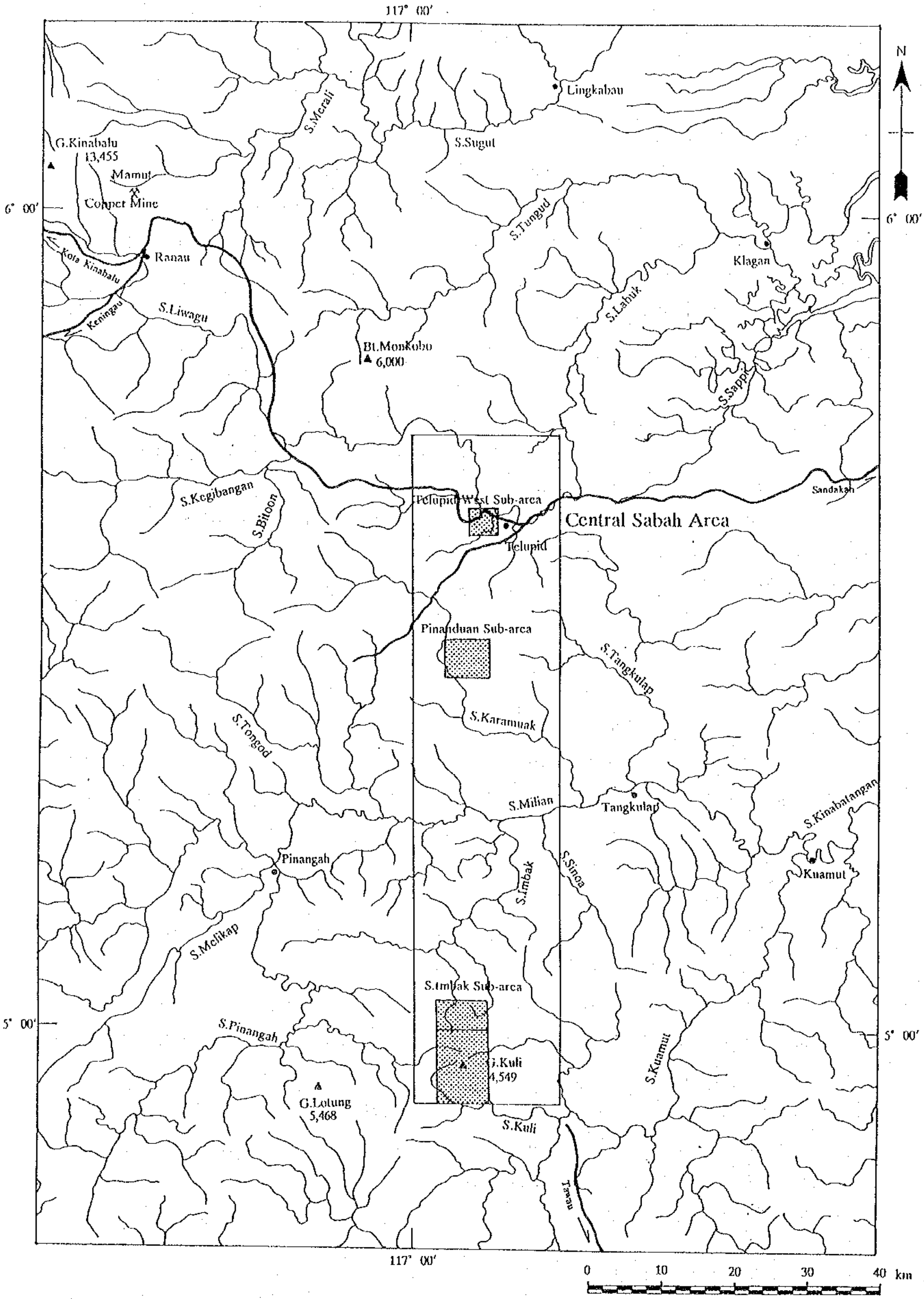


Fig. I -1 Location of the Central Sabah Area

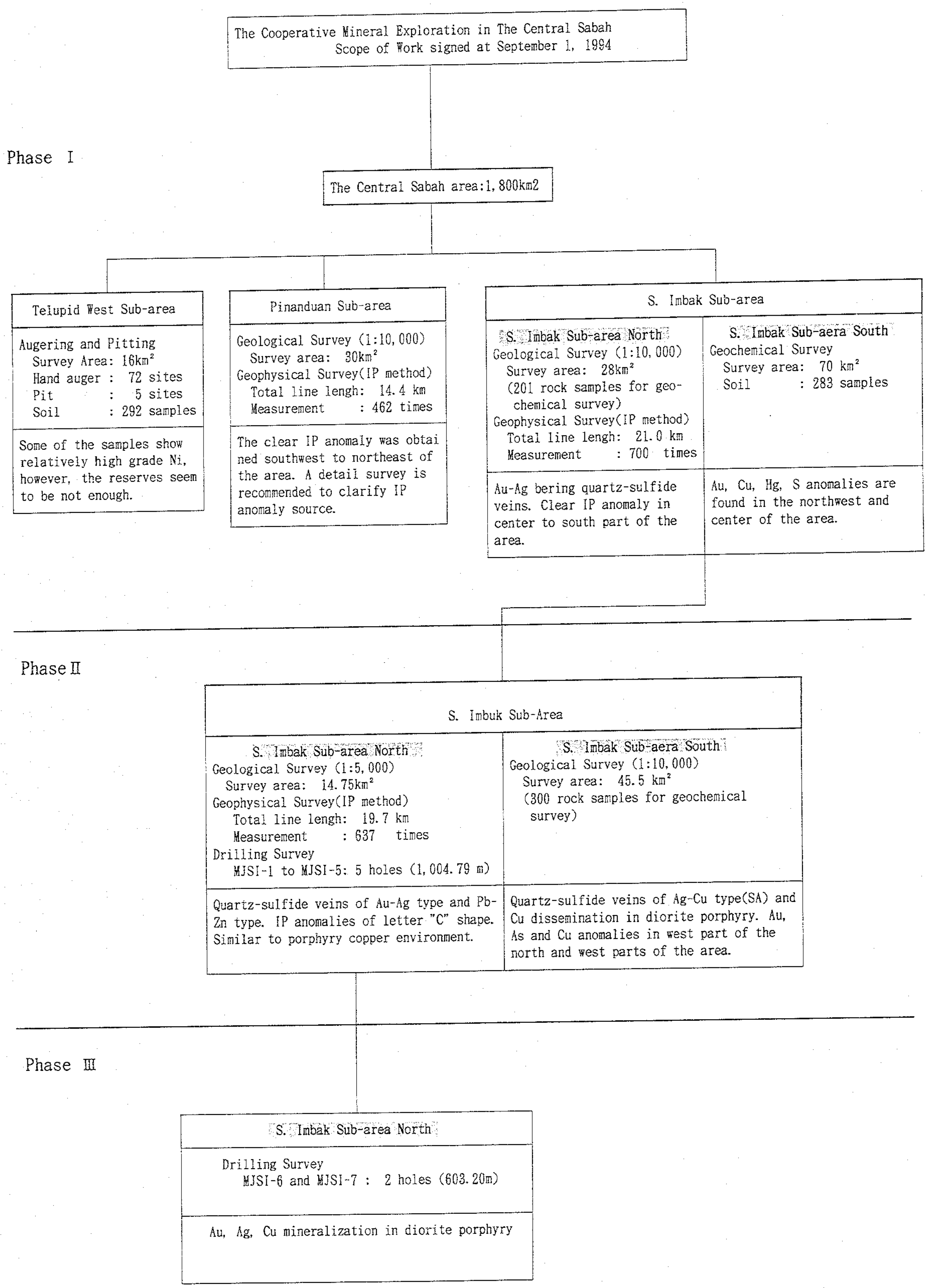


Fig. I -2 Flow chert of the project

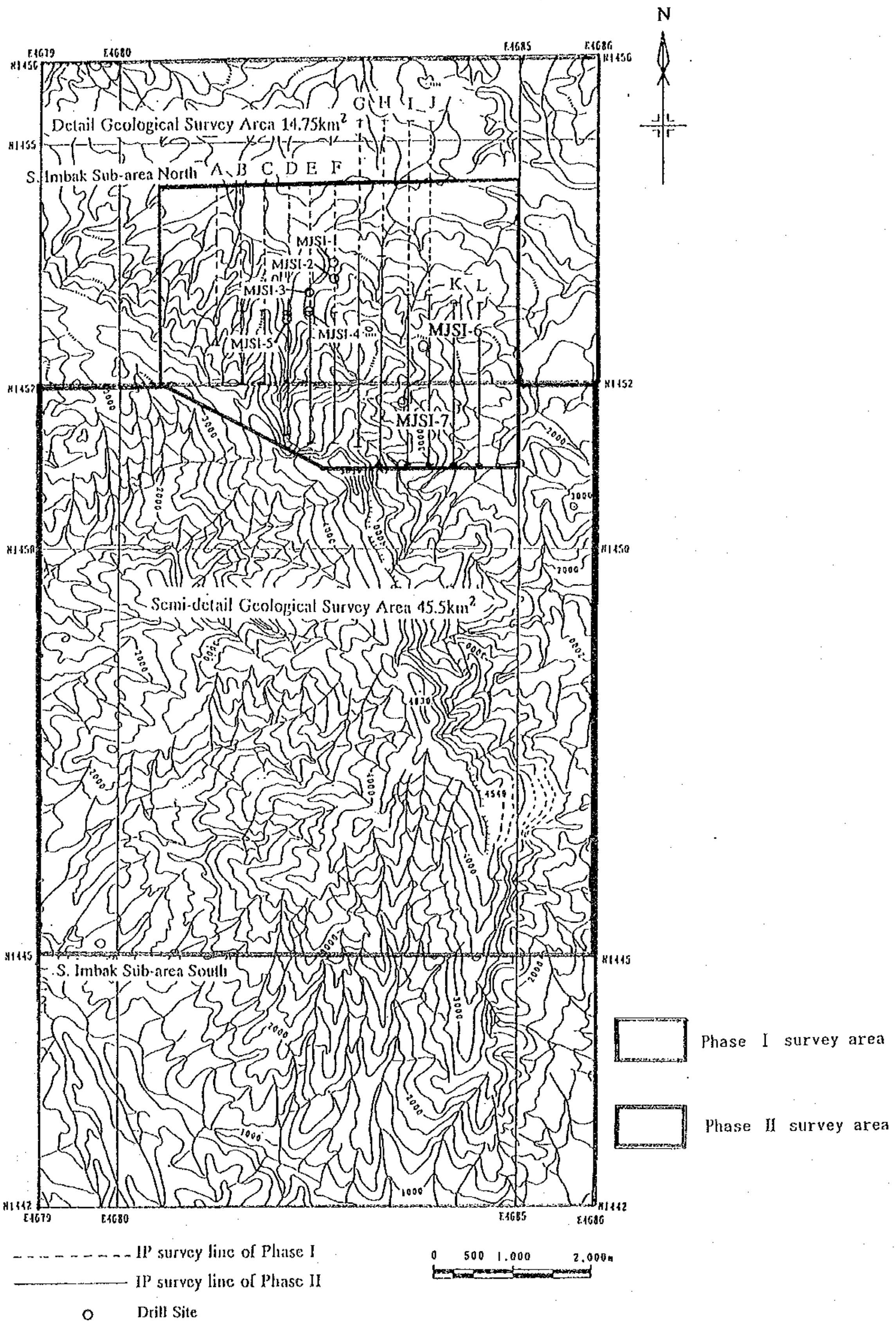


Fig. I -3 S. Imbak Sub-area

(14.75 km^2) and South(45.50 km^2). Follow-up detail geological, geophysical and drilling surveys were conducted in S. Imbak Sub-area North and, in the S. Imbak Sub-area South, semi-detail geological survey was conducted.

In the Phase III survey, additional drilling work was conducted in the S. Imbak Sub-area North.

The amount and content of work are summarised in Table I -1 and Table I -2.

1–3 Members of the project

The members who participated in the project are as follows:

1. Project Planing and negotiation

Japanese Counterpart

Shingoro Tuschiya	Metal Mining Agency of Japan
Yoichi Iida	Ministry of International Trade and Industry
Yoshiaki Igarashi	Metal Mining Agency of Japan
Tetsuo Suzuki	Metal Mining agency of Japan

Malaysian Counterpart

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

2. Inspection of field work

Eishi Endo	Metal Mining Agency of Japan
Tetsuo Suzuki	Metal Mining Agency of Japan
Naoki Sato	Metal Mining Agency of Japan
Yoshiaki Igarashi	Metal Mining Agency of Japan

Table I -1 Summary of work amounts

Phase I (1994)

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

Phase II (1995)

Survey Method	Work Amount
(1) Geological Survey 1) S. Imbak Sub-area North (detail survey) 2) S. Imbak Sub-area South (semi-detail survey)	Survey Area 14.75 km^2 Survey Route 41.7 km Survey Area 45.5 km^2 Survey Route 77.0 km Rock Samples for Geochemical Survey 300 samples
(2) Geophysical Survey (IP method) S. Imbak Sub-area North	Total Line Length 19.7 km Number of Lines 11 Lines Number of Measurement 637 Times
(3) Drilling Survey S. Imbak Sub-area North	Hole No. / Depth / Inclination MJSI-1 201.25 m -90° MJSI-2 200.30 m -90° MJSI-3 200.84 m -90° MJSI-4 202.20 m -90° MJSI-5 200.20 m -90°

Phase III (1996)

Content	Amount of Work
Drilling Survey S. Imbak Sub-area North	Hole No. / Depth / Inclination MJSI-6 300.50 m -90° MJSI-7 302.70 m -90°

Table I -2 Work amounts of laboratory studies

Phase I

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
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
Geophysical survey			
1) Resistivity measurement			20 samples
2) Porlarizability measurement			20 samples

Phase II

Laboratory Studies	Geological Survey	Drilling Survey	Total
1) Thin section	40 samples	11 samples	51 samples
2) Polished sectoion	20 samples	14 samples	34 samples
3) X-ray diffraction analysis	70 samples	12 samples	82 samples
4) Fluid inclusion filling temperature	10 samples		10 samples
5) Chemical analysis			
a)Rock (15 elements: Au, Ag, Cu, Pb, Zn, Sb, As, Hg, K, Na, Sr, Rb, Ca, Mg, S)	300 samples		300 samples
b)Ore Assay (7 elements: Ag, Au, Cu, Mo, Pb, S, Zn)	50 samples	47 samples	97 samples
3. Geophysical survey			
1) Resistivity measurement			21 samples
2) Porlarizability measurement			21 samples

Phase III

Laboratory work	Drilling survey
1) Thin section	11 samples
2) Polished section	13 samples
3) X-ray diffraction analysis	22 samples
4) Ore Assay (7 elements: Ag, Au, Cu, Mo, Pb, S, Zn)	51 samples

3. Field Survey

Japanese Counterpart

Masatsugu Okazaki	Team Leader, Geol., geochem. and drilling surveys	Bishimetal Exploration Co., Ltd.
Kazutoshi Sugiyama	Geological survey	Bishimetal Exploration Co., Ltd
Makoto Kawamura	Geol. and Geochem. surveys	Bishimetal Exploration Co., Ltd
Masatane Kato	Geophysical survey	Bishimetal Exploration Co., Ltd
Kohei Sugawara	Geophysical survey	Bishimetal Exploration Co., Ltd
Kazuto Matsukubo	Geophysical survey	Bishimetal Exploration Co., Ltd
Hiroshi Hyodo	Geophysical survey	Bishimetal Exploration Co., Ltd
Takayuki Yokoyama	Geophysical survey	Bishimetal Exploration Co., Ltd
Susumu Endo	Geophysical survey	Bishimetal Exploration Co., Ltd
Takashi Matsuoka	Drilling survey	Bishimetal Exploration Co., Ltd
Junichi Yamagata	Drilling survey	Bishimetal Exploration Co., Ltd

Malaysian Counterpart

Alexander Yan	Deputy Director	Geological Survey Dept., Malaysia
Joanes Muda	Geologist	Geological Survey Dept., Malaysia
Wong Vui Chung	Geologist	Geological Survey Dept., Malaysia
Dzazali b. Hj Ayub	Geophysicist	Geological Survey Dept., Malaysia
Salleh Adanan	Senior Assistant	Geological Survey Dept., Malaysia
Japili Samin	Senior Assistant	Geological Survey Dept., Malaysia

1-4 Survey period

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

Phase I

Geological and geochemical surveys including augering and pitting.

	October 10, 1994	to	January 7, 1995
Geophysical survey	October 10, 1994	to	December 28, 1994

Phase II

Geological survey	July 17, 1995	to	September 29, 1995
Geophysical survey	July 20, 1995	to	September 10, 1995
Drilling survey	August 3, 1995	to	November 7, 1995

Phase III

Drilling survey	September 8, 1996	to	December 25, 1996

Chapter 2 Geography of the survey area

2-1 Location and access

Malaysia, a member of the ASEAN countries, comprises Peninsular Malaysia, Sarawak and Sabah. The total population of Malaysia is 18.0 millions. The total area is approximately 330,000 km²

The State of Sabah, occupying area of 73,700 km² in the northeastern part of Borneo island, has a population of approximately 1.393 millions. Kalimantan is to the south, Sarawak on the southeast and surrounded by the South China, Sulu and Celebes seas, respectively, on the west, north and east.

The state capital is Kota Kinabalu sited on the west coast of Sabah. Direct international flights from various cities (Singapore, Hong Kong, Taiwan, Philippines, Japan) and domestic flight (Kuala Lumpur, Tawau, Sandakan) connect Sabah through the Kota Kinabalu International Airport. There are paved roads connecting major cities such as Kota Kinabalu–Ranau–Sandakan and Sandakan–Lahad Datu–Tawau.

The Central Sabah area, occupying 1,800 km² (NS 90 km, EW 20 km), extends southward from Telupid in the center of Sabah. The major road connecting Kota Kinabalu and Sandakan runs through the northern part of the area. Other existing roads in the area branches southeast from Telupid connecting small villages and the another branches timber road, that goes south from Telupid along the project area. This latter road is recently connected to the timber road that goes northward from Tawau.

2-2 Topography and drainage system

The state of Sabah has four characteristic topographic features. Steep, rugged mountains trends north to northeast in the western part of Sabah along the coast. Highland occupies the eastern part and volcanic mountains are found in the southern part. Flat plains occur along rivers and their lower tributaries. Mt. Kinabalu, which is the highest mountain in the southeast Asia, rises up to 13,455 ft in western end of the Kinabalu area. Highland dominates in the Labuk and Segama areas. Swamps occur at the lower part of meandering rivers. Volcanic highland dominates in the Semporna area.

The main drainage systems in Sabah are S. Pegalan, Sungai Sugut, Sungai Labuk, Sungai Kinabatangan, Sungai Segama, Sungai Tingkayu, Sungai Kalumpang, Sungai Kalabakan. Among these river systems, Sungai Pegalan flows into the South China Sea, Sungai Kalumpang and Kinabatangan flow down to the Celebes Sea and other river systems flow into the Sulu Sea in the east. These river systems generally form deep valley at the upper stream and are extremely meandered down stream. Mongrove swamps occur near the coast.

2-3 Climate and vegetation

The survey area experianced tropical monsoon climate. The northeastern monsoon occurs during early November to March, while the northeastern monsoon starts in May and ends in August. Annual rainfall varies depending on the region from 1,500 mm to 4,000 mm. In the west coast area, the rainy season corresponds to the southwestern monsoon, while the east coast has rainy season during northeastern monsoon. In recent years, these distinction of rainy season and dry season is not clear. Temperature is 22 C° to 33 C° throughout the year.

The maximum and minimum temperatures for each month and monthly rainfall in Kota Kinabalu on the west coast, Sandakan on the east coast and Tawau on the south coast are shown in Table I-3. Generally, the east coast has more rainfall than the west coast.

The north and central parts of the Central Sabah area is mainly covered by secondary jungle, whereas in the south primary jungle remains in many places. The S. Imbak Sub-area, which is located at the south end of the Central Sabah area, is totally covered by primary jungle.

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

Sabah is geologically complex resulting from active tectonism since Mesozoic. The geological members constituting Sabah are metamorphic rock of Crystalline Basement(Cb), Cretaceous to Eocene sedimentary rocks accompanied by basaltic eruption (K, KP), Eocene to middle Miocene sedimentary rocks characterized by flysch sediments (P1, P2, P3 and P4) and early Miocene to Pleistocene sedimentary rocks (N1, N2, N3, N4 and N5). The geological map (Yin, 1985) of Sabah including the survey area is shown in Fig.I-4.

The Crystalline Basement(Cb), consisting of schist, gneiss and amphibolite, is pre-Triassic rock and forms a basement in this area.

The Chert-Spilite Formation (KPSC) and the Sapulut Formation (KPCp) are the Cretaceous to Eocene rocks. The Chert-Spilite Formation consists of limestone, radiolaria chert, sandstone, conglomerate, spilite, volcanic breccia, agglomerate dolerite and pillow lava. Together with ultramafic rocks and gabbro (Ub), these rocks of the Chert-Spilite Formation are considered to be fragments of ophiolite sequence rocks, a part of the oceanic lithosphere of early Cretaceous age. The blocks of dismembered ophiolite, being scattered all over Sabah, are emplaced by complicated tectonic movement during the Oligocene to Miocene, and thrusted over Eocene to middle Miocene sedimentary rocks. The Sapulut Formation mainly consists of mudstone accumulated at the center of an oceanic trough.

The Paleocene to Oligocene sedimentary rocks are distributed in western and northern parts of Sabah and represented by the Trusmadi Formation and Crocker Formation. The former consists of weakly metamorphosed slate, phyllite and quartzite and the latter consists of flysch type sediments of sandstone and mudstone.

The Miocene to Pliocene sedimentary rocks occur in the south, north and southwest parts of Sabah. They are the Kalabakan Formation, Kalumpang Formation, Garinono Formation, Labang Formation, Ayer Formation and Kuamut Formation. The latter four formations of slump sediments consist of blocks of older rocks, such as chert, limestone, gabbro, sandstone and serpentinite in mud matrix. They are considered to be a chaotic formation of tectonic melange. The late Miocene sedimentary rocks are the Tanjong Formation and Sandakan Formation consisting of a sequence of sandstone and mudstone of shallow marine sediments.

Three main periods of igneous activities are found in Sabah. The earliest one is early Triassic intrusions of tonalite, granodiorite, trondhjemite and granite which are associated with the pre-Triassic basement rocks. The second period is the early Cretaceous igneous activity of ophiolite sequence rocks such as gabbro, dolerite and basalt. The third period occurred in Late Miocene to Quaternary times and is represented by post-orogenic intrusives and extrusives. The former one corresponds to the intrusion

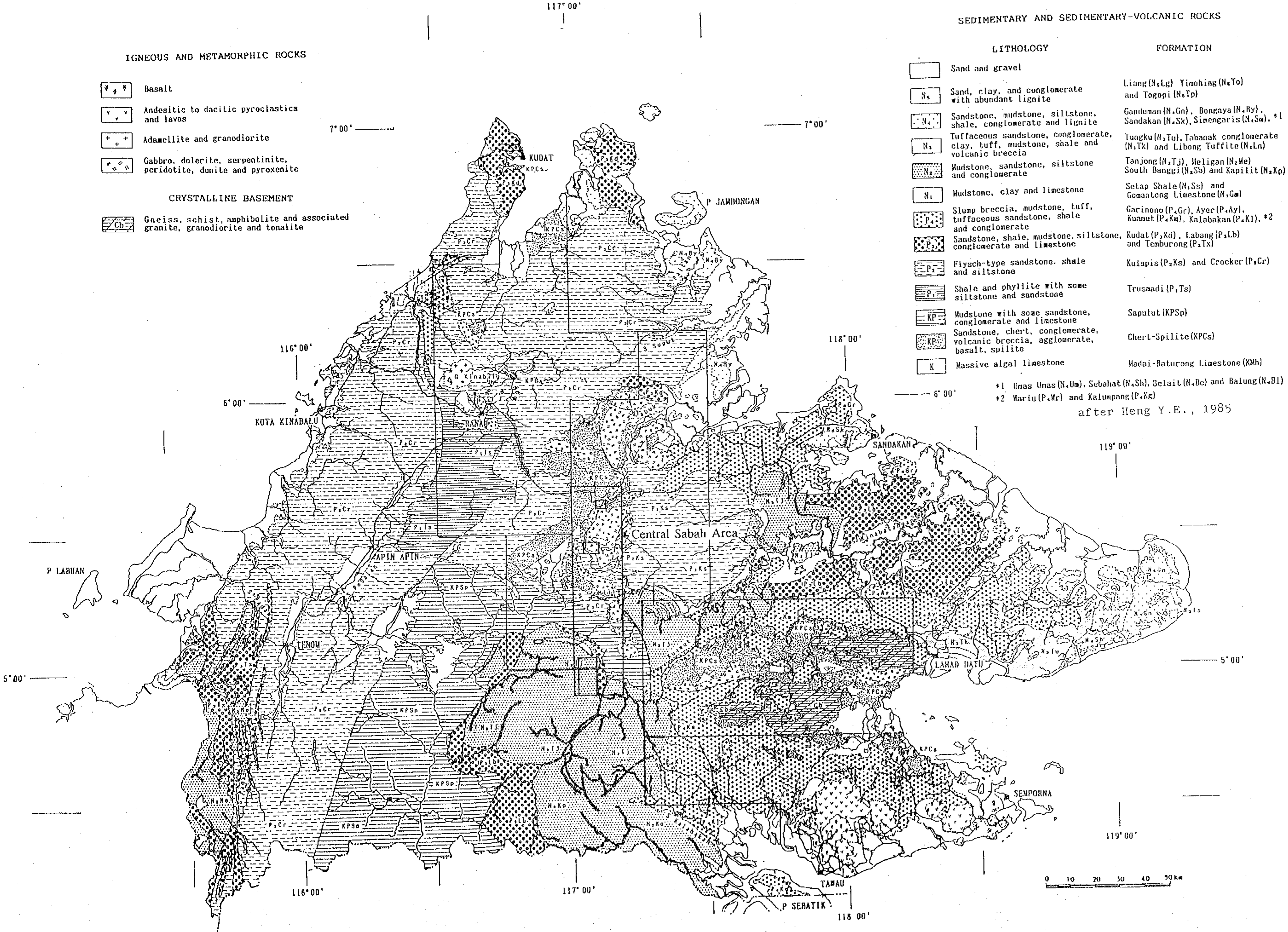


Fig. I -4 Geological map of Sabah, Malaysia

of granitic rocks such as adamellite and granodiorite in Gunong Kinabalu area and the latter corresponds to the calc–alkaline extrusive rocks, such as dacite, andesite and basalt, in the Semporna Peninsula.

In the Central Sabah Area, bodies of dismembered ophiolite consisting of ultramafic rocks and basalt with pillow structure are scattered over the northern part. The sedimentary rocks of the Central Sabah Area consist of Sapulut Formation (late Cretaceous to late Eocene), Kulapis Formation and Crocker Formation (Eocene to Oligocene), Labang Formation (Oligocene), Garinono Formation (Oligocene to middle Miocene), Tanjong Formation (early Miocene to middle Miocene). The Sapulut Formation is distributed in the southern part of Central Sabah area surrounding the ultramafic body and is overlain by the Labang Formation and Tanjong Formation. The Crocker Formation is widespread in the center of the Central Sabah Area surrounding the body of ultramafic rocks, while the Kulapis Formation occur in the central east of the area. The Garinono Formation, a tectonic melange, occurs at the eastern margin of ultramafic rocks.

3–2 Mineralization and mining activities

The principal metallic ore deposits in Sabah comprise porphyry copper deposit closely related with plutonic rocks, Cyprus–type massive sulfide deposit related to spilite extrusion and hydrothermal gold–silver deposits closely related with volcanic rocks. Chromium and platinum deposits are related to the ultra–basic rocks, lateritic aluminum and nickel deposits and manganese deposits in sedimentary rocks are also found. The distribution map of the main metallic ore deposits and mineral showings (after K.M. Leong, 1976) are shown in Fig. I–5.

The Mamut mine is the only active mine in Sabah. The Mamut deposit, a porphyry copper type, is located to the north of Ranau in the Kinabalu area. This ore 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. The development work of the mine started in 1973 and operation was started in 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 1,200.

The Bidu Bidu Hill ore deposit is in the latest stage of exploration work and the development work will commence in the near future. This is a Cyprus–type massive sulfide deposit emplaced in basalt lava. Exploration work for this ore deposit is being carried out by a Malaysian company. The ore reserves of 3,600 thousand tons with Cu 3.6 %, Au 1 – 2 g/t and Ag 8–15 g/t have been confirmed by the drilling work (approximately 40,000 m) for this deposit.

The exploration work of gold–silver deposits occurred in volcanic rocks in the Semporna area is being carried out by a Malaysian company. The area surveyed by them covers a wide area from the

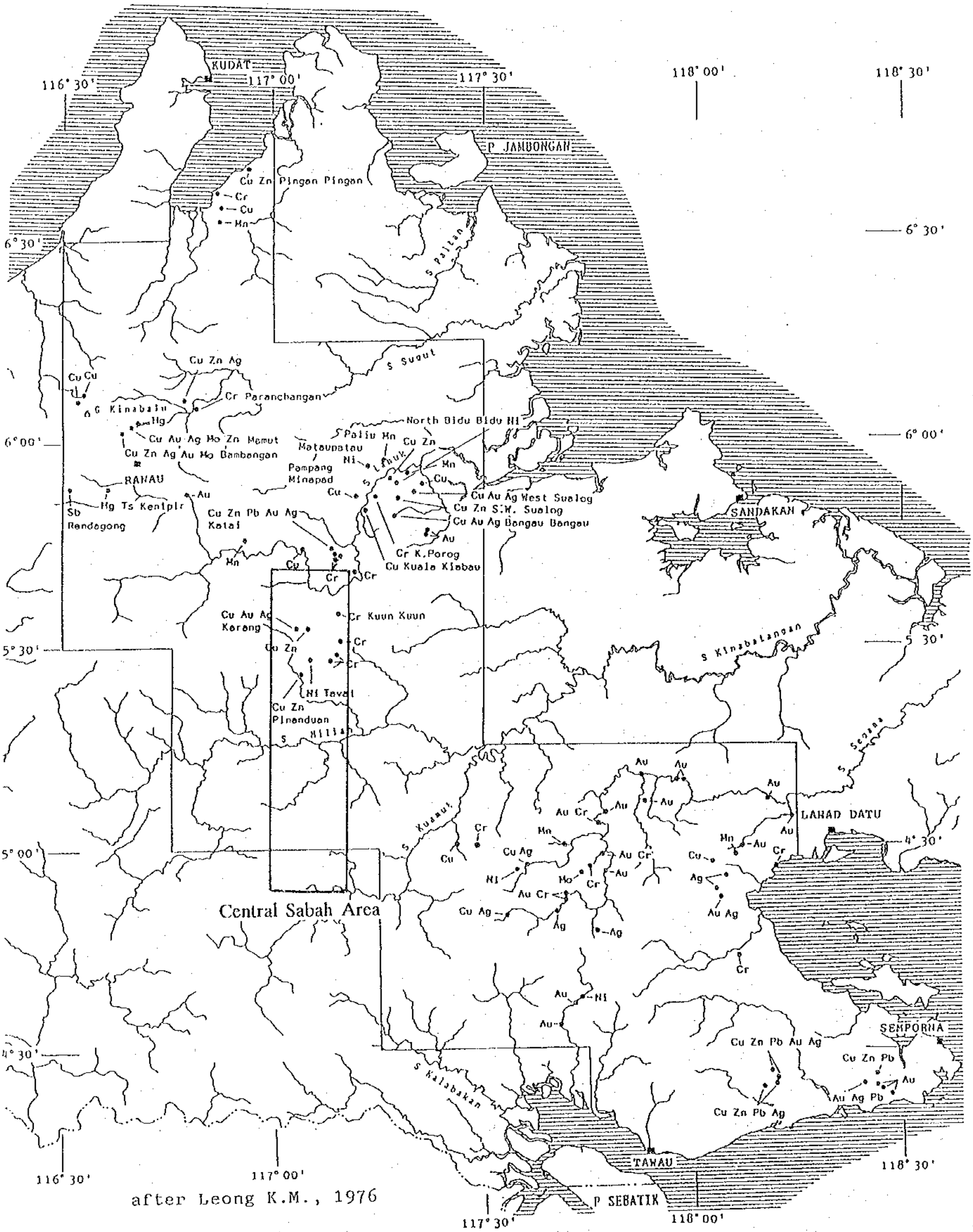


Fig. I -5 Distribution of mineral occurrences in Sabah, Malaysia west of Semporna to northern Tawau. The exploration work consists of mainly soil geochemical survey and trenching. A few drill holes have been completed for the Mantri area.

Within the Central Sabah area, exploration work, including drilling, augering and pitting was conducted in 1964 by the Soriamont Investment Co. in Pinanduan, an eastern tributary of the S. Karamuak. The boreholes showed that uncommercial zones of sulfides mineralization in peridotite, although at the surface there are more than a million tones of limonitic clay containing Cu 0.7 % as secondary oxides.

Chapter 4 Survey results

4-1 Telupid west Sub-area

The laterite soil of the Telupid West Sub-area shows similar vertical profile and chemical characteristics of the typical Ni laterite deposits elsewhere in the world. The typical laterite soil succession of the Telupid West Sub-area consists of laterite soil, laterite soil with weathered peridotite fragments and saprolite. Al consistently decreases with depth, while Co, Cr, Fe increase in with depth and reach to their maximum values at the base of the laterite soil with rock fragments before the saprolite horizon. Ni consistently increases with increase of depth and reaches its maximum at the bottom of the saprolite horizon immediately above the peridotite bedrock.

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

Although relatively high grade soil (more than Ni 0.8 %) occur along and around crest of the central hill, the thicknesses are restricted from 2 m to 3 m. In The flat areas the thickness of the laterite soil reaches more than 5 m, but the Ni grade is poor.

4-2 Pinanduan Sub-area

Geological investigation conducted in the area shows that serpentinized peridotite, consisting mainly of harzburgite, predominantly occur with minor lenses of dunite and small intrusive bodies of gabbro. The alteration and mineralization found in the area is not extensive. It occurs only in restricted areas surrounding gabbro intrusives where relatively intense serpentinization accompanied by weak pyrite dissemination occur. No clear evidence of the mineralization and alteration that reflects Cu, Ag and Ni anomalies extracted during the Supra-regional survey was found on the surface.

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

Relatively intense IP anomaly obtained in the southwestern part of the area correspond to the sites of sulfide mineralization with chalcopyrite found by the previous survey. This may imply an occurrence of considerable amount of sulfides beneath the surface. The most intensive anomalies were obtained over the area from the southwestern to the 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 beneath the surface of the area.

4-3 S. Imbak Sub-area North

Mineralization and alteration in the form of silicification/pyrite disseminations are located in the central to southeastern part of the area where many small intrusions of diorite porphyry occur. Quartz-sulfides veins up to 25 cm sporadically occur. The distribution of Au-Ag type quartz-sulfides veins seem to be restricted in the southwest part of the silicification/pyrite dissemination zone, while, Pb and Zn veins tend to occur in the northeast part of the silicification/pyrite dissemination zone.

The drilling survey shows that the mineralization is more intense in the diorite porphyry than in the sedimentary rocks. The most prominent mineralization is a 15 m wide Zn mineralization with an Ag rich zone of 3 m wide at MJSI-4. The occurrence of Au rich-quartz-sulfides veins are confirmed close to the intrusion of the diorite porphyry at MJSI-5 and native gold is associated with arsenopyrite.

The Au-Ag, Cu, Pb, Znmineralization in the area is closely related to the igneous activity of the diorite porphyry. The geological setting of the area, mineral assemblages of ore minerals, alteration and fluid inclusion (300° C to 400° C) suggest that the mineralization of the area is not epithermal. The most possible geological environment for the mineralization of S. Imbak Sub-area is an outer margin of the mineralization similar to that of a porphyry copper type environment. The alteration is characterized by abundant sericite located in the center to the western part of the silicification/pyrite dissemination zone and it is considered to correspond to the phyllic alteration zone of a typical porphyry copper type mineralization. A chlorite rich zone corresponding to the propylitic zone of typical porphyry copper type, also occur in the S. Imbak Sub-area North surrounding the sericite rich zone. The Au rich quartz-sulfides vein with arsenopyrite occur within the sericite rich zone close to the diorite porphyry. The mineral assemblages of ore mineral (pyrite-pyrrhotite-arsenopyrite) suggest the hydrothermal ore fluids to be of intermediate sulfidation state.

The results of geophysical survey (IP method) in Phase I and Phase II clarified the strong IP anomalous zones which show a medium to high chargeability values of more than 20 mV/V. The Au, Ag and Cu anomalies of the rock geochemical survey in the central to southern part of the area correspond to the medium to high chargeability anomalies of more than 20 mV/V. Some core samples (diorite porphyry with pyrite dissemination and silicification/argillization, sandstone with fracture filling pyrite) from the drill hole MJSI-4 show high chargeability values of over 60 mV/V.

The strong IP anomalous zone within the silicification/pyrite dissemination zone resembles a letter "C" shape open ended to the east. The highest chargeability is located in the center of Line F and it extends toward both to east and to south. The strong IP anomalous zone also occur in the south of the area, along an E-W direction.

The drilling survey of Phase II was conducted in the area of strong IP anomalies and failed to intersect distinguished mineralization. The strong IP anomalies in the area probably reflect pyrite veins and dissemination near the surface.

Letter "C" shape IP anomaly is commonly observed in the arc of porphyry copper mineralization elsewhere in the world and it is known that the main mineralization occurs in the center of letter "C" shape anomaly. If a mineralization similar to porphyry copper type exits in the S. Imbak Sub-area, the area at center of letter "C" anomaly with relatively lower IP anomaly seem to be better target for drilling. The drilling sites for Phase III was decided in the area of relatively lower IP anomaly at the center of letter "C" shape anomaly, then, it was, later, found that the area of the proposed drilling sites was covered by the area of Reserved Virgin Jungle in where cutting tree is strictly prohibited. Therefore, the drilling survey of PhaseIII was conducted shifting the drilling sites further east and it failed to intersect distinct mineralization.

The area at the center of letter "C" shape anomaly should be examined in future.

4-4 S. Imbak Sub-area South

The S. Imbak Sub-area South is overlain by the Tanjong Formation of early to middle Miocene age. Many small bodies of diorite porphyry intrude the sedimentary rocks of the Tanjong Formation.

The main mineralization and alteration in the S. Imbak Sub-area South occur in the silicification/pyrite dissemination zone of central north (SA), center (SB) and east (SC) portions of the area. The occurrences of many intrusive diorite porphyry bodies in the mineralization zones suggest the mineralization and alteration in the S. Imbak Sub-area South are directly related to the diorite porphyry. Geological information and geochemical survey suggest the mineralization zone (SA) is the south extension of the mineralization zone (NA) of the S. Imbak Sub-area North. It is characterized by the quartz-sulfides veins in the silicification/pyrite dissemination zone. The most prominent veins were observed in the mineral showing of IMS-1 where Ag and Cu rich veins with maximum width of 35 cm occur. Other than this, Type② vein with Ag occur in the mineralization zone (SA). The mineral showing IMS-2 of the mineralization zone (SB) is similar to that of porphyry copper type with dissemination of pyrite and chalcopyrite both in the diorite porphyry and the sedimentary rocks. In the mineralization zone SC, distinct mineralization was not found.

The rock geochemical survey of S. Imbak Sub-area, including North and South, shows that the most prominent geochemical anomalies occur covering the area from the mineralization zone (NA) to the west part of the mineralization zone (SA) and are characterized by Au, As and Cu associated by Pb and Zn. The area covering the mineral showing IMS-2 in the mineralization zone (SB) is characterized by Cu, Au and S. No clear chemical anomaly is not found in the mineralization zone (SC). The elements such as Ca, Mg, Na and Sr are considered to be indicators of the alteration. These elements are depleted in the mineralized zones. K enrichment is presumed only in the mineralization zone (NA) of the S. Imbak Sub-area North.

In the S. Imbak Sub-area North, a clear alteration zoning similar to typical porphyry copper mineralization was obtained. The center of the alteration, corresponding to the phyllic zone, is located in the west part of the mineralization zone (NA) and it is surrounded by propylitic zone and argillic zone. Although, clear zoning of the alteration was not found in the S. Imbak Sub-area South, alteration in the mineralization zones (SA) and (SB) are slightly higher than surrounding areas because of the occurrences of quartz and sericite rich samples.

The filling temperature of fluid inclusions in the mineralization zones (NA), (SA) and (SB) show that average temperature of all the samples fall in a range of from 300° C to 400° C, corresponding to the temperature of phyllic zone of the typical porphyry copper type.

From the above, the mineralization zone (NA) of the S. Imbak Sub-area North is the center of the mineralization and alteration in the S. Imbak Sub-area. While, the mineralization zones (SA) and (SB) are the centers of the mineralization and alteration in the S. Imbak Sub-area South and more intense alteration and mineralization are expected underneath the surface. Therefore, these two zones are considered to be the most promising areas in the S. Imbak Sub-area South.

Chapter 5 Conclusions and recommendations

5-1 Conclusions

1. Telupid west Sub-area

The laterite soil of the Telupid West Sub-area shows similar vertical profile and chemical character to the laterite soil of the typical Ni laterite deposit elsewhere in the world. The soil profile in the Telupid West consists of, from top to bottom, 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 Sub-area. Although vertical chemical variation exists at each site, it is considerably small compared with a large horizontal variation. This, in addition to shallow development of laterite soil especially around the central hill, may suggest the laterite soil of the Telupid West Sub-area to be immature.

Although relatively high grade soil samples (more than Ni 0.8 %) were obtained along and around the crest of the central hill, their thicknesses are restricted from 2 m to 3 m. However, the thickness of the laterite soil may exceed 5 m in the flat area, with poor Ni grade. The limited lateral and vertical distribution of Ni along and around the crest of the central hill warrants no further exploration in the Telupid West Sub-area.

2. Pinanduan Sub-area

Intensive alteration and mineralization were not found through the geological survey in the area. The mineralization is only restricted to the intrusive bodies of gabbro where relatively strong serpentinization occurs accompanied by weak pyrite dissemination. No evidence of the mineralization and alteration that reflect Cu, Ag and Ni anomalies extracted during the Supra-regional survey were 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. However, no clear indication of IP effect, corresponding to alteration and weak pyrite dissemination found during geological survey was obtained.

Relatively intense IP anomaly obtained in the southwestern part of the area correspond to the location of Cu bearing sulfide mineralization found by the previous survey. This may imply the presence of considerable amounts of sulfide beneath the surface. The most intensive anomalies were obtained over the area from the southwestern to northeastern part (northern part of Line B north, Line D middle, Line E north, Line F south and Line G middle). No alteration and mineralization were found by geological survey over this area, however, these anomalies suggests possible sulfide veins or dissemination beneath the surface of the area.

The intense IP anomalies over the geochemical anomalies warrants a further detailed survey to be conducted in the area.

3 S. Imbak Sub-area North

The S. Imbak Sub–area North consists of early to middle Miocene Tanjong Formation and the diorite porphyry intruding the Tanjong Formation. The mineralization closely associated with the intrusion of the diorite porphyry, occurs in the silicification/pyrite dissemination zone in the center to south part of the area and it shows mainly two type of occurrences: quartz sulfides veins in the sedimentary rocks and a network of sphalerite veins and dissemination in the diorite porphyry.

The quartz–sulfides (pyrite, arsenopyrite, sphalerite, galena, chalcopyrite) veins measuring from a few cm to 25 cm wide sporadically occur in the sedimentary rocks of silicification/pyrite dissemination zone. These quartz–sulfides veins are classified into three types: Typ① Au and Ag vein, Au≧Ag, Type ② Au and Ag vein, Ag>Au, Type ③ Pb and Zn vein. Type① and Type② occur in the zone of higher alteration corresponding to phyllic zone in the west of the silicification/pyrite dissemination zone, while Type③ tend to occur in the east part of the silicification/pyrite dissemination zone.

Among the seven holes(MJSI–1 to MJSI–7) conducted during the project, the most prominent mineralization was found at MJSI–4 where sphalerite–(chalcopyrite) network veins and patches with Zn grade ranging from 0.40 % to 1.00 % occur in the diorite porphyry for 15 m . This Zn mineralization zone includes a 3 m long Ag rich (Ag 37.2 g/t to 90.5 g/t) zone. Some minor mineralization was, also, observed in the other holes, such as MJSI–5 and MJSI–7. In both of these holes, the diorite porphyry contains disseminated pyrite and pyrrhotite with rare occurrences of chalcopyrite associated with pyrrhotite. The Au bearing quartz–sulfides veins occur in the sedimentary rocks close to the intrusion of the diorite porphyry. The drilling survey also suggests that the distribution of diorite porphyry in the underground is larger than expected.

The geological information, mineral assemblage of ore minerals, filling temperature of fluid inclusion (300° C to 400° C) suggest that the most possible geological environment of mineralization in the S. Imbak Sub–area is similar to that of the outer margin of porphyry copper environment.

The results of geophysical survey in the Phase I and Phase II revealed strong IP anomalous zones over the area of the silicification/pyrite dissemination zone. The Au, Ag and Cu anomalies of the rock geochemical survey in the center to south part of the area correspond to the medium to high chargeability anomalies of more than 20 m V/V. The distribution of these strong anomalies show a letter "C" shape opening to east. This shape of IP anomaly distribution is similar to typical porphyry copper type mineralization elsewhere in the world and the main copper mineralization is known to occur in the area with relatively weak IP anomaly at the center of circular strong anomalies.

The drilling survey conducted in the Phase II at the target of very strong IP anomalies and in the PhaseIII in the east part of the area with Type 2 and Type 3 IP anomalies resulted in intersecting only minor mineralization. The area at the center of "C" shape anomalies is recommended as a target for further exploration work in the S. Imbak Sub-area North.

4 S. Imbak Sub-area South

The S. Imbak Sub-area South, similar to the S. Imbak Sub-area North, consists of early to middle Miocene Tanjong Formation and diorite porphyry intruding to the Tanjong Formation. The mineralization of the area, closely associated with the intrusion of the diorite porphyry, occurs in the silicification/pyrite dissemination zone at the center of the northern (SA), central (SB) and eastern (SC) parts.

The mineralization zone SA is considered to be the south extension of the silicification/pyrite dissemination zone of S. Imbak Sub-area North (NA) and is characterized by Ag and Cu enriched quartz-sulfides veins and Type② vein of the S. Imbak Sub-area North. The western part of the zone is covered by Au, As and Cu high value zones of the rock geochemical survey and alteration is slightly more intensive than the surrounding area. The mineralization zone SB (mineral showing IMS-2) is characterized by disseminations of pyrite and chalcopyrite in the diorite porphyry and the sedimentary rocks. It is covered by anomalies of Au, Cu and S. The Cu grade is slightly low, however, it shows similar mineralization to that of porphyry copper type. Distinct mineralization and clear geochemical anomalies are not found in the mineralization zone (SC). The alteration zoning and fluid inclusion temperature suggest a similar environment to the phyllic zone of porphyry copper type mineralization for mineralization zones (SA) and (SB).

The survey results suggest that the most likely potential areas for mineralization in the S. Imbak Sub-area South are the western part of the mineralization zone SA and SB and further detail survey should be conducted in future.

5-2 Recommendations

1. Telupid West Sub-area

Although relatively high Ni grade soil occurs along and around crest of the central hill, the thicknesses are restricted from 2 m to 3 m. The thickness of the laterite soil reaches more than 5 m in flat area, but Ni grade is poor. The limited lateral and vertical distribution of relatively high Ni, only along and around the crest of the central hill does not warrant further exploration and exploitation of Ni laterite of the Telupid West Sub-area. However, neighboring areas with a similar geological environment to Telupid West Sub-area should be examined.

2. Pinanduan Sub-area

Drilling is recommended to clarify the source of IP anomalies at the upper stream of S. Pinanduan. Prior to the drilling operation, a detail geological survey (3km × 3km) including rock geochemical survey and IP geophysical survey to trace a detail distribution of anomaly are recommended to decide the drilling target.

3. S. Imbak Sub-area North

If the mineralization similar to porphyry copper type exists in the S. Imbak Sub-area North, the locations of drilling site conducted in PhaseII and Phase III is in the peripheral area of the main mineralization. The center of mineralization probably exists in the area at the center of a letter "C" shape geophysical anomaly. The drilling survey with more than 300 m deep holes is recommended in the area at the center of "C" shape geophysical anomaly for further evaluation of the S. Imbak Sub-area North (Fig. I -6).

4. S. Imbak Sub-area South

The mineralized zone (SA) and (SB) show a similar type of mineralization to that of (NA) in the S. Imbak Sub-are North. As shown in Fig. I -7, detail geological survey and IP survey are recommended prior to drilling survey.

Mineralization zone (SA)

Area: 3.15 km² (1.5 km × 2.1 km)

IP survey lines: 12 km (1.5 km × 8 lines)

Mineralization zone (SB)

Area: 4.20 km² (2.0 km × 2.1 km)

IP survey lines: 16 km (2.0 km × 8 lines)

A similar type of mineralization occurs along the G. Kuli range in S. Imbak Sub-area North and South. In addition to these, a similar mineral showing was recently found in the area further south of these areas, south of S. Kuli. This suggests that the area along the G. Kuli range is cover by a similar type of mineralization with high potentiality for Au and Cu mineralization. A detail survey covering from the S. Imbak Sub-area to the south of S. Kuli is awaited.

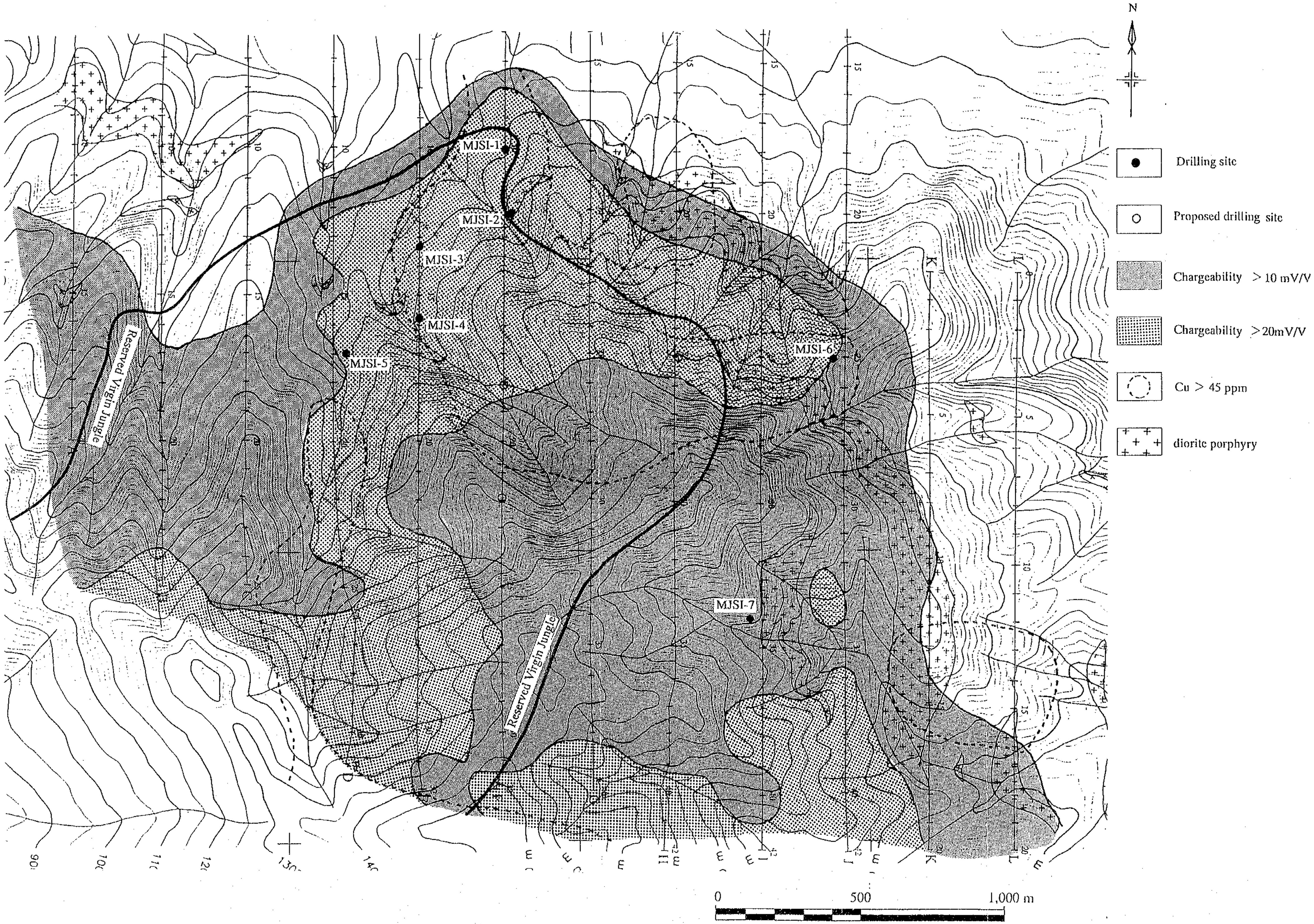


Fig. I -6 Recommendation for future work in S. Imbak Sub-area North

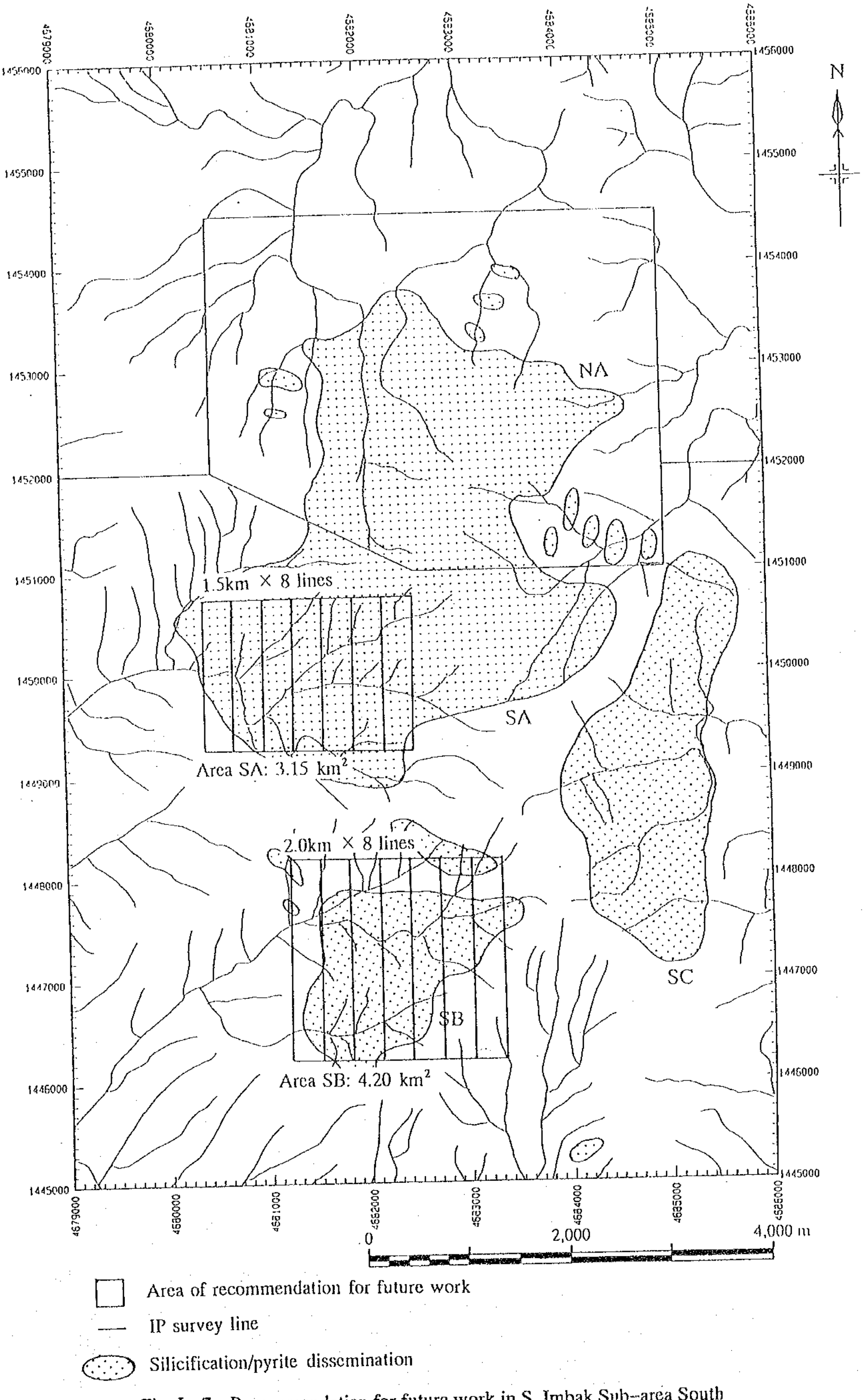


Fig. I -7 Recommendation for future work in S. Imbak Sub-area South