REPORT ON THE MINERAL EXPLORATION IN SABAH, MALAYSIA

CONSOLIDATED REPORT

MARCH, 1988

JAPAN INTERNATIONAL COOPERATION AGENCY
METAL MINING AGENCY OF JAPAN

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PREFACE

In responce to the request of the Government of Malaysia, the Government of Japan agreed to conduct a collaborative mineral exploration project to confirm the possibility of occurrence of mineral resources in Sabah Region, Malaysia.

Its implementation was entrusted to the Japan International Cooperation Agency. As the project deals with the geological survey and investigation of mineral resources, the Japan International Cooperation Agency entrusted its implementation to the Metal Mining Agency of Japan.

This project was carried out in three years from 1985 to 1987 and completed as scheduled with a great collaboration of the relevant Governemtal Agencies of Malaysia, especially the Geological Survey of Malaysia.

This consolidated report summarizes the survey results of those three years.

In closing, we wish to express our sincere appreciation to the Governmental Organizations of Malaysia for their assistances and cooperations extended during the course of the project.

February, 1988

Kensuke Yanagiya
President
Japan International Cooperation Agency

Jun-ichiro Sato
President
Metal Mining Agency of Japan

Yin Ee Heng
Director-General
Geological Survey of Malaysia

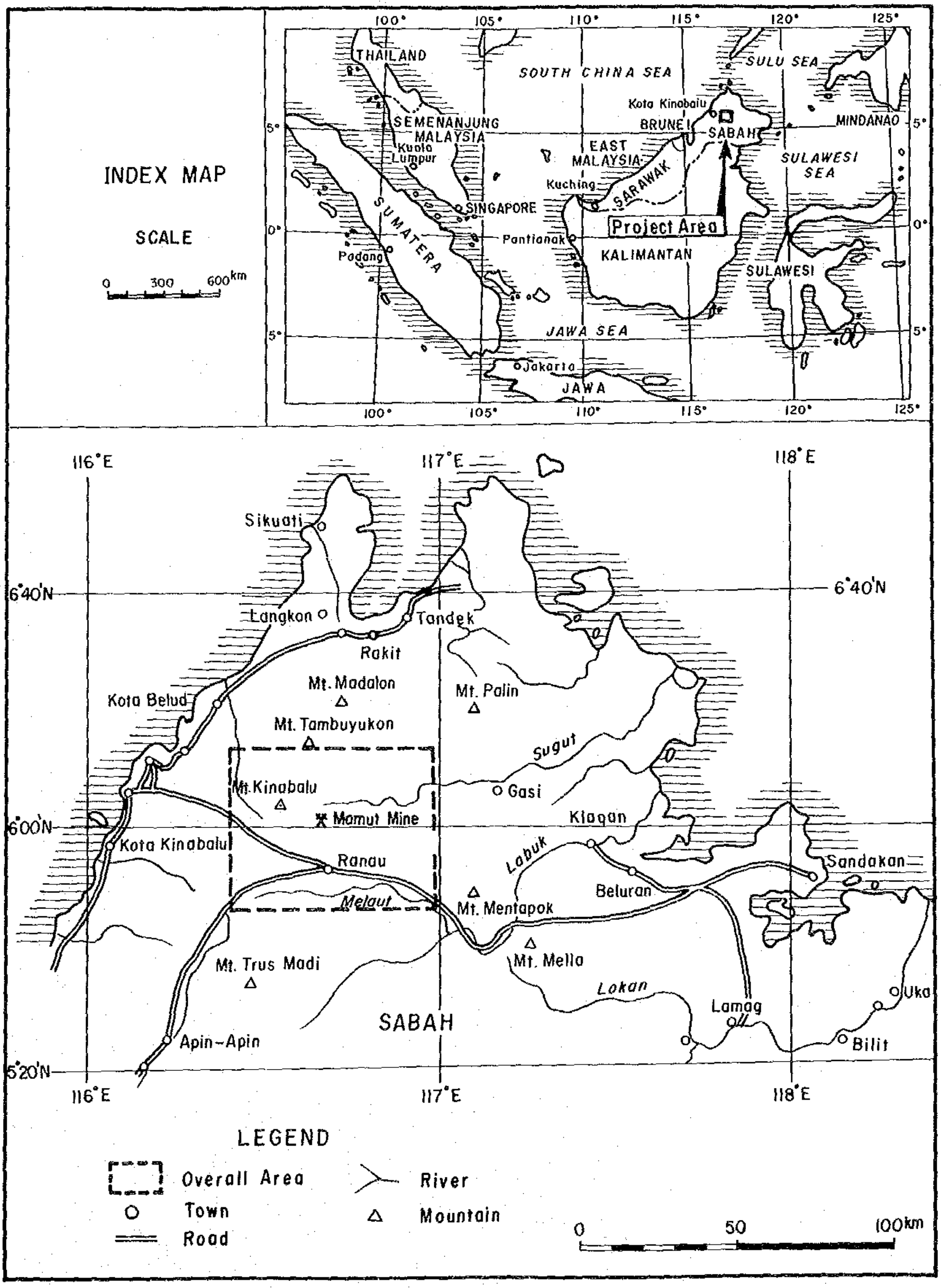

Fig. 1 Location Map of Survey Area

ABSTRACT

In the Kinabalu Mountain - Ranau area, Sabah, Malaysia, thick geosynclinal sediments (from late Cretaceous to early Miocene), ultrabasic or basic igneous rocks (late Miocene) and intermediate to acidic igneous rocks (late Miocene) are widely distributed. Porphyry copper type ore deposit/showing, a series of massive sulphide copper floats (to be seemed as the Cyprus-type) and the occurrence of chromite ore have been recognised. Among all of these, the porphyry copper type mineralizations are seen predominant and as a consequence, one of them, so called Mamut copper mine has been under operation since 1975.

The collaborative mineral exploration of Sabah, Malaysia was carried out for the purpose of clarification and evaluation of the occurrence of ore deposits by detailed geological, geochemical, geophysical surveys and drilling in the three areas of the Bambangan, the Mankadau and the Paliu. These areas seems to have the highest potentials for finding ore deposits among the showings and geochemical anomalous zones obtained through the previous surveys.

The survey results of these three years can be summarized as follows:

1. Bambangan (A, a) area

This area has an extent of 100 km^2 including Mamut ore deposit and small known outcrops at 4 km southwest from Mamut. A few information can be obtained in the area by surface surveys, due to widely distributed Pinosuk Gravels which seem to be glacial sediments of Quaternary period. For this reason, in the first year (Phase I) geophysical survey using the CSAMT method was carried out on the whole area. Subsequently, IP and SIP geophysical surveys were followed in the low resistivity zone which resulted most similar to Mamut ore deposit among the detected three anomalous resistivity zones. Drilling of 10 holes (total length of 3,460.2 m) was also carried out on the known mineralized zones and IP anomalous zones. As a result, the existence of a porphyry copper type mineralized zone was revealed in adamellite porphyry dikes intruded in N-S direction and in its surrounding sedimentary rocks in the Bambangan creek located north side of the small known outcrops.

In the second (Phase II) and third (Phase III) year of the project, drilling of 8 holes in total (2,610.8 m) was carried out to confirm the lateral and vertical extensions of the mineralized zone as well as its grade. It had also the purpose to confirm the extention of pyrite dissemination zone intersected by a drill hole of the first year drilling at eastward of the Bambangan creek.

From the results of these surveys, it was confirmed that the mineralized zone along the Bambangan creek is a porphyry copper type mineralized zone containing mostly disseminated/-

fine veinlets pyrite and minor chalcopyrite, with an extention of 400 m in N-S direction, 200 - 250 m in E-W direction and 90 m of thickness at its central part. Its average grade resulted as Cu 0.14%, Au 0.07 g/T and Mo 31 ppm. However, this mineralized zone is overlain by the Pinosuk Gravels of 70 - 170 m thick and with a grade of mineralization very low in comparison with the one from Mamut ore deposit (Cu 0.56%, Au 0.6 g/T). The results, indicate as a consequence, that there is a low possibility for new mine development so far at present stage is concerned.

However, it is suggested that some mineralized zones which may be as similar zone as these of the Bambangan, occurs in some places underneath of the Pinosuk Gravels.
A area other than the A-1 area, two low resistivity zones were detected by CSAMT method. Among these, A-3 zone in Kundasang side seems to have a relation with mineralization, but no further survey has been done. Therefore, for this anomaly (A-3), the follow-up IP.SIP geophysical survey (drilling based upon the results of IP.SIP survey) is considered necessary.

2. Mankadau (B, b) area

This area has an extent of 100 km² including Mankadau river and its tributary which lies 15 km northeast of Mamut ore deposit.

The ultrabasic or basic igneous rocks are predominant in the area, where it has been recognized a series of floats of high grade massive sulphide copper ore (Cu 25 - 60%) in the Lingangaa creek (a tributary of Mankadau river) and a small chromite ore deposit at 1.5 km northeast of Paranchangan village down stream of the Mankadau river.

In the first year (Phase I), with a main purpose of investigating the source of the massive sulphide copper ore floats, a geophysical, CSAMT survey to cover the whole area and a soil geochemical survey in the area of 4 km² at the Lingangaa creek (where the ore floats are collectively distributed) were carried out. As the results, many chromite ore floats were newly discovered at the uppermost stream of the Lingangaa creek, however, any meaningful occurrence/anomalous zone to show an existence of sulphide copper ore and chromite ore could not be obtained. For this reason, in the second year (Phase II), semi-detailed geological survey and soil geochemical survey were carried out in a widened area of 50 km². The studies also included the execution of a detailed survey on the known chromite ore deposits in northeast of Paranchangan. However, no indications to suggest the source or place of occurrence both sulphide copper ore and chromite ore deposit occurring in the Lingangaa creek by these surveys.
Regarding to known chromite ore deposit in the Paranchangan, results indicated a low potential for occurrence of an economically minable ore deposit, because of a poor distribution of dunite

which has close genetic relation with chromite.

3. Paliu (c) area

This area is located at 25 km east of Mamut ore deposit. In the area two anomalous zones of Cu, Pb, Zn by stream sediments geochemical survey were detected by the collaborative exploration work between Malaysia and West Germany in 1982. They recommended a follow up survey on these anomalies.

During the first year (Phase I), in order to clarify the sources and characteristics of these geochemical anomalous zones, geological and geochemicl surveys for stream sediment and soil were carried out over an area of 4 km^2. As a result, a small and weak anomalous zone of Cu, Pb, Zn was located at the central area. Then in the second year (Phase II), 10 trenches were carried out for these anomalous zones. The surveys led to the following results; the anomalous spot in the trench of No. 2 indicates the content of Pb, maximum 0.605% in a silicious sandstone, and in the trench of No. 6 indicates the contents of 0.10 - 0.19 g/T of gold accompanied by stringers of pyrite and quartz, so that it seems to have a low potential for an occurrence of ore deposit.

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PART I GENERAL

Chapter 1 Outline of Survey

1-1 Survey Area and Purpose of Survey

In response to the request of the Government of Malaysia, the Government of Japan agreed to conduct a collaborative mineral exploration project in the state of Sabah.

The project area was agreed and signed on June 15, 1985 between the Economic Planning Unit in Prime Minister's Office of Malaysia and the Japanese mission. The area has a E-W length of about 52 kilometres and N-S width of about 40 kilometres, situated in the east of Kota Kinabalu of State capital.

The area contains the Mamut mine, a well known operating mine, and various kind of surveys were made in the Area. Regarding geology and ore deposit, the detailed surveys have been carried out, however they are local and centreed on the Mamut mine (Fig.1).

The past surveys had to be localized because the main target was the ore deposit. These surveys did not always fully illuminated the relatinships between the minerali-zaion, geological structure and igneous activity hindered by a steep topography of Mt. Kinabalu and the Pinosuk Gravels of the Quaternary glacier and mud flow sediment which covers the surrounding part of Mt. Kinabalu.

The purpose of this survey, therefore, is to evaluate the potential for ore deposit by elucidating the geological structure with higher accuracy and by grasping the geological environment connected to the occurrence of ore deposit through various investigations, including basic survey for the areas: Bambangan, Mankadau and Paliu, which were selected in base of the existing data.

Among these three areas, the Bambangan area consists of the area "a" (6 km^2) covering the known outcrops plus its surrounding area "A" (94 km^2); the Mankadau area consists of the area "b" (4 km^2) covering the distribution of copper ore floats and of the surrounding area "B" (96 km^2). The Paliu area consists of the area (4 km^2) covering the known geochemical anomalous zones.

These three areas are indicated as I, II and III in order to distinguish the survey period from the first year to the third year.

The location of these three areas are shown on Fig.I-1.

1-2 Method of Survey and Survey Amount

The survey was executed during three years from 1985 to 1987 in field seasons.

The method of survey and amount by year are shown in Table 1-1. Fig.I-2 and I-3 show the process of survey indicating the area for each year.

The survey methods are outlined as follows:

(1) Geological Survey

Semi-detailed survey was carried out in bII area, while detailed survey in aII, bI and cI.

The semi-detailed survey was executed using 1/10,000 topographical map, prepared for this purpose, and afterwards compiled to 1/10,000 geological map.

The detailed survey was carried out using 1/5,000 topographical map enlarged from 1/10,000 map in aII area, then compiled to 1/5,000 geological map. On the other hand, for bI and cI, 1/2,500 route map was made by field survey and compiled to 1/5,000 geological map.

(2) Geochemical Survey

Semi-detailed survey for stream sediments was applied in cI area, while detailed survey for soil in bI and cI. However, as no positive results in bI area were obtained in Phase I, a semi-detailed survey for soil was conducted in bII area covering wider areas. The stream sediments were sampled at 50 m intervals along creek and sieved through a 80 mesh screen to obtain silty soil. The soils were collected in a grid system of 50 x 50 metres (grid sampling) for detailed survey, while for semi-detailed survey the soils were collected by selecting an average of 5 samples in every one km^2 along geological survey line.

The collected samples were analized in the Geological Survey of Malaysia, Sabah for Cu, Pb, Zn, Mo and Au. Among these, Au analysis was made for selected samples.

The statistical treatment of the data was done in Japan.

(3) Geophysical Survey

Preliminary CSAMT survey was carried out along the routes previously planned in AI and BI areas by keeping an interval of about 400 m between the stations. Semi-detailed survey was conducted with a higher survey point density than the preliminary survey, i.e. a survey point density of 4 points per square kilometres in aI area and 9 points per square kilometres in bI area where geochemical survey lines were utilized. IP and SIP methods were carried out in the low resis-

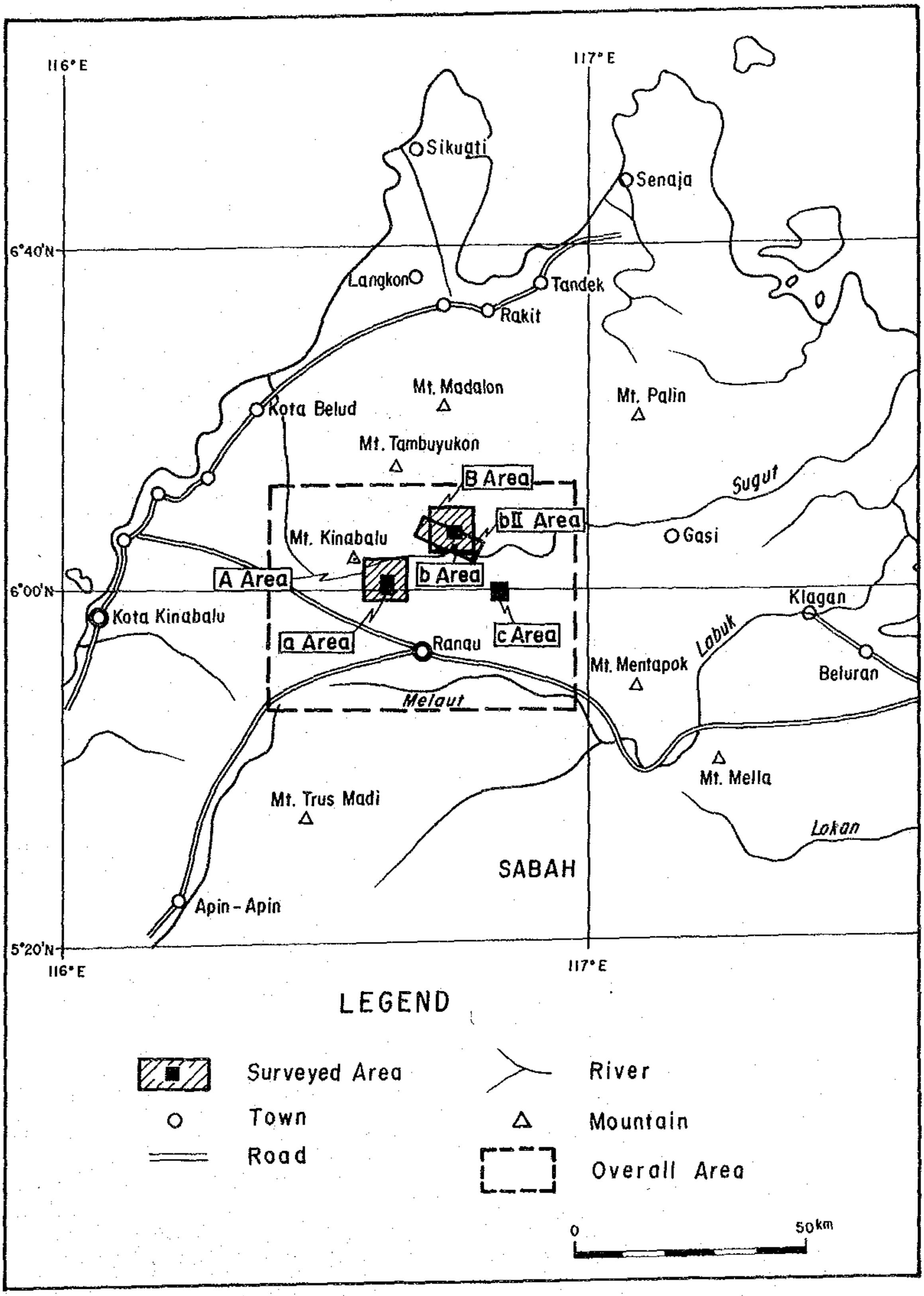


Fig. I-1 Detailed Location Map of Surveyed Area

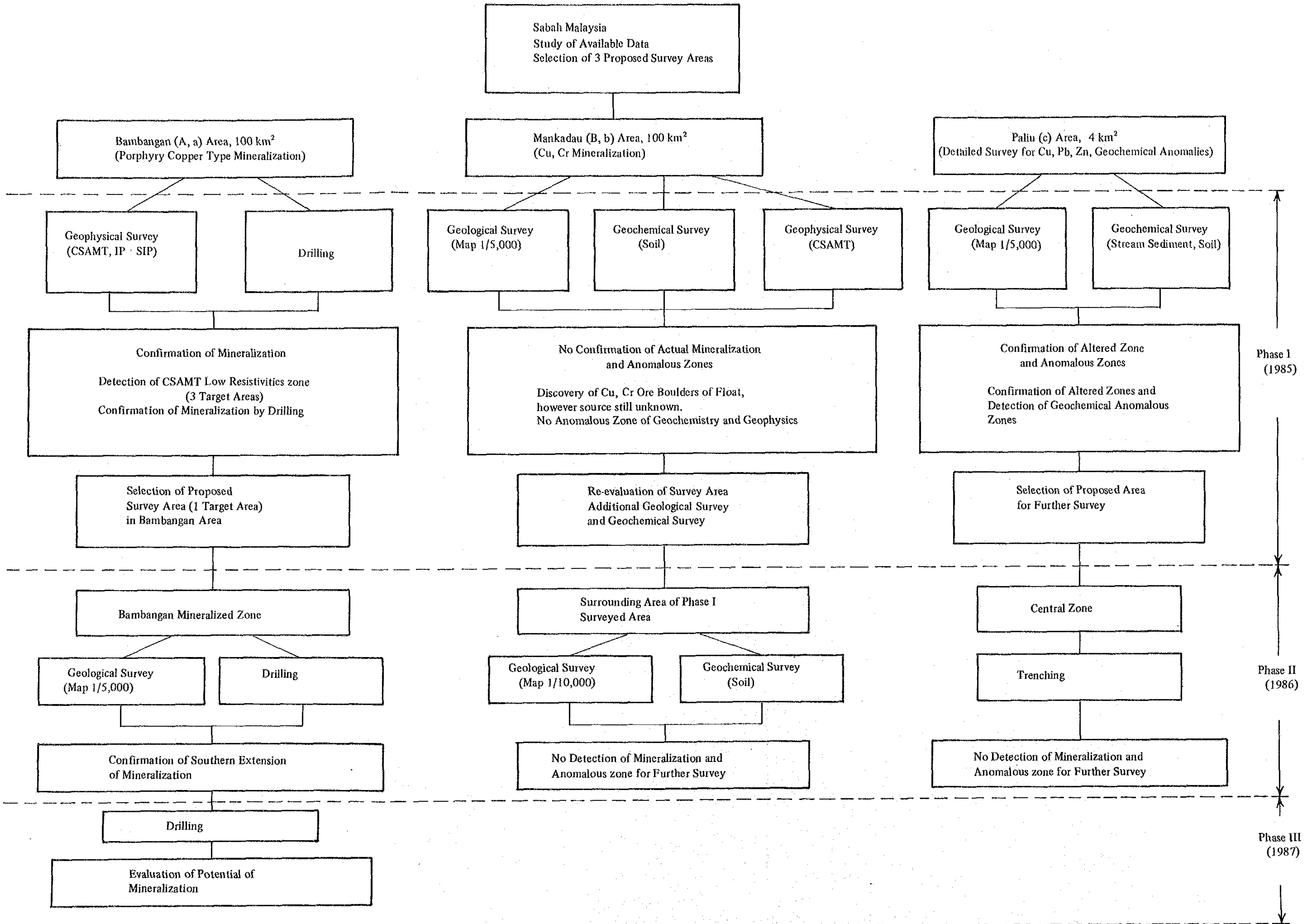


Fig. I-2 Flowsheet Showing Selection of Each Phase Survery Area, Sabah (Phase I, Phase II, Phase III)

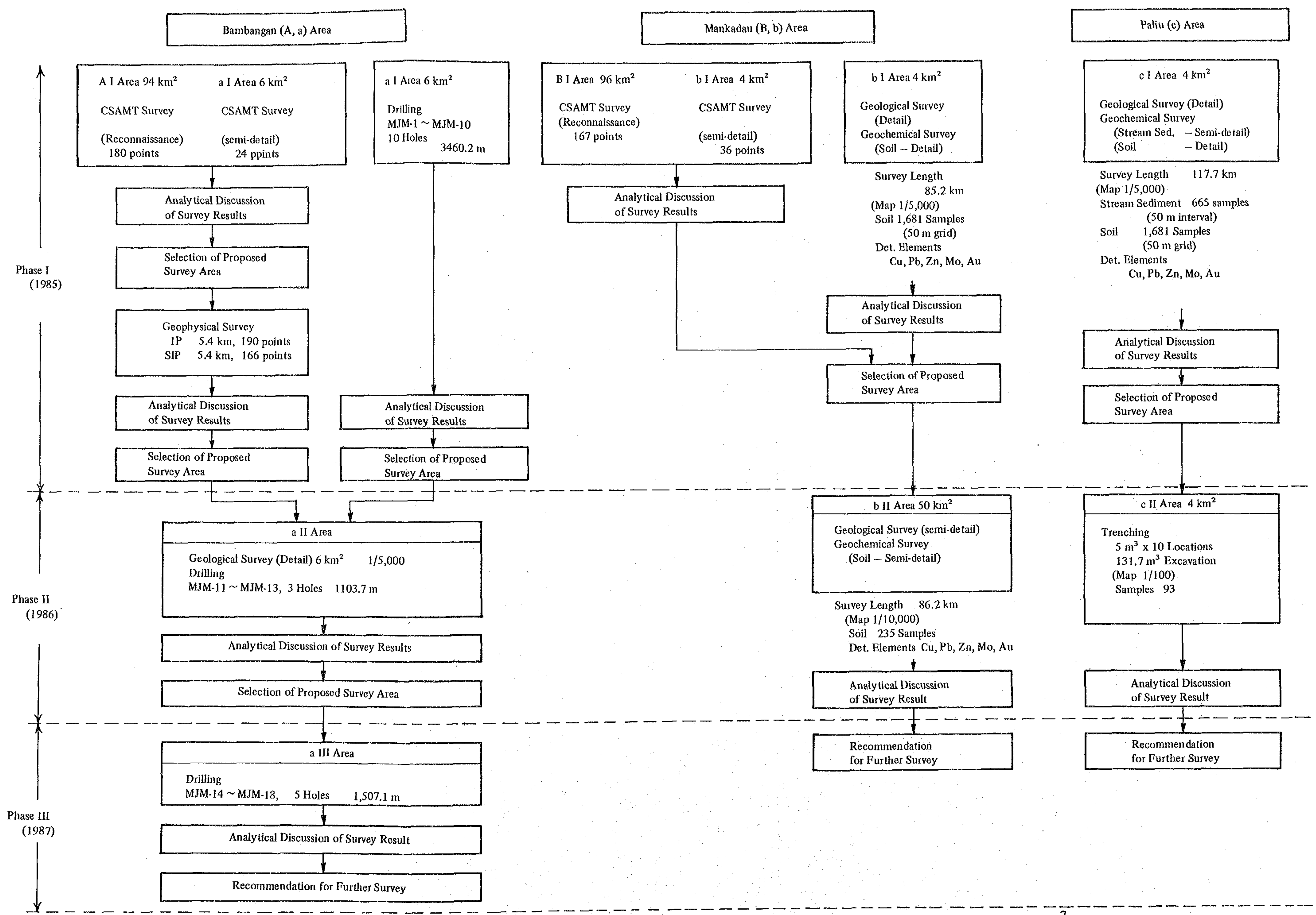


Fig. I-3 Flowsheet Showing Details of Survey, Sabah

Table I-1 Method and Amount of Survey

Year	Bambangan (A, a) Area	Mankadau (B, b) Area	Paliu (c) Area
Phase I	CSAMT Survey (Reconnaissance) AI Area 94 km^2, 180 Points CSAMT Survey (Semi-detail) aI Area, 6 km^2, 24 Points IP Survey AI, aI Area 5.4 km, 190 Point SIP Survey AI, aI Area 5.4 km, 166 Point Drilling survey aI Area 10 Holes 3,460.20 m (MJM-1 ~ MJM-10)	Geological Survey (Detail) bI Area, 4 km^2 1/5,000 Geological Map Soil Geochemical Survey (Detail) bI Area, 4 km^2 1681 Samples (Pathfinder : Cu, Pb, Zn, Mo, An) CSAMT Survey (Reconnaissance) BI Area 96 km^2 167 Points CSAMT Survey (Semi-detail) bI Area 4 km^2 36 Points	Geological Survey (Detail) cI Area, 4 km^2 1/5,000 Geological Map Steam Sediment Geochemical Survey (Semi-detail) cI Area. 4 km^2 665 Samples (Pathfinder : Cu, Pb, Zn, Mo) Soil Geochemical Survey (Detail) cI Area 4 km^2 1681 Samples (Pathfinder : Cu, Pb, Zn, Mo, Au)
Phase II	Geological Survey (Detail) aII Area 6 km^2 1/5,000 Geological Map Drilling aII Area 3 Holes 1103.7 m (MJM-11 ~ MJM-13)	Geological Survey (Semi-detail) bII Area 50 km^2 1/10,000 Geological Map Soil Geochemical Survey (Semi-detail) bII Area 50 km^2 235 Samples (Pathfinder : Cu, Pb, Zn, Mo, Au)	Trenching Survey cII Area 10 Trenches (131.7 m^3)
Phase III	Drilling aIII Area 5 Holes 1,507.1 m (MJM-14 ~ MJM-18)		
Total	Geological 6 km^2 Geophysical Survey CSAMT Method 204 Points IP Method 190 Points SIP Method 166 Points Drilling 18 Holes 6,071.00 m	Geological Survey 54 km^2 Geochemical Survey Soil 1,916 Samples Geophysical Survey CSAMT 203 Points	Geological Survey 4 km^2 Geochemical Survey Steam Sediment 665 Samples Soil 1,681 Samples

tivity structure zone obtained by CSAMT survey in AI and aI areas. Four survey lines spaced 200 m (total length 5.4 km) were surveyed at the station interval of 50 m. All data obtained were analized and interpreted in Japan.

(4) Drilling

Two drilling machines (TGM-2C and TGM-5) were brought from Japan and drilling work was done by wire-line method. The final diametre of each drill hole is to be kept in BQ-WL size.

(5) Trenching

In cII area, 10 locations were selected and tenching work was carried out by man power.

1-3 Duration of Survey and Survey Team

The field survey started on 8th August, 1985 and completed on 9th October, 1987.

The duration of survey in each Phase and the members of survey team is listed in Table I-2.

Table I-2 Member List of Survey

	Classification	Field Survey Period	Member	
			Japanese Counterparts	Malaysian Counterpart
	Planning and Negotiation of Scope of Work		Makoto Ishida (MMAJ) Takeshi Nakayama (") Eiji Ueda (JICA)	Mohd Usof Ismail (EPU) Husniarti Tamin (") Ho Yoka Leng (") Wong Peng Har (") Daisy Rajoo (") Santokh Singh (GSM,KL) Yin Ee Heng (") David Lee Thien Choi (GSM, Sabah) Lim Peng Siong (")
(1985) Phase I	Planning and Negotiation of Survey Programme		Takanori Kamei (MITI) Kojiro Komura (") Makoto Ishida (MMAJ) Michihisa Shimoda(") Yasuhisa Yamamoto(") Jiro Ohsako (") Atsushi Osame (") Yasuo Endo (")	Yin Ee Heng (GSM, KL) Datuk Seri Radin Soenarno (") Al Haj Epu (") David Lee Thien Choi (GSM, Sabah)
	Geological Survey and Geochemical Survey	Aug. 17, '85 ~ Oct. 24, '85	Hajime Shimizu (B.E.C.) Hiroshi Fuchimoto(") Hisao Takeda (") Tadashi Yamakawa(")	Lim Peng Siong (GSM, Sabah) Tungah B. Surat (") Muhd. Yusop Ramli (") Chan Fook On (")
	Geophysical Survey (CSAMT Method)	Sept. 28, '85 ~ Dec. 1, '85	Tomio Tanaka (") Kohei Sugawara (") Kazuto Matsukubo(")	Joanes Muda (") Kwan Houng En (") Kirman B. Sukardi (")
	Geophysical Survey (IP.SIP Method)	April 3, '86 ~ May 24, '86		
	Drilling	Sept. 21, '85 ~ Aug. 7, '86	Koji Kudo (") Tomie Tozawa (") Toshio Murayama(") Mahito Hamazaki (") Isao Matsuoka (") Mitsuru Ambo (") Hiroshi Saito (")	Salleh Adanan (") Roger Jinijo Totu(") Kamil Kamaruddin(")

<table>
<tr><th rowspan="2"></th><th rowspan="2">Classification</th><th rowspan="2">Field Survey Period</th><th colspan="2">Member</th></tr>
<tr><th>Japanese Counterparts</th><th>Malaysian Counterpart</th></tr>
<tr><td rowspan="4">(1986) Phase II</td><td>Planning and Negotiation of Survey Programme</td><td></td><td>Seiichi Ishida (MMAJ)
Tadaaki Ezawa (")
Yoshitaka Hosoi (")</td><td>Yin Ee Heng (GSM, KL)
David Lee Thien Choi (GSM, Sabah)</td></tr>
<tr><td>Geological, Geochemical Survey</td><td>Sept. 20, '86 ~ Nov. 1, '86</td><td>Hajime Shimizu (B.E.C.)</td><td>Lim Peng Siong(GSM,Sabah)</td></tr>
<tr><td>Trenching</td><td>Oct. 20, '86 ~ Nov. 1, '86</td><td>Tadashi Yamakawa(")
Takashi Nagamine (")</td><td>Mohd. Yusop Ramli (")
Chan Fook On (")</td></tr>
<tr><td>Drilling</td><td>Sept. 19, '86 ~ Dec. 20, '86</td><td>Mahito Hamazaki (")
Shigeo Sekiguchi (")
Hiroshi Saito (")</td><td>Johnty Enggihon (")
Kwan Houng En (")
Kirman B. Sukardi (")
Roger Jinijo Totu (")
Francis Geoffery (")
Chua Yun Ling (")
Arnold Bangose (")
Abdullah Sirom (")</td></tr>
<tr><td rowspan="2">(1987) Phase III</td><td>Planning and Negotiation of Survey Programme</td><td></td><td>Seiichi Ishida (MMAJ)
Natsumi Kamiya (")</td><td>Yin Ee Heng (GSM, KL)
Fateh Chand (")
David Lee Thien Choi (GSM, Sabah)</td></tr>
<tr><td>Drilling</td><td>July 1, '87 ~ Sept. 30, '87</td><td>Hajime Shimizu (B.E.C.)
Hirofumi Taniguchi(")
Mahito Hamazaki (")
Shigeo Sekiguchi (")
Takashi Satoh (")
Yoshihito Masuto (")
Yoshio Itoh (")
Hiroshi Saito (")</td><td>Lim Peng Siong (GSM, Sabah)
Francis Intang (")
Japili Samin (")
Roger Jinijo Totu(")
Chua Yun Ling (")
Francis Geoffery (")</td></tr>
</table>

(Abbreviation)

EPU : Economic Planning Unit
GSM KL : Geological Survey of Malaysia, Kuala Lumpur
GSM, Sabah : Geological Survey of Malaysia, Sabah
MITI ... Ministry of International Trade and Industry
JICA : Japan International Cooperation Agency
MMAJ : Metal Mining Agency of Japan
B.E.C. : Bishimetal Exploration Co., Ltd.

Chapter 2 Previous Surveys

On the geology and mineralization of Central - North Region of Sabah State including Kinabaru mountain area, various surveys have been carried out by the Geological Survey of Malaysia, private exploration companies and foreign/domestic research institutes etc. allowing the collection of numerous data and information. Exploration activities became active in southeast part of Kinabalu mountain, especially, after the Labuk Valley Project (conducted by United Nations in 1965) which gave the opportunity of finding Mamut ore deposit.

The major items of geological survey conducted in surrounding area of Kinabalu mountain, from early 1960's to commencement of this Collaborative Mineral Exploration, are summarized as follows:

1960: Soriano y Cia. obtained the prospecting right in the Karang area (1,000 mile^2).

1962: Sabah Geological Survey recognized the occurrence of cinnabar by panning in the downstream of a stibnite outcrop at Randagong (southwest of Ranau). Soriano y Cia. started exploration of copper deposit of various areas in Sabah State. Geochemical survey was carried out in the Karang-Karamuak area, resulting in the detection of copper anomalies in the northern part of the Mankadau area in the Tambuyukon area. Boulders of copper ore discovered in some rivers such as Sansogon and Lingangaa, lead to establish in the area mineral lease.

1963: The Labuk Valley Project was conducted by the special fund of the United Nations. At first, reconnaissance geochemical survey was started in the Labuk-Karamuak area. Soriano y Cia. continued geochemical survey by stream sediment of a regional scale, and in addition, carried out geoelectrical survey and pitting in the Mankadau area. However, the prospecting was terminated by the failure to find out massive copper deposit as seen on the outcrop.

1964: Soriamont Investment Co., (successor to Soriano y Cia.) detected the anomalies of geochemical and electrical surveys at the prospect of Karang in the Karamuak area. Further, floats of boulder of copper ore were discovered in Nungkok by reconnaissance geological survey in the Kinabalu mountainous area. Reconnaissance geochemical survey (640 mile) was conducted in the Karamuak area, following the survey of the previous year.

Sabah Geological Survey indicated the possibility of occurrence of copper ore deposit in the Kinabalu area at the time of geological mapping for the quadrangle geological survey by finding out quartz boulders containing chalcopyrite along the road between Tenompok and Konborongah on the southern skirt of Kinabalu mountain.

1965: Soriamont Investment Company newly obtained the prospecting right (60 mile^2) in the Nungkok area and conducted geological mapping and geochemical survey, having resulted in the discovery of the copper mineralized zone (in silicified mudstone intruded by quartz diorite) on the western slope of Mt. Nungkok.

Labuk Valley Project (United Nations): A reconnaissance geochemical survey was conducted, having detected eight copper anomalous areas including M-1 and M-2. Among these, M-1, M-2 and Bambangan areas were investigated for follow-up survey (Annual Report 65).

Sabah Geological Survey conducted geological mapping of Mamut (M-1 and M-2) and Bambangan areas which had been investigated by the United Nations for the follow-up survey among the geochemically anomalous zones detected by the Labuk Valley project. It was recognized the occurrence of porphyry copper in the upper reaches of M-2.

1966: Soriamont Investment Company continued the exploration in the Nungkok area and performed the electric survey and drilling of five holes in the extent of 1,000 m x 400 m. Sabah Geological Survey conducted drilling of 30 shallow holes and excavation of more than 200 pits centering on the M-2 area, having confirmed the copper mineralized zone of 0.7 per cent in grade over an extent of 150,000 square metres. The exploration by pitting and auger drillling in the Bambangan area did not warrant the economical development of the deposit.

Meanwhile, the Sabah State Government decided to invite international tenders for the exploration right of the Mamut and Bambangan areas (Anuual Report 66).

1967: Soriamont Investment Company continued the exploration of the Nungkok area, however, it was suspended without confirmation of the ore reserve to warrant economical development.

The OMRD (Overseas Mineral Resources Development) Company made a successful bid for the exploration right of the Mamut and Bambangan areas of 50 square miles in December after severe competition with the major mining companies of the world.

1968: The OMRD Co. conducted the exploration of the first phase (land survey, geological mapping, electrical survey and drilling) from April to November.

1969: The exploration of the second phase was completed in November.
At the same period, OMRD established the OMRD-Sabah Company in May. The Mamut Mine Development Co., Ltd. was established in December in Japan, which was to be in charge of the feasibility study of the development plan of the mine.

1973: The mining right was authorized to OMRD-Sabah. The development works were commenced.

1975: In May, the operation of the Mamut mine was started.

1968-69: Jacobson, G. carried out detailed geological mapping of the Kinabalu area. His work was published as Report 8 which gives an account of the geology, structure, geological evolution of Mount Kinabalu and mineralization of the area.

1971: Tokuyama, A. and Yoshida, S. studied the structures of the Crocker Formation in the Ranau-Kinabalu area. They postulated the existence of the strike-slip Kinabalu Fault.

1978: Leong, K.M. studied the occurrences of metamorphic rocks (garnet amphibolite, garnet corundum amphibolite, glaucophane-talc schist) of Sabah, including those in the Ranau ara. He postulated the Blueschist belt of Sabah.

1980: Lee, D.T.C. studied satellite imageries of the west coast of Sabah.

1981: Hoppe, P., Weber, H.S. and Yan, A. as part of the Malaysian-German Mineral Exploration Project, all the stream sediment samples collected by the UNDP survey were reanalized for Cu, Pb, Zn, Ni, Co and results were evaluated.

1981-82: Hoppe, P. studied photogeology (1:50,000, 1:25,000 and Landsat imageries) of the Ranau-Kinabalu area between 1981 and 1982 as part of the Malaysian-German Mineral Exploration Project.

1983: H.D. Tjia studied the Quaternary tectonics of Sabah and Sarawak (including the Ranau-Kinabalu area).

Chapter 3 General Geology of the Surrounding Area of Mt. Kinabalu

The state of Sabah is situated in the northern part of Borneo Island.

The geology of this state is characterized by

- The "Crystalline Basement" consisting of schist, gneiss of the Jurrassic or older age.
- The "Northwest Borneo Geosyncline", overlaying the Basement and consisting of sedimentary rocks and igneous rocks which form the geosyncline and orogenic belt in the age from the later Cretaceous to the late Neogene.
- The structural belt, so called, "Kinabalu Fault" (Tokuyama, Yoshida, 1974) trending to NW-SE direction in the northern part of Sabah. (Fig. I-4)
- The Kinabalu mountain mass is situated in the structural belt where the ultrabasic - acidic igneous activities took place.

The Northwest Borneo Geosyncline is conspicuous with the distribution of spilite extrusives in late Cretaceous, the sedimentary rocks and the Rajang Group composed of flysch-type sediments (Eocene to early Miocene) of the product of the geosyncline.

The igneous activity includes intrusion of ultrabasic rocks belonging to Cretaceous and intrusion of plutonic rocks during and after the orogenic age (middle Miocene to Pliocene) followed by the extrusion of andesite and basalt. The geology of a series of typical geosynclinal orogenic movement and the structure are shown in Fig.I-5, Fig.I-6 and Map-1.

The characteristics of the basement rocks, sedimentary rocks, main igneous rocks and geological structures are as follows :

(1) Crystalline Basement

The Crystalline Basement is mainly composed of crystalline schist and gneiss, forming the basement of Sabah State. It is distributed in a small scale in the upper stream of the Bambangan river and at the foot of Mt. Kinabalu.

(2) Chert-Spilite Formation

The Chert-Spilite Formation is the products of basic volcanic activities in the early age (late Cretaceous to early Palaecene) of the Northwest Borneo Geosyncline. It chiefly consists of spilitic basalt lava and its pyroclastic rocks with chert and greywacke intercalation. Basalt lava has a pillow structure and is widely distributed in the Mankadau area. The drill hole in the Bambangan area also encountered this rock.

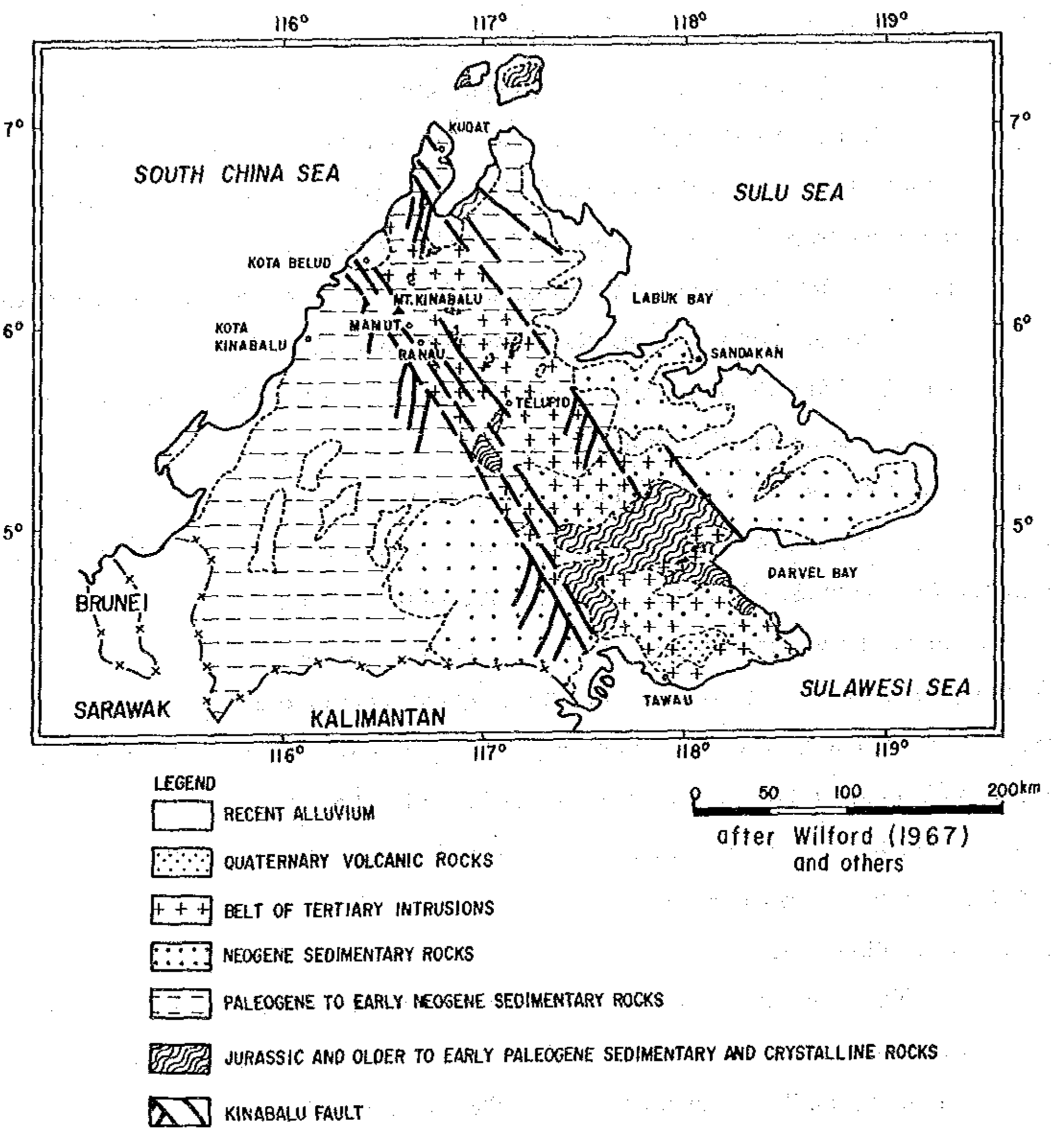


Fig. I-4 Generalized Geological Map of Sabah

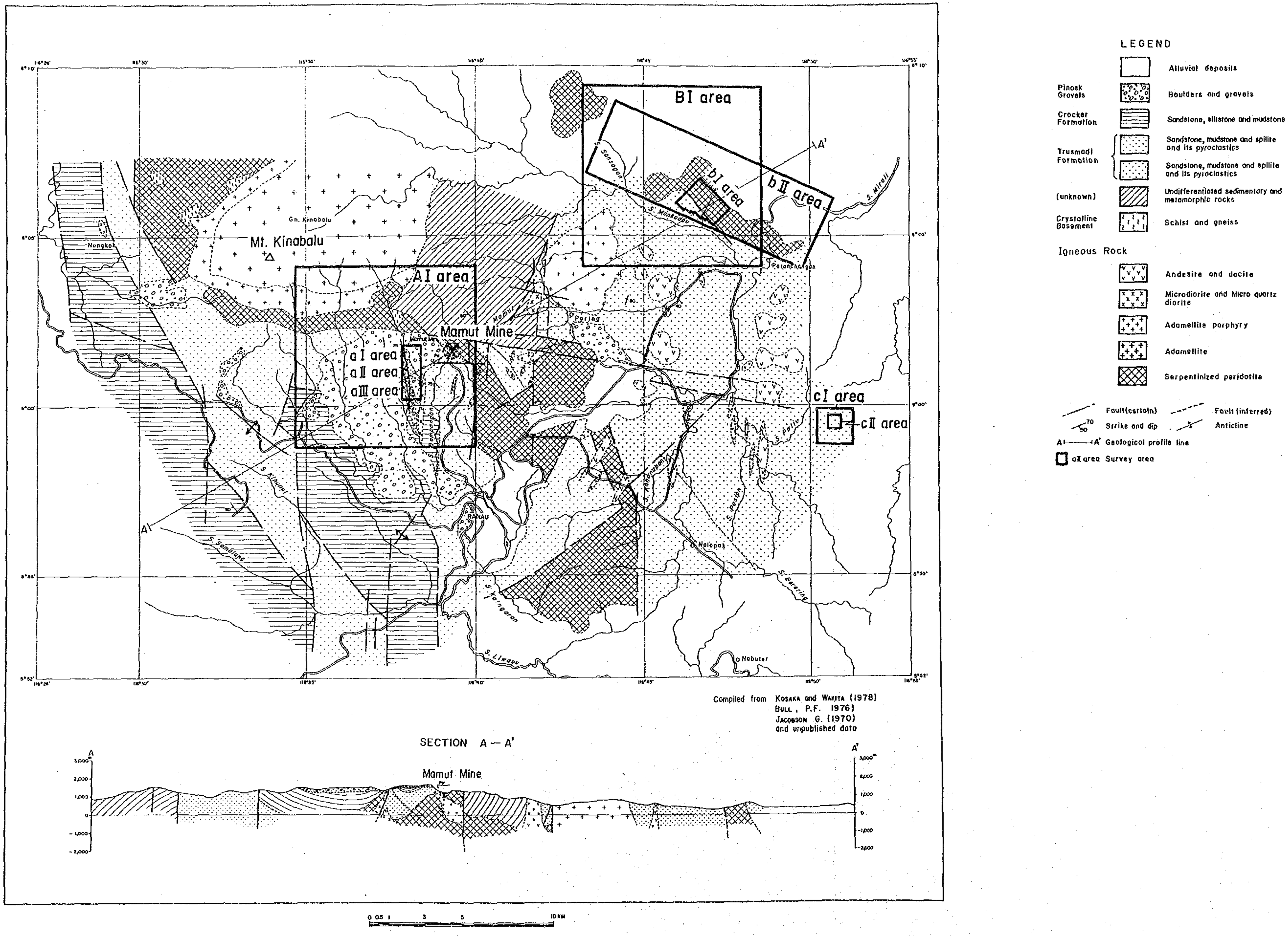
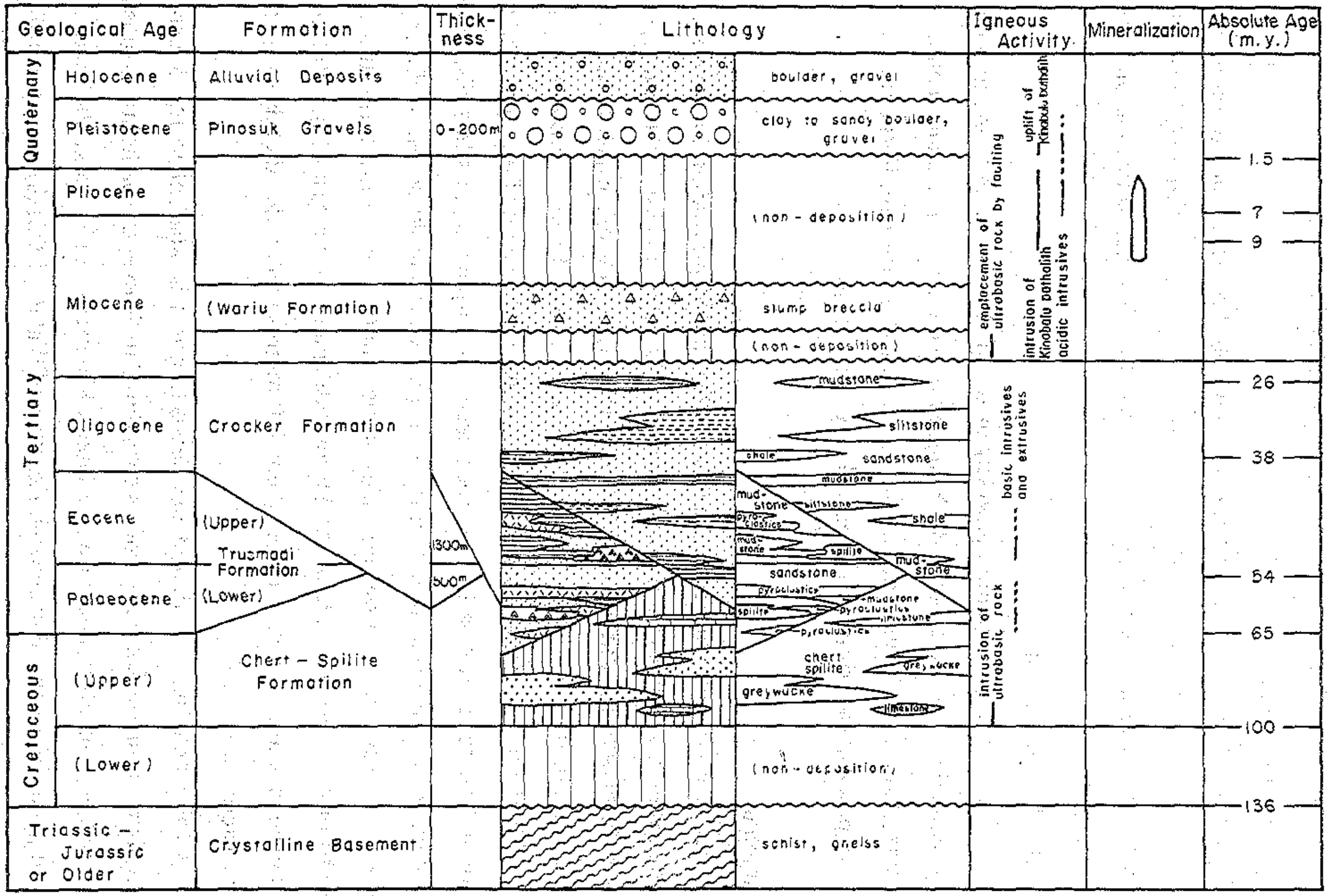


Fig. I-5 Geological Map of Kinabalu Area



(Compiled mainly from Kosaka and Wakita, 1975)

Fig. I-6 Generalized Stratigraphic Section of Kinabalu Area

(3) Rajang Group

The Rajang Group is a thick sedimentary rocks deposited in the Northwest Borneo Geosyncline in the Paleocene to early Miocene time. From the rock facies, it is divided into two formations such as the Trusmadi and the Crocker.

(i) Trusmadi Formation

The Trusmadi Formation is distributed on the eastern side of the N-S line connecting Mamut mine and Ranau. It consists of gray to dark gray argillaceous rock and slate and is partially intercalated by siltstone, sandstone and rarely pyroclastics.

(ii) Crocker Formation

The Crocker Formation is widely distributed from the N-S line to Kundasang on the west and around Mt. Nungkok to the west of the Kinabalu mountain mass. It is rather arenaceous as compared with the Trusmadi Formation, being composed of sandstone, siltstone and gray or red shale.

(4) Adamellite

The intrusive batholith of adamellite is distributed protruding in the surface, slightly extending northeaseterly, with an area of 60 mile^2 (155 km^2) showing a peculiar landform with an altitude of 4,101 metres above sea level, which is said to be spread over 500 mile^2 (1,300 km^2) in subsurface (Jacobson 1970). Therefore, it is distributed both on the surface and underneath of the whole extent of the survey area as batholith. The peripheral part of the rock becomes porphyritic, and it is distributed surrounding the Kinabalu mountain mass as adamellite porphyry, especially dominantly on the southern and western sides of the mountain in a zonal form. It is also exposed on the northern side of the Poring settlement to the east of the mountain mass forming a low mountain mass (about 750 metres in altitude) slightly extending northeasterly.

As the whole area of Mamut ore deposit, which is adjacent to the Kinabalu mountain mass on the southern side, is considered to lie over the batholith in subsurface, the stocks of adamellite porphyry (about 800 metres in N-S and 300 metres in E-W, dipping 40° eastward in general; Kosaka and Wakita, 1975) are widely distributed within and in the vicinity of the ore deposit, forming the main host rock of the deposit and having been directly involved in the mineralization. The dikes observed in abundance on the top and in the peripheral part of the stock, are all the cupolas or apophyse branched off from the Kinabalu adamellite batholith.

Adamellites have been dated to be 9 m.y. of absolute age, corresponding to the later stage of the orogenic movement which took place from the Miocene to early Pliocene, or immediately after that age.

(5) Peridotite

The peridotite in the survey area is distributed on the southern and western sides of the adamellites of the Kinabalu mountain mass. In the Mankadau area, it is distributed in the southeastern part of Mamut and on the southwest of Ranau. The rock consists mainly of peridotite, and dunite is observed locally. These rocks have been sheared and fractured into breccia in many cases. Serpentinization is generally observed.

In Sabah State, the peridotite is often distributed in contact with spilite lava, and showing a wide distribution being in contact with the psilite basalt lava on the southern side of the fault laid between them.

The intruding age of peridotite is considered to be earlier than that of adamellite, probably of late Cretaceous.

(6) Pinosuk Gravels

The Pinosuk Gravels is the Quaternary sediments. Covering all the above-mentioned rocks it is distributed for an extent of about 50 square kilometres at an altitude between 1,500 and 1,200 metres on the southern side of the Kinabalu mountain from the upper flank

of the relatively gentle slope, where a steep landform of the intrusive mass comes to an end, toward the south through the Pinosuk settlement. The lower end of it collapsed and flowed out as mud flow to reach the Ranau floodplain on the southeast, and the great boulders have remained in the riverbed of the large and small rivers flowing at the periphery and in the alluvial floodplain of the Ranau basin.

The kinds of pebbles and boulders include all the rock constituting the geology of the area such as adamellite, adamellite porphyry, ultrabasic rocks and the Tertiary sedimentary rocks, and naturally, sometimes the pebbles of mineralized rock are contained.

The size of the pebbles varies widely from 1 to 50 centimetres to 1 to 5 metres, rarely reaching up to 10 to 20 metres. They are generally subangular and sometimes breccias and rarely round are found.

The groundmass mainly consists of coarse-grained sand of adamellitic origin, and the grade of consolidation is varied.

The radiometric carbon age on buried wood has found 7,980 ± 100 years for the uppermost part, and 34,000 (+2,000 - 1,800) years and 39,900 + α years for other parts, leading to the assumption of the age of the later Quaternary Diluvium.

Jacobson (1970) divided the bed into two sections by the unconformity plane based on the genesis. He defined the lower section to be the conglomerate formed by periglacial phenomena at the time of ice age of the Kinabalu mountain, and the upper section to be the sediments of mudflow from high mountain, partly containing reworked moraine of glacier.

(7) Alteration

These formations are metamorphosed by intrusion of the Kinabalu batholith, especially the Trusmadi Formation is subjected to contact metamorphism at the contact on the eastern and southern sides of the mountain mass. The peripheral zone of the formation reaching up to 1,500 metres from the contact has been altered to hornfels, schist or quartzite. This phenomenon can be observed along the Bambangan creek in the sedimentary rocks in the drilling area.

(8) Geological Structure

Regionally the survey area is located in the structural zone named "Kinabalu Fault" (Tokuyama. Yosiha, 1974) which is a swarm of strike faults of a NW-SE system. This structural zone is considered to provide the places for intrusion and extrusion of the ultravasic to acidic ingeous rocks.

Except for the above NW-SE fault, a faulting system of N-S is developed around Mt. Kinabalu. Accordingly the block movements were repeated, making the outside blocks (southern side and eastern side) shlipped down towards the eastern and southern sides of the Kinabalu mountain mass.

Faulting systems of E-W and NE-SW are also observed, controlling local structures, though they are in a small scale as campared with these of NW-SE and N-S.

Chapter 4 Geography of Survey Area

4-1 Location and Accessibility

The survey area is situated in the State of Sabah which extends to the northern-most end of Borneo Island.

The area is centered on the town of Ranau (with population of about 2,000) and located at 70 km east from the state capital city, Kota Kinabalu (116° East Longitude and 6° North Latitude), having an extent of 52 km along E-W direction by 40 km along N-S direction.

It takes about two hours by car to reach Ranau from Kota Kinabalu on the sealed road of 105 km. The three target areas for survey are located 12 km NNW to Bambangan area, 25 km NNE to Mankadau area and 20 km NE to Paliu area respectively from Ranau. Each area is connected to Ranau by car road, however, due to unsealed and rough roads, all the communication are often cut off in rainy season by flood of rivers and creeks and by landslide along the road. However, the road in area "a" of Bambangan area is well maintained due to the existence of water intake belonging to Mamut mine.

4-2 Topography, Climate and Vegetation

The Crocker Range runs northeasterly along the coast facing the South China Sea on the west, controlling strongly the topography of Sabah State, in which the highest peak of Kinabalu shows an altitude of 4,101 metres. The mountains are mostly 900 to 1,500 metres in height.

At the foot of the western slope of the range, an alluvial plain of about 10 kilometres wide forms the coastal zone, which sometimes continues to the low coastal mangrove swamp.

An extensive highland, 200 to 1,000 metres high above sea level, is distributed on the eastern side of the Crocker Range, through which large rivers in Sabah State running toward the east form lowlands, flowing into the Celebes Sea through the low mangrove swamp at the mouth of the rivers.

Among the survey target areas, Bambangan area is situated at southeast of Mt. Kinabalu, showing a variable topography from northwest to southeast, presenting a southern steep slope in Mt. Kinabalu (altitude 3,600 - 2,000 m), a fault scarp trending E-W of altitude 2,000 - 1,300 m, a hilly terrain of relatively gentle slope at south of the fault and a plateau covered by the Pinosuk Gravels. The water flow in the south-north direction is developed within the area.

Mankadau area is situated on east side of Mt. Kinabalu and occupies the Crocker Range and the central highland, and its western end is highland of 1,800 m altitude. However, southwestern part of the area become lower plateau by the Mankadau river with altitude of 500 - 250 m.

In Paliu area, two peaks of the intrusive rock are protruded, showing a steep landform in its surrounding area with 50 degrees in inclination of the slope.

The sedimentary rocks on both sides are dissected in many parts to form V-shaped valley by rapid stream rising in the intrusive peaks. The steep slopes in the sedimentary rocks become gentle toward the southern margin of the area, where a soft landform is shown.

Climate in Sabah State is tropical and oceanic, and also the area belongs to the monsoon district. However, the variation in precipitation by season is small except for a part of the coastal zone. From October to March, the monsoon blows from the northeast, and from May to August from the southwest. Therefore, it rains relatively heavily in the coastal zones in the seasons, in which the wind is against.

The annual precipitation in the mountanous area of inland is 1,500 to 2,000 milimetres, and it is more than 3,000 milimetres in many areas of coastal zone and in the mountain. The annual precipitation at the Mamut mine is shown to be 2,100 to 4,000 milimetres.

No seasonal variation of temperature is clearely observed, and it is shown to be 24° to 30°C with the mximum of 34°C in the coastal area, and 12° to 22°C in the mountanous area, showing a notable daily variation in the latter.

The vegetation on the hill and in the mountain is so-called the jungle type, and the coastal area is generally represented by the swampy zone where mangrove grows thick. All the survey areas are the zone of jungle in which tall and dwarf trees, herbaceous plants and ferns grow very thick because of high moisture, causing the spending much time for clearing the route for the survey.

Chapter 5 Conclusions and Recommendations

5-1 Conclusions

In the Collaborative Mineral Exploration of Sabah Area, various surveys were carried out for three years (first - third year) in Bambangan area and two years (first and second year) in Mankadau and Paliu areas.

The conclusions obtained from such surveys are as follow :

1. Bambangan area

Geophysical survey and drilling were mainly carried out to find a copper mineralized zone similar to Mamut ore deposit. As a result, a blind mineralized zone of porphyry copper type with pyrite and minor amount of chalcopyrite was found along the Bambangan creek.

However, the mineralized zone has extremely low assay value of both Cu and Au and covered by the Pinosuk Gravels of 70 - 170 m thickness, so that it was concluded to have a low potential for development so far at the present stage is concerned.

The mineralized zone of the Bambangan creek area, as stated above presents so far, a low economic value. However, it is strongly suggested that a possiblility of bearing of unknown mineralized zone underlying thick Pinosuk Gravels, similar to the zone which has already been clarified, may be occurred.

2. Mankadau area

Geological, geochemical and geophysical surveys were carried out to clarify a source of high grade massive copper floats (Cu 25 - 65%) as well as chromite ore floats and the extention and grade of known chromite ore deposit. However, the source of copper and chromite ore float could not be confirmed and also dunite as a host rock for chromite ore deposit is poorly developed in the chromite ore deposit area. Therefore, it is considered that a possibility of occurrence of minable deposits is low.

3. Paliu area

Geological and geochemical surveys and trenching were carried out to clarify the characteristics of found geochemical anomalous zone, but no showings as a target for drilling could have been obtained and consequently, a potential for occurrence of ore deposit seems to be low.

Basing on the above mentioned survey results of each area, it was finally concluded that no minable ore deposits could be confirmed in this collaborative mineral exploration project, despite of obtaining a favorable result of finding a similar mineralized zone in the vicinity of the existing ore deposit.

5-2 Recommendations

From the above-mentioned conclusions, the following recommendations can be mentioned.

1. In area "a" including Bambangan mineralized zone of Bambangan area (a), although some portions indicate partly over Cu 0.4%, the average grade of Cu 0.14% present low economic values, so that no further survey is considered necessary.

Besides the above mentioned mineralized zone, two more low resistivity zones (A-2 and A-3) were detected by CSAMT geophysical survey. One of them, the low resistivity zone of Kudan-sang side in A-3, seems to bear a relationship with mineralization, however, no further survey was carried out to clarify its nature. Therefore, in consideration of the above, a confirmation survey to determine the characteristics of this low resistivity zone is highly recommended. This study should be based on an IP.SIP geophysical survey and followed by drilling supported by the mentioned geophysical technique.

2. In the Mankadau area and the Paliu area, any future survey will not be needed, because no prospective occurrences and indications have been obtained there.

PART II BAMBANGAN (A, a) AREA

Chapter 1 Geology

1-1 Outline of Geology

The area is situated in 2.5 km west of the open pit of the Mamut mine, on the southeastern slope of the Kinabalu mountain with an elevation of 1,300 to 1,800 m ASL as high as the mine.

The geological survey in the Bambangan area (6 km^2) was carried out in Phase II because of many available data relating with the geology and ore deposit.

While the geology is difficult for full delineation because of thick cover of the Quaternary Pinosuk Gravels, the geology of the area can be presumed from the geology along the Bambangan creek and the result of drilling of 18 holes conducted in the area, is as follows.

The geology of the area, as shown in Map II-1 and 2, is characterized by the "Crystalline Basement", sedimentary rocks of unknown age, metamorphosed rocks, the Trusmadi Formation, the Crocker Formation, and the Pinosuk Gravels as sedimentary rock and peridotite, adamellite, adamellite porpohyry, micro-diorite as intrusive rock.

The Chert-Spilite Formation is distributed below surface, underlying the Trusmadi Formation, which is not shown in Map II-1, only found in the drill holes.

The geological structure is not well known as the area is widely covered by the Pinosuk Gravels. However, prominent fault systems of N-S and E-W direction are observed.

1-2 Geology

The detailed geological survey was carried out in the all area in Phase II.

The geological map of all area is shown in Map II-2.

1-2-1 Basement Rocks

It is distributed in upper stream of the Bambangan creek, which belongs to outer zone of the surveyed area. It reportedly consists of crystalline schist and gneiss.

1-2-2 Sedimentary Rocks

(1) Chert-Spilite Formation

Distribution: No exposure of the formation is located on the surface, however, it has been confirmed at the bottom of the drill hole MJM-10.

Thickness: More than 200 metres.

Rock Facies: Irregular alternation of spilite and hornfels is observed. Spilite is grayish green, and has generally been silicified and chloritized, and partly epidotized. Although pyrite dissemination is observed, it is local and very weak.

Geological Structure: It appears that the formation dips southward judging from the drilling data.

(2) Trusmadi Formation

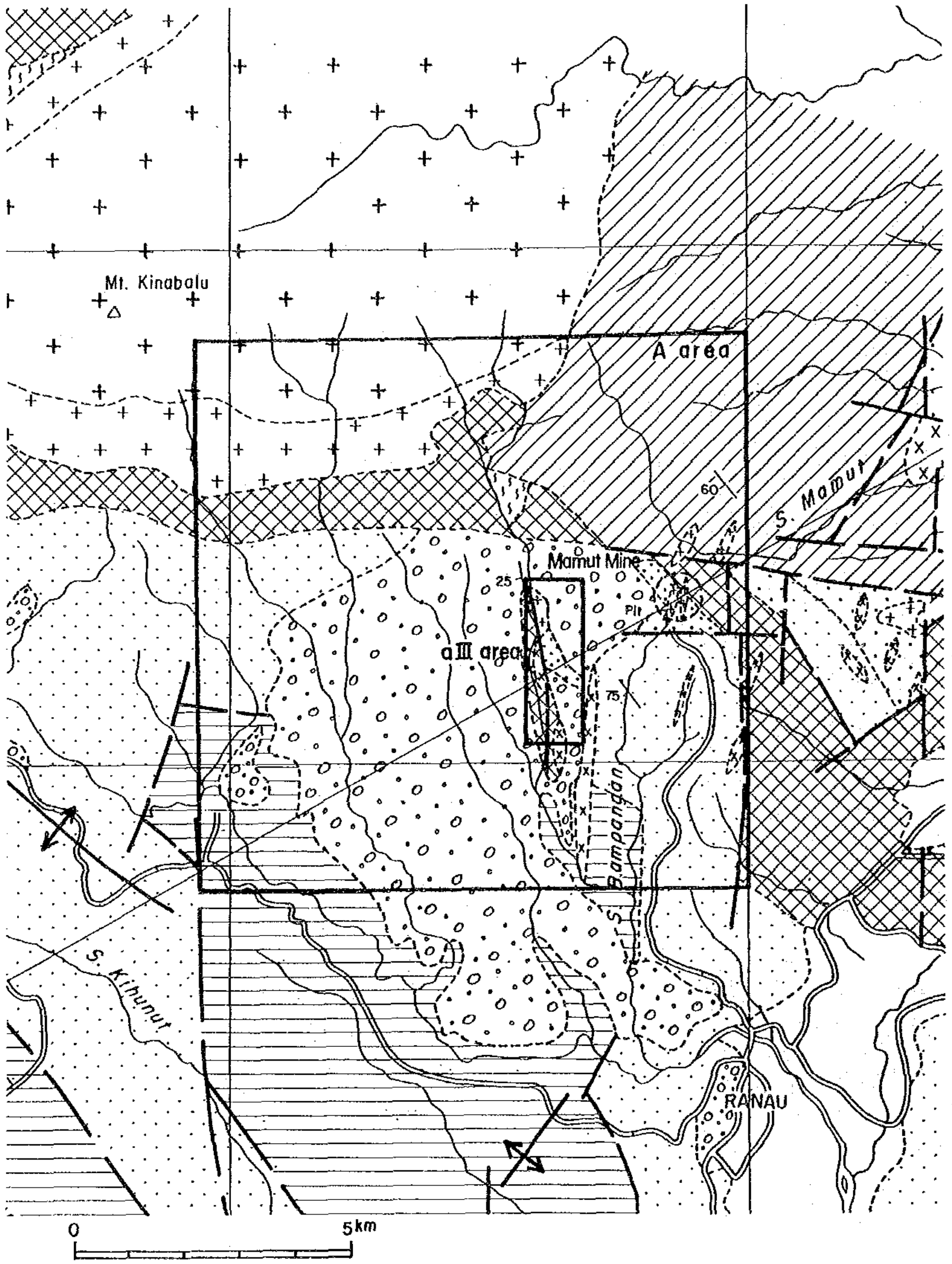
Distribution: Although the exposure is limited in the Bambangan creek and along the road connecting both the Mamut open pit and the intake of mine water. The turbidite is not only locally distributed in the southwestern side of the Mamut mine, but also widely encountered in the drill holes, which are from about 150 m to 200 m below the surface in the drill holes of MJM-1 and MJM-3, from the surface to 300 m in MJM-5 and from 202.75 m to 350.50 m (bottom of the hole) in MJM-13. It is also distributed from 111.4m to 141.70m just under the Pinosuk Gravels in MJM-15 and is alternated with hornfels in MJM-14 and MJM-16.

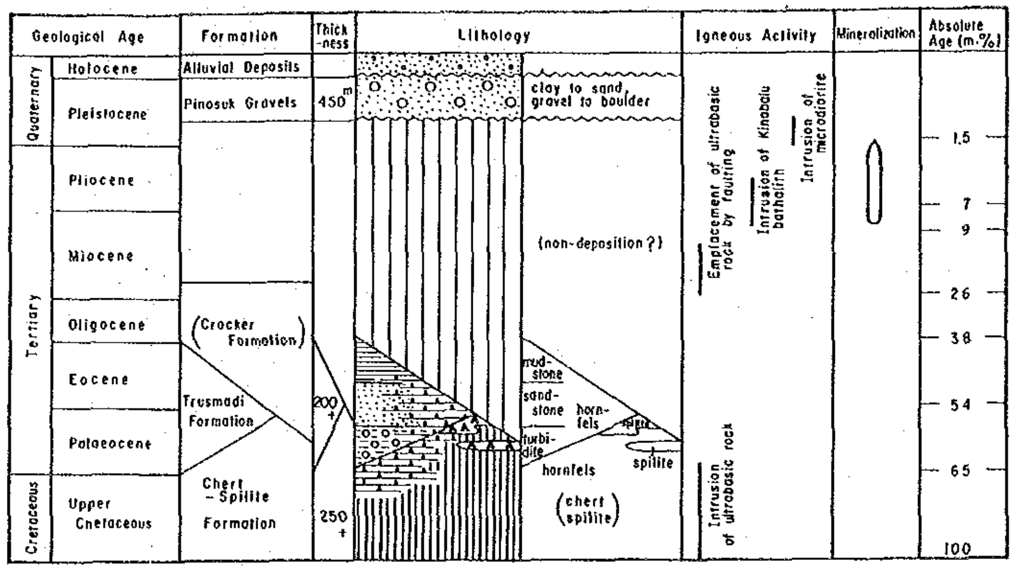
Thickness : Approximately 300 m

Rock Facies: The formation consists of gray to dark gray mudstone, siltstone and sandstone, rarely of pyroclastic rocks which are considered to be of the flysh-type geosynclinal sediments.

The formation distributed from the central part to the northern part of the area has almost been altered to dark gray hornfels due to intrusion of adamellites forming the Kinabalu mountain. The mudstone distributed near the mine road has been weakly altered to hornfels, which is likely to be a transitional zone.

The mudstone is massive and shows no bedding, often containing the fragments of the same rock. The sandstone is also massive, often interbedded with thin layers of mudstone and shale. The hornfels is massive and hard, showing a sharp fracture. It is yellowish brown when weathered. The mudstone and the sandstone





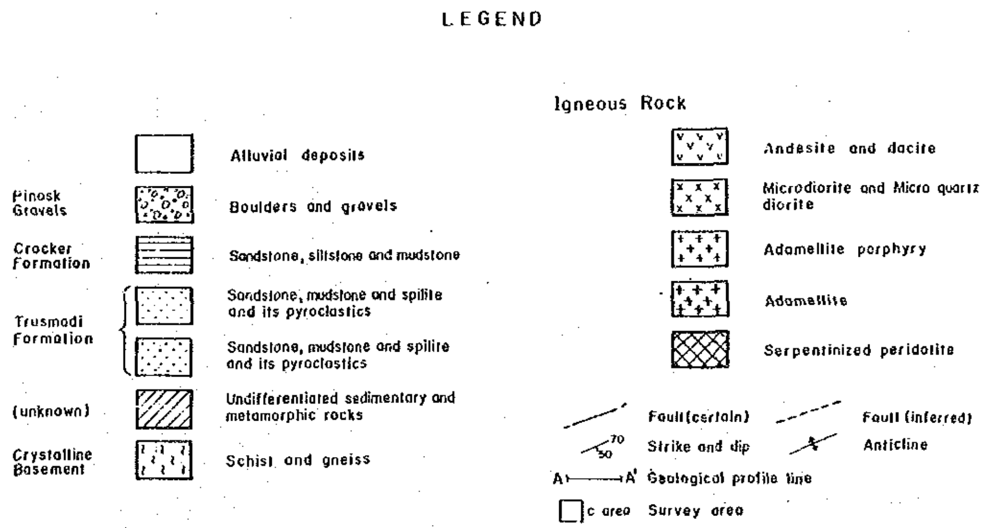


Fig. II-1 Geological Map of Bambangan (A, a) Area

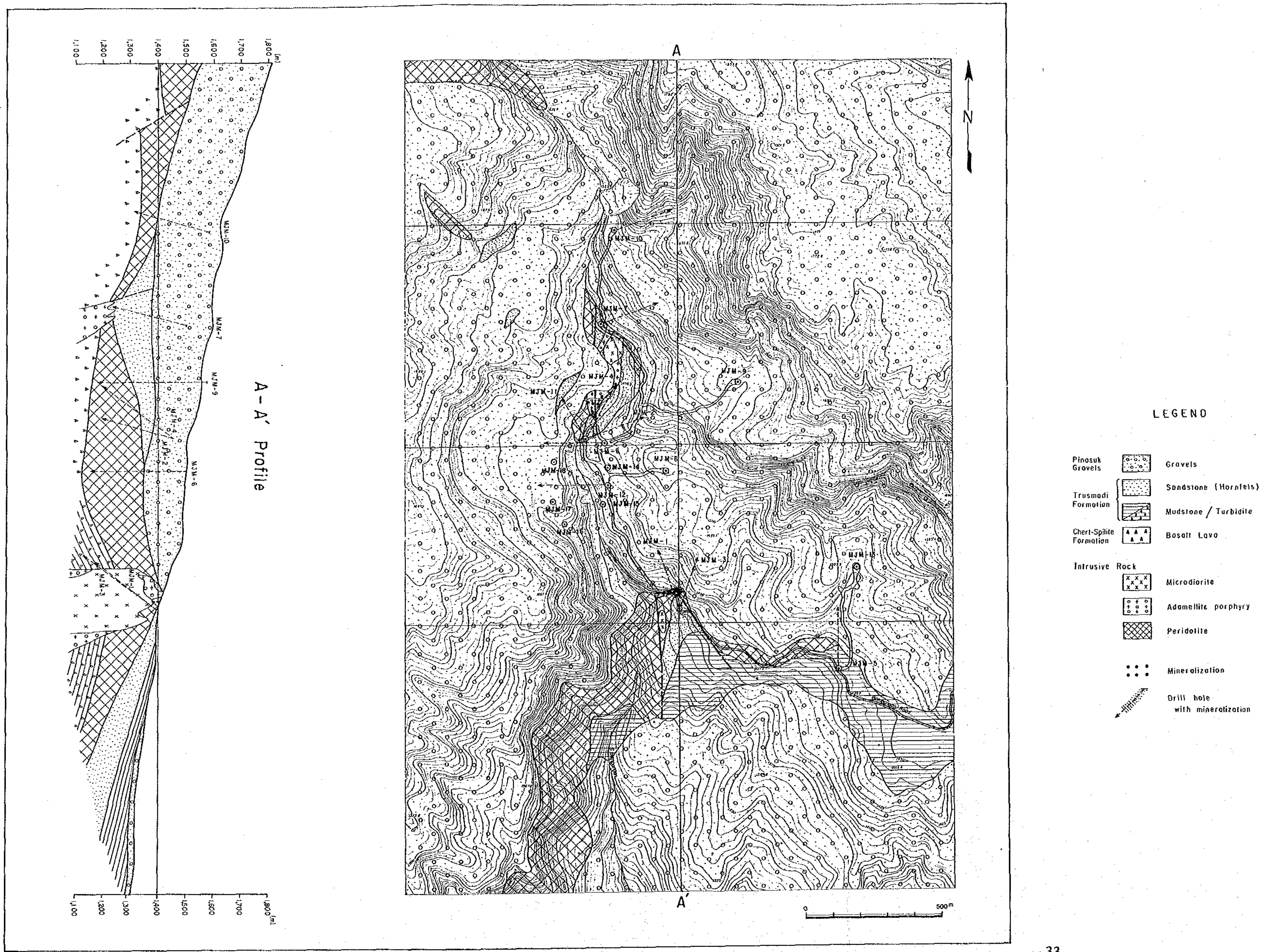


Fig. II-2 Geological Map of Bambangan (a) Area

are transitionally altered to hornfels.

Stratigraphic Relation: Although the formation is in fault contact with peridotite as described later, the relationship with the underlying formation can not be clarified.

Time of Sedimentation: It is considered to be formed in Paleocene to Eocene.

(3) Pinosuk Gravels

Distribution: The Gravels spread over the whole survey ara as shown in the geological map. It is distributed from the highland higher than 1,800 m ASL far away to the lowland in the vicinity of Ranau.

Thickness: The result of drilings shows that the thickness is 270 m to 290 m around the drill holes MJM-9 and MJM-10, which increases to 400 m to 500 m toward the east, being reduced toward the south.

Rock Facies: The Gravels is generally grayish brown, and often forms steep cliffs. The kind, shape and size of gravels, the kind of matrix and the degree of consolidation vary greatly from place to place.

The Gravels generally consist of subangular to subrounded pebbles of adamellite, adamellite prophyry, microdiorite, hornfels, mudstone, sandstone and peridotite, rarely containing carbonized wood pieces.

It is soft and loose near the surface so called "Loose Pinosuk" for about 50 metres in thickness, grading to "Solid Pinosuk" toward the depth.

In terms of the size of gravels, boulders predominate in the Loose Pinosuk and are also dominant in the upper part of the Solid Pinosuk, reaching up to 10 metres in diametre and cobbles (several to 10 cm in size) are dominant in the lower part.

The matrix consists of sandy to silty or clayey materials and sandy materials is common in the Loose Pinosuk.

Structure: The bottom of the Gravels show a bottom shape of ship showing a long axis trending north to south, having a basin structure pitching gently toward the south.

Stratigraphical Relation: The bed unconformably overlies the lower sequences.

Time of Sedimentation : Radiocarbon age was measured as late Pleistocene.

1-2-3 Igneous Rocks

There are three kinds of intrusives consisting peridotite, adamellite porphyry and microdiorite.

(1) Peridotite

Distribution: It is exposed only on a small scale, beside the one forming a steep cliff in the lower reaches of the Bambangan creek, but it is considered to have a considerable stretch underground as confirmed in all drill holes except for the holes of MJM-5, MJM-12 and MJM-14.

The peridotite is generally underlying the hornfels layers of the Trusmadi Formation, but it shows a form overlying the hornfels layers in the drill holde of MJM-9. The rock tends to thin toward the east from the west, and is often cut by faults and dikes of a north to south system.

Rock Facies: The rock is melanocratic and equigranular, and consists of serpentinized olivine, with a small quantity of pyroxene. Locally, pale green talc is found in abundance.

(2) Adamellite Porphyry

The adamellite porphyry is the intrusive rock which is most closely associated with the mineralization.

Distribution: The rock is exposed in two places, one is along the Bambangan creek and the other is in the vicinity of the mine road. It is also encountered in the lower part of the drill holes such as MJM-2, 4, 7, 8, 11, 12, 14, 15 and 18. The shape of Bambangan body estimated from the drilling results is a dike on a small scale having an extent of 50 to 100 m from the east to west and 400 m from the north to south, located at an level of about 1,300 to 1,400 m ASL. It is cut by the Bambangan fault, and the western portion becomes swollen toward the lower southern part (Fig.II-7). The shape of the rock in the vicinity of the mine road can not be delineated, because it is intruded by microdiorite of the later stage, and it is likely to show a cylindrical shape of 300 to 400 m in diametre. The occurrence of another stock with flat top has been confirmed in the lower part (approximately 1,100 m above sea level) of the drill hole MJM-5.

Rock Facies: The rock is leucocratic and holocrystalline, showing a porphyritic texture, and large phenocrysts of potash feldspar up to 3 to 4 cm long are characteristically found in the rock. Beside potash feldspar, the phenocrysts consist of plagioclase, hornblende, biotite and a small quantity of pyroxene. The groundmass is holocrystalline, consisting of fine-grained quartz, potash feldspar, biotite and hornblende. Sometimes it is difficult to distinguish the matrix from phenocrysts, being grading to adamellite.

(3) Microdiorite

Distribution: The occurrence of the rock has been confirmed in two places along the Bambangan creek and the drill holes of MJM-1 and MJM-3. The former has an extent of 250 m long and 70 m wide extending north-northwesterly from the exposures. The latter is likely to be a cylindrical stock of more than 200 m in diametre.

Rock Facies: It generally shows a equigranular texture, consisting of hornblende, biotite, plagioclase, and small quantities of quartz and potash feldspar. The garnet is scattered as a phenocryst in places.

The boundary with adamellite porphyry is sharp in the drill core, and clay is sometimes found along the boundary.

1-3 Geological Structure

Although full understanding on the geological structure of the area could not be attained, because the survey area is widely covered by the Pinosuk Gravels, the geological structure as the followings can be interpreted as a result of comprehensive study on the results of drilling of 18 holes and geophysical survey.

The faults of a N-S system are dominant in the area, and these of a NW-SE system are combined with them. It shows the movement of fault blocks as if the southwestern side slipped down. Furthermore, association of the faults of NE-SW and E-W systems make the geological structure more complicated.

A prominent fault running in the E-W direction through the northern boundary of the area is presumed to have been formed in association with the uplift of the Kinabalu mountain mass and to be almost concurrent with the stage of mineralization of the Mamut deposit.

Although the fault of N-S system known as the Bambangan fault can be confirmed in the adamellite porphyry exposed in the Bambangan creek, the fault encountered in the drill holes such as MJM-2, MJM-8 and MJM-12 seems to correspond to the one in the above. A large-scale fault zone encountered in the hole of MJM-12 from the depth of 348.30 m is considered to be a part of the Bambangan fault, and it is likely that adamellite porphyry and microdiorite have intruded along these tectonic lines.

The fault trending east-northeasterly in the vicinity of the mine road is located on the northern side of the drill holes MJM-1 and MJM-3, having controlled the distribution of adamellite porphyry.

Chapter 2 Mineralization

The Bambangan outcrop in the vicinity of the mine road and the Bambangan creek outcrop in the upper reaches of the creek beyond the intake of mine water are only the mineralization found in the area, as the porphyry copper type associated with the intrusion of adamellite porphyry (Fig.II-2).

For the former mineralized zone, OMRD conducted drilling for the outcrop exposed below the road (this could not be found at present because of collapse of the cliff), and then two holes (MJM-1 and 3) in Phase I of this project executed for the outcrop above the road, but both holes did not intersect the mineralized zone.

Although malachite stains are observed along the cracks of adamellite porphyry in the latter Bambangan creek outcrop, the extension toward depth was not intersected by MJM-2 and MJM-4 drill holes. The mineralized zone, which was found in and around the adamellite porphyry stock extending to N-S direction by drilling (MJM-8) in Phase I, is similar to those in the Mamut ore deposit, but very small and weak zone.

As the area is thickly covered by the Pinosuk Gravels, it is very limited to observe the mineralized zone . But judging from the drilling results, the mineralization seams to be characterized by fine pyrite, chalcopyrite dissemination/stringer as network shape. It is prominent in and around adamellite porphyry and the surrounding rock.

The ore minerals mainly consists of pyrite, chalcopyrite accompanying minor amounts of molybdenite and pyrrhotite, and native copper, cuprite, tenorite, chalcocite, malachite as secondary minerals.

Native copper, cuprite and other secondary copper minerals occur in the shallow part in oxidized zone, while pyrite, chalcopyrite are abundant in more deeper part. However, both primary zone and oxide zone are not so clear as other porphyry copper deposits have.

Molybdenite is found in many holes but does not show any trend in its occurrence. The zonal arrangement of ore minerals which is commonly observed in the porphyry copper deposits, cannot be recognized, though the data are limited.

The Mamut deposits are rich in gold which provides a considerable benefit to the company, while the Bamgangan mineralized zone is poor in contrast with the Mamut's.

The size of mineralized zone is about 400 m in N-S direction, and about 200 - 250 m in E-W direction, showing the shape of ellipsoid. The mineralized zone is covered by thick Pinosuk Gravels with a thickness of 70 - 170 m.

Chapter 3 Geophysical Survey

3-1 CSAMT Survey

3-1-1 Outline of Survey

The objectives of this survey are to clarify the resistivity structure in Bambangan area and to delineate the zone of low resistivity which may be related with mineralization.

In the Bambangan area, a reconnaissance survey was covered in "AI" area, while semi-detailed survey covered in "aI" area including known outcrops.

In the reconnaissance survey area "A", CSAMT survey stations were taken along the ridges and creeks while in the semi-detailed survey area, the stations are taken, as much as possible, along the lines of grid system to increase an accuracy of the measurement.

Reconnaissance

Survey ($94km^2$); 180 stations with station interval of 500 m

Semi-detailed Survey ($6km^2$); 24 stations with station interval of 300 m

In CSAMT method, electric signals are sent from a long fixed dipole while at the receiver site, signals are detected from a short dipole, and the analogue signals are converted to the digital signals by an installed microprocessor to calculate an apparent resistivity and phase.

Data recorded in the field were reprocessed by a big computer in Japan and made several corrections to interprete resistivity structure, shown in Fig. II-3-1 4.

3-1-2 Result of Survey

Resistivity zone with a resistivity of more than 100 ohm-m are widely distributed in northwestern part, western part and eastern part of the reconnaissance survey area. Resistivity zone detected in the northwestrn and western part correspond with peridotite, while the eastern part with hornfels, originated from sandstone and mudstone layers.

In the resistivity zone and the surrounded conductive zone with a resistivity of less than 100 ohm-m, the deeper structure seems to be separated into several geological units accompanied by many faults (Fig.II-3-1 4).

In the conductive zone with a resistivity of less than 100 ohm-m, three conductive zones were confirmed (Fig.II-4) as follows;

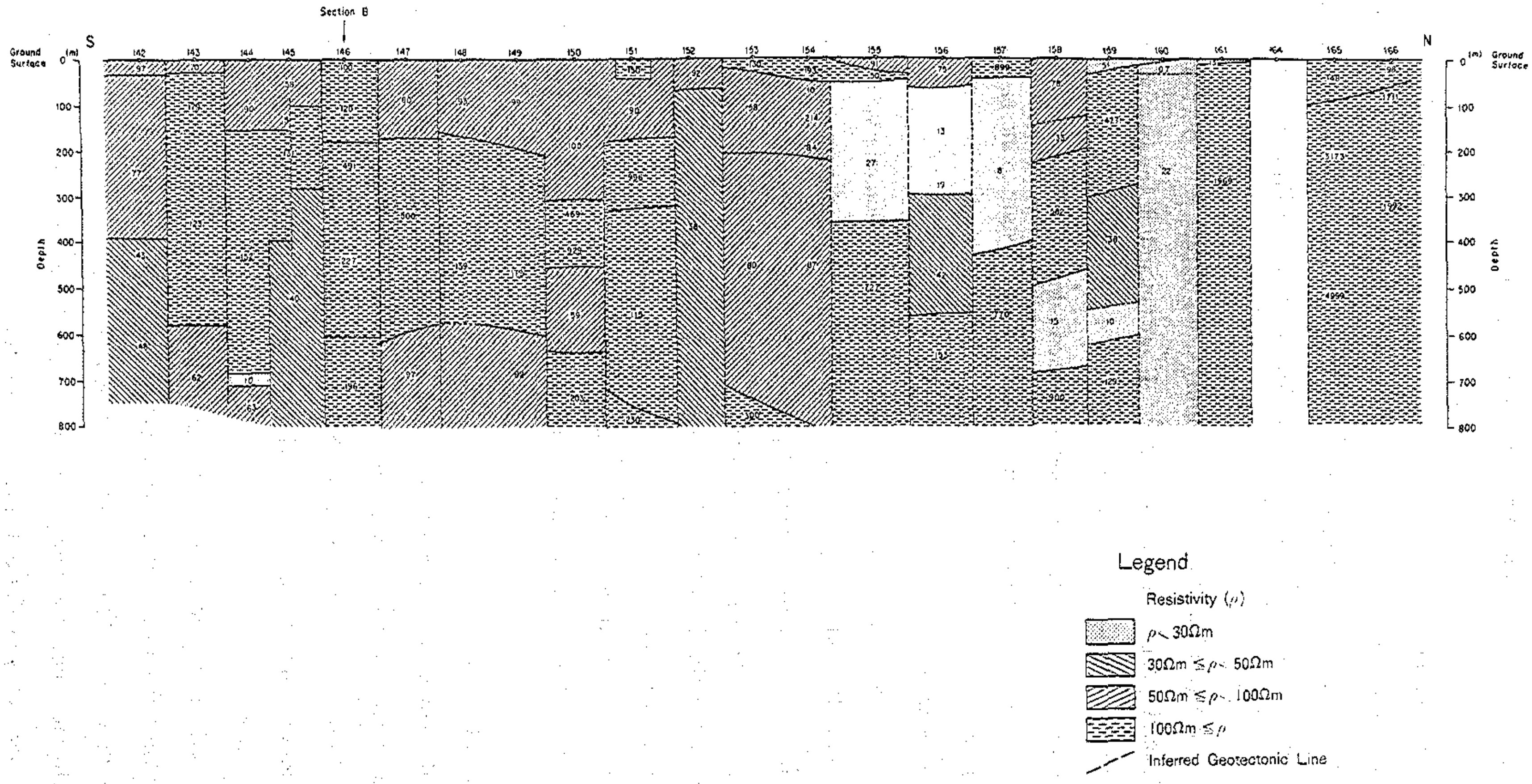


Fig. II-3-1 Resistivity Structural Map in Bambangan (A) Area (Section A)

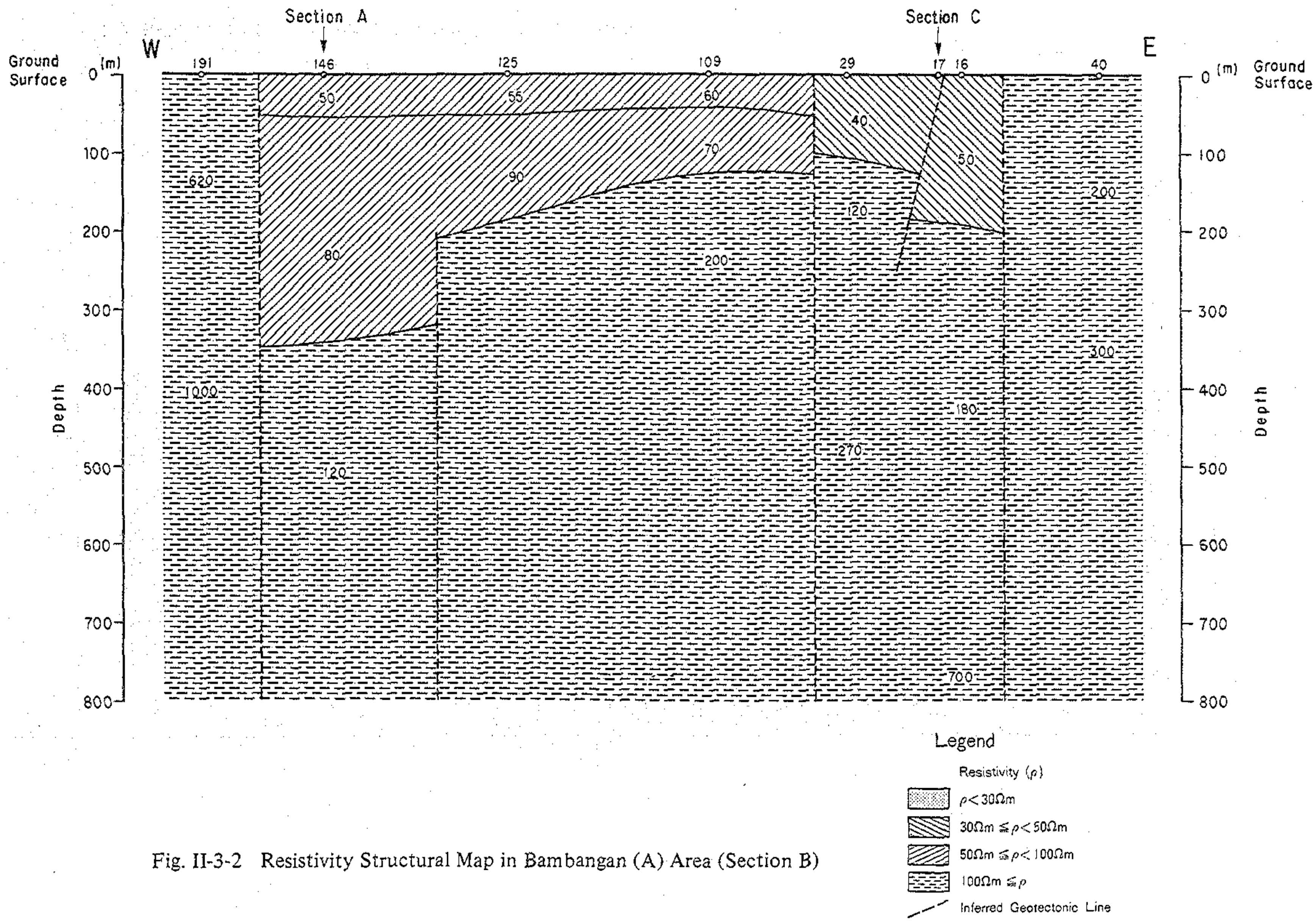


Fig. II-3-2 Resistivity Structural Map in Bambangan (A) Area (Section B)

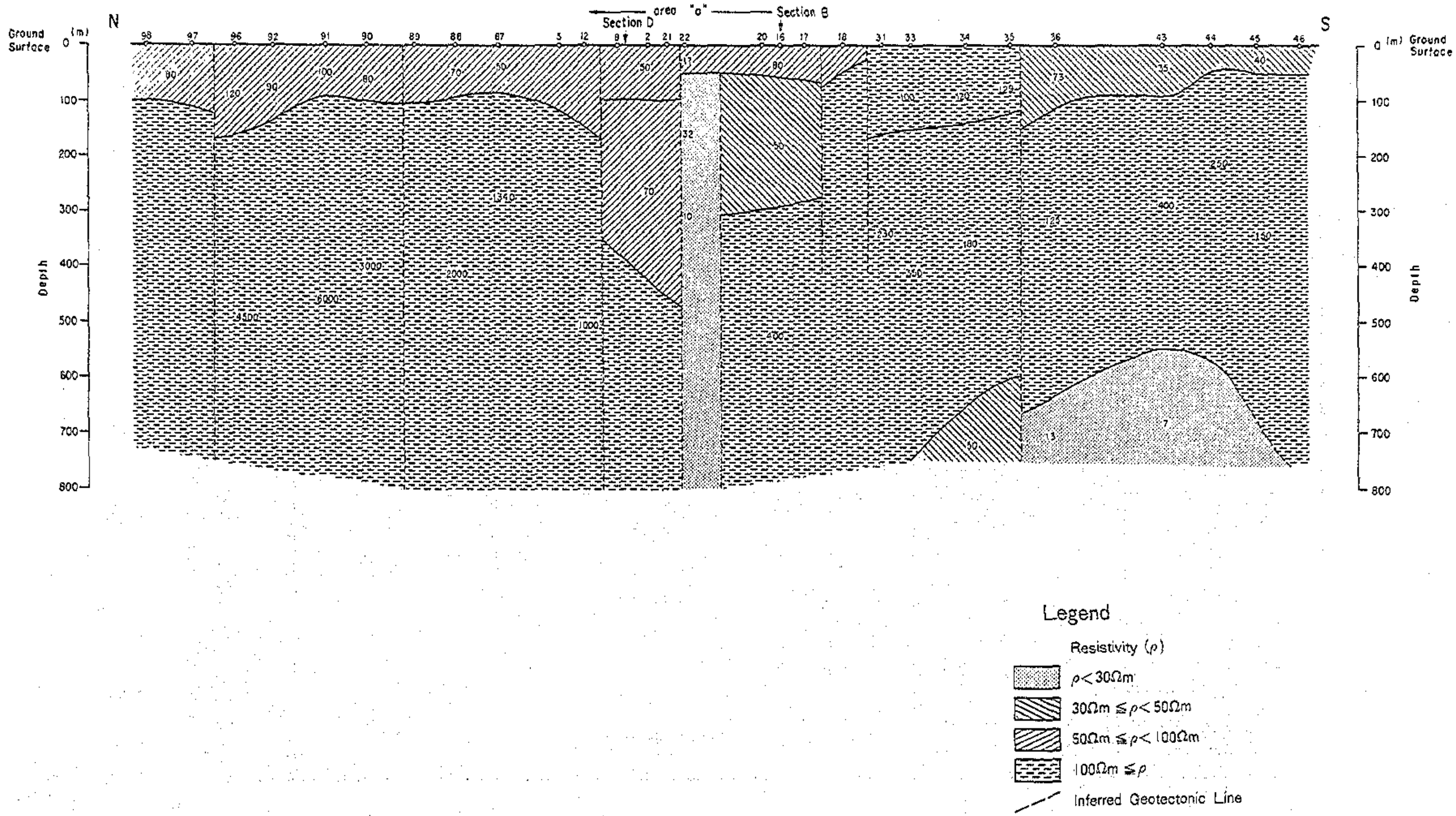


Fig. II-3-3 Resistivity Structural Map in Bambangan (A) Area (Section C)

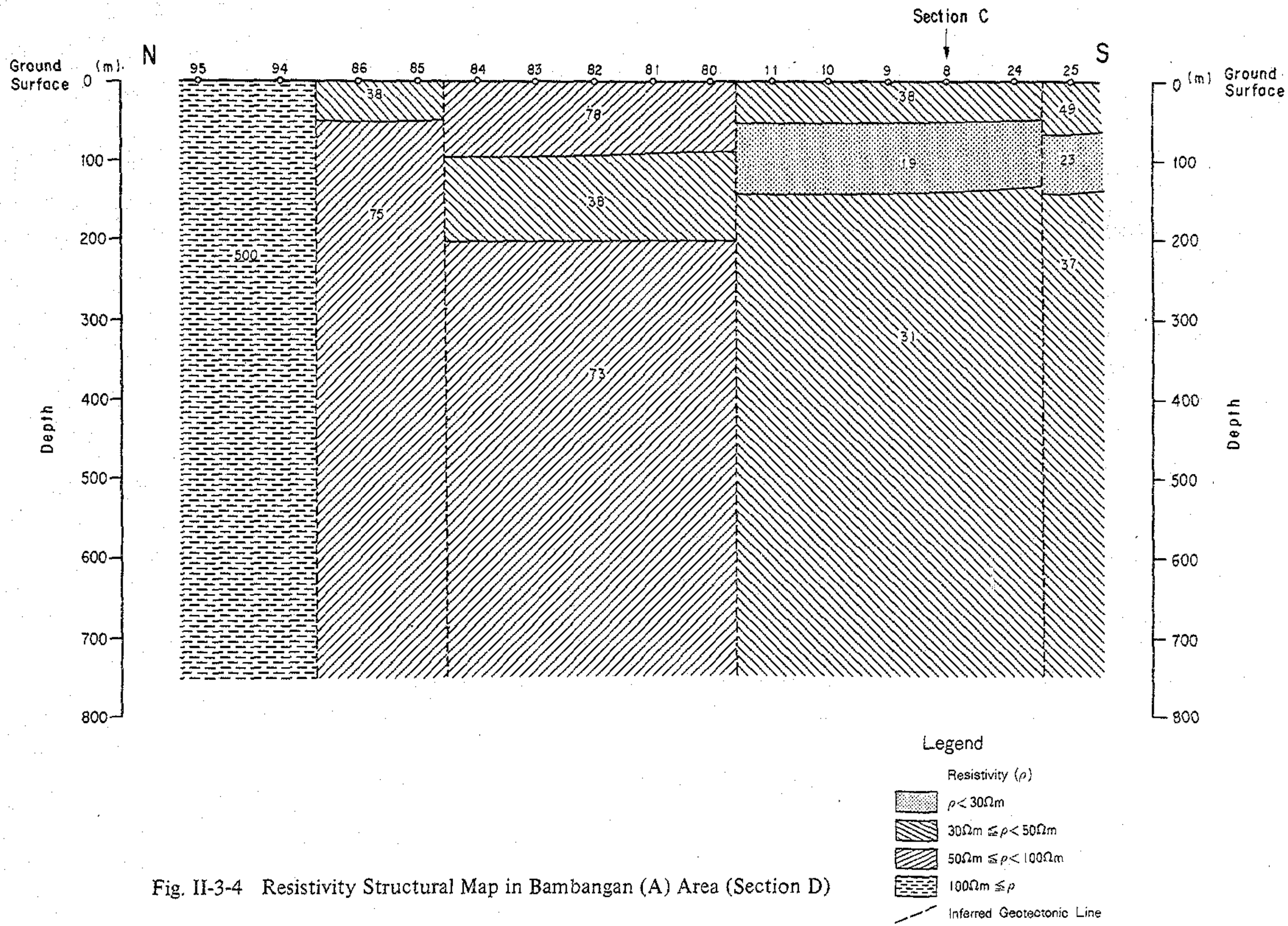


Fig. II-3-4 Resistivity Structural Map in Bambangan (A) Area (Section D)

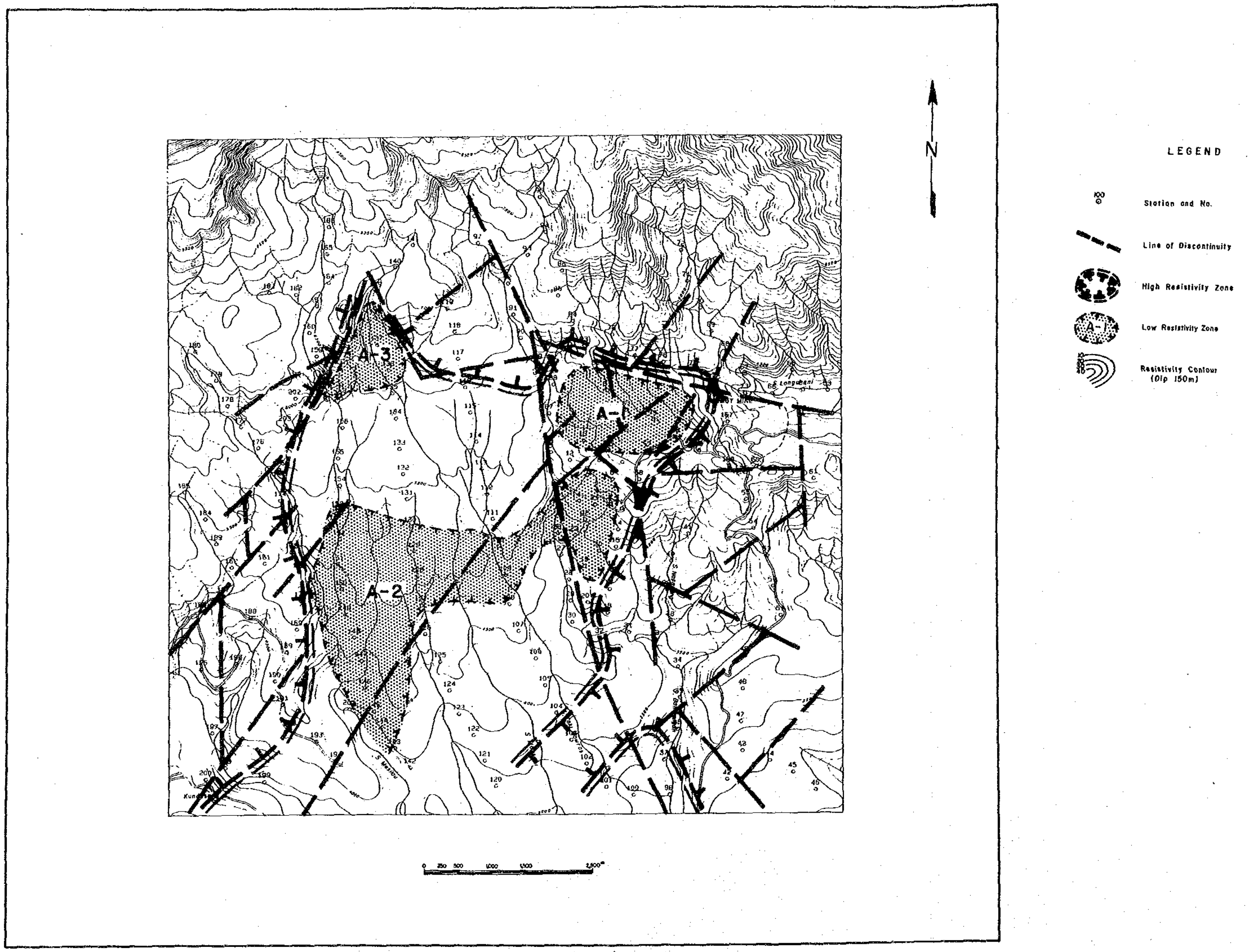


Fig. II-4 CSAMT Interpretation Map of Bambangan (A, a) Area

(1) A-1 Zone

This zone is located in the west of Mamut open pit with a dominant resistivity distribution of 50 - 70 ohm-m, which show a wide north-south distribution in the shallow zone but narrower to the depths. The upper layer correspond to the Pinosuk Gravels, while the deeper ones seem to correspond to a mineralized alteration or argillization.

(2) A-2 Zone

A low resistivity zone is distributed over the Bambangan and "aI" area showing a tendency to connect to the west with the previous A-1 anomalous zone.

Several conductive zones are seen which seem to reflect the fault zone, with dominant distribution of low resistivity of less than 30 ohm-m. This conductive zone is considered to be due to clay or underground water filled in the fractured zone having less possibility of mineralization, as no IP anomalies were detected in this area by IP Survey conducted by OMRD BHD.

(3) A-3 Zone

This zone is located in the northwestern part of the area extending towards NE-SW direction, showing low resistivity zone of less than 30 ohm-m extend to the depths from the surface but becoming wider at the depths.

The resistivity distribution of this conductivity zone surrounded by resistive zone resembles A-1 zone showing a possibility of being associated by mineralization at the depths. Since Mamut mine is also located in this complex resistivity structure, it is inferred that the mine is located in the low resistivity zone surrounded by the high resistivity ones.

Orebody itself shows 50 - 100 ohm-m in the strongly mineralized zone and 100 - 150 ohm-m

in the weak mineralized zone. While the wall rock is considered to have a resistivity of more than 150 ohm-m.

Consequently, among three conductive zones detected in A-1, A-2 and A-3 areas, a conductive zone similar to Mamut mine can be seen in A-1 area in the west of Mamut mine, and in A-3 area in the western edge of the area in Kundasang side.

3-2 IP and SIP Survey

3-2-1 Outline of Survey

The resistivity underground structure in the A area were studied using the results of previous CSAMT survey. The A-1 low resistivity zone at the west of Mamut mine was assumed to be caused by the alteration associated with mineralization.

IP and SIP surveys were carried out in the A-1 low resistivity zone in order to clarify the nature of the low resistivity zone and to check the possibility of the existence of sulphide minerals, which is a good conductor of the mineralization.

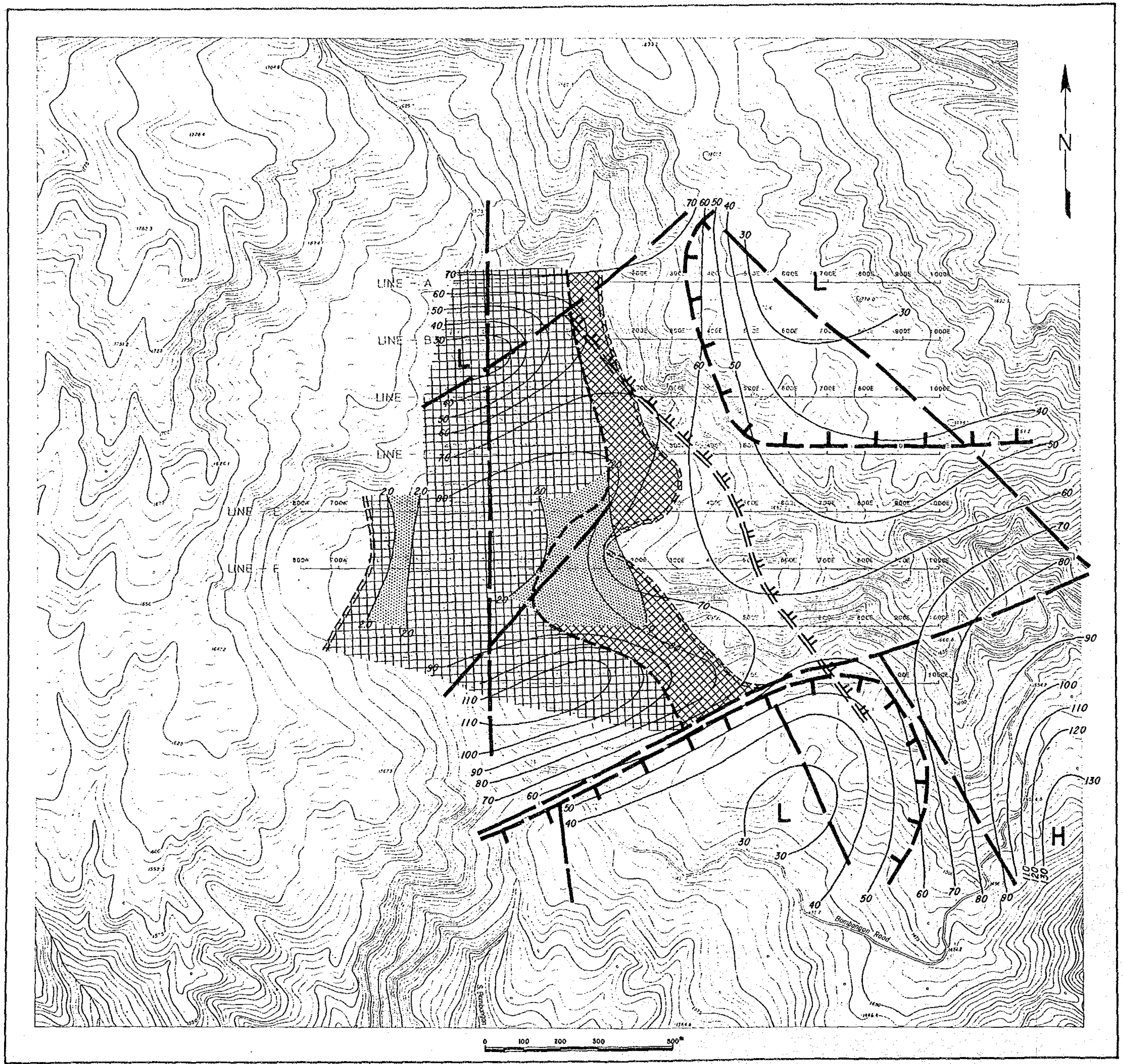
			Electrode Separation		
Method	Line Length	Stations	Spacing	Factor	Array
SIP	1.1 km x 1 1.3 1.7 5.4	166	a = 100 m	n = 1 - 5	Dipole
IP	1.1 x 1 1.3 x 2 1.7 x 1 5.4	190	a = 100 m	n = 1 - 5	Dipole

3-2-2 Result of Survey

(1) Resistivity derived from IP/SIP survey in the area show a common feature with that from the previous CSAMT survey (Fig.II-5) The IP/SIP resistivity contrast within the Pinosuk Gravels is not remarkable, but some difference of resistivities within it could be observed.

The pinosuk Gravels is distributed in the whole area. According to the drilling results of the MJM-9, its thickness is 273 m and it is divided into two layers, namely, upper and lower layers. The former is very loose and porous and its thickness will be 50 to 60 m from previous CSAMT survey, the thickness of formation derived from IP/SIP survey seems to correspond to the upper Pinosuk Formation.

According to IP and SIP results, shallow resistivities of n = 1 - 2 indicate values



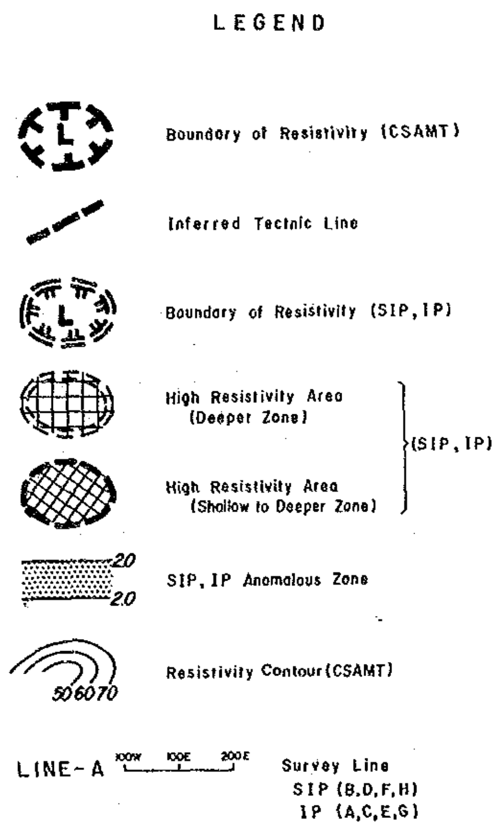


Fig. II-5 Geophysical Interpretation Map of Bambangan (A, a) Area

of less than 409 ohm-m, however, the remaining depths show 60 ohm-m with resistivity increasing its value with depths. Assuming the resistivity of the upper Pinosuk Gravels to be less than 50 ohm-m, to lower to be 50 - 709 ohm-m and the rest to be more than 70 ohm-m, then the resistivity change suggests the existence of NE-SW conductive zone which passes through the centre of the area.
In the western part of the area including the Bambangan creek, peridotite and microdiorite are distributed so that they cause the resistivity response to be higher than 70 ohm-m. This resistivity zone seems to extend to southern part of the area and increasing in depth.

The Pinosuk Gravels seem to have a thickness of about 150 m at the south-eastern part of the area and increasing its thickness towards northeast.
The low resistivity layer, corresponding to the Pinosuk Gravels, decrease its depth towards south, that is, 230 m at line D and 120 m at line H.
A moderate resistivity layer, corresponding to the compact Pinosuk Gravels and sandstone, is distributed widely in the eastern part of the area.

(2) There is no remarkable IP anomaly in the area, except for one remarkable IP anomaly observed in a high resistivity zone of more than 70 ohm-m at the west bank of Bambangan creek (near 500 W of Line E and F) and several local and weak anomalies caused by EM coupling and/or noise at the depth in the resistivity zone of less than 60 ohm-m.
The IP anomaly at the west bank of the Bambangan creek showed a PFE of 3.0 to 4.0%. This anomaly may be caused by a west-dipping anomalous souce below 500 W of Line E, and may extend towards north and south.

(3) It was necessary to check the relation between a remarkable IP anomalous source near 500 W of Line E and Mamut ore deposit, so that in-situ SIP survey was carried out at the Mamut mine. From this survey, two kinds of spectral types were observed; ① one shows a flat pattern between 0.125 Hz and 32 Hz detected in the high-grade ore zone, and ② the other shows monotonic decrease of phase with frequency between 0.125 Hz and 3 Hz detected in the low grade ore zone.
An IP anomaly near 500 W of Line E shows a similar spectral type as the latter one, but magnitude are different each other. This difference may be due to the type and size of its anomalous source and the content of the sulphide minerals.
Therefore, it can be concluded that there is no existence of similar orebody as

Mamut ore deposit near 500 W of Line E but may exist a N-S trending anomalous source of sulphide dissemination.