REPORT
ON
THE MINERAL EXPLORATION:
SUPRA-REGIONAL SURVEY
IN
CENTRAL SABAH, MALAYSIA

(PHASE III)

(Geochemical and Heliborne Geophysical Surveys)

MARCH, 1993

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 decided to conduct a Supra-Regional Survey Project in the Sabah area and entrusted the survey to the Japan International Cooperation Agency (JICA) and the Metal Mining Agency of Japan (MMAJ).

The JICA and MMAJ sent to Malaysia a survey team headed by Mr. Takehiko Nagamatsu from 7th July 1992 to 23rd December 1992.

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

We hope that this report will serve for the development of the project and contribute to the promotion of friendly relations between our two countries.

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, 1993

Kensuke Yanagiya

Kensuke Yanagiya
President
Japan International Cooperation Agency

Takashi Ishikawa

Takashi Ishikawa

President

Metal Mining Agency of Japan

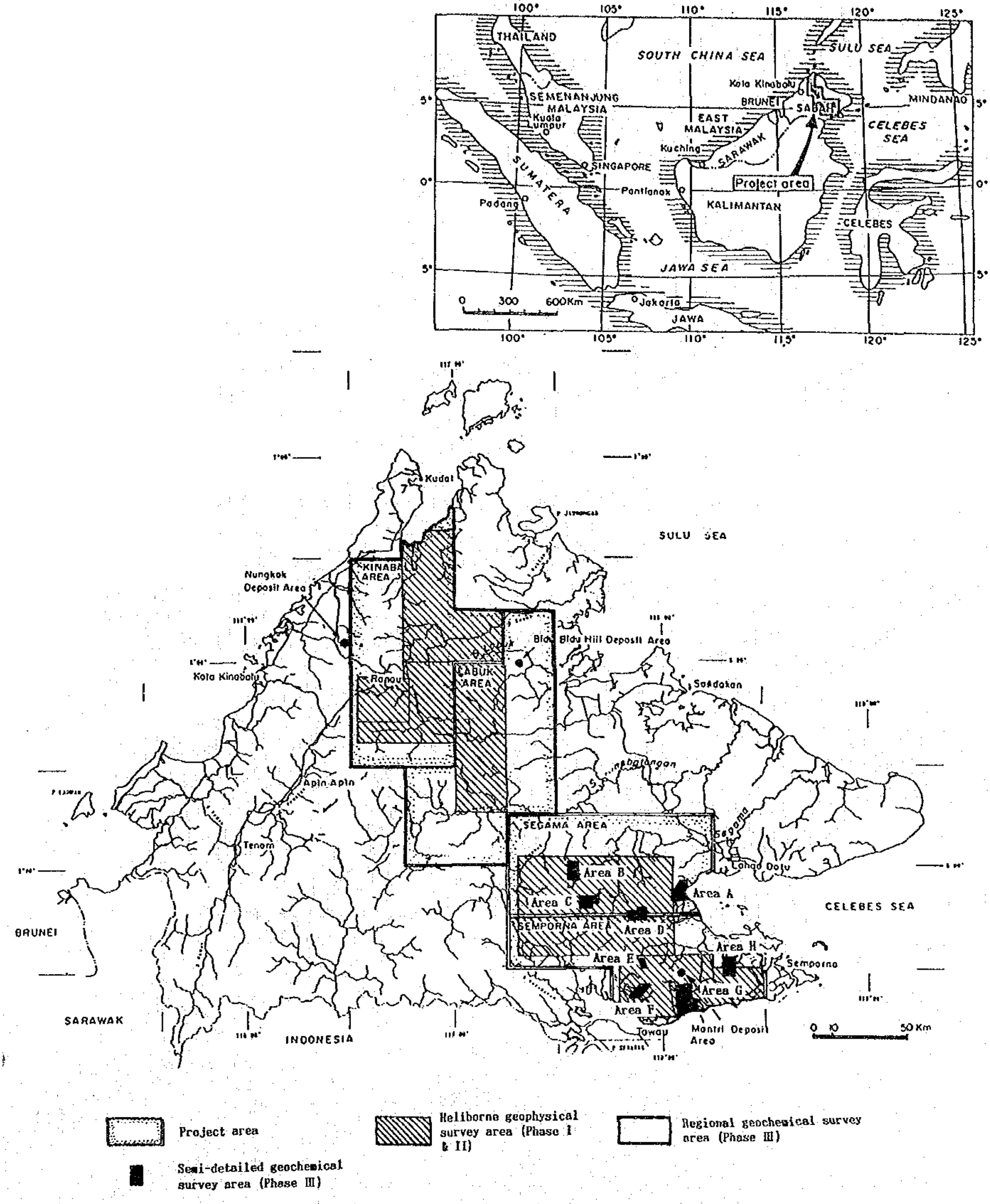

Fig. 1 Location map of the project area

ABSTRACT

The Government of Malaysia and the Government of Japan agreed a four-year mineral exploration project, starting from 1990, in the central Sabah area. The Scope of Work for this project was signed by both governments on 1st August 1990. Objectives of this project are to clarify the mineral potentiality and to obtain useful data for future development of mineral resources in this area. This report includes the survey results of the third year (PhaseIII).

The regional geochemical survey for Kinabal and Labuk areas and semi-detailed geochemical survey for eight areas in the Segama and Semporna areas were completed in this phase. The regional survey was carried out by the same manner of the regional survey for Segama and Semporna areas in Phase II. The eight semi-detailed survey areas were delineated by the results of the regional geochemical survey conducted in Phase II. Interpretation of the heliborne geophysical survey data for Northern Kinabalu area were also conducted in this phase.

Results of the regional geochemical survey in the Kinabal and Labuk areas delineated many mineral potential areas including known mineral showing zones. This results suggest that the survey methods applied are quite useful for the survey in this project area. The results of this survey delineated the following areas as the potential area of mineral resources.

Kinabalu area: lower stream of Sungai Sugut, middle stream of Sungai Sugut, east of Ranau and the most upper stream of Sungai Karamuak.

Labuk area : tributary of Sungai Imbak, middle stream of Sungai Imbak, lower stream of Sungai Karamuak, middle stream of Sungai Karamuak, the area between Sungai Karamuak and Sungai Milian, Sungai Mailo area, Sungai Sugut area at the north, west of Telupid and Bidu Bidu Hill deposit area.

Among the areas in the Kinabalu area, the two areas along Sungai Sugut have potentiality of porphyry copper ore deposits. Analytical results of the lateritic soil samples collected at the east of Ranau indicate high value of Ni (1.08 %). The potentiality of this area is nickel ore deposits. At the most upper stream of Sungai Karamuak, one stream sediment sample indicates extremely high contents of Ti (51.07 %). This area may have potentiality of titanium ore deposits.

Among the potential areas delineated in Labuk area, three areas including the tributary of Sungai Imbak, the middle stream of Sungai Imbak and the lower stream of Sungai Karamuak, are interpreted to have potentiality of gold ore deposits.

Especially, several samples collected from the tributary of Sungai Imbak indicated extremely high gold values (maximum value: 6,530 ppb). The middle stream of Sungai Karamuak is delineated as the potential area of chromium ore deposits. The area between Sungai Karamuak and Sungai Milian is the potential area of copper ore deposits. Extremely high contents of Cr was confirmed in the area of Sungai Mailo. This area may have possibility of chromium deposits. As the rsesults of soil geochemical survey, high contents of Ni (1.06 %) and Co (0.22 %) were confirmed. This has potentiality of lateritic nickel ore deposits. Significant geochemical anomalous zones were also delineated in the Bidu Bidu Hill ore deposit area. This ore deposits are going to be developed in the near future.

As the results of semi-detailed geochemical survey for the Segama and Semporna areas, significant mineralized zones with geochemical anomaly were confirmed in Area B. This zone extend 5 km x 2 km and the best assay results gave 2.12 % Cu and 3.04 % Zn. Other than this area, significant hydrothermally altered zones were confirmed in Area E, Area F and Area G.

Results of interpretation for heliborne geophysical survey in the Northern Kinabalu area confirmed highly magnetized bodies near surface in the northern part. In the central part, highly magnetized rocks are expected in the depth. At the south western part, highly magnetized bodies near surface are divided by NW-SE and N-S trending magnetic discontinuity lineaments. High count radiometric zones distributed in the entire area are mainly contributed by potassium. In the southwestern and southeastern parts, very high radiometric anomalous zones showing large contribution of uranium (U) and thorium (Th) are located on low magnetic anomalies caused by Chert-Spilite formation.

As the results of regional survey thirteen areas were delineated as the potential areas of mineral resources. Among these areas, further exploration work should be carried out for the twelve areas, excluding the Bidu Bidu Hill area, in order to clarify the mineral potentialities. Because the exploration works have been completed for the Bidu Bidu Hill area, further exploration work is not recommended.

Among the eight completed areas of the semi-detailed survey, significant promising zones are confirmed in Area B. Further exploration work should be carried out for this area in order to confirm the nature and scale of the mineralized zones.

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Part I General

Part II Survey results

Part III Conclusions and recommendations

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 August 1990, the Supra-regional Survey was carried out in the central part of Sabah, Malaysia. The area selected for this survey (Fig. 1) is thought to have higher mineral potentiality in Sabah, because many known mineral occurrences are distributed. This project is four years project starting from 1990 and this report includes the survey results of Phase III.

Purpose of this survey is to clarify the mineral potentiality in this area for the future mineral development of mineral resources. In order to execute this purpose, a regional geochemical survey for the Kinabalu and Labuk areas, and a semi-detailed geochemical survey for selected eight areas in the Segama and Semporna areas are completed in this survey. The semi-detailed survey areas are the areas delineated by the results of the regional geochemical survey in Phase II. Data analyses and interpretation for the heliborne magnetic and radiometric surveys in Northern Kinabalu area was also conducted in this phase.

1-2 Survey results of Phase I and II

(1) Survey results of Phase I

In the Phase I, the satellite image analyses using MSS and TM data, orientation geochemical survey over three known mineral deposit areas, and heliborne survey including data acquisition and data processing over selected areas were completed. The results of these survey are conclusively summarized as follows;

1) Satellite image analysis

① The ring structure delineated in and around Ranau and N-S trending fault zone in the Kinabalu area shows close relationship with intrusives in which mineralization is recognized.

② These ring structures observed over the survey area are thought to be important for the mineral exploration in the area.

2) Orientation geochemical survey

① All the sample medias (stream sediments, soil and pan concentrates) adopted in this survey are useful for the mineral exploration in this project area.

② Stream sediment geochemical samples indicate longer distance of influence compare to other sample medias. Consequently, stream sediment sample is the optimum sample media for the regional geochemical survey.

③ Optimum sample density of stream sediments is 2 km^2/sample, and soil is 0.5 km^2

/sample.

④ Optimum sampling point for stream sediments is the edge of water flow and upper part of B horizon for soil.

⑤ Useful pathfinder elements for the geochemical survey in this project area are twelve elements including As, Au, Ba, Cr, Cu, Mn, Mo, Pb, S, U, W and Zn.

(2) Survey results of Phase II

In the period of Phase II, the regional geochemical survey, using stream sediments as the sample media, was carried out over the areas of Segama and Semporna. Continuing from Phase I, data acquisition and data processing of the heliborne geophysical survey were conducted during this phase. The data analyses of the heliborne geophysical survey, excluding Northern Kinabalu area, were also conducted in this phase.

As the results of these surveys, following areas were delineated as the promising areas in the Segama and Semporna areas.

① Between Sungai Sabahan and Sungai Diwata area (Segama area)
② Upper stream of Sungai Segama area (Segama area)
③ Upper stream of Sungai Danum area (Segama area)
④ Surroundings of Silam village (Segama area)
⑤ Between Sungai Balung and Sungai Kalumpang (Semporna area)
⑥ Nearby Nagos (Semporna area)
⑦ Upper stream of Sungai Sipit (Semporna area)
⑧ Upper most stream of Sungai Kalumpang area (Semporna area)
⑨ Sungai Apas area (Semporna area)
⑩ Surroundings of Tawau Hill (Semporna area)

Among these promising areas, ①, ② and ③ have potentiality of Cyprus-type copper deposits. Target of area ④ is chromite deposits. The areas from ⑤ to ⑩ have potentiality of vein-type hydrothermal gold deposits.

During Phase II, regional stream sediments were also collected in a part of the Kinabalu and Labuk areas. The data analyses for these samples are made in Phase III together with the samples in Phase III.

1-3 Coverage and outline of Phase III survey

The regional geochemical survey was carried out in the Kinabalu and Labuk areas. Data analyses of this regional geochemical survey include the samples collected in the Kinabalu and Labuk areas in Phase II. In addition, a semi-detailed geochemical survey was carried out for eight promising areas in the Segama and Semporna area. These eight areas are the areas delineated by the results of regional geochemical survey in Phase II. The heliborne survey in this phase is only the data analyses for Northern Kinabalu area. Locations of the survey areas are shown in Fig. 1. The work amounts conducted in this phase are summarized in Table I-1 and the laboratorial studies for these surveys are shown in Table I-2.

The survey in this phase emphasizes to delineate mineral potential areas in the Kinabalu and Labuk areas using the regional geochemical survey method and in the Segama and Semporna areas using a semi-detailed geochemical survey method.

The base camp for the regional geochemical survey was established at Ranau in the Kinabalu area. Sampling work was conducted by camping (eight sites) and flying camp along stream.

1-4 Survey member

The members of the project are as following;

(1) Project planning and prior negotiation

Japanese counterpart		Malaysian counterpart		
Haruhisa Morozumi	MMAJ	David Lee Tain Choi	Director	GSM
Yuuji Kajitani	MMAJ	Lim Peng Siong	Principal Geologist	GSM
		Alexander Yan	Senior Geologist	GSM

MMAJ; Metal Mining Agency of Japan GSM; Geological Survey of Malaysia

(2) Field survey

Japanese counterpart			Malaysian counterpart		
Takehiko Nagamatsu	Team leader	BEC	Lim Peng Siong	Principal Geologist	GSM
Tadahiko Monma	Geochemical	BEC	Alexander Yan	Senior Geologist	GSM
Masahiko Nono	Geochemical	BEC	Joanes Muda	Geologist	GSM
Yoshinori Tsuguma	Geochemical	BEC	Paulus Godwin	Geologist	GSM
Masatsugu Okazaki	Geochemical	BEC	Cleafos Totu	Geologist	GSM
Motomu Goto	Geochemical	BEC	Salleh Adanan	Geologic Assist.	GSM
Masayuki Saito	Geochemical	BEC	Japili Samin	Geologic Assist.	GSM
			Jolouis Supilin	Geologic Assist.	GSM

BEC; Bishimetal Exploration Co., Ltd. GSM; Geological Survey of Malaysia

The data analyses of the heliborne geophysical survey was carried out by Mr. Susumu Sasaki (Bishimetal Exploration Co., Ltd.) in Japan.

1-5 Survey period

Period of the field survey in this phase is as following;

Geochemical Sampling ; 7th July 1992 to 9th December 1992.

Geochemical field analysis ; 4th December 1992 to 23rd December 1992.

Table I-1 Summary of work amounts

(1) Regional geochemical survey

Method	Unit	Sampling			Data analysis		
		Kinabalu	Labuk	Total	Kinabalu	Labuk	Total
Coverage	km^2	6,730	5,570	12,300	7,430	7,670	15,100
Stream sediments	Sample	2,976	2,332	5,308	3,342	2,974	6,316
Pan concentrates	Sample	173	137	310	193	169	362
Soil	Sample	48	203	251	48	225	273
Rock	Sample	50	51	101	52	70	122
Ore	Sample	6	5	11	6	5	11

(2) Semi-detailed geochemical survey

Method	Samples	Area A	Area B	Area C	Area D	Area E	Area F	Area G	Area H	Total
Coverage	km^2	85	70	72	55	18	54	146	70	570
Stream sediments	Samples	—	140	140	—	—	—	—	—	280
Soil	Samples	340	144	140	221	72	122	581	282	1,902
Rock	Samples	2	12	7	4	1	1	2	1	30
Ore	Samples	2	8	5	2	1	2	1	0	21

Table I-2 Work amounts of laboratorial studies

Study item	Regional survey	Semi-detailed survey	Total
(1) Thin section	6 samples	26 samples	32 samples
(2) Polishes section	3 samples	12 samples	15 samples
(3) X-ray diffraction analyses	—	15 samples	15 samples
(4) Chemical analyses			
stream sediments (21 elements)	5,308 samples 111,468 elements	280 samples 5,880 elements	5,588 samples 117,348 elements
Soil (6 elements)	251 samples 1,506 elements	— —	251 samples 1,506 elements
Soil (21 elements)	— —	1,902 samples 39,942 elements	1,902 samples 39,942 elements
Rock (21 elements)	101 samples 2,121 elements	30 samples 630 elements	131 samples 2,751 elements
Ore (7 elements)	11 samples 77 elements	21 samples 147 elements	32 samples 224 elements

Chapter 2 Geography of survey area

2-1 Location and accessibility

Malaysia, being a principal member of ASEAN countries, consists of Western Malaysia situated in the Malay Peninsular and East Malaysia situated in northern and southwestern Borneo. Population of West and East Malaysia in total is 16.5 millions. The area of the country is approximately 330,000 km².

Eastern Malaysia comprises the State of Sabah and State of Sarawak. The project area is situated in the State of Sabah, from its northwestern part to its southeastern part and the coverage is 26,500 km². The area is subdivided into four areas (Fig. 1). These are named Kinabalu area, Labuk area, Segama area and Semporna area.

The capital of the State of Sabah is Kota Kinabalu on the west coast of the state. In Kota Kinabalu, international airline services are available. Regular flight lines are also available between Kota Kinabalu and some cities on the east coast of Sabah. Principal road connects Kota Kinabalu, Ranau and Sandakan and other main road connects from Sandakan to Tawau through Lahad Datu. These roads pass through the central part of the Kinabalu and Labuk areas and eastern part of the Segama and Semporna areas. In the Kinabalu area, many roads run out from Ranau. In the Labuk area, there are some roads for log transportation. However, vehicles can not be used at the southern and northern part of the area. In the Segama and Semporna areas, there are some roads used for plantation and log transportation on the east coast area. In the western part of the Segama area, rivers are mainly used for transportation. In the eastern to southern part of the Semporna area, roads for plantation are developed.

2-2 Topography and drainage system

The State of Sabah is divided into three categories in terms of topographic features. Steep mountains trending north northeast dominate in the western side along the coast. Heights occupy the eastern area and volcanic mountains are found in the southern part. Flat plain is along rivers and their down streams. Mt. Kinabalu which is the highest mountain in the southeast Asia, rise up to 13,455 ft in western end of the Kinabalu area which is occupied by steep topography. Highland dominates in the Labuk and Segama areas. Swamp extends at the end of main rivers and the rivers are extremely meandering there. Highland dominates in the Semporna area except the young volcanics region with volcanic topography.

The main drainage system in the project area are Sungai Pegalan, Sungai Sugut

Sungai Labuk, Sungai Kinabatangan, Sungai Segama, Sungai Tingkayu, Sungai Kalumpang, Sungai Kalabakan etc. Among these river systems, Sungai Pegalan flows to South China Sea, Sungai Kalumpang and Kinabatangan flows down to Celebes Sea and other river systems are to Sulu Sea at the east. These river systems form deep valley at the upper stream and extremely meandering at the down stream in general. The river also forms swamp area at the mouth of the river.

2-3 Climate and vegetation

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

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

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

3-1 General geology

The survey area occupies wide area in the northwest to southeast of the State of Sabah. Known mineral showings are found mostly in this region.

This area is underlain by crystalline rocks (Cb), sedimentary rocks accompanied by spilite eruption (K, KP), sedimentary rocks characterized by flysh sediments (P_1, P_2, P_3 and P_4) and other sedimentary rocks (N_1, N_2, N_3, N_4 and N_5). Cb is pre-Triassic rock and forms a basement in this area. K and KP were deposited in the age from Cretaceous to Eocene, which was earlier time of the northwestern Borneo geocyncline. P_1, P_2, P_3 and P_4 were deposited in Eocene through middle Miocene. N_1, N_2, N_3, N_4 and N_5 were deposited during early Miocene through Pleistocene. Orogenic movement is realized in middle Miocene through Pliocene.

Cretaceous ultra-basic intrusives, syn- and post-orogenic plutonic intrusives and effusive rocks such as dacite, andesite and basalt in Pliocene through Holocene and recognized as the result of the igneous activities.

Geologic map (Y.E. Heng, 1985) of the State of Sabah including the survey area is shown in Fig.I-1. This map tells that crystalline rocks such as schists and gneisses, which form basement, and sedimentary rocks are mainly distributed in the Segama area. Sedimentary rocks accompanied by spilite effusion occupied wide area both in the Labuk and Segama areas. Ultra-basic rocks can be seen in the Kinabalu, Labuk and Segama areas, whose distribution is closely related with that of the sedimentary rocks accompanied with spilite effusion. Plutonic intrusions such as adamellite and granodiorite are characteristic in the Kinabalu area. Volcanic rocks such as dacite, andesite and basalt are characteristic in the Semporna area. This volcanic belt extends northeast until the southern part of Philippine.

3-2 Mineralization and mining activities

Principal metallic ore deposits in the survey area comprise porphyry copper deposit closely related with plutonic rocks, Cyprus-type massive sulfide deposit related to spilite effusion and hydrothermal gold-silver deposits closely related with volcanic rocks. Chromium or platinum deposits related with ultra-basic rocks, lateritic aluminum and nickel deposits and manganese deposits in sedimentary rocks are known as well. The distribution map of main metallic ore deposits and mineral showings in the project area (after K.M. Leong, 1976) are shown in Fig. I-2.

The Mamut mine is the only active mine in the project area. The Mamut deposit is porphyry copper type, located to the north of Ranau in the Kinabalu area. This

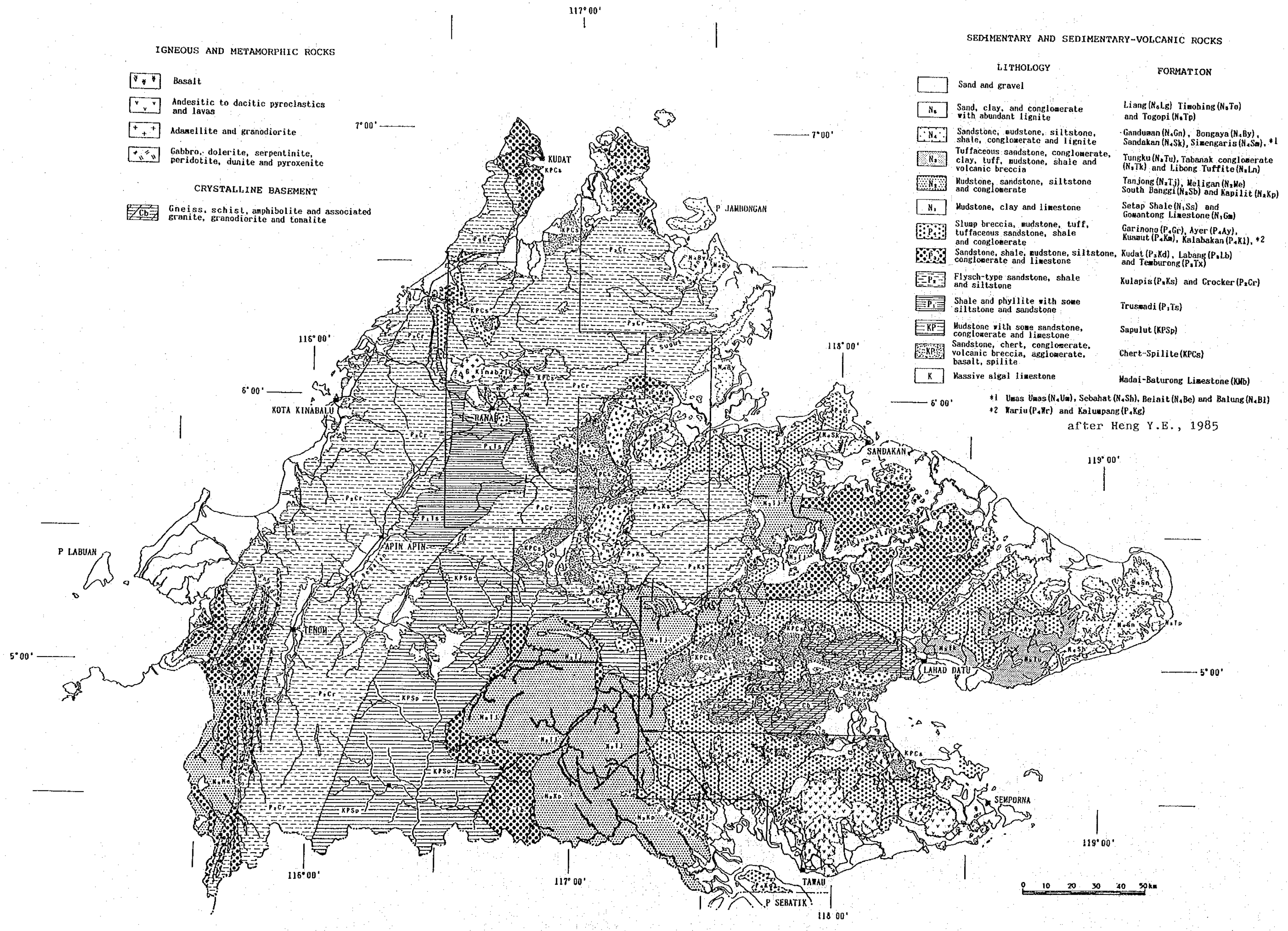


Fig. I-1 Geologic map of Sabah, Malaysia

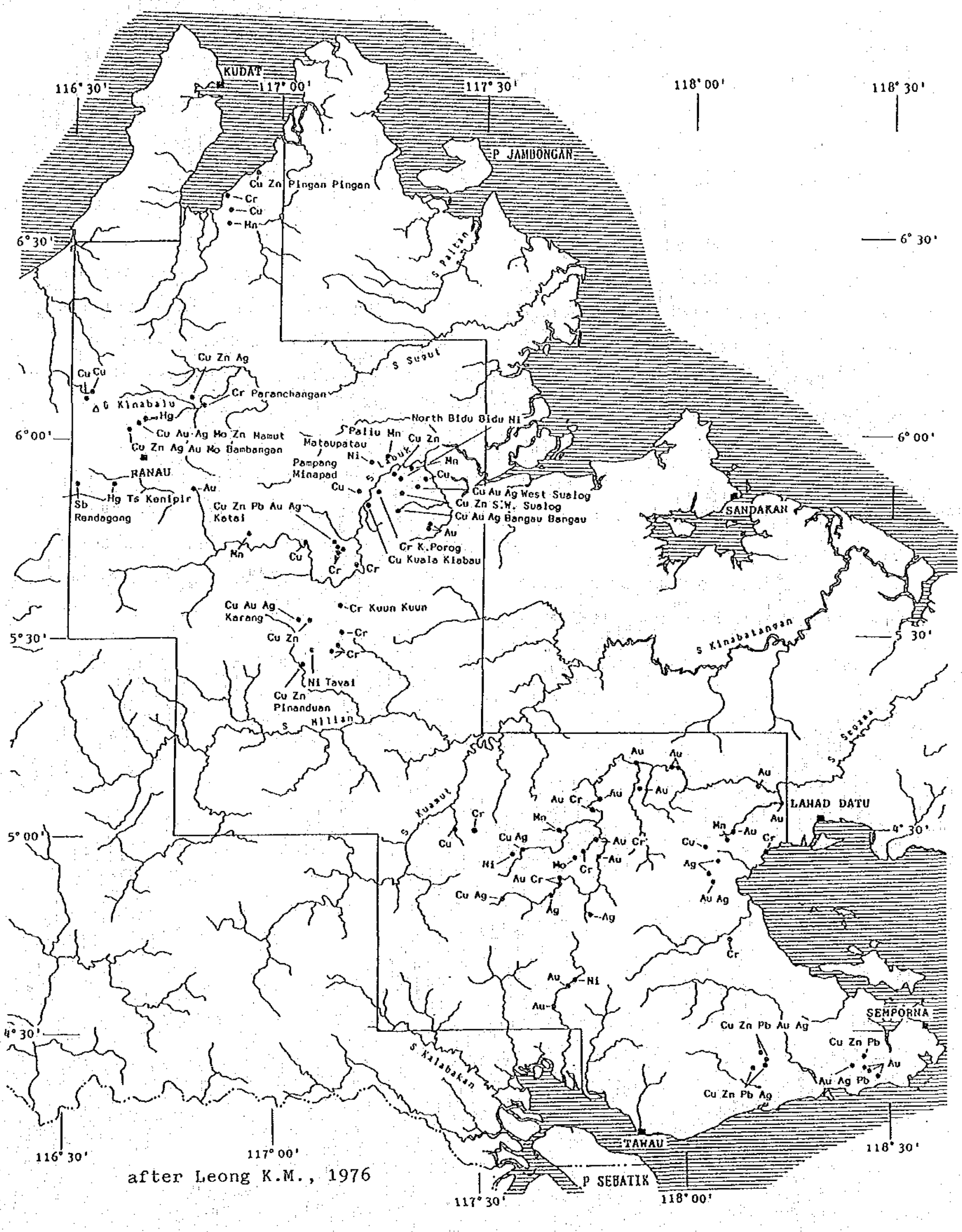


Fig. I-2 Distribution map of mineral occurences in the project area ore deposit was discovered by a geochemical survey conducted by United Nations. The Overseas Mineral Resources Development Co., Ltd., Japan, obtained the exploration right on the Mamut area through international tender in 1968, and carried out exploration work from 1968 to 1972, then began development work in 1973. The mine has been operated since May, 1975. The current production of crude ore is 20 thousand tons per day with the grade of 0.47 % Cu. Staffs and workers of the Mamut Copper Mining Sdn. Bhd. are about 1,300.

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

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

Chapter 4 Survey results

4-1 Regional geochemical survey

Continuing from the regional geochemical survey for the Segama and Semporna areas in Phase II, a regional geochemical survey, which are composed of stream sediments, pan concentrates and rocks as the sample media, was carried out in the Kinabalu and Labuk areas. In addition, soil geochemical reconnaissance survey was carried out in the area of ultra-basic rocks to clarify a potentiality of residual laterite deposits.

(1) Pathfinder element

Same elements in Phase II were adopted for the pathfinder elements in this survey. These are as follows;

Stream sediment sample (21 elements).

As, Au, Ba, Co, Cr, Cu, Hg, K, Mg, Mn, Mo, Na, Ni, Pb, S, Sb, Sr, Ti, U, W, Zn.

Soil sample (6 elements).

Al, Co, Fe, Cr, Ni, Pt.

In addition to above geochemical survey, the representative rock samples were analized for 21 elements which are same elements for the stream sediment samples to clarify the geochemical nature of the background rocks in the survey area.

Qualitative Mineral Examination (QME) was also carried out for the pan concentrates to clarify the qualitative mineral composition of the pan concentrates.

(2) Data analyses

The distribution maps of elements (Appendix 3 and 11) were prepared to clarify the distribution tendencies of each element. Data analyses were made using single element analysis and multi-element analysis. Exploratory Data Analysis (EDA) (Kurzl,H., 1988) method was adopted as the single element analysis to delineate the threshold values. Cluster and factor analyses were applied as the multi element analysis in this survey.

Exploratory Data Analysis (EDA) method delineates threshold value by means of statistics data processing, and distribution pattern of each element is not affected in this method. The cluster analysis is a grouping method of elements which have close relationship among them. Factor analysis is the method to delineate factors which form the relationship among the elements.

The data analyses were separately conducted for Kinabalu area and Labuk area, because of the different geology between the survey areas.

(3) Survey results in Kinabalu area

Geologic reconnaissance survey was simultaneously carried out in the regional geochemical survey. Geologic map was prepared using the previous geologic data and the data obtained from the present survey. The geologic map is shown in Fig. II-1-1. The following results were obtained for each survey method.

Stream sediment geochemical survey

Stream sediment samples collected in Kinabalu area are listed in Appendix 1 and the analytical results are shown in Appendix 2. Locations of the samples are shown in Fig. II-1-2 and Plate II-1-1.

Distribution maps of each element and distribution map of anomalous samples are shown in Appendix 3 and in Fig. II-1-4, respectively. These maps give the following results:

① Among the analyzed elements, the maximun value of Cr (59,548 ppm), Hg (14,767 ppb), Sb (3,488.0 ppm) and Ti (51.07 %) are significantly high.

② Correlation coefficient among the elements including Cr, Co, Mg, Mn and Ni are higher than that of other elements. These pairs of elements reflect the existence of ultra-basic rocks and Chert-Spilite formation in this area.

③ The distribution maps of Co, Cr, Mg, Mn, Na, Ni, Sb, Ti and Zn indicate that these elements have close relation with ultra-basic and basic rocks. The elements including As, Ba, K, Pb, S, Sr and U show comparatively high values in the area of muddy sedimentary rocks.

④ The samples with anomalous (more than threshold value) and high values (more than background plus standard deviation) of Au, Cu, Hg, Mo, Pb, S and Sb are found in the area of Mamut mine and the surroundings. This anomalous zone is quite significant.

⑤ Anomalous and high value samples of Au, Cu, K and Pb are found in the lower stream of Sungai Sugut. This area is interpreted to have potentiality of copper ore deposits.

⑥ Anomalous and high value samples of Au, Cu and Hg are found in the middle stream of Sungai Sugut. This area is situated on a lineament delineated from satellite image analyses of TM data. This area also has potentiality of copper ore deposits.

⑦ A sample collected from the upper stream of Sungai Karamuak, indicated significant high contents of Ti. This area may have potentiality of titanium ore deposits. The minerals in this sample is mostly ilmenite.

Cluster and factor analyses were applied as the multi element analysis. The obtained dendrogram (Fig. II-1-5) clearly indicates the cluster related to ultra-basic and basic rocks, and cluster related to sedimentary rocks. Other than these cluster, clusters of As-Au-Hg and Zn-Cu-S are also delineated in this analyses.

The results of factor analyses indicate that the factor 1 is closely related with the elements including Co, Cr, Cu, Mg, Mn, Ni and Zn. Factor 3 is closely related with the elements of Mo and Pb and factor 4 is Au respectively. High factor score sample for these three factors overlap in the area of Mamut mine as shown in Fig. II-1-6, and clearly delineates this copper ore deposits. Similar overlap of factor scores are found in the area of ⑤ and ⑥.

Pan concentrate survey

The samples collected in the survey area is shown in Appendix 4 and their locations are shown in Fig. II-1-3. The results of QME are shown in Appendix 5. The amounts of sample is different depend on the geology at the sampling point. Large amounts of samples were collected around the zone of ultra-basic rocks and remarkably small amounts of sample (less than 1 gram) were collected in the area of sedimentary rocks. The collected minerals is composed mainly of rock forming minerals, and reflect the geology at the sampling point.

Rock geochemical survey

The representative rock samples were collected to clarify the geochemical nature of the background geology in the survey area. The location of rock samples are shown in Fig. II-1-3. List of sample and analytical results are shown in Appendix 6 and 7 respectively.

The contents of the elements including Co, Cr, Mg, Ni and Zn tend to show higher values in the ultra-basic rocks and the elements including Cu, Sb, Zn and Ti give higher values in the basic rocks. The elements including As, Hg, Pb and U are closely related with the sedimentary rocks such as sandstone and shale. The relationship between elements and rocks show the same geochemical nature observed for the typical rocks.

Soil geochemical survey

The soil geochemical reconnaissance survey was carried out in the area of ultra-basic rocks to clarify a potentiality of residual laterite deposits. The location of soil samples are shown in Fig. II-1-3 and the descriptions of samples are the analytical results are shown in Appendix 8. The analytical results show that the maximum value of Ni is 10,797 ppm. This sample is situated 4 km east of Ranau and the contents of Co is also high value (1,212 ppm).

(4) Survey results in Labuk area

Geologic reconnaissance survey was simultaneously carried out in the regional geochemical survey. Geologic map compiled from previous geologic data and the data obtained from the present survey is shown in Fig.II-1-7. Sampling work for the central to eastern part of the survey area was completed using the logging road. The following results in each survey method were obtained.

Stream sediment geochemical survey

Stream sediment samples collected in Kinabalu area are listed in Appendix 9 and the analytical results are shown in Appendix 10. The locations of the samples are shown in Fig. II-1-8 and Plate II-1-2.

The distribution maps of each element obtained from the statistical data processing are given in Appendix 11 and the distribution map of anomalous samples are shown Fig.II-1-10. The data processing and the distribution maps give the following results.

① Among the elements, the maximun value of Au (6,530 ppb), Cr(117,538 ppm), Hg (24,735 ppb) and Ni(6,778 ppm) give higher values.

② High correlation coefficients are found among the elements including Co, Cr, Cu, Mg, Ni and Zn. U has negative correlation with these elements.

③ According to the distribution maps of each element and of anomalous samples, the anomalous and high content samples of Co, Cr, Mg, Mn, Ni, Sb, Zn are found in the area of ultra-basic and basic rocks.

④ The samples with more than 1,000 ppb Au (maximum; 6,530 ppb) are concentrated in the area of tributary of Sungai Imbak where Tanjong formation is distributed. Anomalous samples of Hg(24,735 ppb) and Pb are also found in this area. During the survey, small in scale andesite porphyry which may have some relationship with mineralization was confirmed in this area.

⑤ Three anomalous samples of Au (maximum 2,900 ppb) are found at the south bank of the middle stream of Sungai Imbak. In this area, a sample with high W (95 ppm) content is confirmed. Some samples with more than 1,000 ppb Hg are scattered in the surroundings.

⑥ Several samples with more than 100 ppb Au (maximum 881 ppb) are concentrated in the lower stream of Sungai Karamuak, southern part of the area, where Crocker formation is distributed.

⑦ The anomalous samples of Cu (maximum 608 ppm) are found in the area between Sungai Karamuak and Sungai Milian. This area is situated at the southern vicinity of the lower stream of Sungai Karamuak.

⑧ Significant anomalous zone of Cr was found in the area of the middle stream of Sungai Karamuak where ultra-basic rocks are observed. Most samples in this area show more than 50,000 ppm Cr and the maximum is 101,691 ppm Cr. In this area, samples with high Cu contents (maximum 580 ppm) are also confirmed.

⑨ Extremely high contents of Cr (maximum 117,538 ppm) are found in the upper stream of Sungai Mailo, south of Telupid, over the area of ultra-basic rocks.

⑩ High and anomalous samples of Cu (maximum 212 ppm) are concentrated along Sungai Sugut in the northern part of the area. Samples with higher contents of Au and Ba are also found in this area. This anomalous area extends from the eastern margin of Kinabalu area.

⑪ Anomalous zones of Cu are found in the area of Bidu Bidu Hill ore deposit area. The maximum value of Cu in this area is 516 ppm, and Au is also comparatively high.

The results of the cluster analyses (Fig. II-1-11) clearly divide elements into the cluster related to ultra-basic and basic rocks, and the cluster related to sedimentary rocks.

Results of the factor analysis delineated six factors. Among these factors, factor 1 seems to be related with ultra-basic rocks and weakly related with copper mineralization. Factor 2 and factor 3 seem to be related with sedimentary rocks. Factor 4 may have weak relation with gold mineralization. Factor 5 has relation with Hg, but factor 6 is not clear the relationship. Among these factors, factor 1, 4 and 5 were selected and the distribution map (Fig. II-1-12) of these facters are prepared . As the results, high factor score zones of factor 4 are found in the area of Sungai Sugut and the area from Sungai Milian to Sungai Imbak.

Pan concentrate survey

List of samples collected in this survey is shown in Appendix 12 and their locations are shown in Fig. II-1-9. The results of QME analysis are shown in Appendix 13. The results of the QME analysis indicate that mineral composition reflects the geology at each sampling point.

Rock geochemical survey

List of the rock samples is given in Appendix 14. Locations of rock samples are shown in Fig. II-1-9 and analytical results are shown in Appendix 15. The results show that contents of As, Hg and U are higher in sedimentary rocks. The elements including Cr, Mg, Na, Sb and Zn give higher values in ultra-basic and basic rocks. Chert in Chert-Spilite formation has higher contents of Ba, Mn and Pb compare to other kind of rocks.

Soil geochemical survey

List of samples and the analytical results are shown in Appendix 16. Locations of the soil samples are shown in Fig. II-1-9. The samples with the maximum value of Ni (10,587 ppm) and of Cr (2,173 ppm) are found at the west of Telupid in the central part of survey area. Thick lateritic soil over serpentinite is found in this area.

4-2 Semi-detailed geochemical survey

A semi-detailed geochemical survey was carried out for eight selected areas in Segama and Semporna areas. These areas are selected as the areas with mineral potentiality based on the results of the regional geochemical survey in Phase II. The survey results for these eight areas are summarized as below;

(1) Area A

Area A is situated in a eastern part of Segama area. Semi-detailed soil geochemical survey was completed in this area in order to clarify the potentiality of Cyprus-type copper deposits. Geology of this area and locations of sampling site are shown in Fig. II-2-2 and Fig. II-2-3 respectively.

Geology of Area A consists of crystalline basement with limestone, Chert-Spilite formation and Kuamut formation of Oligocene to middle Miocene in age.

As the results of soil geochemical survey, anomalous and high value samples of Cu and Zn are scattered. Pyrite dissemination is confirmed at the upper stream of Sungai Sabahan where Kuamut formation occurs. Analytical results of a sample collected in this mineralized zone, show slightly high values of Cu (107 ppm) and Zn (117 ppm). Observation of a polished section confirmed the existance of minor amount of chalcopyrite and sphalerite.

(2) Area B

This area is situated at the upper most stream of Sungai Danum in the central part of Segama area. This area was also interpreted to be a potential area of Cyprus type copper ore deposits in the results of regional geochemical survey in Phase II. Geologic map of this area and locations of samples are given in Fig. II-2-6 and II-2-7 respectively.

Soil and stream sediment geochemical surveys were adopted for this area. Because of steep topography, the survey was conducted along streams.

Geology of this area consists of ultra-basic and basic rocks, Chert Spilite formation and Kuamut formation in ascending order.

As the results of soil geochemical survey, significant anomalous zone of Cu and Zn are confirmed in the central and southwest parts of the area where Chert-Spilite formation crops out.

The results of stream sediment geochemical survey also delineated significant anomalous zones in the same parts of the area where anomalous zones of soil geochemical survey are cofirmed. This promising zones were also clearly delineated by the results of factor analysis.

During the sampling work significant copper mineralization was confirmed in the detected geochemical anomalous zones. This mineralized zone consists of stockwork and dissemination of sulfide minerals and extends 5 km x 2 km. Assay results for the ore sample collected in this mineralized zone give 2.12 % Cu and 3.04 % Zn which are the best. This mineralized zone is also strongly silicified, chloritized and brecciated.

(3) Area C

Area C is situated at the upper most stream of Sungai Segama in the southern central part of Segama area. Potentiality of this area is also Cyprus type copper ore deposits. Soil and stream sediment geochemical survey were simultaneously carried out in this area. Geologic map and location map of samples are shown in Fig. II-2-12 and Fig. II-2-13 respectively.

Geology in this area consists of pre-Triassic phyllitic schist and green schist, ultra-basic and basic rocks of Cretaceous to early Tertiary in age, Chert-Spilite formation of Cretaceous to early Eocene in age and Kuamut formation of Oligocene to middle Miocene in age.

Geochemical anomalous zone of Cu are mainly found in the area of green schist. As the results of surface survey, sulfide disseminations, mostly pyrite, are confirmed in this geochemical anomalous zone. As the results of soil geochemical survey, a geochemical anomalous zone with Cu, Pb, S, Zn anomalous samples was confirmed in the southern central part of the area. This anomalous zone may reflect some mineralization.

Mineralization in this area is found in the sheared zones of green schist. Because of the geology, potentiality of Cyprus type copper deposits in this area is thought to be low.

(4) Area D

Area D is situated at the middle stream of Sungai Tingkayu in a central southern margin of Segama area. The exploration target in this area is also Cyprus type copper deposits. The soil geochemical survey was completed in this area. The geologic map and the sample location are shown in Fig. II-2-18 and Fig. II-2-19 respectively.

Geology of Area D consists of pre-Triassic amphibolite schist and green schist, ultra-basic and basic rocks of Cretaceous to early Tertiary in age, Chert-Spilite formation of Cretaceous to Eocene in age and Kuamut formation of Oligocene to middle Miocene in age. Intrusives of andesite porphyry is found in the area of green schist. No significant mineralization was confirmed during the fieldwork.

The geochemical anomalous zones delineated in this survey are small in scale and are scattered and no significant anomalous zones were confirmed. Because of limited distribution of Chert-Spilite formation, potentiality of Cyprus type copper ore deposit is thought to be low.

(5) Area E

Area E is situated at upper most stream of Sungai Kalumpang in the central part of Semporna area. In order to clarify the potentiality of epithermal gold deposits, soil geochemical survey was conducted in this area. Geology of this area and the location of geochemical samples are shown in Fig. II-2-22 and Fig. II-2-23, respectively.

Geology in this area consists of Kuamut formation of Oligocene to middle Miocene in age, and andesite and its pyroclastics of Pliocene in age.

As the results, anomalous zones of As, Au, Cu, Hg, Mo and Pb are overlapped in the southeastern part of the area. Results of a factor analysis (Fig. II-2-25) also clearly delineated this zone. On the surface, silicified zones are observed in this anomalous zone and this fact suggests the existence of hydrothermal alteration in this zone. However, significant mineralized zones have not been confirmed on the surface.

(6) Area F

Area F is situated in the southern central part of Semporna area, and is the upper stream of Sungai Tawau. A soil geochemical survey was carried out in order to clarify the potentiality of epithermal gold deposit in this area. The geologic map and sample location map are given in Fig. II-2-26 and Fig. II-2-27, respectively.

Geology in Area F consists of Pliocene volcanics (andesite) and Pleistocene volcanics (dacite and basalt).

As the results of soil geochemical survey in this area, anomalous zones of As, Cu, Hg, Pb and S are overlapped in the northern part of the area where andesite and its pyroclastics are observed. In this part, some silicified and argillized zones with pyrite dissemination and hot spring were confirmed. Results of factor analysis also clearly delineated these altered zones. Judging from the relation between altered zone and anomalous elements, this altered zone may have some relation with hot spring activity.

(7) Area G

Area G is situated along Sungai Apas, in the southern central part of the Semporna area. The target in this area is also epithermal gold deposits. The soil geochemical survey was conducted in this area as same as the areas of Area E and Area F. The geologic map and sample location map of this area are given in Fig.

II-2-30 and Fig. II-2-31, respectively.

Geology in Area G consists of Pliocene volcanics (augite-hypersthene andesite and hornblend andesite) and Pleistocene volcanics (dacite and hypersthene andesite). A small stock of granodiorite porphyry, possibly Pliocene in age, occurs in a southeastern part of the area. The central to eastern part of the area is widely occpied by tuff, sand, silt and ash and these sediments are strongly weathered. The tuffaceous sediments are mostly dacitic tuff and are possibly Pleistocene in age.

As the results of soil geochemical survey, anomalous zones of several elements overlap in the southeastern and southwestern parts of the area (Fig. II-2-32). The southeastern part is the area of granodiorite porphyry and the surroundings. The southwestern part is the area of strongly argillized andesite. Anomalous zones of As, Au and Pb overlap in the northwestern part of the area where altered andesite occurs. These anomalous zones were also delineated in the results of factor analysis.

The significant mineralized zone has not confirmed in this area. Judging from the geochemical survey results, the potential areas may be limited in the altered zones and nearby gronodiorite porphyry stock.

(8) Area H

Area H is situated along Sungai Sipit in the eastern part of Semporna area. A soil geochemical survey was conducted in this area in order to clarify the potentiality of epithermal gold deposits. Geologic map and sample location map are given in Fig. II-2-34 and II-2-35, respectively.

Geology in this area consists of Kalumpang formation of Oligocene to middle Miocene in age and andesite of Pliocene in age. Chert-Spilite formation occurs in a limited area of northeastern part of the area. Anomalous zones of several elements overlap in the area of Chert-Spilite formation and southern margin of the area where andesite crops out. Other than these two area, anomalous zones are scattered. Therefore, these two areas may have some potentiality in this area. But the potentiality seems to be low, because no significant mineralized zones were confirmed on the surface.

4-3 Heliborne geophysical survey

Data analysis and interpretation for Northern Kinabalu area are carried the in this phase. The data acquisition and processing for this area have been completed in previous phase(Phase II). A total field magnetic map and a magnetic anomaly map are shown in Fig. II-3-3 and Fig. II-3-4. A radiometric total count map, Radiometric ternery map and radiometric anomaly map are shown in Fig. II-3-5, Fig II-3-6 and Fig. II-3-7, respectively.

N-S trending magnetic discontinuity lineaments are dominated and high-count anomalies are aligned in the N-S direction. This direction of N-S is the same as the strikes of the faults inferred by the satellite image analysis, so that these lineaments seems to reflect main geologic structure.

And there are distributed magnetic discontinuity lineaments in the directions of NW-SE, NE-SW and ENE-WSW in the whole area.

High count radiometric zones distributed in the whole area are contributed by potassium mainly.

In the northern part, magnetic anomalies of large amplitude and short wavelength aligning in E-W and ENE-WSW directions are due to highly magnetized Chert-Spilite formation near surface, which are bounded at north and south edges by magnetic discontinuity lineaments trending in E-W and ENE-WSW directions and divided by N-S trending magnetic discontinuity lineaments.

In the central part, low magnetic anomalies of long wavelength and relatively large amplitude at the western side are due to the highly magnetized ultra-basic rock in the depth.

At the south western part, a number of large-amplitude magnetic anomalies of relatively short wavelength aligned in NW-SE direction are caused by the highly magnetized rocks such as ultra-basic rocks, adamelite, granodiorite and Chert-Spilite formation near surface. These highly magnetic rocks are bounded at north and south edges by NW-SE trending magnetic discontinuity lineaments and divided by N-S trending magnetic discontinuity lineaments. Very high radiometric anomalous zone showing large contribution of uranium (U) and thorium (Th) is located on low magnetic anomalies caused by Chert-Spilite formation.

Chapter 5 Conclusions and recommendations

5-1 Conclusions

A regional geochemical survey was carried out for Kinabalu and Labuk areas. The survey method adopted in this survey is the same as the survey in Segama and Semporna areas of Phase II. A semi-detailed geochemical survey for the selected eight areas was also carried out in this phase. These eight areas are situated in Segama and Semporna areas and are selected areas as potential areas of mineral resources in the regional survey of Phase II.

The results of regional geochemical survey for Kinabalu and Labuk areas clearly delineated the known mineral showings in these areas. Consequently, the survey methods applied are useful method in this project area.

The results of the stream sediment geochemical survey delineated following promising areas of mineral resources in Kinabalu and Labuk areas.

Kinabalu area: ①lower stream of Sungai Sugut, ② middle stream of Sungai Sugut, ③ east of Ranau and ④ the most upper stream of Sungai Karamuak.

Labuk area : ⑤ tributary of Sungai Imbak, ⑥ middle stream of Sungai Imbak, ⑦ lower stream of Sungai Karamuak, ⑧ middle stream of Sungai Karamuak, ⑨ the area between Sungai Karamuak and Sungai Milian, ⑩ Sungai Mailo area, ⑪ Sungai Sugut area at the north, ⑫ west of Telupid and ⑬ Bidu Bidu Hill deposit area.

Results of the regional geochemical survey for Kinabalu area delineated the Mamut ore deposits as a significant geochemical anomalous zone. The nature of the anomalies in the areas of ① and ② are similar to the nature of the Mamut ore deposits. These two areas may have potentiality of porphyry copper deposits which is the type of the Mamut ore deposits. One lateritic soil sample collected at the east of Ranau(③) show comparatively high value (1.08 %) of Ni. This area has potentiality of residual nickel ore deposit. One stream sediment sample collected in the most upper stream of Sungai Karamuak(④) show significant high value (51.07 %) of Ti. This area may have potentiality of titanium deposits.

Among the promising areas delineated in Labuk area, anomalous zones of Au and Hg are found in three areas of ⑤tributary of Sungai Imbak, ⑥ middle stream of Sungai Imbak and ⑦ lower stream of Sungai Karamuak. Especially, samples with high values (maximum; 6,530 ppb) of Au are concentrated in the tributary of Sungai Imbak. This area have higher potentiality of gold deposit. The middle stream of Sungai Karamuak(⑧) is the potential area of chromium and copper ore deosits. The target in the area between Sungai Karamuak and Sungai Milian (⑨) is copper ore deposits. The area along Sungai Mailo(⑩) in the south of Telupid has potentiality of chromium ore deposits because extremely high value (maximum 117,538 ppm) samples were confirmed in this area. The area along Sungai Sugut(⑪) in a northern part has potentiality of copper ore deposits. This potential area extend to Kinabalu area. As the results of soil geochemical survey, lateritic soil samples in the west of Telupid (⑫) indicates high values of Ni (maximum 1.06 %) and Co (maximum 0.22 %). This area has potentiality of residual nickel ore deposits. Anomalous zones are also confirmed in the Bidu Bidu Hill deposit area(⑬) where significant Cyprus type copper deposit is known.

The semi-detailed geochemical survey for eight areas were conducted in Segama and Semporna areas. This survey results delineated significant anomalous zone and confirmed mineralized zones in Area B. This mineralized zone extends 5 km x 2 km and the ore samples collected in this area show 2.12 % Cu and 3.04 % Zn. Other than Area B, weakly mineralized and altered zones were also confirmed. Especially, strongly argillized zones with geochemical anomalies are confirmed in the areas of Area E, Area F and Area G.

The data analyses and interpretation of heliborne geophysical survey for Northern Kinabalu area are conclusively summarized as following;

In the northern part, highly magnetized bodies are expected near surface. These bodies correspond to ultra-basic rocks and Chert-Spilite formation on the surface. In the central part, the highly magnetized ultra-basic rocks are expected in the depth. At the south western part, highly magnetized bodies near surface are divided by NW-SE and N-S trending magnetic discontinuity lineaments.

High count radiometric zones distributed in the entire area are mainly contributed by potassium. In the south western and south eastern parts, very high radiometric anomalous zones showing large contribution of uranium (U) and thorium (Th) are located on low magnetic anomalies caused by Chert-Spilite formation.

5-2 Recommendations

The following survey method are recommendable for the survey in Phase IV on the bases of the survey results of Phase III;

1) The promising areas delineated in this survey cover comparatively wide area and therefore, further exploration work should be carried out in order to delineate exact target zones. Locations of these promising areas are shown in Fig. I-3. The following survey method should be applied for these areas.

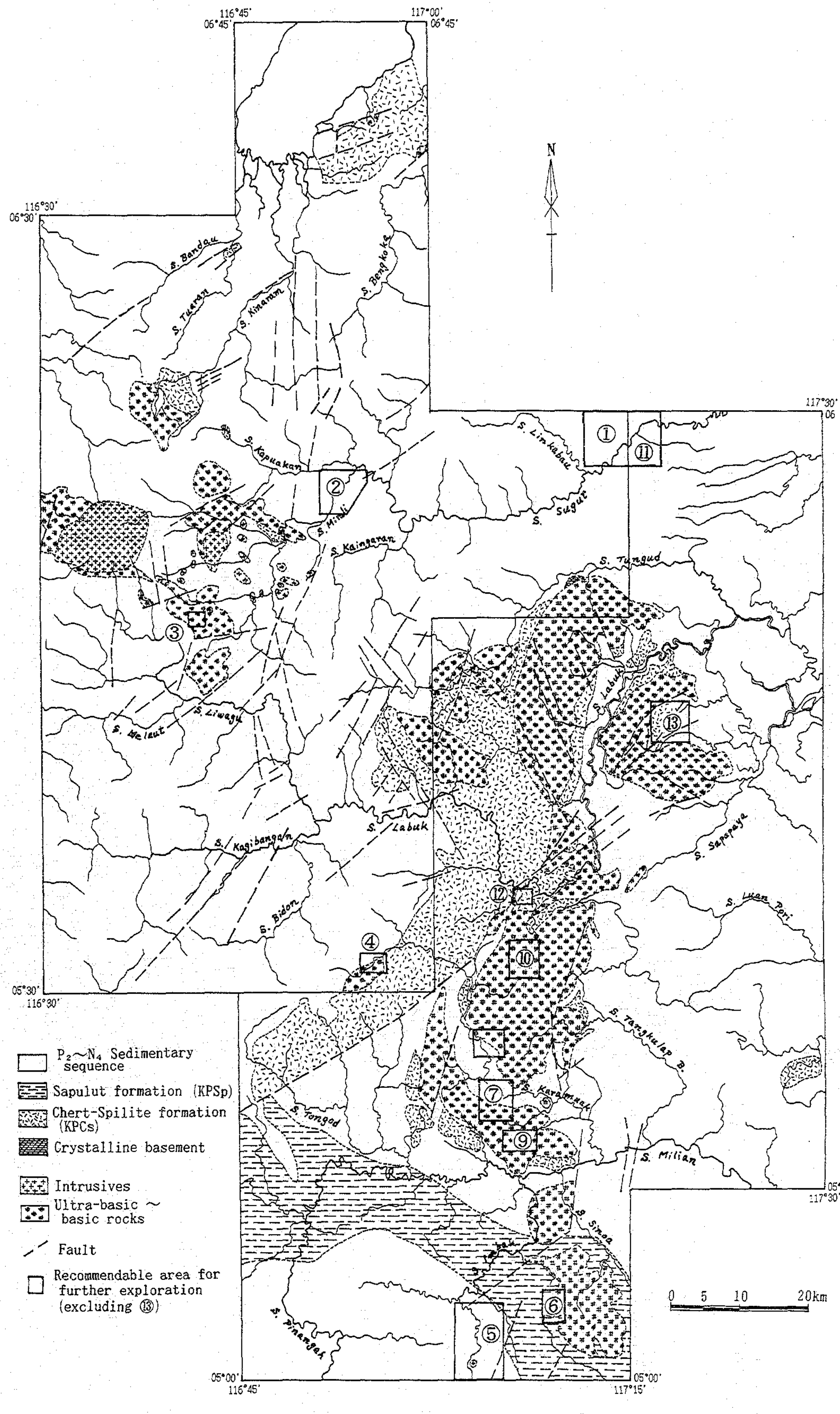


Fig. I-3 Recommendation map of surveys

Kinabalu area

① Lower stream of Sungai Sugut	: soil geochemical survey
② Middle stream of Sungai Sugut	: soil geochemical survey
③ East of Ranau	: soil geochemical survey
④ Upper most stream of Sungai Karamuak	: stream sediment geochemical survey

Labuk area

⑤ Tributary of Sungai Imbak	: soil geochemical survey
⑥ Middle stream of Sungai Imbak	: soil geochemical survey
⑦ Lower stream of Sungai Karamuak	: soil geochemical survey
⑧ Middle stream of Sungai Karamuak	: soil geochemical survey
⑨ Area between S. Karamuak and S. Milian	: stream sediment geochemical survey
⑩ Sungai Mailo area	: stream sediment geochemical survey
⑪ Sungai Sugut area	: soil geochemical survey
⑫ West of Telupid	: soil geochemical survey

A preliminary geologic survey also should be carried out for these selected areas. The areas where exploration work have been completed are not included in this recommendation. In the survey for areas ③ and ⑫, situation in the depth should be clarified.

2) The significant mineralized zone in Area B delineated in the semi-detailed survey, should be investigated geologically in order to clarify the nature of mineralization in detail.

Part Ⅱ Survey results

Chapter 1 Regional geochemical survey

1-1 Survey methods and work amounts

1-1-1 Methodology

Continuing from the regional geochemical survey for Segama and Semporna areas in Phase II, a regional geochemical survey was carried out for Kinabalu and Labuk areas in order to clarify the mineral potentiality in these areas. The sample medias used in the regional survey are stream sediments and pan concentrates. In addition, a rock geochemical survey using representative rock samples in these area was conducted to examine the geochemical nature of the background geology. Soil samples were also collected to examine the mineral potentiality of lateritic soil in the areas of ultra-basic rocks. A reconnaissance geologic survey and sampling work for laboratorial studies were simultaneously carried out along the geochemical sampling routes.

The stream sediment samples were collected from the entire areas. At each sampling site the sample was collected from the edge of stream flow which is the optimum samplimg point delineated in the survey results of Phase I. The sample is minus 60 mesh fraction sample. Sample density applied is 2 km^2/sample except flat area and the density in the flat area is 4 km^2/sample. The sampling work could not be conducted in the mountainous areas of a central part of Kinabalu area. The sampling work also could not be conducted in a northern part of Kinabalu area and a northeastern part of the Labuk area where is widely occupied with swamp.

At the each sampling site, the scale of stream, color and grain size of sediment etc. were described and sample list was prepared. More than 150 grams of -60 mesh fraction sample were collected at each sampling site. After drying up the sample, the sample was divided into two samples. One is for chemical analyses and other is for storage in the Geological Survey of Malaysia, Sabah office. The samples for the chemical analyses were sent to the laboratories in Japan and Canada.

Sampling work for pan concentrates was also carried out along the streams where sampling of stream sediments were conducted. The sample is collected by panning of five pan (approximately 25 liters). The sample density of the pan concentrate sample is planned to be 40 km^2/sample. The sample was dried up and weighed. If the weight of the sample is more than 10 grams, 10 grams was studied and remaining sample was stored in the office of Geological Survey of Malaysia. Qualitative Mineral Examination (QME) was conducted for these samples in Japan.

During the survey, representative rock samples were collected and chemically analyzed. The elements analysed are 21 elements same as the stream sediment samples. About 150 grams of each sample was used for the chemical analyses and remaining sample was stored in Geological Survey of Malaysia.

Soil samples were collected in the area of ultra-basic rocks. Each sample was collected at the top of B horizon. The sampling density is 3 km^2/sample. The sample collected are dried up then sieved and -80 mesh fraction sample was collected for the chemical analyses.

The fieldwork was conducted by eleven Malaysian and seven Japanese geologists. The work was conducted by camp and flying camp along the streams.

1-1-2 Coverage of work

The work amount completed for each area is the following:

	Kinabalu area	Labuk area	Total
Geochemical survey			
Stream sediments	3,342 samples	2,974 samples	6,316 samples
Pan concentrates	193 samples	169 samples	362 samples
Rock	52 samples	70 samples	122 samples
Soil	48 samples	225 samples	273 samples
Laboratorial studies			
Thin section	5 samples	1 samples	6 samples
Polished section	1 samples	2 samples	3 samples
Ore assaying	6 samples	5 samples	11 samples

(Including the samples collected during Phase II)

Elements chemically analyzed (21 elements) for stream sediment and rock samples and their detection limit are the following:

Element	Detection limit	Element	Detection limit	Element	Detection limit
As	1 ppm	K	0.01 %	S	0.001 %
Au	2 ppb	Mg	0.01 %	Sb	0.2 ppm
Ba	10 ppm	Mn	5 ppm	Sr	1 ppm
Co	1 ppm	Mo	1 ppm	Ti	0.01 %
Cr	2 ppm	Na	0.01 %	U	0.2 ppm
Cu	1 ppm	Ni	1 ppm	W	2 ppm
Hg	10 ppb	Pb	2 ppm	Zn	1 ppm

The elements (6 elements) and their detection limit for the soil samples are as follows:

Element	Detection limit	Element	Detection limit	Element	Detection limit
Al	0.01 %	Cr	2 ppm	Ni	1 ppm
Co	1 ppm	Fe	0.01 %	Pt	5 ppb

The elements assayed for the ore samples and their detection limits are as the following:

Element	Detection limit	Element	Detection limit	Element	Detection limit
Au	0.1 g/t	Pb	1 ppm	S	0.01 %
Ag	0.1 g/t	Zn	1 ppm		
Cu	1 ppm	Mo	1 ppm		

The elements applied in this survey was selected based on the results of the orientation geochemical survey in Phase I.

1-1-3 Data processing and analyses

The analytical results of the stream sediment samples were input in computer. Statistical data treatment, single element and multi element analyses were made using these input data.

In order to carry out the single element analyses, histograms and cumulative frequency graphs were prepared and statistics for each element were calculated. A half value of the detection limit was used for the sample indicating less than the detection limit of the element in this calculation. The mean values calculated are geometric means. Based on this calculated results, distribution map of each element was drawn by computer. The contents of each element were divided into following four ranks:

Less than background (B) value.
More than background value, less than B + standard deviation(SD).
More than B + Standard deviation, less than B + 2SD.
More than B + 2SD.

The drainage system of the survey areas were input in the computer using digitizer and distribution maps of each element were prepared. The coorelation matrix among the elements were also calculated. Exploratory Data Analysis (EDA) method was applied to delineate the threshold value (anomalous value) for each elment.

As the multi element analyses, cluster and factor analyses were utilized in this survey. The cluster analysis is a grouping method of the elements using coorelations among the elements. The factor analysis is the method to delineate the factor which forms the relationship among the samples.

For the pan concentrate samples, magnetite and ilmenite were separated using magnet and the remaining samples were observed under a microscope to detect the minerals and their volume percentage. Then weight percentage was calculated using the specific gravity for each mineral.

The number of sample for rock and soil samples is not enough to treat statistically. Therefore, studies were made for the results of the chemical analyses. The data analyses and interpretation were made using newly prepared geologic maps for the survey area.

1-2 Survey results of Kinabalu area

1-2-1 Geology and mineralization

The Kinabalu area is underlain by pre-Triassic crystalline rocks, Cretaceous to Tertiary ultra-basic to basic rocks and Tertiary to Quaternary sedimentary rocks according to Y.E. Heng; 1985. A geologic map is shown in Fig.II-1-1 compiled using the previous geologic data and the data obtained from the present survey.

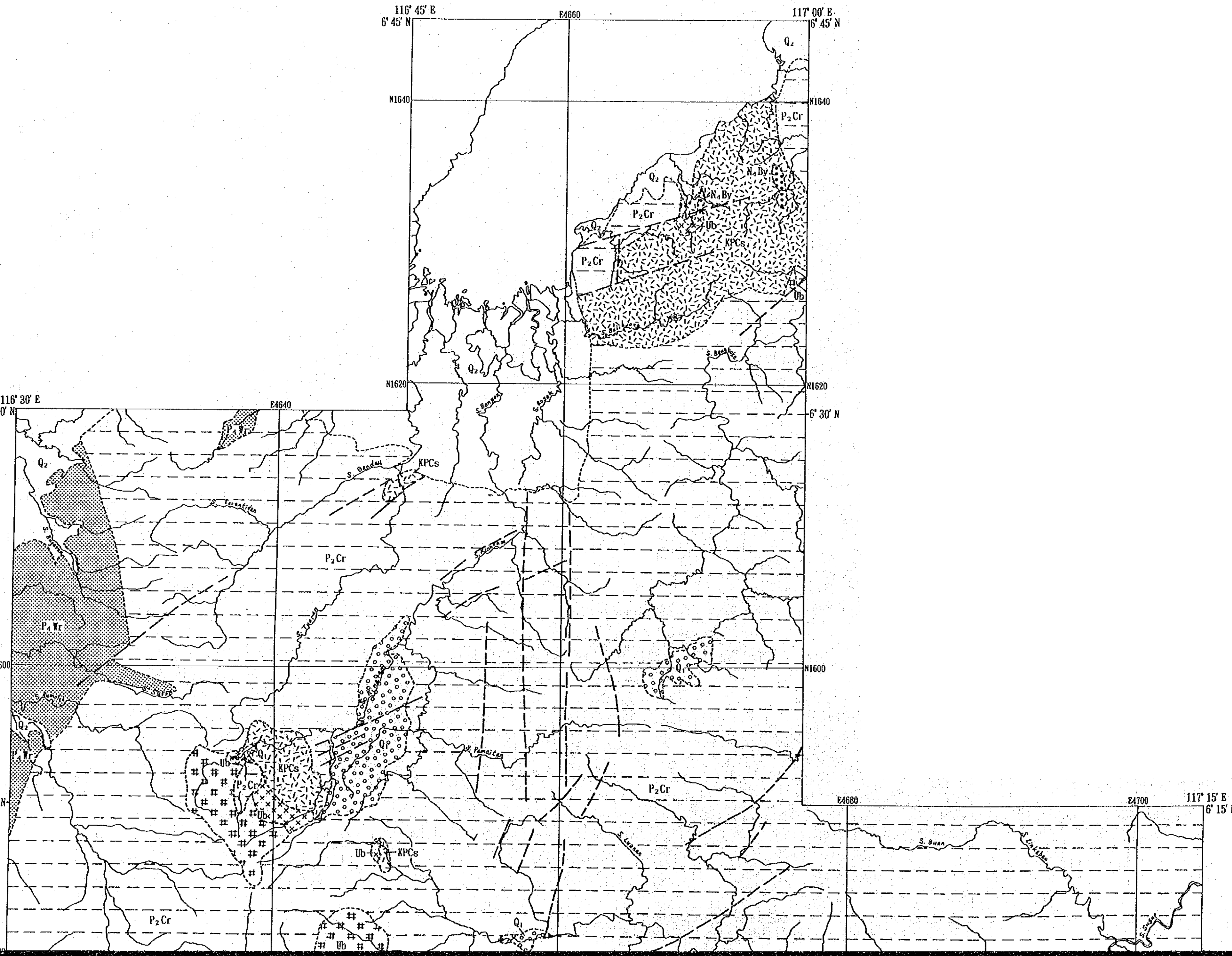
The crystalline rocks (Cb) are found as the basement rocks in the eastern part along Sungai Tungud. These rocks are composed mainly of amphibolite and schist. Cretaceous to Tertiary ultra-basic to basic rocks (Ub) are found in the surrounding zones of the crystalline rocks, surroundings of Ranau in the central part, nothern end and south eastern parts of the area. The ultra-basic rocks are composed mainly of serpentinite and serpentinized peridotite. The basic rocks are composed of dolerite and gabbro. Chert-Spilite formation (KPCs) is found in the surrounding zones of the ultra-basic to basic rocks and is composed of sedimentary rocks accompanied by basaltic lavas. The Chert-Spilite formation consists of sandstone, chert, basaltic pillow lavas and basaltic pyroclastic rocks deposited during Cretaceous to Eocene in age.

In the southern part of the area, Trusmadi formation (P_1Ts) widely covers the area. This formation consists of phyllite and shale with subordinate siltstone and sandstone. The river systems in this formation form extremely steep topography. Crocker formation (P_2Cr) of Eocene to Oligocene in age occupy most the parts of Kinabalu area. This formation mainly consists of sandstone, and shale and siltstone beds are intercalated. In the eastern marginal part of the area, Kudat formation (P_3Kd) is distributed in a limited area. This formation consists of sandstone, siltstone, shale, mudstone and conglomerate. Wariu formation (P_4Wr), Oligocene to middle Miocene in age, is distributed in the limited area of northwestern part of the area. This formation is composed of sandstone, mudstone and minor tuff.

Small intrusive bodies including adamellite, granodiorite, andesite porphyry and dacite porphyry are distributed in the central part of the area.

Pleistocene terrace deposits (Q_1) are found along the rivers and alluvium sediments (Q_2) are found along the coast and rivers.

Distribution of the ultra-basic to basic rocks and the Chert-Spilite formation show close relationship among them. These ultra-basic, basic rocks and the Chert-Spilite formation are regarded as a part of ophiolite. The ultra-basic rocks and basic rocks are sporadicaly distributed and form complecated geologic structure.


116° 45′ E
6° 45′ N
E4660
117° 00′ E
6° 45′ N
N1640
N1620
N1600
116° 30′ E
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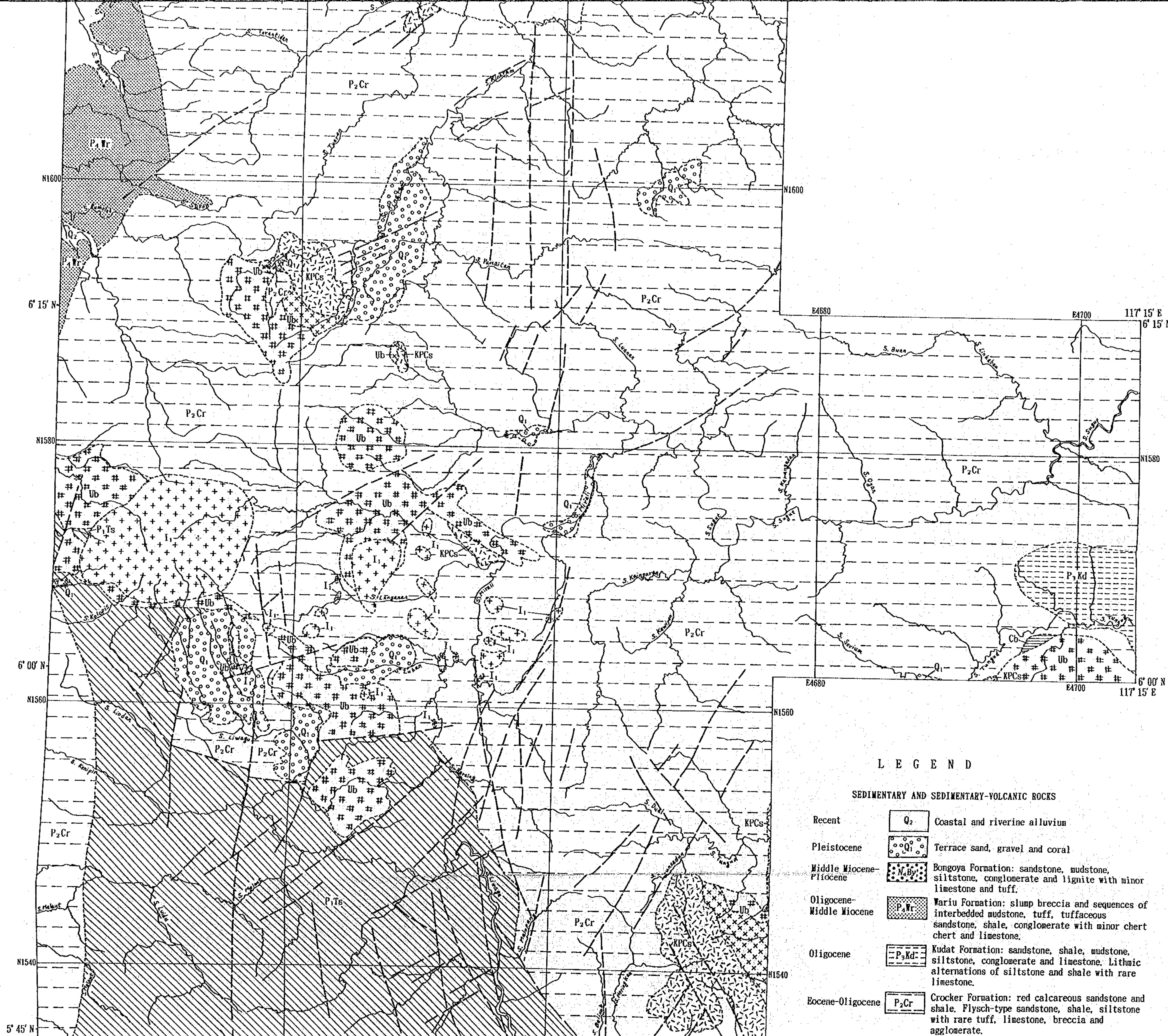
E4640
6° 30′ N
6° 15′ N
E4680
E4700
117° 15′ E
6° 15′ N
Q_2
P_2Cr
N_4By
Ub
KPCs
P_4Wr
Q_1
S. Bendau
S. Luanan
S. Buan
S. Penaitan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N1580
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N1560
N1540
5° 45′ N
E4680
E4700
117° 15′ E
6° 15′ N
N1580
6° 00′ N
N1560
N1540
P₂Cr
P₄Wr
KPCs
Ub
P₁Ts
I₁
Q₁
Q₂
P₃Kd
Cb
LEGEND
SEDIMENTARY AND SEDIMENTARY-VOLCANIC ROCKS
Recent
Q₂
Coastal and riverine alluvium
Pleistocene
Q₁
Terrace sand, gravel and coral
Middle Miocene-Pliocene
N₄By
Bongoya Formation: sandstone, mudstone, siltstone, conglomerate and lignite with minor limestone and tuff.
Oligocene-Middle Miocene
P₄Wr
Wariu Formation: slump breccia and sequences of interbedded mudstone, tuff, tuffaceous sandstone, shale, conglomerate with minor chert chert and limestone.
Oligocene
P₃Kd
Kudat Formation: sandstone, shale, mudstone, siltstone, conglomerate and limestone. Lithmic alternations of siltstone and shale with rare limestone.
Eocene-Oligocene
P₂Cr
Crocker Formation: red calcareous sandstone and shale. Flysch-type sandstone, shale, siltstone with rare tuff, limestone, breccia and agglomerate.

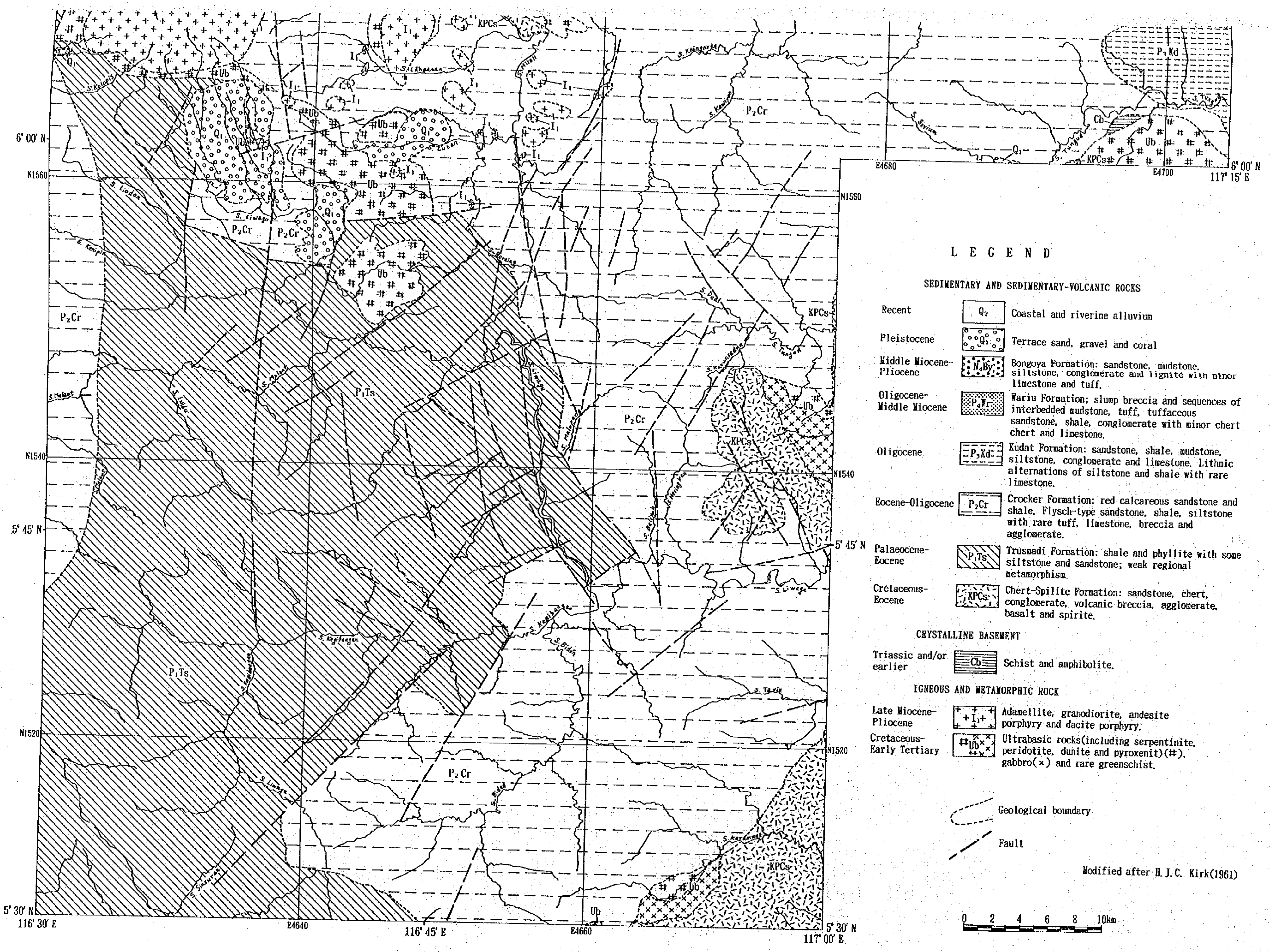

Fig. II-1-1 Geologic map of Kinabalu area

The most significant fault system is N-S system. Other systems including ENE-WSW, NE-SW and NNW-SSE systems are also recognized (Y.E. Heng; 1985).

The most significant mineralization in the survey area is Mamut ore deposits situated north of Ranau. This ore deposit is porhyry copper type ore deposits hosted by adamellite of Pliocene to late Miocene in age. Other known mineral showings are found in Chert-Spilite formation and intrusive rocks. But these showings are small in scale.

1-2-2 Sampling

Samples of stream sediments and pan concentrates were collected along the rivers. Samples of rock and soil were collected along the river and road. Sampling was carried out from the base camp established in Ranau. But the sampling in the remort areas was mostly carried out by tentative base camp or flying camp.

Descriptions of stream sediment at the sampling sites such as geology, scale of the stream, color and size of sediments, etc. were conducted and were listed as shown in Appendix 1. The location of samples are shown in Fig. II-1-2 and Plate II-1-1.

The sampling site of pan concentrates was described about geology, river scale etc., and the samples were weighed. List of these samples are shown in Appendix 4. The locations of samples are shown in Fig. II-1-3.

Rock samples collected are typical rocks in the survey area. The samples were described about the coordinates and geologic unit at the sampling point. The locations of the samples are shown in Fig. II-1-3. Float samples were collected instead of the rock of outcrops in the strongly weathered zone.

The soil sampling was carried out in the zone of ultra-basic to basic rocks (Ub). The samples were described about the coordinates, geology and topography at the each sampling site and color of soil. The location of samples are shown in Fig. II-1-3.

In addition to the above mentioned geochemical sampling, geological survey was carried out and the laboratorial samples were also collected. The laboratorial studies include thin section observation, polished section observation and ore assaying. The locations of the laboratorial samples are shown in Fig. II-1-3.

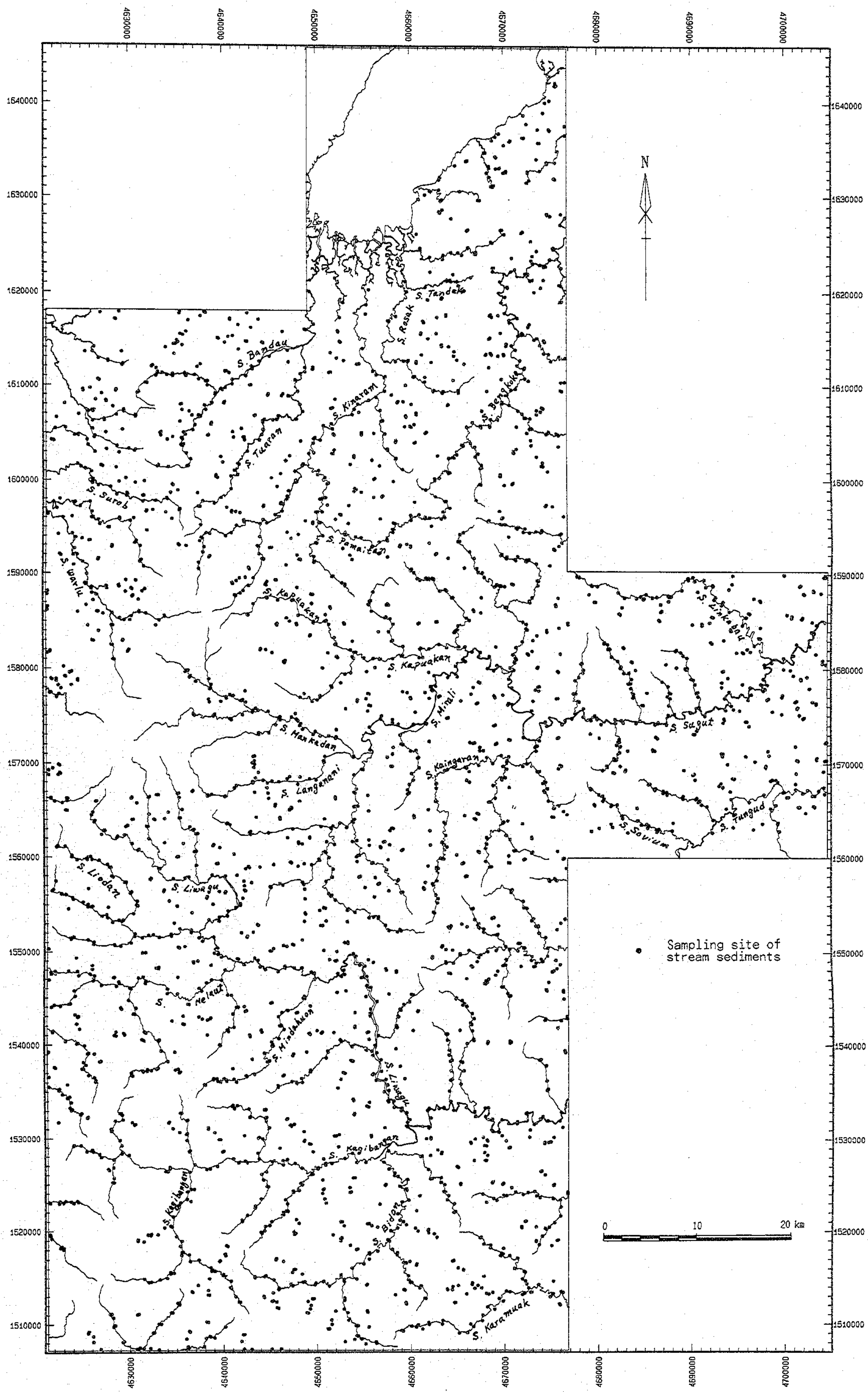

Fig. II-1-2 Location map of stream sediment samples in Kinabalu area

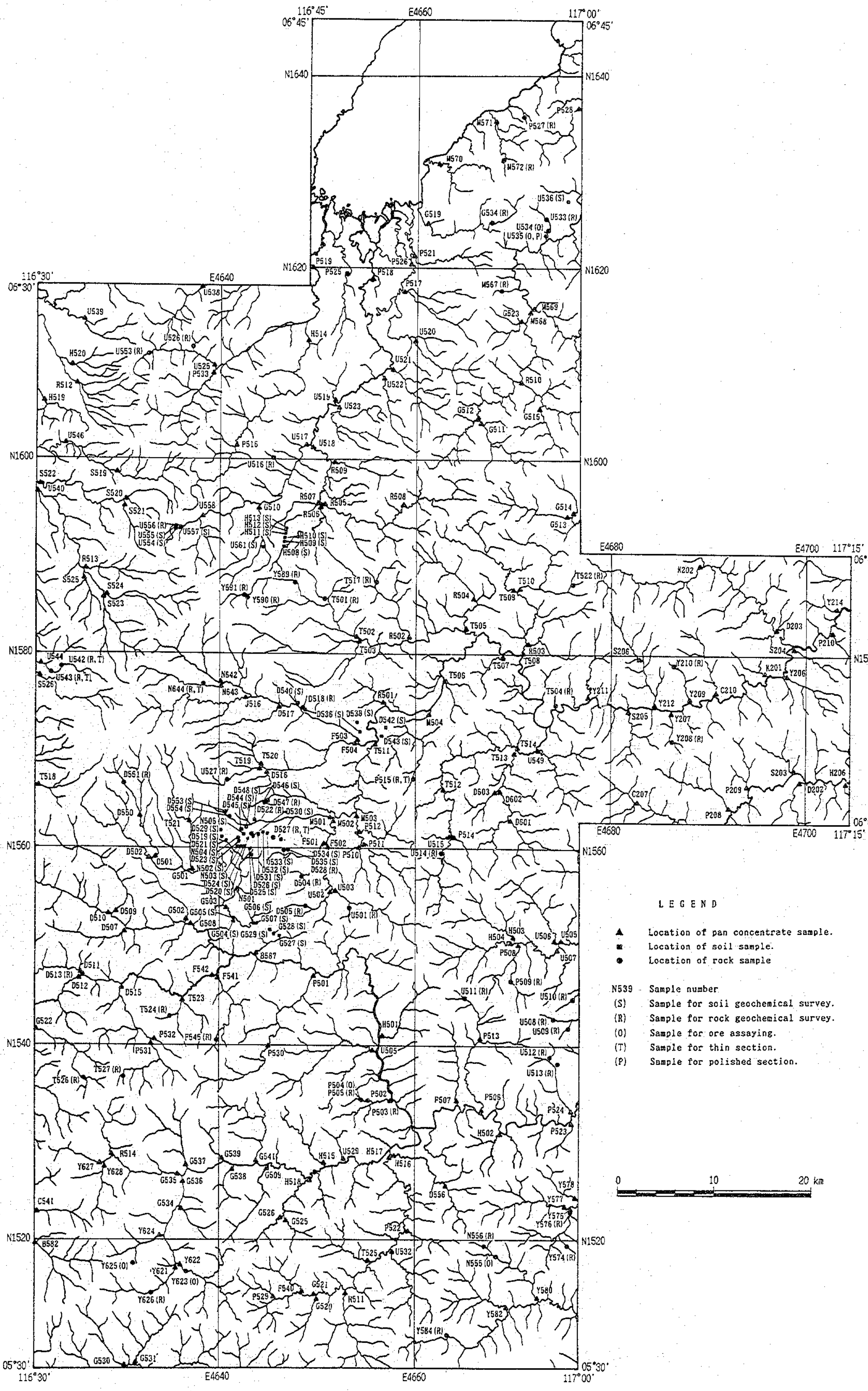

Fig. II-1-3 Location map of samples for geochemical and laboratorial studies in Kinabalu area