No. 23

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

(CONSOLIDATED REPORT)

MARCH 1994

JAPAN INTERNATIONAL COOPERATION AGENCY

METAL MINING AGENCY OF JAPAN

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

(CONSOLIDATED REPORT)

MARCH 1994

JAPAN INTERNATIONAL COOPERATION AGENCY
METAL MINING AGENCY OF JAPAN

PREFACE

In response to the request of the Government of Malaysia, the Japanese Government agreed to conduct a Supra-Regional Survey Project in the Sabah area and entrusted thesurvey to the Japan International Cooperation Agency(JICA) and the Metal Mining Agencyof Japan (MMAJ).

The JICA and MMAJ sent a survey team to Malaysia during the period from 1990 to 1993.

The team exchanged views with the officials concerned of the Government of Malaysia and conducted a field survey in the central part of Sabah. After the team returned to Japan, further studies were made and report were prepared. This report includes all the survey results of this project.

We hope that this report will serve as a useful guide for the development of mineral resources in Sabah and contribute to promote the 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, 1994

Kensuke Yanagiya

Kensuke Yanagiya
President
Japan International Cooperation Agency

Takashi Ishikawa

Takashi Ishikawa
President
Metal Mining Agency of Japan

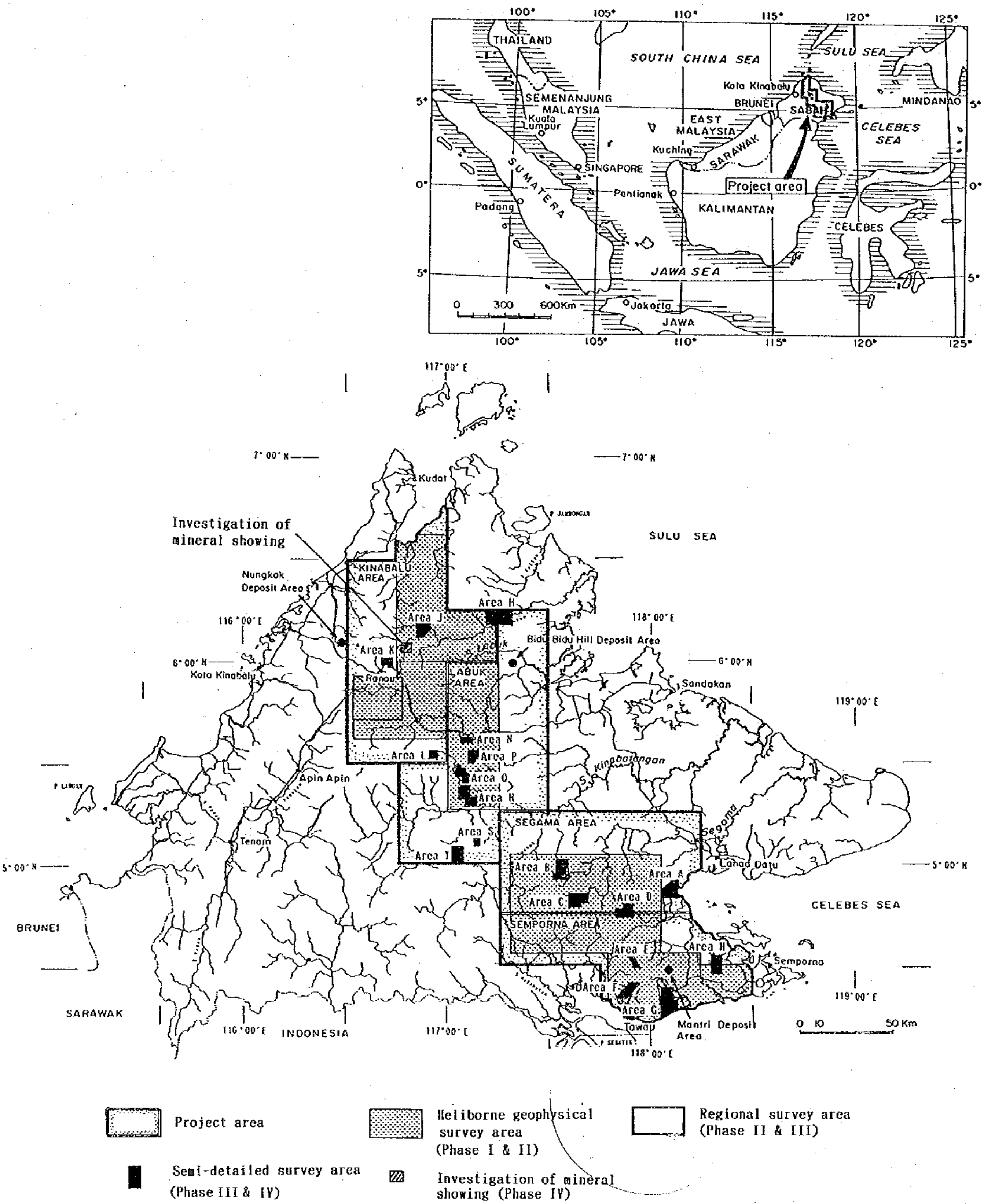

Fig. 1 Location map of the project area

ABSTRACT

The Government of Malaysia and the Government of Japan agreed on a four-year mineral exploration project, starting from 1990, covering the central part of Sabah. The Scope of Work for this project was signed by both governments on 1st August 1990. Objectives of this project are to identify the mineral potential and to obtain useful data for future development of the mineral resources in the area. This report includes all the survey results from Phase I to Phase IV of the project.

The survey conducted in this project are collection and compilation of existing data, satellite image analyses, geological survey, geochemical survey, heliborne geophysical survey and investigation of known mineral showings. The survey conducted for each phase are as below:

- Phase I : Collection and compilation of existing data, satellite image analyses, orientation geochemical and heliborne geophysical surveys.
- Phase II : Regional geochemical survey and investigation of mineral showings in the Segama and Semporna areas, and heliborne geophysical survey.
- Phase III : Semi-detailed geochemical surveys for eight selected areas in the Segama and Semporna areas, and regional geochemical survey and investigation of mineral showings in the Kinabalu and Labuk areas.
- Phase IV : Semi-detailed geochemical survey in ten selected areas in the Kinabalu and Labuk areas, semi-detailed geological survey in one area in the Segama area, investigation of the Tampang area in the Kinabalu area and overall data analyses and interpretation.

Results from the semi-detailed survey in eighteen selected areas have delineated five areas as potential areas for mineral resources. Name of these areas and the targets are as follows;

① Area T (southern margin of the Labuk area) : gold and/or porphyry copper deposits

② Area N (west of Telupid in the Labuk area) : lateritic nickel deposits

③ Area Q (along S. Karamuak in the Labuk area): vein and/or disseminations of copper deposits.

④ Area B (along S. Danum in the Segama area) : vein and/or disseminations of copper deposits.

⑤ Area K (east of Ranau in the Kinabalu area): lateritic nickel deposits

Among these potential areas, Area T is the most significant. Some mineralized samples collected from Area T indicate more than 10 g/t Au (maximum 18.4 g/t Au, 931.4 g/t Ag). As only a semi-detailed survey was carried out and in order to delineate more accurately the mineralized zones, a detailed exploration work should be conducted for these areas.

During this survey numerous basic data were obtained. These data will contribute to assist in carrying out further exploration work more effectively and to identify new potential areas. These data should be treated as follow:

(1) The satellite images should be used for a geological survey and exploration work in order to understand the large scale structure.

(2) The heliborne survey data should be used to understand the hidden geological structure. It is also possible to delineate a large scale altered zone.

(3) Some geochemical anomalous zones which are not covered by the semi-detailed survey should be examined in the future work.

(4) Many anomalous zones were obtained by the semi-detailed geochemical survey, but some anomalous zones show no clear relationship with mineralization, These anomalous zones should however be examined to understand the nature of the anomalies.

All data obtained in this survey were input in magnetic tape, so that anybody could access to any part of the data for re-examination and further investigation. Because these data are the basic data for the exploration work in this area, the data should be used to assist in carrying out further exploration work more effectively.

CONTENTS

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 completed in the central part of Sabah, Malaysia. The area selected for this project (Fig. 1) has a high mineral potential in Sabah, due to the many known mineral occurrences in this area. This project was carried out over a period of four years starting from 1990. This report is the final report that includes the overall results of this project.

Purpose of this survey is to apprise the mineral potential in the area for the future development of mineral resources. In order to execute this purpose, collection and compilation of existing data, satellite image analyses, heliborne geophysical, regional geochemical surveys and investigation of mineral showings were conducted in most part of the area. Based on these survey results, a semi-detailed survey was conducted over the selected areas where high mineral potential was expected.

Work flowchart of this project is shown in Fig. I-1.

1-2 Outline of survey and work amounts

The project area is situated stretching from north western part to south eastern part of the State of Sabah covering an area of 26,500 km². The area is subdivided into four areas namely; Kinabalu, Labuk, Segama and Semporna areas from the northwest to the southeast, respectively. The areas are shown in Fig. 1.

The work conducted in this project for each phase are as below:

Phase Ⅰ :
① Collection and compilation of existing data.
② Geochemical orientation survey in order to select optimum geochemical survey method for the project.
③ Satellite image analyses in order to investigate the geology and geological structure.
④ Heliborne geophysical survey in order to examine the geological structure.

Phase Ⅱ :
① Regional geochemical survey in the Segama and Semporna areas.
② Additional heliborne geophysical survey and interpretation.
③ Investihation of mineral showings in the Segama and Semporna areas.

Phase Ⅲ :
① Regional geochemical survey in the Kinabalu and Labuk areas.
② Semi-detailed geochemical survey in eight selected areas in

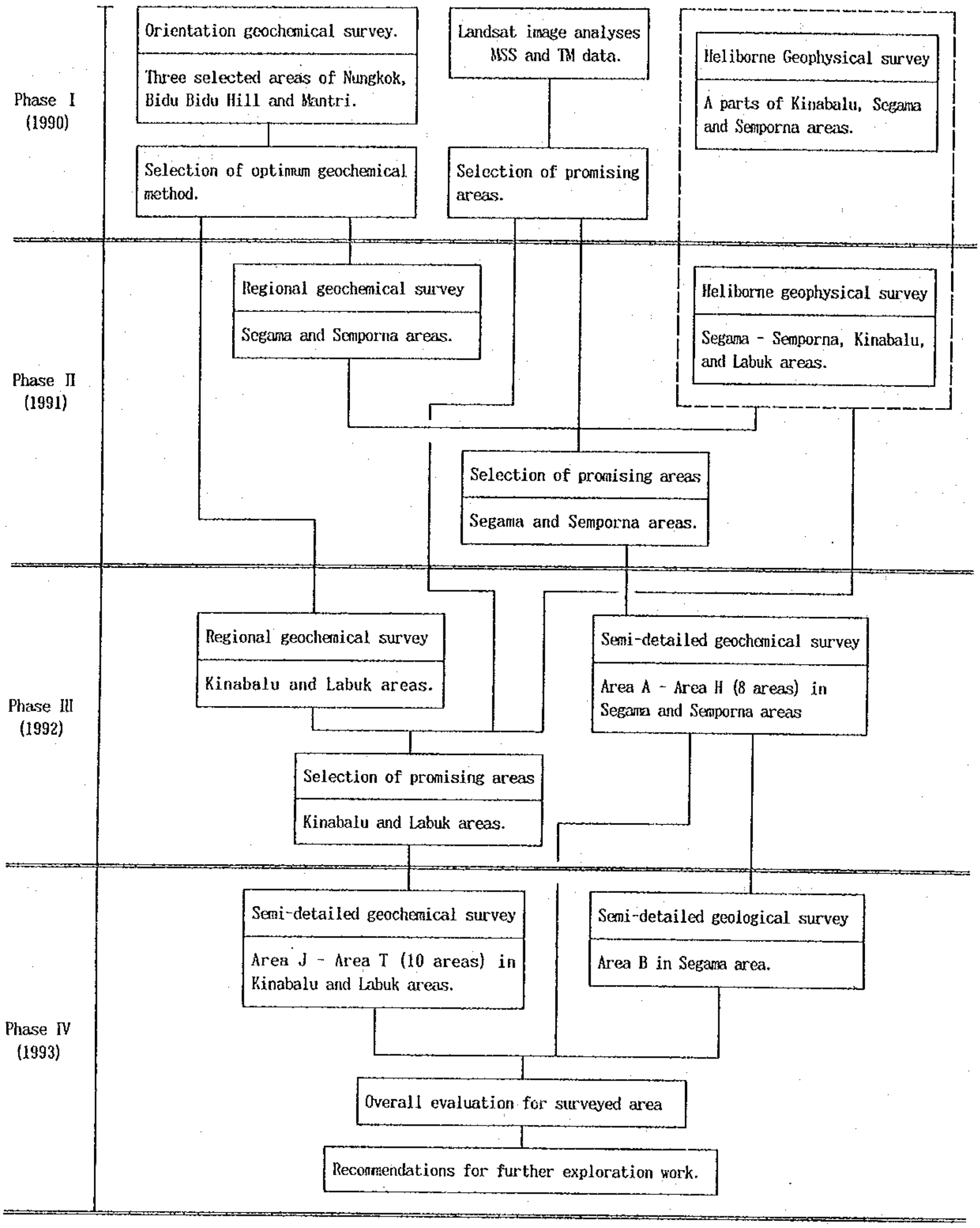

Fig. I-1 Work flowchart of the project

the Segama and Semporna areas.

③ Investigation of mineral showings in the Kinabalu and Labuk areas.

Phase IV : ① Semi-detailed geochemical survey in ten selected areas in the Kinabalu and Labuk areas.

② Semi-detailed geological survey in one area in the Segama area.

③ Overall evaluation and preparation of final report.

The work amounts completed in this project are shown in Table I-1 and laboratorial studies conducted during this survey are shown in Table I-2.

1-3 Survey member

The members of the project are as following;

(1) Project planning and prior negotiation

Japanese counterpart		Malaysian counterpart	
Takashi ISOBE	MITI	Yin Ee Heng	Geological Survey of Malaysia
Yukitosi KAWASAKI	MITI	Fateh Chand	Geological Survey of Malaysia
Ritsuo KITA	MFA	Wong Yew Choong	Geological Survey of Malaysia
Hajime IKEDA	JICA	Shu Yeoh Khoon	Geological Survey of Malaysia
Nobuyuki OKAMOTO	JICA	Wan Mazlan	Ministry of Primary Industry
Kyouichi KOYAMA	MMAJ	Mohd Irwar Serigar	Economic Planning Unit
Toshio SAKASEGAWA	MMAJ	David Lee Tain Choi	Geological Survey of Malaysia
Takafumi TSUJIMOTO	MMAJ	Lim Peng Siong	Geological Survey of Malaysia
Nobuyuki MASUDA	MMAJ	Alexander Yan	Geological Survey of Malaysia
Yuuji KAJITANI	MMAJ		
Toru NAWATA	MMAJ		
Hiroshi SHIMOTORI	MMAJ		
Kenzo MASUTA	MMAJ		
Haruhisa MOROZUMI	MMAJ		
Yoshiaki IGARASHI	MMAJ		

MITI; Ministry of International Trade and Industry
MFA ; Ministry of Foreign Affairs

(2) Field survey

Japanese counterpart			Malaysian counterpart		
Takehiko NAGAMATSU	Team leader*1	BEC	Lim Peng Siong	Principal Geologist	GSM
Shuro MATSUHASHI	Team leader*2	OMRD	Alexander Yan	Senior Geologist	
Masahiko NONO	Team leader*3	BEC	Joanes Muda	Geologist	GSM
Tadahiko Monma	Geochemical	BEC	Paulus Godwin	Geologist	GSM
Tsuyoshi SUZUKI	Geochemical	BEC	Allagu Balaguru	Geologist	GSM
Yoshinori TSUGUMA	Geochemical	BEC	Cleafos Totu	Geologist	GSM
Masatsugu OKAZAKI	Geochemical	BEC	Salleh Adanan	Geologic Assist.	GSM

Japanese counterpart			Malaysian counterpart		
Motomu GOTO	Geochemical	BEC	Japili Samin	Geologic Assist.	GSM
Masayuki SAITO	Geochemical	BEC	Rojer Totu	Geologic Assist.	GSM
Manabu ISHII	Geochemical	BEC	Kamil Kararuddin	Geologic Assist.	GSM
Junnichi Yamagata	Geochemical	BEC	Jolouis Supilin	Geologic Assist.	GSM
Hirosi HYODO	Geochemical	BEC			
Kazutoshi SUGIYAMA	Geochemical	BEC			
Makoto	Geochemical	BEC			
Susumu SASAKI	Geophysical	BEC			
Masatane KATO	Geophysical	BEC			

BEC; Bishimetal Exploration Co., Ltd. GSM; Geological Survey of Malaysia
OMRD; Overseas Mineral Resources Development Co., Ltd.
*1; Phase I, II and III. *2; Investigation of mineral showings *3; Phase IV.

1-4 Survey period

The period of the field survey for each phase is as follow;

Phase I : 18th October 1990 - 13th January 1991.

Phase II : 16th July 1991 - 20th January 1992.

Phase III : 7th July 1992 - 23th December 1992.

Phase IV : 21th June 1993 - 7th September 1993.

Table I-1 Summary of work amounts

(1) Landsat image analyses (Phase I)

Data	Prepared image	scene	scale	Coverage
MSS data	False color image	4 scenes	1:200,000	26,500 km²
TM data	False color &	3/4 scene	1:100,000	19,125 km²

(2) Heliborne geophysical survey (Phase I - Phase II)

	Kinabalu area	Labuk area	Segama area	Semporna area	Total
Coverage	5,020 km²	2,300 km²	2,820 km²	3,210 km²	13,350 km²
Line length	9,919.2 km	4,554.0 km	5,094.0 km	8,011.2 km	27,578.4 km

(3) Orientation geochemical survey (Phase I)

Coverage and sample media	Unit	Area			Total
		Nungkok	Bidu Bidu Hill	Mantri	
Coverage	km²	16.2	16.1	16.1	48.4
Stream sediments	sample	240	243	243	726
Soil	sample	246	246	243	735
Pan concentrates	sample	32	32	32	96

(4) Regional geochemical survey (Phase II - Phase III)

Coverage and sample media	Unit	Name of area				Total
		Kinabalu	Labuk	Segama	Semporna	
Coverage	km²	7,500	7,700	5,900	5,400	26,500
Stream sediments	sample	3,342	2,974	2,740	2,580	11,636
Pan concentrates	sample	193	169	175	160	697
Soil	sample	48	225	74	17	364
Rock	sample	52	70	51	50	223
Ore	sample	6	5	5	5	21

(5) Semi-detailed geochemical survey (Segama and Semporna areas in Phase III)

Coverage and sample media	Unit	Area A	Area B*1	Area C	Area D	Area E	Area F	Area G	Area H	Total
Coverage	km²	85	70	72	55	18	54	146	70	570 km²
Stream sediments	sample	—	40	140	—	—	—	—	—	280 sample
Soil	sample	340	44	140	221	72	122	581	282	1,902 sample
Rock	sample	2	12	7	4	1	1	2	1	30 sample
Ore	sample	2	8	5	2	1	2	1	0	21 sample

*1: Semi-detailed geological survey was carried out in the area covering 32 km² in Phase IV.

(6) Semi-detailed geochemical survey (Kinabalu and Labuk areas in Phase IV)

Coverage and sample media	Unit	Area J	Area K	Area L	Area M	Area N	Area P	Area Q	Area R	Area S	Area T	Total
Coverage	km²	38	30	20	119	21	26	42	75	12	70	453
Stream sediments	sample		—	80	—	—	105	85	150	25	—	445
Soil	sample	150	240	—	476	170	—	85	150	25	280	1,576
Ore	sample	0	3	0	0	2	0	2	0	0	13	20

Table I-2 Summary of laboratorial studies

(1) Laboratorial studies

Phase	Survey method	Thin Section	Polished section	X-ray diffract	Polished thin sect.	QME*1	EPMA	Physical Properties
	Unit	sample	sample	sample	sample	sample	sample	sample
Phase I	Photogeologic interpretation	51	25	11	5	—	5	—
	Orientation geochemical survey	30	15	16	8	96	8	—
Phase II	Regional geochemical survey	22	10	10	—	387	—	—
	Heliborne geophysical survey	—	—	—	—	—	—	106
Phase III	Regional geochemical survey	6	3	—	—	310	—	—
	Semi-detailed geochemical survey	26	12	15	—	—	—	—
Phase IV	Semi-detailed geochemical survey	12	10	10	—	—	—	—
	Semi-detailed geological survey	5	13	10	—	—	—	—

*1: Qualitative mineral examination

(2) Chemical analyses

Phase	Survey method	Stream sediments	Soil	Rock	Ore	Whole rock	Pan con -centrates
	Unit	element	element	element	element	element	element
Phase I	Photogeologic interpretation	—	—	—	468	1,377	—
	Orientation geochemical survey	13,794	16,905	—	—	—	3,168
Phase II	Regional geochemical survey	132,888	678	2,561	70	—	—
Phase III	Regional geochemical survey	111,468	1,506	2,121	77	—	—
	Semi-detailed geochemical survey	5,880	39,942	630	147	—	—
Phase IV	Semi-detailed geochemical survey	6,145	26,538	—	140	—	—
	Semi-detailed geological survey	—	—	—	46*1 322	—	—

*1: Number of collected ore samples.

Chapter 2 Geography of survey area

2-1 Location and accessibility

Malaysia, being a principal member of ASEAN, consists of Western Malaysia situated in the Malay Peninsular and East Malaysia situated in northern and south western part of Borneo. The total population of West and East Malaysia in total is 16.5 millions. The area of the whole country is approximately 330,000 km^2.

Eastern Malaysia comprises the State of Sabah and State of Sarawak. The project area is situated in the State of Sabah, stretching from its northwestern part to its southeastern part and covers an area of 26,500 km^2. 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 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 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 branched out from Ranau. In the Labuk area, there are several roads for log transportation. However, it is inaccessible for vehicle in the southern and northern part of the area. In the Segama and Semporna areas, there are some roads used for the plantation estate and for log transportation on the east coast area. In the western part of the Segama area, rivers are the main mode of transportation. In the eastern to southern part of the Semporna area, roads system for the plantation estate are well 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. Highland occupies the eastern area and volcanic mountains are found in the southern part. Flat plain is along rivers and their lower tributary. Mt. Kinabalu which is the highest mountain in the southeast Asia, rise up to 13,455 ft in the western end of the Kinabalu area which is occupied by steep topography. Highland dominates in the Labuk and Segama areas. Swamps are found at the lower part of main rivers where they are extremely meandered. Highland dominates in the Semporna area except the young volcanics region with volcanic topography.

The main drainage systems in 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 into the South China Sea, Sungai Kalumpang and Kinabatangan flows down to the Celebes Sea and other river systems are into the Sulu Sea in the east. These river systems generally form deep valley at the upper stream and extremely meandered down stream. The river also forms swampy 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 dry and little rain season, from August to January is the rainy season. Precipitation in the dry season is 100 - 250 mm in a month and in the rainy 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 Kota Kinabalu at the west coast, Sandakan at the east coast and Tawau at the south coast are shown in Table I-3. As shown in this table, east coast has more rainfall than the west coast.

Vegetation in the survey area mainly consists of primary and secondary jungle except the area under 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 a wide area streching from the northwest to the southeast corner of the State of Sabah. Known mineral showings are mainly found in this region. The gological map of this area is shown in Fig. I -2, which is based on the existing geological map of Sabah (Heng Y.E. 1985) with modification of some parts based on the results of this survey.

This area is underlain by crystalline rocks (Cb), sedimentary rocks accompanied by spilite eruption (K, KP), sedimentary rocks characterized by flysch 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, during the 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 begin in middle Miocene through Pliocene.

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

Crystalline rocks such as schists and gneisses, which form the basement, and sedimentary rocks are mainly distributed in the Segama area. Sedimentary rocks accompanied by spilite occupied a wide area both in the Labuk and Segama areas. Ultra-basic rocks are found distributed in the Kinabalu, Labuk and Segama areas, and closely related with the sedimentary rocks with associated spilite. Plutonic intrusions such as adamellite and granodiorite are typically found in the Kinabalu area. Volcanic rocks such as dacite, andesite and basalt are found mainly in the Semporna area. This volcanic belt extends northeast toward the southern part of the Philippine.

3-2 Mineralization and mining activities

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

The Mamut mine is the only active mine in the project area. The Mamut deposit

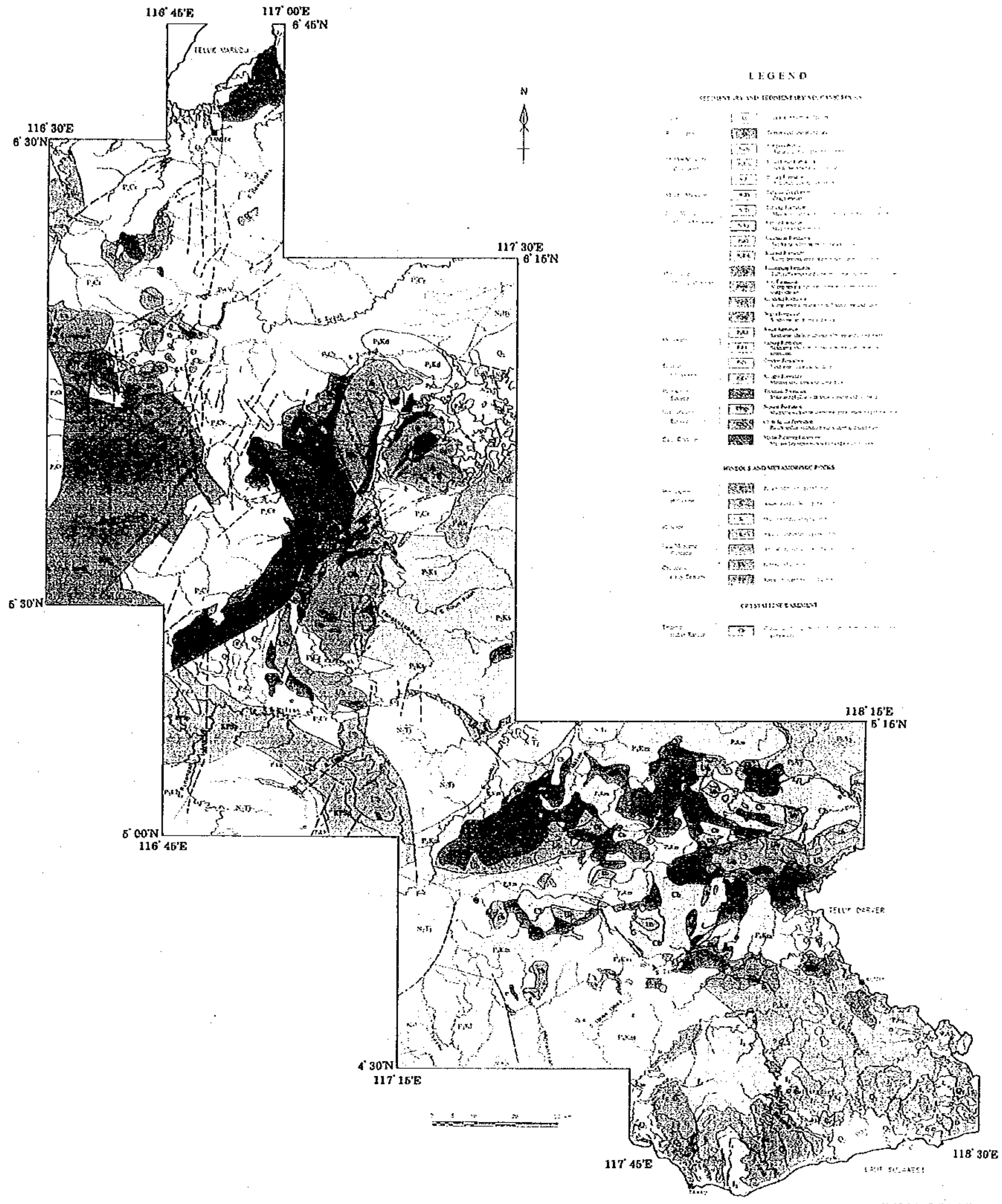

Fig. I-2 Geologic map of the project area

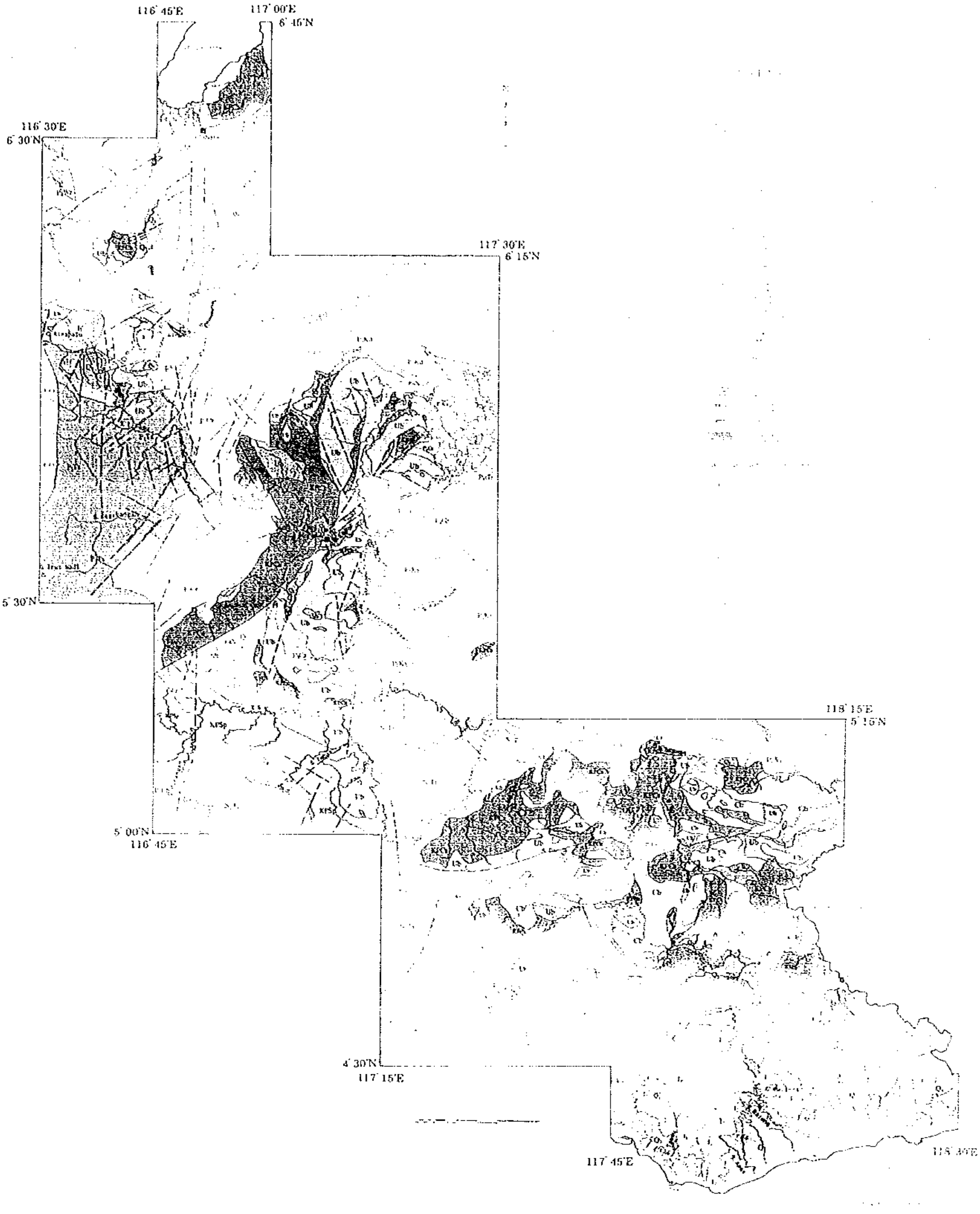

Fig. I-2 Geologic map of the project area

Fig. I-3 Distribution map of mineral occurences in the project area is porphyry copper type, located to the north of Ranau in the Kinabalu area. This ore deposit was discovered by a geochemical survey conducted by the United Nations Development Programe (UNDP). The Overseas Mineral Resources Development Co., Ltd., Japan, obtained the exploration right on the Mamut area through international tender in 1968, and carried out further exploration work from 1968 to 1972, and began development work in 1973. The mine has been operating since May, 1975. The current production of crude ore is 20 thousand tons per day with the grade of 0.47 % Cu. The number of staffs and workersof the Mamut Copper Mining Sdn. Bhd. is about 1,300.

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

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

Chapter 4 Survey results

In order to identify the mineral potential in the project area, collection and compilation of existing data and geochemical orientation survey was conducted in Phase Ⅰ. Based on the orientation survey results, a regional geochemical survey was completed in Phase Ⅱ and Ⅲ. From the results of the regional geochemical survey, 18 promising areas for mineral resources were delineated and a semi-detailed survey was subsequently carried out over these 18 areas in Phase Ⅲ and Ⅳ. In addition, satellite image analyses and heliborne geophysical survey were conducted in Phase Ⅰ and Ⅱ in order to identify the geological structure of the project area. Investigation of mineral showings was also conducted in Phase Ⅱ and Ⅲ.

These survey results are summarized as below.

4-1 Orientation geochemical survey

The objective of the orientation geochemical survey is to select the optimum geochemical survey method in this project area. The survey was conducted in three separate areas where different type of mineral deposits occured. These types are porphyry copper type ore deposits (Nungkok ore deposits), Cyprus type massive sulfide deposits (Bidu Bidu Hill ore deposits)and hydrothermal type gold deposits (Mantri ore deposits). Existing data indicate that there is a high potential for these type ore deposits in the project area.

In the orientation survey, stream sediments, pan concentrates and soil were tested as the sample media. Three samples from different positions were collected at each sampling site in order to select the optimum sampling point for stream sediment and soil. Chemical analyses were conducted for stream sediments (19 elements), pan concentrates (33 elements) and soil (23 elements) in order to select the pathfinder elements in the project area. Several kinds of data processing and analytical methods were applied to select the optimum data treatment method.

The survey results are summarized as below;

① Edge of stream is the optimum sampling point for geochemical sample of stream sediments.

② A soil sample collected from the upper part of horizon B is the optimum sample for soil geochemical survey.

③ Most pathfinder elements in pan concentrates show higher concentration than in stream sediments. Nature of pan concentrates depend on the geology of the area, and it is difficult to collect sample of similar nature. Therefore, chemical analyses are not necessary for pan concentrates if stream sediments sample are collected in the same area.

④ However, the pan concentrate survey is applicable and useful due to its efficiency for the survey in a limited area or for the survey of specified minerals.

⑤ Based on the survey results, useful pathfinder elements for stream sediments and soil in this area are 12 elements including As, Au, Ba, Cr, Cu, Mn, Mo, Pb, S, U, W and Zn.

⑥ Judging from the distance of influence, in other words relationship between geochemical anomalous zone and known mineral showing, the sample density should be at least 4 km^2/sample for stream sediments and 1 km^2/sample for soil. Therefore, the optimum sample densities are thought to be 2 km^2/sample for stream sediments and 0.5 km^2/sample for soil samples. But, in the flat area, 4 km^2/sample for stream sediments is enough sample density because of the longer distance of influence.

⑦ Therefore, stream sediments should be used for a regional geochemical survey, and a soil survey should be used for more detailed survey in a limited area.

⑧ The method of data analyses should depend on the geology in the area, type of ore deposits expected, kind of sample media used, etc., but at least one method of single element analysis and one method of multi element analysis should be applied for the data analyses.

The entire project area is covered by 1/50,000 topographic map sheets, but the accuracy of the map sheet are poor where streams and contour lines are not clear in some flat areas. In order to locate the sample point on the map, aerial photographs should be used in the regional geochemical survey. Furthermore, it is necessary to use Global Positioning System in some part of the area to locate the sampling point.

From the results of the orientation survey, the regional survey should be carried out using following way.

① Stream sediments should be used as the sample media in this survey, and the sample should be collected from the edge of stream. The sampling site should be selected from the first or second order stream.

② The sample density in this survey should be 2 km^2/sample except in flat area. The sample density of 4 km^2/sample should be adopted for the flat area.

③ At least twelve elements including As, Au, Ba, Cr, Cu, Mn, Mo, Pb, S, U, W and Zn should be used as the pathfinder elements for this survey.

In addition to the regional geochemical survey, a reconnaissance soil geochemical survey in the area of ultra-basic rocks (approximately 600 km^2) should be carried out in order to identify the potential of lateritic nickel deposits. The details are as follows;

① The soil sample should be collected in the area of ultra-basic rocks. The sampling point should be at the top of the horizon B.
② The sample density should be 3 km^2/sample.
③ The pathfinder elements for this survey should be Al, Co, Fe and Ni.

Fieldwork for these survey should be carried out by following manner.

① Topographic map of 1/50,000 scale and aerial photograph should be used to determine the location of the sample site.
② Global Positioning System should be used in the area where it is difficult to locate the sampling site in the topograpgic map sheet.
③ During the fieldwork for the regional geochemical survey, a geological field check should be conducted for the area where the satellite image analysis gives different geology to the existing geological map sheet.
④ If new mineral showings are discovered during the regional geochemical survey, the occurrences should be described and the mineralized samples should be collected.

Details of survey methods for Phase Ⅲ should be decided based on the survey results of Phase Ⅱ.

4-2 Satellite image analyses

(1) Data used and image generation

The satellite image analyses were completed in Phase I using five scene of Landsat MSS data and one scene of Landsat TM data. The aerial coverage of these images is shown in Fig. Ⅱ-2-1. The false color image generated by TM data is shown in Fig. Ⅱ-2-2.

(2) Methodology

Integrated analyses were executed to determine geological units and to interprete geological structure on the MSS images at a scale of 1/200,000 and TM images at a scale of 1/100,000 from the viewpoints of tonal distribution, drainage pattern, topography and vegetation. Eighteen geological units were classified in the MSS images and fifteen units were classified in the TM images. The results of the classification are shown in Table Ⅱ-2-2 (MSS images) and Table Ⅱ-2-3. Interpretation map and geological structure map drawn by MSS images and the ground truth are shown in Fig. Ⅱ-2-3 and Fig. Ⅱ-2-4 respectively. Fig. Ⅱ-2-5 and Fig. Ⅱ-2-6 are the interpretation map and geological structure map by TM images respectively.

(3) Interpretation of MSS images

Results of the interpretation including the ground truth are summarized as below;

① Distribution of geological units delineated by the satellite image analyses correspond mostly to existing geological maps. But some part show differences between them, and these part are better be investigated in the future.

② Small scale ring structures delineated in and around Ranau in the Kinabalu area have close relation with intrusives. As pyrite disseminations are observed in these intrusives, attention should be paied to the ring structure in the future exploration.

③ Many ring structure were also confirmed in areas other than the Kinabalu area, it is important to understand the relationship between the ring structure and mineralization for the further exploration work in this area.

④ Results of the ground truth indicate that an establishment for the stratigraphic relationship for Chert-Spilite formation and ultra-basic rocks is quite important for the exploration work of the Cyprus type massive sulfide deposits and chromite deposits.

⑤ The assay results of lateritic soil samples show significant concentration of nickel (upto 0.86 % Ni). The lateritic soil covers wide area in the area of ultra-basic rocks, and the lateritic soil should be investigated to determine the potential of nickel deposits in this project area.

(4) Interpretation of TM images

As ground resolution of the TM data is 30 m, images generated in this survey using TM data give more accurate data for interpretation compare with the MSS images with ground resolution of 80 m. In this survey, the principal compornent compressed image was generated. As this image contain the information of spectrum and topography, this image was suitable for photogeological interpretation.

Results of the interpretation were summarized as follows;

① The results delineated a new fault zone with a direction of N-S in the east of Ranau in the Kinabalu area. Geology of the east and west sides of this fault zone show significant differences. This fault zone is large in scale and possibly play important role for the mineralization in this area.

② A number of ring structure delineated near Ranau have close relationship with distribution of intrusive bodies. As mineralization was confirmed in these intrusive bodies, the ring structure in this area is important for future exploration work in this area.

③ The area along Sungai Labuk was delineated as the area showing similar geological setting of the Bidi Bidu Hill ore deposit area. It is better to carry out geological survey in this area in order to determine the relationship between the geology and mineralization.

The best available data were used in this survey. However, cloud covers certain part of the survey area, and the interpretation for the Semporna area was difficult. It is recommended to use a Synthetic Aperture Radar image for the interpretation in future.

4-3 Heliborne geophysical survey

(1) Coverage of work

Heliborne survey was completed in the six sub-divided areas including the Northern Kinabalu, Southern Kinabalu, Labuk, Segama, Northern Semporna and Southern Semporna areas. The coverage is 13,350 km^2 and the total surveyed length is 27,578 line-km. Magnetic susceptibility and radioactivities for the representative rocks in the survey area were measured and the results were used the interpretation. The location map of the survey areas are shown in Fig. II-3-1. Known mineral occurrences mainly occur in this survey area.

(2) Methodology

The heliborne survey consists of magnetics and gamma-ray radiometrics. The measurement and data processing were made by Aerodat Limited of Canada.

Specification of this survey are as follows:

①	Method	Heliborne geophysical survey
②	Items	Total intensity of geomagnetic field Gamma-ray radiometrics (U, Th, K and total count)
③	Flight level	150 m ± 30 meters terrain clearance Magnetometer Sensor 150 m terrain clearance Spectrometer Sensor 180 m terrain clearance
④	Line spacing	Traverse line 500 m, Tie line 10 km
⑤	Navigation	GPS (Global Positioning System)
⑥	Traverse ground speed	Approximately 75 knots (135 km/h)

Operation bases were established near the survey area for the field survey. A magnetometer was pui in operation at each operation base to record diurnal variations of the earth's magnetic field.

Maps of total field magnetics (Fig. II-3-2) and total count radiometrics (Fig. II-3-3), and a radiometric ternary map (Fig. II-3-4) were prepared for the interpretation. Several types of magnetic and radiometric maps of 1:50,000 and 1:100,000 in scale generated in Phase II and III were also used for the interpretation. Based on the interpretation, magnetic anomaly map (Fig. II-3-5) and radiometric anomaly map (Fig. II-3-6) were prepared and the relationship between the anomalies and the geology was studied.

(3) Ground survey

Magnetic susceptibilities and radioactivities were measured for representative rocks in the area. Rocks of high magnetic susceptibility of more than 10^{-3}CGSemu are gabbro, serpentinite, basalt, andesite, amphibolite, biotitehornfels, adamellite, granodiorite and tuff. High radiometric count rocks of more than 100 cps are sandstone, shale, biotite hornfels, adamellite and granodiorite.

High magnetic and high count rocks such as biotite hornfels, adamellite and granodiorite will cause large-amplitude magnetic anomalies and high-count radiometric anomalies at the same location.

(4) Survey results

The survey results are interpreted as follows;

① In the Northern Kinabalu area, N-S trending magnetic discontinuity lineaments are dominated and high-count anomalies which are mainly contributed by potassium are also aligned in the N-S direction. This direction of N-S is the same as the strikes of the faults infered by the satellite image analysis, so that these lineaments seem to reflect main geological structure. In the northern part of this area, magnetic anomalies of large amplitude and short wave-length aligning in E-W and ENE-WSW directions are due to highly magnetized Chert-Spilite formation near surface. These highly magnetized bodies are divided by N-S trending magnetic discontinuity lineaments.

② In the western margin at the central part of the Northern Kinabalu area, low magnetic anomalies of long wave-length and relatively large amplitude are due to the highly magnetized rocks in the depth. At the southwestern part of the Northern Kinabalu area, a number of large amplitude magnetic anomalies of relatively short wave-length aligned in a NW-SE direction are caused by highly magnetized rocks including ultra-basic rocks, adamelite, granodiorite and Chert-Spilite formation near surface. These highly magnetized rocks are divided by N-S trending magnetic discontinuity lineaments. Very high radiometric anomalous zones showing large contribution of uranium and thorium are located on low magnetic anomalous zones.

③ Non-magnetized and high radiometric zones are widely distributed in the area of sedimentary rocks (mainly sandstone) in the Southern Kinabalu area. On the other hand, high magnetized and low radiometric zones are found in the area of the Chert-Spilite formation (KPCs) and ultra-basic rocks (Ub) in the Labuk area. The survey results correspond to the geology of both the areas.

④ In the Southern Kinabalu area, magnetic anomalies of relatively long wave-length and small amplitude are aligned in the directions of NW-SE at the western part, N-S at the central to southeastern part, and E-W at the southern part, which are caused by dacite and/or gabbro with magnetic susceptibility of 0.2 to 0.7×10^{-3} CGSemu and at a depth of 1 to 2 km below ground level. These parts show high total counts on the radiometrics total count map, so undoubtedly these magnetic anomalies are due to deeper sources.

⑤ In the Labuk area, N-S trending magnetic discontinuity lineaments cut main lineaments of different directions and obscure the high magnetic bodies. Radiometric discontinuity lineaments also indicate a N-S direction. The N-S system in the Southern Kinabalu and Labuk area is interpreted to be the latest structure in both the areas.

⑥ Distributions of magnetic and radiometric anomalous zones correspond well to the geology in the Segama area, and Northern and Southern Semporna areas. These distributions suggest that highly magnetized and low radiometric ultra-basic rocks occupy the Segama area, low magnetic and high radiometric sedimentary rocks crop out in the Northern Semporna area, and high magnetic and comparatively low radiometric volcanic rocks are distributed in the Southern Semporna area.

⑦ Many magnetic anomalies of small amplitude and relatively long wave-length are distributed in the high magnetic zone at the southwestern part of the Segama area, and are caused by intrusive rocks such as ultra-basic rocks at the shallower part (surface to 500m below ground level).

⑧ Many magnetic anomalies of small amplitude and relatively long wave-length are found at the central to eastern part of the Northern Semporna area, and are due to shallower intrusive rocks such as ultra-basic rocks, because low radiometric count anomalies spot in high count zone at the same locations.

⑨ According to the geologic map, andesite is distributed broadly in the circular. zone of the Southern Semporna area, but highly magnetized bodies corresponding to andesite are spotted by low and/or non magnetized bodies and radiometrics total count anomalies are found at the same locations. Hence, the existence of altered zones losing magnetization are suggested at the same spots.

⑩ The geochemical survey delineates uranium concentrated zones in the surroundings of Tawau in the Southern Semporna area. But the heliborne survey gives negative results. The potentiality of uranium deposits in this area is thought to be low.

4-4 Regional geochemical survey

(1) Coverage of work

A regional geochemical survey using stream sediments, pan concentrates and rocks as the sample media was completed for the entire area in this survey. In order to determine the potential of nickel ore deposits, lateritic soil samples were collected from the area of ultra-basic rocks. Geological reconnaissance survey was simultaneously carried out along the geochemical sampling route, and rock samples were collected for the laboratorial studies. Overall interpretation was made using these whole data set.

(2) Methodology and work amounts

Following elements were adopted as the pathfinder elements in this survey.

Stream sediments (21 elements)

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

Soil (6 elements)

Al, Co, Fe, Cr, Ni, Pt

In order to examine the composition of heavy minerals in the pan concentrate sample Qualitative Mineral Examination (QME) were conducted.

Representative rock samples collected in this survey were chemically analyzed for 21 elements, same as for the stream sediments, in order to examine the geochemical characteristic background of the rocks.

The survey was completed over the entire area of 26,500 km^2. The samples collected during the survey are as follows:

Geochemical survey:	stream sediments	11,636 samples
	pan concentrates	697 samples
	rock	223 samples
	soil	364 samples
Laboratorial studies:	thin section	28 samples
	polished section	13 samples
	X-ray diffraction	10 samples
	ore assaying	21 samples

(3) Data processing and analyses

The analytical data were treated statistically by computer, and distribution maps of each element were generated. For the data analyses, single element analysis and multi element analysis methods were utilized. Exploratory Data Analysis (EDA) method (Kurzl H., 1988) was used for the single element analysis. Cluster and factor analyses were applied as the multi element analysis.

EDA method delineate the threshold value without consideration of the distribution pattern of each element. The cluster analysis is a grouping method of the elements using correlations among the elements. The factor analysis is the method to delineate the factor which form the relationship among the samples.

The data treatment was made together for the samples collected in the four areas.

(4) Survey results

Geologic reconnaissance survey was simultaneously carried out during the regional geochemical survey. Geological map compiled from previous geologic data and the data obtained from the present survey is shown in Fig. I-2. The survey results are summarized as follows:

Stream sediment geochemical survey

List and analytical results of the stream sediment samples collected in this survey are listed in the Phase II and III reports. Locations of these samples are shown in Fig. II-4-1. The statistics calculated are shown in Table II-4-1. Correlation matrix is shown in Table II-4-2. Distribution maps of each element are shown in attached Atlas. Distribution of Au and Cu are also shown in Fig. II-4-2 and Fig. II-4-3 respectively.

The data processing and the distribution maps give the following results.

① Among the elements, the maximun values of Au (9,320 ppb), Cr(11.75 %), Hg (24,735 ppb), Sb (3,488.0 ppm) and Ti (51.07 %) give extreamely high values compare generally with geochemical survey in other areas.

② High correlation coefficients are found among the elements including Co, Cr, Mg, Mn, Ni and Zn due to wide distribution of ultra-basic rocks and the Chert-Spilite formation. No elements have good correlation with Au. The elements which indicate good correlation (more than 0.500 correlation coefficient) with Cu are Mg, Mn, Na, Ni, S and Zn.

③ According to the distribution maps of each element, the anomalous and high content samples of Co, Cr, Mg, Ni, Sb and Zn are found in the area of ultra-basic rocks. In the area of ultra-basic rocks, Ba and K characteristically show low values.

④ High contents of As, Ba, K, S and U are found in the area of argillaceous rocks.

⑤ High contents of Cu, Mn, Na and Zn are found in the area of Chert-Spilite formation.

⑥ In the volcanics areas of the Semporna area, contents of Ba, Cu, K, Sr, Ti, U and Zn show comparatively high values.

⑦ Crystalline basements have higher contents of Sr, Ti and Zn.

Judging from the results of the regional geochemical survey, followings are noted.

① A number of high contents and anomalous samples of Au, Cu, Hg, Mo, Pb, S and Sb are found in and around Mamut mine in the central part of the Kinabalu area. The most conspicuous anomalous zone was detected in this area.

② Significant anomalous zones of Au are found at the tributary of Sungai Imbak in the Labuk area and the surroundings of Mt. Wullersdorf in the Semporna area. Anomalous zones of As, Hg and Pb are also found in the anomalous zones of Au in the Sungai Imbak area. In this area, diorite porphyry with mineralization was confirmed. The area of Mt. Wullersdorf includes the Mantri deposit area where the orientation survey was conducted. In this area, gold mineralization and anomalous zones of As and Pb are found.

③ The most conspicuous anomalous zones of Cu is found in the surroundings of Mamut mine. The Bidu Bidu Hill copper deposits in the Labuk area is delineated as conspicuous Cu anomalous zone. Other than these anomalous zones, significant anomalous zone of Cu was also delineated in the Sungai Karamuak area. During this survey mineralized zones were confirmed in the upper stream of Sungai Danum. This area was also delineated as Cu anomalous zone, but it is not conspicuous.

④ Hydrothermally altered zones are found in many places in the volcanic zone of the Semporna area. These altered zones are argillized and are correspond to the anomalous zones of Hg.

⑤ A sample collected from tributary of Sungai Karamuak at the southern marginal part of the Kinabalu area shows extremely high contents of Ti (51.07 %) in the Chert-Spilite formation. The minerals in the sample are mainly ilmenite and potential of titanium is expected.

The results of the cluster analyses (Fig.II-4-4) clearly divide elements into the clusters related to volcanics, sedimentary rocks, alteration, gold mineralization, copper mineralization, crystalline basements and ultra-basic rocks.

Results of the factor analysis delineated six factors (Table II-4-3). Among these factors, factor 1 seems to be related to ultra-basic rocks. Factor 2 have relationship with sedimentary and volcanic rocks. Factor 3 seem to be related to mineralization. Factor 4 have relationship with Chert-Spilite formation, crystalline basements and volcanic rocks. Factor 5 has relation with mineralization and argillaceous rocks. But factor 6 does not show any clear relationship with mineralization.

A conspicuous high factor score (negative factor) zone of factor 3, which has some relationship with mineralization, is found in the area of Mamut mine. Following to this high factor score zones, significant high factor score zones are found in the areas of Sungai Imbak in the Labuk area, surrounding areas of Mt. Wullersdorf and most of the upper stream of Sungai Kalumpang in the Semporna area. Within these areas, mieralization and alteration are confirmed in this survey. Judging from the results of factor analysis, high factor score zones of factor 3 are important for future exploration work.

Pan concentrate survey

List of samples and their locations are shown in the reports of Phase II and III Weight of the collected sample clearly reflect the background geology. Significant volume of samples were collected in the area of ultra-basic to basic rocks. But small amount of samples were collected from the area of sedimentary rocks.

The heavy minerals detected in this survey include magnetite, chromite, hematite, ilmenite, goethite, pyrite and zircon. Other than these minerals, a minor amounts of leucoxene, rutile, monazite, tourmaline and native gold were observed. Some samples contain comparatively large amounts of pyroxenes and hornblende. The samples with small amounts collected in the area of sedimentary rocks contain mainly quartz and plagioclase. Among these heavy minerals, a large volume of magnetite and chromite were found in the area of ultra-basic rocks. Pyrite and ilmenite were found in the samples from the Chert-Spilite formation and volcanics. Comparatively large amounts of goethite and zircon were found in the area of sedimentary rocks. Native gold are found in the samples collected in the Segama and Semporna areas. The samples with native gold are mostly found in the area of the Mantri deposits in the Semporna area.

Rock geochemical survey

Representative rock samples were collected in this survey in order to understand the geochemical nature of the background geology. List and locations of rock samples and the analytical results are shown in the report of Phase II and III . Followings were confirmed in this survey.

① The elements of Co, Cr, Mg, Ni and Zn show higher values in the ultra-basic rocks.

② Basic rocks such as from the Chert-Spilite formation and basalt lavas show higher values of Cu, Sb, Zn and Ti.

③ The elements including As, Hg, Pb and U indicate higher values in the samples of sedimentary rocks.

④ The elements of As, Au, Cu, Hg, Pb and S show higher values in the altered zones of volcanics in the Semporna area.

⑤ Normal relationship is found between the analytical results and the types of rocks.

Soil geochemical survey

In order to determine the potential of latelitic nickel deposits, a soil geochemical survey was completed in the area of ultra-basic rocks. List and location of samples and the analytical results are shown in the reports of Phase II and III. The survey results are summarized as follows:

① A sample collected at 4 km northeast of Ranau in the Kinabalu area indicates high contents of Ni (10,797 ppm) and Co (1,212 ppm). The potential for lateritic nickel deposits is thought to be high.

② West of Telupid in the Labuk area, lateritic soil is well developed in the ultra-basic rocks. The samples collected in the area show high values of Ni (maximum 11,382 ppm), Co (maximum 2,173 ppm) and Fe (maximum 46.37 %). This area also has potential for lateritic nickel deposits.

③ The lateritic soil samples collected in the Segama and Semporna areas indicate approximately 3,000 ppm Ni. Because of poor development of laterite, potential for lateritic nickel deposits is thought to be low.

(5) Laboratorial studies

Thin Section

Observation results of thin sections confirmed layered structure in the peridotite, dunite and gabbro. Intrusive rock from the southern marginal part of the Labuk area is confirmed to be hydrothermally altered diorite porphyry.

A sample collected from the Trusumadi formation in the Kinabalu area is metamorphozed sedimentary rock. Alteration minerals such as chlorite, montmorillonite and zeolites are found in the samples of Chert-Spilite formation and volcanics.

Polished section

Chalcopyrite, bornite and chalcocite are observed as the copper mineral in the samples of the Chert-Spilite formation. A sample of mineralized andesite porphyry collected at the southern margin of the Labuk area shows pyrite, limonite, goethite and malachite under the microscope. Samples collected from the upper stream of Sungai Danum in the Segama area show pyrite and sphalerite with minor covelline and bornite. The samples collected from the altered volcanics show pyrite, goethite and pyrolusite under the microscope.

X-ray diffraction analysis

Quartz, chlorite, sericite, montmorillonite etc, were observed as the alteration minerals in the mineralized samples collected in the upper stream of Sungai Danum. Alteration minerals including montmorillonite, kaolinite, halloysite, chlorite, sericite, cristobalite, quartz and K-feldspar were detected in the samples collected from altered volcanic zones in the Semporna area. Judging from the these minerals, acidic to intermediate alteration is expected in these volcanics.

Ore assaying

The most significant assay results were obtained from the samples collected at the upper stream of Sungai Danum in the Segama area. These sampes are float sample. Among these samples, one sample gives 1.2 g/t Au, 42.6 g/t Ag, 0.9 % Cu and 3.9 % Zn and the other sample gives 0.4 g/t Au, 15.0 g/t Ag, 5.1 % Cu. The area where these samples are distributed was selected as one of the semi-detailed survey areas.

(6) Delineation of potential areas

Judging from the results of the regional geochemical survey, 18 small areas including four areas from the Kinabalu area, six areas from the Labuk area, four areas from the Segama area and four areas from Semporna area, were selected as potential areas for mineral deposits. The semi-detailed geochemical survey was conducted for these selected areas. The targets of the semi-detailed survey are copper, gold nickel and titanium ore deposits.

4-5 Semi-detailed geochemical survey

A semi-detailed survey was carried out in 18 selected areas. These areas were selected as the areas with mineral potential on the basis of the results of the regional geochemical survey in PhaseII and III. The survey results are summarized as below;

(1) Coverage of work

The survey was conducted in the following 18 areas.

Segama area : Area A, B, C and D.
Semporna area : Area E, F, G and H.
Kinabalu area : Area J, K, L and M.
Labuk area : Area N, P, Q, R, S and T.

Locations of these areas are shown in Fig. II-5-1.

(2) Methodology and work amounts

A soil geochemical survey was adopted for the areas where the targets are for gold and/or copper ore deposits. The survey was made along streams in the areas of steep topography and a stream sediment geochemical survey was also conducted together with soil geochemical survey. The areas where these two methods were carried out are Area B, C, Q, R and S. The stream sediment geochemical survey was conductedin Area L and P where the targets were titanium and chromium deposits respectively. In the potential areas for lateritic nickel ore deposits (Area K and N), two soil samples at different depth were collected in the same sampling points. During the semi-detailed geochemical survey in Phase II, significant mineralized zones were detected in Area B in the Segama area. An additional semi-detailed geological survey was carried out in Phase III over the mineralized zones in Area B.

The survey methods adopted in this survey are the same as the regional geochemical survey except the sample density. The basic sample density applied is 4 samples/km^2. Coverage and the number of samples collected in this survey are as follows;

Coverage	:	1,023 km^2
Stream sediments	:	725 samples
Soil	:	3,478 samples
Rock	:	30 samples
Ore	:	87 samples
Thin section	:	41 samples
Polished section	:	35 samples
X-ray diffraction	:	25 samples

(3) Data processing and analyses

Single element and multi element analysis methods, which are the same methods used for the regional geochemical survey, are also adopted in this survey. From the results of the single element analyses, distribution maps of each element were generated. The threshold values were delineated by E.D.A. method. The factor analysis was the method used for the multi element analysis.

A reconnaissance geological survey was simultaneously carried out along the sampling route and samples for the lsaboratorial studies were collected. The interpretation was made using all data obtained in this survey.

(4) Survey results

The survey results from eighteen selected area are summarized as follows;

① Soil geochemical survey was carried out for Area A located in the eastern margin of the Segama area. Cyprus type copper deposits is the original target in this area. From the results of the survey, no significant anomalous and mineralized zones were detected in the area of Chert-Spilite formation which are the host rocks of Cyprus type copper deposits. However, weak mineralized zones were detected in the area covered by the Kuamut formation. The potential in this area is thought to be low as anomalous zones are small.

② Area B is situated in the upper stream of Sungai Danum in the central part of the Segama area. The soil and stream sediment geochemical surveys were carried out in this area. The target in the area was Cyprus type copper deposits. Conspicuous anomalous zones were confirmed from the southern to the southeastern part of the area. Significant mineralized zones were also confirmed on the surface. In addition to these geochemical survey, semi-detailed geochemical survey was carried out over the anomalous areas in the final phase of the project.

The southern part of this area is covered by a semi-detailed geological survey. The survey area is underlain by the Kuamut formation which was overthrusted by basic igneous rocks at the south. The basic rocks consists of mainly dolerite. Mineralization of pyrite and chalcopyrite stockwork and/or dissemination was confirmed in this area. Copper grades of the mineralized zones are low in general. However, the some copper concentrated parts show high copper grades upto 10 % of copper. The mineralized zones are scattered and extentions of these zones are not clear. Further exploration work should be carried out to understand the extensions of these mineralized zones.

③ Area C is situated in the central southern part of the Segama area. The target in this area was Cyprus type copper deposits. The soil and stream sediment geochemical surveys were conducted in this area. From the results of this survey, it was confirmed that the distribution of Chert-Spilite formation being host rocks of Cyprus type copper deposit was limited. Pyrite disseminations were found in green schist, but are not significant. The potential of this type of mineralization is thought to be low. A conspicuous but small scale anomalous zone is found in the southern part of the area where the Kuamut formation occurs. Some work should be conducted over this anomalous zone in the future.

④ Area D is situated at the southern margin of the Segama area. The soil geochemical survey was completed in this area. No conspicuous anomalous zones were obtained in this survey, and only some barren quartz veins were recognized in the surface survey. No potential is expected in this area.

⑤ The soil geochemical survey was carried out for the areas of Area E. F and H in the Semporna area. The target in these areas is hydrothermal gold deposits. These areas ocuppied by Tertiary volcanics and sedimentary rocks. The conspicuous anomalous zones are found in the area of strongly altered (argillization and some silicification) zones. No significant mineralized zones are found in these altered zones. But some hot springs were found during this survey. These anomalous zomes possibly have relation with hydrothermal activity of hot spring.

⑥ Area G is situated in the south central part of the Semporna area. The initial target in this area was hydrothermal gold deposits. Conspicuous anomalous zones are confirmed in the area of strongly argillized volcanic rocks. Anomalous zones are found in the surroundings of intrusive bodies of grano-diorite. The anomalous zones found in the area of altered volcanics are similar to the anomalous zones in the areas of Area E, F and H. The relationship between the anomalous zones and the intrusives should be examined in future exploration work.

⑦ Area J and M are situated along Sungai Sugut in the Kinabalu area. A soil geochemical survey were conducted on these two areas in order to examine the potential for porphyry copper deposits. From the result, anomalous zones are found in the area of alluvium and/or terrace deposits in both the areas. No significant mineralized zone was confirmed in these areas. The anomalous zones may be related to mineralized gravels in the alluvium and/or terrace deposits which were supplied from Mamut mine area. Mamut mine, which is significant porphyry copper ore deposits, is situated at the upper stream of Sungai Sugut.

⑧ The areas of Area K in the Kinabalu area and Area N in the Labuk area were examined to determine the potential for lateritic nickel deposits. A soil geochemical survey was completed for these two areas. In this survey, two samples from different depths (50 cm and 150 cm) were collected at each sampling point. From the results, some samples show more than 1.00 % Ni in both areas. The samples collected at the deeper part tend to indicate higher values. Comparing between these two areas, Ni contents of the samples in Area N have higher values than those from Area K in general. Further work should be carried out for the Ni concentrated zones delineated in this survey in order to determine the concentration at depth, because maximum concentration is known at the boundary between lateritic soil and basement rocks in general.

⑨ Area L is situated at the upper stream of Sungai Karamuak in the southern margin of the Kinabalu area. In order to examine the potential of titanium, a stream sediment geochemical survey was completed in this area. During the regional geochemical survey, a sample with 51.07 % Ti was confirmed in this area, but the maximum contents of Ti was 12.40 % in this survey. As no significant Ti values are confirmed in this survey, the potential for titanium ore deposit is thought to be low in this area.

⑩ Area P is situated at south of Telupid in the central part of the Labuk area. A stream sediment geochemical survey was completed in this area. The target in this area is chromite ore deposits. Anomalous zones are confirmed at southwestern and northeastern part of this area. Further work should be carried out on these anomalous zones. However, the chromite deposits are possibly small scale because no chromite floats are detected during the survey.

⑪ Area Q is located at the middle stream of Sungai Karamuak in the south central part of the Labuk area. The targets in this area was copper and chromite deposits. Soil and stream sediment geochemical surveys were simultaneously carried out in this area. Mineralized zones of pyrrohtite with minor chalcopyrite have been reported in this area. A gossan sample collected in this survey shows 4.1 g/t Au. From the results of the geochemical survey, pathfinder elements including Au, Cu and Hg show higher values compare to the values in the other semi-detailed survey areas. The results of factor analysis delineated a factor indicating mineralization. More than twenty years ago, exploration work for copper and nickel had been conducted in this area. In addition to copper and nickel, potential for gold was confirmed in this survey. Further exploration work should be carried out in this area.

⑫ Area R is located in the south central part of the Labuk area. In order to clarify the potential for copper, soil and stream sediment geochemical survey was completed in this area. No significant mineralized zones were detected in this survey. From the results of the geochemical surveys, the pathfinder elements includind Au, Cu, Hg, Pb and S indicate lower values compare to the values in the other semi-detailed survey area. Mineral potential in this area is thought to be limited.

⑬ Area S is located in the south of the Labuk area. Because of Au anomalous zones delineated by the regional geochemical, potential for gold deposits was expected in this area. Soil and stream sediment geochemical surveys were completed in this area to assess the gold potential. No significant mineralized zones were recognized on the surface in this survey. The pathfinder elements which have direct relation with mineralization, indicate low values comparing to other semi-detailed survey areas. The potential is thought to be low in this area.

⑭ Are T is also located at the south of the Labuk area. During the regional geochemical survey, significant Au anomalous zones were found in this area. A soil geochemical survey was conducted in this area in order to assess the potential for gold deposits. Geology in this area consists of sedimentary rocks. Dykes of diorite porphyry are found at the southern margin of this area. In and around the dykes, altered and mineralized zones were confirmed. The assay results for gossanized samples from the mineralized zones indicate significant values of Au and Ag. The maximum values are 18.4 g/t Au and 931.4 g/t Ag. Observation results of polished sections indicate ruby silver, freibergite and argentite as the silver minerals. Ratio of Au to Ag is low and the silver minerals occuring in the area are relatively low temperature type. These facts suggest that the mineralized zones in this area are also possibly to be the upper part of porphyry copper mineralization. Significant geochemical anomalous zones were also detected in the areas of mineralization and/or alteration. Judging from the results, the potential for mineral deposits in ths area is thought to be very high.

4-6 Investigation of mineral showings

From the results of collection and compilation of existing data, investigation of known mineral showings was carried out in the Segama and Semporna areas in Phase II and in the Kinabalu and Labuk areas in Phase III. Based on the results of the investigation, Bt. Tampang area in the Kinabalu area was selected as a promising area, and the survey was conducted in Phase IV. These survey results are summarized as follow:

① Among the mineral deposits, a gold deposit which occurs in the Semporna area has the highest possibility to be discovered in both the areas of Segama and Semporna. The gold deposit expected in the area is vein and/or stockwork type hydrothernal gold deposits and occurs in volcanics and its pyroclastics of late Miocene to Pliocene age.

② Following to the hydrothermal gold deposits, the Cyprus type copper deposit in the Chert-Spilite formation has higher possibilty to be discovered in the Segama and Semporna areas. As the stockwork mineralized zones are recognized in the area of Kg. Silum at the east of the Segama area, possibility of this type mineralization is expected in this area.

③ From the results of the investigation in the Kinabalu and Labuk areas, four areas, namely Bt. Tampang in the Kinabalu area, Sungai Telupid, Kg. Porog and Sungai Tungud areas in the Labuk area, are thought to have high potential for mineral deposits

④ From the results of a detailed survey for the Bt. Tampang area, gold mineralization was confirmed. The gold deposit is epithermal quartz stockwork vein related with calc-alkaline volcanic activity of late Miocene age, but assay results give low values ranging from 0.10 g/t to 2.48 g/t Au.

Chapter 5 Conclusions and recommendations

5-1 Conclusions

This Supra-regional survey was carried out within a period of four fiscal years, in four phases of Phase I, II, III and IV started from October 1990 and ended at February 1994. The orientation geochemical survey was conducted in Phase I, and then after the satellite image analysis, heliborne geophysical survey, regional geochemical survey and semi-detailed survey were carried out over the four years. These survey results are conclusively summarized as follows:

Orientation geochemical survey

① The orientation survey was carried out over three known mineralized areas in order to delineate the optimum geochemical survey methods in this project. From the results of the regional and semi-detailed geochemical survey, the survey methods applied in these survey delineated known mineralized zone very clearly. Therefore, the survey method decided by the orientation survey are useful and applicable for this project area.

Satellite image analyses

① No significant differences are recognized between the interpreted results and the existing geological map.

② Significant fault zones with a direction of N-S in the Kinabalu area and many ring structures were newly discovered in this analyses. The results indicated that this analysis is quite useful to understand the large scale geological structure in this area.

Heliborne geophysical survey

① The anomaly maps of magnetics and radiometrics reflect well the geology and the geological structure in this area. Significant discontinuous lineaments with a direction of N-S are distributed in the Kinabalu area. On the other hand, NE-SW trending discontinuous lineaments are dominance in the Labuk area. The differences of the geological structure in each area are clearly delineated in this survey results.

② Strongly altered volcanic zones in the Semporna area are delineated from the anomaly maps. The altered zone indicate low magnetics and high radiometric count.

③ The survey results indicates high magnetic bodies at depth in the southern part of the Kinabaru area. High magnetic bodies are also expected at shallow depth in the northern part of the Semporna area.

Regional geochemical survey

① Geochemical anomalous zones are found in and around the known mineralized zones. The results indicate that this survey was effective for exploration work in this project area.

② Samples with high contents of Cu, Hg, Mo and S are found in the surrounding area of Mamut mine. The elements including As, Au, Pb and S show higher values in the known mineralized zone of gold in the Semporna area. High concentrations of As and Hg are recognized in the altered volcanic zones in the Semporna area. These facts suggest that the concentrations of elements depend on the type of mineralization and/or alteration. In another words, it is possible to expect the nature of the mineralization on the basis of the assemblage of anomalous elements.

③ Because the survey covers a wide area, distribution tendencies of each element are observed for the entire project area. Therefore, it is possible to make relative evaluation and to carry out efficient exploration work for the target areas selected in future exploration.

Semi-detailed survey

The semi-detailed survey was completed for eighteen areas which were selected as the promising areas for mineral resources by the regional geochemical survey.

Among eighteen areas investigated in this survey, five areas were selected as potential. These five areas and their targets are as follows;

① Area T in the south of the Labuk area : gold and/or porphyry copper
② Area N west of Telupid in the Labuk area : lateritic nickel
③ Area Q along S. Karamuak in the Labuk area: vein or disseminations of copper
④ Area B along S. Danum in the Segama area : vein or disseminations of copper
⑤ Area K east of Ranau in the Kinabalu area : lateritic nickel

Among these areas, the most significant mineralized zones were confirmed in Area T. The assay results from the samples collected in this area indicate a maximum of 18.4 g/t Au, and 932 g/t Ag. Area N and Area K were selected as potential area for lateritic nickel ore deposits. In these areas, some samples indicat more than 1.00 % Ni. The samples in this survey is collected from a depth up to 1.50 m. Concentration of nickel are usually know at the boundary between the latritic soil and the basement rocks situated at depth. Chalcopyrite and pyrrohtite mineralization is known in Area Q. Mineralized zones of pyrite and chalcopyrite were confirmed in Area B in this survey.

Investigation of mineral showings

① Among the mineral deposits, an epithermal gold deposit which may occurs in the Semporna area, has the highest possibility to be discovered in the Segama and

Semporna areas. Following to the gold deposit, the Cyprus type copper deposit, hosted by the Chert-Spilite formation, has possibility to be discovered in the Segama and Semporna areas.

② From the results of investigation, four areas are selected as the potential area of mineral deposits in the Kinabalu and Labuk areas. These are Bt. Tampang area for gold in the Kinabalu area and Sungai Telupid, Kg. Porong and Sungai Tungud areas for the Cyprus type copper deposits in the Labuk area.

③ Further detailed survey was conducted for the Bt. Tampang area. From the results, epithermal quartz stockwork gold mineralization which related with calc-alkaline volcanic activity of late Miocene age, was confirmed in the area. However, assay results give low values ranging from 1.0 g/t to 2.48 g/t Au.

5-2 Recommendations for the future

Juging from all the survey results in this project, the following items are recommended for future exploration work in the project area;

(1) Results of the interpretation of satellite images confirm N-S trending fault zones in the Kinabalu area and a number of ring structures. The satellite image analysis is quite useful to understand the entire geology and the relationship between the geology and mineralization. Consequently, the satellite images generated in this survey should be used for future exploration work in this area.

(2) Results of the heliborne geophysical survey reflect well the geology and the geological structure in this survey area. Because the low magnetics and high total count radiometrics zones correspond to altered volcanic zones, it is possible to delineate hydrothermally altered zone. The data of this survey should be used to make more accurate interpretation of the geological structure in future survey.

(3) Results of the regional geochemical survey clarify the distribution tendencies of each element over the entire survey area. In this survey, many geochemical anomalous zones of each element were delineated, but the semi-detailed survey was only conducted over the significant anomalous zones. Therefore, the remaining anomalous zones should be examined in future. Significant anomalous zones were also detected in the known mineralized zones such as Bidu Bidu Hill ore deposits and Mantri area. These areas are excluded for the semi-detailed survey because exploration work has been conducted.

(4) The sample density in the semi-detailed survey was basically 4 samples/km^2. Because of the space samples in the survey area, only the outline of the mineralized zones were confirmed in this survey. Therefore, detailed survey

should be carried out on the newly discovered potential zones in this survey in the future. The potential areas delineated in this survey and the recommendable survey method for these areas are as follows:

① Area T in the south of the Labuk area:
geological survey, trenching and geophysical survey (IP method)

② Area N west of Telupid in the Labuk area:
geological survey, pit survey and trenching

③ Area Q along S. Karamuak in the Labuk area:
geological survey and geophysical survey (IP method)

④ Area B along S. Danum in the Segama area:
trenching

⑤ Area K east of Ranau in the Kinabalu area:
geological survey, pit survey and trenching

If these survey give attractive results, drilling survey shoud be conducted These areas are shown in Fig. I-4.

(5) A huge amounts of heliborne geophysical and geochemical data obtained in this survey were input in the magnetic tapes. The drainage data of 1:50,000 in scale were also input. These data are basic data in this area and anybody can access to any part of the data for re-examination in future investigation. If these data are used for the future exploration, the work can be carried out quite effectively. Therefore, computer software for the operation should be obtained and training for the operator should be carried out in near future.

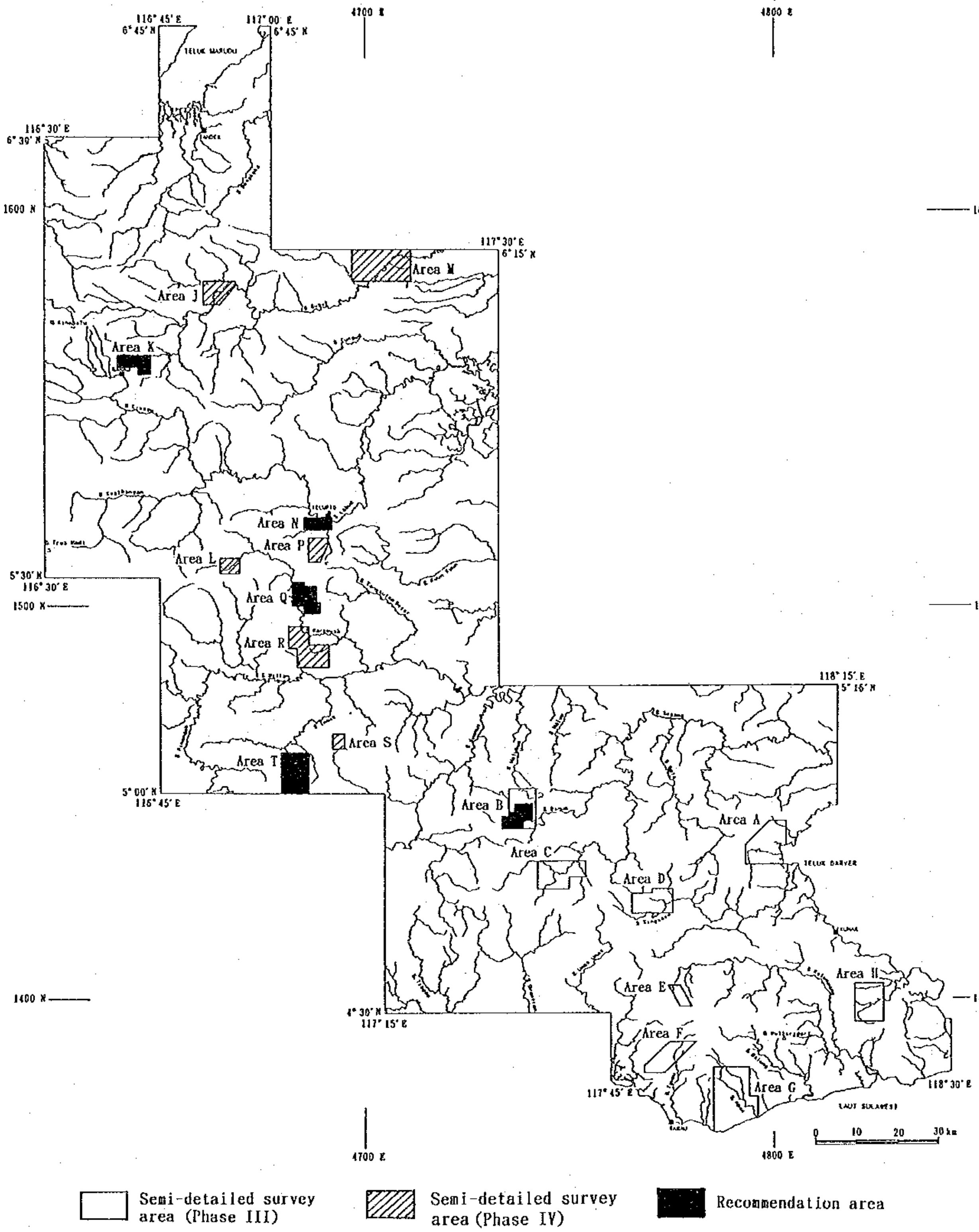

Fig. I-4 Recommendation map of surveys

Part Ⅱ Survey results

Chapter 1 Orientation survey

1-1 Coverage of work

This orientation survey was carried out in Phase I for the purposes of determining suitable survey methods for the regional and semi-detailed geochemical surveys planned in Phase II, III and IV. The details of the method include type of sample media, pathfinder element, sample location, sample density and method of data analyses. The survey areas including known ore deposits were selected to understand the relationship between mineralization and geochemical features. Three known representative deposit areas, namely Nungkok ore deposit, Bidu Bidu Hill ore deposit and Mantri ore deposit, were selected to define the relationship between different types of ore deposits and their geochemical characteristics.

Nungkok deposit, which is one of the principal porphyry copper deposit, was selected in this survey. This ore deposit is similar to the Mamut-type copper deposit in the Kinabalu area and is situated at the western foothill of Mt. Kinabalu. Bidu Bidu Hill deposit, which is a Cyprus type massive sulfide deposit and its structure is well known, was selected for the survey. This deposit is situated at the northern part of the Labuk area. In the Semporna area, the Mantri deposit, which is well studied as one of the Au-Ag deposits occurs within Tertiary volcanics, was selected for this survey.

1-2 Geochemical survey

An orientation geochemical survey was completed in three areas, in order to delineate the optimum survey method for the regional and semi-detailed geochemical surveys in later phases.

(1) Sample media

Three kind of samples including stream sediments, pan concentrates and soil were tested in this survey in order to select the optimum sample media. Three stream sediment samples were collected from different positions of a stream at one location to decide the suitable sampling site. Soil samples were also taken from three different horizons at each location to find out suitable sampling horizon that reflect the geochemical pattern. These are as below;

Stream sediment	Sample A:	bank.
	Sample B:	edge of stream.
	Sample C:	middle in stream.
Soil	Sample A:	A zone of soil classification standard.
	Sample B	upper part of B zone.
	Sample C	lower part of B zone

(2) Chemically analyzed element

Following elements were chemically analyzed in order to select usefull pathfinder elements.

Stream sediments (19 elements)

Ag, As, Au, Co, Cr, Cu, Fe, Hg, Mn, Mo, Ni, Pb, Pt, S, Sb, Sn, U, W, Zn

Soil (23 elements)

Ag, As, Au, Co, Cr, Cu, Fe, Hg, K, Mn, Mo, Na, Ni, Pb, Pt, Rb, S, Sb, Sn, Sr, U, W, Zn

Pan concentrates (33 elements)

Ag, As, Au, Ba, Ce, Co, Cr, Cu, Fe, Ga, Ge, Hg, La, Mn, Mo, Ni, Pb, Pt, Re, S, Sb, Se, Sn, Ta, Te, Th, Ti, U, V, W, Y, Zn, Zr

The pan concentrate sample was also studied by Qualitative Mineral Examination (QME).

(3) Data treatment and analysis

Several analytical methods were tested in this survey in order to determine suitable data analysis methods for the geochemical survey in later stages. Following analytical methods were applied in this survey.

Stream sediment and soil samples

Single element analysis: EDA method, Lepeltier method and correlation matrix. Multi element analysis : cluster analysis and factor analysis.

Pan concentrate sample

Single element analysis: EDA method.

Exploratory data analysis (EDA) method (Kurzl H., 1988) delineates threshold value by means of statistic data processing and distribution pattern of each element is not affected in this method. Lepeltier method (Lepeltier C., 1969) delineated the threshold value due to the hypothesis that distribution of each elements form a log normal distribution pattern. This method is similar to the Sinclair method (Sinclair A. J., 1973).

Cluster method being one of the multi element analysis method is grouping method of elements which has close relationship among them. Factor analysis is the method to delineate factors which form the relationship among elements.

Computer was used for these data treatment and analyses.

(4) Survey results

(a) Sample media

Stream sediment samples, which consist of three kind of samples A, B and C, were analyzed separately. Results of data analyses for stream sediment samples in each survey area are summarized as follows:

Nungkok deposit area

The sample B gave higher geometric means than the samples A and C in general. The elements in sample B indicate higher correlation coefficient with each other. The factor delineated by sample B have a closer relationship with the elements, and clearly delineate factor related to the mineralization. These results suggest the sample B is better for the survey than the samples A and C.

Bidu Bidu Hill deposit area

Results of data treatment indicate comparatively high geometric means for elements in the case of sample B. Sample A has higher correlation coefficient among the elements. Distribution of factor scores for sample B clearly delineates the existing mineralizedzones.

Mantri deposit area

Results of data treatment indicate that elements in sample A or C have higher geometric means than those of sample B. The mean values of sample B mostly indicate intermediate values. Factors delineated from sample A do not correspond to the results of the single element analysis. Sample B and C show similar results in the factor analysis and ore deposits were clearly delineated by these samples. Between the sample B and C, the sample B gave higher values of communality in the factor analysis than the values of sample C. These results suggest no significant difference between the sample B and C, but the sample B is slightly better than the sample C.

Based on these results for three survey areas, as mentioned above, the sample collected at the edge of stream, sample B, is thought to be the best sampling site.

In the case of soil sample, three kind of samples were also collected. Results of the data analyses for these samples are summarized as below;

Nungkok deposit area

Comparing the geometric mean for each element, most elements have higher values in the sample A. However, distribution patterns of elements in sample A have irregular shape on the cumulative frequency graph compare to the patterns of the samples B and C. The sample B and C give higher correlation coefficients among the elements than those of sample A. From the results of the cluster analysis, cluster which is thought to be related to the mineralization was delineated only from the samples B and C. Factor analysis for the sample B give higher communality values than the other two kind of samples. These results suggest the sample B is better than other two kind of samples.

Bidu Bidu Hill deposit area

The geometric means indicate no conspicuous tendency for the elements in all three kind of samples. Sample B and C indicate higher correlation coegfficency among the elements compare to those of sample A. The factor which has close relation to mineralization was delineated only from the sample B and C, and the elements indicating the mineralization in sample B have higher factor loading values than the sample C. These results suggest that the sample B is the most suitable for the survey among the three kind of samples.

Mantri deposit area

The sample A or C show higher geometric means for the elements, and sample B give mostly middle values. Among the elements, the sample B has a closer correlation. Factor scores delineated by sthe factor analysis for the sample A and B indicate mineralization, but factor scores of the sample C do not. The factor of sample B indicate higher factor loading values compare to other two kind of samples. Judging from these results, sample B is the most suitable for the survey in this area.

The survey results from the three orientation survey areas indicate that the sample B is the most suitable sample for soil geochemical survey in this area. Because soil of horizon A in the project area is limited, and it is difficult to collect soil sample with similar nature. The concentrations of some elements in the Bidu Bidu hill area show significant differences between the samples collected along stream and the samples collected at the hill side. The samples collected at the hill side indicate more concentration of elements. This may come from the fact that soil at the hill side is more developed than the soil along stream.

Pan concentrate samples were also collected in these three areas and chemically analyzed. The samples collected from the Nungkok deposit area indicate higher geometric means for most elements than the geometric means of stream sediments. In the case of the Bidu Bidu Hill deposit area, half of the elements show higher geometric means than the stream sediment samples. The sample in the Mantri deposit area show similar tendency of geometric means to the samples in the Bidu Bidu Hill deposit area.

Results of the qualitative mineral examination (QME) showed significant differences of mineral composition among the survey areas. Required time for the sampling is also significantly different among these survey areas. Because of these differences, the results of chemical analyses for pan concentrates are not suitable for treating statistically, and the anomalous zone deliniated by these data may have errors. The elements which were chemically analyzed for both of stream sediments and pan concentrates show that the data analyses for stream sediments give better results than those for pan concentrates.

From the results of this survey, it is confirmed that three kind of the sample media used in this survey are applicable to delineate mineralized zones. However, each sample media has different characteristics, and therefore selection of sample media should be made on the basis of the purpose of the survey.

In the stream sediment geochemical survey, anomalous samples were delineated 1.5 km away from the Nungkok ore deposits, several hundred meter away from the Bidu Bidu Hill ore deposits and 2.0 km away from Mantri ore deposits. The distance of influence from the ore deposits are significantly long except the Bidu Bidu Hill ore deposits being a blind ore deposit, and therefore the stream sediment sample is suitable for a regional geochemical survey in this area. However, these three known ore deposits are the most significant and are widespread in this project area, therefore sampling site should be located adopting 1 km as the distance of influence in the planning of a regional geochemical survey.

The results of soil geochemical survey confirmed a 1.5 km of distance of influence in the Nungkok deposit area and 1.0 km in the Bidu Bidu Hill and Mantri deposit areas. The distance of influence of soil samples are shorter than those of stream sediment samples in general, and the anomalous soil samples are found mostly in the mineralized zone. Therefore, soil geochemical survey is suitable for a detailed geochemical survey in a cinfined area. The ore deposits investigated in this survey are significant in this project area, and therefore 500 m or less should be applied for the distance of influence in case to locate sampling site in a soil geochemical survey in this project area.

The pan concentrate survey is convenient and applicable method to carry out the survey in a small area or for specified minerals. However, if this survey carry out together with a stream sediment survey, it is not necessary to conduct chemical analyses for the pan concentrates and the pan concentrate survey should be limited to clarify the mineral composition of the survey area.

(b) Pathfinder elements

In this survey, 19 elements for stream sediments, 23 elements for soil and 33 elements for pan concentrates were chemically analyzed. Judging from the results of data analyses, following elements are delineated as useful pathfinder elememts for each ore deposit area.

Stream sediment sample

Nungkok deposit area:	As, Au, Cu, Mo, S, W
Bidu Bidu Hill deposit area:	Au, Cu, Mn, Pb, U
Mantri deposit area:	As, Au, Cu, Pb, Zn

Soil sample

Nungkok deposit area:	As, Au, Cu, Mo, S, W
Bidu Bidu Hill deposit area:	Au, Cu, S, U
Mantri deposit area:	As, Au, Cu, Pb, S

Pan concentrate sample

Nungkok deposit area:	Au, Cu, Mo, S, Se, W
Bidu Bidu Hill deposit area:	—
Mantri deposit area:	Ba

As shown above, the pathfinder elements delineated from the stream sediment survey are quite similar to those from soil survey. On the whole, following 10 elements are thought to be the usefull pathfinder elements for these three types ore deposits in the project area.

As, Au, Cu, Mn, Mo, Pb, S, U, W, Zn

Results of pan concentrate survey in the Mantri deposit area confirmed close relation between the concentration of Ba and the mineralization. Therefore, Ba is thought to be a useful pathfinder element for the survey of Au-Ag mineralization. Because of the geological setting of the project area, potential for chromite ore deposits related to ultra-basic rocks are thought to be high. It is usefull to apply Cr as the pathfinder element in the regional stream sediment survey. In addition, lateritic soil are developed in the area of ulta-basic rocks. Therefore, Co, Ni and Al should be selected as the pathfinder elements in the soil geochemical survey.

(C) Data analyses

In this survey, single element and multi element analysis methods were examined and these analytical method gave good results. The methods of data analyses should be selected depending on the geology of the survey area, type of mineralization, coverage of survey area and sample media used. Consequently, results of the field survey are also very important for the selection of the analytical method. However, each method also has its limitation, so that at least one single element analysis and one multi elements analysis methods should be applied for the data analyses.

(5) Fieldwork 0f a regional geochemical survey

Judging from the results of this survey and the data analyses, followings can be pointed out for the execution of a regional geochemical survey.

① The sample density of 2 km^2/sample is ideal for the regional stream sediment survey. However, because longer distance of influence are expected for topographically flat area, a 4 km^2/sample sample density is good enough in the flat area.

② In case of above mentioned sample density, it is better to collect the stream sediment samples from the first or second order stream.

③ The project area is entirely covered with 1/50,000 in scale topographic map sheets. But the accuracy of the map are poor and the contour lines in flat area are not clear. Therefore it is better to use aerial photographs together with the topographic map sheet. In some area, it is also necessary to use Global Positioning System in order to confirm the exact sampling location.

Chapter 2 Satellite image analyses

2-1 Coverage of work

The satellite image analyses were completed in Phase I using five scene of Landsat MSS data and one scene of Landsat TM data. The aerial coverage of these images is shown in Fig. II-2-1.

2-2 Data used

Five scene of MSS data and one scene of TM data taken by the Landsat launched by NASA, USA were processed to generating the images. The details of the data are shown in Table II-2-1. Although it was attempted to select data with less clouds, the area is still covered by up to 30 % of clouds. These data were received by the ground receiving center in Thailand.

Table II-2-1 List of Landsat data used

Data	Path	Row	Date	ID number	Cloud cover	Sun elevation
MSS	116	057	01/04/84	40625-01472	1211	54 °
MSS	117	056	25/08/85	50542-01553	1011	55 °
MSS	117	057	17/10/84	40824-01511	3233	55 °
MSS	118	055	13/03/84	40607-01592	0001	52 °
MSS	118	056	18/07/83	40367-02015	1112	52 °
TM	117	056	07/10/89	520460-1513400	1124	56.4 °

Using MSS data, false color images were generated by Computer Compatible Tape (CCT). Band 1, 2 and 4 in false color correspond to blue, green and red respectively. Contrast and edge enphancement processing were applied for the image to assist in the photogeological interpretation.

The false color images of TM data were generated using the band 2 (blue), band 3 (green) and band 4 (red). In addition, principal component compressed images were generated using CCT. Contrast stretch processing were used for these images in order to interpret the images. The images are shown in Fig. II-2-2.

2-3 Methodology

Integrated analyses were executed to classify geological units and to interpret geological structure on the MSS images at a scale of 1/200,000 from the viewpoints of tonal distribution, drainage pattern, topography and vegetation. The

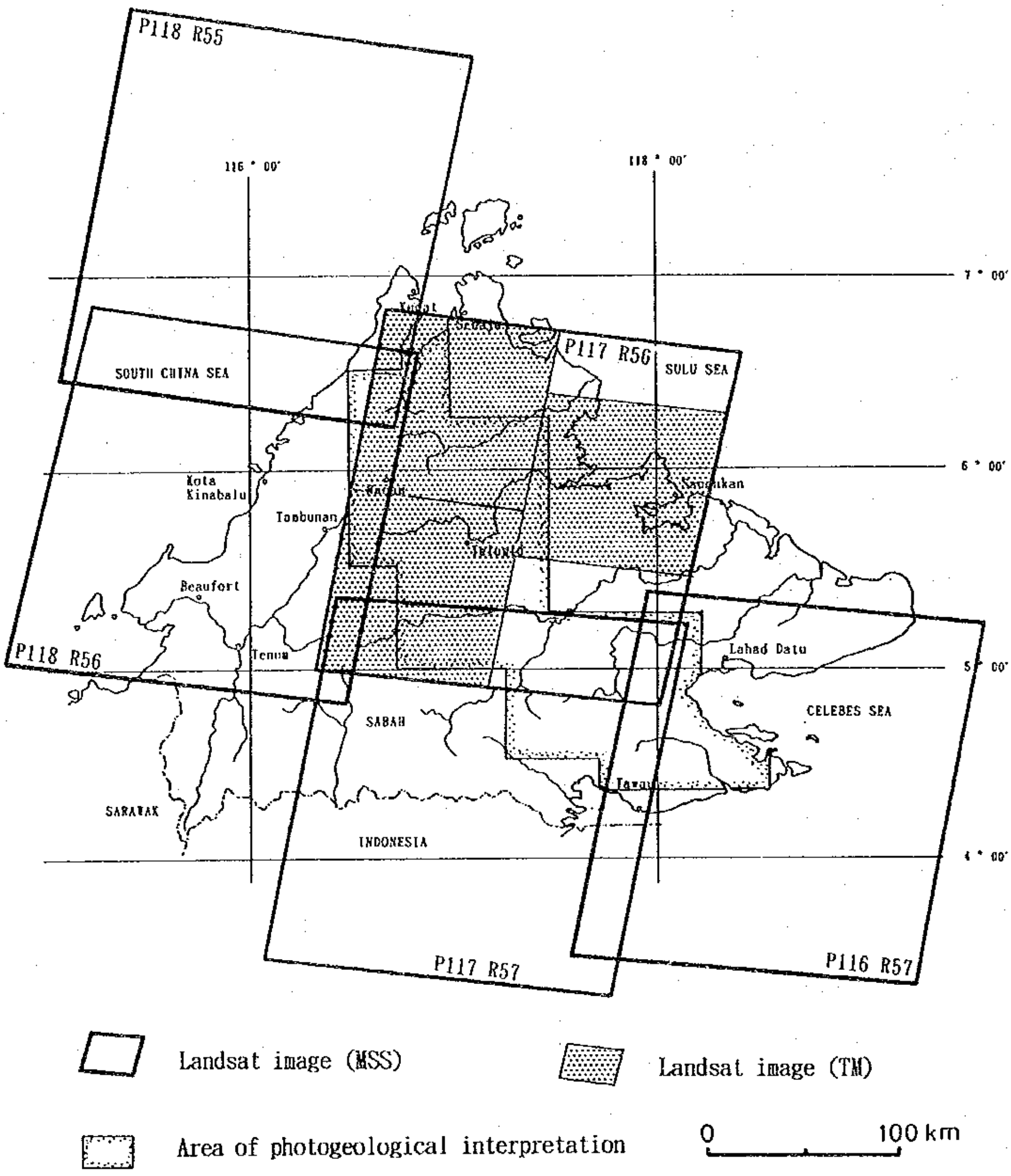

Fig. II-2-1 Index map of Landsat data

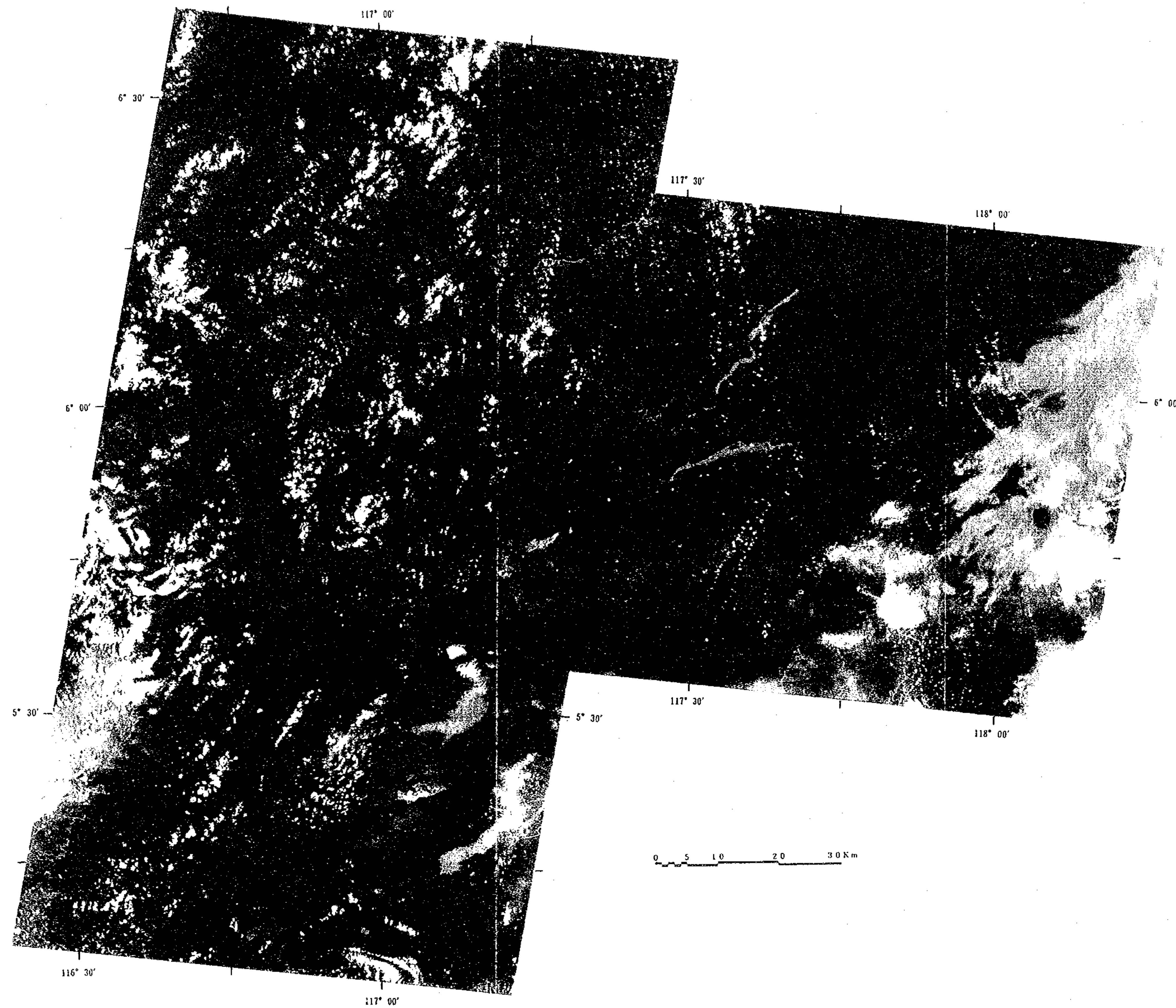

Fig. II-2-2 False color image of TM data

ground truth were executed based on the classified geological units and the structure to confirm the geology and to search for the possibility of further classification.

In addition, integrated analyses were also conducted on the TM images at a scale of 1/100,000 in order to classify the geological unit and to interpret the geological structure in detailed.

The geological units classified by the analyses of MSS and TM images are shown in Table Ⅱ-2-2 and Table Ⅱ-2-3 respectively.

2-4 Survey results

2-4-1 Interpretation of MSS images

(1) Lithologic classification

Eighteen geological units were classified in the MSS images as shown in Table Ⅱ-2-2. Fig. Ⅱ-2-3 was drawn from the photogeologic interpretation of the MSS images and the ground truth. The distribution and the characteristics of the classified units are as follows;

(a) Sedimentary rocks

Unit J : This unit is distributed in the Segama area in the southern part of the survey area, characterized by very high density of drainage system and higher resistance to erosion and therefore rougher topography. Lineaments trending northwest are detected in some parts. This unit corresponds to metamorphic rocks of Triassic/or older in age and forms a basement of Sabah.

Unit Pa-1 : This unit occupied wide area both in the Segama and Labuk areas in the central part of the survey area. The unit ub described later is also distributed in the same area. Rougher and intermediate topography are observed. Resistance against erosion is variable in the area. This unit corresponds to the Chert-Spilite formation (KPCs) and mainly consisting of sandstone, chert, basalt and spilite.

Unit Pa-2 : This unit is distributed in the south of Kinabalu area. The unit has a strong resistance against erosion and therefore has a rougher topography. This unit corresponds to the Trusumadi formation (P_1Ts), consisting of shale and phyllite.

Unit Pa-3 : The unit is distributed in the southwest of the Labuk area and has a low undulated topography. The unit is characteristized by low

Table II-2-2 Photogeological interpretation chart of MSS data

Units	Color	Drainage		Morphological expression					Vegetation	Comparison with existing data
		Pattern	Density	Rock resistance	Cross section of vallay & ridge	Texture	Bedding or schistosity	Lineament		
Q	dark red, bluish gray	anastomotic	high	very low	- / -	smooth	-	-	dense	recent alluvial clay, sand
Nc	red to dark red	subdendritic	moderate	low	⌣ / ⌢	smooth	bedded	low	very dense	mudstone, shale, sandstone
Nb-5	dark red	parallel	very high	moderate	∨ / ∧	intermediate	well bedded	low	very dense	sandstone
Nb-4	dark red	annular	moderate	moderate	⌣ / ⌢	smooth	well bedded	none	very dense	sandstone, mudstone
Nb-3	red	annular	moderate to high	moderate	⌣ / ⌢	intermediate	well bedded	low	very dense	mudstone, siltstone
Nb-2	red	dendritic	high	very high	∨ / ∧	very high	poorly bedded	low	very dense	calcareous sandstone
Nb-1	red	trellis	moderate	low to moderate	⌣ / ⌢	smooth to intermediate	bedded	low	very dense	sandstone, mudstone
Na	pale red, blue	subparallel	moderate	low	⌣ / ⌢	smooth	poorly bedded	none	very dense	slump breccia
Pb	dark red	trellis	high	low	⌣ / ⌢	smooth	bedded	very low	very dense	sandstone, shale
Pa-4	red to dark red	dendritic, trellis	very high	moderate to high	∨ / ∧	rough to intermediate	well bedded locally	low	very dense	alternating beds of sandstone and shale
Pa-3	red	dendritic	moderate	moderate	⌣ / ⌢	smooth	bedded	low	very dense	mudstone
Pa-2	red	dendritic	high	very high	∨ / ∧	very high	poorly bedded	low	very dense	shale, phyllite
Pa-1	red	dendritic, trellis	high to moderate	high to moderate	∨ / ∧	rough to intermediate	bedded locally	low	very dense	chert, spilite
J	red	subdendritic	very high	high	∨ / ∧	rough	schistosity	moderate	very dense	schist, gneiss
Tv-2	red	subdendritic	very high	high	∨ / ∧	rough	-	moderate	very dense	andesite lava, andesitic volcanic breccia and tuff
Tv-1	dark red	trellis	high	high	∨ / ∧	rough	-	low	very dense	dacite lava, pyroclastics
gt	red	trellis	moderate	moderate to low	⌣ / ⌢	intermediate to smooth	layered	low	very dense	diorite, microgranite
ub	greenish dark gray	dendritic	high	very high to moderate	∨ / ∧	rough to very rough	poorly layered	low	very dense	peridotite

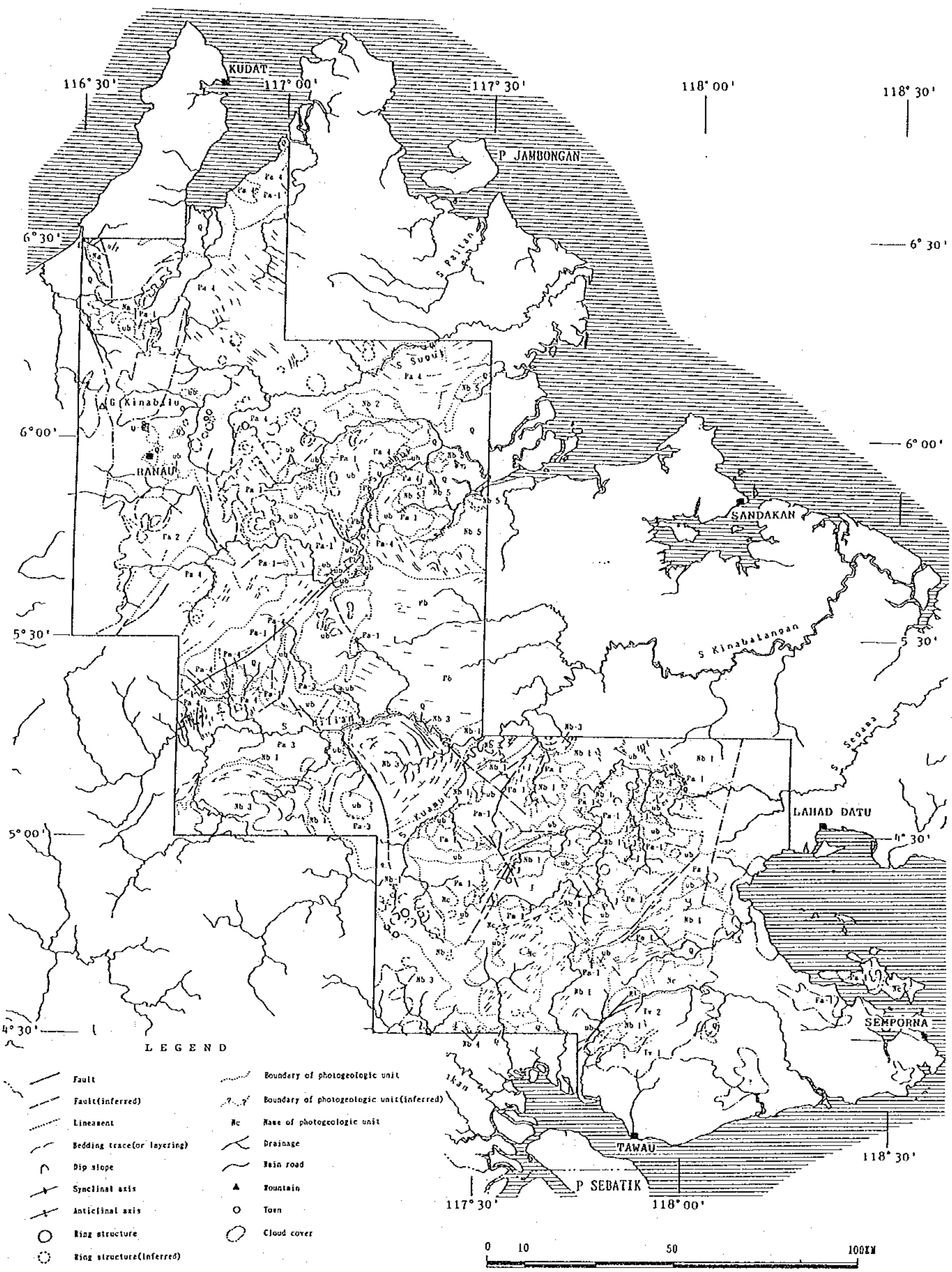

Fig. II-2-3 Interpretation map of Landsat images of MSS data resistance against erosion. This unit corresponds to mudstone that dominate the Sapulut formation (KPSp).

Unit Pa-4 : This unit occupies a wide area from the Kinabalu area through Labuk area. Topography in this area is rough and dendritic drainage pattern can be recognized. In the northern part of the unit, bedding planes trend northwest to east and the part is characteristic of lattice drainage pattern. This unit corresponds to Crocker formation (P_2Cr) composed of flysh-type sandstone.

Unit Pb : The unit is distributed in the Labuk area in the central eastern part of the survey area. Topography in this area is rather flat. The unit does not have resistance against erosion and has lattice drainage pattern. The unit is unconformably overlaid by an upper unit. The unit correspond to the Kulapis formation (P_2Ks), consisting of red calcareous sandstone and shale.

Unit Na : The unit occupies smaller area in the western most part of the Kinabalu area. The tone in the images is characteristic of pale red and blue. Topography in the area is flat and the resistance against erosion is weak. This unit corresponds to Wariu formation (P_4Wr) and comprising of slump breccias.

Unit Nb-1 : This unit is distributed in the area from the Segama area through the west of the Semporna area. Topography in the northeast part of the Segama area is rather flat, on the other hand, topography in the west part of the area is rather rough with gentle undulation. In the western part of the Segama area, some ring structures less than 5 km in diameter can be seen. This unit is conformably overlain by the upper unit of Nb-3. The unit is correspond to the Labang formation (P_3Lb) and the Kuamut formation (P_4Km), both of which mainly composed of sandstone and mudstone.

Unit Nb-2 : This unit occupies small area in the northern part of Labuk area. Topography in this area is very rough. The unit is easely discriminated from other surrounding units from the topographical point of view. The stratigraphical relation is not interpreted from the images. The unit corresponds to the Kudat formation (P_3Kd) which mainly composed of calcareous sandstone.

Unit Nb-3 : The unit is distributed in the area from the southern part of the Labuk area through Segama area to the western part of the Semporna area. This unit has well developed beddings and forms cuesta. Ring-shaped drainage system is easily recognized. The unit corresponds to the Tanjong formation (N_2Tj) and mainly consists of mudstone and siltstone.

Unit Nb-4 : The unit occurs in a small area in the western part of the Semporna area and has the same features as unit Nb-3. The unit corresponds to the Kapilit formation (N_2Kp) consisting of sandstone and mudstone.

Unit Nb-5 : This unit is distributed along Sungai Labuk in the north of the Labuk area. Topography in this area is rather rough. Drainage system is very dense and has a pattern of parallel lines. The unit corresponds to the Bongaya formation (N_4By) consisting of sandstone.

Unit Nc : The unit is distributed in the Semporna area in the south of the survey area. Topography in this area is flat. The area is utilized for plantation. This unit is supposed to extend to the east. But the extension was not able to be confirmed due to the clouds on the images. The unit corresponds to the Kalumpang formation (N_4Kg) composed mainly of mudstone and shale.

Unit Q : The unit is distributed along the coast and in the drainage basins of main rivers. Topography in the area is quite flat. Resistance against the erosion is quite low as well. Drainage system in the area is dense and has a anastomotic and ropy shapes.

(b) Volcanic rocks

Unit Tv-1 : The unit is distributed in the Semporna area in the south of the survey area. Topography in the area is rough. The area is characteristic of radial drainage system. However, the drainage system could not be traced due to clouds cover. The unit correspond to Pliocene dacite and its pyroclastic rocks.

Unit Tv-2 : The unit is also distributed in the Semporna area. Topography in the area is rough. The area is characteristic of dense sub-dendritic drainage system. Lineaments at a smaller scale can be traced. The unit corresponds to the Pleistocene andesite lavas and andesitic pyroclastics.

(c) Intrusive rocks

Unit ub : The unit mainly distributed both in the Labuk and Segama areas. The area is characteristic of extremely rough topography except some areas of intermediate rough topography. The tone of the images in the area is greenish dark grey, which is different from the other area. Bedded structure can be partly traced. The unit corresponds to ultra-basic rocks of Cretaceous to early Tertiary age.

Unit gt : The unit is distributed in the northeastern corner of the Semporna area. The surface of the area is rather smooth. The area is characterized by the lattice pattern of drainage system and bedded structure. The unit corresponds to the rock mass which composed of Pliocene diorite, micro-diorite and micro-granite.

(2) Geological structure

The north to central part of the survey area is dominated by NW-SE to E-W trending geological structure. The direction of NW-SE gradually changes to a direction of E-W. In this area, unit Pa-4 and Pb are widely distributed. In the southern part of the survey area, Unit J, forming the basement in this area, crops out in the southern part of the Segama area. The upper units conformably overlain on Unit J and Tertiary volcanics occurs as well. Basin structure approximately 10 km in diameter is found in Unit Nb-3. Geological structure map of this area is shown in Fig, II-2-4.

The area is not prevailed by faults and lineaments. Furthermore, ruptures on a large scale such as those that controll the geological structure of this area can not be detected. The largest fault in this area is in the Labuk area and trends NE-SW. This fault puts the Unit Pa-1 in contact with the Unit Pa-3 and Pa-4. In the south of this fault, another faults trending NNE-SSW are also recognized.

In the southern part of the Segama area, the basement, Unit J, is in fault contact with other younger units. The fault trends NE=SW. Lineaments are a few km to 10 km long and indicate only structural features of each unit.

Ring structures are scattered in the entire area. The ring structure in the southern part of the Kinabalu area is the largest and is approximately 10 km in diameter. Some ring structure on a small scale related with intrusive rocks are found in and around Ranau. In the western part of the Segama area, ring structures, about 5 km in diameter, are concentrated in the area of Unit Nb-1.

Unit ub, ultra-basic rocks, occurs in a zone extending from the northwestern part to southeastern part of the area. This distribution pattern possibly indicate a structural zone of this direction. But, no structural trend can be distinguished in the images.

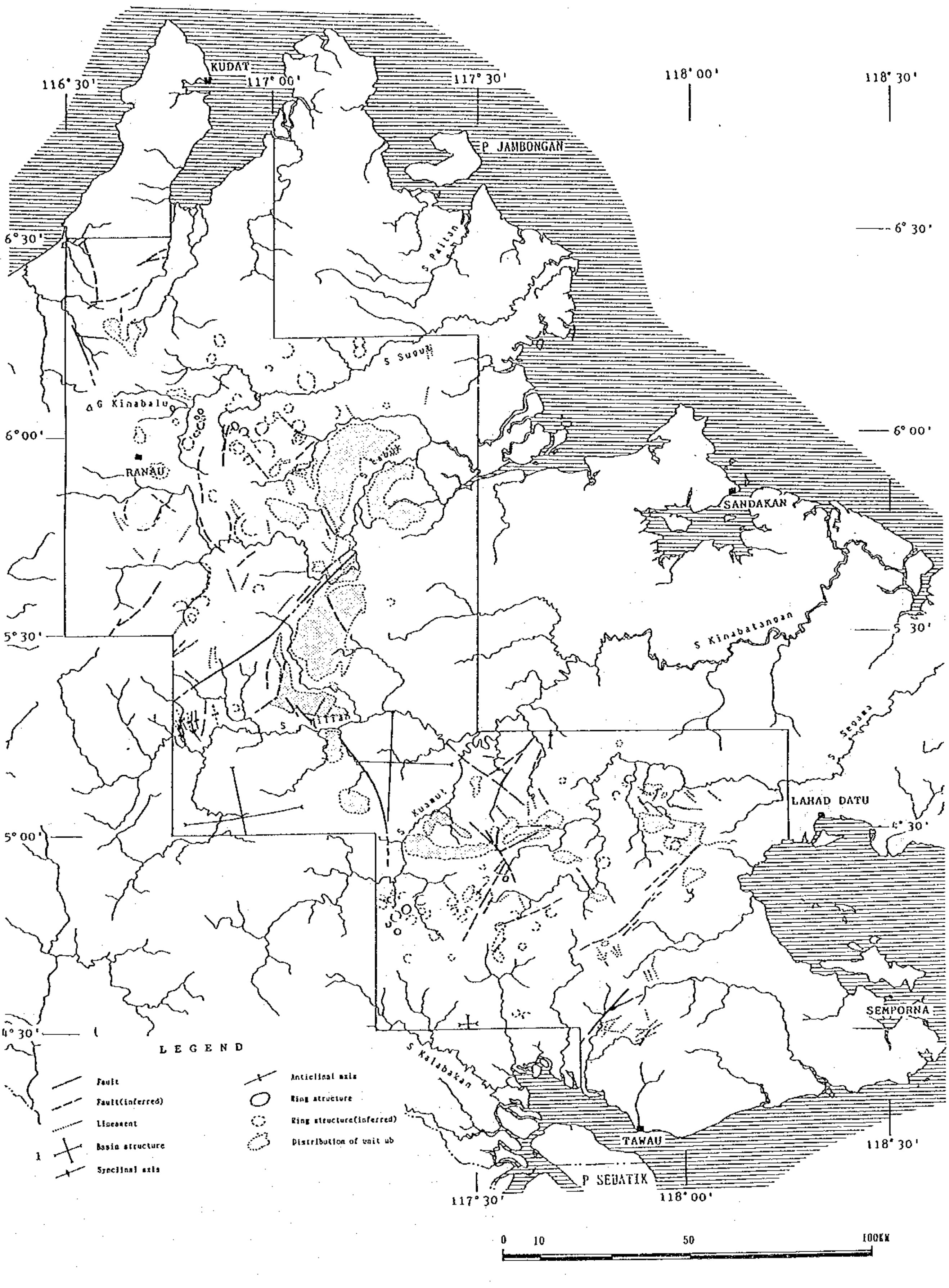

Fig. II-2-4 Geological structure map of MSS images

2-4-2 Interpretation of TM images

(1) Lithologic classification

Fifteen geological unit were classified in the area by this photogeologic interpretation at a scale of 1/100,000. The interpretation chart and the interpretation result are shown in Table II-2-3 and Fig. II-2-5 respectively.

Distributions and characteristics of each geological unit are given below. The classified units in this interpretation are basically the same as the results of interpretation for the MSS images in the previous survey, and few new geological units are discriminated in this interpretation.

(a) Sedimentary rocks

Unit Pa-1 : This unit is widely distributed over the area between central and west parts of the Labuk area and it is closely associated by Unit ub. Variable topographic features, relatively rough to intermediate, within the unit indicates that resistance against erosion is not uniform through out the area. This unit corresponds to Chert-Spilite formation (KPCs) which mainly consisting of chert, basalt and spilite.

Unit Pa-2 : This unit is distributed in thesouthwest vicinity of the Kinabalu area. A high resistance of this unit is reflected by very rough topography. The unit shows characteristics similar to those of Unit Pa-4, however, resistivity is different between them. This can be explained either by contemporaneous hetorotopic facies relation between them or by a lithologic variation within a formation. This unit corresponds to the Trusumadi formation (P_1Ts), consisting of shale and phyllite.

Unit Pa-3 : The unit is distributed over the area between the southern part of the Labuk area and the northwestern part of the Segama area. It, typically, shows very undulated, rough texture except in northwest part of the Segama area where it shows a relatively flat topography. The characteristics of the Unit Pa-3 are similar to those of Unit Pa-4. The unit corresponds to mudstone dominated Sapulut formation (KPSp).

Unit Pa-4 : This unit, characterized by rough topography and dendritic drainage pattern, occupies a wide area, from the Kinabalu area to the Labuk area. In the north part of the survey area, a continuous bedding plane with changing trend, NW-SW to E-W, and a characteristic lattice drainage pattern are observed. This unit corresponds to the Crocker formation (P_2Cr) composed of flysh-type sandstone.

Table II-2-3 Photogeological interpretation chart of TM data

Units	Color		Drainage		Morphological expression					Vegetation	Comparison with existing data
	False color	PC compressed	Pattern	Density	Rock resistance	Cross section of vallay & ridge	Texture	Bedding or schistosity	Lineament		
Qb	dark red to red	purple and creamy yellow	anastomotic	high	very low	– / –	very smooth	–	–	dense	recent alluvial clay, sand
Qa	dark red	light gray	subparallel	high	low	⌣ / ⌢	rough	–	–	dense	terrace clay, sand, gravel
Nb-5	dark red	brown and pale orange	parallel	very high	moderate	∨ / ∧	intermediate	well bedded	low	very dense	sandstone
Nb-3	dark red	brown and purple	annular	moderate to high	moderate	∨ / ∧	intermediate	well bedded	low	very dense	mudstone, siltstone
Nb-2	red	orange	dendritic	high	very high	∨ / ∧	very rough	poorly bedded	low	very dense	calcareous sandstone
Nb-1	dark red	brown	trellis	moderate	low to moderate	∨ / ∧	smooth to intermediate	bedded	low	very dense	sandstone, mudstone
Pb	dark red	brown	trellis	high	low	⌣ / ⌢	smooth	well bedded	very low	very dense	sandstone, shale
Pa-5	red	pale red	dendritic	high	low	⌣ / ⌢	smooth	bedded	low	very dense	mudstone, slump breccia
Pa-4	red to dark red	brown, orange and pale red	dendritic, trellis	very high	moderate to high	∨ / ∧	rough to intermediate	well bedded locally	low	very dense	alternation beds of sandstone and shale
Pa-3	dark red	brown	dendritic	moderate	moderate	∨ / ∧	rough and smooth	bedded	low	very dense	mudstone
Pa-2	red	pale red	dendritic	high	very high	∨ / ∧	very high	poorly bedded	low	very dense	shale, phyllite
Pa-1	red	pale red and dark red	dendritic, trellis	high to moderate	high to moderate	∨ / ∧	rough to intermediate	bedded locally	low	very dense	chert, spilite
ad	dark red	dark gray	subdendritic	high	very high	∨ / ∧	rough	–	moderate	very dense	adamellite
gb	dark red	dark gray and dark red	subdendritic	moderate	moderate	⌣ / ⌢	rough	poorly layered	low	very dense	gabbro, dolerite
ub	dark brown	dark purple	dendritic	high	very high to moderate	∨ / ∧	rough to very rough	poorly layered	moderate	very dense	peridotite

Fig. II-2-5 Interpretation map of Landsat images of TM data

Unit Pb : This unit is distributed in the eastern part of the Labuk area and characterized by a relatively flat topography. A low resistance of the unit resulted in a formation of lattice drainage pattern in the area. The unit correspond to the Kulapis formation (P_2Ks), consisting of red calcareous sandstone and shale, and it has unconformable boundaries with underlying and overlying formations.

Unit Nb-1 : The unit has a restricted distribution in the northwestern part of the Segama area, and it is characterized by rather undulated, flat topography and clear beddings. It is conformably overlain by Unit Nb-3. The unit is correspond to the Labang formation (P_3Lb) and the Kuamut formation (P_4Km), both of which are mainly composed of sandstone and mudstone.

Unit Nb-2 : This unit, characterized by a very rough topography, occupies a small area in the eastern part of the Kinabalu area. Although the topographic features easily separate this unit from the surrounding unit, its stratigraphic relations with other units are not known from interpretation of the images. The unit correspond to the limestone-dominant Kudat formation (P_3Kb).

Unit Nb-3 : The unit, showing clear bedding and questa, is distributed in the southern part of the Labuk area. An annular drainage system, reflecting geological structure of the area, is the characteristic drainage system of the unit. The unit correspond to the Tanjong formation (N_2Tj) which composed of mudstone and siltstone.

Unit Nb-5 : This unit occupies a restricted area in the northeastern part of the Labuk area. An annular drainage system, reflecting geological structure of the area, is the characteristic drainage system of the unit. The unit corresponds to the Bongaya formation (N_4By) which composed of sandstone.

Unit Qa : The unit is found on slopes of mountains in the northeast of Ranau, Kinabalu area. It shows a relatively rough texture of low resistance. The unit corresponds to Pinosuk Gravels of glacier deposits.

Unit Qb : The unit is distributed along coast lines and main drainages. It shows very flat topography and very low resistance. A drainage pattern of the unit is anastomotic and its density increases close to coast lines.

(b) Intrusive rocks

Unit ub : This unit is widespread in the Labuk area and it shows scattering distribution around Ranau of the Kinabalu area. Very rough topography is the characteristic feature of the unit, however, it shows an intermediate roughness in certain part of the unit and locally layered structure is observed. It shows a characteristic tone on the images, dark brown on false color images and dark purple on principal component compressed images. The unit corresponds to the ultrabasic rocks of Cretaceous to early Tertiary age.

Unit gb : This unit is distributed in northwest and southwest of Telupid in the Labuk area and in southeast of Ranau in the Kinabalu area. It is characterized by a topography of intermediate roughness and relatively rounded ridge pattern. A layered structure is, locally, observed. The unit corresponds to the gabbro and dolerite of Cretaceous to early Tertiary age.

Unit ad : A scattered distribution of the unit is found in north of Ranau in the Kinabalu area. It is characterized by a rough topography and a dark tones. A few lineaments are locally found. The unit correspond to the adamellite intrusive bodies of middle to late Tertiary age.

(2) Geological structure

Based on the results of this interpretation, a geological structure map is illustrated as shown in Fig. II-2-6. The geological structure are summerized as follows:

(a) Kinabalu and Labuk areas

Geological structure in the Kinabalu area is characterized by general trends of NW-SE and E-W which is observed in the area of unit Pa-4. This geological unit is widely found in the north and central parts of this area. The geological structure of this unit consists of synclinal and anticlinal structures, and strike-slip faults. The faults trending NW-SE, NE-SW and N-S cutting the general trends are also found in the image and forms complicated structure in the area. This geological structure is not found in the west part of the Kinabalu area, and is bounded by faults trending N-S which occurs from Bandau to 10 km east of Ranau. This fault system is a significant fault zone. This fault zone separates the Kinabalu area and each side shows completely different geological structure.

In the Labuk area, the unit ub is distributed in north and central parts of the area, the unit Pa-1 occurs from the central to the western part of the area with a direction of NE-SW, and the unit Nb-3 unconformably covers these units. These

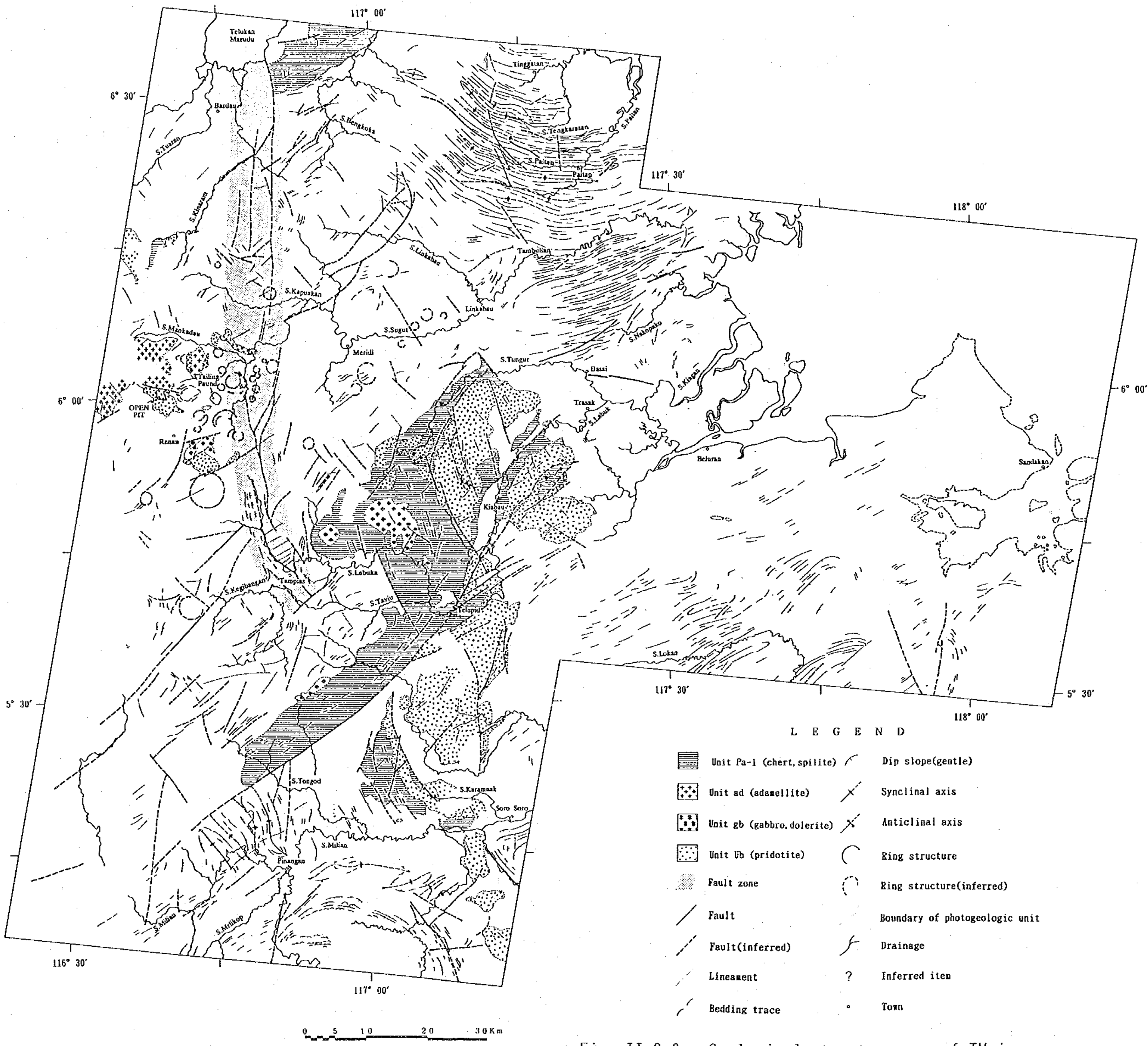

Fig. II-2-6 Geological structure map of TM images

distributions give complicated structure in this area. General trend of NE-SW is dominated in the north and central parts of the area where units ub and Pa-1 are distributed. In these parts, fault systems of NE-SW, N-S and NW-SE are also observed. In the south part of the area, basin structure is observed in the area where geologic unit Nb-3 occurs. This structure which continue further south, outside of the survey area, is gentle and 10 km in diameter. The unit Nb-3 unconformably covers the undelying units and shows different geologic structure to the underlying units. Consequently, this basin structure is thought to be formed in a later stage, when compare to the structure observed in the north and central parts of the area.

(b) Ranau and the surroundings

A significant fault trending N-S is found approximately 10 km east of Ranau. This fault separated the area to different geological settings. Mineral deposits represented by Mamut mine is found in the west side of this fault and no mineral deposits is known in the east side of this fault. The Mamut mine area is in the area of unit Pa-4 and shows complicate structure because of intruded or emplaced rocks, such as adamellite and ultra-basic rocks, corresponding to the geological units of ad and ub. Many ring structures, several km to 10 km in diameter, are found in the area of unit Pa-4. Existing geological maps indicate that some of the ring structure corresponds to the granodiorite stocks, and these ring structures characteristically align along the N-S trending fault. Although intrusives are not observed in some ring structures, these ring structures are possibly retated to subsurface intrusive bodies. Units ad and ub are not recognized at the east side of this N-S trending fault, and only faults and lineaments are found within the unit Pa-4.

(c) Bidu Bidu Hill and the surroundings

Fault system trending NW-SE is dominated in the Bidu Bidu Hill area. Among these fault, shape of the fault and distribution of geological units suggest that the fault bounding the unit ub and Pa-1 is thrust fault. This characteristic features are also found along Sungai Labuk which is widely covered by alluvium. Faults trending NNW-SSE are also found in the area of unit ub. NW-SE trending lineaments are observed in the Bidu Bidu Hill ore deposit area which is situated in a area of unit Pa-1. Geological unit corresponding to micro-gabbro from to existing geological map, is discriminated on the image in this area. Although the unit ub shows rough and massive topography in general, layered structure trending NE-SW is observed in small area in the east of the Bidu Bidu Hill ore deposits.

Chapter 3 Heliborne geophysical survey

3-1 Coverage of work

Heliborne geophysical surveys, consisting of magnetics and gamma-ray radiometrics, were carried out, in order to identify the distribution of magnetic and radiometric rocks and to observe magnetic anomalies caused by mineralization and alteration. The areas are shown in Fig. II-3-1.

In Phase I and II, the data acquisition work in six areas, Northern Kinabalu, Southern Kinabalu, Labuk, Segama, Nothern Semporna and Southern Semporna, were completed. The surveyed areas covered about 13,350 km^2 in total and the line lengths flown is 27,578.4 line-km in total.

In Phase I, magnetic susceptibilities and radioactivities were measured at 106 points where representative rock and ore samples crop out, in order to use these data for interpretation. In Phase II, representative rock samples in the Segama and Semporna areas were collected for the measurement of magnetic susceptibilities and radioactivities.

3-2 Methodology and work amounts

(1) Specification

Specifications of the heliborne geophysical survey are as follows:

①	Method	Heliborne geophysical survey
②	Items	Total intensity of geomagnetic field Gamma-ray radiometrics (U, Th, K, and Total count)
③	Flight level	150 ± 30 metres terrain clearance Magnetometer Sensor 150 m terrain clearance Spectrometer Sensor 180 m terrain clearance
④	Line spacing	Traverse line 500 m Tie line 10 km
⑤	Equipment	Equipment used are shown in Table II-3-1.
⑥	Navigation	GPS (Global Positioning System)
⑦	Traverse ground speed	Approximately 75 knots (135 km/h)

The geomagnetic field in the general area has a total intensity of about 36,000 nT, an inclination of 6 ° to 8 ° south and a declination of 1 ° east of south.

The methods of the data processing are same for these six areas.

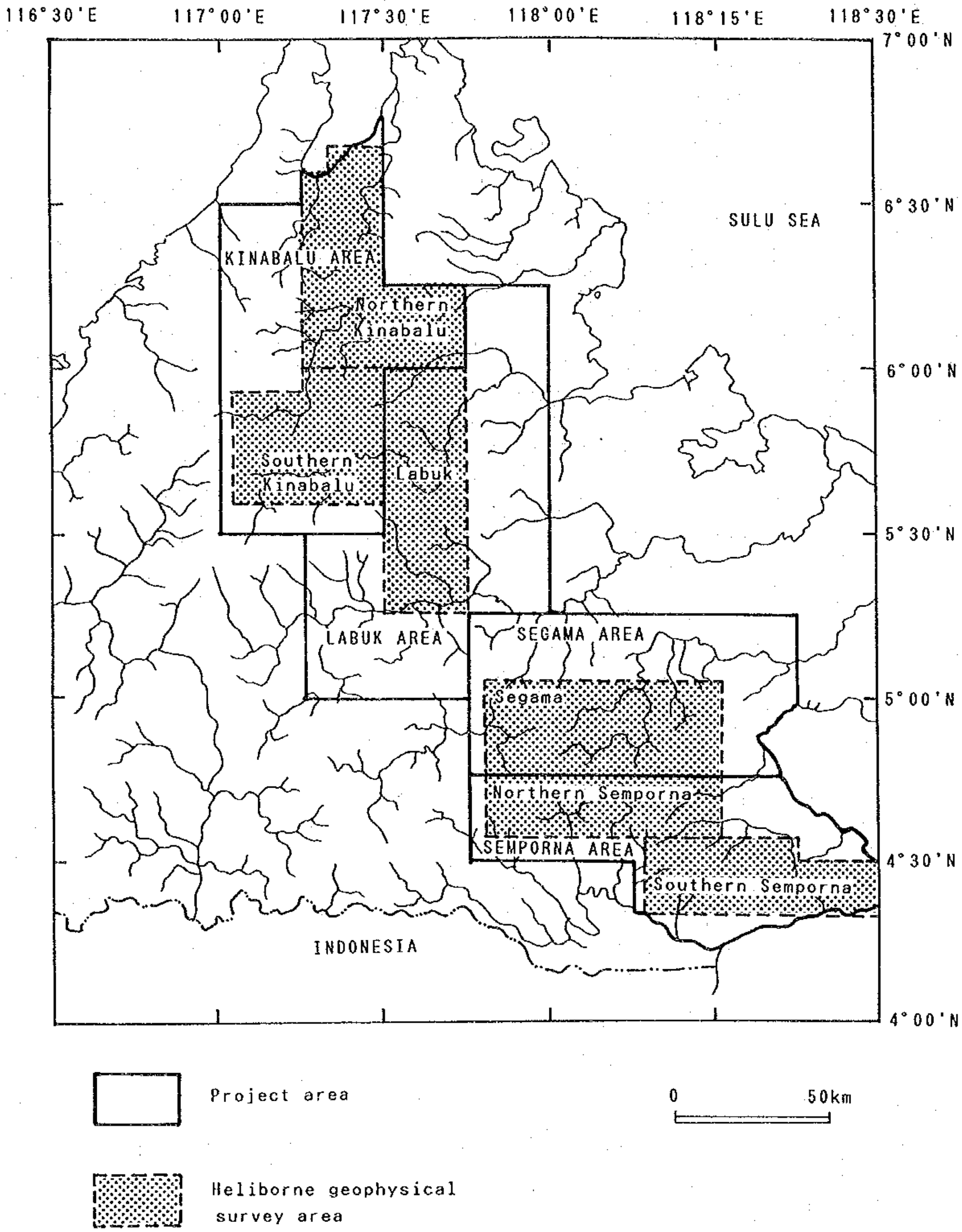

Fig. II-3-1 Location map of heliborne geophysical survey area

Table II-3-1 Specification of heliborne geophysical survey instruments

Name	Model	Manufacturer(Country)	Specifications
Airborne Magnetometer Cesium Magnetometer Sensor	HSM2 V1W2321H8	IFG/Aerodat(Canada) Scintrex(Canada)	Resolution; 0.001 nT Sensitivity; 0.005 nT, Range; 20,000 - 100,000 nT
Spectrometer	Pgam6000/ Pgam6100/ Pgam6500	Picodas Group (canada)	Crystal volume; 32.7ℓ (downward), 4.1ℓ (upward) Crystal resolution; >12 %, Range; 0.1 - 3.0 meV/256 ch, 0.1 photopeak resolution Window; / Lower Limit / Higher Limit Bi(upward) 1138 1154 Total(upward) 1034 1233 Tl208(downward) 201 233 Bi214(downward) 138 154 K40(downward) 113 129 Total(downward) 034 233
Data Acquisition System/ Graphic Recorder	DGR33	RMS Instruments Ltd. (Canada)	Analog Inputs; 32, Analog Input Range; ±10V, Chart Resolution; 4x4 dots/mm, Chart Sensitivity; 10 mV/cm to 10 V/cm Interface; RS-232-C x 4 ports Data Sample Rate; 10/sec Event Markers, Manual Fiducial Mark 5/sec Magnetometer, Navigation 1/sec Spectrometer
Cartridge Tape Recorder	TCR12	RMS Instruments Ltd. (Canada)	Recording Density; 6400 BPI Recording Capacity; 11.7 MBytes
Station Magnetometer	M234	Barringer Research (Canada)	Sampling Rate; 1 sec, Resolution; 0.1 nT Accuracy; 0.5 nT, Range; 20,000 - 90,000 nT
Radar Navigator	PNAV2001	Picodas Group (Canada)	Resolution; 0.5 m
GPS Receiver	TANS12017-10	Trimble(U.S.A.)	Accuracy; ±10 m
Barometric Altimeter	1241M	Rosemount(U.S.A.)	Relative Accuracy; ±7 ft, Resolution; ±10 ft
Radar Altimeter	KRA-10A	King(U.S.A.)	Range; 40 - 2,500 ft, Resolution; 5 ft, Accuracy; 5 %
Flight Path Recorder	AG2400 DXC101 DXF40A	Panasonic(Japan) Sony(Japan) Sony(Japan)	VHS style Video-Recorder in NTS format Video Camera Video Monitor
Helicopter	TwinStar AS355F2	Aerospatial(France)	Type; Twin-engine turbine(Allison 250-C20F) Size; 10.3 ft(H)x 42.5 ft(L)x 8.3 ft(W) Main Rotor Diameter; 35.1 ft, Useful Load; 2,928 lb(1,212 Kg)

(2) Work amounts

Work amounts for each area completed in this survey and the direction of the survey lines are as following;

Survey area	Northern Kinabalu	Southern Kinabalu	Labuk	Segama	Northern Semporna	Southern Semporna
Traverse line	E-W			N-S		
Tie line	N-S			E-W		
Line length (km)	5,655.0	4,274.5	4,554.0	5,094.0	3,800.9	4,210.3
Total line length (km)	27,578.4					
Area (km^2)	2,700	2,320	2,300	2,820	1,130	2,080
Total area (km^2)	13,350					

(3) Field survey

① Data aquisition/processing — Aerodat Limited (Canada)

② Survey period

Kinabalu area in Phase I	13th Dec. 1990 - 6th Jan. 1991
Southern Semporna area	1st Jan. 1991 - 8th Feb. 1991
Segama area	12th Feb. 1991 - 20th Mar. 1991
Labuk area	24th Sep. 1991 - 17th Nov. 1991
Southern Kinabalu area	24th Sep. 1991 - 20th Jan. 1992
Northern Semporna area	6th Jan. 1992 - 10th Jan. 1992
Northern Kinabalu area	24th Sep. 1991 - 20th Jan. 1992

③ Operation base

Kinabalu area in Phase I	Ranau in the Kinabalu area
Southern Semporna area	Tawau in the Semporna area
Segama area	Danum Valley Camp in the Segama area
Labuk area	Kundasang in Kinabalu area
Southern Kinabalu area	Kundasang in Kinabalu area
Northern Semporna area	Luasong Forest Centre in the Semporna area
Northern Kinabalu area	Kundasang and Kota Murudu in the Kinabalu area

④ Base station

An IFG-2 proton precession magnetometer was operated at each operation base to record diurnal variations of the earth's magnetic field.

3-3 Data processing

(1) Flight path

The flight path is drawn using linear interpolation between x, y positions from the navigation system. These positions are updated every second (or about 0.8 mm at a scale of 1:50,000), and expressed as UTM eastings(x) and UTM northings(y).

(2) Total field magnetics

The aeromagnetic data were corrected for diurnal variations by adjustment with the recorded base station magnetic values. Where needed, the magnetic tie line results were used to further level the magnetic data. No corrections for regional variations were applied. The corrected profile data were interpolated on to a regular grid using an Akima spline technique. A grid cell size of 100 m was used.

A magnetic anomaly due to highly magnetized prism model near the equator shows predominant negative part above a prism and small positive parts at the south and north of a prism, and extends towards east and west. Quality analysis for magnetic anomalies was made taking this characteristics of magnetic anomaly pattern into consideration. A map of total field magnetic is shown in Fig. II-3-2.

As a quantitative analysis, an automatic curve matching method by means of an electronic computer was applied to estimate quantitatively the depth, size and magnetic susceptibility of anomalous body, comparing the observed with the calculated model curves.

(3) Total count radiometrics

Four channels of radiometric data are subject to a four stage data correction process. The stages are; ① low pass filter (seven point Hanning), ② background removal, ③ terrain clearance collection and ④ Compton stripping correction.

Variations in radiometric backgrounds were removed by manual adjustments made after inspection of preliminary contour maps. The compton stripping factors used were;

alpha	0.35 (Th into U)	a	0.09 (U into Th)
beta	0.30 (Th into K)	b	0.00 (K into Th)
gamma	0.73 (U into K)	g	0.03 (K into U)

where alpha, bata and gamma are the forward stripping coefficients and a, b and g are the backward stripping coefficients. These coefficients are taken in part from the sample checks done at the start of each flight.

The altitude attenuation coefficients used were 0.0072(TC), 0.0085(K), 0.0082 (U) and 0.0067 (Th)/feet.

Radiometric data were corrected to a mean sensor terrain clearance of about 145 m. This has resulted in an amplification of the corrected count rates by factors 2.37 (Total Count), 2.77(K), 2.67(U) and 2.23(Th) from those which would be seen at the nominal survey clearance of 180 m.

The corrected data were interpolated on a square grid (grid cell size 100 m) using an Akima spline technique.

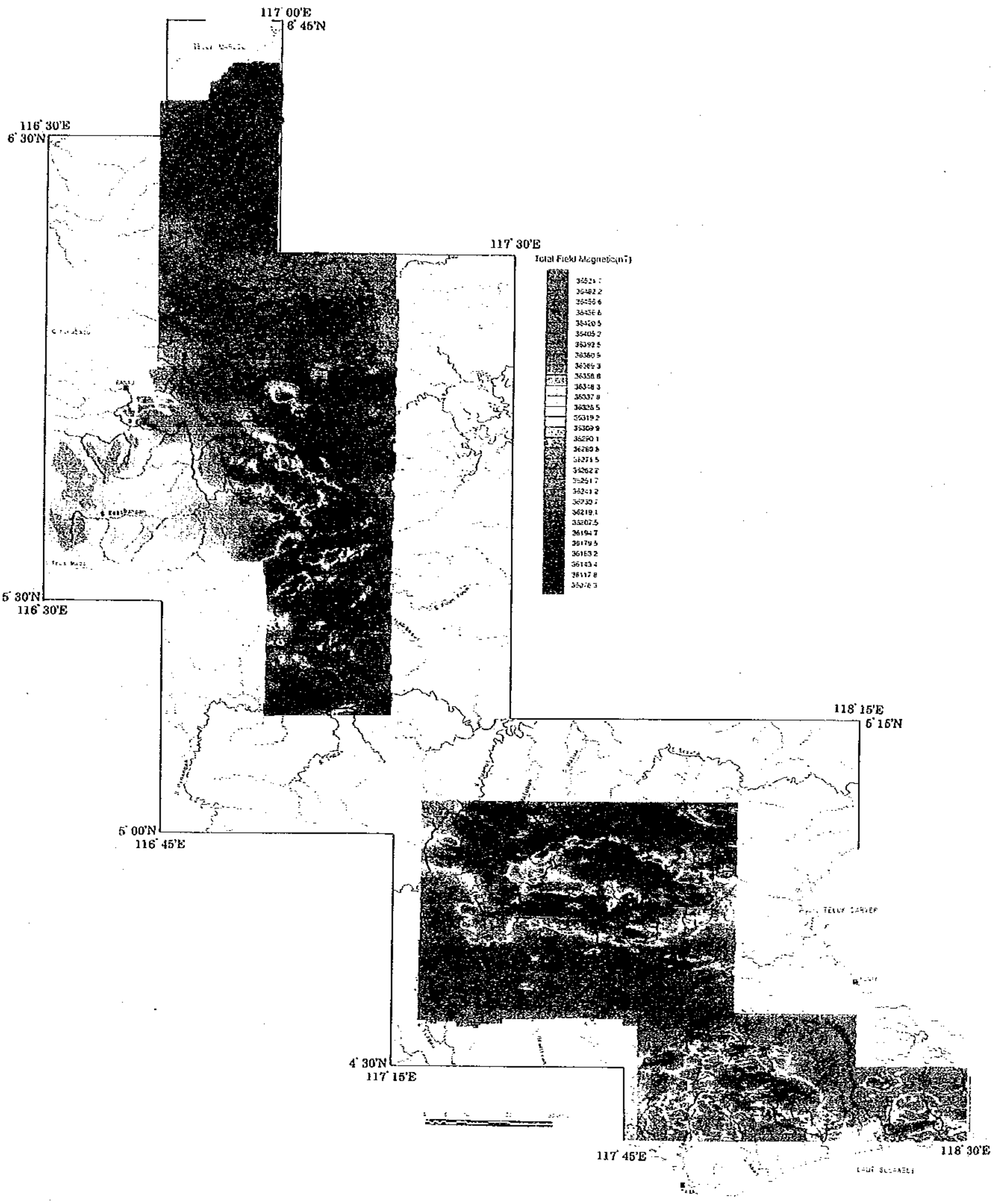

Fig. II-3-2 Total field magnetics of the survey area

The total count radiometric map is shown in Fig. II-3-3.

(4) Ternery map

The ternery map is made from the gridded pottasium, uranium and thorium data. Each data type is assigned a color - red (potassium), yellow (uranium) and blue (thorium). The intensity of color assigned to each grid cell is varied according to relative amplitude. The highest pottasium count rates are assigned the most intense red. The lowest potassium count rates are assigned the leaser intense red - almost white. The three color maps are then printed in the same map.

Variations in color intensity on the ternery map should mimic the total count contour map. Variations in color hue are variations in the relative surface radio element geochemistry. A reddish area is relatively high in pottasium. A yellowish area is relatively high uranium. A bluish area is relatively high in thorium. In theory, the neutral color (equal relative amounts of K, U and Th) is grey to black - it is colorless.

Ternery map generated are shown in Fig. II-3-4.

3-4 Survey results

(1) Ground Survey

In Phase I, magnetic susceptibilities and radioactivities were measured at 106 points, and the results were classified into 24 kinds of rocks. Rocks of high magnetic susceptibility of more than 10^{-3}CGSemu are gabbro, serpentinite, basalt, andesite, amphibolite, biotite hornfels, adamellite, granodiorite and tuff, which will induce magnetic anomalies of large amplitudes on the total field magnetics maps. High count radiometric rocks of more than 100 cps are sandstone, shale, biotite hornfels, adamellite and granodiorite, which will generate high-count radiometric anomalies on the total count radiometrics maps.

High magnetic and high count rocks such as biotite hornfels, adamellite and granodiorite will cause large-amplitude magnetic anomalies and high-count radiometric anomalies at the same locations.

In Phase II, 102 samples were collected in the Segama and Semporna areas for measuring the magnetic susceptibilities and radioactivities.

The magnetic susceptibilities show the similar results as those in Phase I survey. Amphibolite, shale, gneiss, granodiorite, dolerite, andesite and basalt show high magnetic susceptibility of more than 10^{-3}CGSemu, which will induce

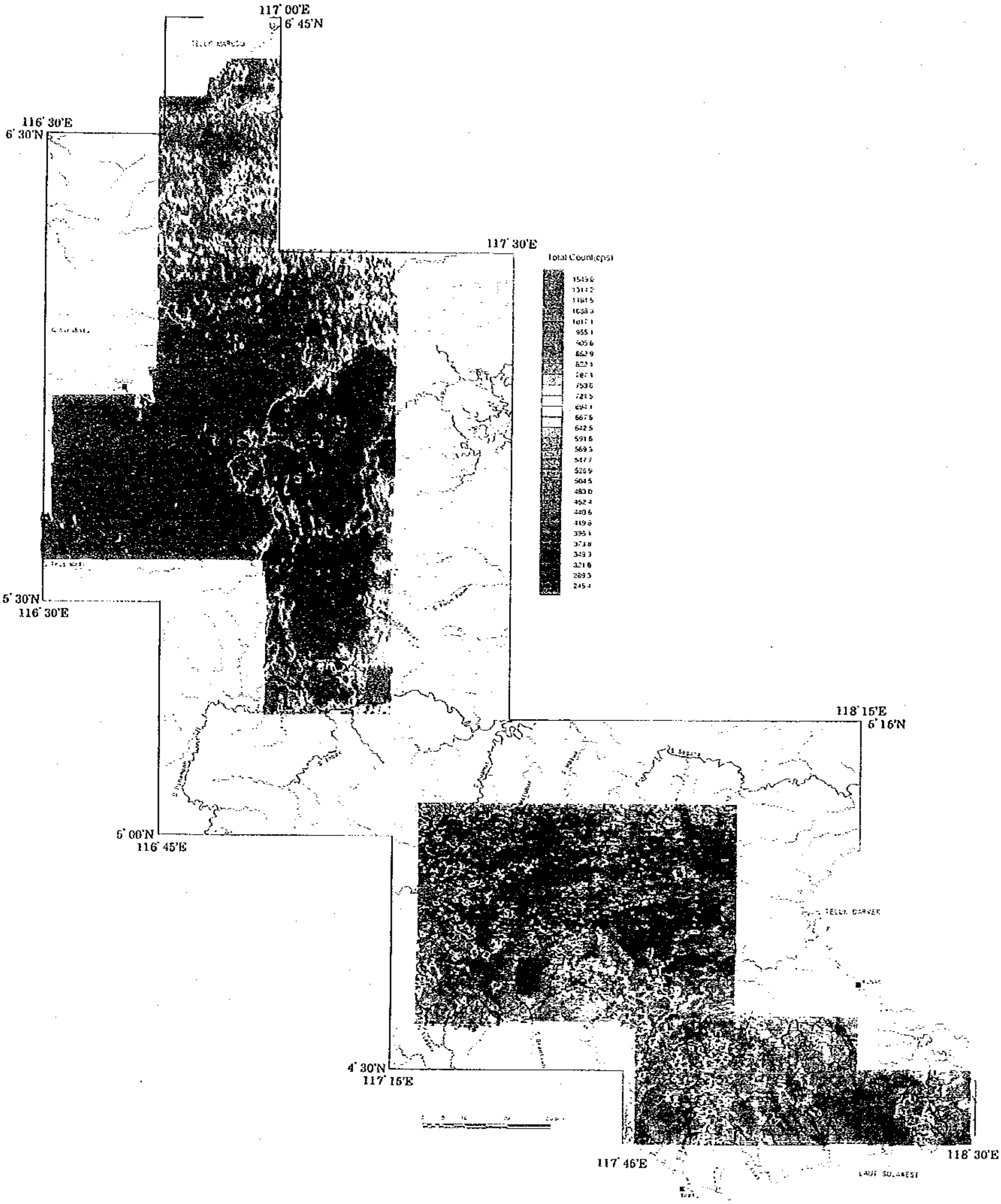

Fig. II-3-3 Radiometric total count of the survey area