No. 23

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

(PHASE II)

(Investigation of Locality of Mineral Occurrence)

FEBRUARY, 1992

JAPAN INTERNATIONAL COOPERATION AGENCY

METAL MINING AGENCY OF JAPAN

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PREFACE

The Government of Japan, in response to the request of the Government of Malaysia, has decided to conduct a mineral exploration programme in the State of Sabah, Malaysia and has entrusted the survey work to the Japan International Cooperation Agency. The Agency, considering the importance of technical nature of the survey work, in turn, has sought the cooperation of the Metal Mining Agency of Japan to accomplish the work.

The survey work in the survey area will be carried out within a period of four years commencing from 1990.

Metal Mining Agency of Japan dispatched the survey mission consisting of seven members to the Sabah from July, 1991 to January, 1992 as a part of the survey work in the second fiscal year.

The survey work in Sabah was carried out successfully with cooperation of the Malaysian Government authorities, the Geological Survey Department (Geological Survey of Malaysia), Ministry of Primary Industries.

This report summarizes the result of the investigation of the localities of mineral occurrence among the survey work carried out in the second fiscal year and also forms a part of the final consolidated report which will be submitted to the Government of Malaysia after completion of the survey work.

We wish to take this opotunity to express our heartfelt gratitude to the officials of the Government of Malaysia, Ministries of Foreign Affairs and International Trade and Industry of Japan, the Embassy of Japan in Malaysia, the Consulate of Japan in Kota Kinabalu, Sabah, and the authorities concerned.

February, 1992

Kensuke Yanagiya

President

Japan International Cooperation Agency

Genichi Fukuhara

President

Metal Mining Agency of Japan

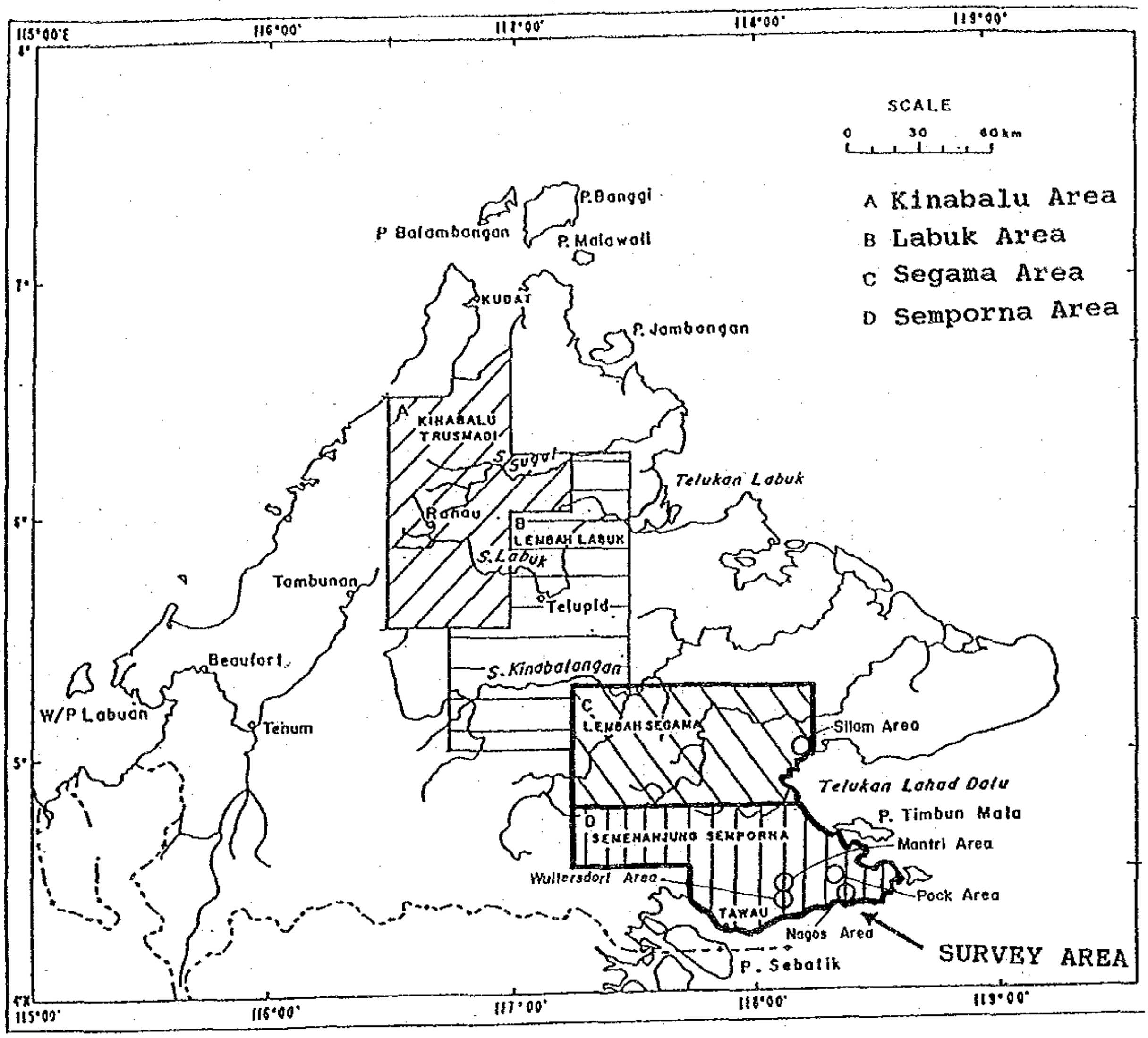

Figure 1 Location Map of Survey Area

SUMMARY

The mineral exploration programme has been carried out in the state of Sabah, Malaysia since 1990 in response to the request of the Government of Malaysia.

The investigation of the localities of mineral occurrence and indoor experiment and chemical analysis of the samples taken in the survey area at the time of the investigation have been carried out as a part of the survey work in the second fiscal year from August, 1991 to February, 1992.

The investigation of the localities of mineral occurrence in the Segama and Semporna regions during August 19 to October 5, 1991 and the additional work at the Sabah office of Geological Survey of Malaysia in Kota Kinabalu during October 6 to October 12, 1991 were carried out by one Japanese geologist.

The contents of the investigation of the localities of mineral occurrence and the indoor experiment·chemical analysis carried out in order to explore and assess the mineral potential of the survey area (Segama and Semporna regions) in Sabah, through understanding geology and mineralization at the localities of mineral occurrence which are found in the survey area and then clarifying the characteristic of the mineralization in the survey area are as follows.

1. The investigation of the localities of mineral occurrence in the field

   Fifty-five localities of mineral occurrence in total, nine in the Segama and forty-six in the Semporna regions, were investigated.

2. Indoor experiment and chemical analysis

   (1) K-Ar age determination (20 samples)

   Twenty samples of representative igneous rock which is distributed in the survey area were dated by means of whole rock K-Ar method.

(2) Chemical analysis of rock (40 samples)

Forty samples of rock in total, twenty same samples as those for K-Ar dating and twenty samples of representative rock at the main localities of mineral occurrence, were chemically analyzed.

(3) Microscopic observation of thin section of rock (40 samples)

Forty thin sections made from the same samples of rock as those for chemical analysis were observed under a microscope.

(4) Assay of ore (50 samples)

Fifty samples of ore taken at forty-seven localities of mineral occurrence out of fifty-five localities investigated were assayed.

(5) Microscopic observation of polished section of ore (30 samples)

The polished sections made from thirty samples of representative ore out of fifty ore samples for chemical analysis were observed microscopically.

(6) X-ray diffraction examination of hydrothermally altered rock (40 samples)

The X-ray diffraction examination of forty samples of hydrothermally altered host rock taken at and around the localities of mineral occurrence in the Semporna region was conducted in order to identify hydrothermal alteration mineral in the hydrothermal alteration zone.

(7) Measurement of the homogenization temperature of fluid inclusions in quartz (20 samples)

Homogenization temperature of fluid inclusions in quartz taken from quartz veins at twenty localities of mineral occurrence in the Semporna region was measured.

As a result of the investigation of the localities of mineral occurrence and indoor experiment·chemical analysis mentioned above, low grade gold-bearing quartz vein or network in the Mantri area and the part of the Nagos area, the mineralization which seems to be the indication of stockwork deposit accompanying, in general, Cyprus type cupriferous massive iron sulfide deposit upwards and chromite ore embedded in ultramafic rock in the Silam area, Segama region were confirmed.

Judging from the above result of the survey, it seems that base metal deposit with possibility of discovery in the future in the Segama and Semporna regions is, firstly, epithermal gold-bearing quartz vein or network, which is embedded in volcanic and pyroclastic rocks of the Miocene to Pliocene age, formed by intermediate to alkaline hydrothermal solution related to the volcanic activity of Miocene to Pliocene in age.

Secondarily, it seems that there is a possibility of the emplacement of Cyprus type cupriferous massive iron sulfide deposit, which is expected to be embedded in spilite of the Chert-Spilite Formation or along the boundary between spilite and overlying chert or shale, in the Silam area, Segama region.

The investigation of the localities of mineral occurrence and indoor experiment·chemical analysis, that is, K-Ar age determination of rock, chemical analysis of rock, microscopic observation of thin section, chemical analysis of ore, microscopic observation of polished section, X-ray diffraction examination, and measurement of homogenization temperature of fluid inclusion, of the samples taken at the time of the investigation conducted in the Segama and Semporna regions in 1991, have revealed the followings.

(1) Localities of mineral occurrence which seem to be the indication of the Cyprus type cupriferous massive iron sulfide deposit were confirmed in the Segama region.

(2) Metal deposit in the Semporna region is epithermal gold quartz vein and network formed by intermediate to alkaline hydrothermal fluid related to the volcanic activity of the Miocene to Pliocene age.

(3) The hydrothermal alteration related to the gold mineralization is different in different areas.

(4) The homogenization temperature of fluid inclusions in quartz taken from gold-bearing quartz vein in the Mantri area, Semporna region, is close to

the formation temperation of the majority of epithermal gold deposits which are distributed in the circum-Pacific area.

As mentioned above, some fruits have been obtained by the survey in the Segama and Semporna regions in 1991. Therefore, it is recommended that the survey in the Kinabalu and Labuk regions in 1992 should be conducted by means of the same methods as 1991.

It is also recommended to carry out the following survey and prospecting in the Semporna peninsula region in the future.

(1) Drilling to search for higher grade gold-bearing quartz vein of the bonanza type which is expected to be emplaced below the network orebody of low grade in the Mantri area.

(2) Drilling to search for the stockwork type or bonanza type ore deposit which is expected to be emplaced below the silicified zone in the Nagos area.

(3) Detailed geological mapping and investigation of the hydrothermal alteration zone in the area, where hydrothermally altered volcanic and pyroclastic rocks are distributed in the Semporna peninsula region, other than Mantri, Wullersdorf, Pock and Nagos areas.

In case the hydrothermal alteration zone is confirmed, the following survey as the next step is recommended.

a) Geochemical prospecting of soil for gold
b) X-ray diffraction examination of hydrothermally altered rock
c) Measurement of homogenization temperature of fluid inclusion in quartz
d) K-Ar dating and chemical analysis of rock
e) Microscopic observation of rock

Secondarily, the detailed geological mapping of the Chert-Spilite Formation in the Silam area, Segama region is recommended in order to find a indication of Cyprus type cupriferous massive iron sulfide deposit.

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PART I THE GENERAL

CHAPTER 1 INTRODUCTION

1-1 Progress of the Survey

In response to the request of the Government of Malaysia, the Government of Japan decided to conduct a mineral exploration programme, which will be carried out within a period of four years commencing from 1990, in the State of Sabah, Malaysia, in order to explore and assess the mineral potential of the survey area.

The digitizing of the topographical and geological maps, 1:500,000 in scale respectively, of the survey area and topographical data, 1:50,000 in scale, of the detailed survey area and drawing of the superimposed bird's-eye views synthesized by the digitized topographical and geological data of the survey area and by the digitized topographical and Landsat image data of the detailed survey area as well as collection, compilation and analysis of the existing data on geological survey, investigation of the mineral deposit and occurrence, and prospecting which were carried out in the survey area were done from October, 1990 to February, 1991 as a part of the survey work in the first fiscal year.

The work for collection, compilation and analysis of the existing data was carried out at the Sabah office of Geological Survey of Malaysia in Kota Kinabalu, Sabah, for sixty days from October 7, 1990 to December 5, 1990.

1-2 Conclusion and Recommendation Based on the Survey in the First Fiscal Year

1-2-1 Conclusion

As the result of the analysis of the existing data collected, it seems that the base metal deposit with high possibility of its existence in Sabah is, firstly, Cyprus type cupriferous massive sulfide deposit similar to the West-Sualog deposit, which was prospected by drilling after discovery by drilling in 1982 and is under feasibility study, in the Bidu Bidu Hills area in central Sabah. The West-Sualog deposit is associated with ophiolitic rocks belonging to the Chert-Spilite Formation of the Cretaceous to Eocene age. The foot wall rock of the West-Sualog deposit is basalt and the hanging wall rock is shale. As the Chert-Spilite Formation has an comparatively extensive distribution in Sabah, it is possible that the West-Sualog type massive sulfide deposit is found associated with ophiolitic rocks belonging to the Chert-Spilite Formation.

Secondarily, it is possible that the porphyry copper type deposit might be found. Exploration for the porphyry copper deposit has been carried out considerably in the Kinabalu area around the Mamut Mine compared with other areas. It seems that the areas, where the porphyry copper type deposit occurs with high possibility, after the Kinabalu area, are the Gunung Pock area and the Bukit Mantri-Gunung Wullersdorf area in the Semporna Peninsula. Although the outcrop of the porphyry copper deposit has not been found in both areas, the small to very small veinlets consisting of sphalerite, galena, chalcopyrite and quartz are found in the silicified dacite and andesite of the Pliocene age. In the Gunung Pock area, microdiorite intrudes into dacite. Dacite and andesite have undergone hydrothermal alteration such as chloritization, epidotization, carbonatization, sericitization, pyritization, kaolinization as well as widespread silicification.

The mineral assemblage consisting of chlorite, epidote and carbonate possibly suggest "propylitic zone" which consists of chlorite, epidote, carbonate, adularia and albite and is distributed in the outermost zone of hydrothermal alteration zone associated with some porphyry copper deposits. The mineral assemblage of quartz, kaolin and chlorite possibly suggest "argillic zone" which is distributed in the inner part than propylitic zone. The mineral assemblage of quartz, sericite and pyrite maybe suggest "phyllic zone" which is found in the inner part than propylitic zone and argillic zone.

Small veins to veinlets consisting chalcopyrite, spalerite, galena and quartz possibly correspond to veins or veinlets which are distributed in the inner part than veins zone in "peripheral zone", in which chalcopyrite, sphalerite, galena, gold and silver are found, of some porphyry copper deposits.

Consequently, it is possible that the porphyry copper type deposit is emplaced underground together with the related acidic to intermediate intrusive rock, and it seems that zinc-lead-copper mineralization and hydrothermal alteration possibly suggest the indication over or around the porphyry copper type deposit emplaced underground.

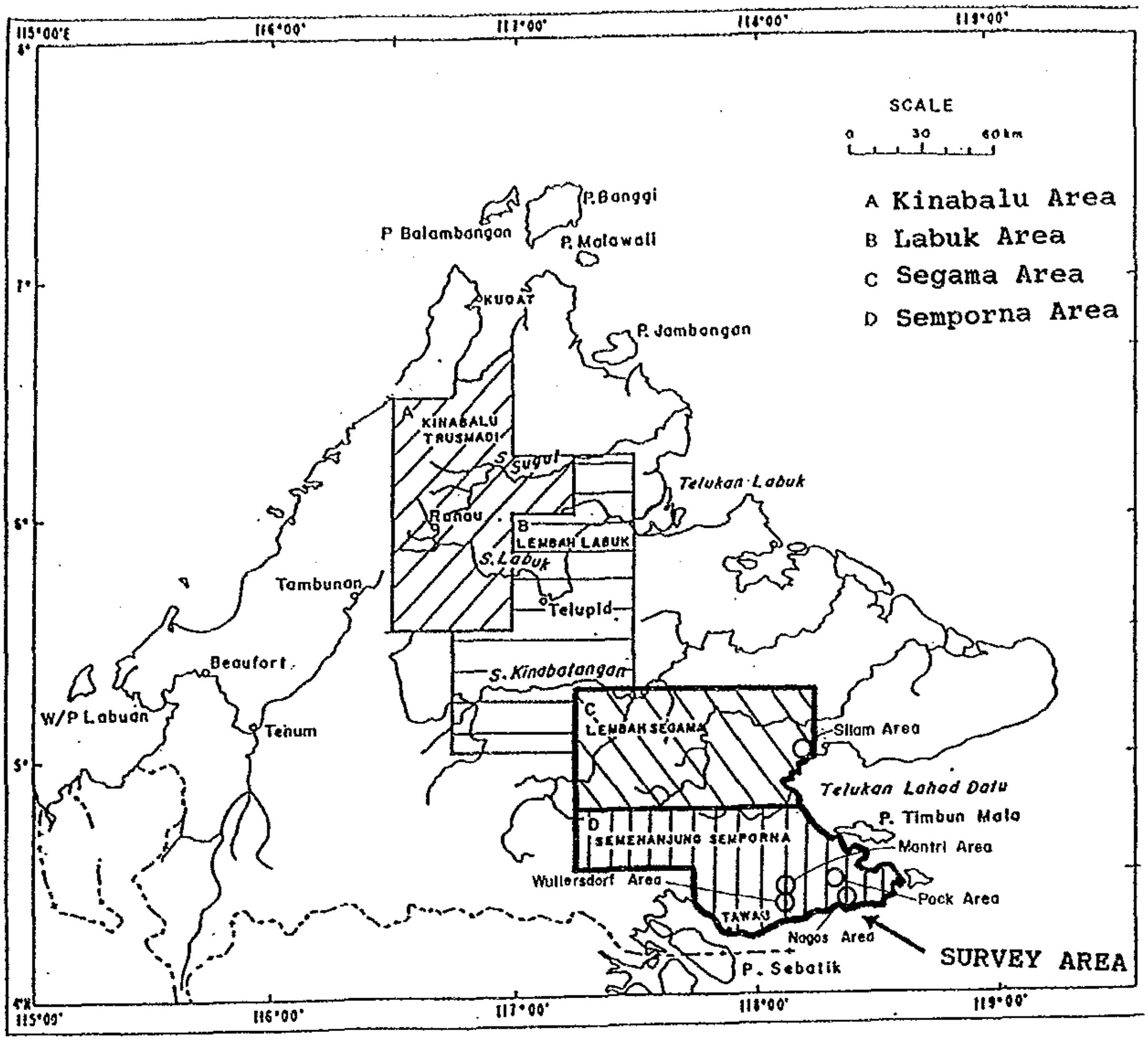


Figure I-1 Location Map of Survey Area

1-2-2 Recommendation

Although many prospectings have been conducted in the survey area up to date and have resulted in discovery of many encouraging prospects, it is difficult to evaluate all the survey area synthetically because method and precision of prospecting are various.

Consequently it is recommended, firstly, that geochemical prospecting based on the same standard should be conducted in the survey area in order to evaluate all the area synthetically. It is desirable to carry out simultaneously geological mapping in the same area as covered by geochemical prospecting to analyze the result of geochemical prospecting effectively.

As the next step, detailed prospecting in the encouraging prospect found by geochemical prospecting is desirable. It is inferred that the area, where Chert-Spilite Formation accompanied by ophiolite is distributed, and Gunung Pock and Bukit Mantri-Gunung Wullersdorf areas are promising at present.

1-3 Outline of the Survey in the Second Fiscal Year (1991)

1-3-1 Survey Area

The survey work for 1991 was carried out in Segama and Semporna regions shown in the Fig. I-1.

1-3-2 Objective of the Survey

The main objective of the survey in 1991 is to explore and to assess the mineral potential of the survey area (Segama and Semporna regions) in Sabah, through understanding geology and mineralization at the localities of mineral occurrence which are found in the survey area and then clarifying the characteristic of mineralization in the survey area.

1-3-3 Members of the Survey Mission

Participants in planning and negotiation and survey members for the second fiscal year (1991) are as follows.

(1) Participants in Planning and Negotiation

a) Malaysian members

D. Lee Tian Choi	Geological Survey of Malaysia, Sabah
Lim Peng Siong	"
Alexander Yan Sze Wah	"

b) Japanese member

Kenzo Masuda	Metal Mining Agency of Japan

(2) Survey Members

a) Malaysian members

Lim Peng Siong	Coordinator, Geological Survey of Malaysia
Alexander Yan Sze Wah	Chief of Counterpart, Geological Survey of Malaysia
Jadda Bin Suhaimi	Counterpart, Geological Survey of Malaysia

b) Japanese member

Shuro Matsuhashi	Chief geologist, Overseas Mineral Resources Development Co., Ltd.

1-3-4 Contents and Result of the Survey

The contents and result of the survey in the second fiscal year (1991) are as follows and quantity of the survey is shown in the following Table I-1.

Table I-1 Quantity of the Survey

Contents of the survey	Quantity
[Investigation of locality of mineral occurrence]	55 localities
[Indoor experiments · chemical analyses]	
1. K-Ar Age determination	20 samples
2. Chemical analysis of rock	
(A) Semporna region (19 constituents: SiO_2, TiO_2, Al_2O_3, Fe_2O_3, FeO, MnO, MgO, CaO, Na_2O, K_2O, P_2O_5, LOI, Ag, Au, Cu, Mo, Pb, S, Zn)	29 samples (551 constituents)
(B) Segama region (19 constituents: SiO_2, TiO_2, Al_2O_3, Fe_2O_3, FeO, MnO, MgO, CaO, Na_2O, K_2O, P_2O_5, LOI, Ag, Au, Co, Cr, Cu, Ni, S)	11 samples (209 constituents)
3. Microscopic observation of thin section of rock	40 samples
4. Chemical analysis of ore	
(A) Semporna region (7 constituents: Ag, Au, Cu, Mo, Pb, S, Zn)	42 samples (294 constituents)
(B) Segama region (9 constituents: Ag, Au, Co, Cr, Cu, Fe, Ni, Pt, S)	8 samples (72 constituents)
5. Microscopic observation of polished section of ore	
6. X-ray diffraction examination	40 samples
7. Measurement of homogenization temperature of fluid inclusion in quartz	20 samples

(1) Investigation of the Locality of Mineral Occurrence

The result of the investigation of the localities of mineral occurrence is as follows.

(A) Segama Region

The result of the investigation is summarized in the Table I-2, and the localities of mineral occurrence and geology of the Silam area, where the localities of mineral occurrence are found, are shown in the Fig. II-1-1 attached at the end of this report.

Every chromite ore body, embedded in serpentinised ultramafic rock on the coast of the Silam area and on the small island in Darvel Bay, seems to be small in scale.

Ore outcrops at four localities of mineral occurrence in the small unnamed island to the south of the Silam harbour are embedded in spilite of Chert-Spilite Formation and seem to be the indication of stockwork deposit accompanying, in general, Cyprus type cupriferous massive iron sulfide deposit upwards.

(B) Semporna Region

The result of the investigation is summarized in the Table I-2 and the localities of mineral occurrence and geology of the Mantri, Wullersdorf, Pock and Nagos areas investigated are shown respectively in the Fig. II-2-1, Fig. II-2-2, Fig. II-2-3 and Fig. II-2-4 attached at the end of this report. Forty-six localities of mineral occurrence in total, namely 19 in the Mantri, 4 in the Wullersdorf, 9 in the Pock and 14 in the Nagos area, were investigated.

Ore deposits which were confirmed in the above-mentioned four areas investigated are epithermal gold-sulfide-bearing quartz veins and networks (stockworks) which precipitated from hydrothermal solution related to the Miocene to Pliocene volcanic activity. Sulfide (mainly pyrite) has been mostly oxidized and altered limonite and hematite due to meteoric water.

Gold over 1.0 g/t have been detected from quartz veins or veinlets at six localities of mineral occurrence in the Mantri area (1.16~3.42 g/t Au) and at the N-12 locality in the Nagos area (1.18 g/t Au).

Silver over 1.0 oz/t has been detected at the M-10 locality in the Mantri area (53.4 g/t Ag). Lead or zinc over 0.5% have been detected at the M-6 locality (0.70% Zn), the M-20 locality (1.02% Pb) and the M-29 locality (0.86% Pb) in the Mantri area and the P-13 locality (0.74% Pb and 2.38% Zn) in the Pock area.

As mentioned above, the localities of mineral occurrence at which gold or lead/zinc was detected concentrate in the Mantri area.

The width of gold-bearing quartz vein is 0.2 to 1.5 meters and quartz veinlets in network are 1 to 6 centimeters wide.

Generally speaking, relatively wide quartz veins are embedded in the brecciated zone and narrow quartz veins and quartz veinlets in network occur along joint.

Quartz veins strike mainly northeast and north to north-northwest and east-west secondarily. In general, northeast direction dominates in the Mantri area and north to north-northwest in the Nagos area.

Faults trending northeast, north-south and northwest are distributed in the Wullersdorf and Pock areas (after Lim (1981) and Lee (1988)).

The host rocks were subjected to intense silicification in the Mantri, Wullersdorf, Pock and Nagos areas and, secondarily, argillization (sericitization, kaolinization), formation of orthoclase and pyritization in the Mantri area, propylitization (chloritization, albitization, carbonatization, pyritization) in the southeastern part of the Wullersdorf area and Pock area, and argillization (kaolinization, sericitization, montmorillonitization) and alunitization in the Nagos area.

Table I-2 Result of Investigation of Localities of Mineral Occurrence in Segama-Darvel Bay and Semporna Peninsula Regions

Region	Area	Location	Mineral Assemblage	Occurrence	Strike & Dip	Scale (m)	Host Rock	Alteration of Host Rock	Nature of Vein Fissure
Segama	Silam	S-1	chromite	lenticular	N60°W·70°N	L=0.6, W=0.17	serpentinite	serpentinization	
"	"	S-5	chromite	lenticular & banded		L=0.15, T=0.15	serpentinite	serpentinization	
"	"	S-6	chromite	lenticular & banded	N25E	L=0.25, W=0.12	serpentinite	serpentinization	
"	"	S-7	chromite	lenticular & banded		L=4.0, T=2.0	serpentinite	serpentinization	
"	"	S-8	chromite	banded		H=1.0+, W=0.2	serpentinite	serpentinization	
"	"	S-9	mal, az, cc, qz, cal	lenticular or vein	N40°E·60°SE	L=0.8, W=0.07	metabasalt	albitization, chloritization, epidotization	
"	"	S-19	lim	lenticular or vein	N25°E·90°	L=1.6+, W=0.35	metabasalt	albitization, chloritization, epidotization	
"	"	S-20	qz+lim	vein	N20°E·54°W	L=1.7, W=0.02~0.05	metabasalt	albitization, chloritization, epidotization	joint
"	"	S-21	qz+py·cp·mal	vein	N27°E·56°W	L=5.0, W=0.01~0.18	metabasalt	albitization, chloritization, epidotization	joint
Semporna	Mantri	M-1	qz+lim	vein	N18°E·52°E	H=2.0+, W=0.2	hydrothermally altered rock	silicification, sericitization	joint
"	"	M-3	qz·lim·hm	network		W=0.06	hydrothermally altered rock	silicification, kaolinization (sericitization)	joint
"	"	M-4	qz+lim·hm	vein	N5°W·90°	H=1.5+, W=0.25	hydrothermally altered andesitic tuff	silicification, sericitization kaolinization	brecciated zone
"	"	M-6	qz+py·sp	lenticular		L=0.35, W=0.08	hydrothermally altered rock	silicification, sericitization	
"	"	M-8	qz·lim	vein	N75°E·45°S	H=2.0+, W=0.06	hydrothermally altered rock	silicification, sericitization	joint
"	"	M-10	qz+lim·hm	vein	N75°E·65°N	L=4.0+, W=0.05~0.1	hydrothermally altered trachy andesite	silicification, sericitization, kaolinization	joint
"	"	M-16	qz+py·lim·hm	vein & network	N80°W·80°N	H=2.0+, W=0.4~0.5	hydrothermally altered andesitic tuff	silicification, sericitization	joint
"	"	M-18	qz	vein & network	N82°W·70°S	L=4.0+, W=0.02~0.1	hydrothermally altered andesitic tuff	silicification, sericitization	joint
"	"	M-19	qz	vein & network	N42°E·70°W	H=2.0+, W=0.02~0.06	hydrothermally altered rock	silicification, sericitization (kaolinization)	joint
"	"	M-20	qz+lim·hm·gn	network		H=2.0+, W=0.01~0.05	hydrothermally altered rock	silicification, sericitization (kaolinization)	joint
"	"	M-21	qz+hm·lim	lenticular & network		W=0.05	hydrothermally altered rock	silicification, sericitization (kaolinization)	joint
"	"	M-22	qz+hm·lim	vein	N5°E·80°E	H=1.2+, W=0.2~0.25	hydrothermally altered andesitic tuff	silicification, sericitization (kaolinization)	joint
"	"	M-23	qz+hm·lim	vein	N43°E·90°	H=3.0+, W=0.8~1.0	hydrothermally altered andesitic tuff	silicification, sericitization	brecciated zone
"	"	M-24	qz+hm·lim	vein	N22°W·85°N	H=1.0+, W=0.5	hydrothermally altered andesitic tuff	silicification, sericitization	joint

Region	Area	Location	Mineral Assemblage	Occurrence	Strike & Dip	Scale (m)	Host Rock	Alteration of Host Rock	Nature of Vein Fissure
Semporna	Mantri	M-25	qz+hm·lim	network	N40°E·90°	H=2.0+, W=0.04	hydrothermally altered andesitic tuff	silicification, sericitization, kaolinization	joint
"	"	M-26	qz+hm·lim	vein	N64°E·68°S	H=2.0+, W=0.12~0.3	hydrothermally altered andesitic tuff	silicification, sericitization, kaolinization	brecciated zone
"	"	M-27	qz+hm·lim	vein & network	N40°E·63°E	H=2.0+, W=0.1~0.15	hydrothermally altered andesitic tuff	silicification, sericitization	joint
"	"	M-28	qz+hm·lim	vein	N35°E·90°	H=2.0+, W=1.5	hydrothermally altered rock	silicification, sericitization, kaolinization	brecciated zone
"	"	M-29	qz+hm·gn	vein	N65°E·70°S	H=2.0+, W=0.02~0.08	hydrothermally altered rock	silicification, kaolinization, (sericitization)	joint
"	Wullersdorf	W-1	py	dissemination			propylite	silicification, chloritization, albitization, (sericitization)	
"	"	W-3	py	dissemination	N73°E	W=1.4	propylite	silicification, albitization, chloritization, sericitization	
"	"	W-4	qz·py·cm	vein & dissemination	N72°E·90°	W=0.6	hydrothermally altered rock	silicification, sericitization	brecciated zone
"	"	W-11	qz+hm·lim	vein	E-W	L=5.0+, W=2.5	hydrothermally altered rock	silicification, sericitization, kaolinization	brecciated zone
"	Pock	P-10	qz·py·cm	vein	N20°E·60°W	L=1.4+, W=0.25	hydrothermally altered rock	silicification, chloritization, sericitization	joint
"	"	P-13	qz·py·sp·gn·cm	vein	N14°W·90°	H=0.6+, W=0.05~0.08	propylite	silicification, chloritization, sericitization	joint
"	"	P-14	qz+lim	vetwork & massive			strongly silicified rock	silicification (sericitization)	joint
"	"	P-15	qz+lim·hm	vein & network	N50°E·90°	H=2.5+, W=0.35	strongly silicified rock	silicification (sericitization)	joint
"	"	P-16	qz+lim·hm·cm	lenticular		H=0.6, W=0.35	hydrothermally altered rock	silicification, sericitization	
"	"	P-20	qz·py·cm	vein	N66°E·85°N	H=1.7+, W=0.2~0.3	propylite	silicification, chloritization, sericitization	joint
"	"	P-21	qz·lim·py	lenticular		H=0.8, W=0.4	propylite	silicification, albitization, chloritization	
"	"	P-22	qz	vein	N32°W·90°	L=2.0+, W=0.06	propylite	silicification, albitization, chloritization, sericitization	joint
"	"	P-23	qz+py·lim	vein	N4°W·74°E	H=0.8+, W=0.2~0.25	propylite	silicification, albitization, chloritization, sericitization	joint
"	Nagos	N-1	qz+cm	vein	N10°W·90°	L=2.5+, W=1.3	hydrothermally altered rock	silicification, kaolinization	joint
"	"	N-2	qz·hm·lim	vein	N33°E·48°E	L=2.0+, W=0.15	hydrothermally altered rock	silicification, sericitization, kaolinization	joint
"	"	N-3	qz+hm·lim	vein	N80°W·70°S	H=1.6+, W=0.6	hydrothermally altered andesitic tuff	silicification, sericitization, kaolinization	joint
"	"	N-4	qz·hm·lim	vein	N14°W·90°	H=2.0+, W=4.0	hydrothermally altered rock	silicification	brecciated zone
"	"	N-5	qz+lim·hm·cm	vein	N20°W·90°	H=4.0+, W=3.0	hydrothermally altered rock	silicification, kaolinization	brecciated zone

Region	Area	Location	Mineral Assemblage	Occurrence	Strike & Dip	Scale (m)	Host Rock	Alteration of Host Rock	Nature of Vein Fissure
Semporna	Nagos	N-6	qz·cm	vein	N4°W·47°E	H=2.0+, W=7.0	hydrothermally altered rock	silicification, kaolinization	brecciated zone
"	"	N-7	qz·cm	lenticular		H=1.2, W=0.35	hydrothermally altered rock	silicification, kaolinization	
"	"	N-8	qz+hm·lim	network		4.0 (L) × 3.0 (W) × 2.0 (H)	strongly silicified rock	silicification	joint
"	"	N-9	qz+hm·lim·cm	network		L=4.5, W=1.5	hydrothermally altered rock	silicification, alunitization, kaolinization	joint
"	"	N-10	qz·cm+lim	vein	N4°W·70°E	H=3.0+, W=0.55	hydrothermally altered andesitic tuff	silicification, alunitization, kaolinization	fault
"	"	N-11	qz+lim·hm·py	network		W=4.0	hydrothermally altered rock	silicification, kaolinization	joint
"	"	N-12	qz+lim·hm	network	N35°E·90°	W=1.5	hydrothermally altered rock	silicification, kaolinization	joint
"	"	N-13	qz·cm+hm·lim	vein	N12°W·80°E	H=2.0+, W=1.25	hydrothermally altered rock	silicification, kaolinization	brecciated zone
"	"	N-14	qz·cm+hm·lim	vein	N12°W	H=1.0+, W=0.5	hydrothermally altered andesitic tuff	silicification, kaolinization	brecciated zone

Abbreviations:

mal : malachite, az : azurite, qz : quartz, cal: calcite, py : pyrite, cp :chalcopyrite
lim : limonite, hm: hematite (secondary), sp : sphalerite, gn : galena, cc : chalcocite, cm: clay mineral
L : horizontal length, T : thickness, H : vertical height, W : width

(2) Sampling

The samples of ore, host rock, hydrothermally altered host rock, and quartz were obtained at the localities of mineral occurrence investigated and also the samples of unaltered igneous rock typical of the each area were taken from the type localities in the each area to perform the following indoor experiments and chemical analyses. The details of the samples obtained are as follows and are shown in the Table I-3.

i) Samples of igneous rock for age determination by means of K-Ar method (20 samples)
Two samples of pillow basalt and two samples of gabbro in the ophiolite series in the Segama region, two samples of microdiorite porphyry, one sample of dacite, one sample of dacitic tuff, two samples of andesite and two samples of basalt in the Mantri-Wullersdorf area and two samples of microgranite, one sample of dacitic tuff, one sample of dacitic welded tuff, two samples of andesite in andesitic agglomerate and two samples of basalt in basaltic agglomerate in the Pock area were taken.

ii) Rock samples for chemical analysis (40 samples)
A total of forty samples, namely twenty samples from typical host rock at the main localities of mineral occurrence in addition to twenty samples from the same localities as the samples for age determination, were obtained.

iii) Rock samples for thin section (40 samples)
Forty samples were taken at the same localities as the samples for chemical analysis.

iv) Ore samples for chemical analysis (50 samples)
Fifty samples, namely ten samples in the Segama region, forty in the Semporna, were taken at the forty seven localities of mineral occurrence (seven localities in the Segama region, forty in the Semporna) out of fifty five localities of mineral occurrence investigated (nine localities in the Segama, forty six in the Semporna). Especially, sampling of ore in the Semporna region was performed in consideration of the possibility of emplacement of gold bearing quartz vein or network.

v) Ore samples for polished section (30 samples)

Thirty typical ore samples for polished section out of fifty ore samples taken for chemical analysis were obtained at the same localities as the ore samples for chemical analysis.

vi) Samples of hydrothermally altered rock for X-ray diffraction examination (40 samples)

Forty samples of hydrothermally altered host rock were taken at or near the localities of mineral occurrence in the Semporna region.

vii) Quartz samples for measurement of homogenization temperature of the fluid inclusions in quartz (20 samples)

Twenty samples of transparent to semitransparent and crystalline quartz which contain many fluid inclusions in general were taken from quartz vein at twenty localities of mineral occurrence out of forty six localities in the Semporna region.

viii) Typical samples of rock and ore for specimen (40 samples)

Typical 40 samples of rock and ore out of 240 samples taken for the various kinds of experiments and chemical analyses were obtained at the same localities.

Table I-3 List of Samples taken in Segama-Darvel Bay and Semporna Peninsula Regions

Location	Analysis of Rock	Thin Section	Dating	Analysis of Ore	Polished Section	X-ray Diffraction	Fluid Inclusion	Specimen
M-1	M-R-1-A	M-T-1		M-O-1-A		M-X-1	M-Q-1	
M-2						M-X-2		
M-3				M-O-3-A	M-P-1	M-X-3		
M-4				M-O-4-A		M-X-4		
M-5						M-X-5		
M-6				M-O-5-A	M-P-2		M-Q-3	M-Q-3-S
M-7						M-X-6		
M-8				M-O-6-A				
M-9						M-X-7		
M-9'	M-R-2-A	M-T-5				M-X-8		
M-10	M-R-3-A	M-T-6		M-O-7-A	M-P-3	M-X-9	M-Q-4	M-O-7-A-S
M-11	M-R-5-A	M-T-8	M-D-1					M-D-1-S
M-12	M-R-6-A	M-T-9	M-D-2					M-D-2-S
M-13	M-R-7-A	M-T-10	M-D-3					
M-14	M-R-8-A	M-T-11	M-D-4					M-D-4-S
M-15	M-R-9-A	M-T-12	M-D-5					
M-16				M-O-8-A	M-P-4	M-X-10	M-Q-5	
M-17	M-R-10-A	M-T-14	M-D-6			M-X-11		M-D-6-S
M-18				M-O-9-A		M-X-12	M-Q-6	M-O-9-A-S
M-19				M-O-10-A				
M-20				M-O-11-A			M-Q-8	
M-21				M-O-12-A		M-X-13	M-Q-9	
M-22				M-O-13-A				
M-23				M-O-14-A		M-X-14	M-Q-10	
M-24				M-O-15-A	M-P-5			
M-25				M-O-16-A		M-X-15	M-Q-12	
M-26				M-O-17-A			M-Q-13	
M-27				M-O-18-A		M-X-17	M-Q-14	
M-28				M-O-19-A	M-P-6		M-Q-15	
M-29				M-O-20-A	M-P-7	M-X-16	M-Q-16	
M-30	M-R-11-A	M-T-15	M-D-7					M-D-7-S
M-31						M-X-19		
Sub Total	10	10	7	19	7	18	13	8

Location	Analysis of Rock	Thin Section	Dating	Analysis of Ore	Polished Section	X-ray Diffraction	Fluid Inclusion	Specimen
W-1				W-O-1-A	W-P-1	W-X-1		
W-3	W-R-2-A	W-T-2		W-O-2-A	W-P-2	W-X-3		W-R-2-A-S
W-4	W-R-3-A	W-T-3		W-O-3-A	W-P-3	W-X-4		W-O-3-A-S
W-8	W-R-5-A	W-T-5	W-D-1					W-R-5-A-S
W-11				W-O-5-A	W-P-4		W-Q-2	W-O-5-A-S
W-12	W-R-8-A	W-T-8				W-X-9		W-R-8-A-S
Sub Total	4	4	1	4	4	4	1	5
P-1	P-R-1-A	P-T-1	P-D-1			P-X-1		P-D-1-S
P-2	P-R-2-A	P-T-2	P-D-2					
P-3	P-R-3-A	P-T-3	P-D-3			P-X-3		P-D-3-S
P-4	P-R-4-A	P-T-4	P-D-4					P-D-4-S
P-5	P-R-5-A	P-T-5	P-D-5					P-D-5-S
P-6	P-R-6-A	P-T-6	P-D-6					
P-7	P-R-7-A	P-T-7	P-D-7					P-D-7-S
P-9	P-R-9-A	P-T-9	P-D-8					
P-10				P-O-1-A	P-P-1	P-X-6		P-O-1-A-S
P-12	P-R-11-A	P-T-11				P-X-8		
P-13	P-R-12-A	P-T-12		P-O-2-A	P-P-2	P-X-9		P-R-12-A-2 P-O-2-A-S
P-14				P-O-3-A	P-P-3	P-X-10	P-Q-2	P-O-3-A-S
P-17	P-R-13-A	P-T-13						
P-19	P-R-14-A	P-T-14				P-X-15		P-R-14-A-S
P-20	P-R-15-A	P-T-15		P-O-6-A	P-P-5	P-X-16		P-O-6-A-S
P-21				P-O-7-A	P-P-6	P-X-17	P-Q-4	
P-22				P-O-8-A		P-X-18	P-Q-5	
P-23				P-O-9-A				
Sub Total	13	13	8	7	5	10	3	11

Location	Analysis of Rock	Thin Section	Dating	Analysis of Ore	Polished Section	X-ray Diffraction	Fluid Inclusion	Specimen
N-1				N-O-1-A		N-X-1		N-O-1-A-S
N-2				N-O-2-A	N-P-1	N-X-2		
N-3				N-O-3-A	N-P-2	N-X-3	N-Q-2	N-O-3-A-S
N-4				N-O-4-A	N-P-3	N-X-4		
N-5				N-O-5-A		N-X-5		
N-8				N-O-8-A	N-P-4		N-Q-4	
N-9				N-O-9-A		N-X-9		
N-10	N-R-2-A	N-T-2		N-O-10-A		N-X-10		
N-11				N-O-11-A			N-Q-7	N-O-11-A-S
N-12				N-O-12-A				
N-15	N-R-1-A	N-T-4				N-X-15		N-R-1-A-S
Sub Total	2	2	-	10	4	8	3	4
S-1	S-R-1-B	S-T-1		S-O-1-B	S-P-1			S-R-1-B-S
S-5				S-O-3-B	S-P-3			
S-5				S-O-4-B	S-P-4			
S-6				S-O-5-B	S-P-5			
S-6				S-O-6-B	S-P-6			
S-7	S-R-8-B	S-T-8		S-O-7-B	S-P-7			S-R-8-B-S S-O-7-B-S
S-7				S-O-8-B	S-P-8			S-O-8-B-S
S-8				S-O-9-B	S-P-9			
S-9	S-R-10-B	S-T-10	S-D-3	S-O-10-A	S-P-10			S-D-3-S S-O-10-A-S
S-10	S-R-11-B	S-T-11	S-D-4					S-D-4-S
S-11	S-R-12-B	S-T-12	S-D-5					
S-12	S-R-13-B	S-T-13						
S-15	S-R-16-B	S-T-16						S-R-16-B-S
S-16	S-R-17-B	S-T-17						S-R-17-B-S
S-17	S-R-18-B	S-T-18	S-D-7					S-D-7-S
S-18	S-R-19-B	S-T-19						
S-21				S-O-13-A	S-P-13			S-O-13-A-S
S-23	S-R-20-B	S-T-20						S-R-20-B-S
Sub Total	11	11	4	10 (8+2)	10	-	-	12
Total	40 (29+11)	40	20	50 (42+8)	30	40	20	40

Abbreviations; M: Mantri, W: Wullersdorf, P: Pock, N: Nagos, S: Segama

(3) Indoor Experiment and Chemical Analysis

(A) Segama Region

(i) K-Ar age determination of igneous rock

As shown in the Table II-1-4 of the Part II, two samples of metagabbro have been dated as 158±30 Ma (late Jurassic) and 210±20 Ma (early Jurassic) and two ages of 55.8±28.3 Ma (Paleocene) and 67.5±19.9 Ma (late Cretaceous) have been obtained from two altered mafic volcanic rocks.

The age of metagabbro are nearly same as those of epidote amphibolite (140±20 Ma), hornfels (160±8 Ma) and tonalite (150±6, 210±3 Ma).

(ii) Chemical analysis of rock sample

The result of the chemical analysis of eleven rock samples and C.I.P.W. Norms calculated from the analyses are shown in the Table II-1-5 of the Part II.

SiO_2 and Na_2O+K_2O of the analyses of three samples of altered mafic volcanic rock have been plotted on the $Na_2O+K_2O-SiO_2$ diagram of the Fig. II-1-8 in the Part II. The Fig. II-1-8 shows that three altered mafic volcanic rocks are situated around the boundary between alkali rock and nonalkali rock after Kuno (1966). Then, $FeO+Fe_2O_3$, Na_2O+K_2O and MgO of the same rocks have been plotted on the MFA trigonal diagram of the Fig. II-1-9 in the Part II. The Fig. II-1-9 shows that three altered mafic volcanic rocks belong to the calc-alkali rock series.

(iii) Microscopic observation of thin section of rock

The thin sections made from eleven same rock samples as analyzed chemically were observed microscopically. The result of the observation is shown in the Table II-1-6 of the Part II.

(iv) Chemical analysis of ore sample

The assay result of ten ore samples is shown in the Table II-1-6 of the Part II.

As shown in the Table II-1-6, chromite ore samples contain 19.32% to 32.42% Cr.

The ore sample taken at the outcrop of the S-9 locality which seems to be a indication of the Cyprus type cupriferous massive iron sulfide deposit contains 6.54% Cu.

(v) Microscopic observation of polished section of ore

The polished sections made from ten same ore samples as analyzed chemically were observed microscopically. The result of the observation is shown in the Table II-1-7 of the Part II.

Ore mineral of chromite ore at five outcrops is chromite. Ore minerals of the Cyprus type cupriferous iron sulfide ore consist of malachite, chalcocite, chalcopyrite and covelline.

(B) Semporna Region

(i) K-Ar age determination of rock

The result of the K-Ar age determination by means of whole rock for sixteen rock samples obtained in the Mantri, Wullersdorf and Pock areas is shown in the Table II-2-5 of the Part II.

Except for basalt, dated as 0.20±0.12 Ma, from Mt. Quoin in the Mantri area, there is no great difference in rock type and area.

Namely, the ages of andesite and andesitic tuff in the Mantri area have been determined 9.09±0.52~11.05±2.55 Ma (late Miocene) and the majority of andesite in the Pock area have been dated as 7.75±1.06 Ma (late Miocene)~13.3±0.5 Ma (middle Miocene).

The age of intermediate intrusive rock in the Wullersdorf area is 8.38±0.70 Ma (late Miocene), and two ages of 9.52±0.23 Ma (late Miocene) and 13.9±3.1 Ma (middle Miocene) have been obtained from intermediate intrusive rocks in the Pock area.

(ii) Chemical analysis of rock sample

The result of the chemical analysis of twenty-nine samples of andesite, andesitic tuff, trachyandesite, basalt, porphyrite and hydrothermally altered host rock taken in the Mantri, Wullersdorf, Pock and Nagos areas and C.I.P.W. Norms calculated from the analyses are shown in the Table II-2-6 and the Table II-2-7 of the Part II respectively.

SiO_2 and Na_2O+K_2O of the analyses of twelve unaltered rocks, namely four samples of andesite and andesitic tuff and one sample of basalt in the Mantri area, six samples of andesite in the Pock area and one sample of andesitic tuff in the Nagos area, have been plotted on the Na_2O+K_2O-SiO_2 diagram of the Fig. II-2-27. Fig. II-2-27 shows that twelve rocks belong to the nonalkali rock series after Kuno (1966).

Then, $FeO+Fe_2O_3$, Na_2O+K_2O and MgO of the same rocks have been plotted on the MFA trigonal diagram of the Fig. II-2-28 in the Part II. The Fig. II-2-28 shows that andesites in the Pock area belong to the tholeiite series and andesites and andesitic tuffs in the Mantri and Nagos areas to the calc-alkali rock series after Irvine and Barager (1971).

(iii) Microscopic observation of thin section of rock

The thin sections made from twenty-nine same rock samples as analyzed chemically were observed microscopically. The result of the observation is shown in the Table II-2-8 of the Part II.

(iv) Chemical analysis of ore sample

The assay result of ore samples taken at the forty localities of mineral occurrence, namely nineteen localities in the Mantri, four in the Wullersdorf, seven in the Pock and ten in the Nagos area, is shown in the Table II-2-11 of the Part II.

As mentioned in the above 1-3-3-(1)-(B) section, little gold (1.16~3.42 g/t Au) at six localities of mineral occurrence in the Mantri and one locality in the Nagos area, little silver (53.4 g/t Ag) at the M-10 locality in the Mantri area, lead or zinc of low grade (0.70~1.02% Pb or Zn) at three localities in the Mantri area and lead and zinc of low grade (0.74% Pb and 2.38% Zn) at the P-13 locality in the Pock area, have been detected.

(v) Microscopic observation of polished section of ore

The polished sections made from twenty samples out of forty ore samples analyzed chemically were observed microscopically. The result of the observation is shown in the Table II-2-9 of the Part II.

The Table II-2-9 shows that the main constituents of quartz vein in the Mantri and Nagos areas are quartz, goethite and secondary hematite whereas quartz (or host rock) and pyrite in the southeastern part of the Wullersdorf area and Pock area.

A little sphalerite and trace of chalcopyrite, chalcocite, covelline and galena in the sample M-P-2 of the Mantri area, trace of chalcopyrite in the sample W-P-1 of the Wullersdorf area, trace of sphalerite in the P-P-2 sample, trace of chalcopyrite and sphalerite in the sample P-P-5 and trace of chalcopyrite in the sample P-P-6 of the Pock area, were identified as accessory minerals.

(vi) X-ray diffraction examination

The result of X-ray diffraction examination of forty samples of hydrothermally altered rock taken at and around the localities of mineral occurrence, namely eighteen in the Mantri, four in the southeastern part of the Wullersdorf, ten in the Pock and eight in the Nagos area, is shown in the Table II-2-10 of the Part II.

Table II-2-10 shows that the hydrothermally altered zone in each area has a different mineral assemblage. Namely, the hydrothermal alteration minerals consist of abundant quartz, abundant - middle amount of potash felspar, middle amount - trace of sericite, kaoline and pyrite in the Mantri area, abundant quartz, abundant - middle amount of plagioclase (albite), middle amount of chlorite, middle amount - trace of sericite and a little - trace of pyrite in the south-eastern part of the Wullersdorf area and Pock area, and abundant quartz, middle amount - a little kaolinite, abundant - middle amount of alunite and middle amount - trace of montmorillonite in the Nagos area.

Therefore, the result of the X-ray diffraction examination reveals that host rock were subjected to silicification, argillization (sericitization, kaolinization, formation of orthoclase and pyritization caused by intermediate to alkaline hydrothermal solution in the Mantri area, silicification, propylitization (chloritization, albitization, pyritization) and sericitization in the southeastern part of the Wullersdorf area and Pock area, and silicification, argillization (kaolinization, sericitization, montomorillonitization) and alunitization generated by acidic hydrothermal solution in the Nagos area.

(vii) Measurement of homogenization temperature of fluid inclusions in quartz

Homogenization temperature of fluid inclusions in nineteen samples of quartz taken from quartz veins at twenty localities of mineral occurrence, namely thirteen in the Mantri, one in the Wullersdorf, three in the Pock and two in the Nagos area, were measured. However, it was impossible to measure homogenization temperature due to no fluid inclusion in one sample.

The histograms made from the homogenization temperature measured are shown in the Fig. II-2-29 to Fig. II-2-35 of the Part II.

The homogenization temperatures of fluid inclusions in thirteen samples in the Mantri area were 140° to 260°C and the temperature of 200° to 290°C was obtained from one sample in the Wullersdorf area. The temperature of three samples from the Pock area ranged from 175°C to 385°C and high temperature of 230°C to 340°C was obtained from two samples in the Nagos area.

It is impossible to discuss the homogenization temperature of fluid inclusion in quartz samples from the Wullersdorf, Pock and Nagos areas due to few samples measured.

The homogenization temperatures of fluid inclusions in quartz taken in the Mantri area are close to the formation temperature (170° to 270°C) of low sulfidation type gold deposit, after Hedenquist (1987), which has the majority of epithermal gold deposits distributed in the circum-Pacific region and is one type of the epithermal gold mineralization accompanying hydrothermal fluid related to the volcanic activity.

1-3-5 Period of the Survey

The period of the survey in Malaysia is as follows.

Travelling:	August 13-August 18, 1991
Survey work in the field:	August 19-October 5, 1991
Supplemental work in Kota Kinabalu:	October 6-October 12,1991
Travelling:	October 13-October 15, 1991

CHAPTER 2 GEOGRAPHY OF THE SURVEY AREA

2-1 Topography and Drainage System

Sabah can be divided into 4 main physiographic sub-regions, namely the Western Lowlands, the Western Cordillera, the Central Uplands and the Eastern Lowlands (Collenette, 1963), as shown on Fig. I-2.

2-1-1 Upper Segama Valley and Darvel Bay Region

The region may be divided into two main physiographic sub-regions, namely the Central Uplands and the Eastern Lowlands (after Collenette, 1962). The Segama Highlands occupies more than three-quarters of the region. The Kuamut Highlands occupies the western portion of the region. The other sub-regions, Segama Valley and Semporna Lowlands, occupy the northeastern and southeastern portions respectively (Fig. I-2).

(A) The Segama Highlands

The Segama Highlands consist mainly of rugged country built up of a variety of igneous, metamorphic and sedimentary rocks. These highlands having a pronounced east-west trend are in most cases bounded by steep scarps, most of which are probably fault scarps. Most mountains have steep slopes and narrow ridges and sharp peaks, e.g. Gunung Tribulation (4,200 feet above sea-level). Summits from 2,000 to 3,000 feet above sea level are common. Gorges, river rapids and waterfalls are abundant.

Flat areas or erosional surfaces are however present in these highlands. A notable feature is the Orchid Plateau, an erosional surface of about 10 square miles and 1,500 feet high bounded by steep scarps. Other flat areas are present in the middle Telewas Valley and in the headwaters area of the Malubuk Valley. Marine terraces 80 to 100 feet above sea level are present in the Silam area.

(B) The Kuamut Highlands

The Kuamut Highlands are rugged areas with most parts over 1,000 feet above sea level. Steep concentric sandstone ridges forming basin-like features are most notable. The steep ridges alternate with river valleys occupying the eroded mudstone strata.

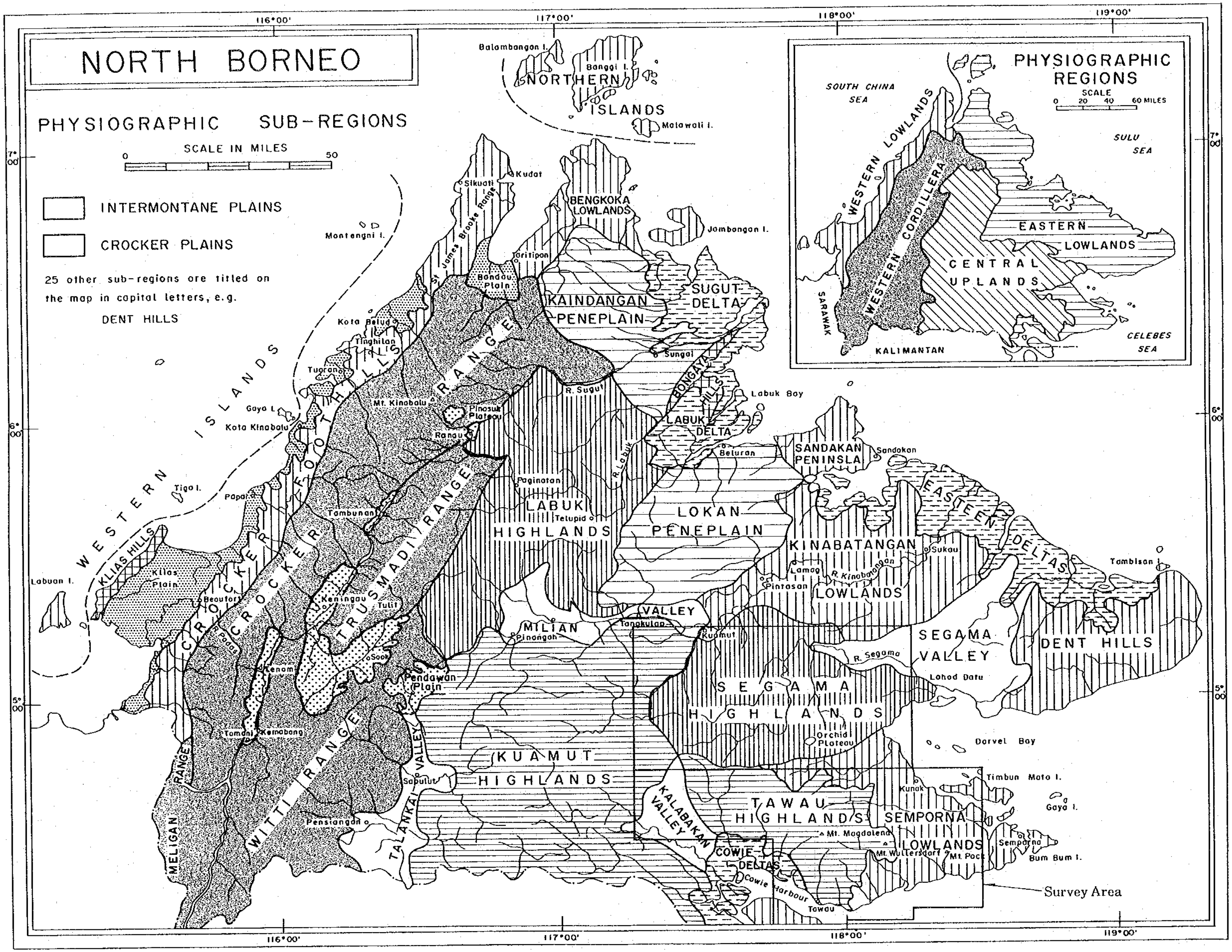


Figure I-2 Physiographic Sub-regions of Sabah (After Collenette P., 1962)

(C) The Segama Valley

The Segama Valley comprises the lower course of Segama River and its tributaries. Within the region, the Segama Valley is mostly low-lying with wide patches covered by alluvium; the higher lands include the limestone hills at Tempadong and Teck Guan Estates and the northeast-trending tuffaceous sedimentary ridges north of the Segama River.

(D) The Semporna Lowlands

Within the region, the most notable features of the Semporna Lowlands are the Madai limestone hills rising to about 1,650 feet above sea level. Plateau-like areas filled with Quaternary lava at Mostyn and lake-bed alluvium in the Tingkayu Valley are also predominant features.

The drainage pattern of the region is roughly rectangular with the rivers flowing either east, parallel to the regional structural trend or north or south across it. The region is mostly drained by the Segama River and its major tributaries, the Danum, Bole, Kawag and the Telewas. In the western region, the Segama and Danum Rivers follow an easterly course, followed by a northerly course and once again an easterly course. The major tributaries of Bole and Kawag follow an essentially northerly course.

The mountainous northeastern part of the Brassely Range separates the rivers draining into the Segama from those draining into the Kinabatangan. The Kuamut, Malubuk, and Malua Rivers draining into the Kinabatangan and the Bilong River essentially follow a northeastly course again roughly parallel with the northeast structural trend in that area. The subsequent drainage pattern of the Bangan and lower Malubuk clearly reflects the basinal bedding structures of the underlying Tanjong Formation.

A low divide separates the headwaters of the Beeston and Surprise from those of Bang and Umas Umas which drain into Cowie Harbour to the south. It is probable that the Upper Beeston, Surprise, Bang, Umas Umas and Tingkayu lie in a area of peneplanation or mature erosional surface, in which the recent rejuvenation of the valleys lower down has not yet reached their respective headwaters.

(Modified from "Geography" in "The geology and mineral resources of the Upper Segama Valley and Darvel Bay area, Sabah, Malaysia", by K.M. Leong, 1974)

2-1-2 Semporna Peninsula Region

The Peninsula has a complex physiography owing to its varied geological structure. In broad outline, the peninsula may be divided physiographically into four areas (i) volcanic hills in several groups forming the spine of the peninsula (ii) dissected hilly areas of the hinterland, mainly on the west and northern sides of the peninsula (iii) coastal lowlands and (iv) offshore islands.

Mount Magdalena, the highest mountain in the region (about 4,200 feet high) forms the hub of a group of high volcanic hills in the centre of the peninsula. From Mount Magdalena, a series of high volcanic ridges extend southwards forming Mount Lucia (3,940 feet), Mount Maria (about 3,400 feet) and, further south, Mounts Kinabutan Besar (1,356 feet) and Kechil, and Mount Andrassy. To the east, and largely separated from the Mount Magdalena massif is the smaller group of volcanic hills centred on Mount Wullersdorf (2,500 feet). Towards the end of the peninsula, volcanic hills form the Mount Pock-Mount Sigalong Range (about 2,000 feet high), and a group of lower hills southwest of Semporna.

A large tract of hilly country without well marked grain forms the hinterland of the peninsula west and north of the Mount Magdalena massif and is underlain mainly by sedimentary rocks. There are very few outstanding peaks in this area, and the summits of the mainly ridge-like hills increase in height gradually inland to an average of about 1,500 feet in the headwaters of the Umas Umas and Binuang Rivers.

The coastal lowlands are extensive (about a quarter of the total region) and are best developed on the southern side of the peninsula. They include the wide flood plains of the lower Kalumpang, Umas Umas, Merutai Besar, Balung, and Sipit Rivers, mainly occupied by swamp, and also large areas of well drained country with low hills between the Apas and Kalumpang Rivers, in the Sipit Valley, and on the northwest coast near Kunak.

The islands are unevenly distributed around the peninsula. Sebatik Island, which is the largest, is the only notable island on the southern side, whereas on the north they are numerous islands both fringing the coast and lying well out in Darvel Bay.

In Darvel Bay most of the larger islands are mountainous with coastal flats either very restricted or absent. Of these islands Timbun Mata is by far the largest and its high peaks (Mount Tanna Batu, 1,954 feet, Mount Sidongal, 1,605 feet), rising sheer from sea level, form prominent landmarks.

Most of the peninsula is drained by the Kalumpang, Tingkayu, Umas Umas, Balung, and Merutai Besar Rivers and their tributaries. Of the smaller drainage basins only those of the Merutai Kechil, Tawau, Apas, and Sipit Rivers are of importance.

The drainage system of the Peninsula is dominated by the Kalumpang River which has a valley over 60 miles long, and drains about a third of the land surface. The main upper tributaries, which include the Malati and the Mantri, rise on the highest ground in the region on the northern slopes of Mount Magdalena, Mount Wullersdorf and neighbouring hills in the heart of the peninsula. These unite to form the main stream which flows eastwards along its turbulent upper reaches. For the lower 15 miles of its course it flows slowly southwards across an extensive flood plain through a wide valley to reach the sea midway along the southern coast.

The Umas Umas River has a common watershed with the Tingkayu-Binuang River system in the remote hills in the northwest of the region. After flowing through a relatively wide upper section of the valley this river follows a constricted course southwards through the hills in its middle reaches, and in the lower part of the valley the river meanders through an extensive coastal flood plain. The tributary streams of the Balung rise on the eastern slopes of Mount Magdalena and Mount Maria and enter a wide alluvium filled valley over 6 miles long north of Quoin Hill. At Kawa Hill the river flows through a narrow gorge in a series of cataracts before entering the coastal plain, across which it meanders for over 7 miles to the sea at Cowie Harbour. The western slopes of Mount Madgalena and neighbouring hills are drained by the River Merutai Besar which flows almost directly south through a relatively wide valley into Cowie Harbour. The watersheds between the headwaters of the Merutai Besar and those of the Kalumpang and Binuang Rivers are quite low (about 500 feet) and the valley consequently forms an important route into the interior of the Peninsula.

The Tingkayu River, lying only in part within the region, and its major southern tributary the River Binuang, drain much of the northern side of the peninsula. The Tingkayu and Binuang Rivers rise in the rugged country adjacent to the Segama Valley in the neighbourhood of Mount Binuang. After flowing through a tortuous narrow upper valley, the Binuang flows eastwards through extensive alluvial flats in the neighbourhood of Mount Baturong, where it joins the Tingkayu. Below this wide middle section of the valley the course of the Tingkayu again becomes constricted as it flows northeastwards between low rocky hills in a series of rapids before reaching its coastal flood plain and delta just to the north of the region. (Simplified from "Topography and geomorphology" in "The geology and mineral resources of the Semporna Peninsula, North Borneo" by H.J.C. Kirk, 1962)

2-2 Climate and Vegetation

As Sabah is situated in the tropical monsoon region, climate of Sabah is hot and humid throughout the year. The northeast monsoon sets in late in October or early in November and lasts until late March. The southwest monsoon begins in May and ends in September. Therefore, the rainy season in the west coast lasts during southwest monsoon season and the east coast experiences its heaviest rainfall during northeast monsoon season. The average annual rainfall is 1,500 to 2,000 millimeters in the interior highlands and is 3,000 millimeters and over in the coast and range areas. The highest rainfall is in the southwest (Beaufort and Labuan) and the lowest is in the interior (Tenom, Keningau and Tambunan) and at Tawau on the southeast coast.

As Upper Segama Valley and Darvel Bay region, which is to be investigated in 1991, is situated in the east coast area, it rains hard in the region during the northeast monsoon season.

Temperature varies little with the season. Although temperatures in the coastal area are 24° to 34°C with 27°C on the average throughout the year, surface temperatures inland are 12° to 22°C falling at a rate of about 1.5°C for every 300 meters increase in altitude so that above about 1,200 meters there is a change from the tropical rainy climate to the warm temperature rainy climate.

Minimum and Maximum temperatures and rainfall in Kota Kinabalu on the west coast, in Sandakan on the northeast coast and in Tawau on the southeast coast are shown in the Table I-4.

Vegetation in the hilly and mountainous districts inland is jungly, whereas swamps in the coastal area are covered with mangroves densely and extensively. The jungle is classified into two types, namely primary or primeval jungle which is kept natural and secondary jungle, in which large trees have been already cut down.

Within the survey area in 1991, the primary jungle is only found in the western part of the Segama Valley region, whereas the secondary jungle occupies rather wider area in general.

Large-scale plantation of coconut palm, cacao and rubber occupies a large extent in the coastal area of Segama Valley and Semporna Peninsula regions.

Table I-4 Statistics of Temperature and Rainfall

Month	Kota Kinabalu			Sandakan			Tawau		
	Temperature (°C)		Rainfall (mm)	Temperature (°C)		Rainfall (mm)	Temperature (°C)		Rainfall (mm)
	Max.	Min.		Max.	Min.		Max.	Min.	
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
Total	——		2,471.5	——		2,844.7	——		1,940.2

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

CHAPTER 3 GENERAL GEOLOGY (GEOLOGY OF SABAH)

3-1 Introduction

Sabah, situated in the northern part of Borneo, has a complex geological history. Several regional tectonic trends converge in this region. The northeast trend of the Palawan-Balabac Island arc stops at the northern islands of Banggi and Balambangan. The northeast trending crescent of the "Northwest Borneo Geosyncline" appears to bend to southeast at Gunung Kinabalu. The Sulu Archipelago volcanic trend links to the Semporna Peninsula in southeastern Sabah. The oldest rocks which form the so-called Crystalline Basement occur in the east Sabah. Basic and ultrabasic rocks and associated chert, spilite, gabbro of the ophiolite suite, occur along an arc stretching from Darvel Bay on the east coast through the upper Sungai Segama valley to the upper Labuk valley, Gunung Kinabalu and swinging northeast to Marudu Bay and to the northern islands. Acid to basic igneous rocks, the products of at least three periods of igneous activities, are exposed in the Semporna Peninsula, and the upper Segama and Gunung Kinabalu area.

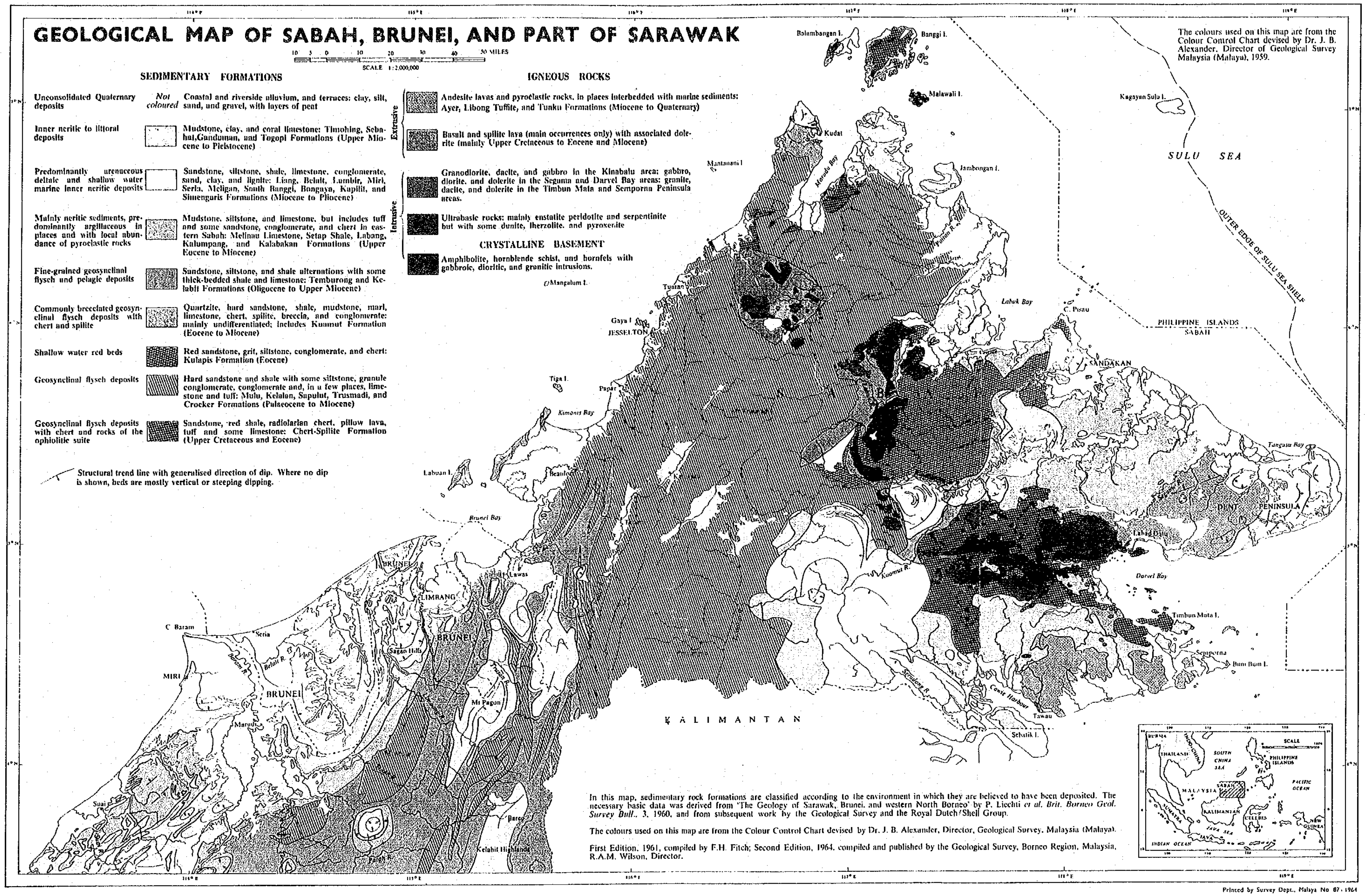
3-2 Summary of Sedimentary Basins and Tectonics

Pre-Cretaceous sedimentation history that culminated in the formation of the Crystalline Basement is little known. Some pelitic and calcareous sediments intercalated with volcanic rocks were probably deposited under a volcanic island arc environment.

During Early Cretaceous time, limestone was deposited in several localities on an emerging basement in eastern Sabah. By Late Cretaceous time, thick clastic and calcareous sediments, chert, limestone and volcanic rocks were deposited over a large part of eastern, central, and southwest Sabah and part of northern Sabah. Deposition was continuous up to Eocene time.

There is no evidence of Cretaceous deposition in western and southwest Sabah but by early Tertiary, an elongated northeast trending marine trough already existed extending from the Kalimantan border into western and northern Sabah, and deposition of thick sequences of sandstone and mudstone occurred uninterrupted into the Upper Miocene when it was terminated by folding and uplift, accompanied by the intrusion of the Kinabalu Batholith.

FIGURE I–3


GEOLOGICAL MAP OF SABAH, BRUNEI, AND PART OF SARAWAK
10 5 0 10 20 30 40 50 MILES
SCALE 1:2,000,000
SEDIMENTARY FORMATIONS
Unconsolidated Quaternary deposits
Not coloured
Coastal and riverside alluvium, and terraces: clay, silt, sand, and gravel, with layers of peat
Inner neritic to littoral deposits
Mudstone, clay, and coral limestone: Timohing, Sebahat, Ganduman, and Togopi Formations (Upper Miocene to Pleistocene)
Predominantly arenaceous deltaic and shallow water marine inner neritic deposits
Sandstone, siltstone, shale, limestone, conglomerate, sand, clay, and lignite: Liang, Belait, Lambir, Miri, Seria, Meligan, South Banggi, Bongaya, Kapilit, and Simengaris Formations (Miocene to Pliocene)
Mainly neritic sediments, predominantly argillaceous in places and with local abundance of pyroclastic rocks
Mudstone, siltstone, and limestone, but includes tuff and some sandstone, conglomerate, and chert in eastern Sabah: Melinau Limestone, Setap Shale, Labang, Kalumpang, and Kalabakan Formations (Upper Eocene to Miocene)
Fine-grained geosynclinal flysch and pelagic deposits
Sandstone, siltstone, and shale alternations with some thick-bedded shale and limestone: Temburong and Kelabit Formations (Oligocene to Upper Miocene)
Commonly brecciated geosynclinal flysch deposits with chert and spilite
Quartzite, hard sandstone, shale, mudstone, marl, limestone, chert, spilite, breccia, and conglomerate: mainly undifferentiated; includes Kuamut Formation (Eocene to Miocene)
Shallow water red beds
Red sandstone, grit, siltstone, conglomerate, and chert: Kulapis Formation (Eocene)
Geosynclinal flysch deposits
Hard sandstone and shale with some siltstone, granule conglomerate, conglomerate and, in a few places, limestone and tuff: Mulu, Kelalan, Sapulut, Trusmadi, and Crocker Formations (Palaeocene to Miocene)
Geosynclinal flysch deposits with chert and rocks of the ophiolitic suite
Sandstone, red shale, radiolarian chert, pillow lava, tuff and some limestone: Chert-Spilite Formation (Upper Cretaceous and Eocene)
Structural trend line with generalised direction of dip. Where no dip is shown, beds are mostly vertical or steeping dipping.
IGNEOUS ROCKS
Extrusive
Andesite lavas and pyroclastic rocks, in places interbedded with marine sediments: Ayer, Libong Tuffite, and Tunku Formations (Miocene to Quaternary)
Basalt and spilite lava (main occurrences only) with associated dolerite (mainly Upper Cretaceous to Eocene and Miocene)
Intrusive
Granodiorite, dacite, and gabbro in the Kinabalu area: gabbro, diorite, and dolerite in the Segama and Darvel Bay areas: granite, dacite, and dolerite in the Timbun Mata and Semporna Peninsula areas.
Ultrabasic rocks: mainly enstatite peridotite and serpentinite but with some dunite, lherzolite, and pyroxenite
CRYSTALLINE BASEMENT
Amphibolite, hornblende schist, and hornfels with gabbroic, dioritic, and granitic intrusions.
The colours used on this map are from the Colour Control Chart devised by Dr. J. B. Alexander, Director of Geological Survey Malaysia (Malaya), 1959.
Balambangan I.
Banggi I.
Malawali I.
Kudat
Mantanani I.
Jambongan I.
Kagayan Sulu I.
SULU SEA
OUTER EDGE OF SULU SEA SHELF
Mangalum I.
Tuaran
Gaya I.
JESSELTON
Labuk Bay
C. Pusu
PHILIPPINE ISLANDS
SABAH
SANDAKAN
Tiga I.
Papar
Kimanis Bay
Labuan I.
Beaufort
Brunei Bay
Tanjusu Bay
DENT PENINSULA
Lahad Datu
Darvel Bay
Timbun Mata I.
Semporna
Bum Bum I.
Kuamut R.
Cowie Harbour
Tawau
Sebatik I.
KALIMANTAN
BRUNEI
LIMBANG
Lawas
C. Baram
Seria
BRUNEI
Sagan Hills
Belait R.
Baram R.
MIRI
BRUNEI
Marudi
Mt Pagon
Suai
Bario
Kelabit Highlands
In this map, sedimentary rock formations are classified according to the environment in which they are believed to have been deposited. The necessary basic data was derived from 'The Geology of Sarawak, Brunei, and western North Borneo' by P. Liechti et al. Brit. Borneo Geol. Survey Bull., 3, 1960, and from subsequent work by the Geological Survey and the Royal Dutch/Shell Group.
The colours used on this map are from the Colour Control Chart devised by Dr. J. B. Alexander, Director, Geological Survey, Malaysia (Malaya).
First Edition, 1961, compiled by F.H. Fitch; Second Edition, 1964, compiled and published by the Geological Survey, Borneo Region, Malaysia, R.A.M. Wilson, Director.
BURMA
THAILAND
SOUTH CHINA SEA
PHILIPPINE ISLANDS
PACIFIC OCEAN
MALAYSIA
SABAH
KALIMANTAN
CELEBES
NEW GUINEA
JAVA SEA
INDIAN OCEAN
SCALE
Printed by Survey Dept., Malaya No 87-1964

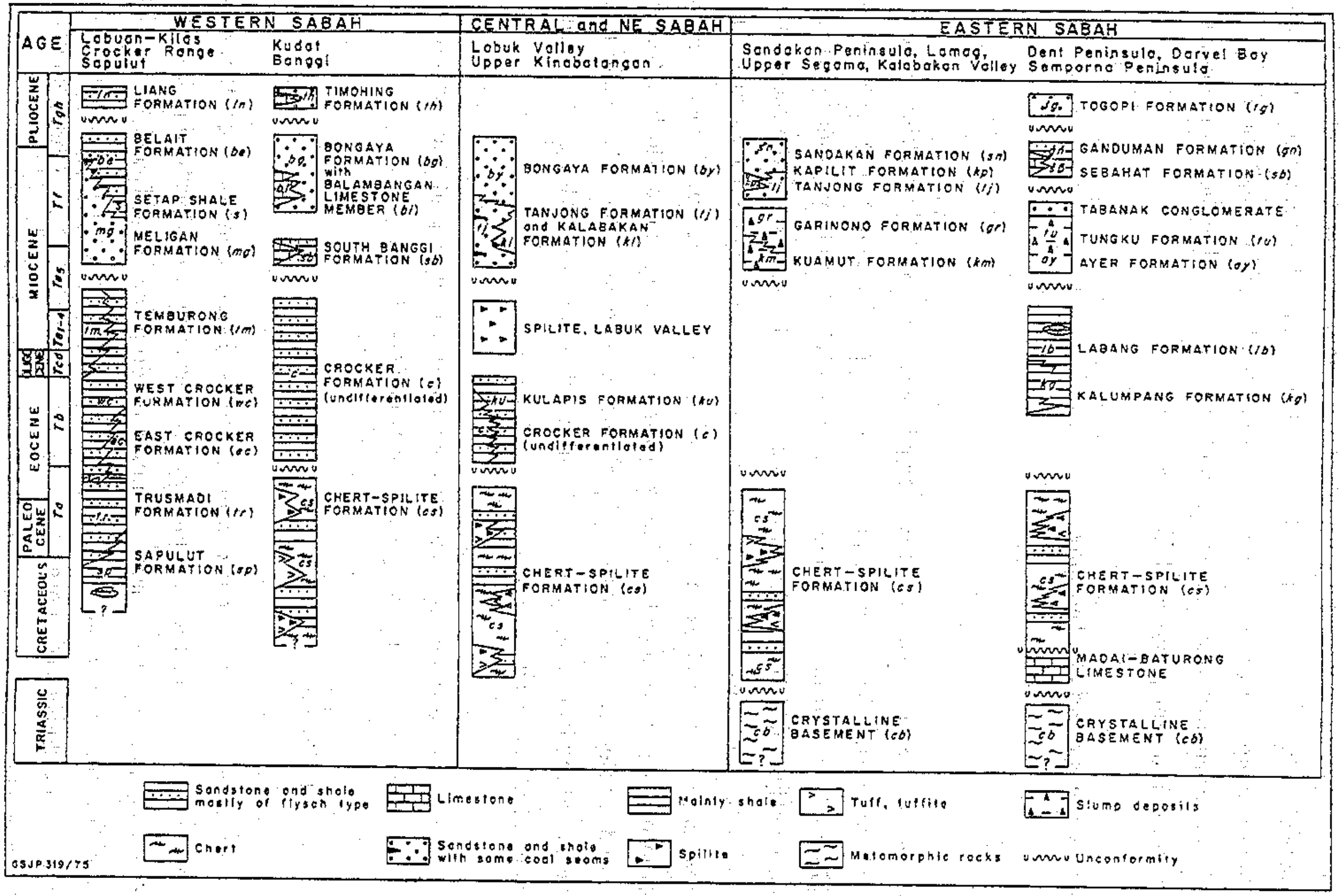


Figure I-4 Stratigraphy of Sabah

(Taken from "Regional Geology of Sabah" in "Annual Report of Geological Survey of Malaysia, 1988")

During this maior Late Miocene tectonic event, slump deposits and pyroclastics accumulated in several deep basins in eastern Sabah, followed by the deposition of sandstone and mudstone with minor amounts of limestone and coal in a chain of circular to sub-circular shallow basins. Rapid uplift in Late Miocene time resulted in the formation of conglomerate at Lahad Datu and cessation of deposition in the area, except in the easternmost part-the Dent Peninsula-where Pliocene sediments were deposited in coastal swamps and shallow-marine waters.

3-3 General Geology and Stratigraphy

3-3-1 Triassic

The oldest rocks in Sabah are the metamorphic rocks of the Crystalline Basement found in eastern Sabah. These rocks occur in the upper Segama valley over an area of about 500 km^2. Small outcrops occur also in the Labuk valley, Gunung Kinabalu area, and in Taritipan and the northern islands. In the Segama area, the rocks have a strong prominent east-west foliation trend. The metamorphic rocks are mainly amphibolites, skarns, quartzites, meta-tuffaceous and meta-volcanic rocks, as well as meta-gabbro and meta-dolerite. Large bodies of granite, granodiorite, tonalite, ultramafic and mafic rocks intruded the metamorphic rocks. The ultramafic bodies are distinctly elongated and commonly aligned east-west along the general metamorphic foliation trend.

Radiometric dates of metamorphic and igneous rocks indicate that the formation of these rocks could be as early as Early Triassic time (210+3 Ma).

3-3-2 Cretaceous-Eocene

Cretaceous to Eocene rocks are quite widespread in eastern and south-central Sabah, and large outcrops occur in the Segama valley, bordering the Crystalline Basement, and in the Pensiangan-Pinangah area. Smaller outcrops are also found in the Labuk valley, near Gunung Kinabalu, at Taritipan and in the northern islands. The Cretaceous-Eocene rocks are represented by two formations, the Chert-Spilite and the Sapulut Formations. The Chert-Spilite Formation is characterised by limestone, radiolarian chert, sandstone, conglomerate, spilite, volcanic breccia, agglomerate, pillow basalt and associated dolerite and keratophyre. The varied rock types suggest a complex environment of deposition, perhaps in several unstable troughs, in a block-faulted emerging basement. The Sapulut Formation consists mainly of argillaceous strata and minor amounts of argillaceous limestone, conglomerate, chert, and sandstone.

The rock assemblage of the Chert-Spilite Formation with ultramafic and mafic rocks has been considered to be part of an ophiolite sequence, whereas the Sapulut Formation is believed to have been deposited in the centre of a marine trough.

3-3-3 Eocene-Oligocene

Rocks of Eocene to Oligocene ages occupy the whole of western and northern Sabah and consist of great thicknesses of flysch-type sequence of interbedded sandstone, siltstone, mudstone and shale, and rare limestone (Crocker Formation), and slate, phyllite, quartzite, limestone, chert and tuff (Trusmadi Formation).

The Eocene rocks are well exposed along the shore of the west coast, and along the numerous rivers which cut across the strike of the strata. Fossils are few; some shale samples contain areanceous foraminifera including species of *Ammodiscus*, *Bathysiphon*, *Haplophragmoides*, *Trochammina*, and *Cyclammina* of Eocene to Early Miocene age. One limestone sample contains a good fossil assemblage indicating an age of Middle Eocene.

The Eocene rocks in parts of central Sabah consist of reddish and purplish sandstone, siltstone, and shale (Kulapis Formation).
Rocks of Oligocene to Early Miocene ages are of limited extent and are found only in southwest Sabah at the border with Sarawak. There, Oligocene strata are mainly shale and mudstone (Temburong Formation) and contain abundant arenaceous foraminifera.

3-3-4 Miocene-Pliocene

Rocks of Miocene-Pliocene age occur mainly in eastern Sabah, but are also found in the north and southwest.

(1) Eastern Sabah

In eastern Sabah, the Early Miocene deposits consist mainly of argillaceous materials, pyroclastics and slump breccias reflecting unstable conditions of deposition. The argillaceous marine sediments occur in the southeast in the

Kalabakan valley (Kalabakan Formation), and mudstone, shale, tuff and tuffite (Kalumpang Formation) in the Binuang area and Kalumpang valley. The slump deposits referred to by Hamilton (1979) as a melange or broken formations occur in the Sandakan Peninsula (Garinono Formation), Dent Peninsula (Labang and Ayer Formations), and in the upper Kinabatangan area (Kuamut Formation). Large blocks of older rocks such as chert, limestone, gabbro, sandstone, and serpentinite are included in a massive grey mud matrix of the slump deposits. Well-bedded sequences of tuff, tuffite, and tuffaceous sediments also occur. Fossil assembalges in the bedded sequence indicate that deposition took place in deep marine conditions. The Early Miocene age of these slump deposits is indicated by foraminiferal fauna.

Late Miocene rocks consist of well-bedded sequences of sandstone and mudstone along the Kalabakan-Kuamut-Kinabatangan valleys (Tajung and Sandakan Formations). These sandstone- mudstone sequences form prominent basin structures. The depositional environments are shallow marine, lagoonal and deltaic to littoral.

Miocene to Pliocene deposits (Dent Group) are represented by a shallow marine sequence of predominantly sedimentary rocks with minor limestone beds. Outcrops are found mainly in the eastern part of the Dent Peninsula. This group of rocks range in age from Late Miocene to Pliocene and are rich in foraminiferal fauna.

(2) Northern Sabah

Miocene strata also occupy the Kudat and Bengkoka peninsulas, Banggi island as well as on the coastal part of the Sungut peninsula. The lower sequence comprises thick massive sandstone, siltstone and minor shale, limestone and calcarenite. The argillaceous beds as well as the limestone and calcarenite contain rich Miocene foraminiferal fauna, including a large percentage of reworked Eocene fauna.

The upper sequence consists of thick-bedded, light-blue, quartzose sandstone and shale (Bongaya and Kudat Formations). The argillaceous beds contain foraminiferal fauna of late Tf (Late Miocene) age.

(3) Southwest Sabah

In the southwest, adjacent to Sarawak, the Miocene rocks (Meligan Formation) are very similar to the Miocene rocks of the Kudat peninsula in that the sandstone is quartzose, light-blue in colour, and massive with minor shale beds and limestone.

3-3-5 Pliocene and Quaternary

By Pliocene time, the greater part of Sabah was fully uplifted and volcanism was active in the east coast. Sedimentation was confined to the coastal areas. In the Dent and Semporna peninsulas, sediments comprising mainly limestone, calcareous sandstone, clay and lignite accumulated.

The sediments contain rich Pliocene-Pleistocene foraminiferal and molluscan fauna as well as echinoids. In the southwest in the Sipitang and the Klias peninsulas, Pliocene deposits (Liang Formation) consist of clay, sand, lignitic clay and conglomerate, resting unconformably on older formations.

Quaternary deposits, consisting of coarse gravel, sand, silt, clay, peat and coral accumulated along the coasts and are now found in raised terraces and in inland plains in Tenom, Klias, Padas valley, and the Sook-Keningau plains.

3-4 Metamorphism

The most intensely metamorphosed rocks are those of the Crystalline Basement. They have been regionally metamorphosed to the grades of the greenschist and the amphibolite facies. Thermal metamorphism also took place around major granite intrusions in the basement, for example, at Litok Klikog and Babais where hornfelses were developed in contact aureoles.

Potassium-Argon dating of the metamorphic rocks gave ages from 210+3 Ma (Early Triassic) to as young as 87+2.5 Ma (Late Cretaceous).

Metamorphism has also affected a thick sequence of Palaeocene-Eocene sedimentary strata of the Trusmadi Formation in western Sabah. The metamorphic rocks consist of slates, phyllites, and quartzites. The low-grade metamorphism is probably a regional phenomenon due to deep burial.

Hornfelses were developed around the Kinabalu batholith which was intruded into the thick sedimentary cover in Miocene time.

3-5 Structure

The major structural feature of Sabah is the large bend, around Gunung Kinabalu, of the prominent northeasterly trend in western Sabah to a southeasterly direction in central and eastern Sabah. Two sets of major faults are apparent - a north - northeast set and a northwest to north-northwest set (Wilford, 1967; Tokuyama & Yoshida, 1974; Lee, 1980). In western Sabah, the north-northeast set is generally parallel or oblique to the main strike of the sedimentary strata, whereas the northwest to north-northwest set cuts across the strata. In southern Sabah both sets of faults occur.

A large strike-slip fault, the "Kinabalu fault", cuts across Sabah from the northwest coast through Gunung Kinabalu and the Labuk valley to the southeast coast between Cowie Harbour and Darvel Bay (Tokuyama & Yoshida, 1974). This fault belongs to the northwest set and is probably the older of the two sets as its topographic expression is generally obscured.

In the Crystalline Basement, major east-west trending faults are evident. These faults are parallel or sub-parallel to the main schistosity that developed in the Crystalline Basement rocks, and are probably developed in Miocene time when major uplifts of the Segama valley area took place.

The sedimentary strata in the western part of Sabah folded during Late Miocene with varying degrees of intensity, from concentric folds in the thick, interbedded sandstone and shale to isoclinal folds in the thinner strata. Minor folds are quite prevalent but major folds are not observed. In the coastal area the fold axes generally trend northeast, but in the Trusmadi area the fold axes trend northwest. In the Kudat Peninsula, minor fold axes generally trend southeast. In the Dent Peninsula, the Miocene and Pliocene strata are folded on an east-west axis whereas in the Semporna Peninsula and Kalabakan area, the strata are folded on a southeast trend.

3-6 Igneous Activities

The igneous rocks of Sabah are varied in composition and origin. At least 3 main periods of igneous activity can be identified. The earliest period gave rise to the tonalite, granodiorite, trondhjemite and granite intrusions which are associated with the pre-Triassic basement rocks. The second period is represented by the basic-ultrabasic rocks, spilite and basalt association and related to the Upper Cretaceous Chert-Spilite Formation. The third period occurred in Late Miocene to Quaternary times and is represented by post-orogenic intrusives and extrusives which occur at Gunung Kinabalu and in the Semporna Peninsula.

In the Darvel Bay-upper Sungai Segama area, granodiorite, trondhjemite, granite and tonalite were emplaced in Early Triassic time followed by late-stage pegmatite and aplite intrusions.

The ophiolite suite, consisting of serpentinite, harzhurgite, pyroxenite, gabbro and dunite with associated chert and spilite occurs both in the Darvel Bay-Upper Segama area as well as in the Labuk valley-Gunung Kinabalu area and the northern islands.

From the Late Miocene to Quaternary time, extensive volcanism and associated shallow intrusions along the Semporna Peninsula and a batholith-size granitic intrusion at Gunung Kinabalu occurred. The post-tectonic volcanic rocks that erupted in the Semporna Peninsula are typical of the calc-alkaline Pacific island arc type, being rich in soda-lime feldspar and generally low in potash. The early eruptions are mainly andesite, dacite and basalt. Several volcanic cones are still recognizable, and hot springs - remnants of volcanism, occur at several places in the peninsula.

The large granite batholith and several minor apophyses at Gunung Kinabalu intruded into thick flysch sediments during Late Miocene time. The intrusive rocks are markedly high in potash compared with the volcanic rocks of equivalent composition in the Semporna Peninsula. (Simplified from "Regional Geology of Sabah" in "Annual Report of Geological Survey of Malaysia, 1988")

CHAPTER 4 SYNTHETIC STUDY ON THE RESULT OF THE SURVEY

4-1 Characteristic of Geological Structure and Mineralization and Structural Control of Mineralization

4-1-1 Segama Region

(1) Chromite Orebody in Ultramafic Rock

Massive, lenticular and banded chromite occur in serpentinized ultramafic rock. Banded and lenticular ores are embedded along foliation of ultramafic rock. Orebody is so small in scale that orebody at the S-7 outcrop, which is biggest in scale among orebodies at the localities of mineral occurrence investigated, is about 4 meters long and 2 meters thick. Orebody at the Hitam prospect to the northeast of Mt. Silam which had been prospected for 1962 to 1963 with trenching and drilling has been reported to be about 13 meters long, 7 meters wide and 60 centimeters thick. Structural control which rules the emplacement of orebody was not confirmed.

(2) Cyprus Type Cupriferous Massive Iron Sulfide Deposit

Four localities of mineral occurrence which were found in spilite of the Chert-Spilite Formation in the unnamed small island to the south of the Silam harbour seem to be the indications of stockwork deposit accompanying, in general, Cyprus type cupriferous massive iron sulfide deposit upwards. Judging from the example at the West Sualog deposit in the Bidu Bidu Hills area, Labuk region, it is inferred that massive sulfide deposit which is expect to be emplaced above stockwork deposit is embedded mainly along bedding or foliation near the boundary between spilite and overlying chert or shale in the Chert-Spilite Formation.

4-1-2 Semporna Region

Ore deposit in the Semporna peninsula region is epithermal gold-bearing quartz vein and network, which are embedded in volcanic and pyroclastic rocks of Miocene to Pliocene in age, formed by hydrothermal fluid related to the volcanic activity of the Miocene to Pliocene age.

The structure controlling the emplacement of the ore deposit seems to be faults which strike northeast, northwest, north-south and east-west.

It is inferred that gold mineralization in the Semporna peninsula region is related possibly to the volcanic activity of the calc-alkali rock series, judging from the assay result of ore and the MFA trigonal diagram made from the analyses of volcanic and pyroclastic rocks.

As seen in the Mantri, host rock was subjected to hydrothermal alteration consisting intense silicification, argillization (sericitization, kaolinization), formation of potash felspar and pyritization caused by hydrothermal fluid, which is mainly intermediate to alkaline, accompanied by gold mineralization. On the other hand, host rock in the Nagos area underwent acidic alteration, which is composed of intense silicification, argillization (kaolinization, sericitization and montmorillonitization) and alunitization and is found, in general, near the top of gold-silver-bearing quartz vein.

4-2 Possibility of Emplacement of "Expected Ore Deposit"

4-2-1 Segama Region

Four localities of mineral occurrence which were found in spilite of the Chert-Spilite Formation in the unnamed small island to the south of the Silam harbour seem to be the indications of stockwork deposit accompanying, in general, Cyprus type cupriferous massive iron sulfide deposit upwards. Judging from the above, there is a possibility of the emplacement of massive sulfide deposit which is expected to be emplaced above stockwork deposit. However, as the outcrops are situated on the small island, it is impossible to carry out prospecting near the outcrops. It seems that there is a possibility of the emplacement of Cyprus type cupriferous massive iron sulfide deposit, which is expected to be embedded in spilite of the Chert-Spilite Formation or along the boundary between spilite and overlying chert or shale, on land in the Silam area.

4-2-2 Semporna Region

As gold deposit in the Mantri area seems to be of the stockwork of low grade as a whole, there is a possibility of the emplacement of the bonanza type (vein type) gold-bearing quartz vein below the stockwork. There is also possibility of the emplacement of the stockwork type deposit and/or bonanza type deposit below the acidic massive silicified and argillized zone in the Nagos area.

Since volcanic and pyroclastic rocks of the Miocene to Pliocene age are also distributed in the area other than Mantri, Wullersdorf, Pock and Nagos areas in the Semporna peninsula area, it seems that there is a possibility of the emplacement of gold deposit in the other area where volcanic and pyroclastic rocks are subjected to hydrothermal alteration similar to that of Mantri and Nagos areas.

In case hydrothermally altered volcanic and pyroclastic rocks in the other area belong to the calc-alkali rock series, the possibility of the emplacement of gold deposit seems to be raised.

CHAPTER 5 CONCLUSION AND RECOMMENDATION

5-1 Conclusion

It seems that base metal deposit with possibility of discovery in the future in the Segama and Semporna regions surveyed in 1991, firstly, is gold deposit in the Semporna region.

Ore deposit in the Semporna peninsula region is epithermal gold-bearing quartz vein and network, which are embedded in volcanic and pyroclastic rocks of Miocene to Pliocene in age, formed by hydrothermal fluid related to the volcanic activity of the Miocene to Pliocene age.

As seen in the Mantri, host rock was subjected to hydrothermal alteration consisting of intense silicification, argillization (sericitization, kaolinization), formation of potash felspar and pyritization caused by hydrothermal fluid, which is mainly intermediate to alkaline, accompanied by gold mineralization. On the other hand, host rock in the Nagos area underwent acidic alteration, which is composed of intense silicification, argillization (kaolinization, sericitization and montmorillonitization) and alunitization and is found, in general, near the top of gold-silver-bearing quartz vein.

As gold deposit in the Mantri area seems to be of the stockwork of low grade as a whole, there is a possibility of the emplacement of the bonanza type (vein type) gold-bearing quartz vein below the stockwork. There is also possibility of the emplacement of the stockwork type deposit and/or bonanza type deposit below the acidic massive silicified and argillized zone in the Nagos area.

Since volcanic and pyroclastic rocks of the Miocene to Pliocene age are also distributed in the area other than Mantri, Wullersdorf, Pock and Nagos areas in the Semporna peninsula area, it seems that there is a possibility of the emplacement of gold deposit in the other area where volcanic and pyroclastic rocks are subjected to hydrothermal alteration similar to that of Mantri and Nagos areas.

It is inferred that gold mineralization in the Semporna peninsula region is related possibly to the volcanic activity of the calc-alkali rock series, judging from the assay result of ore and the MFA trigonal diagram made from the analyses of volcanic and pyroclastic rocks.

Therefore, in case hydrothermally altered volcanic and pyroclastic rocks in the other area belong to the calc-alkali rock series, the possibility of the emplacement of gold deposit seems to be raised.

Secondarily, there is a possibility of the emplacement of Cyprus type cupriferous massive iron sulfide deposit.

Four localities of mineral occurrence which were found in spilite of the Chert-Spilite Formation in the unnamed small island to the south of the Silam harbour seem to be the indication of the stockwork deposit accompanying, in general, Cyprus type cupriferous massive iron sulfide deposit upwards.

Judging from the above, there is a possibility of the emplacement of massive sulfide deposit which is expected to be emplaced above stockwork deposit.

Therefore, it seems that there is a possibility of the emplacement of Cyprus type cupriferous massive iron sulfide deposit, which is expected to be embedded in spilite of the Chert-Spilite Formation or along the boundary between spilite and overlying chert or shale, on land in the Silam area.

5-2 Recommendation

5-2-1 Recommendation for Phase III Survey

The investigation of the localities of mineral occurrence and indoor experiment · chemical analysis, that is, K-Ar age determination of rock, chemical analysis of rock, microscopic observation of thin section, chemical analysis of ore, microscopic observation of polished section, X-ray diffraction examination, and measurement of homogenization temperature of fluid inclusion, of the samples taken at the time of investigation conducted in the Segama and Semporna regions in 1991 to understand geology and mineralization at the localities of mineral occurrence in the both regions and then to clarify the characteristic of mineralization in the regions, have revealed the followings.

(1) Localities of mineral occurrence which seem to be the indication of the Cyprus type cupriferous massive iron sulfide deposit were confirmed in the Segama region.

(2) Metal deposit in the Semporna region is epithermal gold-bearing quartz vein and network formed by intermediate to alkaline hydrothermal fluid related to the volcanic activity of the Miocene to Pliocene age.

(3) The hydrothermal alteration related to the gold mineralization is different in different areas.

(4) The homogenization temperature of fluid inclusions in quartz taken from gold-bearing quartz vein in the Mantri area, Semporna region, is close to the formation temperation of the majority of epithermal gold deposits which are distributed in the circum-Pacific area.

As mentioned above, some fruits have been obtained by the survey in the Segama and Semporna regions in 1991. Therefore, it is recommended that the survey in the Kinabalu and Labuk regions in 1992 should be conducted by means of the same following methods as 1991.

1) The investigation of the localities of mineral occurrence
2) Indoor experiments and chemical analysis
   a) K-Ar age determination of representative rock
   b) Chemical analysis of rock
   c) Microscopic observation of thin section
   d) Assay of ore
   e) Microscopic observation of polished section
   f) X-ray diffraction examination for hydrothermally altered rock (in Kinabalu region)
   g) Measurement of homogenization temperature of fluid inclusions in quartz (in Kinabalu region)

5-2-2 Recommendation for the Future Survey

It is recommended that the following survey and prospecting for gold deposit, firstly, should be conducted in the Semporna peninsula region.

(1) Drilling to search for higher grade gold-bearing quartz vein of the bonanza type which is expected to be emplaced below the network orebody of low grade in the Mantri area.

(2) Drilling to search for the stockwork type or bonanza type ore deposit which is expected to be emplaced below the silicified zone in the Nagos area.

(3) Detailed geological mapping and investigation of the hydrothermal alteration zone in the area, where hydrothermally altered volcanic and pyroclastic rocks are distributed in the Semporna peninsula region, other than Mantri, Wullersdorf, Pock and Nagos areas.

In case the hydrothermal alteration zone is confirmed, the following survey as the next step is recommended.

a) Geochemical prospecting of soil for gold on the surface of the hydrothermal alteration zone.

b) Identification of hydrothermal alteration mineral by means of X-ray diffraction examination to clarify the mineral assemblage of the hydrothermal alteration zone.

c) Measurement of the homogenization temperature of fluid inclusion in quartz (in case quartz vein is confirmed.)

d) Chemical analysis and K-Ar dating of volcanic and pyroclastic rocks.

e) Microscopic observation of volcanic, pyroclastic and hydrothermally altered rocks.

In case a possibility of the emplacement of gold deposit is expected, trenching is recommended as the third step.

Secondarily, the detailed geological mapping of the Chert-Spilite Formation in the Silam area, Segama region is recommended in order to find a indication of Cyprus type cupriferous massive iron sulfide deposit.

Part II The Particular

PART II THE PARTICULAR

CHAPTER 1 SEGAMA REGION

1-1 Contents of the Survey

1-1-1 Investigation of Locality of Mineral Occurrence

The localities of mineral occurrence in the Silam area and on the small islands in Darvel Bay, where chromite mineralization in serpentinised ultramafic rock and Cyprus type cupriferous sulfide mineralization in spilite of the Chert-Spilite Formation which are thought to be typical mineralization in the Segama region were surveyed, in order to understand geology and mineralization at the localities of mineral occurrence in the Segama region and then to clarify the characteristic of mineralization in the region.

Nine localities of mineral occurrence, namely five chromite occurrences (S-1, S-5, S-6, S-7, S-8) in serpentinised ultramafic rock and four localities (S-9, S-19, S-20, S-21) of cupriferous sulfide occurrence in spilite, were investigated.

The locations of nine mineral occurrences are shown in the Fig. II-1-1 attached at the end of this report.

1-1-2 Sampling

Samples of ore at each locality of mineral occurrence and typical rock in the Segama region were taken for the purpose of conducting the following experiment, chemical analyses and microscopic observations to understand mineralization at the localities of mineral occurrence and geology at and around the localities of mineral occurrence in the Segama region.

The contents of the samples taken are as follows and the details are shown in the Table II-1-1. The locations of the samples obtained are shown in the Fig. II-1-2 attached at the end of this report.

(1) Samples of Igneous Rock for Age Determination by Means of K-Ar Method (4 samples)

Four samples, namely one sample of metabasalt (S-D-3) and one sample of metaandesite (S-D-7) belonging to the Chert-Spilite Formation and two samples (S-D-4, S-D-5) of metagabbro in the ophiolite series were taken.

(2) Rock Samples for Chemical Analysis (11 samples)

Eleven samples in total, namely one sample of metaandesite (S-R-19-B), two samples of metagabbro (S-R-13-B, S-R-20-B), three samples of serpentinised ultramafic rock (S-R-1-B, S-R-8-B, S-R-16-B) and one sample of amphibolite (S-R-17-B) in addition to four samples (S-R-10-B, S-R-11-B, S-R-12-B, S-R-18-B) taken from the same localities as the samples for age determination, were obtained.

(3) Rock Samples for Thin Section (11 samples)

Eleven samples (S-T-1, S-T-8, S-T-10, S-T-11, S-T-12, S-T-13, S-T-16, S-T-17, S-T-18, S-T-19, S-T-20) were taken from the same localities as the samples for chemical analysis.

(4) Ore Samples for Chemical Analysis (10 samples)

Ten samples, namely eight samples (S-O-1-B, S-O-3-B, S-O-4-B, S-O-5-B, S-O-6-B, S-O-7-B, S-O-8-B, S-O-9-B) taken from five localities of chromite occurrence (S-1, S-5, S-6, S-7, S-8) in serpentinised ultramafic rock and two samples (S-O-10-A, S-O-13-A) taken at two localities (S-9, S-21) out of four localities (S-9, S-19, S-20, S-21) of Cyprus type cupriferous sulfide occurrence in spilite of the Chert-Spilite Formation, were obtained.

(5) Ore Samples for Polished Section (10 samples)

Ten samples (S-P-1, S-P-3, S-P-4, S-P-5, S-P-6, S-P-7, S-P-8, S-P-9, S-P-10) were taken at the same localities as the samples for chemical analysis.

(6) Typical Samples of Rock and Ore for Specimen (12 samples)

Typical twelve samples of rock and ore out of the above 46 samples taken for the various kinds of experiments and chemical analyses, namely two samples of spilite (S-D-3-S, S-D-7-S), two samples of gabbro (S-D-4-S, S-R-20-B-S), three samples of serpentinised ultramafic rock (S-R-1-B-S, S-R-8-B-S, S-R-16-B-S), one sample of amphibolite (S-R-17-B-S), two samples of chromite ore (S-O-7-B-S, S-O-8-B-S) in serpentinised ultramafic rock, and two samples of Cyprus type sulfide ore in spilite of Chert-spilite Formation, were obtained at the same localities as the above samples.

Table II-1-1 List of Samples taken from Segama-Darvel Bay Region, Sabah

Location	Analysis of Rock	Thin Section	Dating	Analysis of Ore	Polished Section	Specimen
S-1	S-R-1-B	S-T-1		S-O-1-B	S-P-1	S-R-1-B-S
S-5				S-O-3-B	S-P-3	
S-5				S-O-4-B	S-P-4	
S-6				S-O-5-B	S-P-5	
S-6				S-O-6-B	S-P-6	
S-7	S-R-8-B	S-T-8		S-O-7-B	S-P-7	S-R-8-B-S, S-O-7-B-S
S-7				S-O-8-B	S-P-8	S-O-8-B-S
S-8				S-O-9-B	S-P-9	
S-9	S-R-10-B	S-T-10	S-D-3	S-O-10-A	S-P-10	S-D-3-S, S-O-10-A-S
S-10	S-R-11-B	S-T-11	S-D-4			S-D-4-S
S-11	S-R-12-B	S-T-12	S-D-5			
S-12	S-R-13-B	S-T-13				
S-15	S-R-16-B	S-T-16				S-R-16-B-S
S-16	S-R-17-B	S-T-17				S-R-17-B-S
S-17	S-R-18-B	S-T-18	S-D-7			S-D-7-S
S-18	S-R-19-B	S-T-19				
S-21				S-O-13-A	S-P-13	S-O-13-A-S
S-23	S-R-20-B	S-T-20				S-R-20-B-S
Total	11	11	4	10 (8+2)	10	12

1-2 Geology

(1) Stratigraphy

The stratigraphy of the region is summarized in Table II-1-2. An outline of the stratigraphy and geology of the Upper Segama and Darvel Bay region is described below; the distribution of the rock types is shown on the geological sketch map (Fig. II-1-3).

The oldest rocks are of the igneous and metamorphic complex referred to as the Crystalline Basement, which are exposed over a large part of the region. The igneous rocks whose composition range from granite to tonalite are intrusive into the metamorphic rocks; they are believed to be of Lower Triassic (210±5) and/or older age based on limited radiometric age determinations. Tectonic and/or thermal events affected the Crystalline Basement rocks in the Jurassic and Cretaceous. The metamorphic rocks are almost entirely of igneous parentage believed to be earlier than Triassic and possibly of Upper Paleozoic age. They have undergone at least one period of regional deformation and metamorphism whose grade varies from greenschist to amphibolite facies.

The Chert-Spilite Formation consists mainly of spilite, radiolarian chert, agglomerate and other volcanic rocks typically present in an eugeosynclinal environment. The formation is believed to be very thick. Although it was previously regarded as having been deposited in a geosyncline, the present survey has not delineated a specific 'geosyncline' or confirmed a deep basin of deposition. Present evidence indicates that at least parts of the formation in the region were deposited in shallow to neritic marine environment. The time-stratigraphic range of the Chert-Spilite Formation is not yet fully solved; it is believed to range from Upper Cretaceous to Early Tertiary. The formation was severely fragmented and brecciated during the Miocene orogeny and gravity slumping. Large areas covered by Kuamut Formation are believed to be underlain by the Chert-Spilite Formation.

Numerous bodies of *ultramafic and mafic rocks* were emplaced in the Upper Cretaceous to Early Tertiary time. Some of these ultramafic bodies are intrusive into the Chert-Spilite Formation; others are in fault contact. The ultramafic rocks are mostly serpentinized; the mafic rocks include mainly gabbro and dolerite. Many of the ultramafic and mafic rocks occur in associated complexes, possessing lithological, structural and chemical properties which are characteristic of Alpine-type peridotite-gabbro complexes.

The *Labang Formation* in the Lower Malubuk area consists of steeply dipping sandstone, shale and mudstone and some lenses of limestone. The formation appears to have been deposited in an elongated trough trending north-northeast. The relationship of the limestone outcrops to the sandstone and argillaceous rocks of the formation is not clear; thus the age of Upper Oligocene (Te_{1-4}) as assigned which is based on the larger foraminifera in the limestone is only provisional.

The Miocene (Te_5-Tf) rock-units consist of four formations, the Kuamut, Tanjong, Ayer and Tabanak Conglomerate and one member, the Tempadong Limestone Member of the Ayer Formation. The *Kuamut Formation* consists mostly of slump breccia deposits with increasing amount of interbedded sandstone and mudstone in the southern portion of the region and tuffaceous beds in the Malua-Bilong, mid-Danum and Beatrice and in the Limau-Mostyn area. The *Tanjong Formation* consisting mainly of interbedded sandstone and mudstone with rare conglomerate appears to overlie the Kuamut Formation conformably in the Sungai Kuamut area. The Tanjong Formation occurs in three subcircular basins, the Bangan, Tangkong and the Malua-Latangan Basins.

The *Ayer Formation* also consists partly of slump breccia deposits similar to those of the Kuamut Formation. The geological boundary between the Ayer and Kuamut Formations is arbitrary and their stratigraphic relationship is probably gradational. Tuffaceous sedimentary rocks are more common and comparatively more abundant in the Ayer than in the Kuamut Formation. Lenticular-shaped limestone beds in the Mensuli area have been designated as the Tempadong Limestone of the Ayer Formation. The limestone appears to occur in large lenses within the tuffaceous sedimentary rocks. The *Tabanak Conglomerate Formation* consists mainly of pebble, cobble and boulder conglomerates composed mostly of Crystalline Basement rock fragments. The upper age limit of the formation is probably in the Pliocene. *Colluvium* of ultramafic rock debris on the flanks of Gunung Silam was probably caused by the essentially vertical movement of the ultramafic body in Quaternary time.

(2) Regional Structure

The Upper Segama Valley and Darvel Bay region has a long and complex structural history commencing with the deformation of the Crystalline Basement probably in pre-Mesozoic time to essentially vertical movement of the serpentinized ultramafic bodies in the Quaternary. Strong faulting has affected most of the rock-units; the most intense periods of faulting appear to have occurred in Late Oligocene (Te_{1-4}) or Early Miocene (Te_5) and in Late Miocene (Upper Tf) or Early Pliocene (Tg) times. Folding of the sedimentary-volcanic rock units was also associated with the faulting in the latter period.

The dominant foliation trend of the metamorphic rocks of the Crystalline Basement is east-west. This foliation trend was also responsible for giving rise to the zone of weakness in the central part of the region in which the cover rocks (Late Mesozoic-Tertiary) as well as the Crystalline Basement have been affected by numerous Tertiary, essentially east-west trending faults sub-parallel to the foliation trend. It is possible that the serpentinized ultramafic bodies have also been emplaced along the east-west foliation planes of structural weakness in the Crystalline Basement, thus explaining the east-west elongation of several of the ultramafic bodies. In the south and southeastern portions of the region, which are outside the known distribution of the Crystalline Basement, the trend of the major faults is southeast-northwest. However, the northwesterly trend of the faults appears to swing westerly where Crystalline Basement rocks are present. (Simplified from "The geology and mineral resources of the Upper Segama Valley and Darvel Bay area, Sabah, Malaysia", by K.M. Leong, 1974)

Table II-1-2 Stratigraphy of the Upper Segama Valley and Darvel Bay Region

AGE	TERTIARY LETTER CLASSIFICATION (after Adams, 1970)	SEDIMENTARY – VOLCANIC ROCKS	IGNEOUS ROCKS AND ACTIVITY	PALAEOGEOGRAPHY AND DIASTROPHISM
HOLOCENE		RECENT ALLUVIUM : Coastal and fluviatile alluvium including mangrove swamp deposits, calc-tufa and active mud volcano, and salt spring deposits	Calc-tufa deposited by hot springs	Erosion; hot spring, salt spring and mud volcano activity
PLEISTOCENE		OLDER ALLUVIUM : Inland and lake-bed deposits; terrace and raised-beach deposits; COLLUVIUM : ultramafic rock debris	Olivine basalt lava	Uplift, faulting and erosion
PLIOCENE	Th Tg	NON – DEPOSITION	Microtonolite porphyry, andesite porphyry	Uplift, folding and faulting
MIOCENE	Tf_{1-3}	TANJONG FORMATION : Grey and buff coloured sandstone; grey, well-bedded mudstone containing limonitic nodules; plant fragments and leaf fossils in mudstone and sandstone, rare chert-pebble conglomerate and minor coal seams TABANAK CONGLOMERATE FORMATION : Pebble, cobble and boulder conglomerate, tuff, mudstone, tuffaceous shale and sandstone, fossil wood, plant fragments and rare coal seams	Volcanic activity associated with the Tabanak Conglomerate Formation Re-emplacement (?) of ultramafic rocks	Basin formation and deposition - paralic to deltaic environment
	Te_5	KUAMUT FORMATION : slump breccia, sandstone, mudstone, shale, tuff, tuffite and chert AYER FORMATION : Tuff, tuffite, slump breccia, volcanic breccia, mudstone, tuffaceous sandstone shale and rare conglomerate Tempadong Limestone Member : Grey and pink limestone, fossiliferous including coral and foraminifera	Extrusive igneous rocks associated with the Ayer and Kuamut Formations	Gravity sliding and slumping contemporaneous with or following uplift, faulting and volcanic activity Uplift, folding and faulting
OLIGOCENE	Te_{1-4}	?LABANG FORMATION : Grey sandstone, mudstone, shale, calcarenite, and probably including some limestone — ? — ? — ? — ? — ? — ? —		Infilling of probably elongated trough; indications of neritic and probable deep marine environment
	Td	LANGUSAN BEDS : Limestone breccia, tuff and tuffaceous shale — ? — ? — ? — ? — ? — ? — ? — ? — UNCONFORMITY AND/OR FAULT CONTACT — ? — ? — ? — ? — ? — ? — ? — ? —	Volcanic activity	Erosion and reworking of older fossils
EOCENE	Tb		Large bodies of intrusive ultramafic and mafic rocks including peridotite, mainly serpentinized, gabbro, some banded, and dolerite	Towards *Tab* time indication of neritic marine environment
PALAEOCENE	Ta	CHERT-SPILITE FORMATION : Sandstone, shale, mudstone, conglomerate, limestone, limestone breccia, calcarenite, calcilutite, ophicalcite, chert; volcanic breccia, agglomerate, spilite, keratophyre, basalt including pillow lava, tuff, epidote hornfels, some argillite, altered volcanic rocks and dolerite	Volcanic rocks including those of the spilite-keratophyre suite associated with the Chert-Spilite Formation	Eugeosynclinal type of deposits with associated radiolarian chert and basic and spilitic volcanic rocks
UPPER CRETACEOUS				Faulting, uplift of Crystalline Basement and erosion
LOWER CRETACEOUS		MADAI-BATURONG LIMESTONE : Predominantly massive, algal limestone with some pisolitic and oolitic layers		Limestone formation on shoal areas; Crystalline Basement probably submerged mainly at shallow depths
JURASSIC		NON – DEPOSITION		A tectonic/termal event affecting the Crystalline Basement probably occurred at this time
TRIASSIC UPPER				
TRIASSIC LOWER				
PRE-TRIASSIC		CRYSTALLINE BASEMENT : Tonalite, granodiorite, granite; biotite, biotite-garnet, biotite-sillimanite, biotite-hornblende, hornblende, garnet-andalusite (chiastolite) and calc-silicate hornfelses, some schistose, minor pegmatite, aplite and tourmaline-quartz veins; fine-grained amphibolite, epidote amphibolite, actinolite schist; medium to coarse-grained gneissic amphibolite, hornblende-plagioclase gneiss, pyroxene gneiss, quartzo-feldspathic gneiss, quartz-mica schist, chlorite schist, metagabbro, metadolerite, metavolcanics, migmatite and cataclasites including augen, mortar and flaser gneiss. Possibly include the ultramafic rocks on the Darvel Bay Islands and along the Silam coast and also the large approximately concordant ultramafic bodies surrounded by the amphibolite or gneissic amphibolite in the Upper Segama Valley		Emplacement, folding and regional metamorphism of mainly mafic igneous rocks and possibly including some ultramafic rocks. The emplacement of the granito-granodiorite-tonalite bodies was probably synchronous with regional deformation

〰〰 unconformity ; 〰 ? 〰 unconformity but age limit not definitely known; ——— conformity; — ? — ? — relationship not known; 〰 ? 〰 ? 〰 probable gradational contact

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(Taken from "The geology and mineral resources of the Upper Segama Valley and Darvel Bay area, Sabah, Malaysia", by K.M. Leong, 1974)

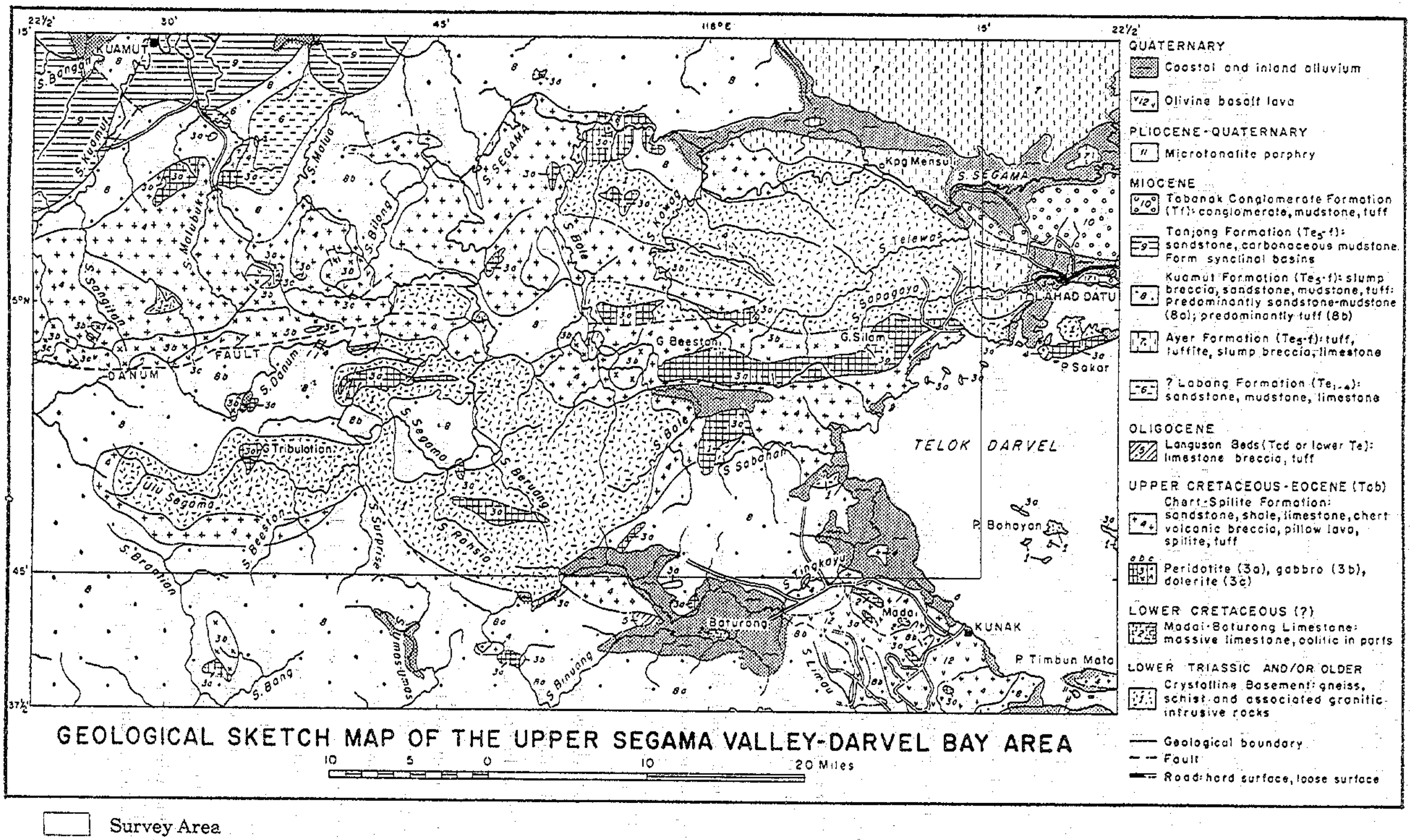


Figure II-1-3 Geological Sketch Map of the Upper Segama Valley-Darvel Bay Area
(Taken from "The geology and mineral resources of the Upper Segama Valley and Darvel Bay area, Sabah, Malaysia" by K.M. Leong, 1974)

1-3 Result of the Survey

1-3-1 Result of Investigation of Locality of Mineral Occurrence

Five localities of chromite occurrence which are embedded in serpentinized ultramafic rock, namely S-1 locality on the coast about 2.5 kilometers southwest of the Silam village, S-5 locality at the southeastern end of Saddle Island, S-6 locality at the southwestern end of Laila Island, S-7 locality at the northern end of the unnamed small island neighboring to the southeast of Laila Island and S-8 locality at the southwestern end of Katung Kalungan Island, and four localities of Cyprus type cupriferous sulfide occurrence in spilite of the Chert-Spilite Formation on the unnamed small island about 1 kilometer south of Silam Harbour were investigated.

The locations of the localities of mineral occurrence investigated and geology of the Silam area are shown in the Fig. II-1-1 attached at the end of this report. The result of investigation of the localities of mineral occurrence is shown in the Table II-1-3 and the assay result of the ore samples taken at the localities of mineral occurrence is shown in the Table II-1-8 in the section 1-4 mentioned below.

Chromite ore body at the outcrops of five localities of mineral occurrence are massive, lenticular, banded, irregular and so on in shape as shown in the Fig. II-1-4 sketch of S-7 outcrop.

Every chromite ore bodies at five localities investigated are very small in scale. The length and thickness of the ore body at the outcrop of the S-7 locality which is biggest in scale among five localities are 4 meters and 2 meters respectively.

The ore bodies at two localities (S-9, S-19) out of four localities of Cyprus type cupriferous sulfide occurrence are lenticular cupriferous sulfide as shown in the Fig. II-1-5 sketch of S-9 outcrop and other two (S-20, S-21) are copper-pyrite-bearing quartz veins as shown in the Fig. II-1-6 sketch of S-21 outcrop. Malachite, azurite and chalcocite oxidized from chalcopyrite are found at the outcrop of the S-9 locality and a little chalcopyrite and malachite are found at the S-21 locality. However, ore body at the S-9 locality only contains much copper, namely 6.54% of copper. Every ore bodies at four localities investigated are very small in scale. The length and width of the ore body at the outcrop of the S-21 locality which is biggest in scale among four localities are 5 meters and 1 to 18 centimeters respectively.

Table II-1-3 Result of Investigation of Localities of Mineral Occurrence in Silam Area, Segama Darvel Bay Region

Locality	S-1	S-5	S-6	S-7	S-8	S-9	S-19	S-20	S-21
Mineral Assemblage	chromite	chromite	chromite	chromite	chromite	mal, az, cc, qz, cal	lim	qz+lim	qz+py·cp·mal
Occurrence	lenticular	lenticular & banded	lenticular & banded	lenticular & banded	banded	lenticular or vein	lenticular or vein	vein	vein
Strike & Dip	N60°W·70°N					N40°E·60°SE	N25°E·90°	N20°E·54°W	N27°E·56°W
Scale (m)	L=0.6, W=0.17	max. L=0.15 T=0.15	max. L=.0.25 W=0.12	L=4.0+, T=2.0	H=1.0+, W=0.2	L=0.8, W=0.07	L=1.6+, W=0.35	L=1.7 W=0.02~0.05	L=5.0 W=0.01~0.18
Host Rock	serpentinite	serpentinite	serpentinite	serpentinite	serpentinite	metabasalt	metabasalt	metabasalt	metabasalt
Alteration of Host Rock	serpentinization	serpentinization	serpentinization	serpentinization	serpentinization	albitization chloritization epidotization	albitization chloritization epidotization	albitization chloritization epidotization	albitization chloritization epidotization
Number of Ore Sample	S-O-1-B	S-O-3-B, S-O-4-B	S-O-5-B, S-O-6-B	S-O-7-B, S-O-8-B	S-O-9-B	S-O-10-A			S-O-13-A

Abbreviations:

mal : malachite, az : azurite, qz : quartz, cal: calcite,
py : pyrite, cp :chalcopyrite lim: limonite, cc : chalcocite,
L : horizontal length, T : thickness, H : vertical height, W : width

Figure II-1-4 Sketch of S-7 Outcrop

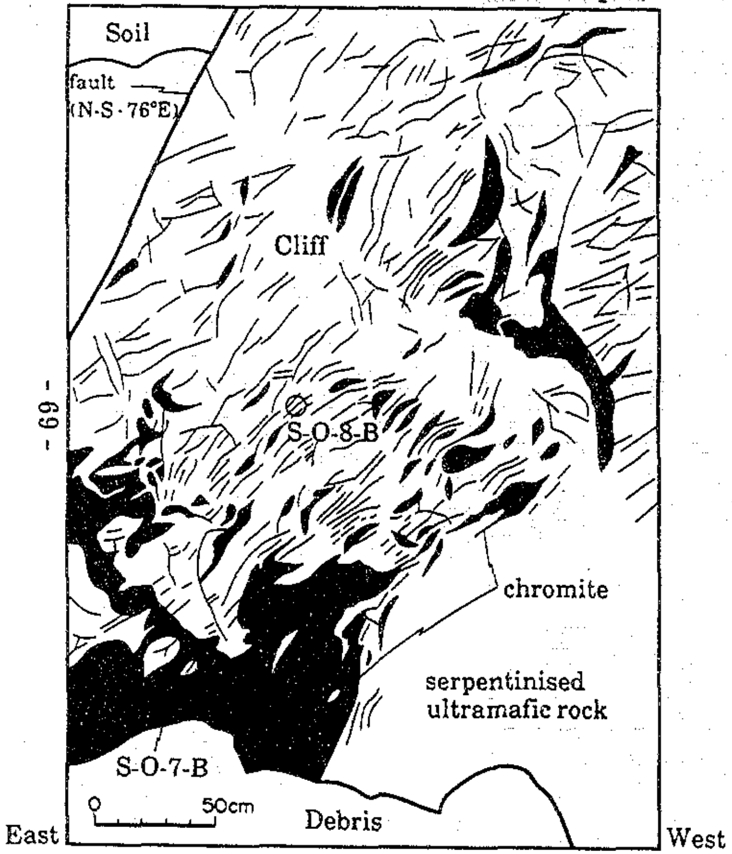


Figure II-1-5 Sketch of S-9 Outcrop

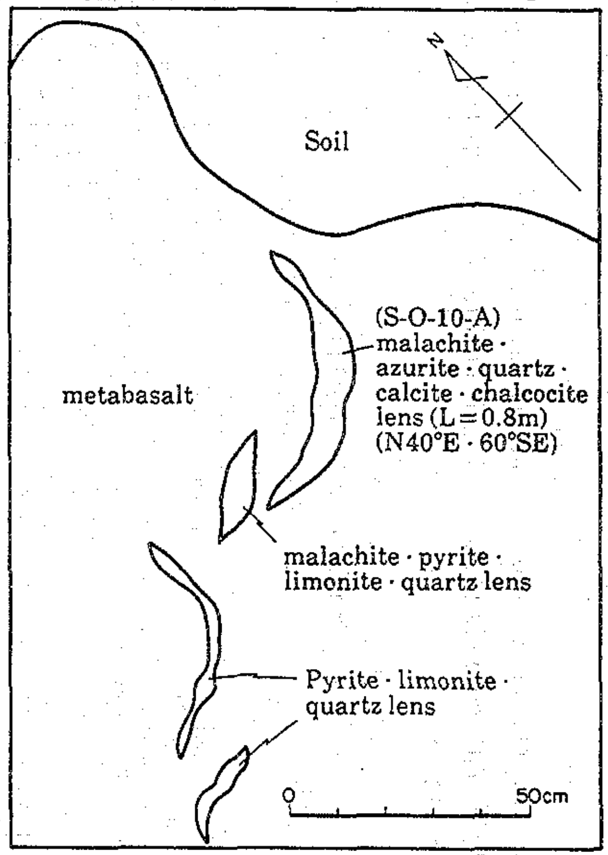
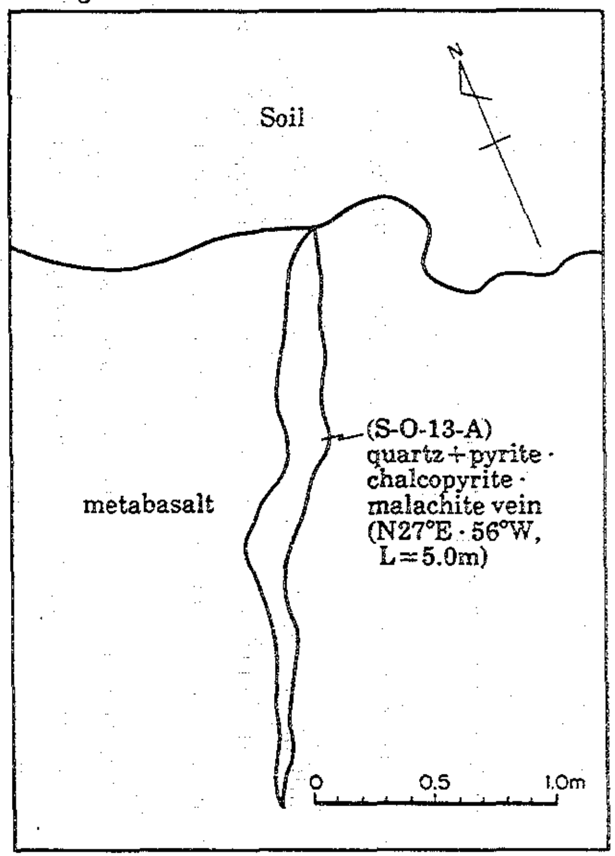


Figure II-1-6 Sketch of S-21 Outcrop



1-3-2 Indoor Experiment and Chemical Analysis

(1) K-Ar Age Determination of Igneous Rock (Four Samples)

The result of the age determination by means of the whole rock K-Ar method for two metagabbros, one metabasalt and one metaandesite taken from the Silam area in the Segama region is shown in the Table II-1-4.

As shown in the Table II-1-4, two metagabbros have been dated as 158±30 Ma (late Jurassic) and 210±20 Ma (early Jurassic) on the average. The age of metabasalt has been determined as 67.5±19.9 Ma (late Cretaceous) on the average and the age of 55.85±28.3 Ma (Paleocene) on the average has been obtained from metaandesite.

The ages of metagabbros are nearly same as those of epidote amphibolite (140±20 Ma), hornfels (160±8 Ma) and tonalites (150±6, 210±3 Ma) after Leong, K. M. (1974).

Table II-1-4 Result of K-Ar Dating of Rock Samples taken in Segama-Darvel Bay Region

Sample Number	Numbers in Laboratory	Sample Type	Potassium (K wt %)	Rad. ^{40}Ar (10^{-8} cc/g)	K-Ar Age (Ma)	Air Cont. (%)	Rock Name
S-D-3	SH-4-281 -282	Whole Rock	0.06 ±0.02	15.9±0.5 16.1±0.6	67.2±19.8 67.8±20.1 avg. 67.5±19.9	47.9 50.4 49.1	Metabasalt
S-D-4	SH-4-283 -284	Whole Rock	0.19 ±0.04	121±2 123±2	157±30 159±31 avg. 158±30	31.5 32.5 32.0	Metagabbro
S-D-5	SH-4-285 -286	Whole Rock	0.31 ±0.03	269±5 268±5	211±20 210±20 avg. 210±20	37.2 37.1	Metagabbro
S-D-7	SH-4-287 -288	Whole Rock	0.02 ±0.01	5.1±0.4 3.7±0.6	64.4±32.1 47.3±24.5 avg. 55.85±28.3	78.9 83.8 81.3	Metaandesite