REPORT ON THE MINERAL EXPLORATION: SUPRA-REGIONAL SURVEY IN CENTRAL SABAH, MALAYSIA (PHASE Ⅲ) (Investigation of Locality of Mineral Occurrence)

MARCH, 1993

No. 23

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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, 1992 to December, 1992 as a part of the survey work in the third 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 third year and also forms a part of the final consolidated report which will be submitted to the Government of Malaysia aafter 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.

March, 1993

Kensuke Yanagiya

Kensuke Yanagiya
President
Japan International Cooperation Agency

Takashi Ishikawa

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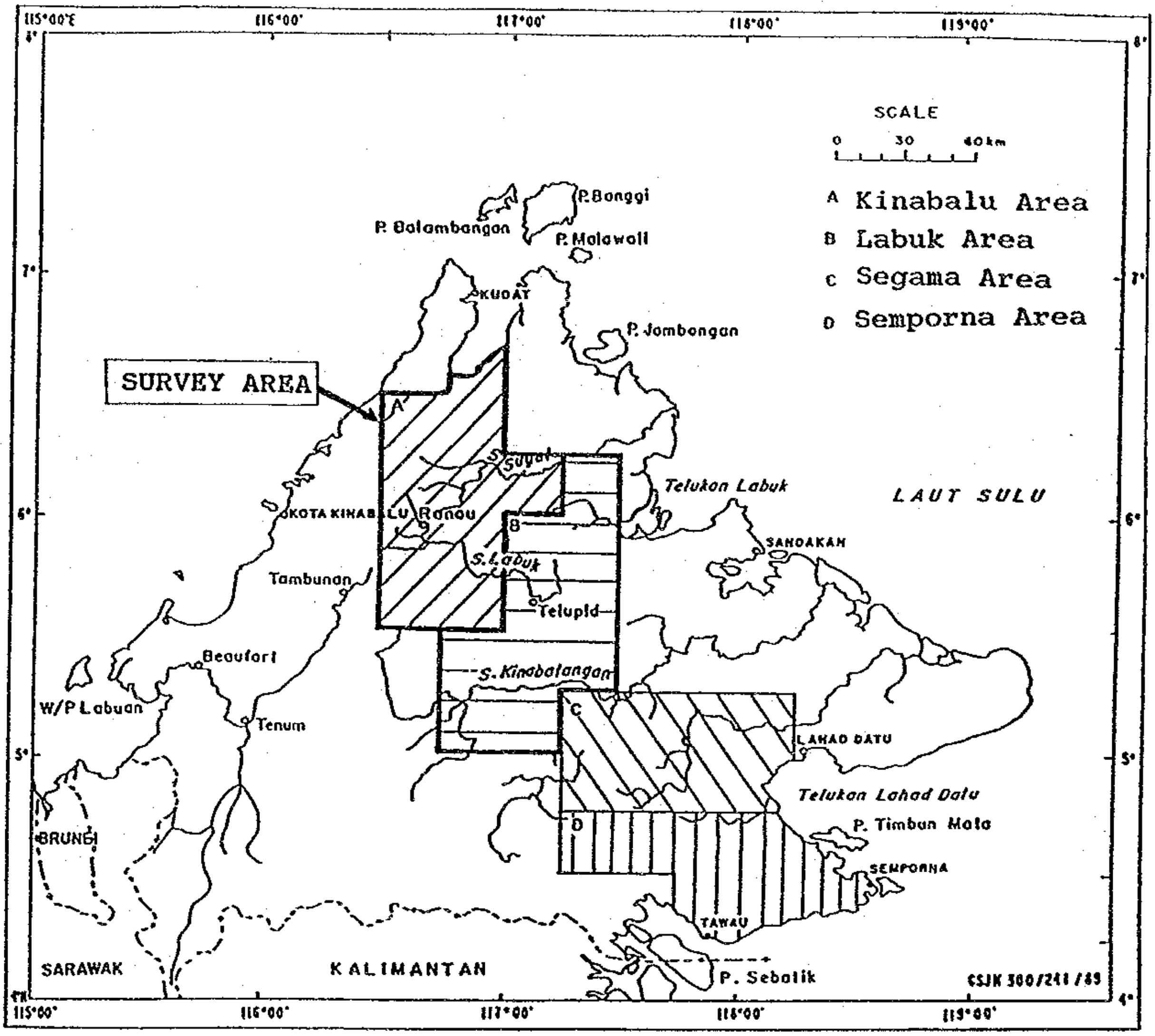

Fig.1 LOCATION MAP OF SURVEY AREA

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 the laboratory work 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 third year from August, 1992 to February, 1993.

The investigation of the localities of mineral occurrence in the Kinabalu and Labuk regions during August 7 to September 1992 and the additional work at the Sabah office of Geological Survey of Malaysia in Kota Kinabalu during September 24 to September 30, 1992 were carried out by one Japanese geologist.

The contents of the investigation of the localities of mineral occurrence and the laboratory work carried out in order to explore and assess the mineral potential of the survey area (Kinabalu and Labuk 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

   Forty localities of mineral occurrence in total, 12 in the Kinabalu and 28 in the Labuk regions, were investigated.

2. Laboratory work

   (1) K-Ar age determination of rock

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

   (2) Chemical analysis of rock

   Forty samples of rock in total, 20 samples same as those for K-Ar dating and

30 samples of representative rock at and around the main localities of mineral occurrence, were chemically analyzed.

(3) Microscopic observation of thin section of rock

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

(4) Assay of ore

Sixty samples in total, 48 samples of ore taken at forty localities of mineral occurrence and 12 samples of Ni-Cr-bearing laterite, were assayed.

(5) Microscopic observation of polished section of ore

The polished sections made from 30 samples of representative ore out of 48 ore samples for chemical analysis were observed microscopically.

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

The X-ray diffraction examination of 15 samples of hydrothermally altered host rock taken at and around the localities of mineral occurrence in the Kinabalu 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

Homogenization temperature of fluid inclusions in quartz taken from quartz vein at 10 localities of mineral occurrence in the Kinabalu region was measured.

As a result of the investigation of the localities of mineral occurrence and laboratory work mentioned above, in the Kinabalu region, mineralized zone of veinlets, network, and dissemination, which consists of quartz and minor amounts of pyrite and limonite and contains, in places, gold with minor amounts of lead, antimony, and mercury, in the hydrothermal alteration zone found at the foot of Bt. Tampang and veined hydrothermal alteration zones, which are accompanied partly by limonite·quartz veinlets containing lead with minor amounts of zinc, copper, and silver, in quartz monzonite porphyry around Bt. Luminantai have been found.

In the Labuk region, besides known ore deposits and mineral occurrences in the Bidu Bidu Hills area, the mineralized zones of Sungai Telupid, Kg. Porog, S. Tungud, Telupid, and S. Ensuan belonging to Cyprus-type curpriferous iron sulfide deposit have been confirmed.

The mineralized zones of Sungai Telupid, Kg. Porog, and S. Tungud out of the above five mineralized zones seem to be promising.

Therefore, the following follow-up works for these promising mineralized zones are recommended.

1. Bt. Tampang mineralized zone

(1) Detailed geological mapping; K-Ar dating, chemical analysis, and microscopic observation of host rock; systematic sampling, assay, and microscopic observation of ore; X-ray diffraction examination of hydrothermally altered rock; measurement of homogenization temperature and salinity of fluid inclusion in quartz taken from quartz veinlets; and geolchemical survey by the use of soil at the foot and hillside of Bt. Tampang.

(2) The same follow-up works as the above, except for geochemical survey, at the foots and hillsides of a hill ranging to the west-northwest of Bt. Tampang, Bt. Kotud, Bt. Tambiau, Bt. Tu'us, and Bt. Kalarakan to the north of Bt. Tampang.

2. Sungai Telupid mineralized zone

Detailed geological mapping; K-Ar dating, chemical analysis, and microscopic observation of host rock; systematic sampling, assay, and microscopic observation of ore; and geochemical survey by the use of soil in and around the mineralized zone.

3. S. Porog mineralized zone

Detailed geological mapping; K-Ar dating, chemical analysis, and microscopic observation of host rock; systematic sampling, assay, and microscopic observation of ore; and geochemical survey by the use of soil at and around outcrops.

4. S. Tungud mineralized zone

Detailed geological mapping; K-Ar dating, chemical analysis, and microscopic observation of host rock; systematic sampling, assay, and microscopic observation of ore; and geochemical survey by the use of soil in and around mineralized zone.

Next, the detailed geological mapping; chemical analysis, microscopic observation, and X-ray diffraction examination of hydrothermal alteration vein; assay and microscopic observation of limonite·quartz veinlets in hydrothermal alteration veins; and measurement of homogenization temperature and salinity of fluid inclusion in quartz taken from limonite·quartz veinlets are recommended in order to clarify whether hydrothermal alteration veins in quartz monzonite porphyry around Bt. Luminantai accompany the upper part of porphyry copper deposit or not.

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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 birds'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 year (1990).

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.

The investigation of the localities of mineral occurrence and laboratory work of the samples taken in the survey area at the time of the investigation had been carried out from August, 1991 to February, 1992, as a part of the survey work in the second year (1991).

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 laboratory work 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. Laboratory work

   (1) K-Ar age determination (20 samples)
   (2) Chemical analysis of rock (40 samples)
   (3) Microscopic observation of thin section of rock (40 samples)
   (4) Assay of ore (50 samples)
   (5) Microscopic observation of polished section of ore (30 samples)
   (6) X-ray diffraction examination of hydrothermally altered rock (40 samples from Semporna region only)
   (7) Measurement of homogenization temperature of fluid inclusion in quartz (20 samples from Semporna region only)

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

1-2-1 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 quarts 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 network 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 network. There is also possibility of the emplacement of the stock work 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 Pilocene 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 network 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 network 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.

1-2-2 Recommendation

1. Recommendation for the Phase III survey

The investigation of the localities of mineral occurrence and the laboratory work, 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 bein 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) Laboratory work

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)

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 ore body of low grade in the Mantri area.

(2) Drilling to search for the network 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.

1-3 Outline of the Survey in the Third Year (1992)

1-3-1 Survey Area

The survey work for 1992 was carried out in Kinabalu and Labuk regions shown in the Fig. I-1.

1-3-2 Objective of the Survey

The main objective of the survey in 1992 is to explore and to assess the mineral potential of the survey area (Kinabalu and Labuk 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 third year (1992) are as follows.

(1) Participants in Planning and Negotiation

a) Malaysian members

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

b) Japanese member

Kenzo Masuda	Metal Mining Agency of Japan
Haruhisa Morozumi	Metal Mining Agency of Japan

(2) Survey Members

a) Malaysian members

Lim Peng Siong	Project Manager, Geological Survey of Malaysia
Alexander Yan Sze Wah	Senior Geologist, Geological Survey of Malaysia
Amin A.Y. Basimin	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 third year (1992) are as follows and quantity of the survey is shown in the following Table I-1.

(1) Investigation of locality of mineral occurrence

In order to explore and assess the mineral potential of the survey area (Kinabalu and Labuk regions) in Sabah, through understanding geology and mineralization at the localities of mineral occurrence found in the survey area and then clarifying the characteristic of mineralization in the survey area, 40 localities of mineral occurrence in total, namely 12 localities including foats at the L-1 locality in the Kinabalu region and 28 Localities including floats at 3 localities which can be nearly regarded as outcrops in the Labuk region, were investigated.

The result of the investigation is summarized in the Table I-2 and the result in each region is as follows.

A. Kinabalu region

The locations of the localities of mineral occurrence investigated are shown in the Fig. II-1-1 and II-1-2 attached at the end of this report and geology of the Bt. Tampang-Bt. Luminantai area and of a read at the western foot of Bt. Tampang are shown in the Fig. II-1-5 and II-1-6 respectively.

(a) The mineralized zone of veinlets, 1 ~ 10 cm wide, network, and dissemination consisting of quartz with minor amounts of pyrite and limonite, embedded in acidic to intermediate volcanic and pyroclastic rocks subjected to hydrothermal alteration, is found at the western and southern foots of Bt. Tampang.

This gold-bearing mineralized zone seems to correspond to the upper part of epithermal gold deposit accompanying intermediate to weak alkaline hydrotehermal fluid related to the volcanic activity, considering that some veinlets in the mineralized zone contain gold (2.68 g/t), antimony (0.13%), and mercury (22.05 ppm, 22.45 ppm) and the alteration mineral assemblage of hydrothermaly altered rock consists mainly of quartz, sericite, kaolinite, and chlorite accompanied, in places, by some potash felspar and smectite and that homogenization temperature of the fluid inclusion in quartz taken from quartz veinlets ranges from 218°C to 259°C except for 278° to 284°C of one sample.

(b) The veined hydrothemal alteration zones accompanied partly by some limonite and quartz are found along many parallel joints in quartz monzonite porphyry around Bt. Luminantai. Hydrothermal alteration veins are narrow in width and form network as a whole.

There is a possibility that these hydrotermal alteration veins may correspond to the SCC zone (sericite-clay-chlorite) accompanying the upper part of porphyry copper deposit, considering that some limonite·quartz veinlet in hydrothermal alteration vein contains lead (2.46%), zinc (0.13%), copper (0.10%), and silver (11.1 g/t) and the mineral assemblage of hydrothermal alteration vein consisting mainly of quartz, chlorite, kaolinite, potash felspar, and kaolinite is similar to that ofthe SCC zone, proposed by Sillitoe et al. (1984), accompanying the upperpart of porphyry copper deposit in the philippines, and that the homogenization temperature of fluid inclusion in quartz taken from limonite•quartz veinlet in hydrothermal alteration vein ranges from 350° to 417°C and is included in the range of that of quartz vein accompanying porphyry copper deposit (300° to 480°C in case of Mamut deposit, after Nagano et al., 1977).

However, seeing that ore samples for chemical analysis (2 samples), clay samples for X-ray diffraction (3 samples), and quartz sample for measurement of homogenization temperature (1 sample) are short of the number and that quartz monzonite porphyry between hydrotermal alteration veins has not been subjected to hydrothermal alteration, a definite conclusion about the above must be reserved.

(c) The mineralized zone of Cyprus-type networked and disseminated iron sulfide consisting of pyrite with a trace of sphalerite and malachite in pillow basalt of the ophiolite complex is found in the old adit about two kilometers east of Kg. Pingan Pingan situated along Marudu Bay in northern Sabah.

Considering that the mineralized zone contains 0.62% of zinc and no copper and is small in extent, it seems that mineralization at this mineralized zone may be weak.

(d) Four outcrops of limonite-bearing quartz veins embedded in faults in the alternating beds of sandstone and shale (sandstone $\gg$ shale) of Trusmadi Formation and floats of high grade stibnite are found in the Samalang river basin in the Randagong area.

The asasy result reveals that no useful metal including antimony is contained in the samples taken at four outcrops of limonite-bearing quartz veins. Therefore, it seems that limonite in limonite-bearing quartz vein has probably been formed by oxidation of pyrite and float of high grade stibnite has been possibly derived from the partial concentration of stibnite in pyrite•quartz vein.

B. Labuk region

The locations of the localities of mineral occurrence investigated are shown in the Fig. II-2-1 attached at the end of this report and geology of the central part of the Bidu Bidu Hills area, Telupid area, and the localities of mineral occurrence along Sungai Telupid in Telupid area are shown in the Fig. II-2-3, II-2-4, and II-2-5 respectively.

(a) Eleven localities of mineral occurrence of the massive, lenticular, veined, networked, and disseminated mineralized zone of Cyprus-type cupriferous iron sulfide, which consists mainly of pyrite, limonite, quartz, and chalcopyrite associated, in places, with minor amounts of bornite, chalcocite, covellite, malachite, sphalerite, and magnetite, in basalt and some dolerite of the ophiolite complex are found along the S. Telupid, situated about 6 kilometers west-northwest of Telupid, for a distance of about 160 meters.

The assay result of 14 ore samples taken at 11 localities reveals that the ore samples from 6 localities contain copper over 0.5% (0.88% ~ 11.05%).

Basalt and some dolerite in which the mineralized zone is embedded have been subjected to chloritization and partial epidotization.

The whole mineralized zone can be regarded as a copper-bearing network ore body, which is relatively big in size, with a length of about 155 meters in the direction of the northeast and a width of about 15 meters.

(b) Two outcrops (Po-2 and Po-3) and floats (Po-1) of massive gossan consisting of limonite and hematite are found around Kg. Porog to the north of Kg. Kiabau in the Bidu Bidu Hills area. Floats at the Po-1 locality can be nearly regarded as a outcrop.

These massive gossans contain 55.58 to 58.34% of iron and 0.11 to 0.40% of copper which still remain in gossans.

These massive gossans are considerably similar to those which are found at the surface of Cyprus-type massive cupriferous iron sulfide deposits of West Sualog and Kiabau in the Bidu Bidu Hills area in point of the megascopic observation, microscopic observation, and assay result.

Therefore, it seems that massive gossans at three localities have been probably formed by oxidation of Cyprus-type massive cupriferous iron sulfide body near the surface and it is possible that massive cupriferous iron sulfide body not oxidized is present under outcrop and its extension.

(c) The semi-massive, networked, and disseminated mineralized zone (Tg-1) of Cyprus-type cupriferous iron sulfide consisting of pyrite, limonite, quartz, and a small amount of chalcopyrite, over 20 meters long and over 8 meters high, in metadolerite of the ophiolite complex are exposed along the S. Unsadan, a tributary of the S. Tungud, situated about 30 kilometers north-northwest of Telupid. One of two ore samples contains 0.27% of copper.

Considering that high Cu·Zn anomalies of the geochemical surveys by the use of stream sediment, conducted by the Malaysia-Germany exploration project for 1980 to 1984 and by the base metal exploration project of Geological Survey of Malaysia for 1986 to 1990, were detected in the upper basin of the S. Unsadan including the Tg-1 mineralized zone, there is a possibility that ore body of bigger size and of higher grade of copper than the Tg-1 mineralized zone may be present near the Tg-1 and that the mineralized zone of Cyprus-type cupriferous iron sulfide other than the Tg-1 may be found in the upper basin of the S. Unsadan.

(d) Veinlets, 2 to 5 centimeters wide, consisting of quartz, pyrite, and chalcopyrite and disseminated zone of pyrite in basalt of the ophiolite complex (TE-1) are found in a scattered pattern at the construction site of Forestry Training Institute of Telupid.

Ore sample taken from a veinlet in the mineralized zone contains 4.63% of copper. This mineralized zone is thought to be of Cyprus-type cupriferous iron sulfide and seems to be samller in size than those at Sungai Telupid and S. Tungud.

(e) The mineralized zone (E-1) of gravel-like, semi-massive, and disseminated Cyprus-type cupriferous iron sulfide consisting of pyrite, limonite, quartz, and a minor amount of chalcopyrite in pillow basalt of the ophiolite complex is found at the roadside, situated about 24 kilometers north-northwest of Telupid, in the upper basin of the S. Ensuan, a tributary of the S. Labuk. The whole mineralized zone is lenticular in shape with a length of 2.2 meters and a maximum width of 1.5 meters.

The sample taken from a gravel-like ore, 15 centimeters long and 10 centimeters wide, contains 1.27% of copper.

The mineralization at the E-1 locality seems to be weak, judging from that there is only one small lenticular mineralized zone.

(2) Laboratory work

A. Kinabalu region

i) K-Ar age determination of rock

The result of K-Ar dating of 9 representative rock samples is shown in the Table II-1-5 in the section 1-3-2-(1) of the Part II.

Five samples of acidic and intermediate intrusive rocks, which are aligned roughly in the direction of the north-south from Kg. Tagap to Bt. Kamunsu and include quartz monzonite porphyry around Bt. Luminantai, have been dated as 6.85±0.17 to 7.47±0.20 Ma (late Miocene) and the ages of 2 samples of basalt and 1 sample of gabbro in the ophiolite complex have been determined as 17.0±0.65 Ma (middle Miocene), 44.9± 9.3 Ma (middle Eocene), and 57.0±11.45 (late Paleocene) respectively. The age of 70.8±2.2 Ma (late Cretaceous) has been obtained from sandstone taken at the foot of Bt. Tampang.

ii) Chemical analysis of rock

The assay result of 18 representative rock samples including 9 samples for the K-Ar dating is given in the Table II-1-5 in the section 1-3-2-(2) of the Part II.

The analyses of 8 rock samples, namely 3 samples of basalt of the ophiolite complex, 2 samples of diorite porphyrite in the Kg. Merungin area, 1 sample of rhyolite, 1 sample of dacite, and 1 sample of trachytic tuff around Bt. Tampang, out of 18 samples assayed, have been plotted on several diagrams for petrological study.

The result of the petrological study reveals that three basalts have been plotted within the field of MORB (Mid-ocean ridge basalt) in the TiO_2-FeO*/MgO diagram, but has not been able to reveal which of basalt or tholeiite or calc-alkali rock series three basalts belong to. (FeO*: calculated as total FeO from the analyses of FeO and Fe_2O_3)

The petrological study also reveals that two diorite porphyrites have been plotted within the field of IAT (Island arc tholeiite) in the TiO_2-FeO*/MgO diagram and belong to the calc-alkali rock series of the FeO*-FeO*/MgO diagram and that three acidic to intermediate volcanic and pyroclastic rocks have been roughly plotted in the field of IAT of the TiO_2-FeO*/MgO diagram and dacite belongs to the calc-alkali rock series of the FeO*-FeO*/MgO diagram, while rhyolite and trachytic tuff belong to the high alkali tholeiite series.

iii) Microscopic observation of thin section of rock

The result of the microscopic observation of the thin sections made from 18 rock samples taken at the same localities as the samples for the chemical analysis is shown in the Table II-1-6 in the 1-3-2(3) of the Part II.

iv) Assay of ore

The assay result of 14 ore samples taken at 12 localities of mineral occurrence investigated is given in the Table II-1-9 in the section 1-4 of the Part II.

Some veinlets in the mineralized zone of veinlets, network, and dissemination consisting of quartz with minor amounts of pyrite and limonite, embedded in acidic to intermediate volcanic and pyroclastic rocks subjected to hydrothermal alteration, at the western and southern foots of Bt. Tampang, contain 2.68 g/t of gold, 0.13% of antimony, 0.16% of lead and 22.05 ppm of mercury, and 22.45 ppm of mercury.

Some limonite•quartz veinlet in the veined hydrothermal alteration zones found along many parallel joints in quartz monzonite porphyry around Bt. Luminantai contains 2.46% of lead, 0.13% of zinc, 0.10% of copper, and 11.1 g/t of silver.

The mineralized zone of Cyprus-type networked and disseminated iron sulfide, consisting of pyrite with a trace of sphalerite and malachite, in pillow basalt of the ophiolite complex in the old adit about 2 kilometers east of Kg. Pingan Pingan situated along Marudu Bay in northern Sabah contains 0.62% of zinc and no copper.

Limonite-bearing quartz veins embedded in faults in the alternating beds of sandstone and shale (sandstone ≫ shale) of Trusmadi Formation contain no useful metal including antimony, while a float of high grade stibnite near the R-5 outcrop contains 23.79% of antimony.

A float of Cyprus-type massive cupriferous iron sulfide ore in the S. Lingangah contains 2.63 g/t of gold, 216.8 g/t of silver, and 36.58% of copper.

v) Microscopic observation of polished section of ore

The result of the microscopic observation of the polished sections made from 7 representative ore samples out of 14 samples taken for assay is given in the Table II-1-7 in the section 1-3-2-(5) of the Part II. The Table II-1-7 shows that ore at the T-3 locality of mineral occurrence in hydrothermally altered rock at the foot of BT. Tampang is disseminated ore consisting of minor amounts of chalcopyrite and pyrite with a trace of sphalerite, and a float of Cyprus-type massive cupriferous iron sulfide in the S. Lingangah is high grade copper ore consisting of chalcopyrite, bornite, chalcocite, covellite, pyrite, and a very small amount of sphalerite and that a float of high grade stibnite ore in the Randagong area is mostly composed of stibnite with a trace of pyrite.

vi) X-ray diffraction examination of hydrothermally altered rock

The result of the X-ray diffraction examination of 15 hydro-thermally altered rock samples, namely 12 samples taken from hydrothermally altered acidic to intermediate volcanic and pyroclastic rocks and sedimentary rock around Bt. Tampang and 3 samples from hydrothermal alteration veins along parallel joints in quartz monzonite porphyry around Bt. Luminantai, is shown in the Table II-1-8 in the section 1-3-2-(6) of the Part II and indicates that hydrothermal alteration zone at the foot of Bt. Tampang consists mainly of a large quantity of quartz, a small amount to a trace of kaolinite, a trace of chlorite, and a trace of sericite, accompanied, in places, by a middle to small amount of potash felspar and a trace of smectite, and hydrothermal alteration veins around Bt. Luminantai are composed of a large quantity of quartz, a middle quantity to a trace of potash felspar, a minor amount to a trace of sericite, a trace of kaolinite, and a trace of chlorite.

The X-ray diffraction examination reveals that the mineral assemblage of the hydrothermal alteration zone at the foot of Bt. Tampang and hydrothermal alteration veins in quartz monzonite porphyry around Bt. Luminantai is similar to that of the upper part of the hydrothermal alteration zone accompanying epithermal gold deposit of the adularia-sericite type of low sulfidation system formed by intermediate to weak alkaline hydrothermal liquid, or that of the SCC zone (sericite-clay-chlorite) accompanying the upper part of porphyry copper deposit in the Philippines.

vii) Measurement of homogenization temperature of fluid inclusions in quartz

The histgrams of the homogenization temperature of the fluid inclusions in 10 quartz samples, namely 4 samples taken from (gold)-pyrite-limonite-bearing quartz veinlets in the hydrothermal alteration zone at the foot of Bt. Tampang, 1 sample from limonite-bearing quartz veinlet accompanying hydrothermal alteration vein in quartz monzonite porphyry around Bt. Luminantai, and 4 samples from limonite-bearing quartz veins and 1 sample from quartz vein in the Trusmadi Formation in the Kg. Randagong area, are shown in the Figs. II-1-12, II-1-13, and II-1-14 in the section 1-3-2-(7) of the Part II.

The homogenization temperature of 4 samples of the Bt. Tampang area ranges from 218° to 284°C and is included in the range of 200° to 300°C of that of high sulfidation system epithermal gold deposit accompanying hydrothermal liquid related to the volcanic activity in the Circum-Pacific region, or is included in the range of 133° to 349°C of the adularia-sericite type or in the range of 120° to 320°C of the acid-sulfate type gold deposits in the western Pacific island arcs region.

The homogenization temperature of 5 samples of the Kg. Randagong area ranges from 155° to 217°C and is lower than that of (gold)-limonite-pyrite-bearing quartz veinlets around Bt. Tampang.

The homogenization temperature of 1 sample of the Bt. Luminantai area ranges from 350° to 417°C and is included in the range of that of quartz vein accompanying porphyry copper deposit (300° to 480°C in case of Mamut deposit). However, owing to a lack of the number of sample, a definite conclusion must be reserved.

B. Labuk region

i) K-Ar age determination of rock

Eleven representative rock samples, namely 4 samples of basalt, 5 samples of dolerite, and 2 samples of gabbro in the ophiolite complex, out of 32 rock samples taken at and near the localities of mineral occurrence in the Bidu Bidu Hills and Telupid areas for the microscopic observation and assay, were dated by means of the K-Ar method of whole rock. As shown in the Table II-2-4 in the section 2-3-2-(1) of the Part II, basalt and dolerite have been dated as 26.6±8.1 Ma (late Oligocene) to 40.5±4.2 Ma (late Eocene) with a relatively narrow range except for 123±63 Ma (early Cretaceous) of one basalt sample and the ages of 2 gabbro samples have been determined as 13.1 ±2.0 Ma (middle Miocene) and 248.5±116 Ma (latest Permian).

ii) Chemical analysis of rock

The assay result of 32 rock samples, namely 11 samples taken at the same localities as the samples for the K-Ar age determination, 7 samples of basalt, 3 samples of dolerite, 2 samples of gabbro, and 9 samples of ultrabasic rock in the ophiolite complex, is given in the Table II-2-5 in the section 2-3-2-(2) of the Part II.

The analyses of 11 samples of basalt and 8 samples of dolerite out of 32 rock samples assayed have been plotted on several diagrams for the petrological study.

The petrological study by the use of several diagrams reveals that basalt and dolerite which constitute the ophiolite complex and host Cyprus-type cupriferous iron sulfide ore have been mainly plotted within the field of MORB (Mid-ocean ridge basalt) in the TiO_2-FeO*/MgO diagram and consist of alkali basalt, tholeiite, and calc-alkali rock series in the diagrams of SiO_2-Na_2O+K_2O, MgO-FeO*-Na_2O+K_2O, SiO_2-FeO*/MgO, and FeO*-FeO*/MgO. (FeO*: calculated as total FeO from the analyses of FeO and Fe_2O_3)

iii) Microscopic observation of thin section of rock

The thin sections made from 32 rock samples taken at the same localities as the samples for the assay, namely 11 samples of basalt, 8 sampies of dolerite, 4 samples of gabbro, and 9 samples of ultrabasic rock in the ophiolite complex, were observed under a polarization-microscope and the result of the observation is shown in the Table II-2-6 in the 2-3-2-(3) of the Part II.

iv) Assay of ore

The assay result of 46 samples taken in the Bidu Bidu Hills and Telupid areas, namely 34 ore samples obtained at 28 localities of mineral occurrence of Cyprus-type cupriferous iron sulfide ore and 12 samples of Cr-Ni-bearing laterite formed by weathering of ultrabasic rock, is given in the Tables II-2-8 and II-2-9 in the section 2-4 of the Part II.

The assay result of 14 ore samples taken at 11 localities of mineral occurrence of Cyprus-type cupriferous iron sulfide along the Sungai Telupid situated about 6 kilometers west-northwest of Telupid reveals that the ore samples at 6 localities contain copper over 0.5% (0.88 ~

11.05%).

One sample taken from a veinlet, consisting of quartz, pyrite, and chalcopyrite, in the mineralized zone of veinlets and dissemination of Cyprus-type cupriferous iron sulfide at the construction site of Forestry Training Institute of Telupid contains 4.63% of copper.

The sample taken from gravel-like ore, consisting of pyrite, limonite, quartz, and a minor amount of chalcopyrite, in the mineralized zone of semi-massive, gravel-like, and disseminated Cyprus-type cupriferous iron sulfide at the road side, about 24 kilometers north-northwest of Telupid, in the upper basin of the S. Ensuan contains 1.27% of copper.

The massive gossans of limonite and hematite at the localities of mineral occurrence of West Sualog, Kiabau, Porog, and Karang contain 46.29 to 58.34% of iron and 0.11 to 0.40% of copper which still remain in gossans.

The assay result of samples of laterite taken mostly in the Telupid area reveals that the majority of the samples contain 1.11 to 2.22% of chromium and 0.40 to 0.95% of nickel and that laterite rich in chromium contains much nickel in general.

v) Microscopic observation of polished section of ore

The polished sections made from the ore samples obtained at 23 localities, out of 34 ore samples taken for assay at 28 localities of mineral occurrence of massive semi-massive, networked, veined, and disseminated Cyprus-type cupriferous iron sulfide, were observed under a ore microscope. The result of the observation is shown in the Table II-2-7 in the section 2-3-2-(5) of the Part II.

The Table II-2-7 reveals that the mineralized zones of Cyprus-type cupriferous iron sulfide consist mainly of quartz, pyrite, and chalcopyrite, accompanied, in places, locally by magnetite, hematite, and very small amounts of bornite, chalcocite, covellite, and sphalerite, and that massive gossans are composed mostly of limonite, quartz, and a trace of hematite.

1-3-5 Period of the Survey

The period of the survey in Malaysia is as follows:

Travelling:	August 2 ~ August 6, 1992
Survey work in Malaysia:	August 7 ~ September 23, 1992
Supplemental work in Kota Kinabalu:	September 24 ~ September 30, 1992
Travelling:	October 1 ~ October 3, 1992

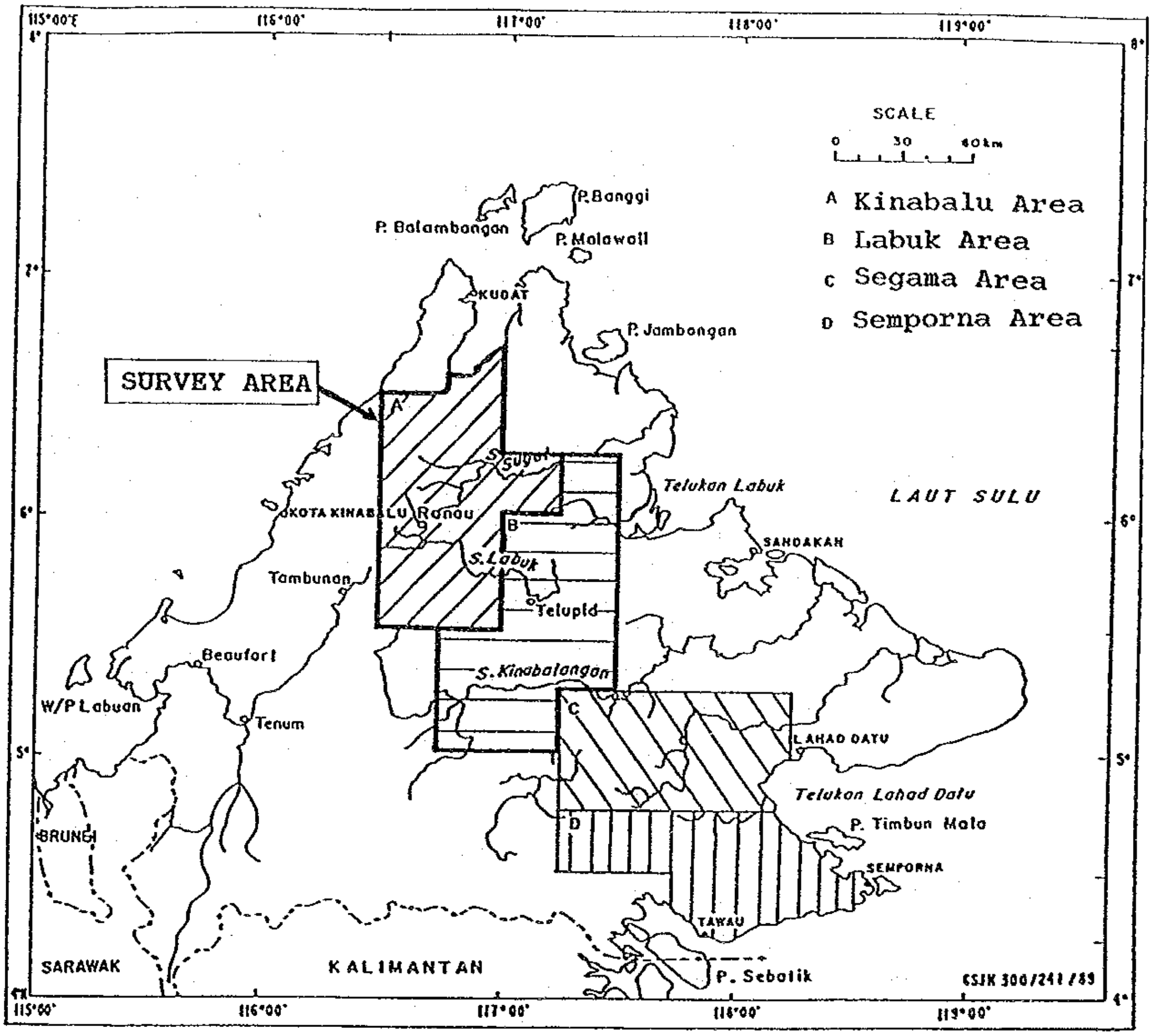


Figure I-1 Location Map of Survey Area

Table I-1 Quantity of the Survey

Contents of the Survey	Quantity
[Investigation of locality of mineral occurrence]	40 localities
[Laboratory work]	
1. K-Ar Age determination	20 samples
2. Chemical analysis of rock 22 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, Mo, Ni, Pb, S, Zn	50 samples (1100 constituents)
3. Microscopic observation of thin section of rock	50 samples
4. Chemical analysis of ore - Sample (A) (10 constituents: Ag, Au, Cu, Fe, Hg, Mo, Pb, S, Sb, Zn) - Sample (B) (8 constituents: Au, Co, Cr, Cu, Fe, Mn, Ni, Pt)	 48 samples (480 constituents) 12 samples (96 constituents)
5. Microscopic observation of polished section of ore	30 samples
6. X-ray diffraction examination	15 samples
7. Measurement of homogenization temperature of fluid inclusion in quartz	10 samples

Table I-2 List of Localities of Mineral Occurrence Investigated in Kinabalu and Labuk Regions

Region	Locality Name	Locality Number	Mineral Assemblage	Occurrence	Strike & Dip	Size of Orebody (in meter)	Host Rock	Alteration of Host Rock	Sample No.
Kinabalu	Lingangah	L-1*	Py·cp·bo·hm·lim+mal	boulder of massive ore	—	max. 3.0×1.3×1.3	—	—	L-1-0
"	Luminantai	Lu-2	lim·gn	network	E-W·90°	L=6.0+, W=17.0	guartz monzonite porphyry	silicification, kaolinization, chloritization, sericitization	Lu-2-0
"	"	Lu-3	lim·qz	network	N60°W·90°	L=6.0+, W=40.0	guartz monzonite porpluyry	silicification, chloritization, sericitization, kaolinization	Lu-3-0
"	Pingan Pingan	PP-2	lim·py·qz+mal	network	N-S·90°	L=5.0+, W=3.0	pillow basalt	chloritization, silicification, epidotization	PP-2-0
"	Randagong	R-1	qz·lim	vein along fault	N86°W·48°N	L=2.7, W=0.05~0.14	sandstone, shale	none	R-1-0
"	"	R-2	qz+lim	vein along fault	N60°W·70°N	H=2.0+, W=2.0	sandstone, shale	none	R-2-0
"	"	R-3	qz+lim	vein along fault	N3°W·70°W	L=1.0, W=0.1~0.15	sandstone, shale	none	R-3-0
"	"	R-5	sb·qz·py	vein along fault	N14°E·70°W	L=3.0+,H=2.0,W=0.25	sandstone, shale	none	R-5-0-1
"	Tampang	T-1	qz+py·lim	network	N45°W·86°N	H=2.0+, W=1.0	dacitic tuff breccia	silicification, sericitization, kaolinization, chloritization	T-1-0-1 T-1-0-2
"	"	T-3	qz+lim·py	lenticular	—	L=0.25, W=0.1	rhyolitic tuff breccia	silicification, sericitization, kaolinization, chloritization	T-3-0
"	"	T-7	py·lim	disseminated~lenticular	—	L=0.3, W=0.15	trachytic tuff breccia	silicification, sericitization, kaolinization, chloritization	T-7-0
"	"	T-10	qz+lim	vein along joint	N20°E·80°W	L=0.8, W=0.01~0.15	tuff	silicification, chloritization, sericitization, kaolinization, montmorillonitization	T-10-0
Labuk	East Sualog	ES-3	py·lim	semi-massive~disseminated	—	L=3.6, H=1.5	pillow basalt	chloritization	ES-3-0
"	Ensuan	E-1	py·lim+qz·cp	massive~semi-massive~ disseminated	—	L=2.2, W=0.1~1.5	pillow basalt	chloritization	E-1-0
"	Karang	Kg-2	lim	semi-massive	N50°E·75°S	H=3.0+, W=2.6	pillow basalt	chloritization	Kg-2-0
"	Kiabau	KB-1**	hm+lim	boulder of massive gossan	—	max. D=0.5	—	—	KB-1-0
"	"	KB-3	qz+lim	vein along joint	N70°E·75°N	L=1.2, W=0.02~0.06	dolerite	choritization	KB-3-0
"	Porog	Po-1**	hm	boulder of massive gossan	—	max. 1.0×0.5	—	—	Po-1-0
"	"	Po-2	hm·lim	massive gossan	N10°W·60°E	L=5.0+, W=6.0	?	?	Po-2-0
"	"	Po-3	hm·lim	massive gossan	N50°W·?	L=71.0+, W=5.5+	?	?	Po-3-0

Region	Locality Name	Locality Number	Mineral Assemblage	Occurrence	Strike & Dip	Size of Orebody (in meter)	Host Rock	Alteration of Host Rock	Sample No.
Labuk	Southwest Sualog	SW-1	qz+hm·lim·py·cp	vein~lenticular~ disseminated	N45°E·?	L=4.8, W=0.1~0.75	basalt	chloritization	SW-1-0
"	"	SW-5	py·lim+qz	disseminated~lenticular	—	0.15×0.10×0.10	pillow basalt	chloritization, silicification	SW-5-0
"	"	SW-6	qz+py·lim·sp+cp	network	N22°W·?	L=5.0, W=0.2~0.45	pillow basalt	chloritization	SW-6-0-1 SW-6-0-2
"	Sungai Telupid	ST-2	py·lim+qz	vein	N20°E·90°	L=4.5, W=0.06~0.1	pillow basalt	chloritization, epidotization	ST-2-0
"	"	ST-3	py·lim·qz	network & lenticular	—	L=3.9+, W=5.0	pillow basalt	chloritization, epidotization	ST-3-0-1 ST-3-0-2
"	"	ST-4	qz+lim·py	vein	N50°E·?	L=1.0, W=0.05~0.25	pillow basalt	chloritization	ST-4-0
"	"	ST-5	py·lim+qz·cp	lenticular	—	L=1.0, W=0.7	pillow basalt	chloritization	ST-5-0
"	"	ST-6	py·lim+qz·cp·bo	vein	N40°E·76°W	L=1.8, W=0.05~0.1	pillow basalt	chloritization	ST-6-0
"	"	ST-9	py·lim+cp·qz	network	N16°~26°E·90°	L=5.5, W=0.5~1.3	metadolerite	chloritization, epidotization	ST-9-0
"	"	ST-10	py+qz·lim+cp	vein~lenticular	N60°E·90°	L=2.5, W=0.05~0.4	basalt	chloritization	ST-10-0
"	"	ST-11	lim·py·qz	vein	N60°E·90°	L=4.0, W=0.1~0.2	basalt	chloritization	ST-11-0-1
			py·lim+cp·qz	vein	N60°E·90°	L=9.5, W=0.05~0.2	basalt	chloritization	ST-11-0-2
"	"	ST-12	py·lim+qz+cp	network & lenticular	N50°E·?	L=20.0, W=0.2~5.0	basalt	chloritization	ST-12-0-1
			py·lim+qz	network & lenticular					ST-12-0-2
"	"	ST-13	qz+lim·py·cp·mal	network	N40°E·?	L=13.5, W=2.0~4.5	basalt	chloritization, epidotization	ST-13-0
"	"	ST-15	qz+mt·lim·py·cp·bo·mal	network	E-W·?	L=10.0, W=1.0~4.0	basalt	chloritization, epidotization	ST-15-0
"	Telupid	TE-1	qz+py·cp	vein and disseminated	N12°W·72°E	L=0.8, W=0.02~0.05	basalt	chloritization	TE-1-0
"	Tungud	Tg-1	py·lim·cp	network, semi-massive, disseminated	N60°W·?	L=20.0+, H=8.0+	metadolerite	chloritization	Tg-1-0-1 Tg-1-0-2
"	Ulu West Sualog	UWS-2	qz+py·lim·cp	network	E-W·?	L=6.5, W=1.5	altered pillow basalt	chloritization, epidotization	UWS-2-0
"	West Sualog	WS-3	py·lim	lenticular	—	L=0.2, W=0.1	pillow basalt	chloritization	WS-3-0
"	"	WS-4**	hm·lim	boulder of massive gossan	—	max. 3.0×2.0×1.0	—	—	WS-4-0
"	"	WS-5	hm+lim	massive gossan	N30°E·?	L=18.0, W=1.3~3.0	—	—	WS-5-0

Abbreviations:
*: boulder of gossan, **: boulder of gossan nearly in situ, py: pyrite, cp: chalcopyrite, bo: bornite, hm: hematite, lim: limonite, mal: malachite, qz: quartz, sb: stibnite, gn: galena, sp: sphalerite, mt: magnetite, max.: maximum, L: length, W: width, H: height, D: diameter, 6.0+: 6.0 and over

Table I-3 List of Samples taken in Kinabalu and Labuk Regions

Region	Locality Name	Locality Number	Dating	Analysis of Rock	Thin Section	Assay of Ore	Polished Section	X-ray Defraction	Fluid Inclusion	Specimen
Kinabalu	Bambangan	B-1		B-1-R	B-1-T					
"	Kamunsu	Km-1	Km-1-D	Km-1-R	Km-1-T					Km-1-D-S
"	Kiapako	K-1	K-1-D	K-1-R	K-1-T					K-1-D-S
"	Lingangah	L-1				L-1-0	L-1-P			L-1-0-S
"	Luminantai	Lu-1	Lu-1-D	Lu-1-R	Lu-1-T					Lu-1-D-S
"	"	Lu-2				Lu-2-0		Lu-2-X		
"	"	Lu-3		Lu-3-R	Lu-3-T	Lu-3-0		Lu-3-X	Lu-3-Q	
"	"	Lu-4		Lu-4-R	Lu-4-T					
"	"	Lu-5						Lu-5-X		
"	Mankadau	M-1	M-1-D	M-1-R	M-1-T					M-1-D-S
"	"	M-2		M-2-R	M-2-T					M-2-R-S
"	Morouporou	Mo-1	Mo-1-D	Mo-1-R	Mo-1-T					Mo-1-D-S
"	Pingan Pingan	PP-1		PP-1-R	PP-1-T					
"	"	PP-2	PP-2-D	PP-2-R	PP-2-T	PP-2-0	PP-2-P			PP-2-D-S
"	Poring Road	P-1		P-1-R	P-1-T					P-1-R-S
"	Randagong	R-1				R-1-0	R-1-P		R-1-Q	
"	"	R-2				R-2-0	R-2-P		R-2-Q	
"	"	R-3				R-3-0			R-3-Q	
"	"	R-4							R-4-Q	
"	"	R-5				R-5-0-1			R-5-Q	
"	"	"				R-5-0-2	R-5-P			R-5-0-3-S
"	Sasapan	S-1	S-1-D	S-1-R	S-1-T					S-1-D-S
"	Tagap	Ta-2	Ta-2-D	Ta-2-R	Ta-2-T					Ta-2-D-S
"	Tampang	T-1		T-1-R	T-1-T	T-1-0-1	T-1-P	T-1-X	T-1-Q-1	
"	"	"				T-1-0-2			T-1-Q-2	
"	"	T-2						T-2-X		
"	"	T-3		T-3-R	T-3-T	T-3-0	T-3-P	T-3-X	T-3-Q	T-3-0-S
"	"	T-4	T-4-D	T-4-R	T-4-T			T-4-X		T-4-D-S
"	"	T-5						T-5-X		
"	"	T-6						T-6-X		
"	"	T-7		T-7-R	T-7-T	T-7-0		T-7-X		
"	"	T-8						T-8-X		
"	"	T-9						T-9-X		
"	"	T-10				T-10-0		T-10-X	T-10-Q	

Region	Locality Name	Locality Number	Dating	Analysis of Rock	Thin Section	Assay of Ore	Polished Section	X-ray Defraction	Fluid Inclusion	Specimen
Kinabalu	Tampang	T-11						T-11-X		
"	"	T-12						T-12-X		
Sub-Total			9	18	18	14	7	15	10	14
Labuk	Boto	Bo-1				Bo-1-0-L				
"	Chromite	Cr-1		Cr-1-R	Cr-1-T					
"	East Sualog	ES-1	ES-1-D	ES-1-R	ES-1-T					ES-1-D-S
"	"	ES-2		ES-2-R	ES-2-T					
"	"	ES-3		ES-3-R	ES-3-T	ES-3-0	ES-3-P			ES-3-0-S
"	Ensuan	E-1	E-1-D	E-1-R	E-1-T	E-1-0	E-1-P			E-1-D-S
"	"	"								E-1-0-S
"	Gambaran	Ga-1		Ga-1-R	Ga-1-T	Ga-1-0-L				
"	"	Ga-2				Ga-2-0-L				
"	Karamuak	Kr-1		Kr-1-R	Kr-1-T	Kr-1-0-L				
"	Karang	Kg-1	Kg-1-D	Kg-1-R	Kg-1-T					Kg-1-D-S
"	"	Kg-2				Kg-2-0	Kg-2-P			
"	Kiabau	KB-1				KB-1-0	KB-1-P			KB-1-0-S
"	"	KB-2	KB-2-D	KB-2-R	KB-2-T					KB-2-D-S
"	"	KB-3		KB-3-R	KB-3-T	KB-3-0				
"	Northeast Sualog	NE-1				NE-1-0-L				
"	Porog	Po-1				Po-1-0	Po-1-P			
"	"	Po-2		Po-2-R	Po-2-T	Po-2-0	Po-2-P			Po-2-0-S
"	"	Po-3				Po-3-0	Po-3-P			Po-3-0-S
"	Pumadagan	Pm-1		Pm-1-R	Pm-1-T	Pm-1-0-L				
"	Ruku Ruku	Rk-1				Rk-1-0-L				
"	Southwest Sualog	SW-1		SW-1-R	SW-1-T	SW-1-0	SW-1-P			SW-1-0-S
"	"	SW-2	SW-2-D	SW-2-R	SW-2-T					SW-2-D-S
"	"	SW-3		SW-3-R	SW-3-T					
"	"	SW-4		SW-4-R	SW-4-T					
"	"	SW-5		SW-5-R	SW-5-T	SW-5-0	SW-5-P			SW-5-0-S
"	"	SW-6		SW-6-R	SW-6-T	SW-6-0-1				
"	"	"				SW-6-0-2	SW-6-P			SW-6-0-2-S
"	"	SW-7		SW-7-R	SW-7-T	SW-7-0-L				
"	Sualog/Pari	SP-1	SP-1-D	SP-1-R	SP-1-T					

Region	Locality Name	Locality Number	Dating	Analysis of Rock	Thin Section	Assay of Ore	Polished Section	X-ray Defraction	Fluid Inclusion	Specimen
Labuk	Sungai Telupid	ST-1	ST-1-D	ST-1-R	ST-1-T					ST-1-D-S
"	"	ST-2				ST-2-O				
"	"	ST-3				ST-3-O-1	ST-3-P			ST-3-O-1-S
"	"	"				ST-3-O-2				
"	"	ST-4				ST-4-O				
"	"	ST-5				ST-5-O				
"	"	ST-6				ST-6-O	ST-6-P			
"	"	ST-7		ST-7-R	ST-7-T					
"	"	ST-8		ST-8-R	ST-8-T					
"	"	ST-9		ST-9-R	ST-9-T	ST-9-O	ST-9-P			
"	"	ST-10				ST-10-O				
"	"	ST-11				ST-11-O-1				
"	"	"				ST-11-O-2	ST-11-P			
"	"	ST-12				ST-12-O-1	ST-12-P			ST-12-O-1-S
"	"	"				ST-12-O-2				
"	"	ST-13				ST-13-O	ST-13-P			ST-13-O-S
"	"	ST-14		ST-14-R	ST-14-T					
"	"	ST-15				ST-15-O	ST-15-P			ST-15-O-S
"	Tangkunap	TP-1				TP-1-O-L				
"	Telupid	TE-1	TE-1-D	TE-1-R	TE-1-T	TE-1-O	TE-1-P			TE-1-O-S
"	"	TE-2				TE-2-O-L				
"	"	TE-3				TE-3-O-L				
"	Tungud	Tg-1	Tg-1-D	Tg-1-R	Tg-1-T	Tg-1-O-1	Tg-1-P			Tg-1-D-S
"	"	"				Tg-1-O-2				Tg-1-O-1-S
"	Ulu Pari	UP-1		UP-1-R	UP-1-T	UP-1-O-L				
"	Ulu West Sualog	UWS-1	UWS-1-D	UWS-1-R	UWS-1-T					UWS-1-D-S
"	"	UWS-2		UWS-2-R	UWS-2-T	UWS-2-O	UWS-2-P			UWS-2-O-S
"	West Sualog	WS-1				WS-1-O	WS-1-P			WS-1-O-S
"	"	WS-2	WS-2-D	WS-2-R	WS-2-T					WS-2-D-S
"	"	WS-3		WS-3-R	WS-3-T	WS-3-O	WS-3-P			
"	"	WS-4				WS-4-O				
"	"	WS-5				WS-5-O	WS-5-P			WS-5-O-S
Sub Total			11	32	32	46(34+12)	23			26
Total			20	50	50	60(48+12)	30	15	10	40

CHAPTER 2 GEOGRAPHY OF THE SURVEY AREA

2-1 Topography and Drainage System

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

The Kinabalu region and the Labuk region which are to be surveyed in 1992 comprise mostly the western Cordillera and the Central Uplands, and the Central Uplands and the Eastern Lowlands respectively.

2-1-1 Kinabalu Region

The Kinabalu region consists mostly of the northeastern parts of the Crocker Range and the Trusmadi Range which compose the Western Cordillera and the Labuk Highlands occupying the northern part of the Central Uplands, and includes the Pinosuk Plateau to the southeast of Gunong Kinabalu, the Ranau Plain in which Ranau is located, the Bandau Plain and a part of the Bengkoka Lowlands along Marudu Bay.

One of the chief geographical features of Sabah is the Crocker Range, a belt of hills parallel and close to the west coast. About one third of the range lies within the survey area. The average height of the hills is between 600 and 900 meters, rising to over 1,200 meters along a central spine.

Dominating the northern end of the range is G. Kinabalu (4,101 meters above sea level) which is about 3,000 meters higher than the surrounding hills and is the highest mountain in South-East Asia.

The Trusmadi Range lies to the east of the Crocker Range and contains the highest peaks outside the Kinabalu massif. The mountains in the range are estimated to exceed 2,400 meters at several points.

An unusual plateau, called Pinosuk Plateau, occurs southeast of G. Kinabalu. Large quantities of rock debris on the plateau cover an area of approximately 40 square kilometers.

The Ranau Plain covers an area of about 23 square kilometers, being about 8 kilometers long and 3 kilometers wide. The Sungai Liwagu enters on the west side and flows out south; smaller rivers and streams flow into the plain from the surrounding hills and join the S. Liwagu. The plain is slightly above river level and is slightly undulating; it does not have the flatness generally associated with flood plains. At least four levels of terraces occur to the west and south of the plain.

North of the Ranau Plain, another smaller plain, called the Sungai Lohan Plain, occurs in the vicinity of the Sungai Lohan and Kampong Silad. Unlike the Ranau Plain, very little has been cleared and cultivated, probably because the soil, being from surrounding ultrabasic rock, is not fertile. The watershed between the east and west coasts of Sabah passes over the summit of G. Kinabalu and southwest along the Crocker Range to Gunong Alab, and then southeast to the Trusmadi Range. The principal rivers are the Sungai Labuk and the Sungai Sugut, draining into the Sulu Sea. The western and northern slopes of the mountain are drained by the Sungai Kadamaian and the Sungai Wariu, which join and flow north to the China Sea. The western and southern slopes of G. Kinabalu are drained by the Sugai which passes through the Ranau Plain and east to the S. Labuk and so into the Sulu Sea. On the east of G. Kinabalu the Sungai Langanan and the Sungai Mankadau rise in rugged and inaccessible foothills and join to form the S. Sugut, which also ends in the Sulu Sea. (Simplified from Collenette, P., 1954 and 1958)

2-1-2 Labuk Region

The Labuk region comprises the Labuk Highlands and the Kuamut Highlands which occupy the northern and central parts of the Central Uplands, the Milian Valley, alluvial plain along the Sungai Milian situated between the Labuk Highlands and the Kuamut Highlands, the Lokan Peneplains occupying the western part of the Eastern Lowlands, the western half of the Labuk Delta, and the southeastern part of the Kaindangan Peneplain, both of which are situated in the northeastern part of the survey area and occupy a part of the Eastern Lowlands.

The Labuk Highlands which are mostly drained by the middle reaches of the Sungai Labuk and the Sungai Karamuak, a north-side tributary of the Sungai Kinabatangan-Milian, and the Kuamut Highlands which are draind by south-side tributaries of the Sungai Milian are hilly and mountainous.

The Labuk Highlands are built largely of ultrabasic and basaltic rocks, each of which gives rise to characteristic topography. The ultrabasic rocks form four main groups of mountains, namely (a) a narrow range extending west and south of the S. Karamuak from Bukit Bungug to Bukit Tingka, (b) a mountain mass between the S. Karamuak and Kampong Malawali on the S. Labuk, culminating in Bukit Tavai, (c) a broad range west of the S. Labuk, including Bukit Meliau, and (d) the Bidu-Bidu Hills between the S. Labuk and the Trusan Sapi.

Mountains built of basaltic rocks occur around the headwaters of the S. Karamuak and north of the S. Labuk, but these rocks have been peneplaned between the two areas.

North of the S. Labuk the northeastern part of the Meliau Range rises to a height of 837 meters at Bukit Masasau, the highest point in the Bidu-Bidu Hills area. The Meliau is a youthful mountain range with deeply incised valleys and steep mountain sides where landslides are a frequent phenomena.

South and east of the S. Labuk, and between the S. Labuk and the Trusan Sapi lie the Bidu-Bidu Hills. These hills have been divided into three physiographic units: the Northern Hills, the Southern Hills, and the Bangau-Bangau Hills. The Northern Hills rise steeply on all sides to an almost horizontal erosion surface at about 450 meters, above which a few ridges rise more gradually to just over 600 meters. Swift-flowing streams have deeply dissected both the erosion surface and the flanks of the hills. The Southern Hills and the Bangau-Bangau Hills are youthful features, similar to the Meliau Range but lower in altitude, rising to a height of about 600 meters.

South of the S. Milian between Kpg Karamuak and Kpg Kuamut in the Kuamut Highlands, arcuate ridges, with scarps facing north and dip slopes on the reverse, are parts of one of the best developed Upper Miocene basins in Sabah.

Between the lower Labuk and Kinabatangan valleys is an extensive area occupied by the Lokan Peneplains, western half of which is included in the survey area. It is a composite peneplain consisting of a series of peneplains separated by steep slopes probably not more than 15 meters high. The accordant summits throughout much of the Lokan Peneplains are mainly 90 to 120 meters above sea level except in the south where they rise towards the lower Kinabatangan river to about 300 meters above sea level.

A monadnock of sandstone and shale south of the southern Bidu-Bidu Hills rises to about 360 meters above sea level and is flanked by erosion surface at 150 to 165, 120 to 135, and 105 meters above sea level. Narrow apophyses of the peneplains extend along the S. Labuk and the S. Karamuak and up the S. Milian towards the Kg. Tongot. The wide extent of the peneplaned area and the irregular boundaries between successive erosion surfaces indicate that they probably represent dissected marine erosion platforms that have been periodically uplifted and slightly tilted. The main peneplanation must be of comparatively recent date since the plains are still so well preserved.

Alluvial flat along the S. Kinabatangan from Kpg Pinangah to Kpg Kuamut, called Milian Valley, are discontinuous and generally less than a mile wide, except where they are joined by the narrow flats on the lower reaches of the tributaries.

The anastomosing distributaries of the Labuk Delta are muddy, tidal waterways with nipah palms and mangrove trees growing in tidal swamps along the banks. Taller trees grow on slightly higher alluvial land behind these swamps.

Most of the region is drained by the S. Kinabatangan-Milian and the S. Labuk and their tributaries. After leaving the Sipazo Gorge on the western edge of the region, the S. Labuk has carved itself a channel about 15 meters deep along an apophysis of the Lokan Peneplains, and then along the western edge of the peneplains from Kpg Rundun to Kpg Bilai, with the southern end of the Meliau Range rising from its western bank. It then flows through a narrow alluvial plain between the Meliau Range and the Bidu-Bidu Hills until it swings east to Kpg Paranchangan at the upriver end of the Trusan Sapi, the first distributary of the Labuk Delta. The village of Klagan occupies an island farther down the main channel, known in that part as the S. Lidong. The river and Trusan Sapi rejoin to form the main river-mouth. The S. Lidon is said to be silting up, and Trusan Sapi to be taking over as the main channel of the S. Labuk. The effects of tidal variation on the S. Labuk are noticeable to about half a mile above the head of Trusan Sapi, above which the river is fast flowing and contains many gravel banks. The level of the river fluctuates considerably and unpredictably; flooding is common in January and February whereas during September and October the river may be forded at several points. In the tidal reaches below the head of Trusan Sapi the S. Labuk flows in many broad meanders and is flanked by partly infilled ox-bow lakes. The course of the river here is rapidly changing. The lower tidal reaches comprise a ramifying network of distributaries of which the largest are Trusan Sapi and Sungai Klagan.

The S. Kinabatangan, known as the S. Milian above the village of Kuamut, is the largest river in Sabah and flows through the southern part of the region, between hills in the west, but through alluvial flats almost all the way below Kpg Tangkulap. The largest tributaries of the S. Kinabatangan-Milian within the region are, from the west, the Karamuak, Tangkulap, and Lokan rivers. There have doubtless been many changes in the unstable drainage pattern on the main peneplaned area of the Lokan peneplains, but peneplanation appears probably to have been primarily associated with the S. Labuk at a time when it reached the sea through the present course of the S. Segaliud. The S. Labuk may then have flowed from Kpg Rundun into the S. Luan Poroi and thence to the S. Lokan as far as Kpg Troyan before turning northeast to enter the present S. Segaliud at Kpg Longmanis. The extreme headwaters of the S. Kuun-Kuun (Lokan) may then have flowed into the S. Luan Poroi. The river flowing to the present mouth of the S. Labuk would then have been the S. Tungud, with a tributary flowing from Kpg Rumidi, the S. Labuk between Rumidi and Rundun villages being occupied by a south-flowing tributary of the S. Labuk.

There appears to have been time for considerable changes in drainage of the Lokan Peneplains, and rivers crossing the plains have cut down into them, indicating that the base level of erosion is now lower than at the time of formation of the plains. It seems most probable that they were formed in Pre-Pleistocene times when sea level was about 45 meters higher than now, and that the changes in drainage were initiated by changes in the erosive power of the rivers due to the Pleistocene fall in sea level.
(Compiled from Fitch, F.H., 1958, Wilford, G.E., 1967, and Newton-Smith, J., 1967)

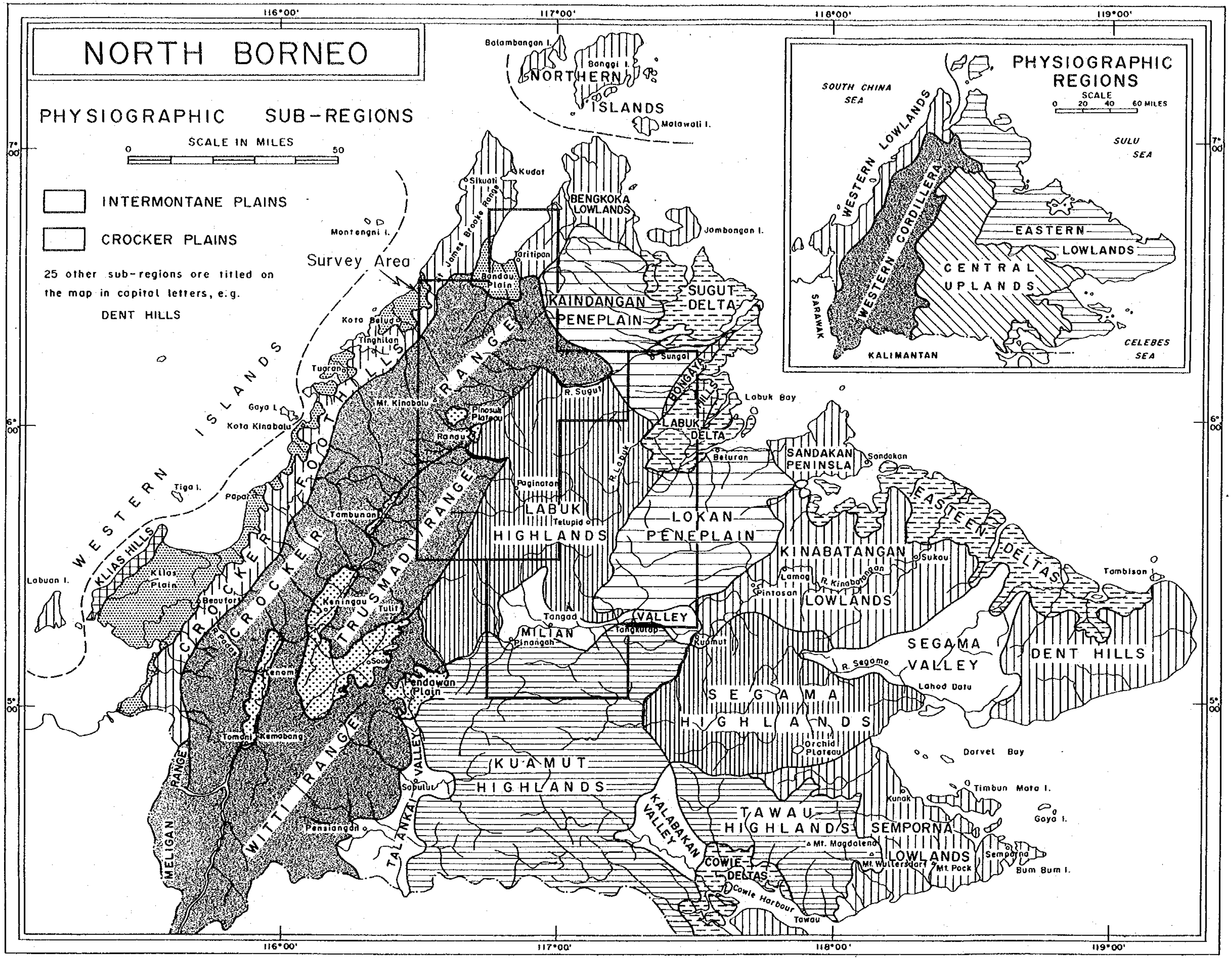


Figure I-2 Physiographic Sub-regions of Sabah (After Collenette P., 1962)

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 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.

Temperature varies little with the season. Although temperature in the coastal area is 24° to 34°C with 27°C on the average throughout the year, surface temperature inland is 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.

Vegetation in the hilly and mountainous districts inland is jungly, whereas swamps in the coastal 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.

2-2-1 Kinabalu Region

The climate is humid-tropical but with equatorial temperature modified by altitude. At Kundasang (1,371 meters), the highest monthly temperature recorded from 27° to 30°C, and the lowest from 10° to 16°C. At Bundu Tuhan (altitude about 1,060 meters above sea level) the variation is from 13° to 27°C. No detailed temperature readings are available for Gunung Kinabalu, but at Panar Laban (3,350 meters) the daily mean is about 16°C at midday, dropping to 4°C at night. On the summit plateau the night temperature sometimes drops below freezing point. Pools freeze over, and occasional snow showers have been recorded.

At Kundasang, the average annual rainfall is about 2,000 millimeters, most of which falls in the second half of the year. At the National Park Headquarters near Tenompok (1,615 meters) the average annual rainfall is about 3,000 millimeters, and at Bundu Tuhan the annual rainfall is about 3,800 millimeters on average. At Kambarangah (2,377 m) the average is about 4,500 millimeters, with monthly maxima up to 760 millimeters. No records are available for the eastern part of the survey region, but it is thought that the rainfall there is about 2,000 to 3,000 millimeters a year. Generally the driest months are February, March, and April, and the wettest months are May, June, September, October, and November.

Gunong Kinabalu is noted for its varied and unique flora. Many of the numeros plant species are endemic to the mountain. Dipterocarp rain forest gives way above 1,200 meters montane oak forest. Moss forest occurs from 1,650 meters to 2,850 meters. Above 2,850 meters the vegetation is less mossy oak forest, and above 3,300 meters Rhododendron-Leptospermum scrub occurs in sheltered places among the rock surfaces. (Compiled from Collenette, P., 1958 and Jacobson, G., 1970)

2-2-2 Labuk Region

The climate is humid-tropical with an average annual rainfall of about 3,810 millimeters and with temperatures ranging from about 21 to 34 degrees Centigrade. The humidity varies from 30 to 100 percent with an average of about 85 percent. Statistics of temperature and rainfall for Sandakan close to the survey region and Rumidi Estate in the Bidu-Bidu Hills area are shown in Table I-4 and I-5 respectively. Rainfall statistics for Pamol (Tungud) Estate in the lower Labuk river area and the upper Kinabatangan river area are shown in Table I-6 and I-7 respectively.

The region is covered by primary and secondary rain forests except in some low-lying parts near Sungai Labuk where it has been cleared for oilpalm and cocoa plantations. (Compiled from Fitch, F.H., 1958 and Newton-Smith, J., 1967)

Table I-4 Statistics of Temperature and Rainfall

Month	Kota Kinabalu			Sandakan			Tawau		
	Temperature (℃)		Rainfall	Temperature (℃)		Rainfall	Temperature (℃)		Rainfall
	Max.	Min.	(mm)	Max.	Min.	(mm)	Max.	Min.	(mm)
January	30.5	22.4	95.1	29.7	24.2	398.2	31.4	22.2	161.4
February	31.6	22.5	61.6	30.5	23.6	229.9	31.9	22.3	132.4
March	31.8	22.8	47.1	31.0	23.8	120.0	32.4	22.6	107.7
April	32.5	23.4	137.5	32.2	23.8	87.5	32.6	22.8	101.3
May	32.5	23.9	287.9	32.5	24.3	110.8	32.8	23.5	113.6
June	31.7	23.3	248.7	32.8	23.6	209.3	32.3	23.0	185.5
July	31.6	23.0	257.2	32.4	23.5	214.5	31.6	22.7	226.3
August	31.7	23.3	263.4	32.9	23.5	183.6	31.3	22.6	217.7
September	31.8	23.2	315.8	32.3	23.5	241.2	31.7	22.5	196.9
October	32.0	23.5	292.9	31.8	23.6	271.9	31.9	22.8	188.1
November	31.4	23.2	314.6	31.2	24.0	324.8	32.4	23.1	174.0
December	31.3	22.7	149.7	29.8	24.4	453.0	32.4	22.4	135.3
Total	――		2,471.5	――		2,844.7	――		1,940.2

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

Table I-5 Temperature and Rainfall Statistics for Rumidi Estate 1965 - 1966

Month	1965				1966			
	Rainfall		Mean Temperature		Rainfall		Mean Temperature	
	mm	Rain days	Max. ℃	Min. ℃	mm	Rain days	Max. ℃	Min. ℃
January	332.0	13	29.9	21.4	400.8	24	30.3	22.4
February	565.4	22	29.6	21.7	282.4	17	30.9	22.2
March	496.1	24	30.6	22.2	218.7	15	32.3	23.1
April	240.3	13	32.6	22.5	116.3	14	33.6	23.3
May	496.1	21	32.8	—	329.4	26	33.2	23.4
June	351.3	23	31.8	22.6	200.2	18	32.8	22.8
July	240.0	19	32.1	22.1	273.6	20	32.3	22.7
August	276.1	19	32.4	22.3	524.0	24	32.4	22.8
September	426.5	21	31.8	22.5	230.9	20	32.9	22.7
October	370.3	21	31.9	22.6	251.0	20	32.0	22.8
November	379.0	26	31.7	22.6	240.3	19	31.6	22.8
December	414.3	26	30.3	22.7	211.1	21	31.3	22.7
Total	4,587.0	248	—	—	3,278.6	238	—	—

Figures provided by the Manager, Rumidi Estate.

Table I-6 Rainfall Statistics for Pamol (Tungud) Estate 1961 - 1966

Month	1961		1962		1963		1964		1965		1966	
	mm	Rain days	mm	Rain days	mm	Rain days	mm	Rain days	mm	Rain days	mm	Rain days
January	360.9	21	923.0	31	1,365.8	30	189.0	23	349.3	14	416.1	21
February	289.8	12	396.0	24	509.0	25	336.6	24	529.3	24	299.5	15
March	194.1	14	519.7	27	409.7	21	200.7	20	519.9	21	172.7	15
April	54.6	16	340.9	17	73.9	7	219.2	25	196.1	12	74.9	5
May	533.4	—	161.3	23	167.1	12	128.8	21	417.3	18	307.1	18
June	148.8	22	336.0	17	263.7	11	339.6	24	456.2	14	172.7	13
July	237.0	19	177.5	19	405.4	17	89.7	11	237.7	16	203.2	9
August	224.0	20	211.6	21	285.0	20	315.0	17	358.9	19	306.8	19
September	287.3	18	571.5	26	240.5	19	236.5	20	458.5	15	271.0	12
October	325.6	23	240.3	21	360.2	21	205.5	19	245.4	20	175.3	12
November	158.8	18	279.1	23	142.7	18	161.5	18	290.3	21	129.3	14
December	464.8	24	677.9	29	262.4	23	308.9	21	317.0	24	208.8	17
Total	3,279.1	—	4,834.9	278	4,485.4	224	2,730.8	243	4,375.9	218	2,737.4	170

Figures provided by the Manager, Pamol Estate.

Table I-7 Rainfall Statistics for the Upper Kinabantangan Area

Place	Monthly Average												Yearly
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Average
Tangkulap	254.3	316.7	88.6	113.3	176.5	195.1	186.9	197.9	328.9	212.1	272.8	219.2	2,562.4
Pinangah	194.6	195.6	97.5	165.1	178.1	204.2	160.3	213.9	262.4	287.8	231.4	228.1	2,418.8
Kuamut	95.0	80.8	26.2	41.1	62.7	81.3	85.3	109.5	94.5	61.0	67.8	106.7	911.9

Average rainfall given in Millimeters; information supplied by the Civil Aviation and Meterological Service Depatrment

Remarks: Tangkulap … average over 5 years
Pinangah … average over 5 years
Kuamut … average over 4 years

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.

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 assemblages 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 environmental 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. Therse 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 are 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.

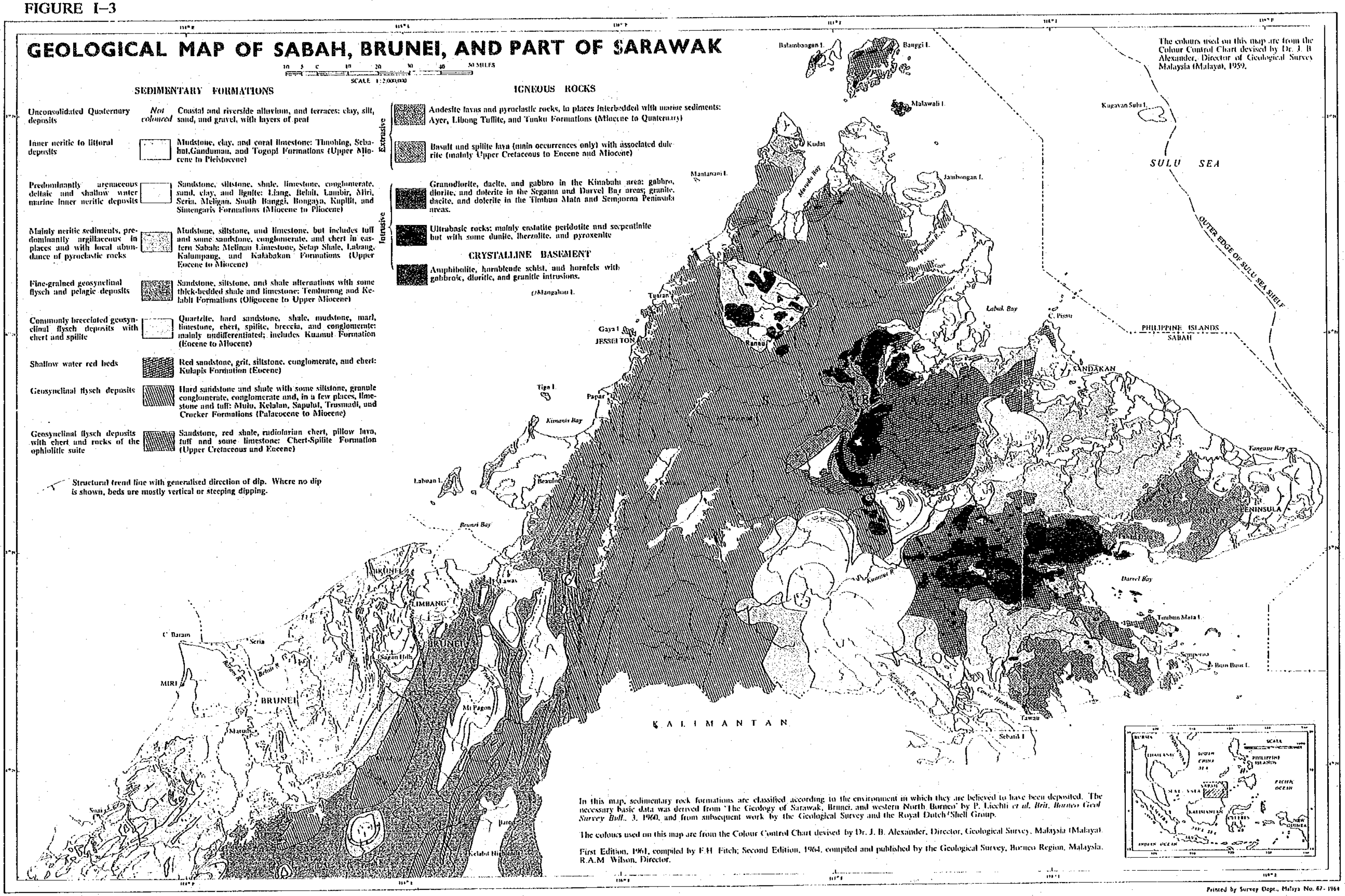
In the Darvel Bay-upper Sungai Segama area, granodiorite, trondhjemite, granite and tonalite were emplaced in Early Triassic time followed by late-stage pegmatite and aplite intrusions.

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")

FIGURE I–3



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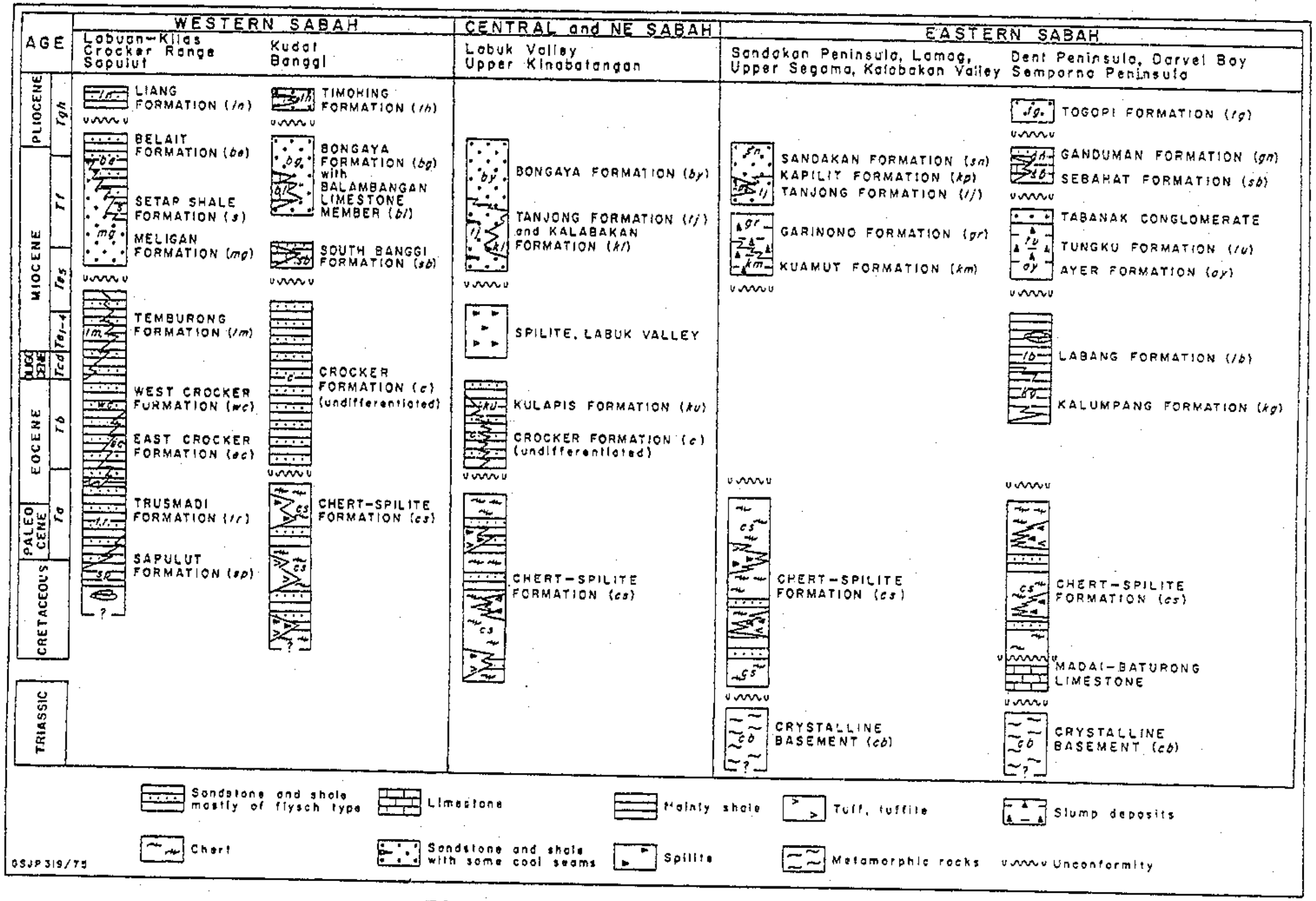

Figure I-4 Stratigraphy of Sabah

(Taken 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 Kinabalu Region

(1) Bt. Tampang area

The mineralized zone of veinlets, network, and dissemination consisting of quartz with minor amounts of pyrite and limonite is found in acidic to intermediate volcanic and pyroclastic rocks, subjected to hydrothermal alteration, at the western and southern foots of Bt. Tampang.
Some veinlets in the mineralized zone contain 2.68 g/t of gold, 0.13% of antimony, 0.16% of lead and 22.05 ppm of mercury, and 22.45 ppm of mercury.
The alteration mineral assemblage of hydrothermally altered rock consists mainly of a large quantity of quartz, a small quantity to a trace of kaolinite, a trace of chlorite, and a trace of sericite and is accomanied, in places, by a middle to a small amounts of potash felspar and a trace of smectite. This mineral assemblage is similar to that of the upper part of the hydrothermal alteration zone accompanying epithermal gold deposit of the adularia-sericite type (Hayba et al., 1986; Heald et al., 1987) or of the low sulfidation system (Hedenquist, 1987), or is similar to that of the hydrothermal alteration zone, ranging from the lower mica·chlorite zone to the upper kaolinite·mica zone, accompanying epithermal gold deposits in Kyushu of Japan. (Izawa et al., 1988)
The homogenization temperature of the fluid inclusions in quartz taken from quartz veinlets in the mineralized zone range from 218°C to 259°C except for 278° to 284°C of one sample and is included in the range of 200° to 300°C of epithermal gold deposit of high sulfidation system (Hedenquist, 1987) accompanying hydrothermal liquid related to the volcanic activity in the Circum-Pacific region, or is included in the range of 133° to 349°C of the adularia-sericite type or in the range of 120° to 320°C of the acid-sulfate type gold deposit in the western Pacific island arcs region (Sillitoe, 1988).
Therefore, the gold-bearing mineralized zone in the Bt. Tampang area seems to correspond to the upper part of epithermal gold deposit accompanying intermediate to weak alkaline hydrothermal fluid related to the volcanic activity which took place probably during Miocene to Pliocene time.

No specific structure which has controlled the emplacement of ore body is found at present.

(2) Bt. Luminantai area

The veined hydrothemal alteration zones accompanied partly by limonite and quartz are found along many parallel joints in quartz monzonite porphyry around Bt. Luminantai. Hydrothermal alteration veins are narrow in width and 1 to 30 centimeters wide. At the Lu-2 locality of mineral occurrence, 35 hydrothermal alteration veins are found along roughly parallel joints (strike: E-W, dip: 90°) for a distance of 17 meters, and at the Lu-3 locality, 46 hydrothermal alteration veins are exposed along roughly parallel joints (strike: N60°W, dip: 90°) for a distance of 40 meters. The both hydrothermal alteration veins at Lu-2 and Lu-3 localities form respectively network as a whole. However, no massive hydrothermal alteration zone is found, because quartz monzonite porphyry between hydrothermal alteration veins has not been subjected to hydrothermal alteration.

There is a possibility that these hydrothermal alteration veins may correspond to the SCC alteration zone (sericite-clay-chlorite) accompanying the upper part of porphyry copper deposit, considering that some limonite·quartz veinlet in hydrothermal alteration vein contains Pb (2.46%), Zn (0.13%), Cu (0.10%), and Ag (11.1 g/t) and the mineral assemblage of hydrothermal alteration vein consisting mainly of quartz, chlorite, kaolinite, potash felspar, and sericite is similar to that of the SCC zone, proposed by Sillitoe et al. (1984), accompanying the upper part of porphyry copper deposit in the Philippines, and that the homogenization temperature of fluid inclusion in quartz taken from limonite·quartz veinlet in hydrothermal alteration vein ranges from 350° to 417°C and is included in the range of that of quartz vein accompanying porphyry copper deposit (300° to 480°C in case of Mamut deposit, after Nagano et al., 1977).

However, seeing that ore samples for chemical analysis (2 samples), clay samples for X-ray diffraction (3 samples), and quartz sample for measurement of homogenization temperature (1 sample) are short of the number and that quartz monzonite porphyry between hydrothermal alteration veins has not been subjected to hydrothermal alteration, a definite conclusion about the above must be reserved.

These hydrothermal alteration veins along joints seems to be found in and around the marginal part of quartz monzonite porphyry body.

(3) Kg. Pingan Pingan area

The mineralized zone of networked and disseminated cupriferous iron sulfide, consisting of pyrite with a trace of sphalerite and malachite, in pillow basalt of the ophiolite complex is found in the old adit about two kilometers east of Kg. Pingan Pingan situated along Marudu Bay in northern Sabah.
This mineralized zone is three meters wide and trends in a north-south direction and seems to be network body of Cyprus-type cupriferous iron sulfide, judging from its mineral assemblage, occurrence, and host rock. Considering that the mineralized zone contains 0.62% of zinc and no copper and is small in extent, it seems that mineralization here might be weak.

(4) Kg. Randagong area

Four outcrops of limonite-bearing quartz veins embedded in faults in the alternating beds of sandstone and shale (sandstone ≫ shale) of Trusmadi Formation and floats of high grade stibnite near the R-5 locality are found in the Samalang river basin in the Randagong area.
The assay result reveals that no useful metal including antimony is contained in the samples taken at four outcrops of limonite-bearing quartz veins. Therefore, it seems that limonite in limonite-bearing quartz vein has probably been formed by oxidation of pyrite and floats of high grade stibnite have been possibly derived from the partial concentration of stibnite in pyyrite•quartz vein.
The homogenization temperature of fluid inclusion in quartz taken from four limonite-bearing quartz veins ranges from 155° to 217°C and is lower than that of (gold)-limonite-pyrite-bearing quartz veinlets in the Bt. Tampang area. Limonite-bearing quartz veins are embedded in faults trending in the north-south, east-west, and northwest directions.

4-1-2 Labuk Region

(1) Sungai Telupid area

The massive, lenticular, veined, networked, and disseminated mineralized zone, which consists mainly of pyrite, limonite, quartz, and chalcopyrite with minor amounts of bornite, chalcocite, covellite, malachite, sphalerite, and magnetite in places, in basalt and some dolerite of the ophiolite complex is found along the Sungai Telupid, situated about 6 kilometers west-northwest of Telupid, for a distance of about 160 meters. The whole mineralized zone can be regarded as a network body with a length of about 155 meters in the direction of the northeast and a width of about 15 meters.

The network bodies in the mineralized zone trend in the N20° to 60°E directins.

Host rock of the mineralized zone is basalt and some dolerite and has been subjected to chloritization and partial epidotization.

This mineralized zone appears to be Cyprus-type networked cupriferous iron sulfide body, judging from its mineral assemblage, occurrence, and host rock.

(2) Kg. Porog area

Two outcrops and floats, which are distributed at the top of a hill and can be nearly regarded as a outcrop, of massive gossan are found around Kg. Porog to the north of Kg. Kiabau in the Bidu Bidu Hills area.

These massive gossans are considerably similar to those which are found at the surface of Cyprus-type massive cupriferous iron sulfide deosits of West Sualog and Kiabau in the Bidu Bidu Hills area in point of the megascopic observation, microscopic observation, and assay result.

Therefore, it seems that massive gossans at three localities of mineral occurrence have been probably formed by oxidation of Cyprus-type massive cupriferous sulfide body near the surface.

(3) S. Tungud area

The semi-massive, networked, and disseminated mineralized zone, consisting of pyrite, limonite, quartz, and a small amount of chalcopyrite, in metadolerite of the ophiolite complex is exposed, for a distance of 20 meters and over and a height of 8 meters and over, along the S. Unsadan, a tributary of the S. Tungud.

Host rock is chloritized, epidotized, and carbonatized metadolerite.

This mineralized zone seems to be Cyprus-type semi-massive cupriferous iron sulfide body, judging from its mineral assemblage, occurrence, and host rock.

In addition to the above mineralized zones, the known mineral occurrences in the Bidu Bidu Hills area, mineral occurrence at the E-1 locality in the upper basin of the S. Ensuan, and mineral occurrence at the TE-1 locality seem to be the mineralized zones of Cyprus-type cupriferous iron sulfide embedded in basalt and some dolerite.

The mineralized zone of Cyprus-type cupriferous iron sulfide found in the Bidu Bidu Hills and Telupid areas seems to be present in the area where basalt, dolerite, gabbro, and ultrabasic rock constituting the ophiolite complex are distributed complicatedly due to many faults and seems to be embedded in basalt and some dolerite associated with gabbro, especially, in the area between relatively big ultrabasic rock bodies within the above area.

It appears that the Bidu Bidu Hills area, Bt. Luminintong area, and the area between Telupid and S. Karang have the above geologic conditions.

It is said that network ore body of Cyprus-type cupriferous iron sulfide accompanies overlying massive ore body in general. However, there is a possibility that each ore body may exist individually or both the ore bodies may occur together at the same depth in the area, where faults dominate and geology is complicated, in the Labuk region.

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

4-2-1 Kinabalu Region

(1) Bt. Tampang area

Since gold-pyrite-quartz-bearing mineralized zone found at the foot of Bt. Tampang seems to correspond to the upper part of epithermal gold deposit accompanying intermediate to weak alkaline hydrothermal fluid related to the vocanic activity, judging from its mineral assemblage, alteration mineral assemblage of the hydrothermal alteration zone accompanying mineralization, and homogenization temperature of fluid inclusion in quartz taken from gold-limonite-pyrite-bearing quartz veinlets, there is a possibility that gold-bearing quartz vein of the bonanza-type or vein-type may be present under this mineralized zone.

There is also a possibility that such a gold-bearing mineralized zone may be found at the eastern and northern foots and hillside of Bt. Tampang other than the western and southern foots.

It is reported by Fitch (1954) that Bt. Kotud and Bt. Tambiau to the north of Bt. Tampang are formed of stocks of andesite and Bt. Kalarakan and Bt. Tu'us to the north of these two hills seem to be also of andesite stocks from the topographic point of view.

Collenette (1958) reported that Bt. Kotud and Bt. Tambiau were of andesite to rhyodacite stocks and Bt. Kalarakan and Bt. Tu'us appeared to be same rock from the photogeologic point of view.

If these hills are formed of not andesite stocks but andesitic to rhyodacitic lava and pyroclastic rock, there is a possibility that gold-pyrite-quartz-bearing mineralized zone, accompanied by hydrothermal alteration zone, as found at the foot of Bt. Tampang may be present at the foots and hillsies of these hills.

There is also a possibility that a hill ranging to the west-northwest of Bt. Tampang may be formed of same rock as Bt. Tampang. If so, it is possible that same gold-pyrite-quartz-bearing mineralized zone accompanied by hydrothermal alteration zone as Bt. Tampang may be found.

(2) Bt. Luminantai area

The veined hydrothermal alteration zones accompanied partly by some limonite and quartz are found along many parallel joints in quartz monzonite porphyry around Bt. Luminantai. Hydrothermal alteration veins are narrow in width (1 to 30 cm) and form network as a whole.

There is a possibility that these hydrothermal alteration veins may correspond to the SCC alteration zone (sericite-clay-chlorite) accompanying the upper part of porphyry copper deosit, considering that some limonite•quartz veinlet in hydrothermal alteration vein contains Pb (2.46%), Zn (0.13%), Cu (0.10%), and Ag (11.1 g/t) and the mineral assemblage of hydrothermal alteration vein consisting mainly of quartz, chlorite, kaolinite, potash felspar, and sericite is similar to that of the SCC zone, proposed by Sillitoe et al. (1984), accompanying the upper part of porphyry copper deposit in the Phillippines, and that the homogenization temperature o fluid inclusion in quartz taken from limonite•quartz veinlet in hydrothermal alteration vein ranges from 350° to 417°C and is included in the range of that of quartz vein accompanying porphyry copper deposit (300°C to 480°C in case of Mamut deposit, after Nagano et al., 1977).

However, seeing that ore samples for chemical analysis (2 samples), clay samples for X-ray diffraction (3 samples), and quartz sample for measurement of homogenization temperature (1 sample) are short of the number and that quartz monzonite porphyry between hydrothermal alteration veins has not been subjected to hydrothermal alteration, a definite conclusion about the above must be

reserved.
Therefore, it is necessary to conduct further detailed geological mapping, assay of ore sample, X-ray diffraction examination, and measurement of homogenization temperature and salinity of fluid inclusion in quartz in order to clarify whether these hydrothermal alteration veins accompany the upper part of porphyry copper deposit or not.

4-2-2 Labuk Region

There is a possibility of emplacement of massive or networked Cyprus-type cupriferous iron sulfide deposit in the Labuk region. The promising mineralized zones of Cyprus-type cupriferous iron sulfide except known ore deposits and mineral occurrences in the Bidu Bidu Hills area are as follows.

(1) Sungai Telupid mineralized zone

The mineralized zone embedded in basalt and some dolerite exposed along the Sungai Telupid is semi-massive, lenticular, veined, networked, and disseminated in occurrence at each locality of mineral occurrence, and the whole mineralized zone can be regarded as a network ore body with a length of about 155 meters in the direction of the northeast and a width of about 15 meters.
In case this mineralized zone is regarded as a network ore body, the network body will be poor in ore and of low copper grade.
However, there is a possibility that network ore body or massive ore body of high copper grade may be emplaced near this mineralized zone.

(2) Kg. Porog mineralized zone

Massive gossans of outcrops and floats consisting of limonite and hematite are consideralily similar to those which are found at the surface of Cyprus-type massive cupriferous iron sulfide deposits of West Sualog and Kiabau in the Bidu Bidu Hills area in point of the megascopic observation, microscopic observation, and assay result.
Therefore, it seems that massive gossans at three localities have been probably formed by oxidation of Cyprus-type massive cupriferous sulfide body near the surface and there is a possibility that massive cupriferous iron sulfide body not oxidized may be emplaced under outcrop and its extension.

(3) S. Tungud mineralized zone

This mineralized zone, over 20 meters long and over 8 meters high, is semi-massive, networked, and disseminated in occurrence, but the whole mineralized zone is nearly semi-massive and poor in copper.
Considering that high copper and zinc anomalies of geochemical surveys by the use of stream sediment, conducted by the Malaysia-Germany exploration project for 1980 to 1984 and by the base metal exploration project of Geological Survey of Malaysia for 1986 to 1990 were detected in the upper basin of the S. Unsadan including this Tg-1 locality of mineral occurrence, there is a possibility that ore body of bigger size and of higher grade of copper than the Tg-1 mineralized zone may be emplaced near the Tg-1 locality and that the mineralized zone of Cyprus-type cupriferous iron sulfide other than the Tg-1 may be present in the upper basin of the S. Unsadan.

CHAPTER 5 CONCLUSION AND RECOMMENDATION

5-1 Conclulsion

It seems that base metal deposit with possibility of discovery in the future in the Kinabalu and Labuk regions surveyed in 1992 may be gold deposit in Bt. Tampang area of Kinabalu region and Cyprus-type cupriferous iron sulfide deposits in and around Sungai Telupid, Kg. Porog, and S. Tungud mineralized zones in the Labuk region.
The mineralized zone of veinlets, network, and dissemination, consisting of quartz with minor amounts of pyrite and limonite, embedded in acidic to intermediate volcanic and pyroclastic rocks subjected to hydrothermal alteration, is found at the western and southern foots of Bt. Tampang.
This gold-bearing mineralized zone seems to correspond to the upper part of epithermal gold deposit accompanying intermediate to weak alkaline hydrothermal fluid related to the volcanic activity which took place probably during Miocene to Pliocene time, considering that some veinlets in the mineralized zone contain gold (2.68 g/t), antimony (0.13%), and mercury (22.05 ppm, 22.45 ppm) and the alteration mineral assemblage of hydrothermally altered rock consists mainly of quartz, sericite, kaolinite, and chlorite accompanied, in places, by some potash felspar and smectite and that homogenization temperature of fluid inclusions in quartz taken from quartz veinlets ranges from 218° to 259°C except for 278° to 284°C of one sample.
Therefore, there is a possibility that gold-bearing quartz vein of the bonanza-type or vein-type may be present under this mineralized zone.
It is possible that such a gold-bearing mineralized zone may be found at the eastern and northern foots and the hillside of Bt. Tampang besides the western and southern foots.
It seems that a hill ranging to the west-northwest of Bt. Tampang, Bt. Kotud, Bt. Tambiau, Bt. Kalarakan, and Bt. Tu'us to the north of Bt. Tampang may be formed of acidic to intermediate volcanic and pyroclastic rocks. If so, there is also a possibility that gold-pyrite-quartz bearing mineralized zone, accompanied by hydrothermal alteration zone, as found at the foot of Bt. Tampang may be present at the foots and hillsides of these hills.

The mineralized zone of Cyprus-type cupriferous iron sulfide found in the Bidu Bidu Hills and Telupid areas seems to be present in the area where basalt, dolerite, gabbro, and ultrabasic rock constituting the ophiolite complex are distributed complicatedly due to many faults and seems to be embedded in basalt and some dolerite associated with gabbro, especially, in the area between relatively big ultrabasic rock bodies within the above area.

It appears that the Bidu Bidu Hills area, Bt. Luminintong area, and the area between Telupid and S. Karang have the above geologic conditions.

It is said that network ore body of Cyprus-type cupriferous iron sulfide accompanies overlying massive ore body in general. However, there is a possibility that eaach ore body may exist individually or both the ore bodies may occur together at the same depth in the area, where faults dominate and geology is complicated, in the Labuk region.

The promising mineralized zones of Cyprus-type cupriferous iron sulfide except known ore deposits and mineral occurrences in the Bidu Bidu Hills area are the Sungai Telupid mineralized zone, Kg. Porog mineralized zone, and S. Tungud mineralized zone, judging from the above geological condition and the result of the survey in 1992.

The Sungai Telupid mineralized zone which is embedded in basalt and some dolerite found along the Sungai Telupid consists mainly of pyrite, limonite, quartz and chalcopyrite accompanied, in places, by bornite, chalcocite, covellite, malachite, sphalerite, and magnetite. This mineralized zone is semi-massive, lenicular, veined, networked, and disseminated in occurrence at each locality of mineral occurrence, and the whole mineralized zone can be regarded as a network ore body with a length of about 155 meters in the direction of the northeast and a width of about 15 meters.

In case this mineralized zone is regarded as a network ore body, network body will be poor in ore and of low copper grade. However, there is a possibility that network ore body or massive ore body of high copper grade may be emplaced near this mineralized zone.

Kg. Porog mineralized zone is composed of two outcrops and floats, which can be nearly regarded as a outcrop, of massive gossan consisting of limonite and hematite. These massive gossans are considerably similar to those which are found at the surface of Cyprus-type massive cupriferous iron sulfide deposits of West Sualog and Kiabau in the Bidu Bidu Hills area in point of megascopic observation, microscopic observation, and assay result.

Therefore, it seems that massive gossans at three localities of mineral occurrence have been probably formed by oxidation of Cyprus-type massive cupriferous sulfide body near the surface and there is a possibility that massive cupriferous iron sulfide body not oxidized may be emplaced under outcrop and its extension.

The S. Tungud mineralized zone consisting of pyrite, quartz, and a minor amount of

chalcopyrite, over 20 meters long and over 8 meters high, is found along the S. Unsadan, a tributary of the S. Tungud, in the Bt. Lumunintong area. This mineralized zone is semi-massive, networked, and disseminated in occurrence, but the whole mineralized zone is nearly semi-massive and poor in copper.
Considering that high copper and zinc anomalies of geochemical surveys by the use of stream sediment, carried out by the Malaysia-Germany exploration project for 1980 to 1984 and by the base metal exploration project of Geological Survey of Malaysia for 1986 to 1990, were detected in the upper basin of the S. Unsadan including this Tg-1 locality of mineral occurrence, there is a possibility that ore body of bigger size and of higher grade of copper than the Tg-1 mineralized zone may be emplaced near the Tg-1 locality and that the mineralized zone of Cyprus-type cupriferous iron sulfide other than the Tg-1 may be present in the upper basin of the S. Unsadan.

In addition to the above, the veined hydrothermal alteration zones accompanied, in places, by some limonite and quartz are found along many parallel joints in quartz monzonite porphyry around Bt. Luminantai. Hydrothermal alteration veins are narrow in width (1 to 30 centimeters) and form network as a whole.
There is a possibility that these hydrothermal alteration veins may correspond to the SCC alteration zone (sericite-clay-chlorite) accompanying the upper part of porphyry copper deposit, judging from the results of assay of limonite•quartz veinlet accompanying hydrothermal alteration vein, X-ray diffraction examination of hydrothermal alteration vein, and measurement of homogenization temperature of fluid inclusion in quartz taken from limonite•quartz veinlet. However, considering that ore samples for assay, clay samples for X-ray diffraction, and quartz sample for measurement of homogenization temperature are short of the number and that quartz monzonite porphyry between hydrothermal alteration veins has not been subjected to hydrothermal alteration, a definite conclusion about the above must be reserved.
Therefore, it is necessary to conduct further detailed geological mapping, assay of ore sample, X-ray diffraction examination, and measurement of homogenization temperature and salinity of fluid inclusion in quartz in order to clarify whether these hydrothermal alteration veins accompany the upper part of porphyry copper deposit or not.

5-2 Recommendation for Phase IV Survey

As mentioned in the above "5-1 Conclusion", it seems that base metal deposit with possibility of discovery in the future in the Kinabalu and Labuk regions surveyed in

1992 may be gold deposit in Bt. Tampang area of Kinabalu region and Cyprus-type cupriferous iron sulfide deposits in and around Sungai Telupid, Kg. Porog, and S. Tungud mineralized zones in the Labuk region.

Therefore, the following follow-up works for the above promising mineralized zones are recommended.

1. Bt. Tampang mineralized zone

   (1) Detailed geological mapping; K-Ar dating, chemical analysis, and microscopic observation of host rock; systematic sampling, assay, and microscopic observation of ore; X-ray diffraction examination of hydrothermally altered rock; measurement of homogenization temperature and salinity of fluid inclusion in quartz taken from quartz veinlets; and geolchemical survey by the use of soil at the foot and hillside of Bt. Tampang.

   (2) The same of follow-up works as the above, except for geochemical survey, at the foots and hillsides of a hill ranging to the west-northwest of Bt. Tampang, Bt. Kotud, Bt. Tambiau, Bt. Tu'us, and Bt. Kalarakan to the north of Bt. Tampang.

2. Sungai Telupid mineralized zone

   Detailed geological mapping; K-Ar dating, chemical analysis, and microscopic observation of host rock; systematic sampling, assay, and microscopic observation of ore; and geochemical survey by the use of soil in and around the mineralized zone.

3. S. Porog mineralized zone

   Detailed geological mapping; K-Ar dating, chemical analysis, and microscopic observation of host rock; systematic sampling, assay, and microscopic observation of ore; and geochemical survey by the use of at and around outcrops.

4. S. Tungud mineralized zone

   Detailed geological mapping; K-Ar dating, chemical analysis, and microscopic observation of host rock; systematic sampling, assay, and microscopic observation of ore; and geochemical survey by the use of soil in and around mineralized zone.

Next, the detailed geological mapping; chemical analysis, microscopic observation, and X-ray diffraction examination of hydrothermal alteration vein; assay and microscopic observation of limonite·quartz veinlets in hydrothermal alteration veins; and measurement of homogenization and salinity of fluid inclusion in quartz taken from limonite·quartz veinlets are recommended in order to clarify whether hydrothermal alteration veins in quartz monzonite porphyry around Bt. Luminantai accompany the upper part of porphyry copper deposit or not.

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CHAPTER 1 KINABAL REGION

1-1 Contents of the Survey

1-1-1 Investigation of Locality of Mineral Occurrence

In order to understand geology and mineralization at the localities of mineral occurrece in the Kinabalu region and then clarify the characteristic of mineralization in the region, 12 localities of mineral occurrence in total, namely 4 localities of epithermal gold-pyrite-limonite-bearing quartz veinlets in acidic to intermediate volcanic and pyroclastic rocks which appear to be of Miocene to Pliocene age in the Bt. Tampang area, 2 localities of limonite-quartz network and limonite network in acidic intrusive rock in the Bt. Luminantai area, 4 localities of quartz-limonite vein and stibnite-quartz-pyrite-limonite vein in the faults in alternating beds of sandstone and shale (sandstone ≫ shale) of Trusmadi Formation of Paleocene to Eocene age in the Kg. Randagong area, 1 locality, which is found in the old adit in the Pingan Pingan area, of Cyprus type cupriferous iron sulfide network embedded in pillow basalt of Chert-Spilite Formation, floats of Cyprus type cupriferous massive iron sulfide which are found in the S. Lingangah, a tributary on the left bank of S. Mankadau, were investigated.
The locations of mineral occurrences investigated are shown in the Fig. II-1-1 and Fig. II-1-2 attached at the end of this report.

1-1-2 Laboratory Work

The following laboratory works on the samples of ore, host rock, hydrothermally alterd rock, and quartz obtained at the localities of mineral occurrence and on the representative rock samples taken near the localities of mineral occurrence were conducted for the purpose of understanding mineralization at the localities of mineral occurrence and geology at and around the localities of mineral occurrence in the Kinabalu region. The list of the samples taken is shown in the Table II-1-1 and locations of the samples are shown in the Fig. II-1-3 and Fig. II-1-4 attached at the end of this report.

(1) K-Ar age determination of rock (9 samples)

Nine representative rock samples, namely 3 samples (Km-1-D, K-1-D, Lu-1-D) taken from acidic intrusive rocks which are found between Bt. Kimudu and Bt. Kamunsu, 2 samples (S-1-D, Ta-2-D) from diorite porphyrite to the west of Kg. Merungin, 2 samples (M-1-D, PP-2-D) of basalt and 1 sample (Mo-1-D) of gabbro in the ophiolite complex, and 1 sample (T-4-D) of sandstone taken at the foot of Bt. Tampang, out of 18 rock samples taken at and near the localities of mineral occurrence for microscopic observation and chemical analysis, were dated by the K-Ar method of whole rock.

(2) Chemical analysis of rock sample (18 samples)

Eighteen rock samples in total, namely 9 samples taken at the same localities as the samples for the K-Ar age determination, 2 samples (Lu-3-R, Lu-4-R) from acidic intrusive rock bodies around Bt. Luminantai, 3 samples (B-1-R, M-2-R, P-1-R) of ultrabasic rock, and 1 sample (PP-1-R) of basalt in the ophiolite complex, 1 sample (T-1-R) of dacite, 1 sample (T-3-R) of rhyolite, and 1 sample (T-7-R) of trachytic tuff around Bt. Tampang, were chemically analyzed.

(3) Microscopic observation of thin section of rock (18 samples)

The thin sections were made from 18 rock samples obtained at the same localities as the samples for chemical analysis and were observed under a polarization-microscope.

(4) Assay of ore sample (14 samples)

Fourteen ore samples taken at 12 localities of mineral occurrence investigated were assayed.

(5) Microscopic observation of polished section of ore (7 samples)

The polished sections were made from 7 ore samples, namely 1 sample of float of Cyprus type cupriferous massive iron sulfid in the S. Lingangah (L-1-P), 1 sample of Cyprus type cupriferous iron sulfide stockwork taken in the old adit in the Pingan Pingan area (PP-2-P), 2 samples from quartz-limonite veins (R-1-P, R-2-P) and 1 sample of stibnite-quartz-pyrite vein (R-5-P) in the Kg. Randagong area, and 2 samples from pyrite-limonite-bearing quartz veinlets in hydrothermally altered rock which is found at the foot of Bt. Tampang (T-1-P, T-3-P), out of 14 ore samples taken for assay, and then were observed under a ore microscope.

(6) X-ray diffraction examination of hydrothermally altered rock (15 samples)

X-ray diffraction examination of 15 hydrothermally altered rock samples, namely 3 samples taken from hydrothermal alteration veins in acidic intrusive rock forming Bt. Luminatai and 12 samples from hydrothermally altered rock which is found at the foot of Bt. Tampang, were conducted for the identification of hydrothermal alteration minerals.

(7) Measurement of homogenization temperature of fluid inclusions in quartz (10 samples)

Homogenization temperatures of fluid inclusions in 10 quartz samples, namely 1 sample taken from limonite-bearing quartz veinlet in acidic intrusive rock around Bt. Luminantai (Lu-3-Q), 4 samples from pyrite-limonite-bearing quartz veinlets in hydrothermally altered rock found at the foot of Bt. Tampang (T-1-Q-1, T-1-Q-2, T-3-Q, T-10-Q), 3 samples from limonite-bearing quartz veins (R-1-Q, R-2-Q, R-3-Q), 1 sample from stibnite-quartz-pyrite vein (R-5-Q), and 1 sample from quartz vein (R-4-Q) in the Trusmadi Formation in the Kg. Randagong area, were measured in order to study the formation temperature of quartz.

Table II-1-1 List of Samples taken in Kinabalu Region for Laboratory Work

1/2

Locality Name	Locality Number	Dating	Analysis of Rock	Thin Section	Assay of Ore	Polished Section	X-ray Defraction	Fluid Inclusion	Specimen
Bambangan	B-1		B-1-R	B-1-T					
Kamunsu	Km-1	Km-1-D	Km-1-R	Km-1-T					Km-1-D-S
Kiapako	K-1	K-1-D	K-1-R	K-1-T					K-1-D-S
Lingangah	L-1				L-1-0	L-1-P			L-1-0-S
Luminantai	Lu-1	Lu-1-D	Lu-1-R	Lu-1-T					Lu-1-D-S
"	Lu-2				Lu-2-0		Lu-2-X		
"	Lu-3		Lu-3-R	Lu-3-T	Lu-3-0		Lu-3-X	Lu-3-Q	
"	Lu-4		Lu-4-R	Lu-4-T					
"	Lu-5						Lu-5-X		
Mankadau	M-1	M-1-D	M-1-R	M-1-T					M-1-D-S
"	M-2		M-2-R	M-2-T					M-2-R-S
Morouporou	Mo-1	Mo-1-D	Mo-1-R	Mo-1-T					Mo-1-D-S
Pingan Pingan	PP-1		PP-1-R	PP-1-T					
"	PP-2	PP-2-D	PP-2-R	PP-2-T	PP-2-0	PP-2-P			PP-2-D-S
Poring Road	P-1		P-1-R	P-1-T					P-1-R-S
Randagong	R-1				R-1-0	R-1-P		R-1-Q	
"	R-2				R-2-0	R-2-P		R-2-Q	
"	R-3				R-3-0			R-3-Q	
"	R-4							R-4-Q	
"	R-5				R-5-0-1			R-5-Q	
"	"				R-5-0-2	R-5-P			R-5-0-3-S

Locality Name	Locality Number	Dating	Analysis of Rock	Thin Section	Assay of Ore	Polished Section	X-ray Defraction	Fluid Inclusion	Specimen
Sasapan	S-1	S-1-D	S-1-R	S-1-T					S-1-D-S
Tagap	Ta-2	Ta-2-D	Ta-2-R	Ta-2-T					Ta-2-D-S
Tampang	T-1		T-1-R	T-1-T	T-1-0-1	T-1-P	T-1-X	T-1-Q-1	
"	"				T-1-0-2			T-1-Q-2	
"	T-2						T-2-X		
"	T-3		T-3-R	T-3-T	T-3-0	T-3-P	T-3-X	T-3-Q	T-3-0-S
"	T-4	T-4-D	T-4-R	T-4-T			T-4-X		T-4-D-S
"	T-5						T-5-X		
"	T-6						T-6-X		
"	T-7		T-7-R	T-7-T	T-7-0		T-7-X		
"	T-8						T-8-X		
"	T-9						T-9-X		
"	T-10				T-10-0		T-10-X	T-10-Q	
"	T-11						T-11-X		
"	T-12						T-12-X		
Total		9	18	18	14	7	15	10	14

1-2 Geology

The stratigrapby of the Kinabalu region is summarized in Table II-1-2. The oldest rocks are upfaulted slices of Crystalline Basement of Mesozoic or earlier age.

The greater part of the survey region is sedimentary rock, probably mainly Eocene. Igneous rocks belong to two, or possibly three, periods of intrusion; the first comprises ultra-basic bodies and the second acid intrusions, of which Gunong Kinabalu is the most notable. Andesite stocks west of Paranchangan may be a hypabyssal phase of the Kinabalu intrusions or may be younger.

1-2-1 Sedimentary rocks

Sedimentary rocks have been divided into four formations described below. They are:

(a) Miocene
(b) Crocker Formation (Eocene)
(c) Trusmadi Formation (Eocene)
(d) Chert-Spilite Formation (Eocene, but may also include some late Cretaceous rocks)

Miocene rocks can be recognized only from their microfaunas; the three older formations have lithological characteristics by which they can be recognised.

(1) Chert-Spilite Formation

Molengraaff (1900) mapped a typical eugeosynclinal succession of sedimentary and volcanic rocks in Sarawak; he considered that these rocks were pre-Cretaceous and introduced the term 'Danau Formation.'

Meanwhile similar sedimentary and volcanic rocks, which had been mapped by various geologists in Sabah as Danau Formation, were re-named the Chert-Spilite association by Fitch (1953) who had evidence of Upper Cretaceous age; later he changed the name to Chert-Spilite Formation (Fitch, 1955) and further work suggested that these rocks range from late Cretaceous to early Eocene (Fitch, 1955; Stephens, 1956)

(2) Trusmadi Formation

The term 'Trusmadi Formation' was introduced to describe predominantly argillaceous rocks occurring in the Trusmadi Mountains.

The Trusmadi Formation occupies a broad belt of hilly and mountainous country approximately 40 kilometers wide stretching from the southern end of the Trusmadi Mountains north-northeast to Sungai Liwagu.

The distinctive feature of the Trusmadi Formation is the predominance of dark argillaceous rock; subordinate beds of siltstone and sandstone occur. On the western side of the Trusmadi Mountains, the argillaceous rocks have been subjected to mild regional metamorphism, resulting in a rather lustrous phyllitic shale which parts readily along the bedding, giving slabs which some what resemble true slate (Collenette, 1955). On the eastern side, the argillaceous rocks are generally indurated but not metamorphosed.

Regularly alternating siltstone and mudstone is a distinctive rock association occurring frequently in the Trusmadi Formation. In general, the regularly alternating siltstone and mudstone seem to be situated close to the boundaries of the Trusmadi Formation; lithologically the association is a transition between the argillaceous facies of the Trusmadi Formation and the Crocker Formation. Quartz veining is common in the Trusmadi Formation, especially in the regionally metamorphosed rocks.

The veins are generally less than an inch in thickness and occur in rather rectangular networks; no thick veins, zugs, or metalliferous minerals were observed.

Three samples from the unmetamorphosed argillaceous facies and five from the alternating siltstone and mudstone were found by the Shell Company of North Borneo Limited to contain micro faunas; these generally suggest an Eocene age.

(3) Crocker Formation

The term 'Crocker Formation' was proposed for the flysch-like sedimentary rocks of which the Crocker Range is built. These rocks comprise massive grey sandstone, closely bedded grey sandstone and siltstone, and grey, red, green, and black, mudstone and shale. The thickness of the Crocker Formation rocks is not known, but it is probably not less than 6,000 meters.
Sedimentary rocks similar to those found in the Crocker Range occur along the eastern margin of the Kinabalu area and comprise sandstone, siltston, mudstone, and shale. Microfossils are common in the mudstone and shale. Shell Company of North Borneo Limited found foraminifers in 12 samples and determined the age as follows:

4 samples determined as Eocene
3 samples determined as probably Eocene
3 samples determined as possibly Eocene
2 samples determined as doubtfully Eocene

(4) Miocene sediments

Outliers of Miocene sediments were mapped about 2 miles south of Ranau, and at the junction of the Liwagu and Kegibangan rivers. Shale samples from these two localities contain Miocene microfaunas, but the rocks there can not be distinguished lithologically from the surrounding Eocene sediments. The areas of the outliers are unknown, but probably do not exceed a square mile each. The dips of the fossiliferous shale and of the adjacent rocks are as steep as the surrounding Eocene rocks; it appears that the two formations are infolded and this suggest that at least some of the severe movements which affected the Kinabalu area are late Miocene or post-Miocene.

(5) Relative age of the Chert-Spilite Formation and the Trusmadi argillaceous rocks

The relative age of the Chert-Spilite Formation and the Trusmadi argillaceous rocks is uncertain. Indirect evidence, outlined below, suggests that the Chert-Spilite Formation may be older than the Trusmadi Formation. Earlier geologist, however, considered that the Trusmadi Formation was older than, or possibly the same age as, the Chert-Spilite Formation (Collenette, 1954).