No. 36

REPORT ON THE MINERAL EXPLORATION IN SABAH, MALAYSIA

PHASE II

MARCH 1987

JAPAN INTERNATIONAL COOPERATION AGENCY
METAL MINING AGENCY OF JAPAN

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PREFACE

In response to the request of the Government of Malaysia, the Japanese Government decided to conduct a mineal exploration in the Sabah, Malaysia and entrusted the survey to the Japan International Cooperation Agency (J.I.C.A.) and the Metal Mining Agency of Japan (M.M.A.J.). This project is designed to be carried out in three phases spaced over three years commencing at the beginning of August, 1985.

Phase II of the project consisting mainly of geological, geochemical survey, and drilling was accomplished jointly by the Japanese team and staff of the Geological Survey of Malaysia, Sabah, in 1987.

This report summarizes the results of the afore-mentioned undertaking and also forms a part of the final consolidated report which will be submitted to the Government of Malaysia after completion of the project.

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

We wish to express our deep appreciation to the officials concerned of the Government of Malaysia for their close cooperation extended to the team.

February, 1987

Keisuke Arita
President
Japan International Cooperation Agency

Jun-ichiro Sato
President
Metal Mining Agency of Japan

Yin Ee Heng
Director-General
Geological Survey of Malaysia

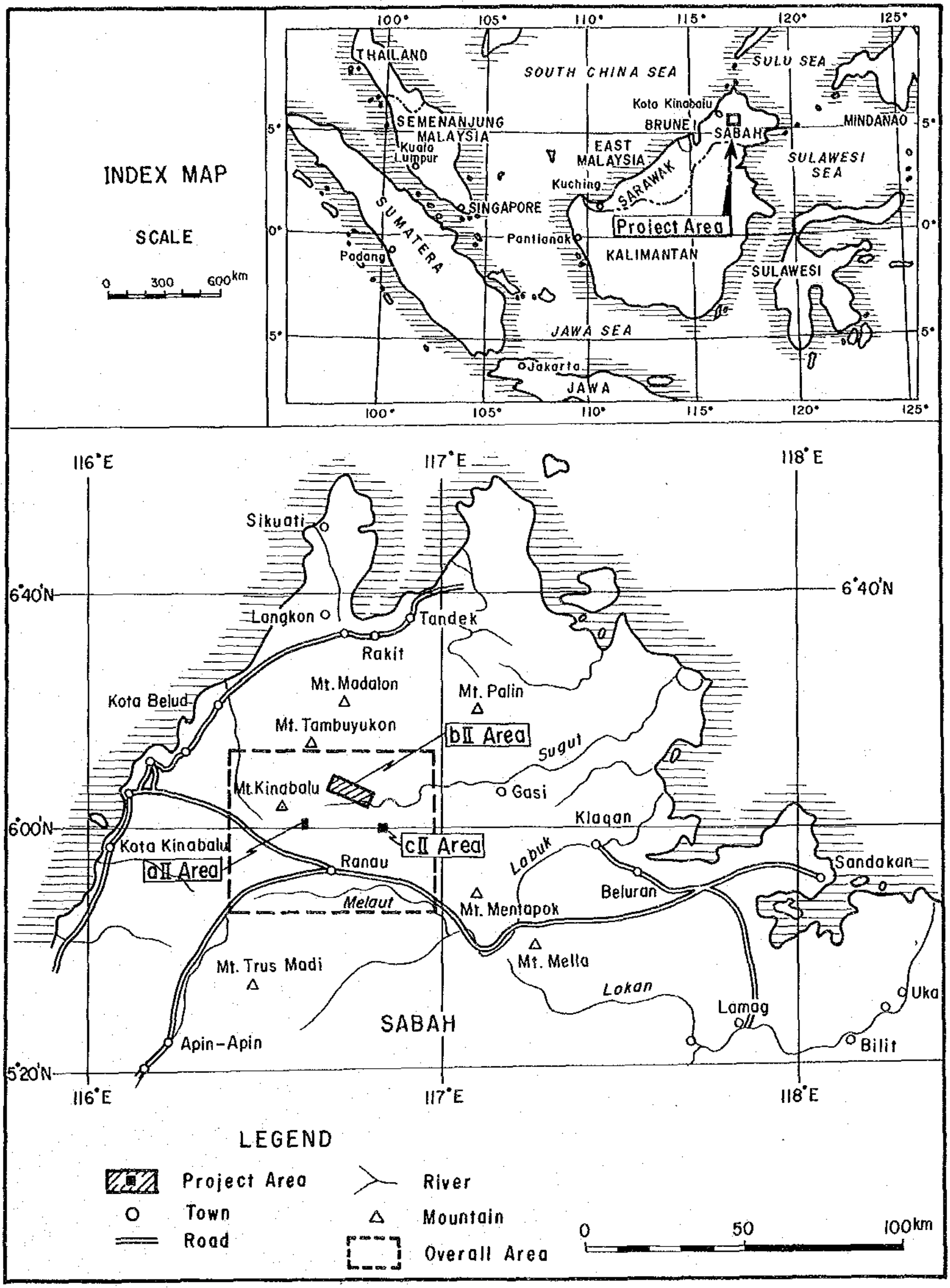

Fig. 1 Location Map of Survey Area

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ABSTRACT

In Kinabalu Mountain area, Sabah, Malaysia, the Mamut copper mine, a porphyry-copper ore deposit associated with the intrusion of the adamellite-porphyry, has been continuing of its operations.

The geology in the area consists of the geocynclinal sediments in the period from late Cretaceous to early Miocene widely distributing, which have been undergone the strong folding and uplifting in latest Miocene followed by the emplacement of the peridotite. At the end of Miocene period intermediate to acidic plutonic rocks intruded in the later orogenic stage and followed by the hypabyssal volcanic activities.

In this year as Phase II of the collaborative mineral exploration, the following three areas have been selected for further exploration, as the geological and geochemical survey, the trenching survey and the diamond drilling.

The surveys and those results are summarized as follows:

(1) all area (Bambangan)

The mineralized zone, intersected by the drill hole of MJM-8 excuted near the Bambangan creek in Phase I, verified as the porphyry-copper type, has been divided into two zones as the secondary enrichment zone (drilling length of 72.20 m, average grade of Au 0.1 g/t, Cu 0.12%, Mo 7 ppm) and the primary sulphide zone (drilling length of 110.10 m, average grade of Au 0.2 gr/t, Cu 0.44%, Mo 59 ppm).

In this Phase II, the diamond drilling of 3 holes with a total length of 1,100 m and the geological survey for the area of 6 km^2 were carried out. Among 3 holes, 2 holes have been allocated to explore the northern and southern extensions of the said mineralized zone. The other hole has been allocated to confirm the northern extension of the pyrite dissemination which was intersected by the drill hole of MJM-5.

As the result of drilling the followings were clarified.

a) In the drill hole of MJM-12 located south of the drill hole of MJM-8, the secondary enrichment zone (drilling length of 51.30 m, average grade of Au 0.21 g/t, Cu 0.35%, Mo 36 ppm) and the primary sulphide zone (drilling length of 30.40 m, average grade of Au 0.06 g/t, Cu 0.17%, Mo 29 ppm) occur, both in the Trusmadi Formation intruded by the small dikes of adamellite-porphyry.

b) The drill hole of MJM-11, aiming the northern extension of the mineralized zone of MJM-8, intersected a weakly oxidized and intermittently mineralized zone (the accumulative drilling length of 60.50 m, average grade of Au 0.12 g/t, Cu 0.07%, Mo 13 ppm).

It can be expected by these drillings that the mineralized zone extends more than 200 m in north-south direction.

(2) bII (Mankadau) area

The peridotite is widely distributed in the area, and the big boulders of massive copper sulphide ore with high copper grade ranging from 40% to 65% are scattered in the Lingangaa creek, a branch of the Mankadau River. For exploring the source of the ore floats, a detailed geochemical survey for soil and a geophysical survey (CSAMT method) were carried out in Phase I, however no indication of the mineralization was detected.

A semi-detailed geochemical survey for soil with a geological survey were carried out in the widened area, to clarify the horizon of massive copper sulphide ore deposit and to confirm the distribution of chromite ore deposit in the area other than those both in the Paranchangan and in the north-west corner of the survey area in Phase I.

As the result of the geochemical survey, the contents of element of Au, Cu, Pb, Zn and Mo were very low. "Cu-Zn" as of the first factor in factor analysis were detected, however it was assumed that the result dues mainly to the difference of rock facies. A weak pyrite disseminated zone was discovered near the anomalous zone, delineated by the re-analysis of geochemical stream sediments which was done by the collaborative exploration work between Malaysia and West Germany, however it seems to be insignificant.

Regarding to the chromite ore deposit in the Paranchangan area, it seems to have a low potentiality for the occurrence of a big scale minable chromite ore deposit, because of poor distribution of dunite which has close genetic relation with chromite.

(3) cII (Paliu) area

In Phase I, some limited geochemical anomalies of Cu, Pb, Zn were detected in the central part by the detailed geochemical survey for soils and stream sediments. This is the same area as where geochemical anomalies of Cu, Pb, Zn were detected by the collaborative exploration work between Malaysia and West Germany. The trenches were excuted for the said anomalous zone in this phase, however, the surveys were only concluded as following results; the anomalous spot in the trench of No.2 indicates the content of Pb, maximum 0.61%, and in the trench of No.6 indicates the content of 0.10-0.19 g/t of gold accompanied by stringers of pyrite and quartz.

PART I INTRODUCTION

CHAPTER 1 Outline of Survey

1–1 Background and Purpose of Survey

In the collaborative mineral exploration of the area, various surveys were conducted in Phase I, as the first year of the project, in three areas such as Bambangan, Mankadau and Paliu, which are likely to have a high potentiality of copper ore deposit from the result of past survey. past survey.

As a result, distinct anomalies of electric surveys with CSAMT and IP methods were detected in the Bambangan area, and the copper disseminated zone in association with adamellite porphyry over the length of 183.30 m were intersected by the drill hole of MJM-8.

In the Mankadau area, although geochemical survey by soil and electric survey with CSAMT method were conducted to investigate the origin of the floats of high-grade massive copper sulphide ore, no anomaly suggesting the mineralization could be obtained.

The Paliu area is an area in which geochemically anomalous zones of copper, lead and zinc in stream sediment were reported by the Malaysia and West Germany collaborative survey team. The detailed geological and geochemical surveys in Phase I detected weak copper disseminated zones and small anomalous zones in soil.

The purpose of the survey was to elucidate the geological structure and to grasp the possible occurrence of ore deposit. In line with the purpose, geological mapping, geochemical survey and drilling were carried out to follow up the results of survey in Phase II.

1–2 Content of Survey

The content of survey in the field is as follows;

a II (Bambangan) Area	geological survey and drilling	
	the area to be surveyed	6 km^2
	total length of traverse	6 km
	three drill holes (1,100 m in total)	
b II (Mankadau) Area	geological mapping and geochemical survey	
	the area to be surveyed	50 km^2
	total length of traverse	70 km
	soil samples	200
c II (Paliu) Area	trenching	
	volume of excavation	50 m^3 (5 m^3 x 10 trenchs)

Table 1 shows the content of survey in Phase I.

1–3 Organization of Survey Team

The members participated in the planning and negotiation on the survey and the field survey are as follows.

Planning and Negotiation

Japanese Counterparts

Seiichi Ishida	Metal Mining Agency of Japan	
Tadaaki Ezawa	〃 〃 〃	
Yoshitaka Hosoi	〃 〃 〃	(Manila representative)

Malaysian Counterparts

Yin Ee Heng, Geological Survey (Head Office in Kuala Lumpur)

David Lee Thien Choi, Geological Survey (Sabah Office)

Field Survey

Japanese Team

Hajime Shimizu	(Leader; geology, geochemistry, core logging and report)	Bishimetal Exploration Co., Ltd.
Tadashi Yamakawa	(Geology and geochemistry)	〃 〃
Takashi Nagamine	(〃 〃)	〃 〃
Mahito Hamazaki	(Drilling)	〃 〃
Shigeo Sekiguchi	(〃)	〃 〃
Hiroshi Saito	(〃)	〃 〃

Malaysian Team

Lim Peng Siong	(Administration and report)	Geological Survey of Malaysia, Sabah
Mohd Yusof Ramli	(Geology and geochemistry)	〃 〃
Chan Fook On	(Chemical analysis)	〃 〃
Johnty Enggihon	(Geology and geochemistry)	〃 〃

Technical Assistant

Kwan Houng En	(Geology and geochemistry)	〃 〃
Kirman B. Sukardi	(Drilling)	〃 〃
Roger Jinijo Totu	(〃)	〃 〃
Francis Geoffery	(Geology and geochemistry)	〃 〃
Chua Yun Ling	(Geology and geochemistry, Drilling)	〃 〃
Arnold Bangose	(Drilling)	〃 〃
Abdullah Sirom	(Geology and geochemistry, Drilling)	〃 〃

Table 1 Outline of Field Survey in Phase II

	Duration	Survey Figures		Remarks
		Area	Length	
Preparatory Work	Sept. 16 ~ 19, '86 4 days	–	–	
Geological & Geochemical Surveys	Sept. 20 ~ Nov. 1, '86 43 days	aII 6 km^2 bII 50 km^2	12.8 km 86.2 km	Geological Survey only Soil Samples 235 pcs.
Trenching Survey	Oct. 20 ~ Nov. 1, '86 43 days	cII 10 trenchs	131.7 m^3	Samples 93 pcs.
Drilling	Sept. 19 ~ Dec. 20, '86 93 days	MJM-11 –60° MJM-12 –50° MJM-13 –90° Total	351.00 m 402.20 m 350.50 m 1,103.70 m	Core Samples 338 pcs.

CHAPTER 2 Geography and Outline of Geology

2–1 Location, Accessibility and Topography

2–1–1 Location and Accessibility

The survey area is located in the surrounding area of Ranau, having a direct distance of 70 km east from Kota Kinabalu. Mt. Kinabalu, the highest mountain (4,101 m, ASL) in south-east Asia region, is situated in a little northwestern part of the survey area.

The survey areas in Phase II, are aII (Bambangan), bII (Mankadau) and cII (Paliu) areas, which have a direct distance from Ranau of, 12 km in NNW, 25 km in NNE and 20 km in NE, respectively.

Regarding the access to Bambangan area, there is a road which belongs to Mamut mine, so that the accessibility is rather convenient as only taking time less than one hour from the central part of the area.

For approaching to the mouth of bII (Mankadau) and cII (Paliu) area, the road which is not maintained well often causes to cut off all communication by flood of stream when it rains heavily, leading to difficulties of maneuvering. In the normal condition, the travelling time is only about one hour.

However, most of the survey and its approaching were done by walking due to the steep topography and the dense jungle.

2–2–2 Topography

Three areas for survey are located within the area showing a steep topography.

The aII (Bambangan) area is located around the steep portion on the south-east side of Kinabalu mountain. The highest point in the north end of the survey area shows the elevation of 1,833.20 m ASL, which is decreasing the elevation toward south. The lowest point in the south end area shows a elevation of 1,300 m ASL, and the topography changes to the elevated plain. Bambangan valley running to the south with a rapid current forms a V shape valley with steep cliffs. The eastern part of the area shows a topography of steep cliff in places due to the occurrence of hard portion of "solid" Pinosuk Gravels.

The bII (Mankadau) area is located in the eastern side of Kinabalu mountain, where is the area graded into the central highland region from the Crocker mountain ranges in the west. In the north-west corner, the topography shows elevation as high as 1,300 m ASL, on the contrary, the elevation reduces to 200 m ASL in the south-east corner of the area along the Mirali River, showing the great discrepancy of its elevations. There are many steep area, with the exception of

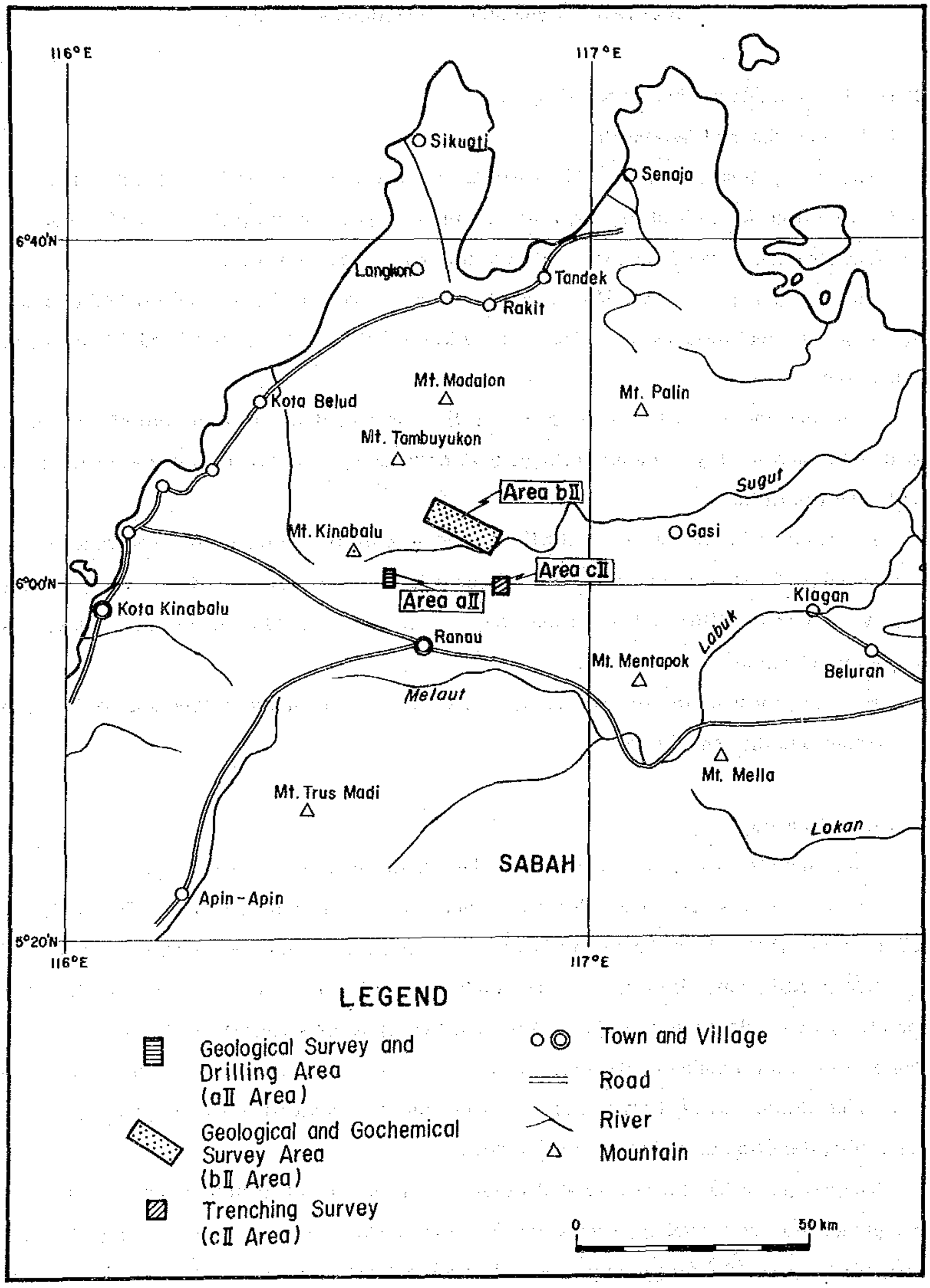


Fig. 2 Location Map of Phase II Area

the low land area along the Mirali River in the east corner and the Mankadau River in the south corner, especially the topography of the north-western area shows a steep V shape valley and water fall in places, along the Sasapan creek running to north and the branch of Mankadau River.

Regarding cII (Paliu) area, the trenchs are located on the steep slope in both side of the ridge separated from the highest point in the area.

2–2 Climate and Vegetation

Climate in Sabah state is tropical and oceanic.

Ranau area belongs to the inland region, it has been said that the period of the rainy season is from October to February, next year. However, the variation in precipitation by season is rather small.

The annual precipitation in the mountainous area is from 1,500 to 2,000 milimetres and exceeds more than 3,000 milimetres in the mountains. The annual precipitation in Mamut mine is shown to be 2,100 milimetres to 4,000 milimetres.

No seasonal variation of the temperature is clearly recorded. It varys from 12°C to 22°C in the mountainous area, showing a notable daily variation. The moisture is high in any part of the region.

Regarding the vegetation, the survey area belongs to the jungle zone, in which tall and dwarf trees, harbaceous plants and ferns grow very thick due to the high moisture, leading to take time for clearing the route for survey.

2–3 Outline of Geology

The intrusive batholith of adamellite is distributed protruding in the surface slightly extending northeasterly, with an area of 155 square kilometres (60 square miles), showing a peculiar landform with an altitude of 4,101 metres ASL, which is said to be spread over 1,300 square kilometres (500 square miles) in subsurface (Jacobson 1970). Therefore, it would be distributed both on the surface and underneath of the whole extent of the survey area as batholith. The peripheral part of the rock becomes porphyritic, and it is distributed surrounding the Kinabalu mountain mass as adamellite porphyry, especially dominantly on the southern and western sides of the mountain in a zonal form. It is also exposed on the northern side of the Poring settlement to the east of the mountain mass forming a low mountain mass (about 750 metres in altitude) slightly extending northeasterly (Fig. 3, Fig. 4).

Because the whole area of the Mamut ore deposit which is adjacent to the Kinabalu mountain mass on the southern side is considered to lie over the batholith in subsurface, the stocks

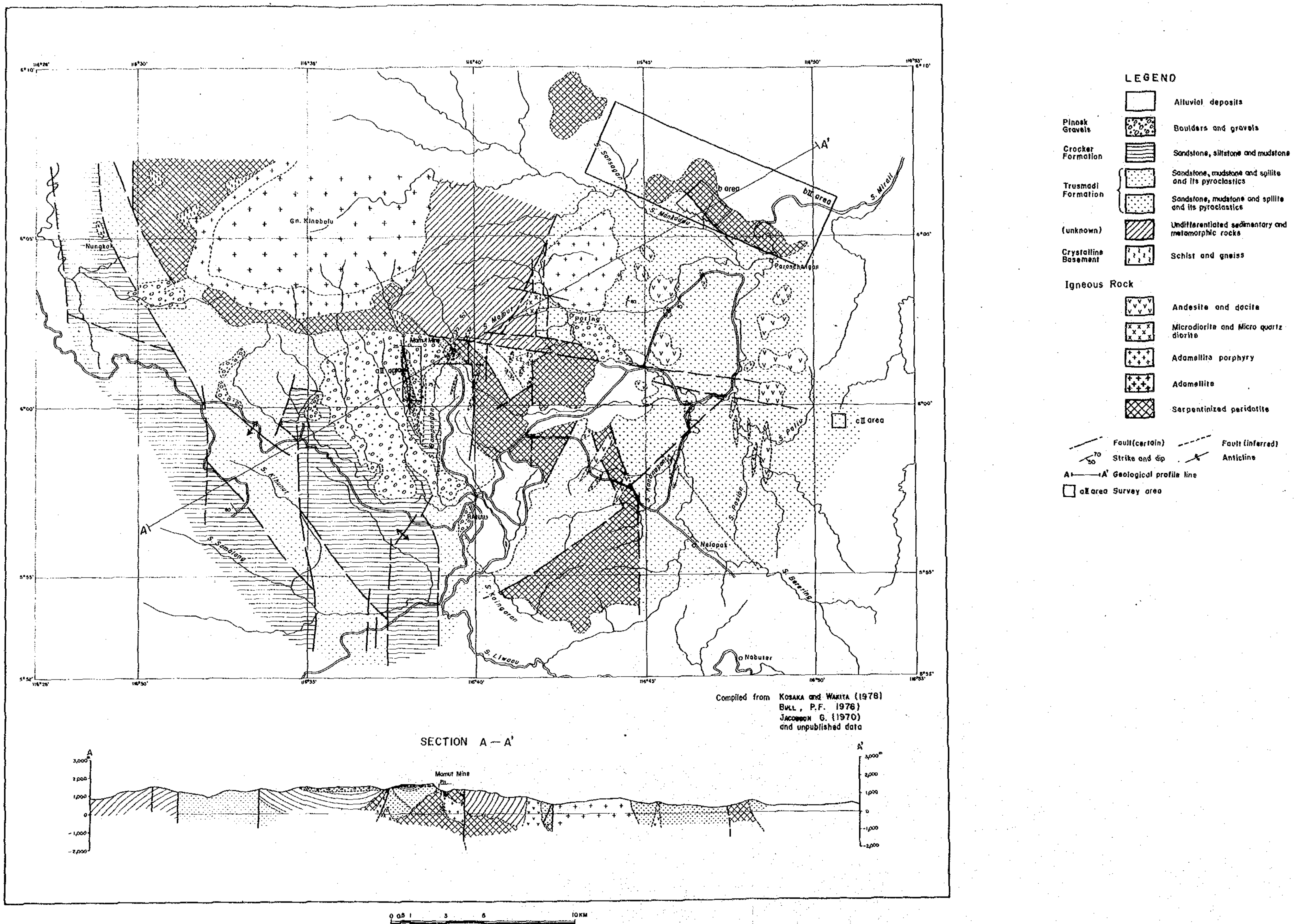
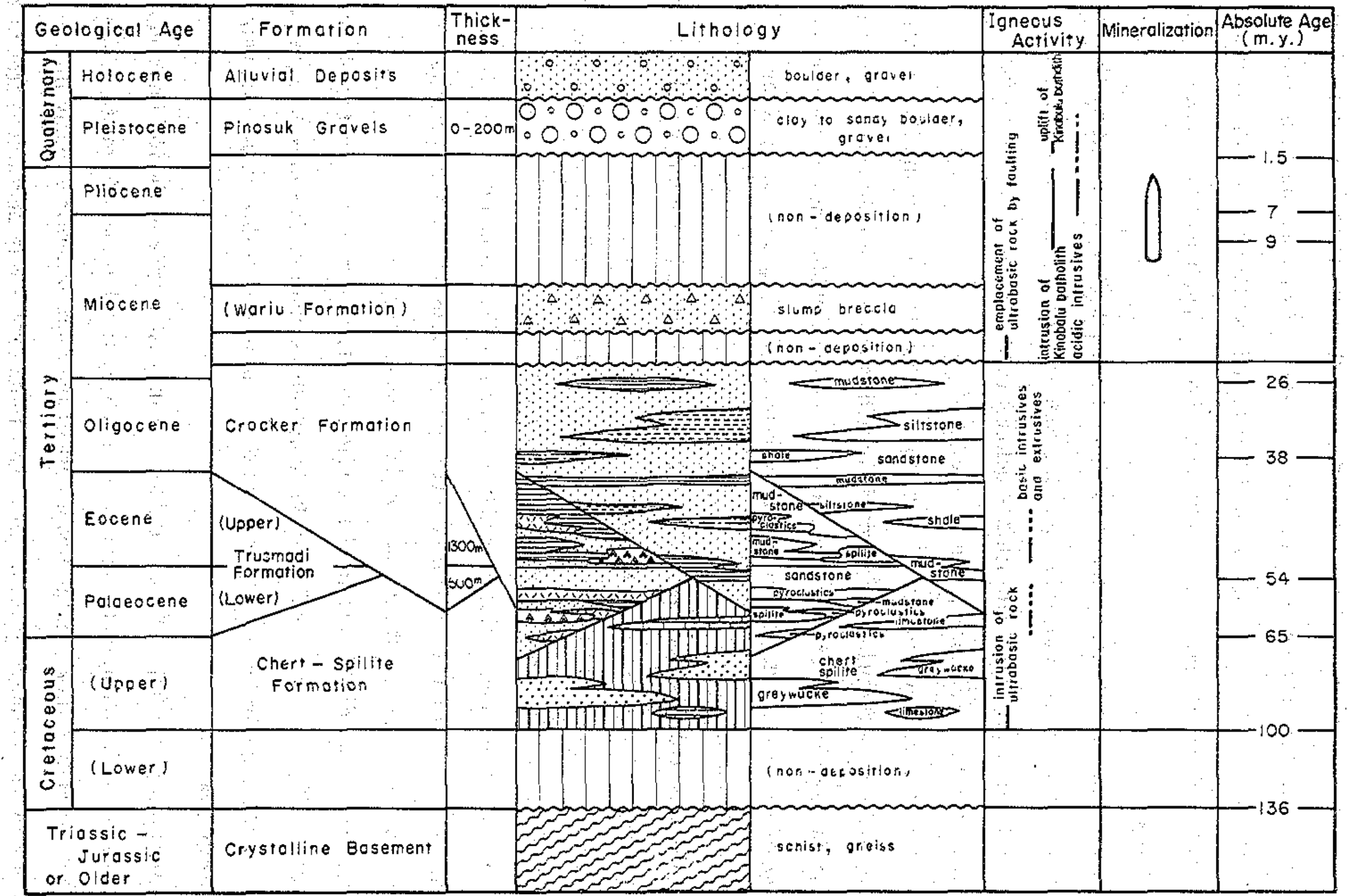


Fig. 3 Geological Map of Kinabalu Area



(Compiled mainly from Kosaka and Wakita, 1975)

Fig. 4 Generalized Stratigraphic Section of Kinabalu Area of adamellite porphyry (about 800 meters in N-S and 300 meters in E-W, dipping 40° eastward in general; Kosaka and Wakita (1975) which is widely distributed within and in the vicinity of the ore deposit, forming the main host rock of the deposit and having been directly involved in the mineralization, and the dikes observed in abundance on the top and in the peripheral part of the stock, are all the cupolas or apophyse branched off from the Kinabalu adamellite batholith.

The rocks which form the basement of the Teritiary sedimentary rocks is the "Crystalline Basement" consisting of schists and gneisses, and their ages are classified as Jurassic and Triassic, or earlier than Jurassic.

The sediments deposited overlying the Crystalline Basement are represented by the Chert-Spilite Formation composed of chert, spilite and the sedimentary rocks, and the Rajang Group composed of flysch-type sediments. The former belongs to the late Cretaceous to Palaeocene sediments and the latter to the Plaeocene to early Miocene.

The Rajang group is divided into two formations such as the Trusmadi and the Crocker. In connection with their age, although the Trusmadi Formation has been classified as Palaeocene to Eocene, and the Crocker Formation as the later (Oligocene to early Miocene) for the time being, the stratigraphy of the two formations has not yet been established because of complexity of geological structure of the area.

Lithologically, the Trusmadi Formation consists of gray to dark gray argillite and slate, and partly siltstone with rare occurrence of pyroclastics.

The Crocker Formation is rather arenaceous as compared with the Trusmadi Formation, being composed of sandstone, siltstone and gray or red shale.

It is said that there are some areas in which the Chert-Spilite Formation shows the lateral gradiation with the upper Trusmadi Formation as contemporaneous heterotopic facies, and it can be said that the stratigraphy of the area has not yet been established.

The sedimentary rocks distributed in the lowland on the southern side of the ultrabasic rocks in the area "bII", has been classified as the Trusmadi Formation. It seems, however, that those sedimentary rocks rather belong to the Chert-Spilite group from the relationship with the upper spilitic basalt lava.

As to distribution of the Rajang Group, the area on the eastern side of the N-S line connecting the Mamut ore deposit and Ranau is almost occupied by the Trusmadi Formation, and the sedimentary rocks including those of the lower part of the Pinosuk Gravels widely distributed from the N-S line to Kg. Kundasang on the west, and those extensively distributed around Mt. Nungkok which forms a small mountain mass of adamellite to the west of the Kinabalu mountain mass, are classified as the Crocker Formation.

It is evident from the observation of complicated distribution of the Crocker Formation between Ranau and Kundasang along the many cuttings of the main road leading to Kota Kinabalu that the two formations have a complicated geological structure by repetition of folding and faulting. The sedimentary rocks which form a part of the wall rocks of the Mamut ore deposit are classified as the Trusmadi Formation.

The sedimentary rocks (partly include metamorphic rocks) widely distributed on the northern side of the easterly trending fault in the M–1 area forming the northern border of the Mamut ore deposit was once classified as the Trusmadi Formation (before 1970), but it is classified as undifferentiated sedimentary and metamorphic rocks at present, without establishment of clear stratigraphical classification.

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

From the viewpoint of the geological history, the ultrabasic rocks are the first of the intrusive rocks of the area, and the Kinabalu batholith intruded in the later stage.

The ultrabasic rocks in the survey area are distributed on the southern side and the western side of the adamellites of the Kinabalu mountain mass, in the area "b II", in the southeastern part of Mamut and on the southwest of Ranau. The rock consists mainly of peridotite, and dunite is observed locally. These rocks have been sheared and fractured to produce breccia in many cases. Serpentinization is generally observed. In Sabah State, the ultrabasic rocks are often distributed in contact with spilite lava, and the they show a wide distribution being in contact with the spilite basalt lava on the southern side of the fault laid between them.

Adamellites constituting the Kinabalu mountain mass have been dated to be 9 m.y. of absolute age, corresponding to the later stage of the orogenic movement which took place from late Miocene to Early Pliocene, or immediately after that age. According to Jacobson (1970), adamellite intruded into the ultrabasic rocks showing a vertical contact (western bank of the Bambangan creek).

The Kinabalu mass itself is composed of adamellite, and porphyritic adamellite and adamellite porphyry in the marginal part. It is the same in the cupolas in the surrounding area of the mass. In the Mamut area, intrusion of these cupolas resulted in forming a dome structure both in the ultrabasic rocks immediately above the cupola and the sedimentary rocks overlying them.

In the Mamut mineralized zone, the presence of granodiorite porphyry dyke is known to form a very small part of the ore deposit, clearly cutting adamellite porphyry. Therefore, it is later than adamellite porphyry which is closely associated with the Mamut mineralization, but it has been subjected to mineralization (although copper grade is about one-third that of those host rocks such as adamellite, ultrabasic rocks and sedimentary rocks), and seems to be the intrusive rock in the later stage of a series of plutonic activity of the Kinabalu adamellite intrusive.

Beside these, microdiorite is found mainly as N-S trending dykes around the Mamut ore deposit area and in the lower reaches of the Bambangan creek of the survey area aII. This rock corresponds to Por-2 among those described as the porphyritic rocks (hypabyssal porphyritic rock) (OMRD's report on investigation of the Mamut ore deposit, January 1971) It was also encountered in the drill hole MJM-1 and MJM-3 and MJM-13, having continued for about 220 meters in MJM-1 and MJM-3), and shows a porphyritic texture with distinct phenocrysts of garnet. Although the time of intrusion of the rock has not been made clear, it might be considered to be in the later stage of activity of the Kinabalu plutonism and also in later stage or final stage of the mineralization associated with it.

On the eastern side of the survey area, dacite and andesite are distributed in the Trusmadi sedimentary rocks which shows a wide distribution, having intruded and extruded as stocks and dykes, or partly as lava. These are thought to represent the later stage of the Neogene igneous activity.

The one of unexpected obstacles for the survey activity in the area was the Pinosuk Gravels, the Quaternary sediment, although it is not related to the Tertiary orogeneic movement, igneous activity or mineralization.

This bed is distributed for an extent of about 50 square kilometres at an altitude between 1,500 and 1,200 metres on the southern side of the Kinabalu mountain from the upper flank of the relatively gentle slope, where a steep landform of the intrusive mass comes to an end, toward the south through the Pinosuk settlement, which gave the name of the bed as type locality. The lower end of it collapsed and flowed out as mud flow to reach the Ranau floodplain on the southeast, and the great boulders have remained in the riverbed of the large and small rivers flowing at the periphery and in the alluvial floodplain of the Ranau basin.

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

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

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

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

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

Faults of a N-S system in the area are dominant, which are divided into sections by the faults of NW-SW system to form blocks. And the block movements were repeated, in which the outside (southern side and eastern side) blocks slipped down on the eastern and the southern sides of the Kinabalu mountain mass.

Faults of a E-W system and a NE-SW system are also present, and they control the local structure, though small in scale as compared with those in the above. For example, weak fracture zones of a NE-SW system are developed in a form of echelon, and the overall ore zones take a northerly extending form. The fault bordering the northern limit of the deposit is notable among E-W system faults, cutting adamellite porphyry, and the southern block slipped down against the northern block. These faults are considered to be related to the uplifting of the Kinabaru Mountain and the movement would have continued from the initiation to the final stage of the mineralization.

PART II aII (BAMBANGAN) AREA

CHAPTER 1 Geology and Mineralization

1–1 Geology

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

The steep slope of the mountain changes to gentle slope toward the south and the area is just located at the converting point.

While the geology is difficult for full delineation because of thick cover of the Quaternary Pinosuk Gravels, the geology of the area can be presumed from the geology along the Bambangan creek and the result of drilling of 13 holes conducted in the area, is as follows.

1–1–1 Stratigraphy

The sedimentary rocks distributed in the area consist of the Chert-Spilite Formation of late Cretaceous to early Miocene, the Trusmadi Formation composed of geosynclinal sediments followed the above, and the Quaternary Pinosk Gravels in an ascending order. The intrusive rocks include the peridotite which is considered to have been emplaced in early Miocene, though the intrusion age is Cretaceous, and adamellites and microdiorite in the latest Miocene.

(1) Chert-Spilite Formation

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

Thickness : More than 200 meters.

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

It has not been made clear whether this formation belongs to the same group as the metamorphic rock (actinolite schist forming the crystalline basement – Kosaka and Wakita, 1975) found in the upper reaches of the Bambangan creek, which is considered to be the basement rock of the area.

Geological Structure : It appears that the formation dips southward judging from the drilling data as shown in Map–1 Geological Section of the Area (D-D').

(2) Trusmadi Formation

Distribution : Although the exposure is limited in the Bambangan creek and along the road connecting both the Mamut open pit and the intake of mine water. The turbidite is not only locally distributed in the southwestern side of the Mamut mine, but also widely encountered

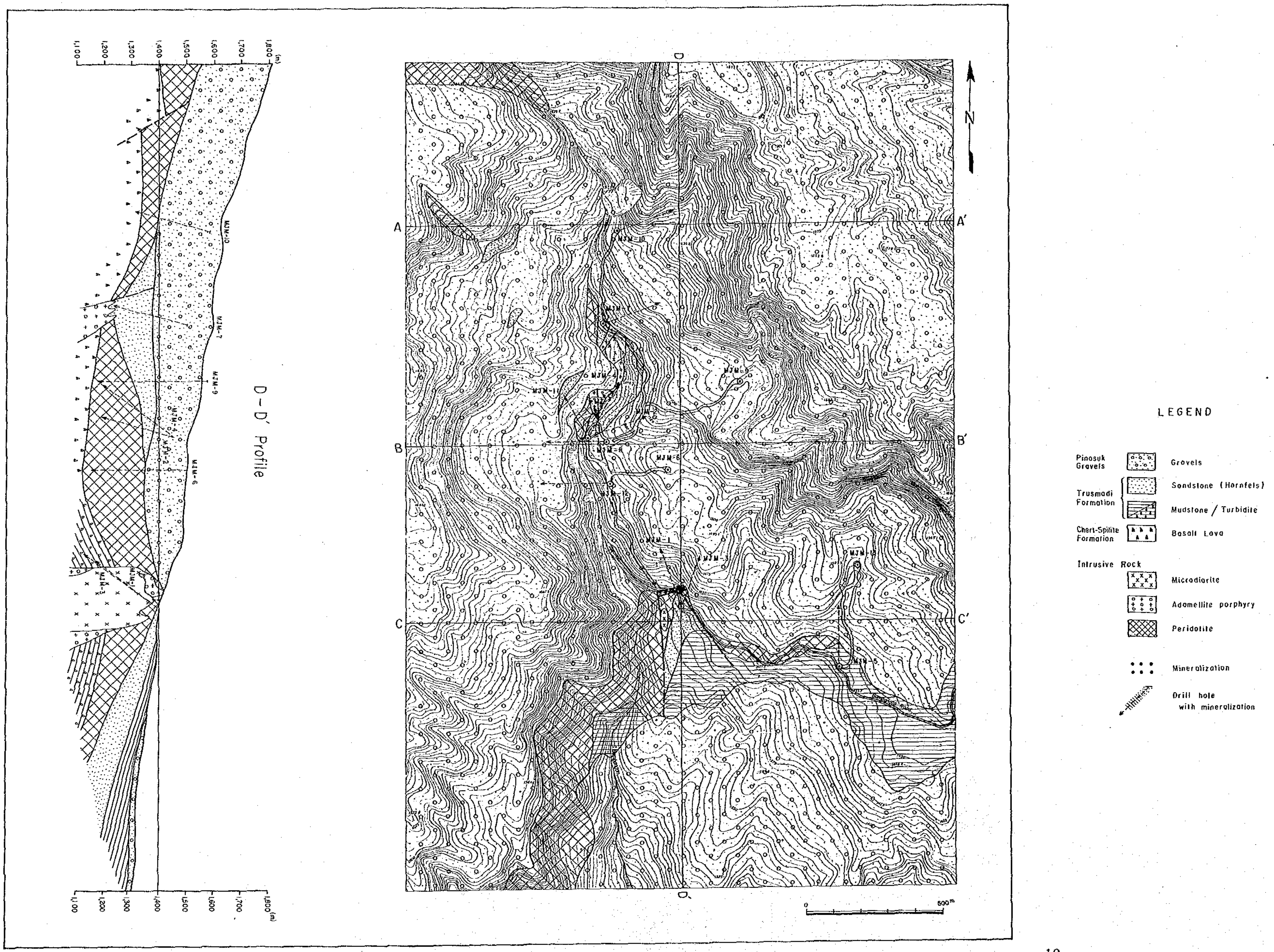


Fig. 5 Geological Map of aII (Bambangan) Area

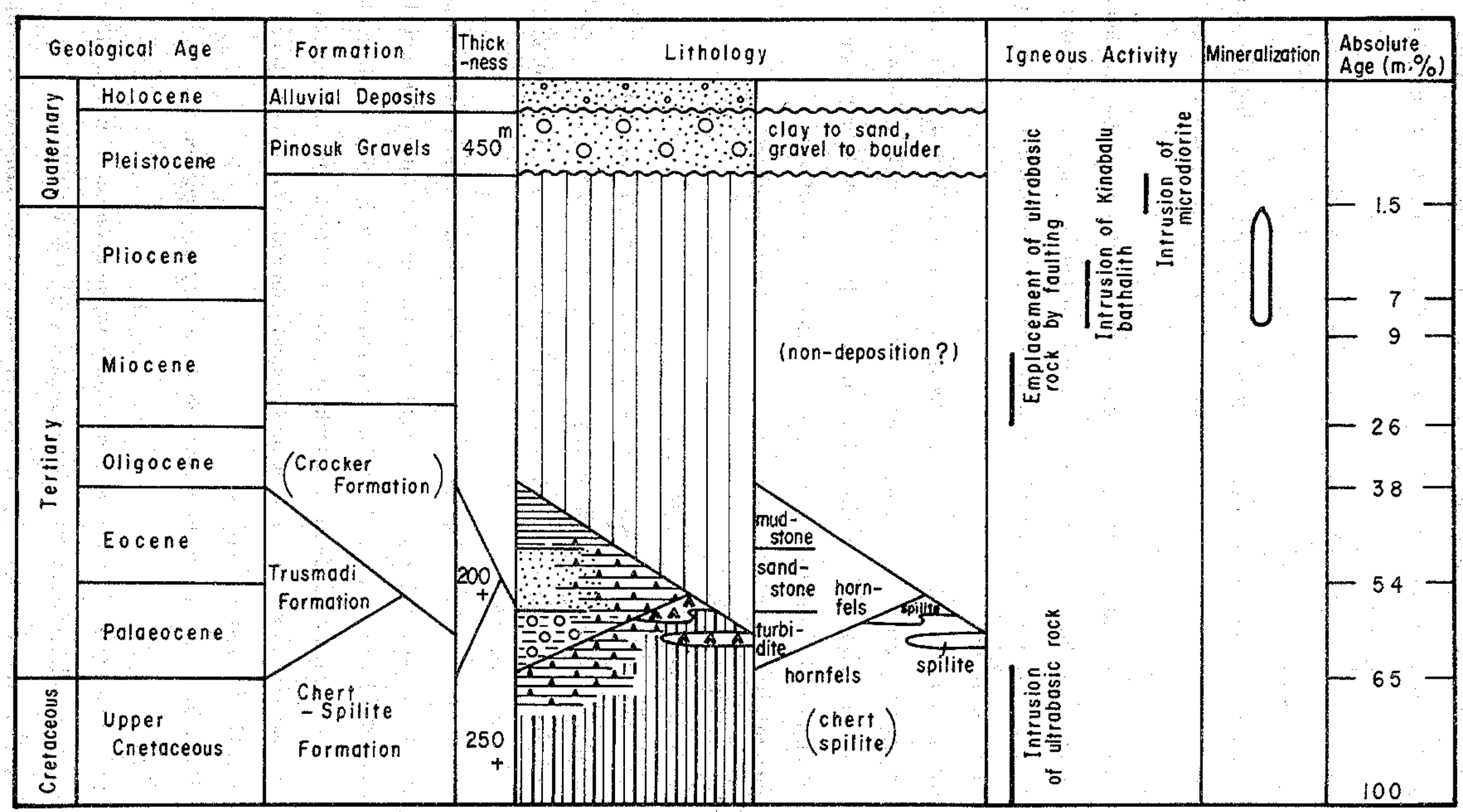


Fig. 6 Generalized Stratigraphic Section of a II (Bambangan) Area

in the drill holes, which are from about 150 m to 200 m below the surface in the drill holes of MJM-1 and MJM-3, from the surface to 300 m in MJM-5 and from 202.75 m to 350.50 m (bottom of the hole) in MJM-13.

It is thought that the turbidite is to be correlated to the Trusmadi Formation.

Thickness : Approximately 300 m

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

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

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

The characteristics of typical hornfels under the microscope is as follows.

K-05 Hornfels (sandstone)

Fragments : quartz $\gg$ plagioclase $>$ opaque

Microscopic Features : fine grained sandstone mainly consisting of quartz particles (0.1 mm in size) with angular to subangular shape. Poorly sorted. Opaque minerals are arranged in some lines. Secondary minerals are calcite in form of vein or patch, sericite, chlorite and biolite (which is embeded among the particles)

McManus J. et al., (1986) stated that it was formed (1) underneath the ophiolite mass being thrust up by the obduction of oceanic crust having been taken into that part and fractured, (2) as the product of mud volcano activity, at the time of obduction (middle Miocene) from the Sulu Sea on the north toward the northeastern Sabah. It is just like the chaotic (massive and pyroclastic with various sizes of pebbles, showing no bedding) sediment, as a result of núee andente-like activity, or (3) by the above two cases.

In the viewpoint of the discussion stated above, it may be suggested that the turbidite would be a mélange.

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

Time of Sedimentation : Although it has been said that the Trusmadi Formation was deposited from Palaeocene to Eocene of Tertiary, and the Crocker Formation from Oligocene to early Miocene, two formations sometimes show the relation of interfinger as the contemporaneous heterotopic facies.

(3) Pinosuk Gravels

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

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

Rock facies : The Gravels is generally grayish brown, and often forms steep cliffs.

The kind, shape and size of gravels, the kind of matrix and the degree of consolidation vary greatly from place to place.

The Gravels generally consists of subangular to subround pebbles of adamellite, adamellite porphyry, microdiorite, hornfels, mudstone, sandstone and peridotite, rarely containing carbonized wood pieces.

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

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

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

The characteristics of the typical gravel under the microscope are as follows.

Y-01a Pinosuk Gravel

Fragments : quartz ≫ plagioclase > hornblend · biotite · K-feldspar > zircon and some serpentine.

Microscopic features : Fragments of mineral and rock are 4 mm in size, distributing in a muddy matrix. Secondary epidote and chlorite can be observed in places.

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

Stratigraphical Relation : The bed unconformably overlies the lower sequences.

1–1–2 Intrusive Rocks

The intrusive rocks in the area consists of peridotite, adamellite porphyry and microdiorite.

(1) Peridotite

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

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

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

The characteristics under the microscope are as follows.

N-05 Peridotite (Lherzolite)

Texture : equigranular

Constituent minerals : olivine > augite > enstatite > opaque minerals

Microscopic features : Holocrystalline. Fairly fresh. Olivine is serpentinized along fissures. Augite is partially replaced by tremolite, serpentine and calcite along diallage parting. Some magnetite and a few chromite are present.

(2) Adamellite Porphyry

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

Distribution : The rock is exposed in two places, one is along the Bambangan creek and the other is in the vicinity of the mine road. It is also encountered in the lower part of the drill holes such as MJM-2, 4, 7, 8, 11 and 12. The one exposed along the Bambangan creek is a dike on a small scale having an extent of 50 to 100 m from the east to west and 400 m from the north to south, located at an level of about 1,300 to 1,400 m ASL as shown in the Fig. 13. It is cut by the Bambangan fault, and the western portion becomes swollen toward the lower southern part. The shape of the rock in the vicinity of the mine road can not be delineated because it is intruded by microdiorite at the later stage, and it is likely to show a cylinderical shape of 300 to 400 m in diameter. The occurrence of another stock with flat top has been confirmed in the lower part (approximately 1,100 m above sea level) of the drill hole MJM-5.

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

The characteristics of the typical sample under the microscope is as follows.

Y-04 Adamellite porphyry

Texture : Porphyrytic, holocrystalline

Phenocrysts : plagioclase > hornblend > quartz > K-feldspar • biotite • magnetite

Microscopic features : Large phenocrysts of K-feldspar (5 mm in size) and hornblend are remarkable in a matrix of an aggregate of fine quartz with a few hornblend and biolite. The rock is fresh except for weak chloritization.

(3) Microdiorite

Distribution : The occurrence of the rock has been confirmed in two places along the Bambangan creek and the drill holes of MJM-1 and MJM-3. The former has an extent of 250 m long and 70 m wide extending north-northwesterly from the exposures. The latter is likely to be a cylindrical stock of more than 200 m in diametre taking into account the result of drill hole BA-1 done by the Overseas Mineral Resources Development Co., Ltd. (OMRD) in 1971 at the site below the mine road (Fig. 5).

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

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

The characteristics of the rock under the microscope is as follows.

Y-05a Microdiotite

Texture : Holocrystalline, porphyritic

Constituent minerals : quartz • hornblende > plagioclase, K-feldspar, biolite > magnetite

Microscopic features : Few groundmass (nearly equigranular). Large christals of hornblende, biotite, quartz and plagioclase (3 ~ 4 mm each in size). Twinned plagioclase is andesine. Alteration is weak as partial replacement of biotite by chlorite.

1–1–3 Chemical Composition of Intrusive Rocks

Table 2 shows the chemical composition of typical adamellite porphyry and microdiorite collected at the Bambangan creek, and Fig. 7 shows the relative proportions of nonmative

Table 2 Chemical Composition of Intrusive Rock in a II (Bambangan) Area

(1) Chemical Composition

Sample No.	Y-04*	Y-05**	Y-10*
SiO_2	63.51	61.66	61.97
TiO_2	0.45	0.51	0.51
Al_2O_3	15.08	14.50	14.30
Fe_2O_3	5.36	5.88	5.58
FeO	3.30	3.65	3.65
MnO	0.11	0.12	0.11
MgO	2.48	3.17	3.47
CaO	4.46	4.66	3.94
Na_2O	3.28	2.93	2.90
K_2O	5.10	4.48	4.37
P_2O_5	0.23	0.19	0.22
S	0.00	0.00	0.00
CO_2	0.00	0.00	0.00
BaO	0.04	0.06	0.04
NiO	0.00	0.00	0.00
Cr_2O_3	0.00	0.00	0.00
H_2O^+	0.66	1.11	2.50
H_2O^-	0.00	0.00	0.00
TOTAL	104.06	102.92	103.56

* Adamellite porphyry
** Microdiorite

(2) Normative Mineral

Sample No.	Y-04	Y-05	Y-10
q	13.79	14.59	15.79
c	0.00	0.00	0.00
or	30.14	26.48	25.83
ab	27.75	24.79	24.54
an	11.36	13.18	13.09
ne	0.00	0.00	0.00
ac	0.00	0.00	0.00
ns	0.00	0.00	0.00
ks	0.00	0.00	0.00
wo	0.00	0.00	0.00
diwo	3.90	3.68	2.12
dien	2.97	2.84	1.68
difs	0.53	0.44	0.27
hyen	3.21	5.05	7.02
hyfs	0.57	0.78	1.18
olfo	0.00	0.00	0.00
olfa	0.00	0.00	0.00
mt	7.77	8.53	8.09
he	0.00	0.00	0.00
il	0.85	0.97	0.97
tn	0.00	0.00	0.00
pf	0.00	0.00	0.00
ru	0.00	0.00	0.00
ap	0.53	0.44	0.51
cc	0.00	0.00	0.00
pr	0.00	0.00	0.00
cr	0.00	0.00	0.00
TOTAL	103.38	101.77	101.04

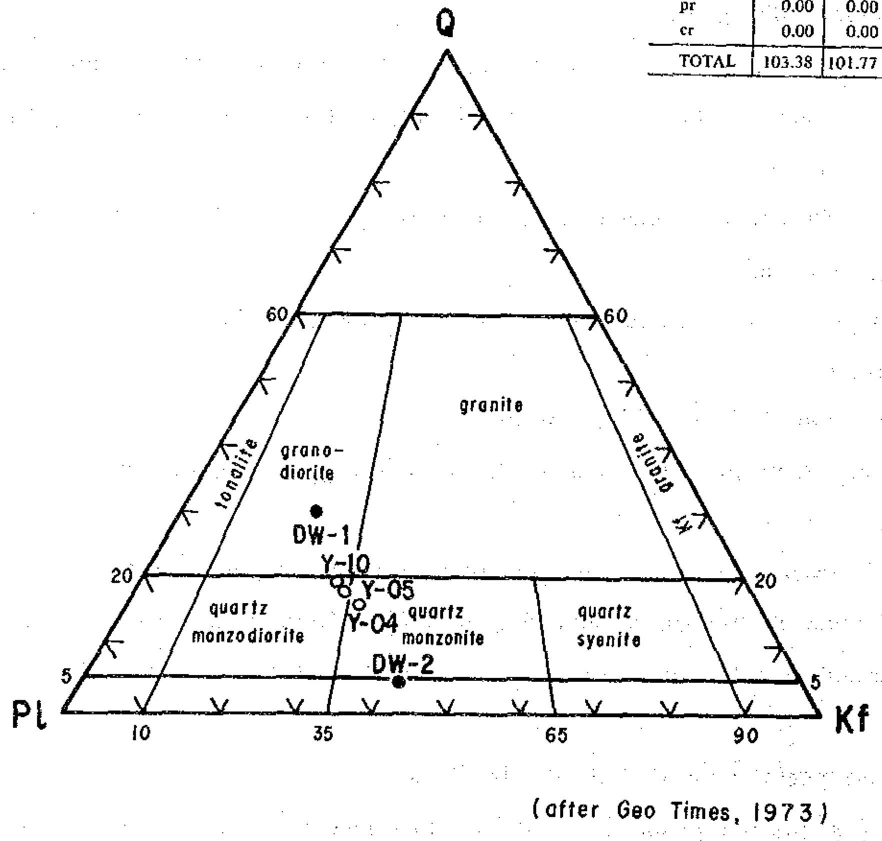


Fig. 7 Normative Q-Kf-Pl Diagram of Intrusive Rocks in a II (Bambangan) Area

minerals which are calculated from the table. Granodiorite in the cII (Paliu) area was also plotted on the same diagram for reference. Where DW-1 is the microdiorite at the depth of 178.80 m in the drill hole MJM-1, and DW-2 is adamellite porphyry at the depth of 75.00 m in the drill hole of MJM-2.

Among the samples plotted, Y-04 (adamellite porphyry) is in the field of quartz monzonite (same as adamellite), and the other Y-04 (microdiorite) and Y-10 (diorite porphyry) are in the field of quartz monzonite. However, these three are very close to each other, suggesting the differentiation from the same magma.

1–1–4 Geological Structure

Although full understanding on the geological structure of the area could not be attained, because the survey area is widely covered by the Pinosuk Gravels, the geological structure as the followings can be interpreted as a result of comprehensive study on the results of drilling of 13 holes and geophysical survey in Phase I.

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

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

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

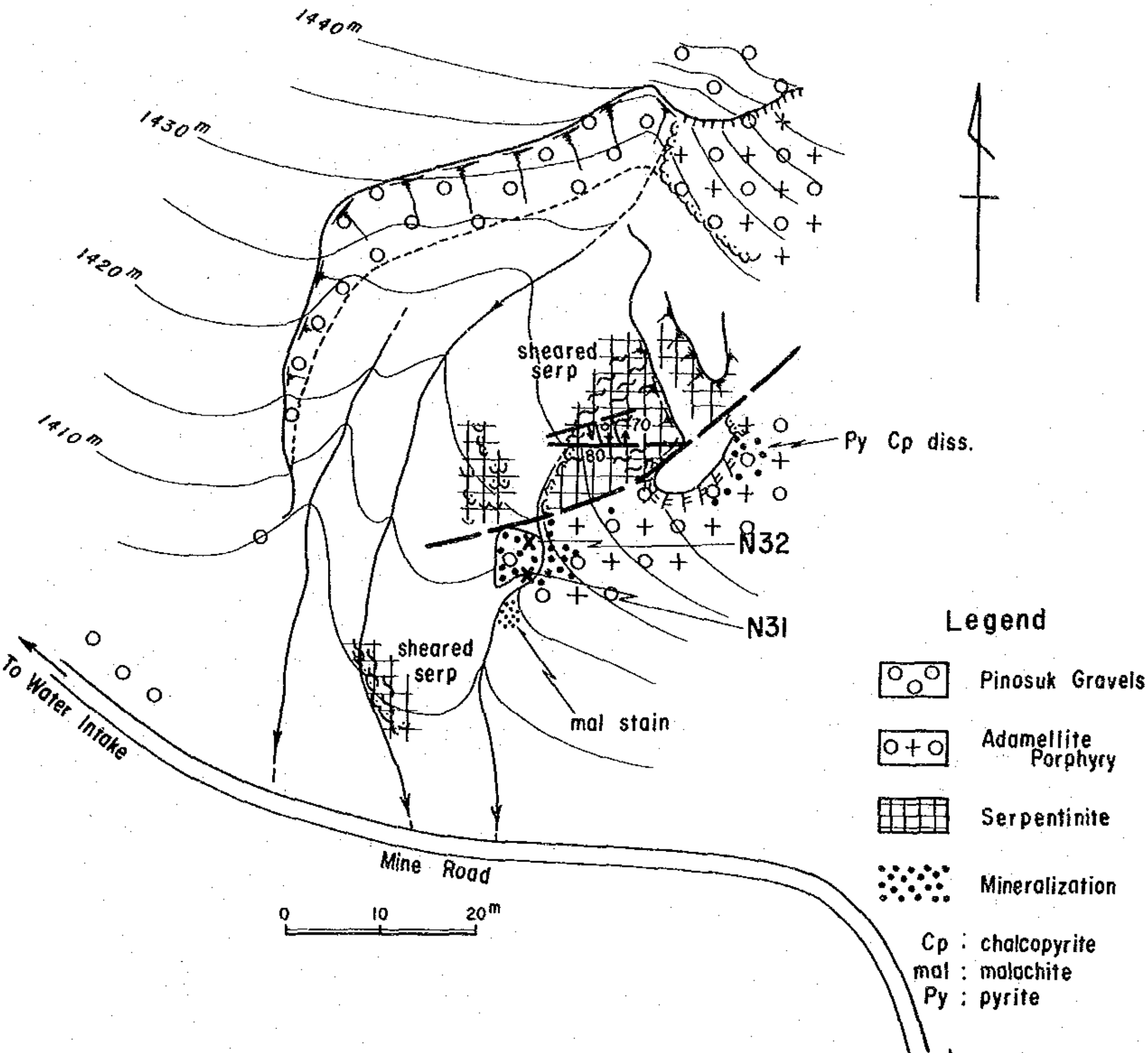
The fault trending east-northeasterly in the vicinity of the mine road is located on the northern side of the drill holes MJM-1 and MJM-3, having controlled the distribution of adamellite porphyry.

1–2 Mineralization

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

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

Although malachite stains are only observed along the cracks of adamellite porphyry in the latter Bambangan creek outcrop, the IP geophysical survey in Phase I detected an anomalous zone extending southward, and a mineralized zone about 180 m wide consisting of dissemination and network of chalcopyrite was confirmed by the drilling of MJM-8 which followed the IP survey.



Sample No.	Au g/t	Cu %	Pb %	Zn %	Mo %	Hg %
N31	0.27	1.80	0.01	0.01	0.023	0.001
N32	0.07	0.07	0.01	0.01	0.001	0.001

Fig. 8 Geological Sketch Showing Bambangan Outcrop

CHAPTER 2 Drilling

2–1 Process of Drilling and Equipments

2–1–1 Drilling Method

Regarding casing process, for the portion of overburden, firstly the hole was started to drill using HW casing pipe with diamond shoe. Secondly, inserting the NW casing pipe with diamond shoe, the work were continued by NQWL with diamond bit. In the same drilling process, after drilling by NQWL, the diameter of hole were extended using NW casing. When NW casing pipe can not be inserted, it was started to drill by NQWL.

If the hole encountered the fractured zone within the depth of BW casing pipe to be inserted and the fractured zone showing the low or high water pressure, the cementation method were taken measure to apply.

For the drilling, bentonite mud water method has been applied, more over mud water mixed with CMC mud oil and mud fluid ("Libonite") when the hole encountered the shear zone or the Pinosuk Gravels.

2–1–2 Drilling Machine and Consumed Materials

The drilling machines were a set of Tone Boring TGM-5 and a set of TGM-2 (both drilling capacities are 510 m in NQ size and 660 m in BQ size). For the pump and mixer, new engines as stand by were installed when a trouble of the worn out of the crank shaft has started.

The specifications of drilling machines and pumps, diamond bits and the details of consumed materials such as bentonite, light oil and mud materials, are shown in Tables 3, 4 and 5.

2–1–3 Form of Works

For the preparations of drilling site, removings and dismantlements of drilling machine, one shift working manner per day was applied, and the drilling work was done by two shifts of twelve hours each in a day. The number of personnel for drilling work per shift were five, consisting of one Japanese engineer, one counter part from the Geological Survey of Malaysia, Sabah and three local employees.

Results of the time table of drilling work are shown in Table 5, the summary record of drilling results is in Table 6, progress record of diamond drilling is in Fig. 10.

2–1–4 Transportation of Machines, Equipments and Materials

All items, which have been kept in the site of MJM-8 hole after Phase I work, were trans-

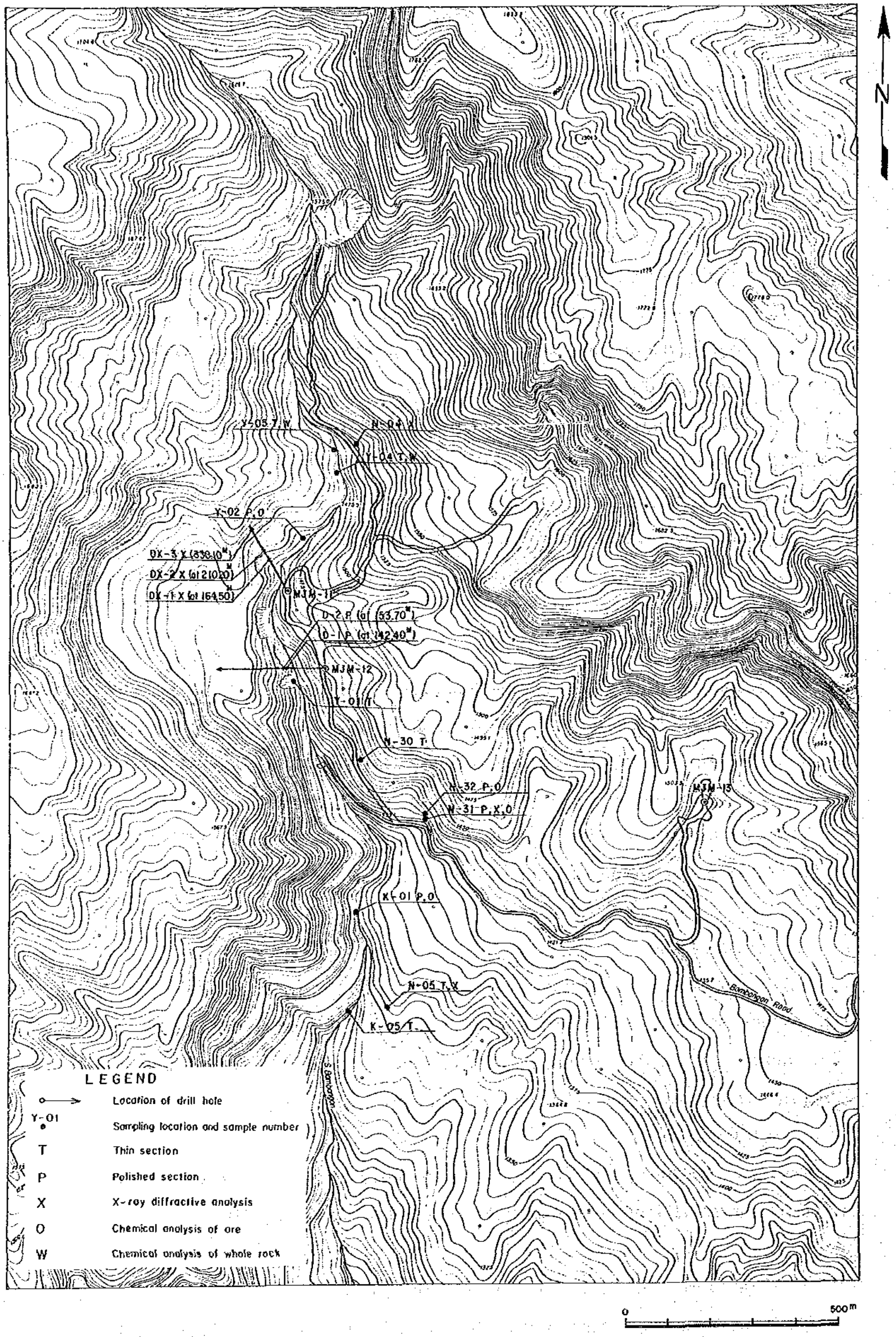


Fig. 9 Location Map of Drill Holes and tested Rock Samples

Table 3–1 Specification of Drilling Machines (MJM-11, -12)

(MJM-11, 12)

Drilling Machine TGM – 5	1 set		
Specifications:			
Capacity	660m (BQWL)		
Dimensions LxWxH(mm)	2,720x1, 130x1, 640		
Hoisting capacity	2,200Kg		
Spindle speed (r.p.m.)	Forward 170, 405, 630, 825		
Engine	"F3L – 912"		
Drilling pump "NAS – 3T4"	1 set		
Cylinder bore dia	75mm		
Capacity	22, 130ℓ/min		
Engine	"TS155C"		
Water supply pump "NES – 100"			
Capacity	100ℓ/min		
Engine	"NS – 65"		
Wire line hoist "WHS – 600"	1 set		
Rope capacity	600m		
Engine	Drilling machine's engine power take off		
Mud mixer "MLE – 100"	1 set		
Capacity	125ℓ		
Engine	YAMMAR "NSA40 – GK"		
Generator	YAMMAR Model "YDG – 2000E"		
Drilling tools			
Drilling rod	NQ-WL	3.0m	83 pcs
	BQ-WL	3.0m	117 pcs
Casing pipe	HW	1.0m	5 pcs
	NW	1.0m	28 pcs
	BW	3.0m	83 pcs
Derrike	Hand made on the spot (wooden)		

Table 3–2 Specification of Drilling Machines (MJM-13)

(MJM-13)

Drilling Machine TGM – 2G	1 set		
Specifications:			
Capacity	640m (BQWL)		
Dimensions LxWxH(mm)	2,430x990x1,520		
Hoisting capacity	2,200Kg		
Spindle speed (r.p.m)	Forward 80, 200, 300, 400		
Engine	"KE – 250"		
Drilling pump "NAS – 3C"	1 set		
Cylinder bore dia	75mm		
Capacity	22, 130 ℓ/min		
Engine	"NS – 130C"		
Water supply pump "NES – 100B"			
Capacity	100 ℓ/min		
Engine	"NS – 65"		
Wire line hoist "WHS – 600"	1 set		
Rope capacity	600m		
Engine	Drilling machine's engine take off		
Mud mixer "MLE – 100"	1 set		
Capacity	125 ℓ		
Engine	"NS – 65"		
Generator	YAMMAR Model "YSG – 2SN"		
Drilling tools			
Drilling rod	NQ-WL	3.0m	61 pcs
	BQ-WL	3.0m	117 pcs
Casing pipe	HW	1.0m	5 pcs
	NW	1.0m	19 pcs
	BW	3.0m	61 pcs
Derrike	Model "DRP-9-5"		

Table 4–1 Drilling Meterage by Diamond Bit

Item	Size of Bit	Type of Bit	Carats per Bit	Matrix	Stones per Carat	Water Way	Total bit Used
Diamond Bit							
	75.3mm	NQ-WL	30	E	25	4	13
	Total		390				13
	59.6mm	BQ-WL	20	E	25	4	11
	Total		220				11
Grand Total			*610				24

E : for ordinary rock

* : Total amount of Diamond Carat

Table 4–2 Drilling Meterage by Diamond Bit

Item	Size	Bit No.	Drilling Meterage by hole (m)				Total (m)
			MJM-11	MJM-12	MJM-13		
Dia-mond bit	NQ WL	T19218	13.80				13.80
		OANQ10-1	87.80				87.80
		1851765	43.60				43.60
		T19219	87.50				87.50
		T19221		14.60			14.60
		TYG00054		75.20			75.20
		TYG00053		35.10			35.10
		TYG00052		36.90			36.90
		TYG00055		77.00			77.00
		1851070			47.80		47.80
		OAN1-5			57.60		57.60
		OANQ13-1			52.00		52.00
		OAN2-2			10.60		10.60
	Total		232.70	238.80	168.00		639.50
Total			Drilled length/Bit (639.50/13)				49.19

Table 4–3 Drilling Meterage by Diamond Bit

Item	Size	Bit No.	Drilling Meterage by hole (m)				Total (m)
			MJM-11	MJM-12	MJM-13		
		OAB15-1	35.70				35.70
Dia-mond bit	BQ WL	OAB17-1	66.60				66.60
		175650		10.80			10.80
		OAB13-1		6.90			6.90
		OABQ6-1		44.90			44.90
		OAB14-1		50.60			50.60
		OAB15-1		10.10			10.10
		175369			29.80		29.80
		OAB17-1			46.50		46.50
		175650			91.20		91.20
		OB1-9		24.10			24.10
	Total		102.30	147.40	167.50		417.20
Total			Drilled length/Bit (417.20/11)				37.93

Table 5 Details of Consumed Materials in Drilling

Description	Specification	Unit	Quantity			Total
			MJM-11	MJM-12	MJM-13	
Light Oil		ℓ	1,480	2,470	1,910	5,860
Bentnite		kg	3,600	6,025	5,950	15,575
Libonite		kg	50	550	120	720
C.M.C.		kg	130	222	255	607
Cement		kg	400	280	400	1,080
Diamond Bit	NQWL	kg	4	5	4	13
do	BQWL	kg	2	6	3	11
do	NW	kg	1	1	1	3
do	HW	pc	1	1	1	3
Diamond Reamer	NQWL	pc	3	2	2	7
do	BQWL	pc	2	4	3	9
Core barrel Assy	NQWL	set	1	2	1	4
do	BQWL	set	1	1	1	3
Inner tube	NQWL	pc	2	2	2	6
Inner tube	BQWL	pc	2	3	2	7
Core lifter	NQWL	pc	3	5	4	12
Core lifter	BQWL	pc	2	3	2	7
Core lifter case	NQWL	pc	1	2	1	4
Core lifter case	BQWL	pc	2	3	2	7

Table 6 Timetable of Drilling Work (1)

Hole No.	Drilling			Shift		Working man		Working time						G. Total
	Bit size	Drilling	Core length	Drilling	Total	Engineer	Worker	Drilling	Other Working	Recovering	Total	Removing	Road constructing and others	
		m	m	shift	shift	man	man	h	h	h	h	h	h	h
MJM-11	HW	16.00	0	2	10	19	93	8°50′	10°20′	0°00′	19°10′	64°00′	56°00′	139°10′
	NQ	232.70	210.70	21	21	21	99	122°40′	129°40′	0°00′	252°20′			252°20′
	BQ	102.30	102.30	9	18	19	149	61°10′	87°20′	0°00′	148°30′	32°00′		180°30′
	Total	351.00	313.00	32	49	59	341	192°40′	227°20′	0°00′	420°00′	96°00′	56°00′	572°00′
MJM-12	NW	15.00	0	5	17	47	173	27°30′	21°40′	0°00′	49°10′	96°00′	136°00′	281°10′
	NQ	239.80	212.30	22	22	32	89	125°50′	136°00′	0°00′	261°50′			261°50′
	BQ	147.40	97.40	27	36	49	212	110°50′	285°20′	8°00	404°10′	64°00′		468°10′
	Total	402.20	309.70	54	75	128	474	264°10′	443°00′	8°00′	715°10′	160°00′	136°00′	1,011°10′
MJM-13	HW	5.00	0	1	5	5	44	5°10′	3°20′	0°00′	8°30′	39°00′	0°00′	47°30′
	NW	14.00	0	2	2	2	17	10°20′	8°10′	0°00′	18°30′			18°30′
	NQ	164.00	129.80	19	30	30	121	92°20′	83°10′	88°00′	263°30′			263°30′
	BQ	167.50	148.30	22	35	49	212	119°20′	168°40′	24°00′	312°00′	80°00′		392°00′
	Total	350.50	278.10	44	72	86	394	227°10′	263°20′	112°00′	602°30′	119°00′	0°00′	721°30′

Table 7−1 Summary Record of Drilling Work, MJM-11

Operation

	Survey Period: Period	days	work day (days)	off day (days)	total man day: Engineer (man)	total man day: worker (man)
Preparation	7. 11. 1986 ~ 14. 11. 1986	8	8	0	16	82
Drilling	15. 11. 1986 ~ 1. 12. 1986	17	drilling 17	0	34	151
			recovering 0	0	0	0
Removing	2. 12. 1986 ~ 10. 12. 1986	9	9	0	9	108
Total	7. 11. 1986 ~ 10. 12. 1986	34	34	0	59	341

Drilling length

Length planed	350.00 m	Surface soil Overburden Quaternary	16.00 m
Increase or Decrease in length	+1.00 m	Core length	313.00 m
Length drilled	351.00	Core recovery	93 %

Core recovery of 100m hole

Depth of hole (m)	core recovery (%)	core recovery cumulated (%)
0 ~ 100	87	
100 ~ 200	90	89
200 ~ 300	98	92
300 ~ 351.0	100	93

Working hours

	h	%	%
Drilling	192°40′	46	34
Other working	227°20′	54	39
Recovering			
Total	420°00′	100	73
Reassemblage	64°00′		11
Dismantlement	32°00′		6
Water transportation			
Road construction and others	56°00′		10
G. Total	572°00′		100

Efficiency of Drilling

Total m/work period(m/day)	351.00m/17 days (20.65 m/day)
Total m/total shift(m/shift)	351.00m/32 shift (10.97 m/shift)

Drilling length/bit(each sized bit)

Bit size	HW	NQ	BQ
Drilled length	16.00 m	232.70 m	102.30 m
Core length	0	210.70	102.30

Casing pipe inserted

Size	meterage (m)	meterage / drilling length x 100 (%)	Recovery (%)
HW	16.00	4.5	100
NW	28.00	8.0	100
BW	248.70	70.8	72.3

Table 7–2 Summary Record of Drilling Work, MJM-12

		Survey Period				total man day	
		Period	days	work day	off day	Engineer	worker
Operation	Preparation	19. 9. 1986 ~ 30. 9. 1986	12	12 days	0 days	36 man	145 man
	Drilling	1. 10. 1986 ~ 29. 10. 1986	29	drilling 28	0	75	230
				recovering 1	0	1	7
	Removing	30. 10. 1986 ~ 6. 11. 1986	8	8	0	16	92
	Total	19. 9. 1986 ~ 6. 11. 1986	49	49	0	128	474

Drilling length				
Drilling length	Length planed	400.00 m	Surface soil Overburden Quaternary	16.00 m
	Increase or Decrease in length	+2.20 m	Core length	309.70 m
	Length drilled	402.20	Core recovery	80 %

Core recovery of 100m hole

Depth of hole (m)	core recovery (%)	core recovery cumulated (%)
0 ~ 100	85	
100 ~ 200	89	88
200 ~ 300	89	88
300 ~ 402.20	61	80

working hours		h	%	%
	Drilling	264°10′	37	26
	Other working	443°00′	62	44
	Recovering	8°00′	1	1
	Total	715°10′	100	71
	Reassemblage	96°00′		9
	Dismantlement	64°00′		6
	Water transportation			
	Road construction and others	136°00′		14
	G. Total	1,011°10′		100

Efficiency of Drilling

Total m/work period(m/day)	402.20 m/29 days (13.87 m/day)
Total m/total shift(m/shift)	402.20 m/54 shift (7.45 m/shift)

Drilling length/bit(each sized bit)

Bit size	HW	NQ	BQ
Drilled length	15.00 m	239.80 m	147.40 m
Core length	0	212.30	97.40

Casing pipe inserted	Size	meterage (m)	meterage / drilling length x 100 (%)	Recovery (%)
	HW	15.00	3.7	100
	NW	60.00	14.9	33.3
	BW	254.80	63.4	70.6

Table 7–3 Summary Record of Drilling Work, MJM-13

		Survey Period				total man day	
		Period	days	work day	off day	Engineer	worker
Operation	Preparation	19. 10. 1986 ~ 22. 10. 1986	4	4 days	0 days	4 man	35 man
	Drilling	23. 10. 1986 ~ 10. 12. 1986	49	drilling 35	0	44	191
				recovering 14	0	14	60
	Removing	11. 12. 1986 ~ 20. 12. 1986	10	10	0	24	108
	Total	19. 10. 1986 ~ 20. 12. 1986	63	63	0	86	394

Drilling length				
Length planed	350.00 m	Surface soil Overburden Quaternary	15.00 m
Increase or Decrease in length	+0.50 m	Core length	278.10 m
Length drilled	350.50	Core recovery	83 %

Core recovery of 100m hole

Depth of hole (m)	core recovery (%)	core recovery cumulated (%)
0 ~ 100	66	
100 ~ 200	84	76
200 ~ 300	94	82
300 ~ 350.50	85	83

working hours	h	%	%
Drilling	227°10′	38	32
Other working	263°20′	44	36
Recovering	112°00′	18	16
Total	602°30′	100	84
Reassemblage	39°00′		5
Dismantlement	80°00′		11
Water transportation			
Road construction and others			
G. Total	721°30′		100

Efficiency of Drilling

Total m/work period(m/day)	350.50 m/49 days (7.15 m/day)
Total m/total shift(m/shift)	350.50 m/44 shift (7.97 m/shift)

Drilling length/bit(each sized bit)

Bit size	HW	NW	NQ	BQ
Drilled length	5.00 m	10.00 m	168.00 m	167.50 m
Core length	0	0	129.80	148.30

Casing pipe inserted

Size	meterage (m)	meterage / drilling length x 100 (%)	Recovery (%)
HW	5.00	1.4	100
NW	19.00	5.4	100
BW	183.00	52.2	100

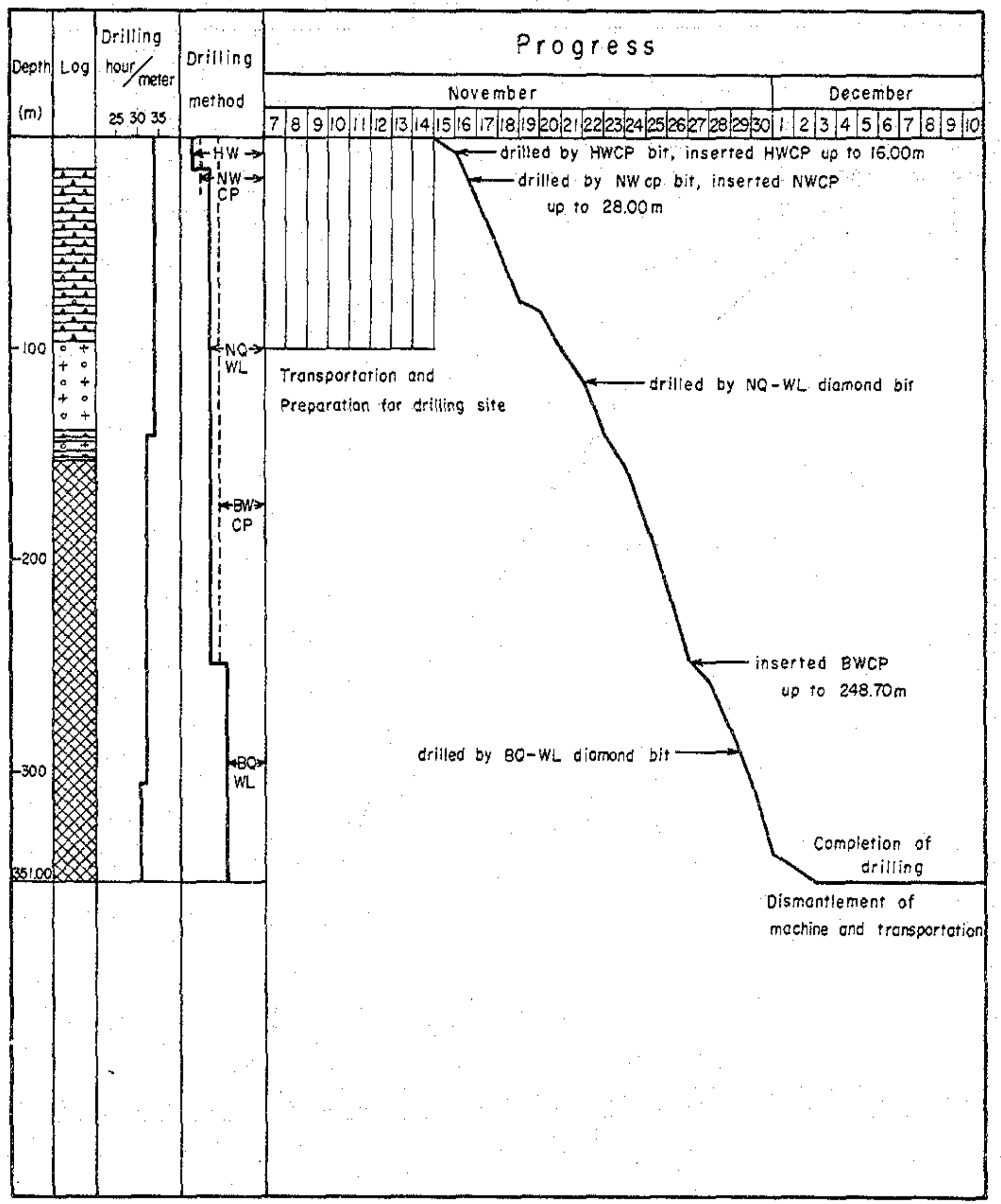


Fig. 10–1 Progress Record of Drilling MJM-11

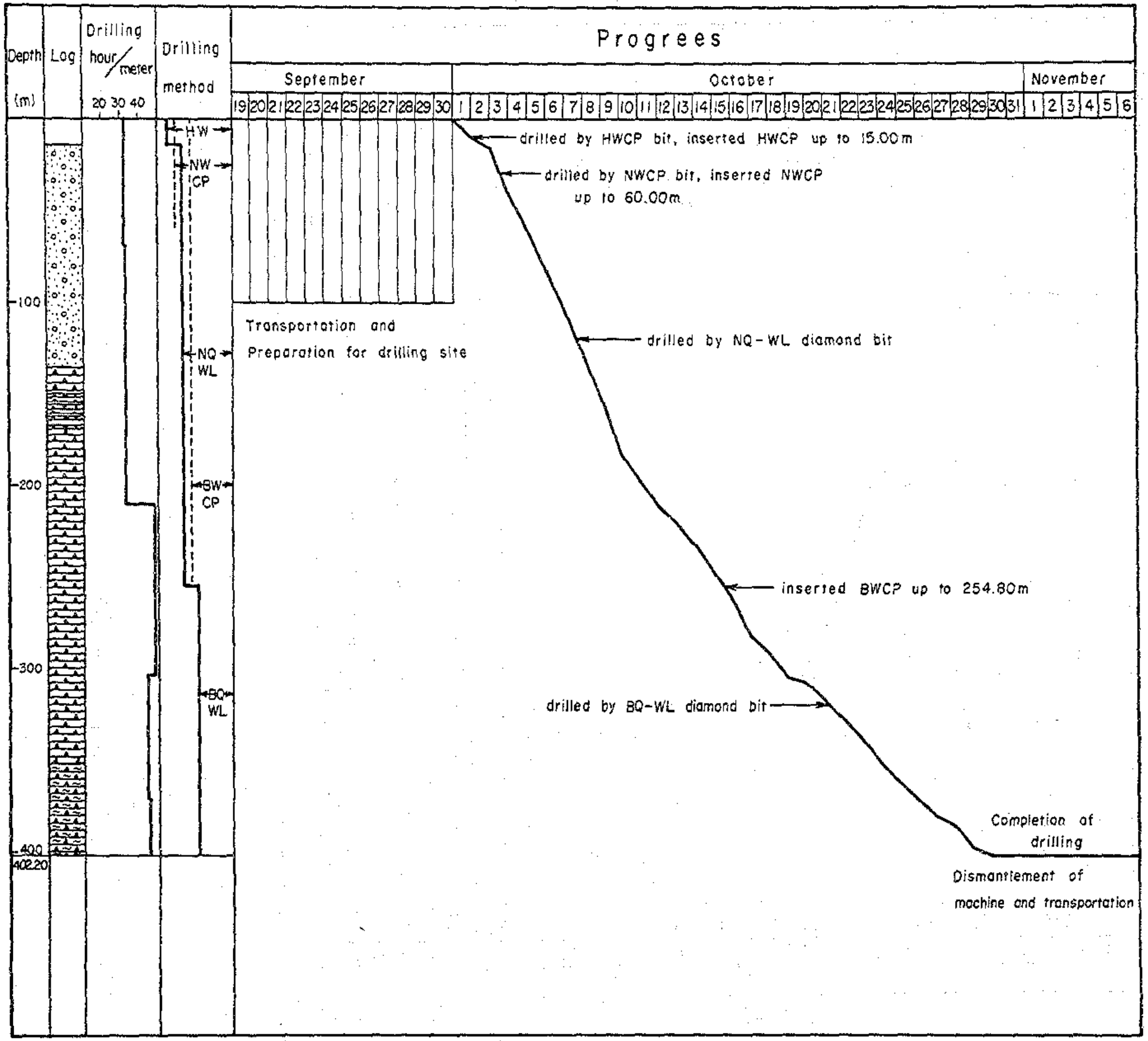


Fig. 10–2 Progress Record of Drilling MJM-12

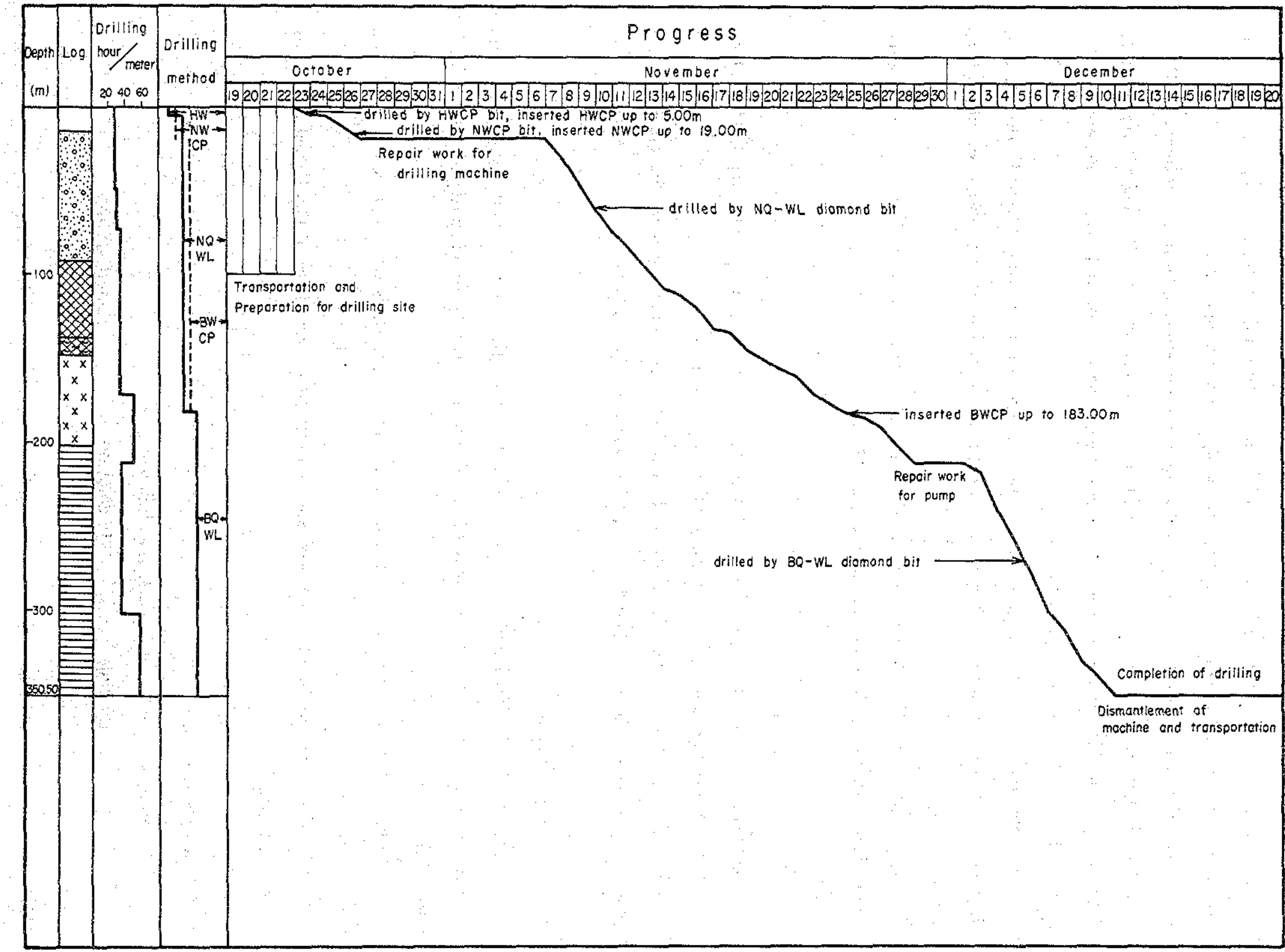


Fig. 10–3 Progress Record of Drilling MJM-13

ferred to the proposed drill site of MJM-12 using buldozer. Simultaneously with the drilling work of MJM-12 hole, the new road to the proposed site of drill hole of MJM-11 and MJM-13 were constructed for the transportation of machine, equipments and materials.

After the completion of the road construction, the preparation work for drilling of MJM-13 hole has started. The drilling machine of TGM-2C, which has been used for MJM-8 drilling work then installed in the same site when the phase I work was completed, were transferred to the proposed site of MJM-13 hole using buldozer.

Drilling rods and mud materials were shipped from Japan and transported to the site near MJM-5 hole via Mamut mine by heavy tracks, then transferred to the proposed site of MJM-13 using buldozer.

After the completion of drilling work of MJM-12, all items were transferred to the proposed site of MJM-11 hole by the same method as MJM-13.

2–1–5 Water Supply

The water for drilling work of MJM-11 hole was collected from the upper reach of Bambangan creek, having a distance of 300 m, using a line of plastic pipe.

For the other holes, the water was obtained from the upper reach of the creek nearby. The distances were 250 m for MJM-12 hole and 200 m for MJM-13 hole.

2–1–6 Dismantlement

After the drilling work, all items were collected, then the machines and equipments were storaged in the advanced camp ground of the Geological Survey of Malaysia in Ranau (near Batu-2, the Mamut mine).

The generators, engines for pump, engines for mixer and tools were installed in the rental house in Ranau.

All cores were put in the core box, and transferred to the office of Geological Survey of Malaysia, Sabah.

2–2 Result of Survey

The drilling conducted in Phase II is as follows:

	Bearing	Inclination	Length of hole
MJM-11	N30°W	–60°	351.00 m
MJM-12	N90°W	–50°	402.20 m
MJM-13	–	–90°	350.50 m

LEGEND

PG Pinosuk Gravels (loose)	Md Microdiorite
PG Pinosuk Gravels (compact)	Ap (Ad) Adamellite porphyry (Adamellite)
Td Turbidite	Pt Peridotite
Ss Sandstone	arg argillized
St Siltstone	bre (frag) brecciated (fragmented)
Mt (Sh) Mudstone (Shale)	shr sheared
Hf Hornfels	silic silicified
Sp Spilite	

Abbreviations

bi ; biotite	pyr ; pyrrhotite	gr ; grained
cal ; calcite	arg ; argillized	grvl ; gravel
chlo ; chlorite	bg ; bearing	imp ; impregnation
cly ; clay	blchd ; bleached	lns ; lens
gt ; garnet	bld ; boulder	netwk ; network
qz ; quartz	bre ; brecciated	oxd ; oxidized
srp ; serpentine	cls ; clastic	strg ; stringer
tlc ; talc	diss ; dissemination	vlt ; veinlet
cp ; chalcopyrite	fin ; fine	wthd ; weathered
limo ; limonite	flt ; fault	xeno ; xenolith
moly ; molybdenite	fract ; fractured	(vp) ; (very poor) (p) ; (poor)
py ; pyrite	frag ; fragmented	(m) ; (moderate) (a) ; (abundant)
mag ; magnetite	cup ; cuprite	epi ; epidote
mar ; marcasite	pyrophy ; pyrophyrite	gt ; garnet
bo ; bornite	kaol ; kaolinite	ank ; ankerite
mal ; malachite		

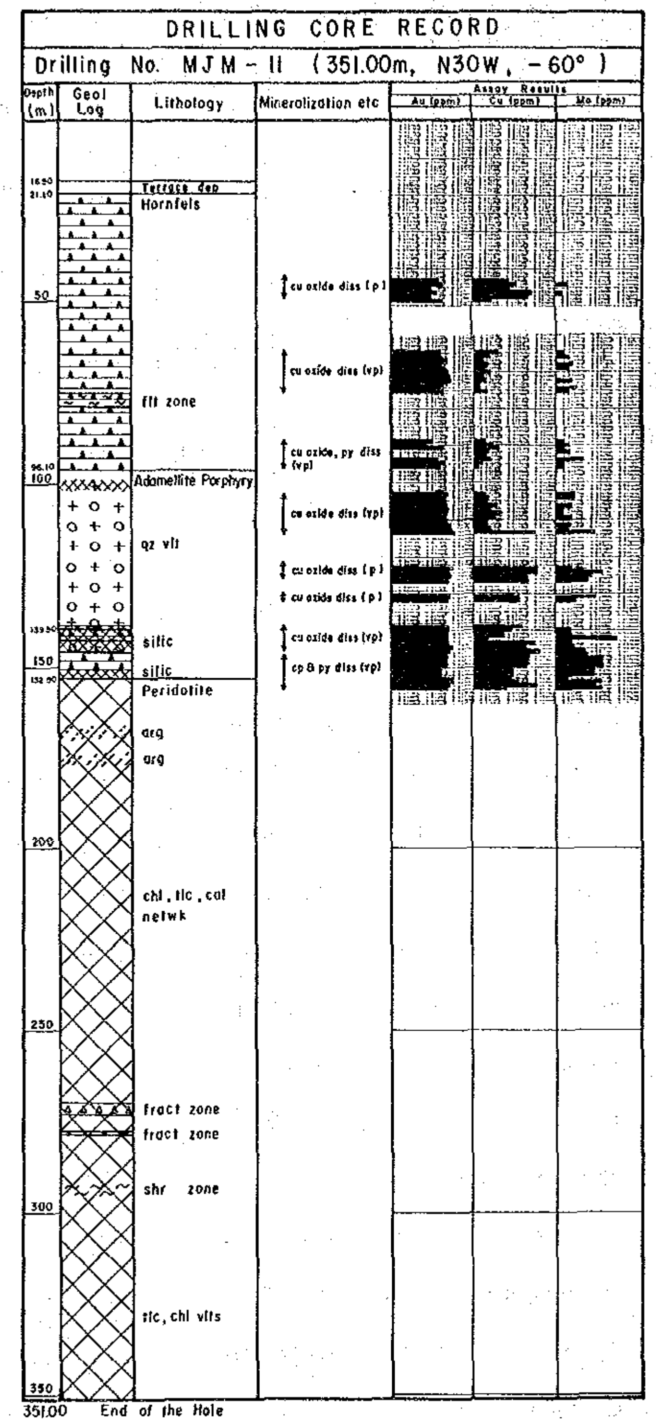


Fig. 11–1 Columnar Section of Drill Hole (MJM-11)

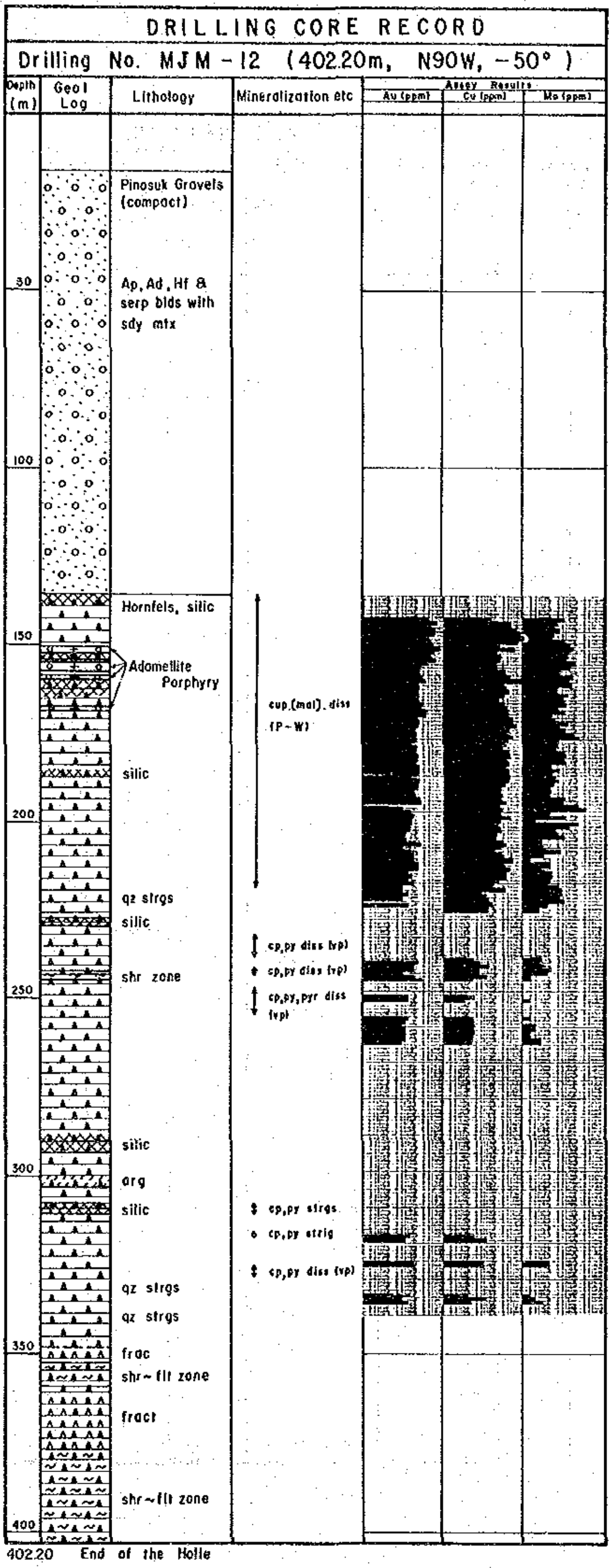


Fig. 11-2 Columnar Section of Drill Hole (MJM-12)

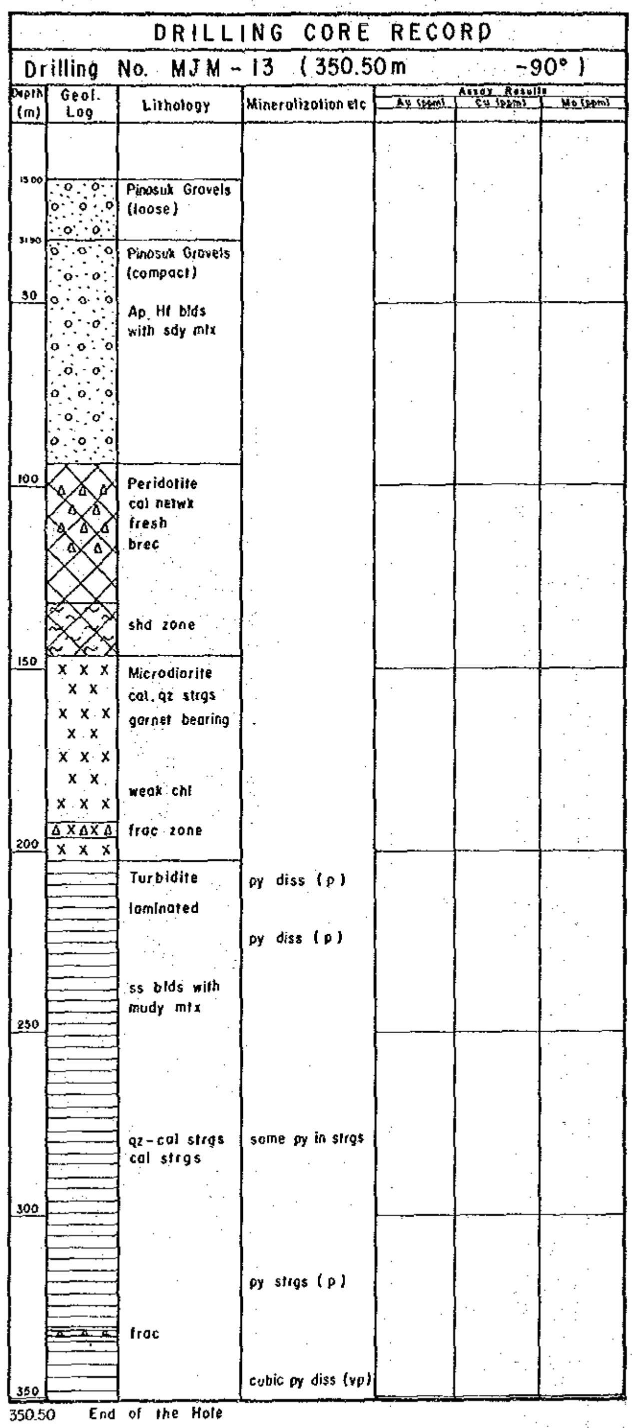


Fig. 11-3 Columnar Section of Drill Hole (MJM-13)

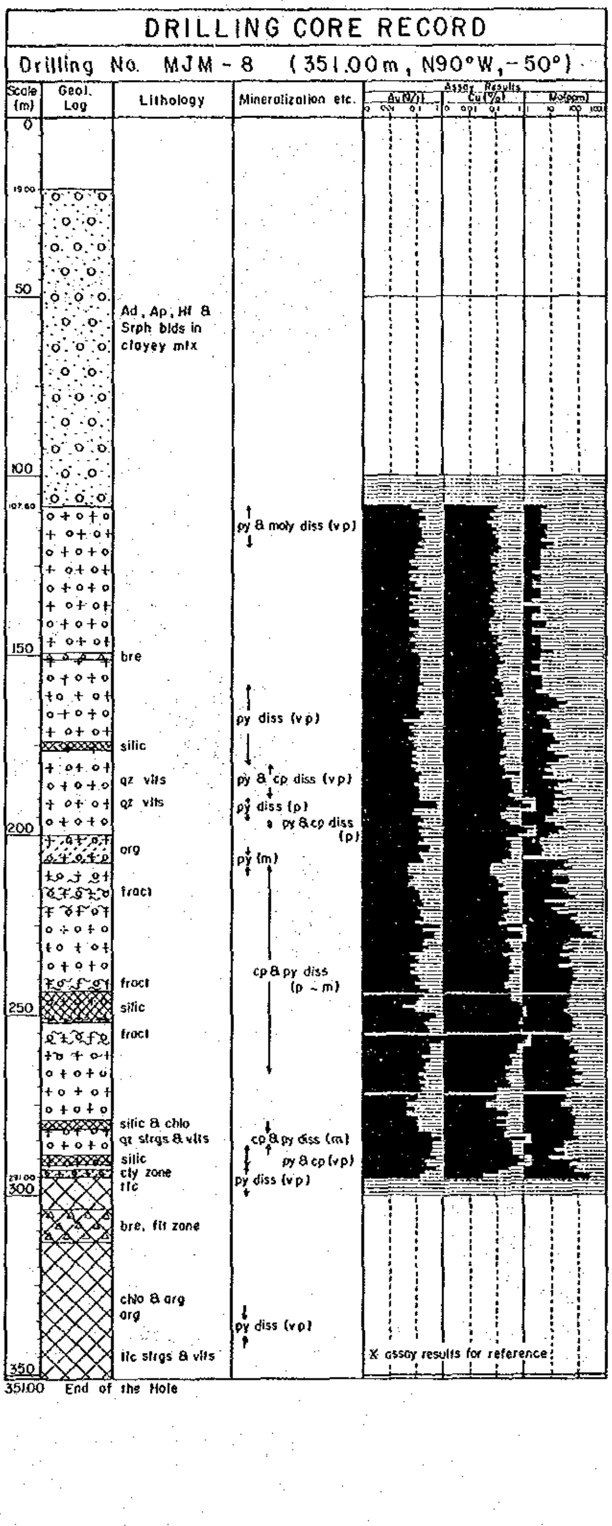


Fig. 11-4 Columnar Section of Drill Hole (MJM-8)

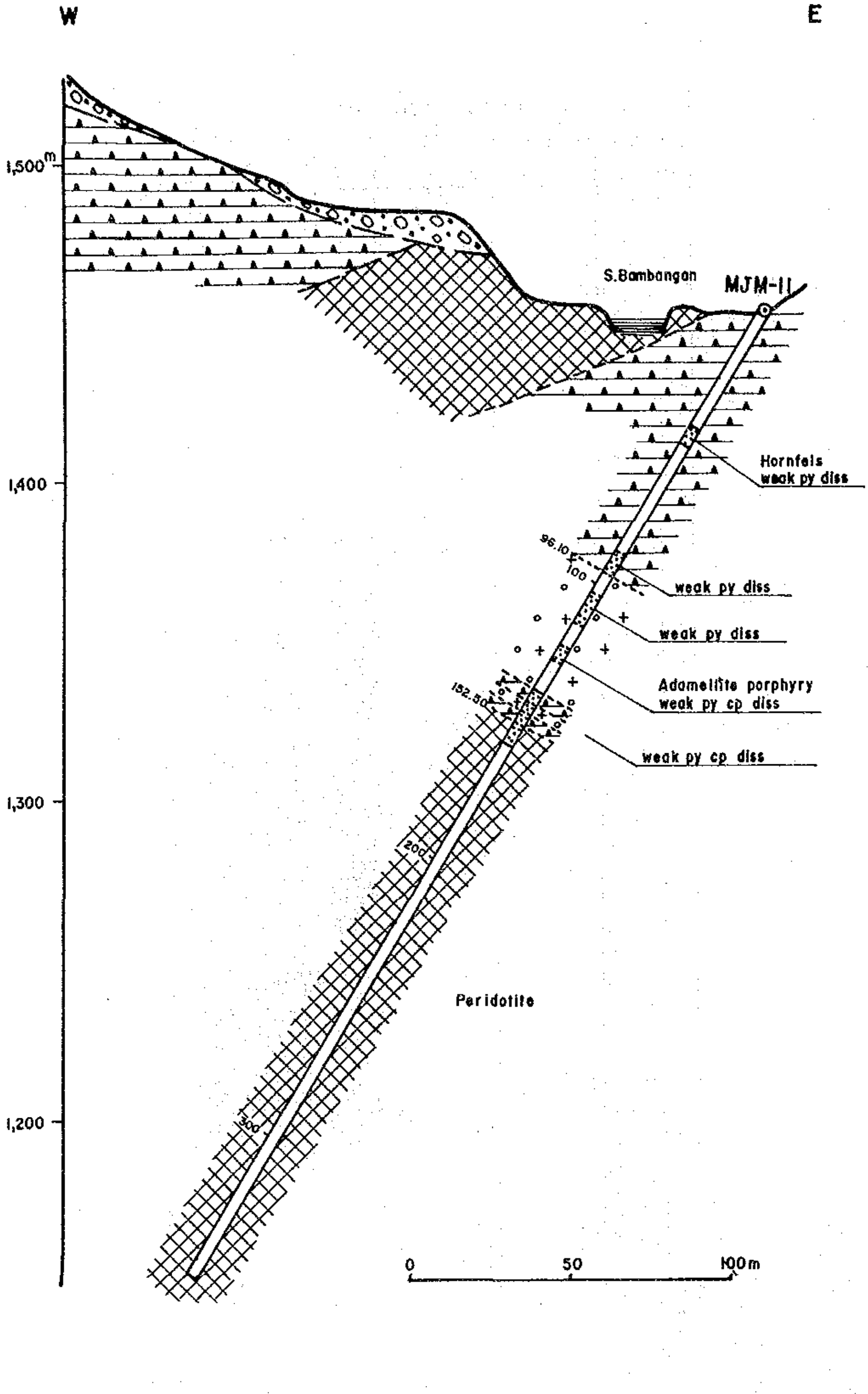


Fig. 12–1 Geological Section of Drill Hole (MJM-11)

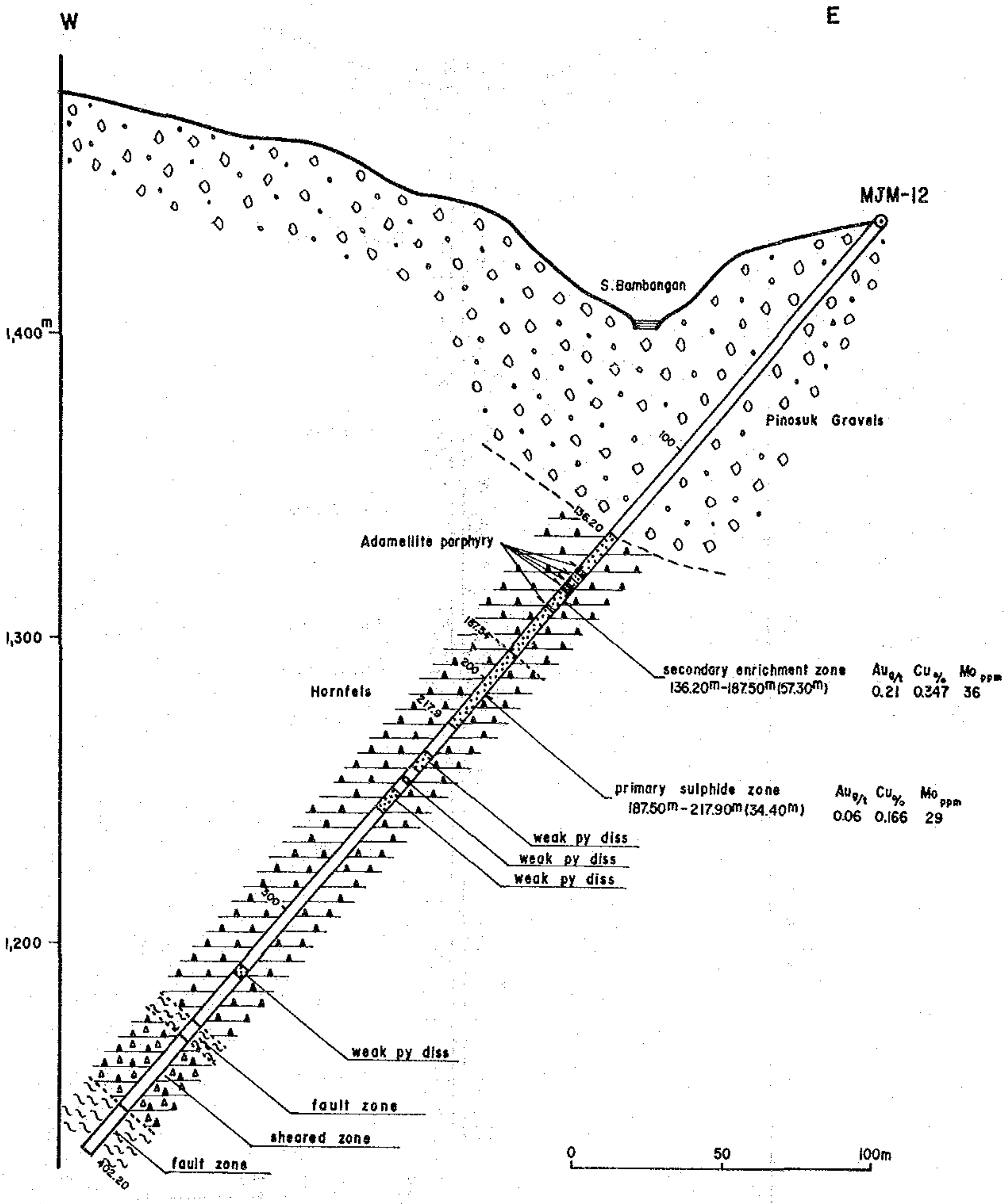


Fig. 12–2 Geological Section of Drill Hole (MJM-12)

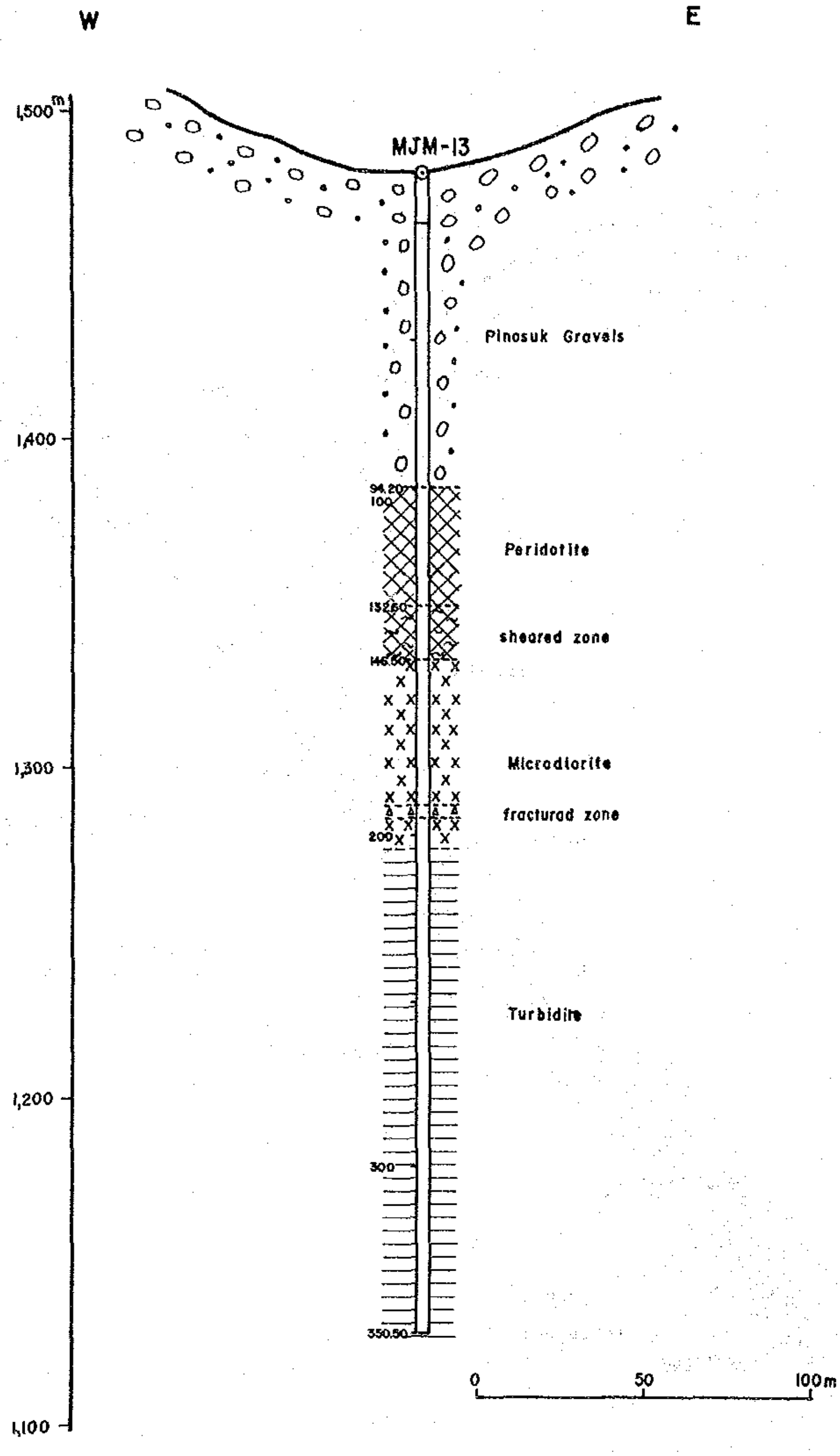
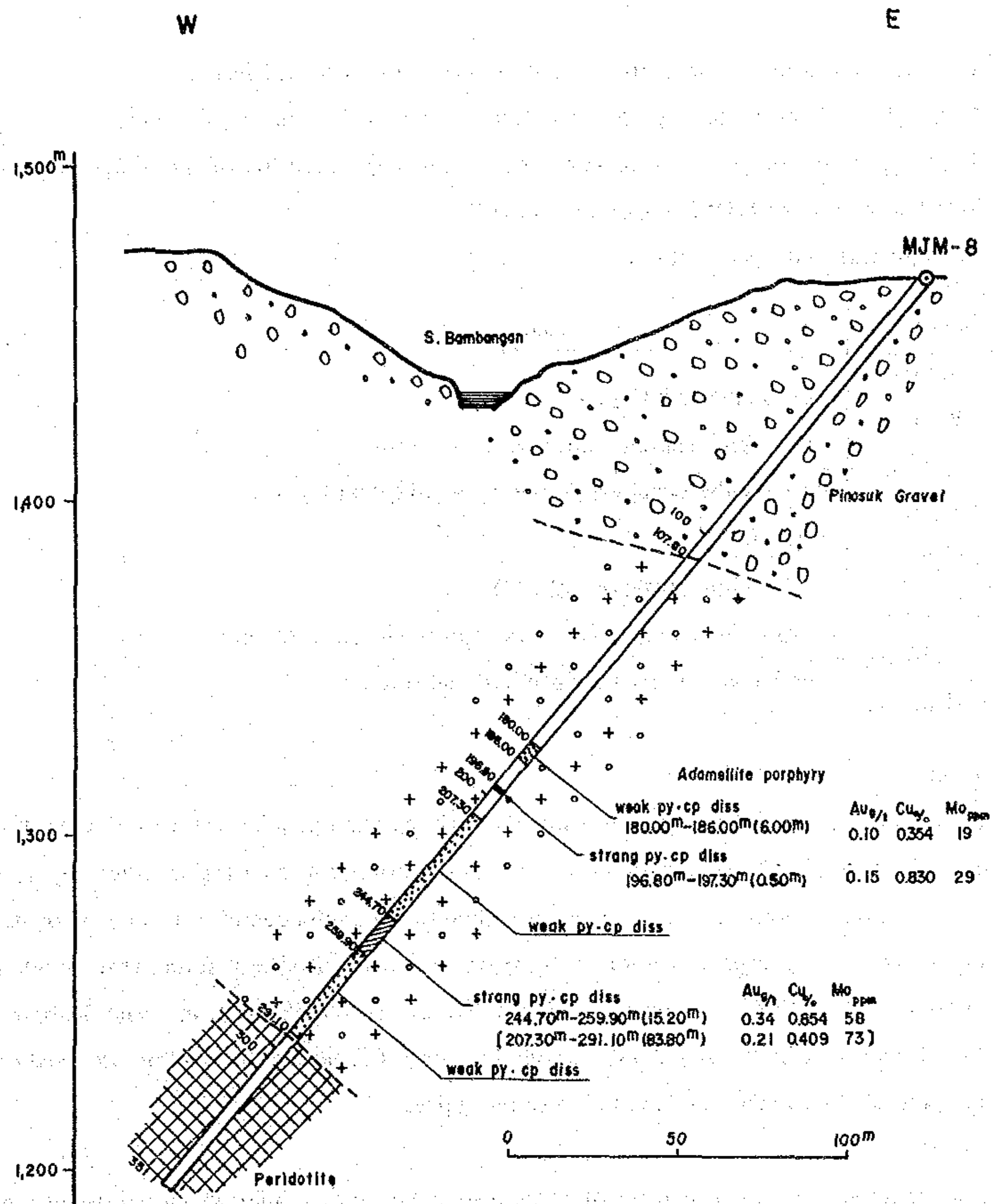


Fig. 12–3 Geological Section of Drill Hole (MJM-13)



	Au g/t	Cu %	Mo ppm
180.00m-186.00m(6.00m)	0.10	0.354	19
196.80m-197.30m(0.50m)	0.15	0.830	29
244.70m-259.90m(15.20m)	0.34	0.854	58
(207.30m-291.10m(83.80m)	0.21	0.409	73)

Fig. 12–4 Geological Section of Drill Hole (MJM-8)

The total length of the three holes was 1,103.70 m. Fig. 9 shows the location of the holes, Fig. 11, the columnar sections, and Fig. 12 and Fig. 13, the geological cross sections.

The geology and the mineralization in each hole are discribed as follows.

(1) Drilling hole MJM-11 (Bearing : N30°W, inclination : –60°, depth : 351.00 m)

The purpose of the hole was to confirm the northern extension of the mineralized zone intersected in the hole of MJM-8 excuted in Phase I.

Geology in the hole is as follows:

Depth	Geology
0.00 m	
	Loose Pinosuk Gravels
20.10 m	
	Hornfels, generally oxidized with gossan.
96.10 m	
	Adamellite porphyry, generally oxidized with gossan.
139.50 m	
	Hornfels
143.00 m	
	Adamellite porphyry dike (?)
146.00 m	
	Hornfels accompanied by weak to moderate oxidation.
152.50 m	
	Peridotite, partly serpentinized and fractured.
351.00 m	

Alteration:

In the hornfels, kaolinization, chloritization, carbonatization, silicification and weak pyritization are observed. In the adamellite-porphyry, kaolinization, carbonatization, silicification and weak pyritization are observed and weak dissemination of molybdenite is locally recognized.

In the peridotite, serpentinization is common, but it is not always found throughout the rock. Besides, talcosation, kaolinization, chloritization, carbonatization, and silicification are popular. Magnetite is disseminated throughout the rock. Pyrrhotite and epidote are partly observed, and weak dissemination of pyrite is also recognized.

Mineralization:

Copper mineralization in a form of weak dissemination or veinlet which is intermittently observed in the oxidized zone with very small quantities of the primary zone starts to occur in the rocks such as hornfels at 42.90 m in depth, adamellite porphyry (seems to be dike) at 96.10 m in depth, through xenolith of hornfels in adamellite porphyry at 140 m to the periphery of peridotite at 156.20 m.

As shown in the assay result, all components shows low grade. It is thought that this intersection represents the peripheral part of mineralization.

The assay result of the weakly mineralized zone is as follows:

Section		(Length)	Au (g/t)	Cu (%)	Mo (ppm)
42.60m	– 49.00m	(6.40m)	0.13	0.053	1.5
64.30	– 75.70	(11.40)	0.09	0.034	2.6
88.20	– 96.10	(7.90)	0.06	0.039	3.1
102.50	– 113.90	(11.40)	0.13	0.063	5.2
122.50	– 127.00	(4.50)	0.15	0.170	21.8
130.50	– 132.00	(1.50)	0.15	0.052	18.0
138.50	– 156.20	(17.70)	0.14	0.089	32.2

(2) Drilling hole MJM-12 (Bearing: N90°W, inclination: –50°, depth: 402.20 m)

The hole was drilled at the location of 150 m to the south of the hole of MJM-8 (on the IP survey line G) drilled in Phase I.

The purpose of this hole was to confirm the southern extension of the porphyry copper-type mineralized zone intersected by the hole of MJM-8 in Phase I. The IP anomalous zone extends in the N-S direction as shown by the result of geophysical survey in Phase I.

Geology in the Hole is as follows;

Depth	Geology
0.00 m – 136.20 m	Pinosuk Gravels, highly oxidized.
136.20 m – 348.30 m	Hornfels, intruded by five dikes of adamallite porphyry, 0.15 m to 2.10 m wide.
348.30 m – 402.20 m	Fault fracture zone.

The fracture zone encountered at the bottom is considered to extend further below, possibly to more than 60 m wide.

Alteration:

Alteration in hornfels consists of silicification, chloritization, argillization and pyritization throughout the rock. Magnetite is rarely scattered.

Mineralization:

In hornfels 136.20 m below the surface immediately after the Pinosuk Gravels, there is an oxidized copper mineralized zone with gossan, where abundant fine crystals of native copper are scattered in the cracks, and streaks or veinlets, and other copper oxide minerals (mainly cuprite accompanied by tenorite and a small quantity of malachite) and secondary sulfide copper ores (mainly bornite accompanied with small quantities of chalcocite and covellite) are observed, with rarely recognizable fine grained chalcopyrite. These oxidized copper mineralized zone continues to the depth of 187.50 m, and after this point changes to the primary mineralized zone mainly consisting of chalcopyrite and pyrite, which becomes poor and disappears below 217.90 m.

The scale and average grade of the mineralized zone are as follows.

Zone	Section (Length)	Au (g/t)	Cu (%)	Mo (ppm)
Oxidazed zone	136.20 m – 187.50 m (51.30 m)	0.21	0.347	36
Primary zone	187.50 m – 217.90 m (30.40 m)	0.06	0.166	29

(3) Drilling hole MJM-13 (Bearing: – , inclination: 90°, depth: 350.50 m)

In the hole of MJM-5 drilled in Phase I, turbidite in the Trusmadi Formation occurred from the surface to the bottom, where a prominent dissemination of pyrite was observed below 335.80 m close to the bottom.

The purpose of the hole of MJM-13 was to confirm the occurrence of the pyrite dissemination on the northern side of the hole of MJM-5 and the possibility of concentration of the copper dissemination, because a copper anomalous zone was detected by the geochemical survey for soil by OMRD in the vicinity of the drill site.

Geology in the hole is as follows;

Depth	Geology
0 m – 94.20 m	Pinosuk Gravels
94.20 m – 146.50 m	Peridotite, serpentinized
146.50 m – 202.75 m	Garnet bearing microdiorite
202.75 m – bottom	Turbidite

A fault zone with 9.20 m width is found at the bottom of peridotite, and a fracture zone is also recognized in microdiorite at the depth of 188 m to 197 m (9 m in width).

Alteration:

In the serpentinized peridotite, talcosation, carbonatization, silicification and chloritization are commonly found throughout the hole, and scattered by magnetite in palces. Some parts display pale reddish color by the occurrence of hematite.

In the microdiorite, carbonatization is predominant, and silicification is partly recognized, with a very small quantity of pyrrhotite dissemination.

In the turbidite, carbonation, silicification and argillation are observed, accompanying with a weak pyritization.

Mineralization is hardly found in the hole.

The chemical analysis of the core from the hole of MJM-8 (bearing: N90°W, inclination −50° 351.00 m), which intersected the mineralized zone, was carried out in this Phase.

The result is as follows:

Section	(Length)	Au (g/t)	Cu (%)	Mo (ppm)
107.80 m – 180.00 m	(72.20 m)	0.1	0.12	7.34
180.00 m – 291.10 m	(111.10 m)	0.2	0.44	59.3
291.10 m – 294.30 m	(3.20 m)	0.3	0.13	133.0

CHAPTER 3 Overall Discussion

Since a porphyry copper-type mineralized zone associated with the intrusion of adamellite porphyry was intersected on the western side of the Bambangan creek as a result of the drilling (Hole MJM-8) conducted in Phase I, the drilling of two holes (MJM-11 and MJM-12) was carried out in this Phase to confirm the extension of the above mentioned mineralized zone. As a result, both holes intersected the copper mineralized zone as aforementioned.

Fig. 13 shows the E-W sections passing through the drill holes intersected the mineralized zone.

As was clarified in the cross section B-B', the hole of MJM-8 directly shifted into the mineralized adamellite porphyry zone at the depth of 107.80 m after passing through the Pinosuk Gravels, and it continued to the depth of 291.00 m.

Although the dip of this adamellite porphyry has not been clarified, the width will be about 120 m if it dips vertically, and it is likely to be about 150 m when the eroded out part, due to the Pinosuk Gravels, is taken into account.

The cross section C-C' includes the profile of the hole of MJM-12. The hole passed through the Pinosuk Gravels at the depth of 136.20 m, and hornfels continued to the bottom of the hole (402.20 m). Five adamellite porphyry dikes with 0.15 to 2.40 m width have intruded for a section from 150.60 m to 159.70 m in depth. Since the rock facies is same as those in the hole of MJM-8, it is thought that the width of the adamellite porphyry has thinned from the hole of MJM-8 toward the hole of MJM-12. However, since the mineralization can be observed in the hornfels up to the depth of 330 m after adamellite porphyry, it is presumed that the adamellite porphyry has intruded up to the horizon close to the drill hole.

According to the report of Kosaka and Wakita (1975), in the Mamut deposit, the ore zone is a widely spread at the place where the adamellite porphyry diverged into many brances like as fins of fish in the rock intruded, it is suggested that the portion which accompanied "fins" plays particularly an important role for the occurrence of the mineralization. A frequent appearance of the small dikes of the adamellite porphyry seems to suggest a mineralization toward the depth.

Fig. 13 shows the outline shape of adamellite porphyry in the vicinity of the Bambangan creek at the level of about 1,300 m, which suggests the possibility that the adamellite porphyry gently subsides toward south.

The pyritized zone in the turbidite intersected in the drill holes of MJM-5 and MJM-13 in the east area is considered to be of the different type of alteration from the porphyry copper-type because of the absence of chalcopyrite and molybdenite.

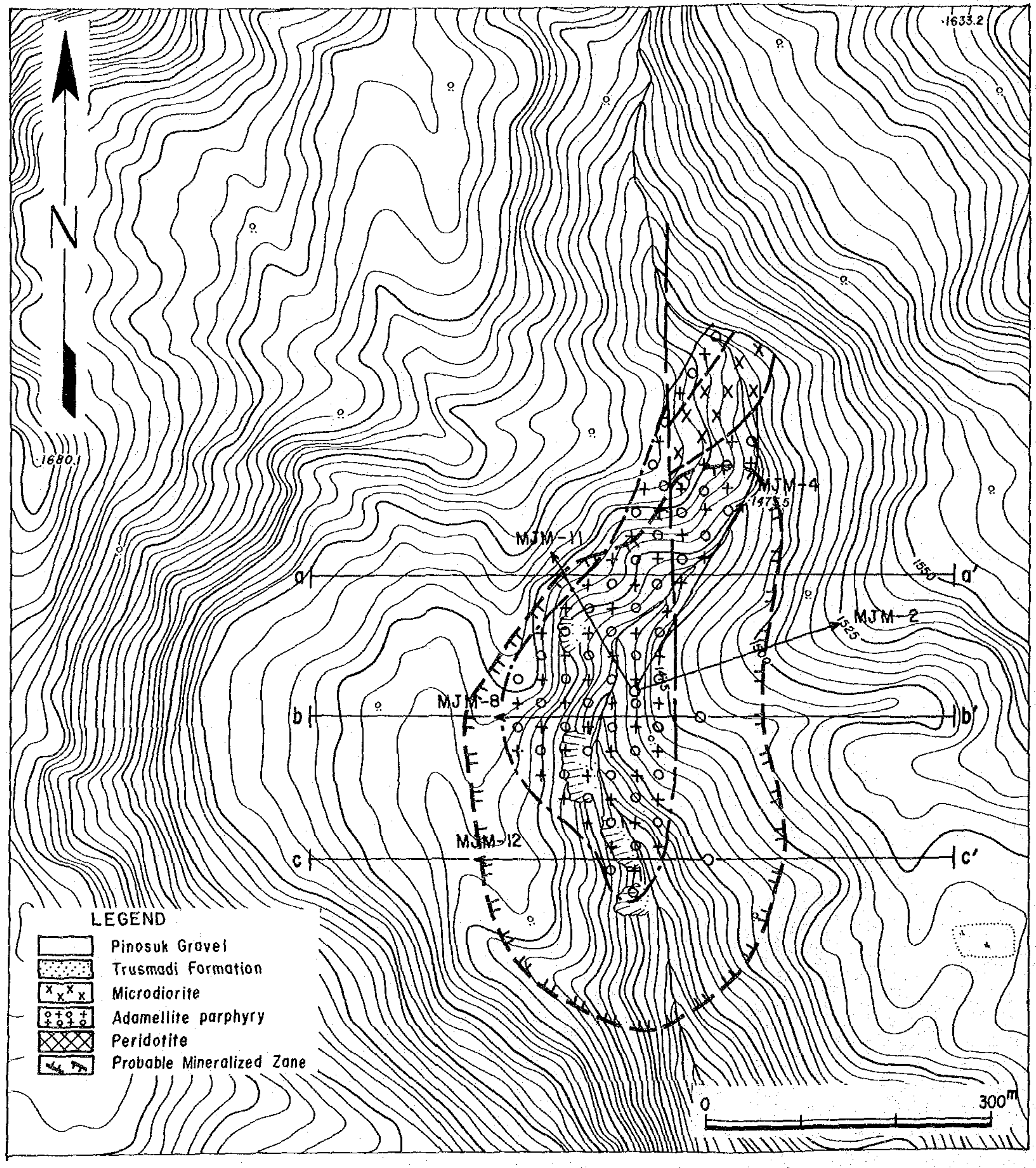


Fig. 13 Map Showing a Mineralized Zone to be expected