REPUBLIC OF THE PHILIPPINES

REPORT ON GEOLOGICAL SURVEY OF NORTHWESTERN LUZON

PHASE Ⅲ

NOVEMBER 1981

METAL MINING AGENCY OF JAPAN

JAPAN INTERNATIONAL COOPERATION AGENCY

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PREFACE

The Government of Japan, in response to the request of the Government of the Republic of the Philippines, decided to conduct collaborative mineral exploration in Northwestern Luzon area of the Philippines and entrusted its execution to Japan International Cooperation Agency (JICA) and Metal Mining Agency of Japan (MMAJ).

Between 5 November, 1980 and 31 March, 1981, Metal Mining Agency of Japan dispatched a survey team headed by Mr. Hirofumi Taniguchi to conduct the Phase III of the project.

The survey had been accomplished under close cooperation with the Government of the Republic of the Philippines and its various authorities.

This report is a compilation of the survey of the phase III, and after complection of the project, the consolidated report will be submitted to the Government of the Republic of the Philippines.

We wish to express our appreciation to all of the organizations and members who bore the responsiblity for the Project, the Government of the Republic of the Philippines, Bureau of Mines and Geo-Sciences (BMG), and other authorities and the Embassy of Japan in the Philppines.

September 1981

Keisuke Arita
President
Japan International Cooperation Agency

Masayuki Nishiie
President
Metal Mining Agency of Japan

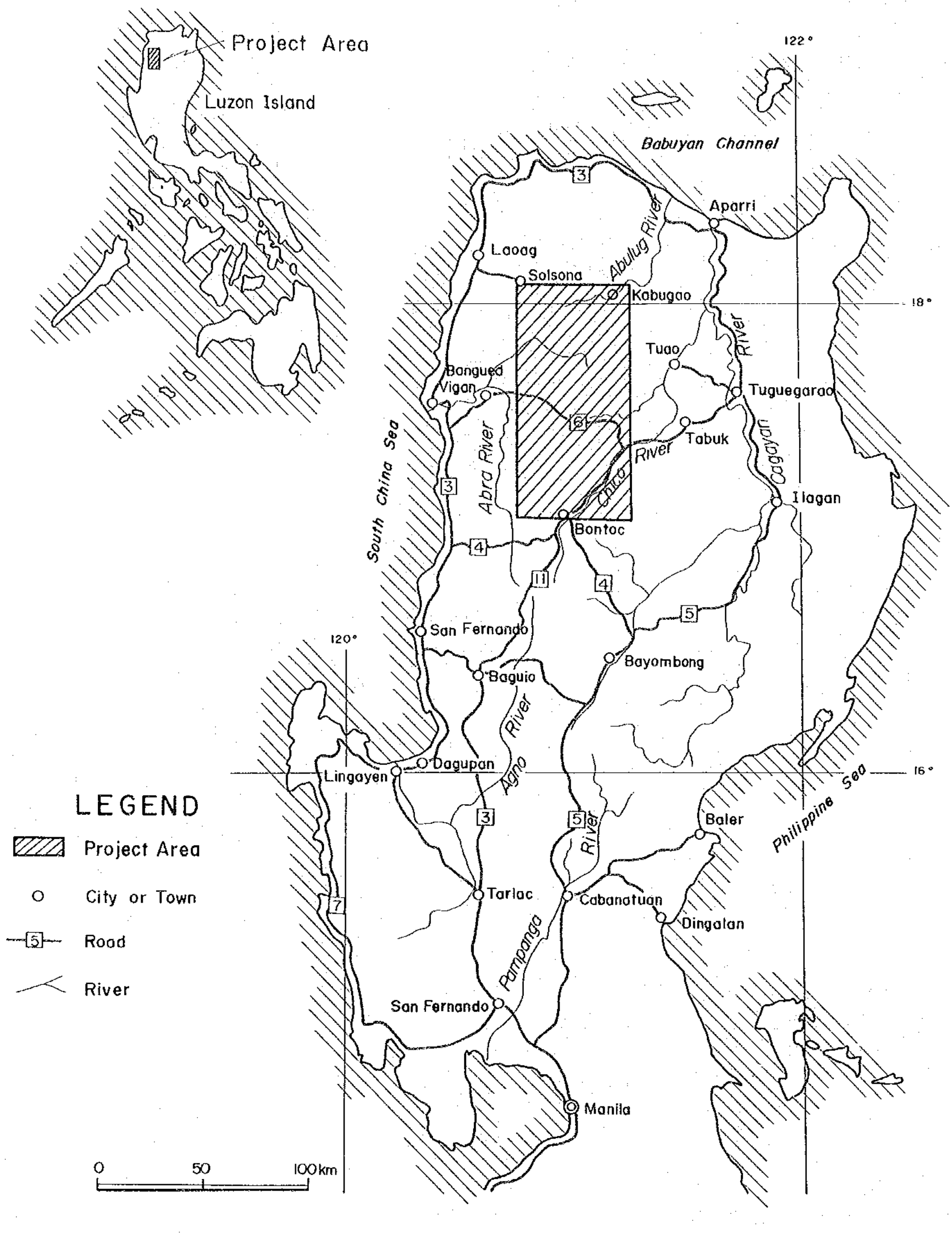

Fig. 1 Location Map of Project Area

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ABSTRACT

The Phase III survey of the Northwestern Luzon Project, Philippines, was carried out in two areas: the Manikbel area, which was selected as the highest potential area for ore deposits, and the Layacan area which was required detailed survey because of its high potential of ore deposits. The survey was conducted with the purpose of making a comprehensive evaluation of the ore deposit by making more clear its field of emplacement, scale, grades, and character of ore deposit and also to establish a basic policies for future exploration and development.

In order to attain these purposes, geological, geochemical and geophysical surveys and drilling exploration were adopted in the Manikbel area, and geological and geochemical surveys in the Layacan area.

As the result of the geological survey, it was made clear that the mineralized zones of dissemination or network of pyrite with secondary copper minerals were formed as crusty shape in the outermost zone of quartz diorite extending 1.5 Km E-W and 1.1 Km N-S. In the Layacan area, numerous clay veins containing pyrite were distributed in quartz diorite and intrudes rocks of its surrounding area, some parts of the veins contain copper sulfides.

As the result of the geochemical soil survey, high copper anomalous zones to be consistent with the distribution of ore deposits in the two above-mentioned areas especially, in the Manikbel area, a high anomalous zone of more than 800 ppm Cu was obtained which also coincides along the distribution of the mineralized outcrops.

It was reconfirmed from the results that the geochemical soil survey is quite effective on the definition of the area of distribution of ore deposit associated with copper minerals and in the estimation of intensity of mineralization.

Geophysical survey was carried out by IP and complex resistivity methods to confirm the lateral and vertical extent of ore deposits found in the Manikbel area delineated earlier by the geological survey. Result of the IP method show anomalies of more than 5% of FE detected in three places, and two of which are on both the eastern and western sides of the distribution or area of ore deposits and the geochemical anomalous zone. The area of distribution of ore deposits as well as the geochemical anomalous zone formed a low FE anomalous zones of less than 5% FE. This may be caused by the ore mineral at the outcrop consists mainly of non-sulfide minerals and that the vertical extent of ore deposit is not

great because of the crust-shape of the deposits. Therefore, in this survey, complex resistivity method was applied on highly anomalous zones detected by IP method to determine the minerals with sulfide concentrations that caused the high IP anomalies. Although the expected results will not be satisfactory for minerals of poor amount of chalcopyrite, it is expected that a good result would be obtained in ore deposits rich in chalcopyrite.

Three holes were drilled with a total length of 932.20 m to confirm the vertical extent of the ore deposit and to know the actual setting of the IP anomalous zone. From the results of the drilling exploration it was clarified that the ore deposit was a zone of pyrite dissemination associated with a small amount of chalcopyrite dipping more steeply than originally assumed from the southern margin of the distribution area of mineralized outcrop. It was also confirmed that the IP anomaly was caused by a networked zone of film- or hair-shaped veinlets of pyrite.

A comprehensive evaluation of the results of the survey hitherto conducted revealed that although these are possibilities for the further exploration in the Manikbel area, future development is not favorable at this stage judging from the shape and the grade of ore deposit, thus, it was necessary in the Layacan area to confirm the lateral and vertical extension of ore deposits and variation of its grade.

GENERAL INFORMATION

1. INTRODUCTION

1–1 Development of Affairs and Purpose of Survey

The survey of this phase was carried out in Northwestern Luzon, Philippines. The detailed geological, geochemical and geophysical surveys were started in the Manikbel area on November 1980 with the program of conducting the survey in three areas such as: Manikbel (15 km^2), Malibcong (10 km^2) and Lacub (5 km^2) which contain the mineralized zones. These three areas were selected as the most promising areas for ore deposits based on the result of the first and the second phases surveys. The survey of two areas such as Malibcong and Lacub became impossible because peace and order situation took a sharp turn for the worse when the field survey of the Manikbel area had been almost completed. As a result of reviewing the survey program, it was concluded that the detailed survey of the area containing the Layacan mineralized zone was to be carried out instead of the two areas.

For these reasons, the detailed geological and geochemical surveys as well as geophysical prospecting were carried out in the Manikbel area, and the detailed surveys of geology and geochemistry in Layacan area in this phase.

It was the purpose of the survey of this year to elucidate the field of ore emplacement and to evaluate comprehensively the ore deposits by determination of the scale, grade and characters of the ore deposits distributed in the Manikbel and Layacan areas, and also to establish a guide for exploration and development in the future.

1–2 Details of Survey Operation

In order to attain the purposes mentioned above, it had been scheduled in the original plan, to carry out surveys in three areas such as Manikbel, Malibcong and Lacub which had been delineated at the end of the second phase in the following ways:

1) Manikbel Area : Detailed geological and geochemical soil surveys, geophysical prospecting (IP and Complex Resistivity Methods) and drilling exploration (two holes, 600 m in total).

2) Malibcong Area : Detailed geological and geochemical soil surveys and electrical prospecting by IP method.

3) Lacub Area : Detailed surveys of geology and geochemistry.

However, as the result of suspension of the surveys in the Malibcong and Lacub areas, and along with the decision to carry out the detailed survey of geology and geochemistry (soil) in the Layacan area instead, the program was changed to conduct drilling for three holes with total length of 900 m in the Manikbel area.

The main objectives of the detailed geological survey in Phase III were the detailed observation of mineralized outcrops as well as the grasp of the relation of their continuation to clarify the distribution feature of the intrusive rocks considered to be related to ore formation and to elucidate the kind and distribution of alteration minerals by mapping the routes in 1:5,000 scale by simplified surveying. The result of the survey was compiled to the maps in scales of 1:10,000 and 1:5,000 showing the geology and ore mineralization (surrounding areas of the main mineralized zones).

In the detailed geochemical survey, soil samples were taken with sampling density of 60 samples/km^2 along the route of geological survey in the Manikbel area since the detailed geochemical soil survey had been carried out during the second phase, and with sampling density of 32 samples/km^2 in the Layacan area because no detailed geochemical soil survey had been carried out in this area. As a result, 191 samples were taken in Manikbel area and all samples were analyzed in Manila for copper, to select the drilling site. In Layacan area, 320 samples were taken, which were analyzed in Japan for copper.

The geophysical prospecting consisting of IP and Complex Resistivity (CR) methods was carried out to delineate the extension of the mineralized zone at depth.

IP survey was planned for total length of 26.5 km with line spacing of 250 m and electrods interval of 100 m , while CR method was carried out using the three survey lines of IP with lengths of 1.6 km each totaling 4.8 km. The result of IP survey was briefly analyzed in the field and used as an important basis for selection of the drilling site.

Drilling exploration with a total length of 932.20 m was carried out in the Manikbel to determine the IP anomalous zone extending to depth. Table 1 shows the outline of the field survey conducted in Phase III.

Table 1 Outline of Field Survey in Phase III

	Name of Survey Area	Survey Period	Area	Amount of Survey Work	Number of Geochemical Sample
Preparatory Survey		Nov. 5 ~ Nov. 19, 1980			
Geological and Geochemical Detailed Survey				Length of Survey Route	
	Manikbel	Nov. 20 ~ Dec. 30, 1980	15 Km^2	110.2 Km	Soil 191 pcs.
	Layacan	Feb. 5 ~ Mar. 20, 1981	10 Km^2	162.8 Km	Soil 320 pcs.
Geophysical Survey				Length of Measured Line	
IP Method	Manikbel	Nov. 20 ~ Dec. 30, 1980		26.5 Km	
CR Method	Manikbel	Jan. 3 ~ Feb. 7, 1981		4.8 Km	
Drilling Exploration	Manikbel	Jan. 6 ~ Mar. 31, 1981		RPJ-1 310.00 m RPJ-2 310.90 m RPJ-3 311.30 m Total 932.20 m	

A brief compilation and interpretation on the results of the field observation, chemical analysis of the geochemical samples were carried out in conjunction with the progress of the fieldworks at base camp. After completing the fieldwork, all survey results were comprehensively compiled and discussed in Manila both by the Japanese and Philippine members. Detailed analytical works and final discussions on the survey results were undertaken in Japan by the Japanese members and two Philippine counterparts.

In gratitude, authors wish to express heartfelt thanks to the Government of the Republic of the Philippines and other authorities concerned for their kind cooperation and support to the Japanese survey team.

Likewise, the authors are indebted to Dr. Toshinori Matsukuma and Dr. Sakuro Honda of Akita University who provided instructive comments on ore minerals and alteration minerals, respectively. Their kind advice and suggestions are gratefully acknowledged.

1–3 Outline of Survey Area

The location of the Manikbel and Layacan areas, the objective areas of this phase survey, is shown in Fig. 2.

The Manikbel area, an area of 15 sq. km, is situated in the upper stream of the Manikbel River and occupies the northern part of the Bucloc area, Abra Province, which was the detailed survey area in the second phase. The area is in a mountainous region with varying altitudes of 400 to 900 m above sea level, especially the northern part of this area shows a steep and rugged topography.

Access to the area is as follows: a road leads from Bangued to Barrio Sallapadan, about seven kilometers west of the survey area. It takes about two hours drive by jeep. From there to Barrio Ud-Udiao, there is no road but only mountain trail is available. It takes about an hour by foot. Because of such poor access of the area, the heavy machines for drilling were transported by helicopter.

The Layacan area has an area of 10 sq. km and situated on the provincial boundary between Mountain and Ilocos Sur provinces in the southwestern end of the project area. The area also presents a steep topography, 450 to 1,000 m in altitude, in which most tributaries of the Layacan River form a number of steep cliffs.

Four-wheel drive vehicle can be used for about 30 km from Bontoc, the capital town of Mountain Province, to Barrio Categan which is west of Besao. From Categan to the survey area, it takes more than three hours by foot along a mountain trail.

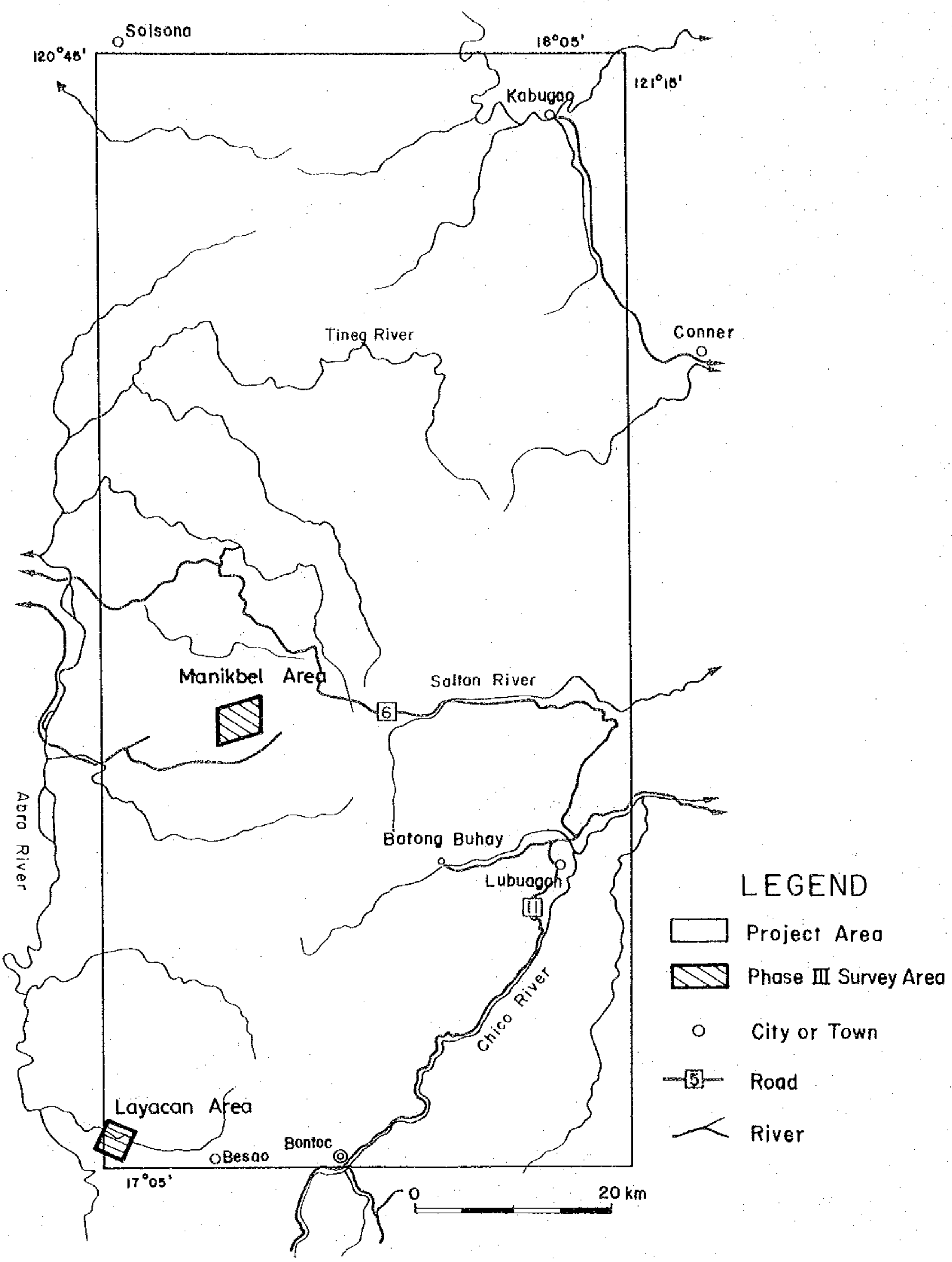

Fig. 2 Location Map of Survey Area in Phase III

All weather paved National Road, Route 3 and 6 run from Manila to Bangued (409 km), and Route 11 connects Baguio City and Bontoc with partly paved road (396 km from Manila).

1–4 List of Members

The list of members engaged in the consultation and fieldworks for the Phase III survey are as follows:

1) Consultation

Japanese Team

Kenji SAWADA	Metal Mining Agency of Japan	(MMAJ)
Hirofumi TANIGUCHI	do	

Philippine Team

Oscar A. CRISPIN	Bureau of Mines and Geo-Sciences	(BMG)
Leonardo R. ANTONIO	do	

2) Field Survey

Japanese Team

Hirofumi TANIGUCHI	(Leader)	MMAJ
Ikuhiro HAYASHI	(Geological and Geochemical Survey)	do
Atsushi TAKEYAMA	(do)	do
Katsumi HAYASHI	(do)	do
Susumu SASAKI	(Geophysical Survey)	do
Katsumi YOKOKAWA	(do)	do
Toshiaki FUJIMOTO	(do)	do
Tomio TANAKA	(do)	do
Akira KODAMA	(do)	do
Akio KATO	(Drilling Exploration)	do
Toshio HATAKEYAMA	(do)	do
Hatsuo KUMANO	(do)	do

Philippine Team

Leonardo R. ANTONIO	(Leader)	BMG
Donno G. CUSTODIO	(Geological and Geochemical Survey)	do
Renne B. DELOS SANTOS	(do)	do
Jessie S. MIGUEL	(do)	do
Orland M. PINEDA	(Geophysical Survey)	do

Elias C. NACALIO	(Geophysical Survey)	do
Cesar L. LUCERO	(Drilling Exploration)	do
Dionesio M. ALERIA	(do)	do

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2. GENERAL DISCUSSION

2–1 Geological Setting of Survey Area

From the two target areas of the Phase III survey, the Manikbel area was selected to have higher potential area for emplacement of ore deposit based on result of the Phase II survey, while the Layacan area was ranked fourth among the promising areas, both of which showed a characteristic geological environment.

The project area occupies the axial zone of the Cordillera Central uplift zone, as mentioned in the reports of Phase I and II, and it is an area characterized by large scale vigorous activities of plutonic and hypabyssal rocks of Late Oligocene to Miocene time intruded into the Paleogene to Miocene formations trending N-S.

Since the plutonic rocks exhibit a gently inclined boundary with the intruded rocks, forming a large mass, it is considered to form a batholith.

However, the distribution of plutonic rocks show a very irregular form and various shapes from one place to another though these might be the effect of the land shape in some part.

The batholith of quartz diorite-granodiorite extending 40 km with a maximum width of 16 km from the southwestern end of the project area north-northeastward to the center part of the area, abruptly changes the apparent form of distribution in the surrounding area of the Manikbel River as the boundary, diverges into several masses with smaller areas of exposure swinging the trend to a N-S direction. Further on the north, the plutonic rocks are not exposed in the central part of the uplift zone being distributed only in the eastern and western wings. These plutonic rocks are of different chemical compositions.

The Manikbel area is situated at the northern end of the large batholithic mass which abruptly changes its form of distribution. In this part, the boundary between quartz diorite and various intruded rocks takes a irregular and complicated form having been intruded by numerous small scale stocks and dykes of quartz diorite porphyry.

Mineralization is hardly observed in the batholithic mass while the mineralization is concentrated in its peripheral zone showing irregular boundary and also in the intruded rocks in the surrounding area. Thus, it can be said that the Manikbel area has a very characteristic environment from a regional geology standpoint.

On the other hand, the Layacan area is situated at the southern end of the batholithic mass mentioned above. It has been assumed that the rock is seated in a relatively shallow depth evident from the shape of the rock body on the north. Small stocks of quartz diorite porphyry are distributed in the area, and most of the main mineralized zones are found within or in the surroundings of these stocks.

From these facts, it is considered that Layacan area is structurally under the same environment as the Manikbel area although the lithology and age of the intruded rocks are different.

2–2 Mutual Relation among Geological Structure, Igneous Activity and Mineralization

Although the two areas including Manikbel and Layacan in which the surveys of Phase III were carried out are different in the distributed formations and mode of exposure of plutonic rocks. Both of which are dominated by two systems of structure, NNE-SSW to N-S and WNW-ESE to NW-SE, the latter being almost perpendicular to the former.

The structures of intrusive rocks and geology of the Manikbel area is shown in PL. I–1–1 by batholithic quartz diorite intruded in NNE-SSW direction, granodiorite stocks intruded in the peripheral part of the batholithic mass, a number of dykes of quartz diorite porphyry and dacite in the direction of NW-SW ∿ WNW-ESE, perpendicular to the direction of intrusion of the above rocks, and faults showing NW-SE and NNW-SSE directions. These structural elements are fundamentally controlled by the NNE-SSW and WNW-ESE system of structures.

On the other hand, plutonic rocks are not exposed in the Layacan area, in which, as shown in PL. I–2–1, the main structural elements are the stocks of quartz diorite porphyry intruded in the direction of WNW-ESE to NW-SE, dacite dykes and other rocks and the faults of NNE-SSW system.

As shown in PL. I–1–4 and PL. I–2–4 mineralized zone of pyrite dissemination associated with small amount of chalcopyrite and chalcopyrite-pyrite-quartz veins predominate in the Manikbel area, and chlorite-calcite-quartz vein containing pyrite as the main ore mineral in the Layacan area. The dissemination type is concentrated in quartz diorite near the contact with andesite lava in the Layacan area, and in addition, in the surrounding of granodiorite penetrating the quartz diorite. The vein type mineralization in the former is found in both quartz diorite and andesite, though scant in number. The veins are mainly developed within quartz diorite stock and in its surrounding area.

From these facts, it can be said that the mineralization in the Manikbel area is closely related to granodiorite stock and in the Layacan to quartz diorite porphyry stock.

The consideration on mutual relation between the geological structure, igneous activities, and mineralizations in the area leads to the following process of development of geological structure and igneous activity.

(1) Quartz diorite-granodiorite were intruded in the form of batholith under the structural control of the N-S and NNE-SSW systems, and with the intrusion, the structures parallel and perpendicular to the batholithic mass were formed.

(2) Among these structures, granodiorite was intruded along the NNE-SSW system which is parallel to the rock as post-igneous activity. At the same time, the structure of WNW-ESE system perpnedicular to the above was magnified and expanded by the intrusion.

(3) Along the WNW-ESE system structure, later stage dykes of quartz diorite porphyry-dacite were intruded in the Manikbel area, and stock-shaped quartz diorite porphyry was intruded in the Layacan area.

(4) In Manikbel area, igneous activity came to a close and approached the stage of stability with formation of the NNW-SSE system faults. Also in the Layacan area, the igneous activity came to a close through the intrusion of dacite dykes of the final stage, and moved toward stability with repetition of a large scale faulting of the NNE-SSW system.

In the Manikbel area, the preceding mineralization consisting mainly of pyrite took place along the numerous fissures formed by the intrusion of batholith in andesite. Along with the intrusion of a granodiorite stock, the main mineralization associated with copper formed the disseminated mineralized zone within the batholith and the stock.

In the stage of activity of quartz diorite porphyry-dacite dykes, the mineralization was on a decline, which can be observed only as localized pyrite dissemination-fine veinlet. In the Layacan area, vein type mineralization consisting mainly of pyrite took place accompanying the intrusion of quartz diorite porphyry stock, which is small in scale and weak in copper concentration. In the stage of activity of dyke rocks, the mineralization entered the final stage, which brought about argillization and local deposition of some gold and silver.

2–3 Relation between Geochemical Anomalous Zone and Mineralized Zone

In the Phase III survey the detailed geochemical soil survey was carried out in both Manikbel and Layacan areas for Cu as the indicator element. As a result, in the Manikbel area, some high anomalous zones were obtained though small in extent, while in the Layacan area, a wide anomalous zone with moderate strength was obtained.

Fig. 3 shows the relation between the geochemical anomalous zones of Cu and the mineralization zones in the Manikbel area.

As shown in the figure, a number of pyrite dissemination zones associated with malachite and small amount of chalcopyrite are exposed in the basin of the Mamising Creek, north of Barrio Ud-Udiao. The Cu anomalous zones were detected in almost the whole area of distribution of these outcrops. Especially, a high Cu anomalous zone with more than 800 ppm Cu was obtained in the area in which MA-2, MA-3, MA-4 and MA-7 outcrops were distributed, which manifested the distribution of the mineralized zone. Although an anomalous zone more than 800 ppm is distributed to the north of MA-4 outcrop, the outcrop can not be observed because of thick vegetation around the place. However, from the strength of the anomaly, the occurrence of mineralization similar to outcrop MA-4 is expected.

In the west of the anomalous zone, BM-No. 3, BM-No. 4 and BM-No. 6 drilling holes conducted by BMG are located. In BM-No. 3, high copper grade was encountered.

Isolated small-scale anomalous zones on the eastern side of the ridge between the Manikbel River and the Mamising Creek extending north-northeastward from Ud-Udiao showed no sizable order of anomaly. Exposure is poor in this area, and no remarkable anomalous zone was found.

In Layacan area, a wide anomalous zone was obtained extending from the center of the survey area to the northwest. The order of anomaly, however, is lower than that of the Manikbel area. The area of anomalous zone (200 ppm Cu) corresponding to the same order of anomaly in the Manikbel area (more than 300 ppm Cu) is narrowed down to two. One extends on the southern side of Balasian River and the other is distributed in the western end of the survey area.

The anomalous zone along the Balasian River includes LA-3 mineralized zone which is rich in bornite and chalcopyrite though small in vein width. An anomaly of more than 800 ppm Cu was obtained in the southwestern end. The distribution of this anomaly is consistent with that of quartz diorite porphyry stock which is considered to have brought the mineralization.

The anomalous zones located in the western end of the survey area were detected in basalt-basic andesite lavas of the Licuan Group Formation I and dacitic pyroclastic rocks of the Tineg Formation. No mineralized zone was found within the anomalous zone.

The mineralized zones of LA-1 and LA-2 are both pyrite-clay veins containing no copper minerals. LA-4 and LM-1 are clay veins in the highly silicified rock containing

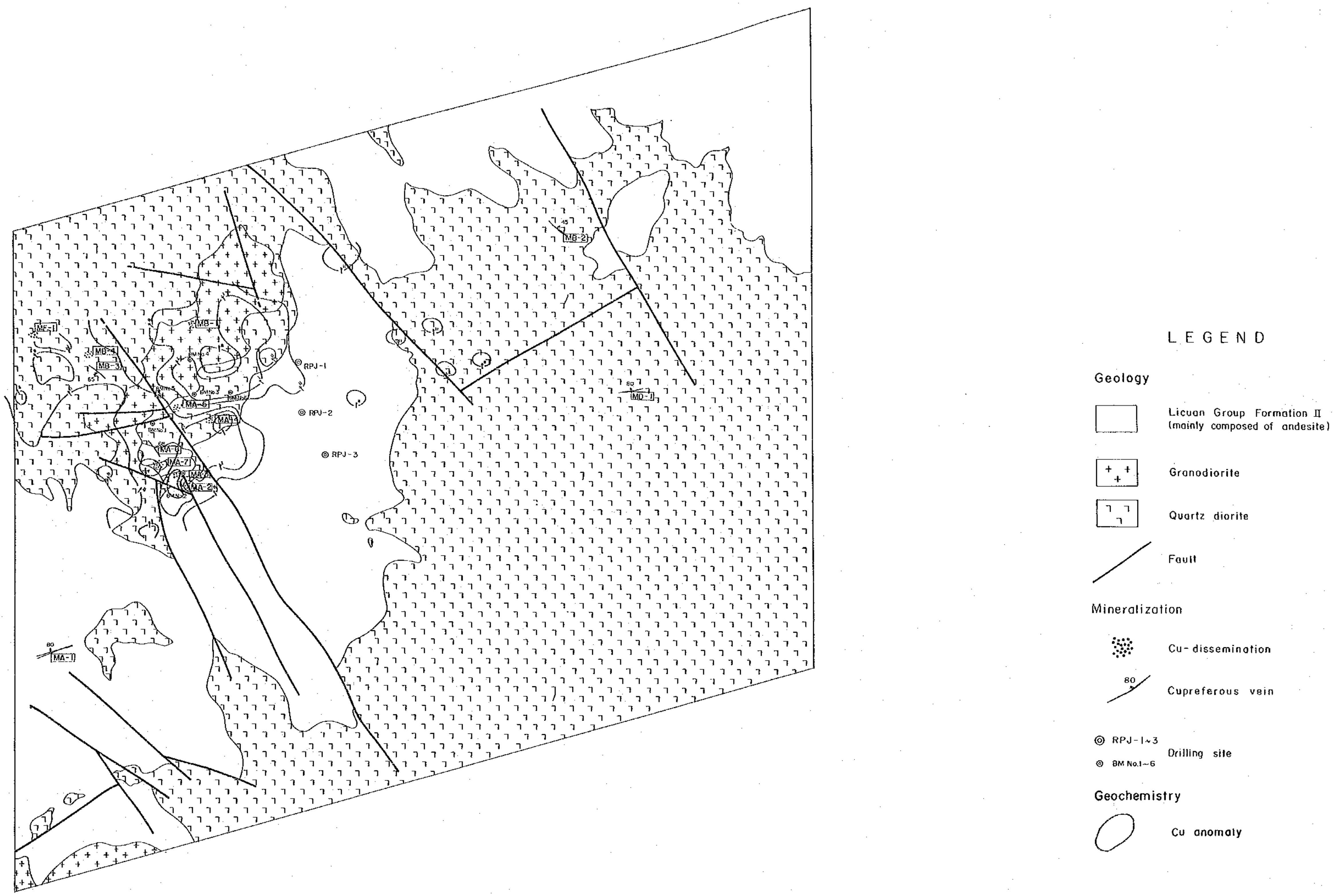


Fig. 3 Relation Map between Geochemical Anomalies and Mineralized Zones in Manikbel Area

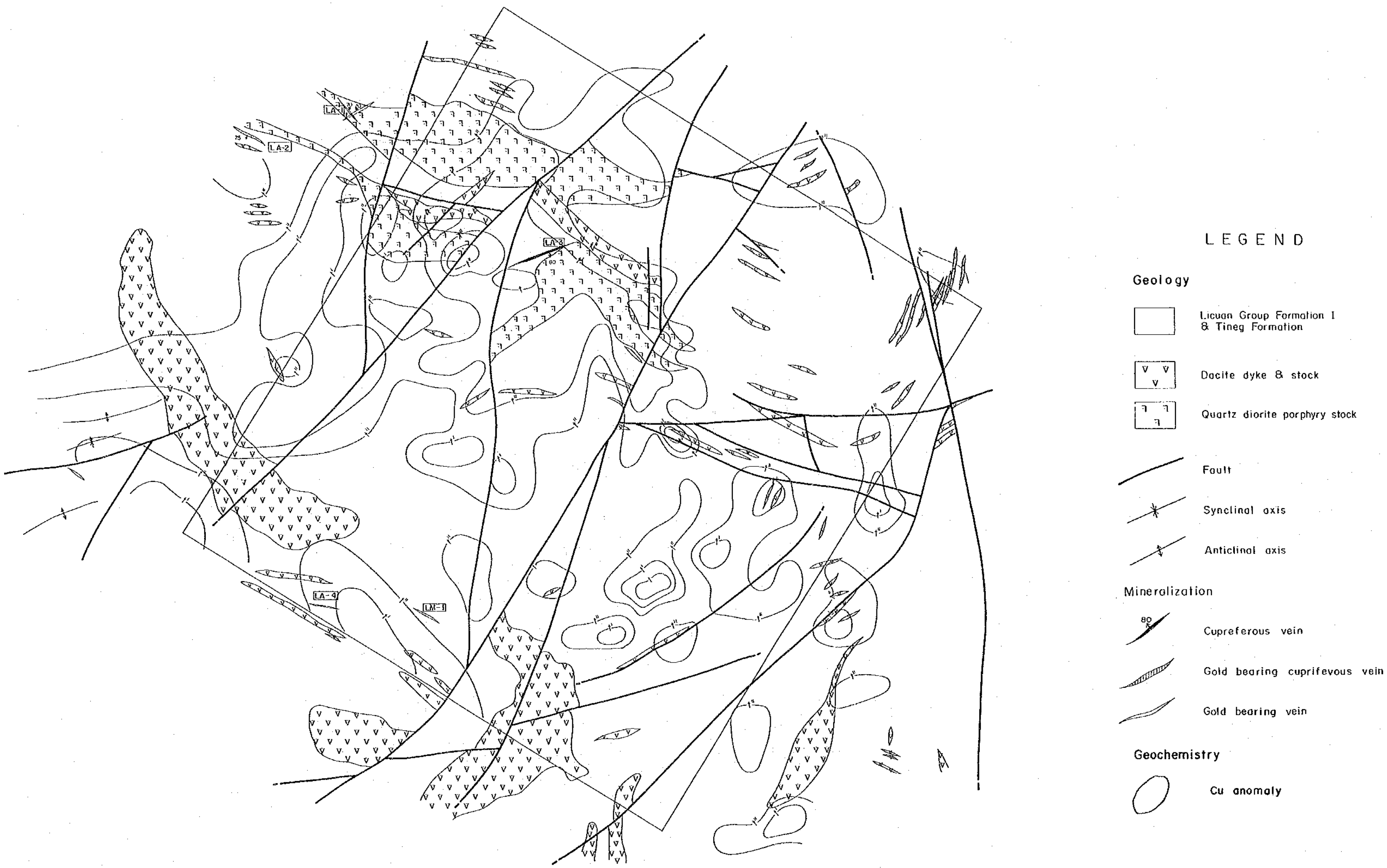


Fig. 4 Relation Map between Geochemical Anomalies and Mineralized Zones in Layacan Area

small amount of copper minerals, in which only small scale moderate order of geochemical anomaly was obtained.

Accordingly, the anomalous zones in the Layacan area are generally moderate to low in order of anomaly, and it appears to be inconsistent with the mineralized zone. It is considered, for the reason cited above, that the mineralization consists mainly of pyrite and the vein which containing copper mineral is very small in number.

The detailed geochemical soil survey using copper as indicator is very effective for estimation of the strength of mineralization since it narrows down the area of distribution of mineralized zone associated with copper minerals. A more notable effect must be expected in a zone covered by thick vegetation.

2–4 Relation between Geophysical Anomalous Zone and Mineralized Zone

The geophysical survey in Phase III was conducted to clarify the lateral and vertical extent of disseminated pyrite mineralized zones exposed in the Manikbel area, especially in the basin of the Mamising Creek. The methods used were electric prospecting by IP method and Complex Resistivity method.

By the IP method, strong anomalies with FE value of more than 7% were detected in the eastern part, the central part and the western part of the survey area, as shown in Fig. 5. In both eastern and western anomalous zone, anomaly is stronger in the northern side gradually becoming weaker toward the south. The western anomalous zone is smaller in scale compared with the two anomalous zones described above. It is a common character of these anomalies to be consistent with the areas of low resistivity less than 1,000 Ωm, showing the IP anomaly of the area, as high FE and low resistivity type.

The relation between IP anomaly and geology is that the eastern anomalous zone is in quartz diorite and the center anomalous zone is mainly in the area of distribution of andesite lava. In the northwestern part, the anomaly covers the stock-shaped granodiorite. The anomalous zone of this part extends toward the southwest along the distribution of granodiorite, and is continued to the eastern anomalous zone. The northeastern part beyond the center of the western anomalous zone is consistent with the distribution of the granodiorite stock and of the andesite lava in the southwestern part.

The mineralized zones in the Manikbel area mainly consist of dissemination fine network of pyrite associated with small amount of chalcopyrite formed in the peripheral part of quartz diorite and, in the surrounding area of granodiorite stock, with abundant

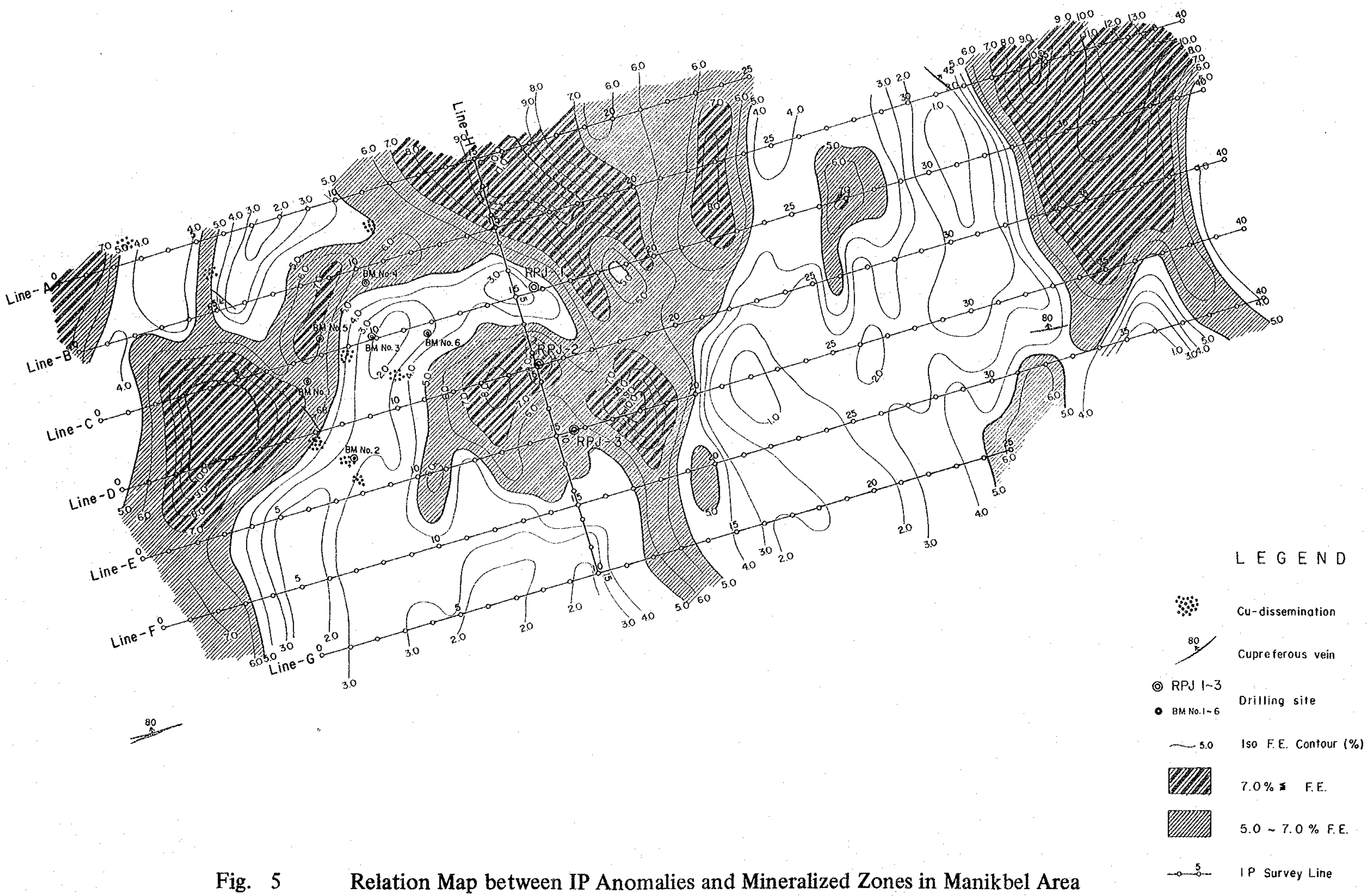


Fig. 5 Relation Map between IP Anomalies and Mineralized Zones in Manikbel Area

malachite and azurite observed on the surface of the outcrop. In the northwestern part of the area, vein type outcrops with notable pyrite are found. Vein type outcrops such as LB-2 and LD-1 are found though quite local in the center to the eastern part.

Concerning the relation between IP anomaly and the mineralized zone, the eastern mineralized zone is in the area of distribution of quartz diorite, in which small scale dissemination zones of pyrite were formed.

It is considered that IP anomalies were caused by these dissemination zones of pyrite.

The central anomalous zone is almost consistent with the area of distribution of andesite lava except for the northwestern part. In the andesite, innumerable minute cracks are developed, and it was known from field observation and the result of drilling that thin films or hair-shape of pyrite were formed along cracks. Therefore, it is considered that IP anomalies of large scale were caused by these minute veinlets of pyrite. The central anomalous zone continues to the depth (n=5) and this agrees well with the result of drilling.

The northwestern part of the central anomalous zone as well as the western anomalous zone are consistent with the distribution of stock-like granodiorite, and it is considered that the remarkable pyrite dissemination observed in the rock generated the FE anomaly. The western anomalous zone is stronger in the shallow part becoming weaker in the depth.

In the low FE zone (FE is less than 5%) between the central and the western anomalous zones, the mineralized zones containing copper are distributed as above mentioned. These mineralized zones contain copper minerals such as malachite, azurite and small amount of chalcopyrite. The result of analysis showed that sulphur grade is low compared with copper grade. Therefore, it is clear that most of the copper was derived from the non-sulfide minerals. However, since malachite and azurite were formed secondarily from copper sulfide, it will be natural to consider that these mineralized zones were primarily chalcopyrite-pyrite minerals.

The following matters may explain why high FE was not obtained in the area of distribution of mineralized zones.

(1) The mineralized zones mainly consist of secondary copper mineral with poor content of sulfides. (2) Although the mineralized zones primarily have the mineral assemblage of chalcopyrite-pyrite, in the dissemination deposit, the chalcopyrite-pyrite zone is poor in total sulfide compared with the pyrite zone. (3) It was made clear from measurement of physical properties that IP phenomena is stronger for network than for dissemination, and

the mineralized zone correspond rather to the dissemination. (4) The thickness of the mineralized zone is relatively thin, and it is expected not continued at depth (from the result of BM·No.6). This low FE zone continues to the depth at least about 300 m. (n–5). Although the low FE zone is consistent with the strong Cu-geochemical anomaly, it is considered that this high anomaly is caused by the secondary copper minerals.

As described above, although high IP anomaly was not obtained in the area of distribution of mineralized zones consisting mainly of non-sulfide copper minerals. High IP amonalies were detected in lateral and vertical in the areas with thin film- or hair-shaped veinlets of pyrite, by which a close correlationship between the total sulfide and IP anomaly was confirmed.

Complex Resistivity method was carried out to discriminate the constituent minerals of the sulfides concentration to discriminate chalcopyrite from pyrite which was confirmed by IP method along the IP survey lines such as Line-C, D and E.

As the result, dissemination-network of sulfide was detected in the same area to the central anomalous zone, and it was confirmed that the low FE zone in-between the central and the western anomalous zones was the area of low distribution of sulfide minerals. However, no distinct result was obtained on discrimination of chalcopyrite from pyrite in the area of distribution of sulfide minerals. The absolute amount of chalcopyrite is low (from the result of drilling in Phase III), and it is considered that a distinct result would have been obtained if there is a mineralized zone rich in chalcopyrite.

In terms of the Complex Resistivity (CR) method, the method of analysis has got to be established and various methods are being tried at present. There is a strong possibility of obtaining a new result by the establishment of an analytical method.

2–5 Relation between Drilling Exploration and Mineralized Zone

The drill survey was carried out in three places as shown in Fig. 6 to confirm the continuation of the mineralized zone, distributed on the Mamising Creek in the valley of the Manikbel River, to the depth, and to know the actual state of the remarkable IP anomalous zone which was obtained on the east side of the mineralized zone and continued to the depth.

The mineralized zone was formed at the boundary between quartz diorite and andesite lava. The quartz diorite is connected in a relatively shallow subsurface to the other quartz diorite which is widely distributed in the eastern part. Therefore, the drill length of 300 meters must be enough for intersecting the rock boundary if the hole is drilled from the site

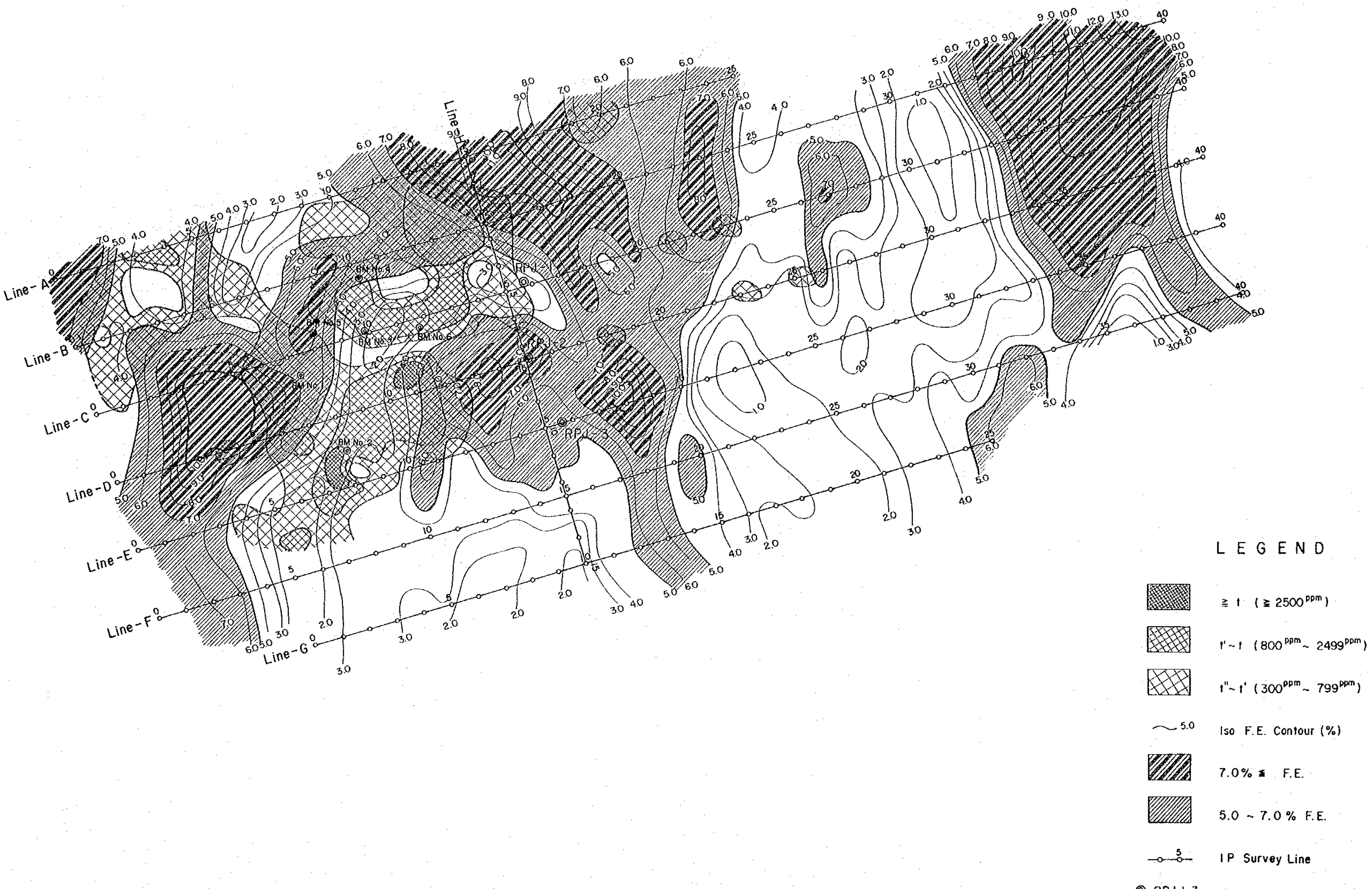


Fig. 6 Relation Map between Geochemical Anomalies and Drilling Sites

selected as shown in Fig. 6.

No IP anomaly was detected at depth in the distribution area of the mineralized zone and geochemical Cu anomalous zone, in which drill exploration had been done by MGB in the past. Accordingly, such area is excluded from probable exploration site in this phase.

Pyrite-dissemination zone associated with small amount of chalcopyrite which is considered to be an extension of the mineralized zone confirmed on the surface was encountered in hole RPJ-1 at the section from 195.20 m to 260 m deep from the collar.

However, in RPJ-2, andesite was exposed to a depth of 263.90 m and a number of dykes intruded in various directions near the boundary with quartz diorite. The mineralized zone observed in RPJ-1 was not encountered.

In RPJ-3, the whole hole length is dominated by andesite, in which the mineralized zone as observed in RPJ-1 was not encountered either.

Expected results were obtained in RPJ-1, the nearest hole to the boundary between andesite and quartz diorite. In RPJ-2 and 3, the boundary showed a steeper inclination than expected, and a remarkable activity of dykes was observed centering on the boundary.

At the extension of the outcrop confirmed in RPJ-1, no secondary enrichment of copper could be observed. However, the thick pyrite dissemination continued to the depth except in intersections of dykes. Dissemination is abundantly observed in andesite as film and hairline veinlet, and thus it is considered to have been detected as a high IP anomaly.

2–6 General Discussion

The results of the geological geochemical and geophysical surveys and drilling exploration in Phase III and their mutual relation were described above. The general discussion on these from the standpoint of "comprehensive evaluation of the mineralized zone", investigation is compiled as follow:

In the Manikbel area, outcrops of pyrite dissemination consist mainly of malachite and azurite associated with small amount of chalcopyrite, and similar vein type mineralized zones are distributed. The vein type mineralized zones are small in scale and low in grade. Therefore, they do not warrant further exploration.

A vein rich in copper located to the west of Ud-Udiao have an unstable shape, and in addition, it is emplaced along the main stream of the Manikbel River. Thus it will hardly be the object of future exploration and development from the topographical conditions.

Detailed geochemical and geophysical surveys and drilling exploration were carried out for the investigation of outcrops consisting of disseminated mineralized zone in the Mamising Creek basin. Exploration conducted by BMG in the past led to the conclusion that these group of outcrops does not warrant further development at this stage. Since these outcrops were formed along the outer periphery of quartz diorite mass, there is no suitable space for exploration in the northwestern part because of wide exposure of the rock mass. In the southwestern part, quartz diorite could not be encountered by RPJ-3 drilled in this phase at the depth of 300 m because of steep dip of the southern edge of the mass. Therefore, problems for future development are expected including the depth of emplacement although copper mineralization was continued to that depth.

The group of these outcrops had been considered to extend homogeneously for a wide extent like a porphyry copper type deposit. From the results of the geophysical survey and drilling exploration, it is presumed to have take a crust-shape along the surficial part of the quartz diorite mass. Copper grade is sometimes high in surface outcrop due to secondary enrichment. However, the drilling results showed a poor occurrence of primary copper minerals. In drilling core samples taken from 3 m sections, copper grade was 0.1 $\sim$ 0.2% in average with the maximum of 0.43%.

Based on the above description, the mineralized zone may develop to a promising ore deposit in the future depending on the result of exploration because there remained a room for exploration in solving the problem of continuation of the mineralization toward the northeast and southwest. However, the evaluation of expectation for future development made from the result of exploration higherto conducted will have to lead to conclude that the area might not be worthy of placing too much hope on it along with the disadvantage of the access.

In the Layacan area, two types of mineralization have been confirmed that is, one is clay veins consisting mainly of pyrite and the other is argillaceous silicified zone containing gold and silver. The former is mainly distributed along the Balasian River, and the veins are generally poor in copper, although some parts of veins contain abundant copper sulfide minerals. The latter is mainly distributed in the southern end of the survey area, and all the veins are small in scale and unstable. They do not appear to warrant further exploration.

Since the porphyry copper type mineralization can not be expected in the area, it is recommended that exploration for vein type deposit would be carried out mainly by drilling in the vicinity of the LA-3 mineralized zone which contains the veins rich in copper sulfide minerals.

3. CONCLUSION AND RECOMMENDATION FOR FUTURE STUDY

3–1 Conclusion

In Phase III, the final phase of the project, detailed geological, geochemical and geophysical surveys and drilling exploration were carried out in the Manikbel area which was selected as the most promising area for ore deposits on the basis of the result of the first and second phase surveys. In the Layacan Area, in which it was considered necessary to conduct more detailed survey because of its high potentiality of ore occurrence, detailed geological and geochemical surveys were also conducted.

The purpose of this survey was to elucidate the field of ore emplacement and to make a comprehensive evaluation of the ore deposit as well as to establish a guidance for explrora-tion and development by clarifying the scale, grade and nature of ore deposits distributed in both two areas in more detail.

Based on these survey results and analytical studies, the following conclusions were deciphred.

1. The stratigraphy of the survey area followed in that of the project area established by the phase I and II. The phase III survey areas were as narrow as 10 and 15 sq. km. Therefore, any new fact which required the modification of the existing stratigraphic classification was not found. Accordingly, the stratigraphic classification established by the phase I and II surveys can be used as the final stratigraphy of the project area.

2. In connection with the chemical composition and absolute age of the intrusive rocks, the data on three samples were added this year. The chemical composition was studied on quartz diorite and dacite of the Manikbel area and on dacite of the Layacan area. The result of analysis showed that all these rocks belong to calc-alkali rock series, and it was revealed that these rocks have the similar composition to many intrusive rocks investigated up to Phase II. Therefore, it can be said that a number of intrusive rocks observed in the project area are the products of a series of igneous activity initiated by the intrusion of batholithic rocks.

The result of dating of the three samples chemically analized showed 15.9 ± 0.8 m.y. for quartz diorite, and 10.5 ± 1.1 m.y. and 9.8 ± 2.0 m.y. for dacites from the two areas, respectively. These result of the dating are within the extent of 26.3 ± 1.8 m.y. ~ 9.8 m.y.

obtained up to Phase II, and that of each rock type is well consistent with the result of measurement in the past.

3. Concerning the geological structure, although it is difficult to know the general view of the areas because of narrow areas of the survey, it is characterized basically by the two systems such as NNE–SSW system and WNW–ESE system which is perpendicular to the former. The process of development of igneous activities and geological structure is considered as follows: (i) The intrusion of batholithic plutonic rocks was initiated along the structure of NNE–SSW system, (ii) plutonic-hypabyssal rocks were intruded along the structures of both systems such as NNE–SSW and WNW–ESE formed in association with the intrusion of batholith. Along with these intrusion, (iii) the structures of both systems were magnified and expanded, to which numerous dykes were intruded. (iv) Igneous activity was closed by the intrusion of dyke rocks, and the areas moved to the stability with repetition of numerous fault movement including the systems such as NNE–SSW, NNW–SSE and NW–SE. The structure of NNE–SSW is one of the basic large structure dominating the project area.

4. Results of the detailed geological survey made it clear that in the Manikbel area, mineralized zones are of dissemination or network type containing non-sulfide copper minerals and vein type mineralization associated with small amount of chalcopyrite. In the Layacan area, veins consist mainly of pyrite and silicified clay veins containing some sulfide minerals.

The main mineralized zone in the Manikbel area consists of dissemination-network type containing non-sulfide copper minerals as the main ore deposit with lateral extent of 1.2 km E–W and 1.1 km N–S. The mineralized zone was mainly formed in quartz diorite near the boundary between quartz diorite and andesite lava. In addition, in the surrounding area of granodiorite stock, the crust-shaped mineralized zone are formed along the surficial zone of quartz diorite.

The main mineralized zone in the Layacan area is pyrite-clay vein formed in stock-shaped quartz diorite porphyry and in its surroundings. Although some sulfide rich veins are partly observed, they are generally poor in copper mineral, and the secondary copper minerals are hardly observed even on the surface of outcrop.

As mentioned above, although the mineralized zones observed in the both areas are different to each other in their types, the field of ore formation is limited within and in the surrounding area of stock-like plutonic rocks ~ hypabyssal rock bodies closely related to the plutonic rocks in origin. Thus the characteristics of "the field of ore emplacement" which had been indicated by the survey up to Phase II were reconfirmed.

5. The geochemical soil survey was conducted in both areas using copper of indicator element. High Cu anomalous zones are well consistent with the mineralized zone obtained in the Manikbel area. However, in the Layacan area, the order of anomaly was very low compared with that of the Manikbel area because of poor content of copper mineral, and also the distribution of anomalous zone was not always consistent with that of mineralized zone in some part.

However, it was confirmed that geochemical soil survey define in general the extent of distribution of mineralized zone and that it was a effective method to know the intensity of mineralization.

6. Geophysical survey was carried out in the Manikbel area by IP and Complex Resistivity (CR) methods. Results of the IP survey show an anomalous zone of more than 5 % FE in three places. However, the distribution area of the mineralized zone was shown to be in the low FE zone of less than 5 %, showing a different result from that of IP survey of Phase II. The IP anomaly is not consistent with the distribution of geochemical Cu anomalous zone. The reason of these result is considered to be as follows: (1) The main ore minerals of the mineralized zone in the Manikbel area consist, as previously mentioned, of non-sulfide copper minerals, (2) the mineralized zone shows the crust-shaped ore deposits, and (3) when the mineralized zone primarily consists of chalcopyrite-pyrite in mineral assemblage, the total amount of sulfide mineral contained in chalcopyrite-pyrite zone is less than that in pyrite zone.

A part of the high IP anomalous zone was confirmed by drilling to be produced mainly by film- and/or hair-shaped veinlet of pyrite in andesite.

The CR method was carried out to determine the constituent minerals – especially in the discrimination of chalcopyrite from pyrite – of the sulfide mineral concentration detected by the IP survey. However, the result was not good because of small amount of chalcopyrite. It is necessary, in the future, to obtain an effective result of analysis by repeated investigation on analytical method wherein data an subjected.

7. The drilling exploration was conducted to confirm at depth the extension of the main mineralized zone observed in the Manikbel area and to know the actual state of the high IP anomalous zone shown at the eastern periphery of the mineralized zone. Three holes with a total drill length of 932.20 m were bored.

Pyrite dissemination zone associated with a small amount of chalcopyrite considerd to be an extension of the outcrop was encountered in the hole of RPJ–1 at the intersection 195.20 m to 260.00 m from the collar. In RPJ–2, although the boundary between andesite and quartz diorite was encountered at 263.90 m depth, the mineralized zone could not be confirmed because of intrusion of dykes near the boundary. In RPJ–3, andesite was exposed throughout the whole length down to the bottom of the hole, and no mineralized zone was observed.

The result of drilling exploration showed that IP anomaly was mainly caused by film- and/or hair-shaped network zone of pyrite developed in andesite.

8. From these results, the comprehensive investigation of the mineralized zones in both areas was made as follows:

The mineralized zone in the Manikbel area consists of dissemination-network zone of pyrite. Some part of the outcrop is rich in copper as the result of secondary enrichment, but it is generally low grade because of small amount of primary copper sulfide mineral.

Quartz diorite has a steep dip at the southeastern part of the outcrop. Therefore, there would be problems for development in connection with the depth even if the extension of the mineralized zone is found.

Accordingly, although some spaces for exploration of the mineralization would be maintained, it does not warrant future development at this stage from a synthetic evaluation standpoint combined with the disadvanlageous accessibility.

In connection with the mineralized zones in the Layacan area, since copper minerals are hardly observed on the outcrop except for a part of the vein. It is difficult to evaluate future development at this stage most veins consist of clay with poor amount of quartz. It is necessary to confirm the lateral and vertical continuity and the variation of grade of the known outcrops by carrying out exploration mainly drilling in the future. The evaluation of the mineralized zone should be made basing on these data.

9. According to the initial plan, the survey of this year was to be conducted at the three

mineralized zones previously selected. Based on the Phase II survey, the potential areas for ore deposits are the Manikbel, Malibcong and Lacub areas.

The Malibcong area is a virgin area with no exploration results in the past. Exploration in the Lacub area was insufficient because only local prospecting had been done intermittently in the area. On the other hand, mineralization of the area is a typical porphyry copper type deposit associated with potash alteration. In these areas, the Phase III survey is scheduled. It is regrettable the survey of the Malibcong and Lacub areas became impossible due to the problem of peace and order situation.

3–2 Recommendation for Future Study

As described above, although the actual state of the mineralized zone in the Manikbel area has been made clearer, exploration has yet to be done for the northeastern and southwestern parts of the mineralized zone. In the Layacan area, only the surficial outcrop was studied without the survey for lateral extension and drilling. Promising mineralized zones are known in areas where no survey was conducted this year. It is necessary to explore these areas as soon as possible.

Recommendations for these areas are described as follows:

1. The acutual state of mineralized zones of dissemination and network in the Manikbel area were clarified by various kind of survey carried out this year. However, the continuity toward the northeastern part as well as the southwestern part of the zone has not been confirmed. In both extension, the boundary between quartz diorite and andesite was located geologically, and also the IP anomalous zone was obtained continuously.

Because the mineralized zones of the area were emplaced at the outer periphery of quartz diorite, drilling exploration would have to be done in the northeastern part, at the northern periphery of the IP-central anomalous zone, in the vicinity of No.16 ~ 17 on Line-A of the IP survey line and No.17 ~ 18 on Line-B. In the southern part, No.0 ~ 1 on Line-E at the southwestern end of the anomalous zone is recommended for drilling. It is necessary to confirm the scale, shape and grade of the mineralized zone.

2. Since the surface of outcrops of the mineralized zone in the Layacan area has been studied in this phase, the lateral and vertical extent of the mineralized zone is to be confirmed mainly by drilling. In this case, the investigation on distribution of the quartz diorite stock

should be an important theme because the mineralized zones are concentrated within and in the surroundings of the stock.

3. In connection with the Malibcong and Lacub areas selected as the object of survey of this year, it is expected that the detailed survey would be carried out as soon as peace and order conditions are restored, for the confirmation of the scale and the grade of the ore deposit as well as for the investigation of the possibility of future development.

4. It was impossible, throughout this year, the final phase of the project, to enter the area along the basin of the Chico River for peace and order situation.

A number of promising ore deposits are known to occur in the area, thereby increasing possibility to a workable deposits.

A geological map was compiled from existing data, but it includes many questionable points. It is desirable that field survey must be carried out as soon as possible and the actual state of geology and ore deposit would be clear.

PART I GEOLOGICAL SURVEY

1. GENERAL REMARKS

The project area lies on the Cordillera Central uplift zone, and consists mainly of volcanic rocks, pyroclastic rocks and normal sedimentary rocks of Eocene to Miocene. The plutonic rocks of Late Oligocene to Middle Miocene intruded into them in a large scale. Among these geological circumstances, the project area is characterized by extensive exposure of plutonic rocks showing various facies in lithology from basic to acidic, displaying the past vigorous plutonic activities.

On the other hand, the Cordillera Central uplift zone is a geologic unit characterized by the occurrence of numerous metallic ore deposits, in which most of them are concentrated, not only forming the great metallogenic district but also a number of potential workable deposits.

In the project area, many mineralized zones and/or indications have been confirmed beside Batong Buhay and Bully Bueno mines which are currently under development for commercial operation. Most of these deposits and mineralized zones were formed at the periphery of the plutonic masses or in their surrounding areas as network or disseminated deposits, and they have a remarkable tendency to have been selectively concentrated to the stocks or dykes showing that these were characteristic field for ore formation.

The ore deposit of Batong Buhay mine which is considered to be the greatest deposit in the project area, is a dissemination and/or network deposit consisting of chalcopyrite, bornite and pyrite showing a typical prophyry copper type deposit. It is formed in quartz diorite porphyry intruding into the vicinity of quartz diorite mass.

Other deposits and mineralized zones have been considered to have basically similar field of formation and characteristics although there might be difference in scale, mineral assemblage and mineral composition.

The geological survey was conducted in the Manikbel and Layacan areas which were delineated as the most promising area for ore deposits by the second phase survey. The main objectives are to clarify the geological environment of each mineralized zone and to evaluate comprehensively its potential.

While the result of the survey will be described in detail in the following chapter, it is noted that the result showed the geological characteristics clearly mentioned above were made more clear and that a basic policy was established for exploration of the ore deposit.

2. GEOLOGY

2–1 General Statement

The geology of the project area consists of the Post-Cretaceous volcanic rocks, normal sedimentary rocks and plutonic rocks.

Based on the survey results in Phase I and II, the volcanic and sedimentary rocks were classified into five units, namely: Licuan Group Formation I and II, Tineg Formation, Mabaca Formation, Alava Formation and Quaternary volcanic rocks in acending order, as shown in Table I–1.

K-Ar dating gave the geological age of the intrusive rocks to be 26.3 ± 1.8 m.y. ∿ 9.8 m.y. showing Late Oligocene to Middle Miocene age.

Although the data on regional geology were scarce because the areas of this phase survey was narrow having only 10 and 15 sq. km, respectively, the survey result corresponded well to the previous stratigraphical classification, and the age determination of plutonic rocks taken from the two areas showed values of 15.9 ± 0.8 m.y. ∿ 9.8 ± 2.0 m.y., which are consistent with the age mentioned above.

The geology of the Manikbel and Layacan areas will be described in the following chapter.

2–2 Stratigraphy and Intrusive Rocks

2–2–1 Manikbel Area

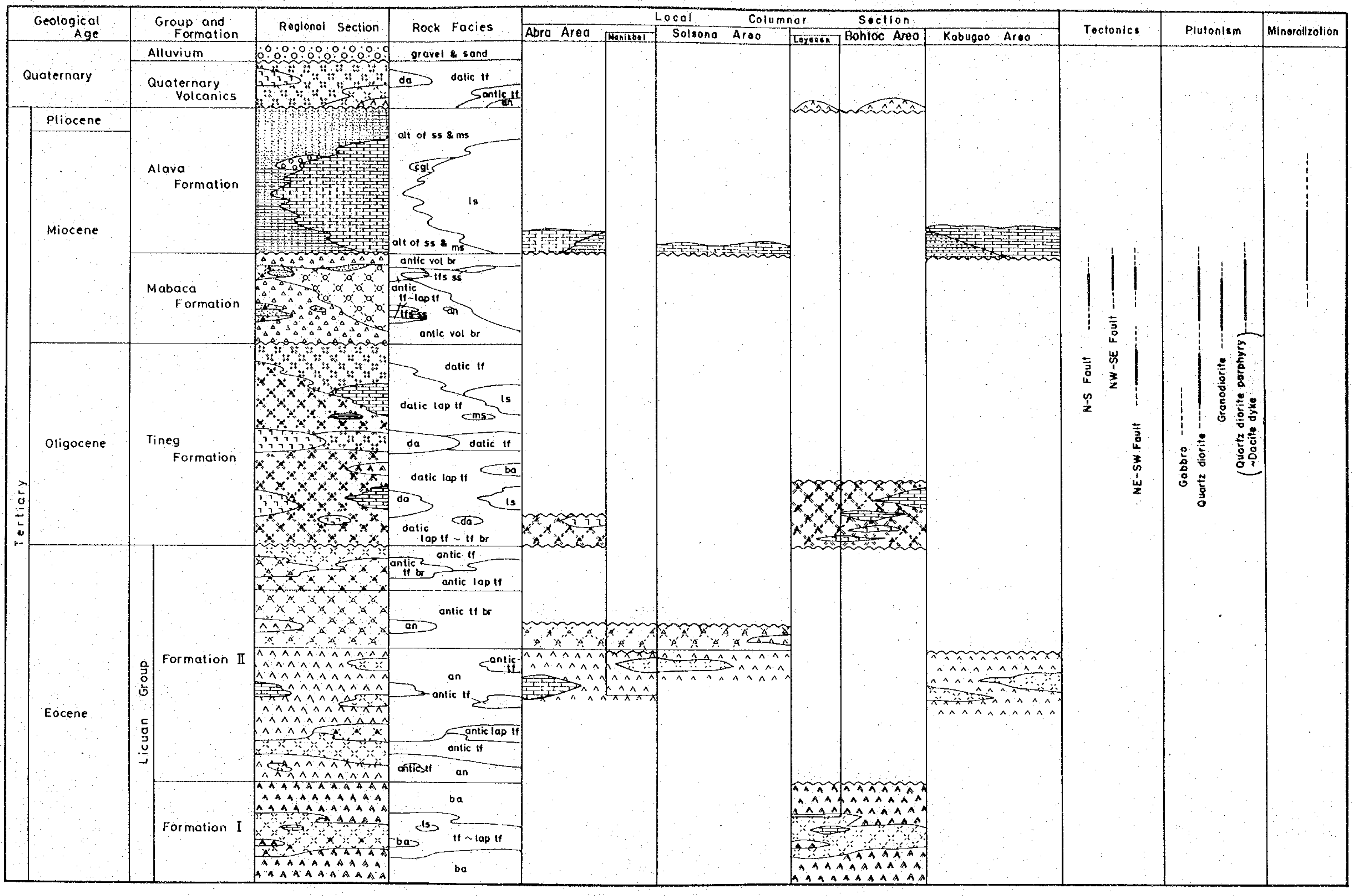
As shown in Fig. I–1, most of the area is overlain by the Licuan Group Formation II consisting mainly of andesite lava as well as batholithic quartz diorite – granodiorite masses intruded into the Formations. From the center to the northern part of the area, numerous dykes of quartz diorite porphyry to dacite are observed.

(1) Licuan Group Formation II

The Formation is distributed along the Manikbel River centering on Barrio Ud-Udiao, in the upstream of the Mabibing and Kulan creeks in the northeastern part of the area. The rocks constituting the Formation are andesite lava and andesitic pyroclastic rocks intercalated with the lava.

The andesite lava is a compact rock showing dark green color with scant phenocrysts and is aphanitic. It remarkably altered to hornfel and is hardened in the vicinity of plutonic rocks with strong silicification and development of fine cracks. Especially the rocks

Table I–1 Generalized Stratigraphic Section of Survey Area



Abbreviation :

ms : mudstone	tf : tuff	da : dacite	tfs : tuffaceous
s.s : sandstone	lap tf : lapilli tuff	an : andesite	datic : dacitic
cgl : conglomerate	tf br : tuff breccia	ba : basalt	antic : andesitic
ls : limestone	vol br : volcanic breccia		alt : alternation

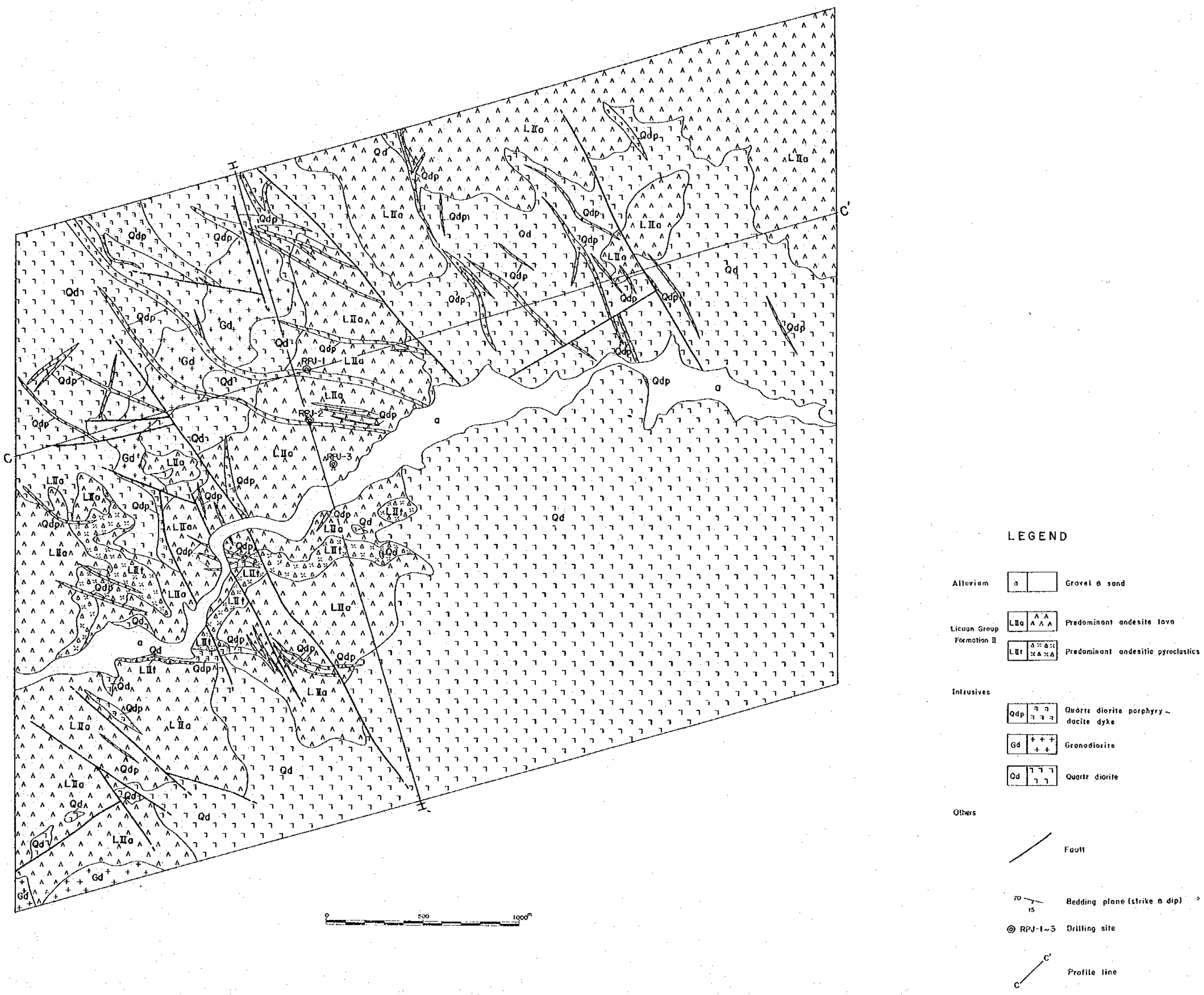


Fig. I-1 Geological Map of Manikbel Area distributed in the area surrounded by Dalipawen Creek, the midstream of the Manikbel River and the Mamising Creek, underwent strong silicification, alteration to hornfels and pyritization, occasionally argillization through thermal metamorphism by plutonic intrusion.

Andesitic pyroclastic rocks consist of well bedded fine- to coarse-grained tuff and tuff breccia containing andesitic breccia. They show dark green to greenish gray color. These pyroclastic rocks are intercalated with andesite lava in the vicinity of Ud-Udiao. They are also affected by plutonic rocks and altered to hornfels.

In this phase survey, the positive data to determine the geological age of the Licuan Group Formation II was not obtained. Therefore, it was defined, as previously reported in the first and the second year, to be Paleocene.

(2) Quartz Diorite

This rock is widely distributed in the southeastern part of the area from the south of Ud-Udiao to the north of Barrio Nagasasan, and in the middle to upstream of the Mamising Creek located in the northwestern part. The area of distribution accounts for the most part of the surveyed area.

The rock is generally medium- to coarse-grained leucocratic and holocrystalline rock. It shows pale-greenish white to pale-greenish gray tint, consisting mainly of quartz, plagioclase and hornblende with accessory biotite and potash feldspar.

Chloritization and epidotization are common, but sericitization is remarkable in the Mamising Creek and the middle to lower stream of the Nagasasan Creek.

Microscopic observation of the rock sampled at about one kilometer east of Barrio Nagasasan is as follows:

Quartz diorite (a–3140)

Texture: Equigranular and holocrystalline texture.

Forming minerals: Plagioclase, quartz, hornblende and K-feldspar.
Plagioclase is euhedral and quartz is anhedral, both of which are abundant. Hornblende is euhedral and in moderate amount. K-feldspar is anhedral and in small amount.

Alteration mineral: Chlorite and opaque minerals.

(3) Granodiorite

The rock is distributed in the middle stream of the Mamising Creek and the uppermost stream of the Ababan Creek in the southwestern end of the surveyed area. Along the

Mamising Creek, it occurs as a stock with 1.2 Km long and 0.2 Km wide in the horizontal section having intruded the quartz diorite, while along the Ababan Creek, it is a part of the batholithic granodiorite widely distributed to the south of the surveyed area.

The rock is leucocratic and holocrystalline and shows pale-greenish gray tint. It consists of quartz, biotite, hornblende and potash feldspar. It is quite similar to the quartz diorite mentioned above megascopically, which the discrimination between the two rocks. Under the microscope, however, the rock contains abundant biotite, which distinguish the two rocks from each other. Chloritization and epidotization are the common alteration, and sericitization is often observed in the rocks distributed in the midstream of the Mamising Creek.

The result of microscopic observation of the rock sampled in the mid-stream of the Mamising Creek is as follows:

Granodiorite (a–3118)

Texture:	Porphyritic and holocrystalline texture.
Forming mineral:	Plagioclase, quartz, potash feldspar, biotite and hornblende. Plagioclase is large in diameter and euhedral, Abundant in amount. Quartz is subhedral and fine-grained, moderate in amount. Potash feldspar is anhedral and fine-grained, moderate in amount. Hornblende is euhedral and coarse-grained, moderate in amount.
Alteration mineral:	Sericite, chlorite and opaque minerals.

(4) Quartz Diorite Porphyry ∿ Dacite

Quartz diorite porphyry to dacite are mainly distributed in the northern basin of the Manikbel River as numerous dykes trending N-S to NE-SW having penetrated the Licuan Group Formation II, quartz diorite and granodiorite. In the southern side of the Manikbel River, however, no dykes are observed in quartz diorite mass, so that these dykes seem to intrude into near the boundary between quartz diorite and the Licuan Group Formation II.

Although the rock is lithologically quite similar to quartz diorite or granodiorite, it is characterized with porphyritic texture, and phenocrysts of quartz, plagioclase and a small amount of hornblende are observed.

It is strongly possible that the rocks were intruded after the mineralization because of its fresh appearance through with some exception. Because of the continuous variation of lithology from quartz diorite prophyry to dacite, they were shown in the geological map as a bundle.

The microscopic observation of this rock taken from the dyke exposed along the Mamising Creek, 0.8 Km north of Barrio Ud-Udiao, is as follows:

Dacite (b–3144)

Texture: Cryptocrystalline texture.

Phenocryst: Plagioclase, hornblende and quartz.
Plagioclase displays euhedral to subhedral cyrstal form of large size. Hornblende is euhedral to subhedral and moderate in amount. Quartz is subhedral and in a small amount.

Matrix: Quartz and plagioclase.
Both crystals are fine-grained and cryptocrystalline.

Alteration minerals: Chlorite, epidote, albite and sphene.

2–2–2 **Layacan Area**

The geology of the Layacan area is composed of, as shown in Fig. I–2, the Licuan Group Formation I consisting mainly of basalt and basic andesite lavas, and the Tineg Formation composed mainly of dacitic pyroclastic rocks and dacite lava. Stocks and dykes of quartz diorite porphyry, dacite and microcrystalline diorite or dolerite are distributed having intruded the above formations.

About one kilometer southwest from the southwestern end of the surveyed area, dacitic to andesitic pyroclastic rocks are exposed. It may be considered to be Quaternary volcanic rocks. The rock description was omitted because the details could not be available due to its narrow exposure.

(1) Licuan Group Formation I

The Formation is widely distributed from the basin of the Balasian River (another name of the lowest stream of the Layacan River) to the northeastern slope of Mt. Quinali (1,090 m), and is also exposed in the basin of the Segseg Creek in the southwestern part of the surveyed area.

The Formation consists mainly of basalt to basic andesite lava associated with pyroclastic rocks and porphyrytic andesite lava.

Basalt and basic andesite lavas are generally dark-greenish gray in color, cryptocrystalline and compact and often show notable amygdaloidal structure. At the contact with quartz diorite porphyry which has intruded this Formation, compact and hard hornfels was formed as the result of thermal alteration.

Pyroclastic rocks are found to be distributed at three places such as at the northeastern

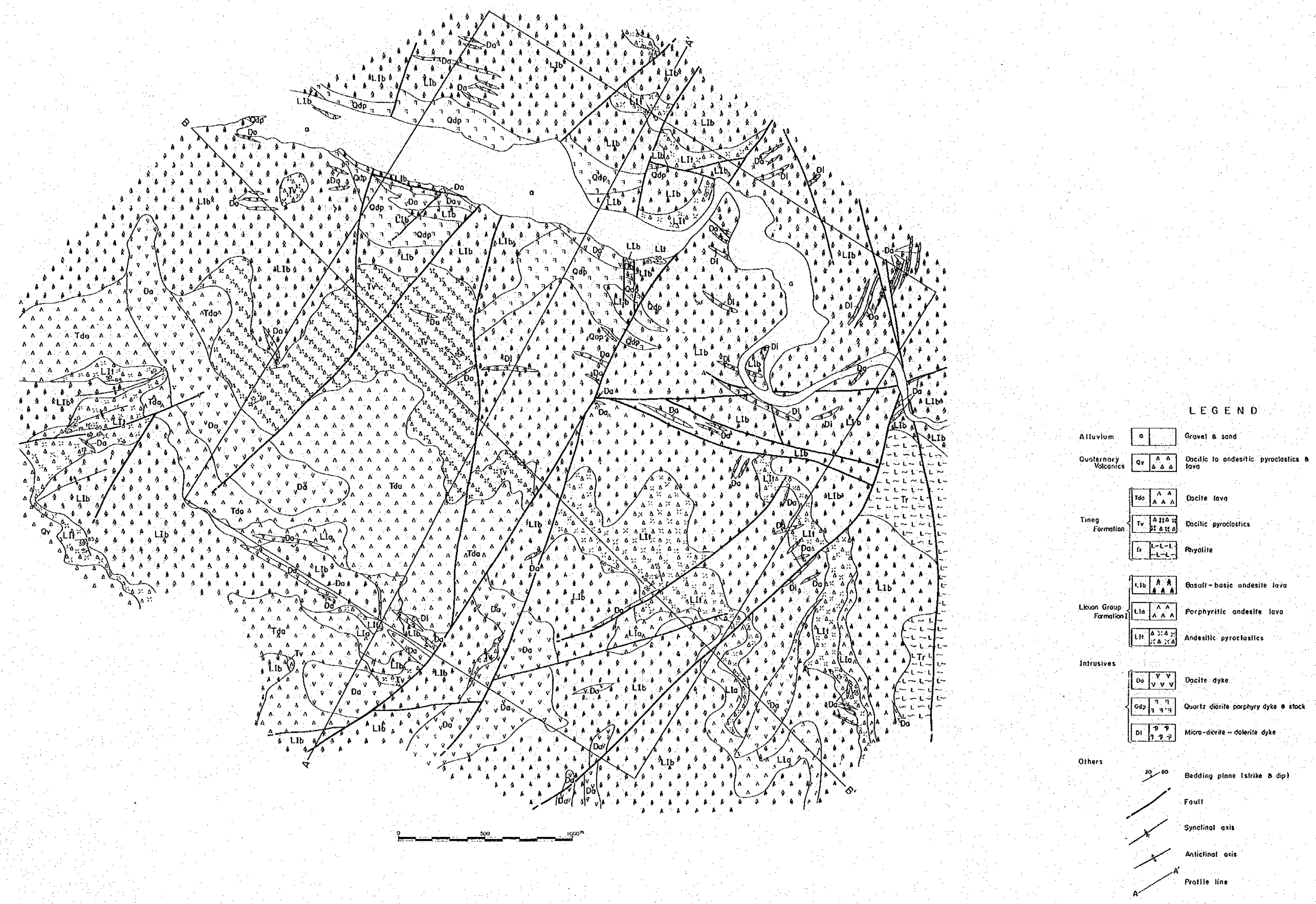


Fig. I–2 Geological Map of Layacan Area

slope of Mt. Quinali, the right bank of the Balasian River and the downstream of the Segseg Creek which is located west of Barrio Patiacan.

The rock consists mainly of well-bedded fine-grained tuff, and it shows dark-greenish to yellow-greenish gray in color. It often becomes coarse-grained and occasionally show fine alternation of fine- and coarse-grained tuffs.

The pyroclastic rock containing breccias of basic andesite predominates at Segseg Creek.

Overlying the rock distributed in the eastern part of the surveyed area is porphyritic andesite showing drak-greenish gray in color. It includes coarse-grained crystals of plagioclass.

Both lava and pyroclastic rocks show strong chloritization and epidotization, and also pyrophyllite and diaspore are observed as alteration minerals.

(2) Tineg Formation

The Formation has a wide distribution next to the Licuan Group Formation I and is exposed in a broad area enclosed by Barrio Patiacan, Barrio Babasig and Mt. Quinali in the western part of the area. It is also found in the east of the Bagset Creek at the eastern end of the area.

The rock shows the facies of dacitic lapilli tuff, decitic coarse-grained tuff and dacite lava in the western part, while in the eastern part, it consists of rhyolite and rhyolitic pumice tuff. It shows different lithologies dependent on the place of distribution. They are, however, considered to belong to the same horizon.

Dacitic lapilli tuff and dacitic coarse-grained tuff are well observed along a mountain trail connecting from Barrio Patiacan to Barrio Pangwew through Babasig. They generally show characteristic tints of pale green to bluish green, and contain abundant lapillis of andesite, rhyolite and silicious rock. Quartz is ubiquitously contained in the groundmass.

They are generally poorly sorted, but the bedding is comparatively well developed. Coarse-grained dacitic tuff is partly observed as the intercalation in lapilli tuff showing distinct bedding, and bluish gray in color.

Dacite lava is distributed centering around the ridge from Barrio Patiacan to Mt. Quinali. It is a porphyritic rock with pale greenish tint with abundant phenocrysts of quartz and plagioclase. Phenocrysts of chloritized hornblende are also observed. It is massive rock with poor development of flow structure.

Rhyolite and rhyolitic pumice tuff is exposed only in the eastern part of the Bagset

Creek. The exposure of lava has not been observed although the distribution has been confirmed by its floats. They are pale grayish white and loose rock showing a weak flow structure, and contains abundant phenocrysts of fine-grained quartz.

Rhyolitic pumice tuff is medium- to coarse-grained tuff containing elongated pumice and fine quartz grains in matrix, and it shows weak welded structure.

(3) Quartz Diorite Porphyry

The rock occurs as a stock penetrating the Licuan Group Formation I having an extent of about 2 km in E-W direction and about 1 km in N-S direction along the main stream of the Balasian River. It is a massive porphyritic rock with light greenish gray to light gray tint, and contains phenocrysts of plagioclass, quartz and chloritized hornblende. Although holocrystalline facies is observed in some parts of this rock, porphyritic texture prevails as a whole. Quartz diorite porphyry generally underwent strong silicification, chloritization and sericitization with pyrite dissemination in places, occasionally showing occurrence of pyrophyllite and diaspore. This is the host rock of the main ore deposits.

The microscopic observation of the representative rock is as follows:

Quartz diorite (a–3319)

Texture:	Holocrystalline and porphyritic texture.
Phenocryst:	Plagioclase, quartz and mafic minerals.
	Plagioclase is large in size with euhedral to subhedral cyrstal form.
	Quartz is anhedral and fine-grained though small in amount.
	Mafic minerals are completely altered.
Matrix:	Quartz, plagioclase and mafic minerals.
	Minerals are fine-grained.

Alteration minerals: Chlorite, epidote, ferrous minerals and sphene.

(4) Dacite

The rock is mainly distributed on the ridge near the vicinity of Barrio Patiacan and at the top of Mt. Quinali. In addition, it occurs at the south end of the surveyed area and other places as stocks and dykes intruding the Licuan Group Formation I, the Tineg Formation and quartz diorite porphyry.

Although the trend of the dykes is mostly concentrated to WNW-ESE system, NNE-SSW system is often observed in the eastern part. It is massive and compact rock showing light-grayish white to gray, occasionally dark gray color.

Phenocrysts of plagioclase, quartz and long prismatic hornblende are usually contained showing distinct porphyritic texture.

Alteration of this rock is very weak compared with quartz diorite porphyry and shows fresh appearance, although silicification is locally observed in the vicinity of Barrio Patiacan.

The result of microscopic observation of the rock which intruded into quartz diorite porphyry at the southern bank of the Balasian River is as follows:

Dacite (b–3350)

Texture:	Crystocrystalline texture.
Phenocryst:	Plagioclase, hornblende, augite and quartz. Plagioclase is euhedral to subhedral and abundant in amount. Hornblende is subhedral and medium-grained. Augite is euhedral to subhedral and small in amount, partly chloritized. Quartz is anhedral and small in amount.
Alteration mineral:	Small amount of chlorite.

(5) Microcrystalline Diorite ∿ Dolerite

This rock is observed as small dykes intruded into the Licuan Group Formation I. The dykes show the main trends of E-W ∿ WNW-ESE, but a trend of NE-SW is partly observed.

Megascopically, these dykes are fine-grained, equigranular and phaneritic, and contain abundant fine-grained mafic minerals.

Alterations of this rock are strong chloritization and epidotization. Especially, at the periphery of dyke, thin veinlets of epidote are often developed in irregular form.

The microscopic observvation of this rock occurred along the Balasian River is as follows:

Dolerite (d–3312)

Texture:	Doleritic texture, holocrystalline.
Forming minerals:	Plagioclase, mafic minerals and quartz. Plagioclase is euhedral to subhedral and medium-grained, abundant in amount. Mafic minerals are completely altered to chlorite and epidote. Quartz is anhedral and fine-grained, small in amount.
Alteration minerals:	Chlorite, epidote, sericite, sphene and ferrous minerals.

2–3 Chemical Composition and Ages of Intrusive Rocks

2–3–1 Chemical Composition of Intrusive Rocks

In order to clarify the chemical composition and nature of the intrusive rocks distributed in the surveyed areas of this phase, three rock samples were taken from the two areas and analyzed. The samples collected are as follows: a sample (b–3143) from quartz diorite distributed in the Manikbel area, a sample (b–3144) from quartz diorite porphyry ∿ dacite dyke intruding quartz diorite in the Manikbel area, and a sample (b–3350) from dacite dyke distributed in the Layacan area.

Table I–2 shows the result of chemical analysis and normative mineral composition (Wt %) calculated from these analytical data.

Various diagrams used in examination and analysis were not shown in this report because the number of samples was only three. However, four kinds of diagram made on all the samples from the project area including these three samples are shown in the consolidated report which are prepared in parallel with this report, and the reader is requested to refer to them.

This table shows that the SiO_2 content of the three samples analyzed range from 57.77% to 62.52%, this belong to the intermediate rock.

The differentiation index (D.I.) is within the range of 49.32 to 55.29 and they are similar to the samples taken in the first and the second phases. On the other hand, the relation between D.I. which shows the extent of the differentiation of magma and oxides in the samples as well as the relation with $MgO - (FeO + Fe_2O_3) - (Na_2O + K_2O)$ correspond well to the characters shown in the samples of the first and the second phases.

From these result, it was proved that all the intrusive rocks analyzed in this phase belonged to the rocks of the calc-alkali series and these rocks can be classified as the products of the middle to later phase of the magmatic differentiation. Further, in the relation of normative orthoclase-albite-anorthite, the samples of this year were plotted within the range shown by the samples taken by the first and the second phase surveys having shown no peculiar range nor trend.

As a result, it was confirmed that the intrusive rocks distributed in the surveyed areas of this phase were formed by the same plutonic activities as the plutonic and hypabyssal rocks distributed widely in the project area.

2–3–2 Ages of Intrusive Rocks

In order to know the intrusion ages of the intrusive rocks exposed in the area, K-Ar

Table 1–2 Result of Chemical Analysis and Normative Mineral Composition of Intrusive Rocks

		Sample No.	b–3143	b–3144	b–3350
		Location	Mamising Cr. (Manikbel)	Mamising Cr. (Manikbel)	Balasian R. (Layacan)
		Rock Name	Quartz diorite	Dacite dyke	Dacite dyke
Chemical Composition		SiO_2	57.77	62.52	60.08
		TiO_2	0.71	0.37	0.50
		Al_2O_3	17.55	16.24	17.64
		Fe_2O_3	2.64	1.64	2.76
		FeO	4.81	4.28	3.81
		MnO	0.18	0.16	0.17
		MgO	3.35	2.13	2.75
		CaO	6.53	5.56	7.02
		Na_2O	2.54	2.15	3.35
		K_2O	2.33	1.30	0.58
		P_2O_5	0.25	0.12	0.21
		$H_2O(+)$	0.95	2.65	0.71
		$H_2O(-)$	0.08	0.36	0.36
		Total	99.69	99.48	99.94
CIPW Normative Minerals		Q	13.40	27.47	18.36
		C	–	1.47	–
		or	13.77	7.68	3.43
		ab	21.49	18.19	28.35
		an	29.60	26.80	31.38
	di	wo	0.48	–	0.87
		en	0.27	–	0.51
		fs	0.19	–	0.31
	hy	en	8.07	5.30	6.34
		fs	5.62	6.19	3.89
	ol	fo	–	–	–
		fa	–	–	–
		mt	3.83	2.38	4.00
		il	1.35	0.70	0.95
		ap	0.58	0.28	0.49
		Total	98.66	96.47	98.87
		Q+or+ab	48.66	53.34	50.13
		D.I.	49.32	55.29	50.70

dating was made on the three samples which were chemically analyzed. The results show, as shown in Table I–3, that the quartz diorite taken from the Manikbel area shows 15.9 ± 0.8 m.y., and quartz diorite porphyry – dacite dykes distributed in both the Manikbel and Layacan area show 10.5 ± 1.1 ∿ 9.8 ± 2.0 m.y. These results seem to suggest that the age of the intrusion of these rocks are determined as Middile Miocen age.

The result of dating conforms with the time of activities estimated from the occurrence and process of differentiation of each intrusive rock. Especially in the Manikbel area, the hypothesis age result of the field observation that the quartz diorite which is considered to be the middle phase of the magmatic differentiation process (D.I. 49, 32) is intruded by the dacite dyke to be the later phase (D.I. 55.92) was confirmed in terms of age. Furthermore, the age of 15.9 ± 0.8 ∿ 9.8 ± 2.0 m.y., the dating result this phase is sufficiently consistent with 26.3 ± 1.8 ∿ 9.8 m.y., the dating result of 17 samples taken from the various intrusive rocks distributed in the project area, and there is no inconsistency found from the standpoint of times (cf. the consolidated report).

2–4 Alteration

In order to investigate the rock alteration observed in both areas of Manikbel and Layacan, X-ray diffractive analysis was carried out on the total 191 samples, having taken 132 samples from the Manikbel area (67 samples from the surface and 65 samples from drilling core) as well as 59 surface samples from Layacan area.

Although the result of the analysis of the whole samples can be seen in Table A–2–1 ∿ 3, the summary of the result of each surveyed area is described in the following chapter.

2–4–1 Manikbel Area

The result of the X-ray diffractive analysis of 67 samples taken from the surface is as shown in Table A–2–1, in which chlorite, sericite, epistilbite, stilbite and laumontite can be cited as the alteration minerals.

Chlorite is detected from almost all samples, and chloritization is one of the most common alteration as well as silicification. Epidote was observed in the field survey together with chlorite, but it was not hardly detected as the result of diffraction.

While sericite was detected mainly from the samples taken throughout the Mamising Creek basin. At the middle stream of the Nagasasan Creek, pyrite dissemination and veinlet-network mineralized zone associated with small amount of copper minerals are distributed along the Mamising Creek, and sericite distribution is almost consistent with them. However,

Table I–3 Result of K–Ar Dating

Sample No.	Rock Name	% K	$\%\,^{40}Ar^{Rad}$	SCC $^{40}Ar^{Rad}$ /gm x 10^{-5}	Isotopes Age (m.y.)
b–3143	Quartz Diorite	1.35 1.36	33.2 35.3	.083 .086	15.9 ± .8
b–3144	Dacite	1.31 1.32	44.5 42.7	.053 .055	10.5 ± 1.1
b–3350	Dacite	.77 .78	31.8 31.8	.030 .030	9.8 ± 2

Remarks : $\text{Isotopes Age (m.y.)} = \frac{1}{\lambda\epsilon+\lambda\beta} \ln \left[\frac{\lambda\epsilon+\lambda\beta}{\lambda\epsilon} \times \frac{^{40}Ar^{Rad}}{^{40}K} + 1 \right]$

$\lambda\epsilon \quad 0.581 \times 10^{-10} yr^{-1}$

$\lambda\beta = 4.962 \times 10^{-10} yr^{-1}$

$^{40}K = 1.167 \times 10^{-4}$ atom per atom of natural potassium

* K-content in this rock was too little to date

sericite was not detected from some samples taken even in the mineralized zone, especially, it was hardly detected from the samples of stock-shaped granodiorite. Local pyrite dissemination zones are found at midstream of the Nagasasan Creek, with which the distribution of sericite is harmonious.

The distribution of zeolites approximately coincides with that of sericite, which also is roughly consistent with the distribution of mineralized zone.

On the other hand, the result of the analysis of 65 samples taken from drilling core, which is shown in Table A–2–2, shows the decrease of sericite compared with the surface samples and remarkably abundant of epidote and zeolites. These variation of alteration feature is very noticeable. In particular, laumontite has been detected from almost all the samples notwithstanding the rock type. Sericite decreases remarkably, and it was observed in the RPJ-1 hole and nothing was detected in both holes of RPJ-2 and RPJ-3 which were predominated with stocks or dykes.

From the result of the X-ray diffractive analysis, it can be said that the rock alteration in the Manikbel area is characterized by sericitization and remarkable occurrences of zeolites, and it is considered that these alterations are caused by the thermal metamorphism accompanied by mineralization judging from the distribution of these alteration minerals.

Potash alteration which is often observed in porphyry copper deposit could not be observed at all and zoning of alteration minerals, which was an object of the survey, was impossible because of scant occurrence of the types of alteration minerals.

2–4–2 Layacan Area

The result of diffractive analysis of 59 samples taken from the Layacan area is shown in Table A–2–3. As known from the table, zeolites are scarcely detected, but kaolinite, pyrophyllite, diaspore and alunite are detected in abundance showing a different type of alteration compared with the Manikbel area.

The distribution feature of the main alteration minerals is as follows:

Although sericite was detected from most of the samples, its distribution is limited to the area such as along the Balasian River and at the upper stream of the Segseg Creek in the southern part of the area. The distribution along the Balasian River is well consistent with the extent of distribution of quartz diorite porphyry exposed along the River, and it is also well consistent with the extent of the mineralized zone which had been known to occur along the Balasian River and Segseg Creek containing vein type deposits.

The distribution of alteration minerals such as pyrophyllite, diaspore and kaolinite is similar to that of sericite, and they are contained in abundance in the samples taken from the Balansian River, the downstream of its tributaries and the upstream of the Segseg Creek.

From these facts, it is considered that the alteration in the Layacan area is characterized by remarkable occurrences of abundant sericite, pyrophyllite and diaspore together with common occurrence of silicification, chloritization and epidotization. This suggests that these are due to hydrothermal alteration associated with mineralization.

Although the alteration of the both areas of Manikbel and Layacan is hydrothermal alteration associated with mineralization, the assemblage of alteration minerals in both areas takes different patterns: that of the Manikbel area is sericite-zeolite, while that of Layacan area is sericite- pyrophyllite-diaspore.

Since it is insufficiently known what is the cause of such difference of alteration, the difference of types of ore deposit and host rocks could be one of the causes.

2–5 Geological Structure

It is quite difficult to know the detailed geological structure of the areas of both Manikbel and Layacan because these survey areas of this phase were narrow; the former being 15 sq.km and the latter 10 sq.km, and also because most of Manikbel area is overlain by plutonic rocks. However, as mentioned already, both areas sit on the characteristic position from the standpoint of regional geological structure, in which a part of structural properties including numerous faults and dykes is shown.

2–5–1 Manikbel Area

The surveyed area of this phase is characterized by the direction of intrusive rocks, such as the batholithic quartz diorite-granodiorite masses, the faults developed in the Licuan Group Formation II, especially those developed in the surrounding area of the stock-shaped granodiorite, and the trend of intrusion of a number of dykes such as quartz diorite porphyry and dacite.

Although the trend of intrusion of batholithic rocks is difficult to determine deducing from the distribution within the area, it is considered to be in NNE-SSW direction from the result of surveys on the first and second phase, which is the oldest and predominating structure. The trend of granodiorite stock which penetrated quartz diorite at midstream of the Mamising Creek shows NE-SW direction, which is consistent with the general trend of the batholith.

From these fact, it can be said that the structures of NNE-SSW to NE-SW systems indicated by batholithic masses and granodiorite stocks are the oldest and the major structure in the surveyed area.

The faults in the area include those of NE-SW ∿ ENE-WSW systems having relatively short strike length and those of NNW-SSE system which are large in scale and cut the former.

The main period of activity of the two fault systems is after the intrusion of the dykes of quartz diorite porphyry and dacite.

It is considered, however, that the faults had been formed potentially before the intrusion of dykes, since some dykes were intruded in the same direction to the faults of NNW-SSE system and that some are considered to have been intruded along the pre-existed fault.

Although most of the dykes of quartz diorite porphyry-dacite show the trend from NNW-SSE to WNW-ESE concentrating in the surrounding area of stock-shaped granodiorite, only few dykes show the directions of E-W and NE-SW.

The faults are great in number though small in scale. Therefore, it can be assumed that innumerable small scale structured zones were formed in the surroundings of the stock associated with its intrusion, which provided the field of intrusion of dykes. It is evident that the intrusion period of dykes is later than that of the stock.

From these evidences, the geological structure of the area is summarized in terms of geologic history as follows: a fundamental structure of NNE-SSW existed in the district formerly, then the along which batholithic quartz diorite-granodiorite were intruded along this structure. As the result of intrusion of the batholith, the structure such as NE-SW system and NW-SE system which is in the conjugate relation with the former were formed, and along the structure of NE-SW system, granodiorite stock intruded. The intrusion of the stock affected and expanded the structure of NW-SE system which had been formed around the stock and after that numerous dykes of quartz diorite porphyry-dacite occurred along this were in structures and that the fault movement roughly parallel with the trend of dykes was caused by the aftermath of intrusion of dykes.

2–5–2 Layacan Area

Although it is considered that the area corresponds to a part of the core of the Cordillera Central uplift zone having been widely overlain by the Licuan Group Formation I which is the oldest formation within the project area, it is notable that no distribution of plutonic rocks has been known in contrast to the Manikbel area mentioned above. And also the geological structure is mainly shown by the numerous faults of NNE-SSW system and a number of intrusive rocks which take the form of stock and dyke running parallel and perpendicular to the faults.

The faults observed in the area consist of two system faults. One is the small scale faults of E-W ∿ WNW-ESE system cutting the Licuas Group Formation I, the Tineg Formation and the stocks and dykes which penetrated the above formation, and the other is the numerous large scale faults of NNE-SSW and N-S systems cutting the faults of E-W system. The formers have short strike length and do not have great significance. However, since the structure which belong to this system is consistent with the direction of intrusion of many intrusive rocks as mentioned later, it has great significance as the field for intrusion of stocks and dykes.

The latter coincides with the direction of the most predominating structure within the project area, all of which are fault having long strike length. Especially, the fault found in the center of the surveyed area has a great extent which controlled the continuation of the Tineg Formation toward the east and also controlled the eastern periphery of the large mass of quartz diorite.

On the other hand, numerous stocks and dykes in the area such as dacite, microcrystalline diorite to dolerite were intruded in the directions of NW-SE to WNW-ESE, although some dykes showed the direction of NNE-SSW. This indicates that the structure of NNE-SSW system is a younger structure in contrast to the fault.

From the above, the geological structure of this area can be summarized as follows: as the result of intrusion of the batholithic quartz diorite of NNE-SSW system found in the northern part of the area, a number of fractured zones parallel and perpendicular to the trend of the plutonic masses were formed, along which numerous stocks and dykes were intruded mainly in the directions of NW-SE and WNW-ESE which are perpendicular to the general trend of the batholith.

It is considered that the structure of NNE-SSW system formed at the time of batholith intrusion, was activated as was the fault movement in the process of intrusion, ascencion and stabilization having resulted into the formation of latest and most extensive structure.

3. ORE DEPOSITS

3–1 General Statement

As a result of the Phase I and II surveys, occurrence of a number of mineralized zones including the two ore deposits which are under construction work for development have been confirmed in the project area. All these mineralized zones contain copper as the main ingredient which is roughly divided into three types such as network-dissemination type, vein type, and skarn type. The network-dissemination type is greatest in number and scale. The two deposits under preparation for development are both network-dissemination type.

While a number of these mineralized zones found in the area are distributed almost throughout the whole area except at the southeastern basin of the Chico River, a remarkable tendency of controlling the mineralized zones are concentrated within the plutonic rocks or in the surrounding areas. This observation readily leads to the understanding that the mineralized zones were formed under a characteristic geological environment.

From the result of a number of observations of the mineralized zones in Phase I and II, inductive consideration of the environment of formation of the zones lead to the conclusion that the most suitable geological environments for ore formation are the areas of vigorous activity of hypabyssal rocks especially along the periphery of acidic plutonic rocks. Areas within or surrounding plutonic or hypabyssal rocks which take the form of stock or dyke are also considered.

Although the field survey of the Batong Buhay mine, the biggest ore deposit within the project area, was impossible because of critical peace and order situation, it is clear from existing data that it was a porphyry copper type network-dissemination deposit.

The three mineralized zones of the Manikbel, Malibcong and Lacub which were originally selected as the targets of the Phase III survey by the surveys up to Phase II on the background of the geological environment mentioned above. The survey of two areas such as Malibcong and Lacub became impossible because of peace and order condition.

The Layacan mineralized zone which had been originally ranked No. 4 next to Lacub mineralized zone became the target of survey. These four mineralized zones show the same geological environment though different in the type of ore deposit.

The survey of this phase was carried out with the main themes such as to clarify the geological environment and mechanism of formation of mineralized zones by grasping more in detail the scale, grade and nature of mineralized zones distributed in the Manikbel and Layacan areas, and to make comprehensive evaluation of them. Therein, the actual condition of mineralization of the two areas was elucidated, and a basic policy for future exploration and development was established. The details of the areas will be described in the following section. The result of chemical analysis of the ore samples taken in both areas is shown in Table A–4.

3–2 Mineralized Zone of Manikbel Area

The mineralized zones observed in the area, as shown in Fig. I–3, consist of network-dissemination type and vein type deposits. The former can be observed in numerous outcrops distributed in the Mamising Creek basin, which the latter are found in several ore veins located on the northern bank of the Manikbel River 700 m east and west of Barrio Ud-Udiao and at the outcrops distributed to the northeast of Barrio Nagasasan. The outline of the outcrops is shown in Table I–4.

For the group of outcrop, Marcopper Mining Corporation and other companies made exploration in the past, and also BMG carried out prospecting by drilling having bored six holes.

3–2–1 Mineralized Zone of Mamising Creek

The mineralized zone consists of more than ten outcrops exposed at the eastern side of the middle stream of the Mamising Creek and in its surrounding tributaries. The extent of distribution of the outcrops confirmed is about 1 km x 1.2 km in N-S and E-W directions, respectively.

Geology of the area consists of andesite lava of the Licuan Group Formation II, batholithic quartz diorite intruding the andesite lava, stock of granodiorite intruding the quartz diorite, and dykes of quartz diorite porphyry-dacite which penetrated all the above rocks. Among these intrusive rocks, the stock of granodiorite intruded into quartz diorite in parellel direction to its rim, and quartz diorite porphyry-dacite dykes show their general trend to be perpendicular direction to rim of the quartz diorite mass. Thus it is considered that the intrusion of stocks and dykes took place under the control of structures brought about by the intrusion of the batholith.

The segregated mineralized outcrops are found mainly in the peripheral area of granodiorite stock, while some are observed in andesite lava and within the granodiorite stock itself.

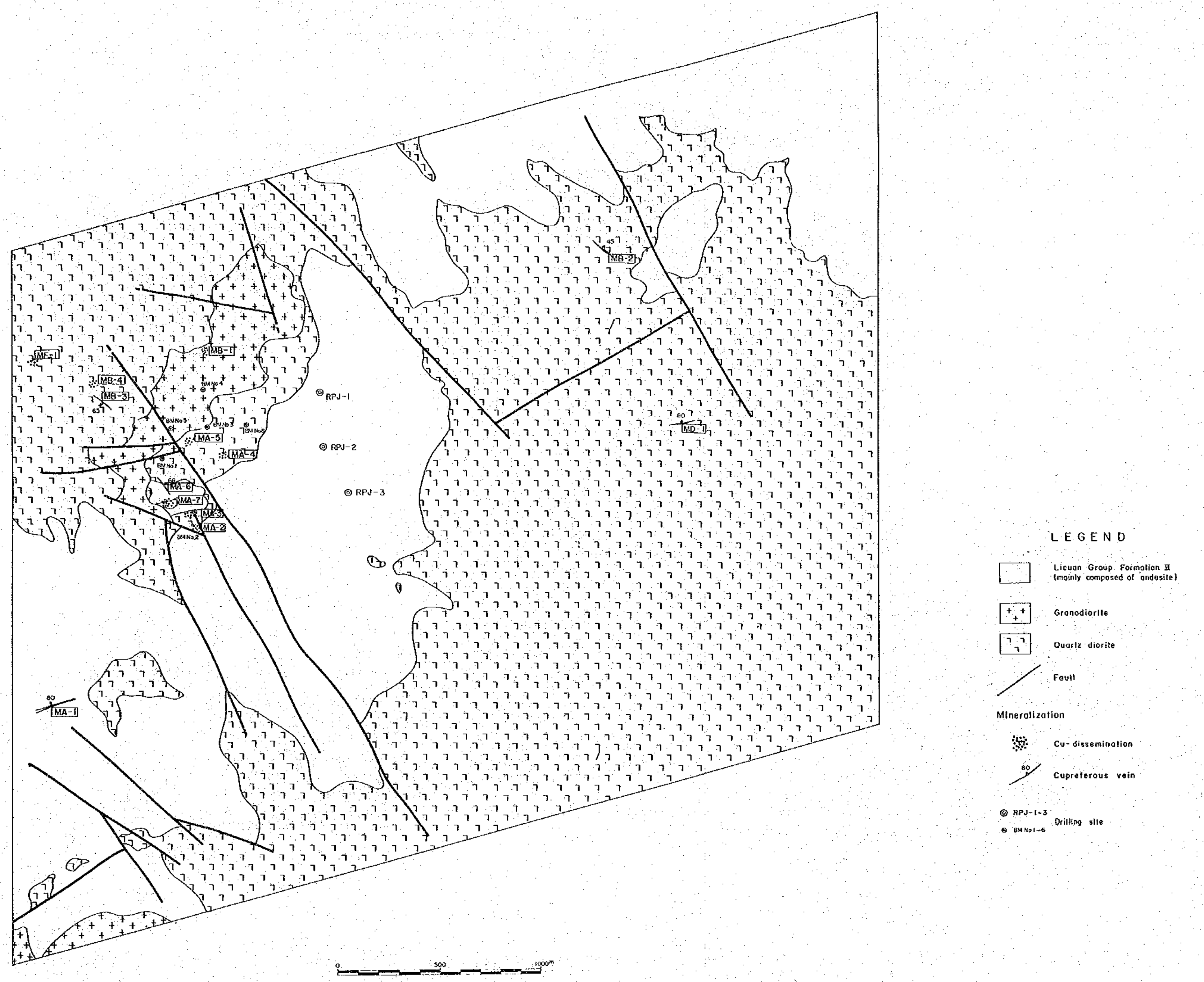


Fig. I—3 Distribution Map of Mineralized Zones in Manikbel Area

Table I–4 Summary of Mineralized Outcrops in Manikbel Area

No.	Outcrop No.	Location	Type	Outcrop Scale or Vein Width	Ore Minerals	Gangue or Alteration Minerals	Host Rock	Analytical Results							Occurrence
								Sample No.	V.W	Au	Ag	Cu	S	Fe	
1	MA–1	In a tunnel by the lower stream of the Manikbel River in Manikbel Area.	Vein	V.W. : max 0.8^{m}	Pyrite, Chalcopyrite	Quartz	Andesite	a–3101 a–3102 a–3103 a–3104 a–3105	0.80^{m} – 0.20 – –	$0.2^{g/t}$ 2.4 0.5 0.1 –	$38.6^{g/t}$ 64.4 37.2 3.2 –	$4.82^{\%}$ 16.39 6.50 0.26 0.16	$5.30^{\%}$ 16.56 7.98 3.79 14.26	– % – – – –	This tunnel was explored before by Marcopper Mining Corporation. Three pyrite-quartz, or pyrite-clay-quartz veins trending NE–SW was observed in this tunnel.
2	MA–2	About six hundred meters north of barrio Ud-udiao, on the eastern side of the lower-middle stream of the Mamising Creek.	Diss. ~ Stringers Net.	O.S. : $4 \sim 5^{m}$	Malachite, Azurite, Pyrite	Quartz, Chlorite	Quartz diorite	a–3121	–	0.0	2.8	2.30	0.10	–	This is a mineralized outcrop consisting of dissemination to stringers and network of malachite, azurite and pyrite. It trends approximately N 15° W.
3	MA–3	About one hundred meters north of MA–2 in the eastern side of the lower stream of the Mamising Creek.	Diss. ~ Stringers Net	O.S. : 2^{m}	Malachite, Pyrite	Quartz, Chlorite	Quartz diorite	a–3122 (A) a–3122 (B)	– –	0.2 0.1	12.5 5.0	0.45 0.82	0.38 0.15	– –	It is a very small-scale outcrop consisting of the same type of mineralization as MA–2. It trends approximately N 20° W.
4	MA–4	About three hundred meters north-northeast of MA–3 in the eastern side of the middle stream of the Manikbel River.	Diss. ~ Stringers Net	O.S. : $10^{m} \times 15^{m}$	Malachite, Azurite, Pyrite	Quartz, Chlorite, Stilbite	Quartz diorite	a–3129 a–3130 a–3131	– – –	– – –	– – –	0.44 11.15 0.47	0.16 0.28 0.07	– – –	This is a large-scale outcrop consisting of dissemination to stringers network of malachite, azurite and pyrite. There are two trenches explored before by Marcopper near this outcrop.
5	MA–5	About two hundred meters west of MA–4 in the eastern side of the middle stream of the Mamising Creek.	Diss.	O.S. : 2^{m}	Pyrite	Quartz, Chlorite	Granodiorite	a–3132	–	–	–	0.45	0.12	–	It is a very small-scale outcrop of pyrite-disseminated granodiorite. Chemical analysis of one sample (a–3132) collected from this outcrop shows copper (Cu) content of 0.45%.
6	MA–6	About two hundred meters northwest of MA–3 in the side of the middle stream of the Mamising Creek.	Vein	V.W. : 0.1^{m}	Pyrite, Chalcopyrite, Malachite	Quartz, Chlorite, Sericite	Andesite	a–3143 (A) " (B) " (C) " (D)	– – – –	0.1 – – –	51.9 – – –	27.87 5.93 11.37 8.00	22.41 0.12 10.68 7.25	– 23.55 – 38.04	It is an outcrop of chalcopyrite-pyrite vein striking N 36° W and dipping 68° NE.
7	MA–7	About one hundred meters south of MA–6 in the eastern side of the middle stream of the Mamising Creek.	Diss. with Vein	O.S. : $10^{m} \times 1.5^{m}$	Malachite	Quartz, Chlorite, Sericite	Andesite Quartz diorite	a–3145 a–3148 a–3149 a–3151	1.50 – – –	0.0 – – –	1.2 – – –	0.43 0.87 0.49 0.08	0.06 0.04 0.04 0.06	– – – –	It is an outcrop exposed by our trenching. It is composed of argillized quartz diorite with malachite stains and white clay veinlets.
8	MB–1	By the middle stream of the Agalo Creek (upper half stream of the Mamising Creek)	Diss.	O.S. : $5^{m} \times 1^{m}$	Pyrite	Chlorite, Sericite	Granodiorite	b–3106	–	–	–	0.14	5.38	–	This is a small-scale outcrop of pyrite-disseminated argillized granodiorite. No copper mineralization was macroscopically found in this outcrop. However, the result of the chemical analysis of the sample (b–3106) collected from this outcrop shows 0.14% Copper.
9	MB–2	By the lower stream of the Kulan Creek, a branch of the Nagasasan Creek.	Vein (?)	V.W. : 0.2^{m}	Pyrite, (Chalcopyrite?)	Sericite, Laumontite	Quartz diorite	b–3114	–	–	–	1.32	16.97	–	It is an outcrop of pyritized, argillized zone trending N 50° W, dipping 45 NE in quartzdiorite.
10	MB–3	In the western side of the middle stream of the Mamising creek, about five hundred meters west-northwest of MA–5.	Vein	V.W. : max. 0.15^{m}	Pyrite, Chalcopyrite, Malachite	Quartz, Calcite, Chlorite	Quartz diorite	b–3117 b–3126 b–3127	– 0.15 –	– – –	– – –	8.52 1.91 0.62	7.71 1.40 0.58	– – –	This is one of the outcrop exposed by our trenching. It is a fissure filling consisting of chalcopyrite gossan vein trending N 50° W, dipping 65° SW.
11	MB–4	In the western side of the middle stream of the Mamising Creek, about one hundred meters of MB–3.	Diss.	O.S. : $2^{m} \times 2^{m}$	Malachite, Azurite	Quartz, Sericite, Chlorite, Epidote	Quartz diorite	b–3130 b–3132 b–3133	– – 0.50	– – 0.0	– – 38.8	4.80 1.75 4.81	0.07 0.03 0.07	– – –	This is a small-scale outcrop consisting of highly silicified, argillized zone with a large amount of malachite and azurite in altered quartz diorite.
12	MD–1	By the lowermost stream of the Malwa Creek, a branch of the Manikbel River, in the eastern part of Manikbel area.	Veinlet	V.W. : 0.03^{m}	Pyrite, Chalcocite		Quartz diorite	d–3113	0.03	0.0	5.7	2.98	37.20	–	This outcrop is composed only of a chalcocite-pyrite veinlet along a fault zone (w= 0.25m) trending N 80° E and dipping 80° NE.
13	MF–1	By the upper stream of the Mabileng Creek.	Diss. with Vein	30^{m} along Cr. V.W. : 0.05^{m}.	Pyrite, Chalcopyrite	Quartz	Quartz diorite	f–3124	0.05	–	–	1.41	3.35	–	This outcrop is composed of dissemination of pyrite and chalcopyrite with pyrite-quartz veinlets trending N 35° W / 64° NE.

The result of observation of the main mineralized outcrops is as follows.

(1) MA–2 Outcrop

It is located on the eastern slope, downstream of the Mamising Creek about 600 m to the north of Barrio Ud-Udiao. It is a small outcrop about five meters long and 1.5 m width consisting of pyrite dissemination-fine network zone formed in porphyritic quartz diorite. It is associated with malachite and azurite, but no chalcopyrite was observed. Pyrite bearing quartz veinlets are observed in small amount. Although the trend of extension is not distinct, the bearing of most quartz veinlets is N15°W seems to show the trend of extension.

The result of analysis of a lump ore sample rich in malachite taken from the outcrop is,

Cu 2.30%, S 0.10%, Au 0.0 g/t, Ag 2.8 g/t,

and sulfide mineral is very small in amount.

Microscopic observation of the sample showed that most of the sulfide was replaced by green copper minerals such as malachite. Very small amount of chalcopyrite is scattered in a vermicular shape. Quartz diorite of the host rock underwent remarkable silicification and chloritization.

(2) MA–3 Outcrop

The outcrop is exposed about 100 m north of MA–2 outcrop, at the eastern margin of BM · No. 2. Mineralized outcrop, similar to MA–2, consists of pyrite dissemination-fine network zone formed in porphyritic quartz diorite, and a quartz vein, 20 ∿ 30 cm width, containing very small amount of pyrite, is found at the eastern end of the outcrop showing the bearing of N 20°W and 70°E. In the part of dissemination and network, abundant malachite and very small amount of azurite were formed. The extent of the outcrop is 5 m in length and 2 m in width, where strike of the quartz veins is considered to show the trend of extension of the mineralization.

At the center of the outcrop, a small test pit extending toward N 10°W with extension of 2 m is found, along which dissemination of pyrite and malachite is observed.

The result of analysis of samples such as pyrite bearing quartz vein (1–3122 (a)) and a sample of lump ore of malachite and pyrite (a–3122 (b)) is as follows:

	Cu %	S %	Au g/t	Ag g/t
a–3122 (a)	0.45	0.38	0.2	12.5
a–3122 (b)	0.82	0.15	0.1	5.0

Although a–3122 (b) was observed microscopically, sulfide minerals were hardly observed as in sample a–3121 mentioned above.

According to the data of BMG, drill hole BM · No. 2 (152.0 m in length) encountered the Cu mineralization at the depth of 21.30 m. Assay of copper was carried out every five feet interval from the top of the mineralization to the bottom of the hole. The length of sections in which the copper grade of each sample is more than 0.30% and the average grade are shown in the following.

Depth (m)	Length of sections(m)	Average grade of Cu(%)
21.30 ∿ 27.35	6.05	0.41
28.90 ∿ 31.90	3.00	1.24
63.85 ∿ 66.85	3.00	0.36
106.40 ∿ 117.05	10.65	0.36
124.65 ∿ 133.75	9.10	0.40

Among these, the mineralization up to about 32 m is assumed to correspond to the downward extension of the outcrop downwards. The section of 28.90 ∿ 31.90 m showing a higher copper grade is considered to be local from the assay grades shown in the upper and lower sides.

(3) MA–4 Outcrop

The outcrop is exposed at a small ridge on the eastern slope in the midstream part of the Mamising Creek extending 15 m N-S direction and 10 m E-W. Small test pits, 3–5 m in length, were excavated toward the center of the mineralization from both ends of the outcrop.

The outcrop is characterized by the dissemination of pyrite and malachite in the country rock of remarkably silicified and chloritized quartz diorite, particularly the mafic minerals. Malachite is often observed as films or micro-veinlets filling the fine cracks in the country rock. Azurite is found in abundance with the concentration of malachite. Copper sulfide minerals, however, have not been observed megascopically.

The occurrence of minerals is quite similar to those of the outcrops such as MA–2 and MA–3 described above.

The assays of three samples such as a lump ore of malachite-pyrite-quartz veinlet (a–3129), a ore of malachite-azurite (a–3130) and a ore containing a small amount of malachite (a–3131) are shown in the following.