REPUBLIC OF THE PHILIPPINES

REPORT ON GEOLOGICAL SURVEY OF NORTHWESTERN LUZON

CONSOLIDATED REPORT

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 a 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).

The survey had been accomplished under close cooperation with the Government of the Republic of the Philippines and its various authorities within a period of three years, 1979 ~ 1981.

This report summarizes the results obtained through the period of three years.

We wish to express our appreciation to all of the organizations and members who bore the responsibility 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 Philippines.

September 1981

Keisuke Arita

President

Japan International Cooperation Agency

Masayuki Nishiie

President

Metal Mining Agency of Japan

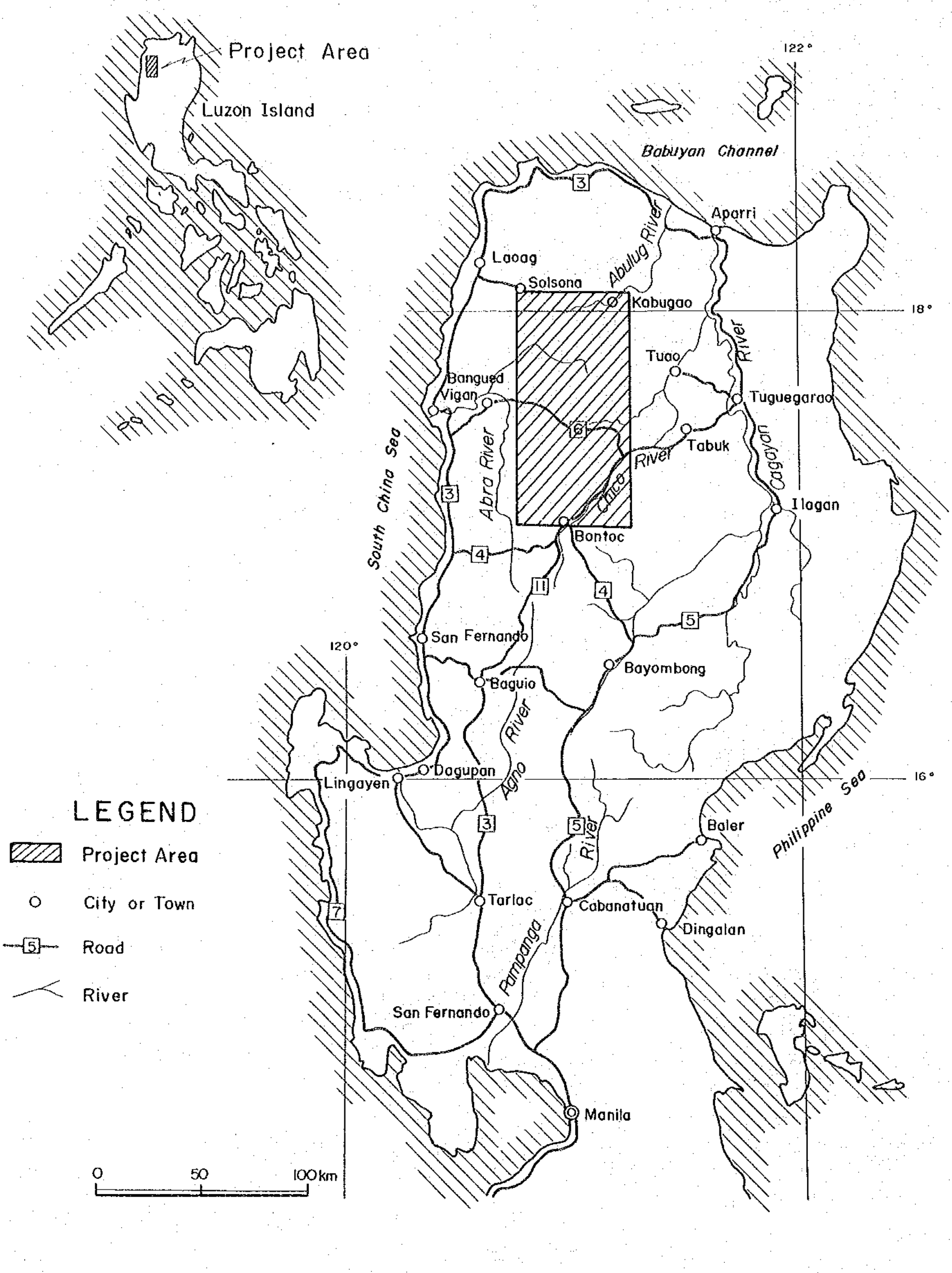

Fig. 1 Location Map of Project Area

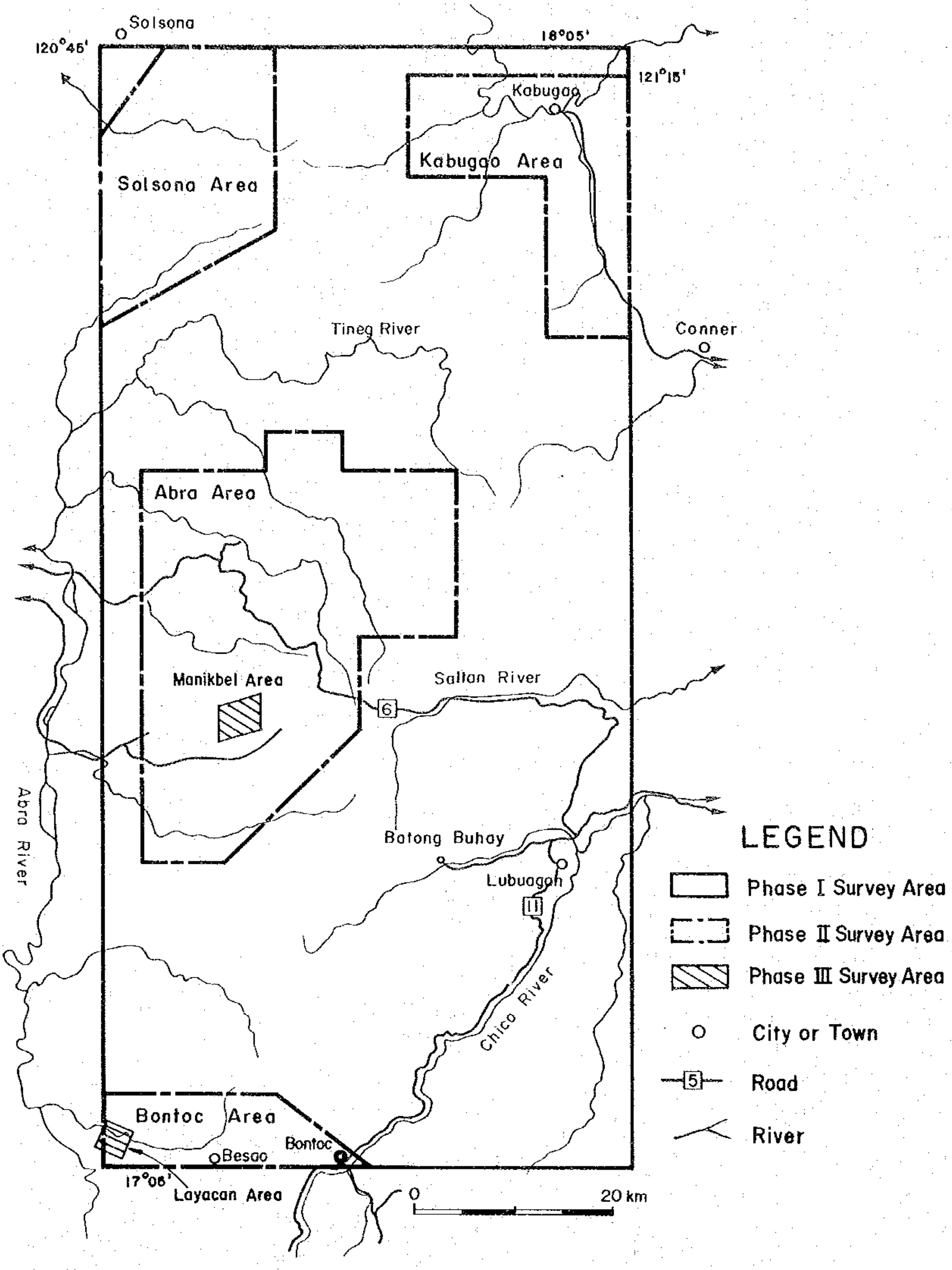

Fig. 2 Location Map of Survey Area

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ABSTRACT

The survey of the Collaborate Mineral Exploration Project in Northwestern Luzon, Philippines was conducted to clarify the detailed occurrences of ore deposits and to evaluate comprehensively their potentialities for development by making clear the mutual relationship among stratigraphy, geological structure, igneous activity and mineralization.

In order to achieve these purposes, the geological, geochemical and geophysical surveys and drilling exploration were carefully done within a period of three years, 1979 – 1981.

From the results of the geological survey, the sequence of the altered volcanic and pyroclastic rocks which had been lumped together as the undifferentiated Cretaceous to Paleogene System were stratigraphically classified as the Eocene basaltic to andesitic volcanic rocks and the Oligocene dacitic volcanic rocks, and the stratigraphy of the project area has been established. The intrusive rocks widely scattered in the survey area were lithologically divided into several rock facies by microscopic observation, chemical analyses and K-Ar dating. The results of these analytical investigations clarified the lithological classification, chemical composition and ages of various intrusive rocks.

Furthermore, the occurrence of numerous ore deposits and mineralized zones were confirmed to be distributed in this area and their distribution features, scale and nature were revealed in detail by the geological investigations during three years.

Based on the above-stated survey results, it has been clarified that the project area consists mainly of the volcanic and its pyroclastic rocks classed as Eocene to Miocene time and the large scale plutonic intrusive masses with various stocks and dykes which are dated as Late Oligocen to Middle Miocene (26.3 – 9.8 m.y.), and the area is considered to be equivalent to the axial zone of the Cordillera Central uplift zone. The mineralization occurs as dissemination-network and vein types in the intermediate to acidic plutonic-hypabyssal intrusive masses and their peripheral volcanic rocks. The principal ore minerals are chalcopyrite, bonite and pyrite, but malachite, azurite and a small amount of covellite are observed at outcrops as the secondary minerals.

The geochemical surveys for stream sediments and soil were carried out to delineate promising area for ore deposits in the whole project and selected areas, and numerous anomalous zones were obtained along the marginal part of the plutonic intrusion masses distributed in each surveyed area. The results obtained show that the geochemical anomalous zone are well consistent with the distribution area of mineralized zones and suggest

that the geochemical stream sediments survey is evidently effective method to delineate promising area from wide unsurveyed or reconnaissance surveyed areas and soil survey with higher sampling density is also effective to confirm the extent of mineralized zone and the intensity of mineralization.

The IP electric survey was conducted in the two promising areas selected by the geological and geochemical investigations and remarkable FE anomalous zones were detected in the distribution area of mineralized zone and their vicinities. One of these high FE anomalous zones were examined its extent towards depth and nature by drilling. From results of drilling, the anomalous zone was proved to be composed mainly of network zones of numerous film- or hair-shaped pyrite. The IP electric survey is the most effective prospecting method in defining the lateral and vertical extent of mineralized zones with abundant sulfide minerals.

The Complex Resistivity survey was also carried out using the IP survey lines to define the kind of minerals consisting of the sulfide concentrated zone, especially to discriminate chalcopyrite from that zone. However, no sufficient result was obtained because of only small amount of chalcopyrite confirmed by drilling.

The drilling exploration was carried out to confirm the continuity of the mineralized and FE anomalous zones. Three holes with total length of 932.20m, were drilled and pyrite disseminated zone to be associated with small amount of chalcopyrite considered to be the extension of the mineralized zone encountered in the RPJ-1 hole. In the other two holes, RPJ-2 and RPJ-3, no mineralized zone was observed.

As mentioned above, the project started from the preliminary survey of 4,300 sq. km^2 area and it was narrowed down, step by step, to the promising area by the various method of survey measurements and the final phase which ended in the detailed survey of two areas (25 sq. km) culminated the project this year.

Although the mineralized zone to which the drillings were done, was enriched at the outcrop by the formation of high grade secondary copper minerals, only pyrite disseminated zone with small amount of primary copper minerals were observed at the depth. Therefore, it was concluded from the results obtained that no significant changes will be obtained from developing further the area at this stage.

PART Ⅰ INTRODUCTION

1. OUTLINE OF SURVEY

1–1 Development of Affairs and Purpose of Survey

A collaborative mineral exploration in the Republic of the Philippines had been conducted in Eastern Mindanao (1972 ~ 1974) and Northeastern Luzon (1975 ~ 1977) by Bureau of Mines and Geo-Sciences (hereinafter referred to as BMG), Philippines, and Metal Mining Agency of Japan (hereinafter referred to as MMAJ). Through these two projects, extensive and enormous basic data on geology and mineral resources had been obtained. These undertakings moreover, contributed effectively to the proper selection and improvement of BMG projects.

Based on the above-mentioned beneficial results, BMG requested to the Government of Japan to conduct geological and mineral exploration surveys in northwestern part of Luzon Island as the third project. The proposed area has been considered to be higher potential zone for mineral resources because of being a similar geological environment to the Baguio Mineral District. However,that area is still unsurveyed area systematically although only fragmentary surveys for geology and ore deposits had been carried out.

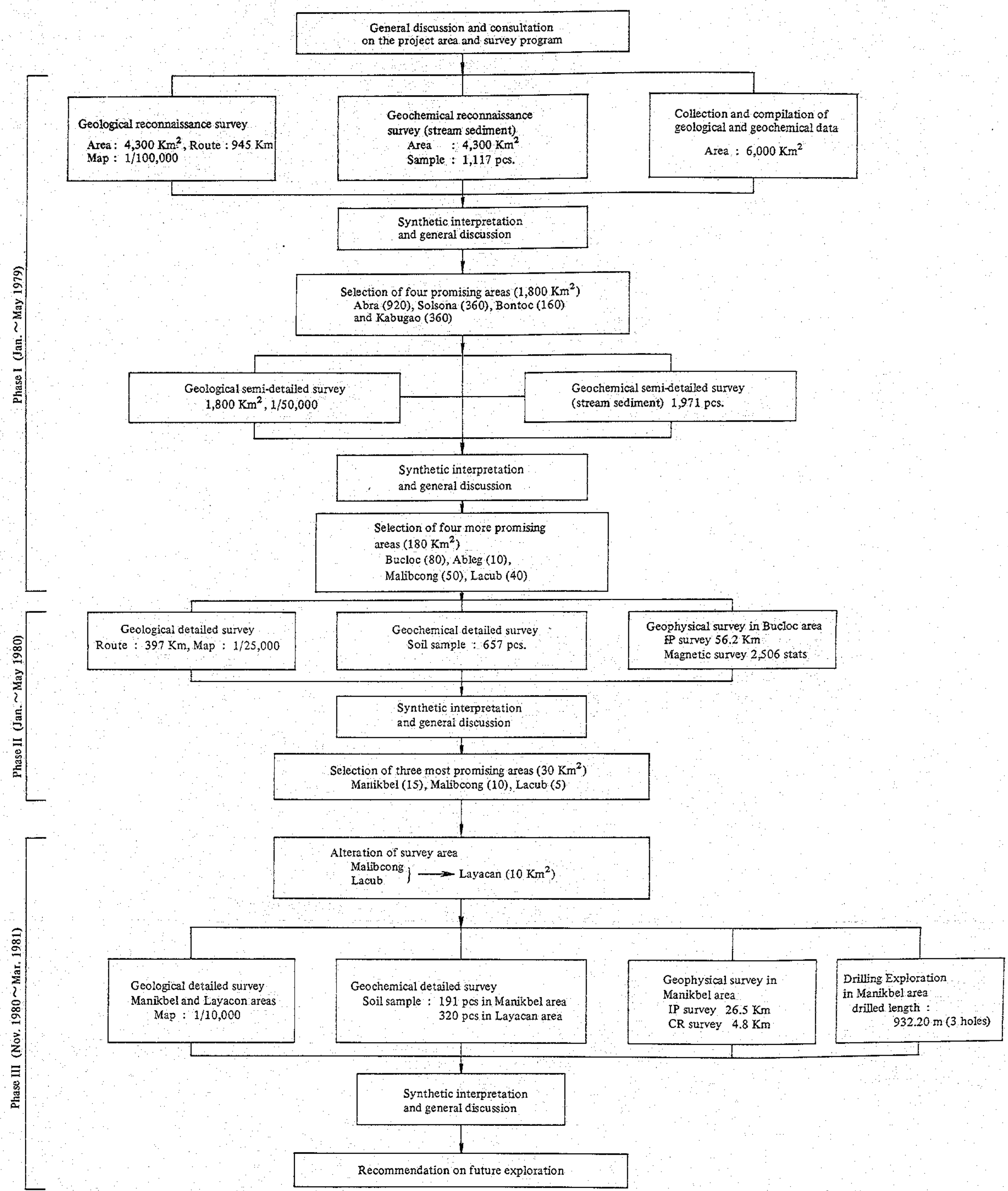
In response to this request, the Government of Japan dispatched a preliminary survey and consaltation mission headed by Mr. Kuroko, Manager of Oversea Department of MMAJ, on July 1978. The mission conferred with BMG staffs regarding the area to be surveyed and work program. After this deliberation, it was agreed upon to start fieldworks of the first phase of new project on January 1979 in that proposed area.

The purpose of this project is to delineate the most promising area for mineral resources and to discuss the possibility of development for these deposits by elucidating the mutual relationship among various geological criteria such as stratigraphy, geological structures, igneous activities and mineralizations through geological, geochemical, geophysical investigations and drilling exploration.

1–2 Details of Survey Operation

The mineral exploration surveys for this project had been operated progressively as shown in TableI–1 in an area covering apploximately 6,000 sq. Km within a period of three years, 1979 ~ 1981, by means of various exploration methods such as geological, geochemical (for stream sediments and soil), geophysical (IP and magnetic) surveys and drilling exploration. These methods were combined to obtain survey accuracy, reconnais-

Table I–1 Flow Chart of Exploration Program



sance – semi-detailed – detailed investigation.

Prior to this venture, BMG carried out an airbone magnetic survey in northwestern part of Luzon Island in 1978. The results of that investigation were compiled and analyzed by Philippine geophysicists and Japanese exparts dispatched by Japan International Cooperation Agency (hereinafter referred to as JICA). Those analytical data were discussed and interpreted inclusive of the results of this project.

Following descriptions are details of fieldworks in each phase of the project.

1–2–1 Phase I Survey

The main objectives of the Phase I survey are to establish a geological stratigraphy, to clarify an outline of geological structures and igneous activities, and to reveal a general feature of mineralization within the project area of approximately 6,000 sq. Km.

To achieve this purpose, the geological and geochemical (for stream sediments) reconnaissance surveys are intended to cover the whole project area by collection and complilation of existing data on geology and mineral resources. However, the preliminary investigation preceding the field works conducted on January 1979 disclosed that peace and order situation in the southeastern part of the area is not feasible for fieldwork. Serious troubles were reported in place which is traced back from the construction of the hydro-electric dams along the Chico and Pasil rivers since last November. In view of the information obtained during that preliminary investigation, an area of apploximately 1,700 sq. Km was considered to be the unfeasible part.

For this reason, the BMG and Japanese survey team decided (1) to exclude the unfeasible area and cover that area in Phase II and III if peace and order situation will be restored ; (2) to carry out the geological and geochemical surveys on the remaining 4,300 sq. Km by increasing the survey - route density of the original plan ; and (3) to draw a geological map on the excluded part using compilation of existing data in Phase I.

The fieldworks for the Phase I surveys were conducted as shown in Table I–2 between February and April in 1979. Those results were compiled in the 1:100,000 scale geological map and geochemical anomalies map.

The synthetic interpretation and discussion on the results of the reconnaissance investigations in Phase I disclosed several promising areas for further mineral resorces survey. In these areas, four having an area of 1,800 sq. Km in total, about 30 per cent of the initial area, were selected for detailed mineral resources investigation in Phase II in order of decreasing potential for mineral resources.

Table I–2 Outline of Field Survey in Phase I

	Survey Period	Area	Length of Survey Room	Number of Geochemical Sample
Preparatory Survey	Jan. 14 ~Feb. 6, 1979			
Geological Reconnaissance Survey	Feb. 7 ~Apr. 14, 1979	4,300 Km^2	945 Km	
Geochemical Reconnaissance Survey	Feb. 7 ~Apr. 14, 1979	4,300 Km^2	945 Km	Stream Sediment 1,117 pcs
Compilation of Existing Data	Apr. 15 ~Apr. 30, 1979	6,000 Km^2		

1–2–2 Phase II Survey

The Phase II survey was carried out in the four areas; namely Abra (920 sq. Km), Solsona (360 sq. Km), Bontoc (160 sq. Km) and Kabugao (360 sq. Km). These four areas were chosen as having high potential for mineral resources by the results of the first phase surveys. The purpose of the Phase II survey is to delineate the most promising area of 30 sq. Km. Geological and geochemical (for stream sediments) semi-detailed investigations were firstly conducted in the above-mentioned four areas purposely to exclude less potential parts, and afterwords conducted detailed geological and geochemical (for soil) investigations and geophysical (IP electric and ground magnetic) surveys in the remaining area to delineate further the most promising area for ore deposits.

The semi-detailed geological and geochemical investigations were conducted simultaneously between January 28, 1980 and April 6, 1980. Geological survey routes of 1,247 Km total length and 1,971 pieces of geochemical stream sediments samples along the geological survey routes were protted on a 1:25,000 scale geological map. All geochemical samples were analyzed by BMG in Manila and those analytical data were used as one of the most important criteria for selection of the area for detailed survey.

The results of these semi-detailed undertakings were compiled as the 1:50,000 scale geological and geochemical anomalies maps. The synthetic interpretation and discussion on the result of the semi-detailed investigations shows four more promising areas; namely Bucloc (80 sq. Km), Ableg (10 sq. Km), Lacub (40 sq. Km) and Malibcong (50 sq. Km), for the detailed survey.

The geological and geochemical detailed investigations which were carried out in the above-described four areas from April 7 to May 2, 1980 include 397 Km in total length of geological route maps (1:25,000) and 657 pieces of geochemical samples which were collected along the geological survey routes. The geochemical samples were analyzed for Cu in Japan. Both the geological and geochemical detailed investigations results were compiled on a 1:25,000 scale geological and geochemical map, respectively.

Considering the result of the analysis of the geochemical samples taken from the Abra semi-detailed investigation area, the geophysical survey was decided to be conducted in the southern part of the Bucloc area where the highest geochemical anomaly for Cu was delineated. The geophysical survey consists of IP electric method and ground magnetic method. Fieldworks started on March 1, 1980 and ended on May 13, 1980. The total length of the IP survey lines and their intervals are 56.2 Km and 200 m respectively, and 2,506 stations were measured for the magnetic survey.

Table I–3 shows the outline of the fieldwork for the second phase survey.

Detailed analysis and interpretation of all the survey results in Phase II resulted in the selection of three mineralized zones having an aggregate area of 30sq. Km namely; Manikbel, Lacub and Malibcong. These are the most promising area for ore deposits for the next phase survey.

1–2–3 Phase III Survey

The survey for Phase III was intended to cover the Manikbel, Malibcong and Lacub mineralized areas, which were chosen as the three most promising areas for ore deposits in the Phase I and II surveys. Phase III survey was conducted in the three areas with the following survey methods:

Table I–3 Outline of Field Survey in Phase II

	Name of Surveyed Area	Survey Period	Area	Amount of Survey Work	Number of Geochemical Sample
Preparatory Survey		Jan. 16 ~ Jan. 27, 1980			
Geological and Geochemical Semi-detailed Survey	Abra Solsona Bontoc Kabugao	Jan. 28 ~ Apr. 6, 1980	920 360 160 360 1,800 Km^2	Length of Survey Route 1,247 Km	Stream Sediment 900 439 134 1,971 pcs 498
Geological and Geochemical Detailed Survey	Bucloc Ableg Malibcong Lacub	Apr. 7 ~ May. 2, 1980	80 10 50 40	Length of Survey Route 397 Km	Soil 333 32 170 122
Geophysical Survey	Bucloc	Feb. 21 ~ May 19, 1980	30 Km^2	IP Survey 56.2 Km Magnetic Survey 2,506 stations	

(1) Manikbel area : geological and geochemical (soil) detailed investigations, geophysical (IP and complex resistivity methods) survey and drilling exploration.

(2) Malibcong area : geological and geochemical (soil) detailed investigation and IP electric survey.

(3) Lacub area : geological and geochemical (soil) investigations.

The fieldwork excluding drilling exploration was first started in the Manikbel area on November 20, 1980, and progressed on schedule. The survey in the Malibcong and Lacub areas, however, was not feasible because peace and order situation in these two areas became very critical when the fieldwork in the Manikbel area was completed.

After discussion on some alternative areas to be surveyed, BMG and MMAJ decided to cover one area, the Layacan mineralized zone (an area of 10 sq. Km), which is located in the Bontoc area and identified during Phase II survey by geological and geochemical semi-detailed investigations.

The objective of the detailed geological investigation in Phase III is to determine the extent and detailed features of each mineralized zone, and photted in a 1:5,000 scale geological route maps. This map was drawn by using measuring tape and handy compass. Final results were then compiled in the 1:10,000 scale geological map and 1:5,000 scale mineralization map.

The detailed geochemical soil survey was carried out in the Manikbel area with 60 pieces per sq. Km of sample density and 32 pieces per sq. Km in Layacan area. Geochemical samples taken from the Manikbel area were analyzed by BMG in Manila which was used in the selection of the drilling sites. However in the Layacan area, all samples were analyzed in Japan.

The geophysical survey consisting of IP method and complex resistivity method covered the central part of the Manikbel area. The total length of IP survey line and their intervals are 250 m and 100 m respectively. A complex resistivity method was conducted along three IP survey lines and the length of each line is 1.6 Km.

The drilling exploration was also done in the Manikbel area. Three bore holes with a total length of 932.20 m were drilled.

Table I–4 shows the outline of the fieldwork in Phase III.

Table I–4 Outline of Field Survey in Phase III

	Name of Surveyed Area	Survey Period	Area	Amount of Survey work	Number of Geochemical Sample
Preparatory Survey		Nov. 5 ~Nov. 19, 1980			
Geological and Geo-chemical Detailed Survey	Manikbel Layacan	Nov. 20 ~Dec. 30, 1980 Feb. 5 ~Mar. 20, 1981	15 Km^2 10 Km^2	Length of Survey Routes 110.2 Km 162.8 Km	Soil 197 pcs Soil 320 pcs
Geophysical Survey IP Method Spectro IP Method	Manikbel Manikbel	Nov. 20 ~Dec. 30, 1980 Jan. 3 ~Feb. 7, 1981		Length of Measured Line 26.5 Km 4.8 Km	
Drilling Exploration	Manikbel	Jan. 6 ~Mar. 30, 1981		RPJ–1 310.00 m RPJ–2 310.90 m RPJ–3 311.30 m Total 932.20 m	

1–3 **List of Members**

The members engaged in the consultation and fieldworks for each phase survey are as follows :

Phase I

1) consultation

Juanito C. Fernandez	BMG	Takeo Kuroko	MMAJ
Francisco A. Comsti	ditto	Okiharu Kaneishi	ANRE
Oscar A. Crispin	ditto	Kazuhiko Morohashi	MMAJ
		Kenji Sawada	ditto
		Takechiyo Takada	ditto
		Yutaka Hatano	JICA
		Hiroshi Fuchimoto	MMAJ

2) Geological and Geochemical Surveys

Leonardo R. Antonio	BMG	Hirofumi Taniguchi	MMAJ
Emil T. Avila	ditto	Ikuhiro Hayashi	ditto
Donno G. Custodio	ditto	Kenji Sawada	ditto
Pablito P. Escalada	ditto	Tadayoshi Seino	ditto
Jessie S. Miguel	ditto	Atsushi Takeyama	ditto
Ediwin M. Rillon	ditto	Tetsuo Sato	ditto
		Yoshiaki Shibata	ditto

Phase II

1) Consultation

Oscar A. Crispin	BMG	Mikio Nakamura	JICA
Leonardo R. Antonio	ditto	Kenji Sawada	MMAJ
		Hirofumi Taniguchi	ditto

2) Geological and Geochemical Surveys

Emil T. Arila	BMG	Hirofumi Taniguchi	MMAJ
Donno G. Custodio	ditto	Tsuyoshi Suzuki	ditto
Rene B. DelosSantos	ditto	Kenji Sawada	ditto
Pablito P. Escalada	ditto	Ikuhiro Hayashi	ditto
Jessie S. Miguel	ditto	Atsushi Takeyama	ditto
Cesar M. Samaniego	ditto	Atsumu Nonami	ditto
		Masataka Ochi	ditto

		Mitsugu Nakamura	ditto

3) Geophysical Survey

Edgar M. Morante	BMG	Susumu Sasaki	MMAJ
Abraham A. Gatdula	ditto	Hiroshi Fukuda	ditto
Elias C. Nacario	ditto	Yoichi Matsuda	ditto
Elmer C. Antioquia	ditto	Ikuo Takahashi	ditto
		Tomio Tanaka	ditto
		Shinichi Sugiyama	ditto
		Akira Kodama	ditto

Phase III

1) Consultation

Oscar A. Crispin	BMG	Kenji Sawada	MMAJ
Leonardo R. Antonio	ditto	Hirofumi Taniguchi	ditto

2) Geological and Geochemical Surveys

Donno G. Custodio	BMG	Hirofumi Taniguchi	MMAJ
Rene B. DeloSantos	ditto	Ikuhiro Hayashi	ditto
Jessie S. Miguel	ditto	Atsushi Takeyama	ditto
		Katsumi Hayashi	ditto

3) Geophysical Survey

Orland M. Pineda	BMG	Susumu Sasaki	MMAJ
Elias C. Nacario	ditto	Katsumi Yokokawa	ditto
		Toshio Fujimoto	ditto
		Tomio Tanaka	ditto
		Akira Kodama	ditto

4) Drilling Exploration

Cesar L. Lucero	BMG	Akio Kato	MMAJ
Dionesio M. Aleria	ditto	Toshio Hatakeyama	ditto
		Hatsuo Kumano	ditto

2. GENERAL INFORMATION ON SURVEY AREA

2–1 Location and Accessibility

The survey area is located in the northwestern part of Luzon Island as shown in Fig. 1 and 2. It covers an area of approximately 6,000 sq. Km bounded by the following lines :

in the north	:	the latitude 18°05′ North
in the south	:	the latitude 17°05′ North
in the east	:	the longitude 121°15′ East
in the west	:	the longitude 120°45′ East

The area covers most parts of the provinces of Abra, Kalinga-Apayao and Mountain Province, and some parts of Ilocos Norte and Ilocos Sur.

The major city and towns located in the area and its vicinity are Bontoc, the capital town of Mountain Province, on the south end ; Tabuk and Tuguegarao of Kalinga-Apayao and Cagayan provinces, respectively on the eastern side, and Bungued,Vigan and Laoag City of Abra, Ilocos Sur and Ilocos Norte provinces, respectively on the western side. Base camp was individually established in Bontoc and Bangued during the survey period.

These cities and towns are very accesible owing to well-meintained roads from Manila. The main roads are the National Road, Route 3, extending to the north end of Luzon Island along the western coastal line running through Vigan and Laoag City (408 Km and 486 Km from Manila, respectively), and Route 5 which is laid across the central part of Luzon and connected to Tuguegarao (482 Km from Manila). Bangeued (409 Km from Manila) and Bontoc (396 Km from Manila) are also linked to Manila by the National Road,Route 6 and 11, respectively. In addtion, domestic airline services are available from Manila to Laoag City and Tuguegarao three flights per week.

From the foregoing statement, it is apparent that access to adjacent regions are rather easy. However, this condition is not available within the survey area. Despite the approach provided by Route 6 and 11, accessibility is extremely poor owing to rugged mountainous topography. Some feeder roads connecting the main routes are locally developed along the Abra and Chico rivers and some of its major tributaries, but in the central part covered entirely by rugged topography, few trails are sporadically found. Route 11 and most of Route 6 were not accessible during the survey period due to the previously stated difficulties. These poor accessibilities and roads conditions hindered the progress of the survey.

Regarding communication system, telephone service can be used from Tuguegarao and

Laoag City to Manila, but from other towns only wireless telegraphy is available.

2–2 Topography

The topographic features of Northern Luzon are generally characterized by two mountain ranges and two lowlands which are paralleled to each other in the N–S direction.

Based on the combination of these physiographic characteristics and geological structures, Durkee-Pederson (1961) further divided these geomorphologic features into several subdivisions, as shown in Fig. I–1 from east to west as ; (1) Sierra Madre, (2) Cagayan Valley, (3) Cordillera Central, and (4) Coastal Folded Belt. Both the Sierra Madre and Cordillera Central are uplift zones and show very high relief. On the contrary, the Cagayan Valley and Coastal Folded Belt are subsided zones showing plain or relatively flat topography.

The survey area is located in the Cordillera Central and most part of the area shows very rugged topography with many precipitous cliffs. Generally the central part of the area is mostly characterized by high mountain ranges with an elevation of 1,800 ~ 2,500 m and numerous peaks reaching over 2,000 m above sea level can be pound in these ranges, such as, Mt. Sicapao (2,352 m), Mt. Sapocoy (2,455 m), Mt. Cauitan (2,596 m),the highest peak in the survey area, and Mr. Mengmeng (2,305 m) from the north to south.

The project area is dissected by two principal drainage system flanking the eastern and western side of the Cordillera Central Mountains. The eastern side is the Chico River which consists of many branches mostly trending NE–SW direction and is one of the biggest tributaries of the Cagayan Valley which debouched into the Babuyan Channel. The west side is drained by the Abra River with branches trending E–W direction and debouched into the South China Sea. In the northwestern part of the area, the NE–SW and NW–SE direction drainages are predominant.

These main river channels are generally controlled by geological structures and formed an extremely V-shaped valley characterized by precipitous cliffs and destructible erosion. Both the Chico and Abra rivers have large discharge all year round which is very advantageous for the construction of hydroelectric dams, particularly along the Chico River due to its strategic condition.

2–3 Climate and Vegetation

The climate of Northern Luzon including the project area can be divided into three types which correspond roughly to the aforementioned physiographic subdivisions.

In the Sierra Madre Mountains, there is no pronounced dry and wet season with prevailing intermittent rains throughout the year. Since most of the typhoons originate near the Philippine Sea, the region is always ravaged by storms causing heavy damages especially to agricultural crops. On the other hand, the Cordillera Central Mountains and its western lowlands have pronounced dry and wet season. The dry season lasts for 6 months from November to April and rest of the year is wet. In the Cagayan Valley, the climate is intermediate between the above-mentioned districts. It is rather dry from November to April. Nevertheless, dry and wet season in this district is not well pronounced.

Since the project area is located in the central portion of the Cordillera Central, the most suitable period for fieldwork is from January to April when the water level in rivers are at its minimum. An average annual precipitation and temperature of approximately 2,000 mm and 28.5 °C, respectively, have been observed in the survey area. Generally, the mountain ranges get the highest amount of rainfall reaching up to 5,000 mm in some case.

Vegetation is relatively dense at the mountain ranges because of heavy rainfall that occur in the area. However, halfway down to the foot of these ranges is denuded due to deforestation and inefficient reforestation scheme.

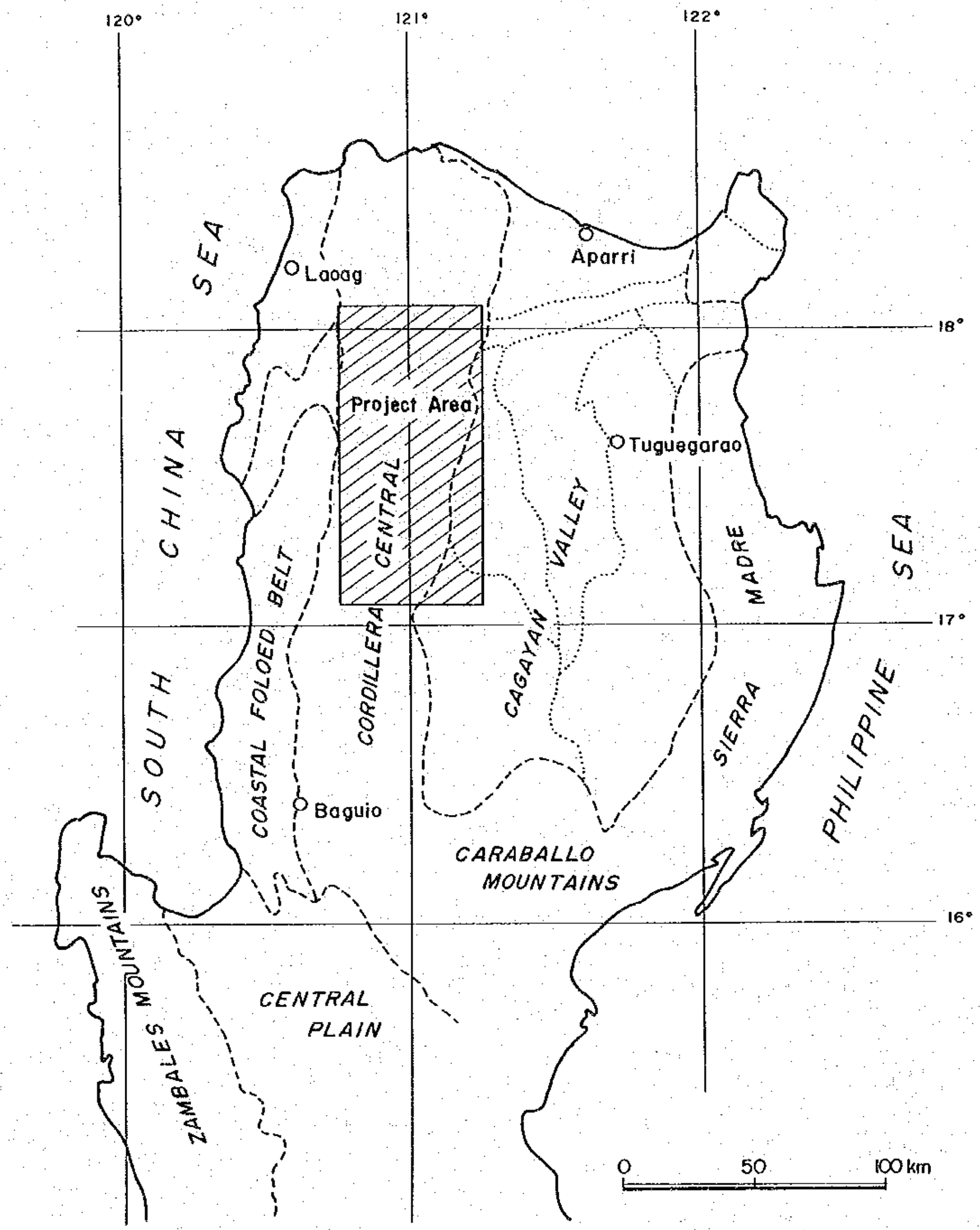


Fig. I–1 Physiographyic and Structural Provinces of Northern Luzon

PART II GEOLOGICAL SURVEY

1. GENERAL REMARKS

The synthesized conception regarding the geology of the Philippine Island is shown in the 1:1,000,000 scale Geological Map of the Philippines (1963) which was complied by BMG based on the results of numerous geological and mineral exploration investigations. From this map geologist can obtain a comprehensive knowlege on the regional geology of the northern part of Luzon Island.

Among numerous data on geology and mineral resources in Northern Luzon including the project area, Corby et al. (1951), Durkee-Pederson (1961) and Fernandez-Pulanco (1964) are very helpful in understanding the geological situation of Northern Luzon. Both Corby et al. (1951) and Durkee-Pederson conducted regional reconnaissance investigation individually in Cagayan Valley basin and its surrounding areas and mainly described the straigraphy of the Neogene Tertiary rocks distributed in the area. However, their invstigations were confined to clarify the stratigraphy of the Neogene Tertiary unit for oil exploration, therefore Pre-Neogene rocks were retained as the undifferentiated "Basement Complex". Fernandez and Pulanco (1964) conducted the regional reconnaissance survey in Northwestern Luzon and systematically described the stratigraphy, geological structures and igneous activities of the Cordillera Central. This report has been reffered by geologists as the most comprehensive write-up published concerning the geology of the area. In this report, the Pre-Neogene unit was devided into the Oligocene and the Pre-Oligocene units, retaining the latter as the undifferentiated "Cretaceous-Paleogene Rocks" (so-called KPg and UV).

Published papers regarding the geological structure of the Philippines by Gervasio (1967, 1971) and W. Hashimoto · T. Sato (1968, 1969, 1970) and Paleontorogical studies by Hashimoto (1938, 1970, 1975) are reffered to in this report.

On the other hand, Bryney (1969), Motegi (1975), Gervasio (1977), Almogela (1977) and Balce et al. (1978) were the previous workers who carried out the detailed investigations on ore deposits in the Philippines. Their papers suggest various information on occurrences and nature of principal ore deposits distributed in Northern Luzon, especially Balce et al. (1978) which is the latest paper concerning the Baguio Mineral District, is useful for mineral exploration in this project area.

MMAJ, JICA (1975, 1976, 1977) showed the results of the collaborative mineral exploration survey in Northeastern Luzon which was conducted within a period of three years, 1975 ~ 1977. It covered the Cordillera Central and the undifferentiated "Cretaceous-Paleogene Rocks" have been stratigraphycally classified in detail.

Considering the compilation and discussion on the above-mentioned existing data, Northern Luzon consists mainly of the Post-Cretaceous rocks overlying the Pre-Cretaceous basement rocks exposed discontinuously along the eastern coastal line. These Post-Cretaceous rocks can be subdivided into the same belts as the topography, that is, 1) Sierra Madre uplift zone, 2) Cagayan subsided zone, 3) Cordillera Central uplift zone and 4) Coastal Folded Belt, from the east to the west.

The Sierra Madre uplift zone is composed mainly of the basement rocks, the Cretaceous to Oligicene volcanic rocks, and the Late Eocene to Oligocene granitic rocks (49 m.y. to 27 m.y.) which have been intruded into the volcanic rocks in the southern part of this zone. The lesser Neogene rocks are sporadically distributed in the western wing of the uplift zone.

The Cagayan subsided zone is circumscribed in part by both the Sierra Madre and Cordillera Central uplift zones, and it has been formed as the relatively subsiding basin caused by the two uplifted zone. In this zone, the Neogene sedimentary rocks accumulated thickly, overlying the Eocene to Oligocene volcanic rocks. The prominent igneous activity is not observed, but the alkaline plutonic rocks have been intruded in the southern periphery of this zone during Late Oligocene to Early Miocene time (25 m.y. to 17 m.y.).

The Cordillera Central uplift zone consists mainly of the Eocene to Early Miocene volcanic rocks which are later in geological time as compared to the Sierra Madre uplift zone, and the Post-Middle Miocene sedimentary rocks. The Miocene plutonic rocks (26 m.y. to 9 m.y.) intruded into the volcanic rocks along its anticlinal axes. The plutonic rocks range from gabbro facies to granodiorite facies.

The Coastal Folded Belt is composed chiefly of intensely folded sedimentary rocks classified as of Post-Miocene age.

As described above, the Northern Luzon region shows the characteristic geological environment, that is, the two uplifted zones and two subsided zones are altenately distributed in the direction of N–S and these four zones have noticeable in their geotectonic development process. Particularly between the Sierra Madre and Cordillera Central, there are some prominent differences in the geotectonic process and the nature and age of the plutonic activities.

Numerous metallic ore deposits of various types are distributed in Northern Luzon, and at present most of them are in operation. These principal ore deposits, however, show the obvious maldistribution in this region. In the Sierra Madre uplift zone, no workable ore deposits have been found although some small-scale deposits are confirmed to be distributed. On the contrary, most of mineable ore deposits are located in the Cordillera Central uplift zone. A particularly great number of these ore deposits are concentrically distributed around Baguio City and form the Baguio Mineral District. The Cagayan subsided zone has no metallic ore deposits because of poor igneous activities, but in the southern end of the zone few deposits such as the Cordon porphyry copper type ore deposits are recognized.

The principal metallic ore deposits distributed in the Cordillera Central are
(1) Porphyry copper type : Santo Tomas, Santo Niño, Kennon, Boneng, Tawi Tawi and Batong Buhay ; (2) Vein type : Acupan, Antamok, Lepant, Suyoc, Abra and Bully Bueno ; (3) Contact metasomatic type ; Thanksgiving and Lammin.

These principal deposits, especially the porphyry copper type deposits, are genetically related to stocks and dykes of porphyries intruded into a marginal part of plutonic masses and their peripheral volcanic rocks and the nature of plutonic rocks. It has been concluded that this geological environment, as stated above, is the optimum field for the formation of ore deposits on the basis of the numerous previous studies. The afore-described maldistribution of ore deposits is considered to be caused by the differences in the nature of plutonic rocks and the geological environment of both of the uplifted zones. From these conceptions, it is conclusively considered that the most promising area for metallic ore deposits in Northern Luzon is the portion having the intense plutonic activities in the Cordillera Central uplift zone.

The Northwestern Luzon Project area was selected based on the above-mentioned geological background and it is located over 70 Km to the north from the Baguio Mineral District and in the backbone of the Cordillera Central. The area consists mainly of the Eocene to Miocene volcanic rocks and the Miocene plutonic and hypabyssal rocks which have been intruded into the volcanic rocks. The Batong Buhay, Abra, Bully Bueno and Lammin ore deposits are distributed in this project area and its periphery. In consequence of these geological circumstance, the project area may be considered to be the most promising area for ore deposits after the Baguio Mineral District.

2. GEOLOGY

2–1 Stratigraphy

The survey area consists mainly of the Post-Cretaceous volcanic rocks, normal sedimentary rocks and intrusive rocks. Most of the volcanic rocks have been lumped together as the undifferentiated Cretaceous to Paleogene System (so-called KPg and UV). However, based on the detailed interpretation of rock facies and determination of some newly collected fossils by this survey, these rocks were stratigraphically classified into five units, namely : Licuan Group, Tineg Formation, Mabaca Formation, Alava Formation and Quaternary volcanic rocks in ascending order, as shown in Table II–1.

Among the intrusive rocks distributed in the area, the plutonic rocks were also subdivided broadly into three facies : gabbro, quartz diorite and granodiorite. The age of some intrusive rocks were determined as of Late Oligocene to Middle Miocene time, such as : quartz diorite 26.3 ~ 9.8 m.y. ; granodiorite 20.3 ~ 13.7 m.y. ; and porphyritic rocks 18.3 ~ 9.8 m.y., by K-Ar dating.

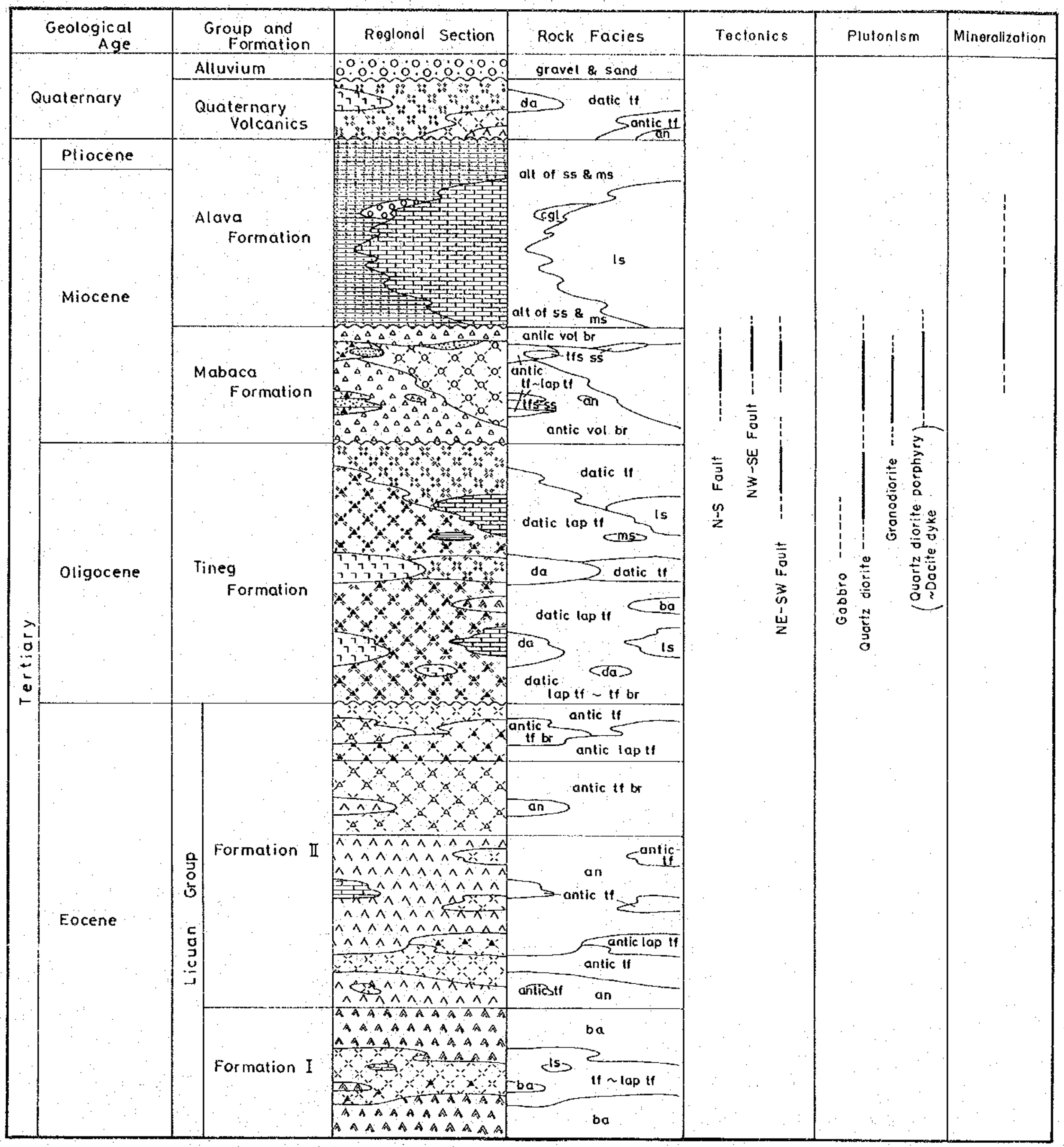
The formation names used in this report are newly given on the basis of the place or river name of each type locality.

Table II-2 shows the stratigraphic correlation between the present survey area and some related areas based on existing data. The Northeastern Luzon Project area is located over 60 Km to the south and it is so far from the present survey area. However, that area was selected as the object of the correlation because it covered the Cordillera Central uplift zone and the undifferentiated Cretaceous to Paleogene units have been stratigraphyically classified in detail. The stratigraphy of the Cagayan Valley (West) by Durkee · Pederson (1961) includes the area around the Mabaca River basin situated in the eastern part of this survey area. The Baguio District by Balce et al. (1978) is the latest data on the geology and ore deposits of the Baguio Mineral District.

The Licuan Group was divided into two formation. One is the Formation I, consisting of basaltic rocks. The other is the Formation II, consisting mainly of andesitic rocks. Formation I and II can be lithologically correlated to the Caraballo Group Formation II and III in the Northeastern Luzon Project area, respectively. The Caraballo Group Formation I and the basement rocks are not distributed in this area.

The Tineg Formation is composed mainly of dacitic pyroclastic rocks and can be considered to be in the same horizon as the Zigzag Formation of the Northeastern Luzon

Table II–1 Generalized Stratigraphic Section of Project 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

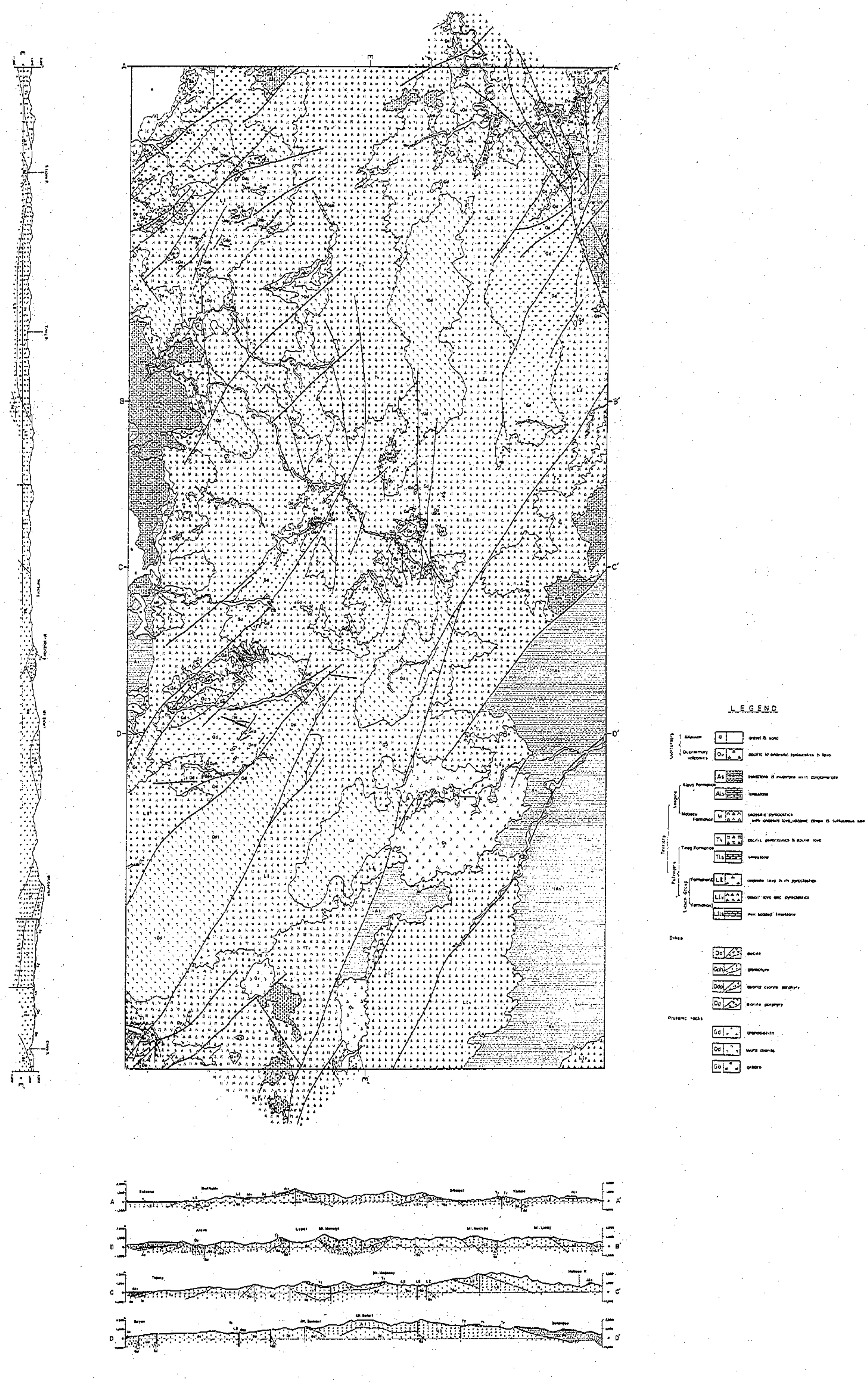


Fig. II–1 Geological Map of Project Area

Table II–2 Stratigraphic Correlation in Northern Luzon

Geological Age	Northwestern Luzon Project (1979 ~ 1981)	Northeastern Luzon Project MMAJ·JICA (1975~1977) Main Area	Northeastern Luzon Project MMAJ·JICA (1975~1977) Baguio Area	Cagayan Valley (Western part) Durkee·Pederson (1961)	Baguio District Balce et al. (1978)
Quaternary	Alluvium Quaternary Volcanics	Terrace Deposit	Terrace Deposit		Alluvium
Pliocene		Matuno F.	Mirador F.	Ilagan F.	Rosario F.
Miocene	Alava F. Mabaca F.	Aglipay F. Santa Fe F. Natbang F. Palali F.	Klondyke F. Kennon F.	Mabaca River Group: Buluan F., Balbalan Sandstone, Asiga F. Sicalao Limestone	Klondyke F. Kennon F. Zigzag F.
Oligocene	Tineg F.	Columbus F. Mamparang F.	Zigzag F.	Basement	Pugo F.
Eocene ~ Cretaceous	Licuan Group: F. II, F. I	Caraballo Group: F. II, F. II, F. I Basement	Pugo F. Basement		Dalupirit Schist

Area in the geological time. However, the Zigzag Formation in the Baguio District which is accompanied by dacitic rocks has been classified as of Miocene time by Balce et al. (1978) although that Zigzag Formation seems to be correlated to the Tineg Formation in lithology. The geological age of the Zigzag Formation should be redetermined in the future.

The Mabaca Formation which is distributed in extremely confined narrow parts within the survey area is considered to be the product of local andesitic volcanic activity. It has no basis to determine the geological age. This formation seems to be lithologically correlated with the Zigzag Formation, but the age of the Zigzag Formation is unclear as stated above. From this state, the Mabaca Formation can not be correlated with other formations and it is pertinent to consider that the distribution of the Mabaca Formation may be confirmed within the present survey area and/or its periphery.

The Alava Formation, consisting of thick limestone and clastic rocks, is dated as Early Miocene to Pliocene time by the determination of newly found fossils. It can be correlated to the Sicalao limestone and Mabaca River Group in the Cagayan Valley (West) area. This Alava Formation is also considered to be correlated lithologically to the Neogene rocks of the Post-Natbang Formation in the Northeastern Luzon area and the Post-Kennon Formation in the Baguio District.

Following description is the details of each formation in this survey area.

2–1–1 Licuan Group

The Licuan Group is the most widely distributed in the survey area as shown in Fig. 1–1 and it consists mainly of andesitic pyroclastic rock and lavas, but basalt lavas are remarkably dominant in the southern part of the area. Consequently, the Group was divided into two formations, namely Formation I and II. Formation I, which consists of basalt lava with pyroclastic rocks; and Formation II, composed of andesitic lava and its pyroclastic rocks. The Formation II seems to overlie the Formation I.

(1) Formation I

Distribution : The Formation I is chiefly distributed in the vicinity of Bontoc and in the middle to lower streams of the Layacan River located in the western portion of Besao. Moreover, it appears to be distributed in the Chico River basin from Bontoc to Barrio Bangad and in or around Barrio Oboob, which is located in the southeastern end of the survey area in accordance with existing data.

Thickness : The thickness of this formation is not exact because this is the lowest formation in the area and has been affected by many faults and intrusion of plutonic rocks. From the field observation, it can be considered to be over 500 m and may be estimated to be more than 1,200 m in the compiled part in thickness.

Rock Facies : This formation is composed mainly of basalt and basaltic andesite lavas accompanied by pyroclastic rocks. In the middle stream of the Layacan River, thin lenticular limestone is intercalated with pyroclastic rocks. All lava and pyroclastic rock have been highly chlorized and epidotized.

The basalt lavas are chiefly exposed along the middle to lower reaches of the Layacan River. They usually show dark green to dark-grayish green, occasionally dark-reddish purple colors, and a predominant amygdaloidal texture. Pillow structures are commonly observed in most of lavas but some of lavas exposed in the western portion of Bontoc are massive lavas with columnar joints, a few meters in thickness, are alternately intercalated with basaltic pillow lavas. Under the microscope, an amygdaloidal texture is distinct, and albitized euhedral to subhedral plagioclase and subhedral to anhedral augite are observed as phenocryst. A groundmass is composed of short columnar plagioclase, orthopyroxene and opaque minerals. Chlorite, epidote, calcite and secondary quartz occur as alteration minerals.

The basaltic andesite lavas are intercalated with basalt lavas distributed in the lower stream of the Layacan River and show dark-greenishigray to dark-bluishgray colors. Usually these lavas are aphanitic but some of lavas contain fine-grained phenocrysts of plagioclase and augite megascopically.

The pyroclastic rocks consist of green to dark green tuff, lapilli tuff and tuff breccia, and thin basaltic to andesitic lavas are occasionally intercalated with the tuff breccia. Most of the tuffs are coarse-grained but the alternation of well-sorted fine-grained tuff and coarse-grained tuff is observed at the middle stream of the Layacan River and the Segseg Creek which is one of the tributaries of the Layacan River. Lapilli tuff and tuff breccia are composed mainly dark green to dark brown basalt to andesite fragments and thinly elongated andesitic pumices. Some of tuff breccia beds rarely contain limestone fragments.

In the middle reaches of the Layacan River, lenticular limestone, less than 2 meters thick, is intercalated with a well-bedded medium - to coarse-grained tuff. This limestone is abundant in fragments of dark green tuff.

Fossil and Age : The limestone (g–102, in Phase I) located in the middle reaches of the Layacan River yields the following larger foraminiferas :

Fabiania cassis Oppenheim

Pellatispira crassicolumnate Umbgrove

Biplanispira minabilis Umbgrove

These fossils are determined as Late Eocene (Tb).

Geological Structure : Noticeable structures have not been found because this formation is composed mostly of lavas. But considering the bedding of its pyroclastic rocks, this formation appears to repeat wavy folds in small-scale with axes trending N–S and to dip gently towards NW to NNW as a whole.

(2) Formation II

Distribution : The Formation II occupies the widest part of the survey area, from the distribution area of the Formation I to the northern end of the survey area.

Thickness : It is considered to be more than 2,000 meters.

Rock Facies : In contrast to the Formation I consisting of basaltic rocks, this formation is composed mostly of andesite lavas and andesitic pyroclastic rocks intercalating lenticular limestone. Generally, lavas are abundant in the lower part and the pyroclastic rocks are in the upper part.

The andesite lavas generally show green, dark green to dark-greenish gray, occasionally dark-reddish gray color. From the field observations, these andesite lavas are divided into three rock facies : basaltic, aphanitic and porphyritic facies. This classification, however, is not necessarily strict, and frequently two or three facies coexist with each other. The basaltic andesite facies is well recognized in and around the Utep Rivers which is in the southern part of this survey area, Solsona and Kabugao. It shows a predominant pillow structure and an amygdaloidal texture. The aphanitic andesite facies is the most common one. It is a fine-to medium-grained massive compact rock, but flow and brecciated structures are observed in some places. The porphyritic andesite facies is sporadically exposed in the central portion of the survey area. This facies is characterized by large phenocrysts of plagioclase. Under the microscope, this rocks shows porphyritic and hyalopilitic textures. Phenocrysts consist of euhedral plagioclase and euhedral to subhedral fine-grained augite, and groundmass is composed mainly of subhedral very fine-grained plagioclase, glass and opaque minerals. Most of plagioclases are altered to chlorite, epidote, sericite and calcite.

The andesitic rock occur as thick deposits overlying the andesite lavas and as interbeds in the lavas. These pyroclastic rocks are composed of light green to dark green or dark-greenish gray well-consolidated tuff, lapilli tuff and tuff breccia, and the tuff breccia is locally accompanied by volcanic breccia. The tuff is usually fine-to medium-grained and well-bedded. In the middle reaches of the Utep River and the upper reaches of the Bucloc River, it is alternated with layers of sandstone and mudstone with 20 – 80 cm units in thickness. The lapilli tuff and tuff breccia are usually massive and consist of angular or subangular essential lapillis and breccias of andesite and basalt, and also accidental breccia of mudstone and thinly elongated pumices.

Generally, both andesite lavas and andesitic pyroclastic rocks have been intensely chloritized and epidotized. Particularly, intense silicification and pyritization are superimposed on the above-mentioned alterations around the contact of these rocks and plutonic rocks.

The layers of limestone are recognized in the downstream of the Malibcong River and upstream of the Bucloc River by the Phase II survey. In the downstream of the Malibcong, River, the gray micritic limestone, 50 m thick, is intercalated with green well-bedded tuff. It strikes N87°E and dips 37°S. At the upstream of the Bucloc River, the limestone is exposed along the gently sloped ridge. Its occurrence is not clear but it is considered to be the interbed in the andesitic pyroclastic rocks. This limestone is thermally metamorphosed by granodiorite and some skarn minerals are observed in the metamorphosed zone.

Fossil and Age : No fossil has been found in this formation. However, a floating block of the tuff breccia considering to be Licuan Group Formation II was collected at the upper reaches of the Mataragan River by the Phase II survey. That block of the tuff breccia contains the fragment of limestone (b–2155) which yields the following larger foraminiferas :

Amphistegina radiata (Fichtel and Moll)

Gypsina vesicularia (Parker and Jones)

Gypsina globulus Reuse

These fossils are determined as the Eocene (Ta3–Tb).

The Formation II can be considered to be Eocene time on the basis of the determination of the fossils.

Geological Structure : The geological structure of this formation has been complicated by the intrusion of plutonic rocks and numerous faults. But, as a whole, this formation seems to dip gently eastward in the northeastern portion and northwest to west in the western part of the survey area with repeating wavy folds with axes trending N–S.

Relation to the Underlying Formation : The contact between this formation and the Formation I has not been observed in the field. Based on the features of the geological structures and distribution of both the two formations, however, it can be considered that the Licuan Group Formation I is conformably overlain by the

Formation II. This relation is consistent with the relation between the Formation II and III of the Caraballo Group in the Northeastern Luzon Project area, which are correlated to the Licuan Group Formation I and II, as already stated.

2–1–2 Tineg Formation

Distribution : The Tineg Formation is mainly exposed in the area from Sagada and its periphery to the upper to middle reaches of the Layacan River, the Saltan and Mabaca river basins, and the portion from the middle to upper stream of the Tineg River to the northern end of the survey area. In the western central part of the area, this formation is also narrowly distributed.

Thickness : The thickness of this formation can be estimated to be over 1,500 m.

Rock Facies : This formation is characterized by dacitic volcanic activity. The main constituent rocks are dacitic pyroclastic rocks and dacite lavas, and pyroclastic rocks are locally accompanied by sandstone, mudstone and limestone.

The dacitic pyroclastic rocks consist of light to dark green, occasionally greenish gray tuff, lapilli tuff, tuff breccia and volcanic breccia. The tuff is well-bedded, highly indurated, fine-or coarse-grained rock, and contains wholly quartz grains and pumices. It often alternates with layers of sandstone and mudstone. The lapilli tuff, which is the most common rock facies in this formation, is composed of lapillis of dacite, rhyolite and lesser amount of andesite, and generally contains thinly elongated light green pumice. Quartz grains are abundant in its matrix. The lapilli tuff is usually massive but shows partially the welded texture suggesting to be terrestrical deposits. The tuff breccia and volcanic breccia are composed of angular or subangular dacite, rhyolite and andesite breccias and contain pumice occasionally. Quartz grains are abundant in their matrix. The volcanic breccia rarely contains fragment of granodiorite.

The dacite lavas are distributed in the middle and upper reaches of the Layacan River, the upstreams of the Mabaca River and the upper streams of the Tineg and Dagara rivers. These lavas are light green to light gray, porous and massive rocks with remarkable phenocrysts of quartz and plagioclase, and occur as thin beds intercalated with the dacitic pyroclastic rocks. In the Tineg River, the dacite lava measures up to 150 m thick. The lavas show no flow structure but partially brecciated. Under the microscope, this rock shows porphyritic texture with abundant phenocrysts of quartz, plagioclase and a minor amount of augite. Groundmass is composed of plagioclase and opaque minerals. Generally, plagioclase and augite are altered to chlorite, sericite, epidote and secondary quartz.

The limestone is widely exposed in and around Sagada as thick sequences, and some lenticular limestone layers, a few meters in thickness, are also found in the upper reaches of the Tineg River and the middle stream of the Balinawan River. At Besao and its peripheral portion, the limestone shows milky white to whitish gray and is massive, but in the Tineg and Baliwanan rivers they are well-bedded and show light gray in color.

Fossil and Age : The limestone (j–106 ℓ and j–116) collected as Sagada by the Phase I survey yields the following larger foraminiferas.

Eurepidina formosa (Schlumberger)

Nephrolepidina sumatrensis (Brady)

These fossils indicate Late Oligocene time (Te_4). The limestone (b–128, b–130, in Phase I) in the Malitep Creek yields the following foraminiferas and they are determined to be the Early Oligocene (Td).

Eulepidina favosa Cushman

Nummulite fichteli (Michelotti)

In Phase II, three samples of limestone were collected from Besao and the Amlsong Creek which is located in the northern portion of Besao, and these samples (h–2506, h–2511 and k–2505) contain the following larger foraminiferas :

Eulepidina formosa (Schlumberger)

Heterostegina borneensis Van der Vlerk

Amphistegina radiata (Fichtel and Moll)

Cycloclypeus sp.

These fossils are determined as the Oligocene age (Tc · Te_{1-4}). On the other hand, the following larger foraminiferas were discovered from the limestone (g–528) taken from the upper stream of the Tineg River.

Eulepidina formosa (Schlumberger)

E. gibossa Yabe

Nephrolepidina sumatrensis (Brady)

These foraminiferas indicate Late Oligocene time (Te_4). Based on these results, the age of the Tineg Formation has been determined as Oligocene time.

Geological Structure : This formation exposed in the eastern part of the survey area shows the monoclinic structure tilting to the west, and in the western portion it also shows the same structure tilting to the west. However, the formation distributed in and around the northern part of the survey area and Sagada shows no remarkable structures, and this formation may flatly cover the higher portion of topography with repeating small-scale wavy folds. These structures are discordant with the structures of the underlying formations.

Relation to the Underlying Formation : Considering the distribution feature of the Tineg Formation, the relation may be considered to be unconformable although the contact between this formation and the Licuan Group Formation II is not observed.

2–1–3 Mabaca Formation

Distribution : The Formation has been considered to be the product of the local andesitic volcanic activity. Its distribution areas are confined in the area from the middle to upper reaches of the Mabaca River, along the Apayao River and the downstream of the Bucloc and Malanas rivers.

Thickness : Less than 1,000 m.

Rock Facies : The main constituents of this formation are andesitic volcanic breccia and volcanic conglomerate accompanied by thin layers of andesitic tuff, lapilli tuff, andesite lava, sandstone and mudstone. The andesitic volcanic breccia and volcanic conglomerate showing light gray to dark green, rarely dark-brownish gray consist mostly of angular to subangular porous and loose andesitic volcanic ejectas with large amount of hornblende phenocrysts, and occasionally they contain fragments of limestone and well-bedded tuff. Matrix of these rocks is composed of fine-grained and poorly-sorted fragments of andesite. The Volcanic conglomerate consisting of rounded pebble - to cobble-sized andesite fragments is remarkably exposed in the Mabaca River. The consolidation of the volcanic tuff breccia and volcanic conglomerate is weak as compared to the pyroclastic rocks of the Tineg Formation and the Licuan Group.

The andesitic pyroclastic rocks are observed in the Apayao River as greenish gray - to reddish gray-colored, fine - to coarse-grained tuff and lapilli tuff containing angular andesite fragments intercalated with volcanic breccia. Both are insufficiently sorted but show bedding.

The andesite lava is locally found in the volcanic breccia. It is lithologically the same as the ejectas of volcanic breccia, and both the andesite lava and the volcanic breccia seem to be the products of the same volcanic activity. Microscopically, this lava shows porphyritic and spherulitic textures. Common phenocrysts are plagioclase, hornblende and augite, and its groundmass consists mainly of plagioclase. These minerals are partially altered to lesser amounts of chlorite, sericite and calcite.

The sandstone and mudstone occur as thin layers in the volcanic breccia and show light gray colored. They are well-bedded.

Fossil and Age : No fossil has been found in this formation. The age of this formation seem to be Early Miocene because of the ages of the underlying and overlying formations.

Geological Structure : The structural characteristics are not clear due to its narrowly confined distribution, but in the Apayao River the semi-basin structure plunging to the northeast is recognized as local structure. On the contrary, the formation distributed in the Mabaca River shows monoclinic structure dipping steeply to the east.

Relation to the Underlying Formation : The contact between this formation and the Tineg Formation has not been observed. However, the prominent differences in the nature of volcanic activity and the structural discordance between the two formations suggests an unconformable relation.

2–1–4 Alava Formation

Distribution : The distribution of this formation has been confined within the eastern and western portions of the survey area. In the eastern portion, it is exposed in the basins of the Saltan and Chico rivers and their tributaries, and also distributed in the eastern basin of the Binuan River. In the western part, it is observed in the downstreams of the Ikmin, Bucloc, Baay and Tineg rivers, and its narrowly exposed area is also found in the middle stream of the Solsona River. The widest distribution area was mapped using existing data due to the unfeasibility of conduction of the fieldworks during the survey period of three years.

Thickness : More than 800 m.

Rock Facies : This formation consists of thick limestone and clastic rocks occuring in its upper and lower parts, and characterized by the lack of volcanic rocks.

The limestone is widely exposed along the road from Dolores to Alava. In this portion, this rock is light cream, occasionally light-brick red reefa limeston, and well bedded in 20 – 30 cm unit in thickness. The limestone distributed in the Mabaca and Binuan rivers show the same lithology as the limestone in the Alava road. All of limestones are abundant in fossils.

The clastic rocks in the lower part of the limestone are composed of light-greenish gray massive calacareous sandstone and well-bedded tuffaceous sandstone, and alternation of grayish white arkose sandsone and gray mudstone is locally exposed in the lower stream of the Bucloc River. These rocks are weakly consolidated and contain plenty of fossil fragments. The clastic rocks in the upper part of the limestone consist of conglomerate, sandstone and mudstone. The conglomerate contains rounded pebbles, 3 – 5 cm in diameter, of dacite, rhyolite, andesite and tuff, and its matrix is calcareous sandstone. No limestone fragments are observed. The sandstone layer is composed mainly of light yellow fine - to medium-grained, well-bedded, calcareous sandstone and dark green massive medium-grained sandstone. The mudstone layer shows gray color and well-developed bedding. In the Mabaca River, the alternation of calcareous sandstone and mudstone is exposed and these sandstone and mudstone contain a large amount of fossil fragments and blick carboniferous materials, respectively.

Fossil and Age : The limestone samples (g–517 and g–518) collected from the Alava road by the Phase I survey yield the following larger foraminiferas :

Miogypsina dehaartii Van der Vlerk

M thecidaeformi Rutten

They are determined as Early Miocene (Te_5). The upper sandstone layer yields the following planktonic foraminifera :

Globorotaria tumida (Brady)

It indicates the Late Miocene age (N17–N18), but other samples suggest a possibility of Pliocene age. In addition, some smaller foraminiferas indicating the Late Miocene to Pliocene time are discovered from the sandstone (b–2165) collected in the lower stream of the Malanas River by the Phase II survey. They are as follows :

Elphidium rugosum (d'Orbiguy)

Nonion grateloupi (d'Orbiguy)

N. labradicum (Dawson)

The limestone (g–2321) in the Solsona River yields plenty of fossils. Some of them are described below :

Miogypsina sp.

Amphistegina radiata (Fichtel and Moll)

Nephrolepidina sp.

Gypsina globulus Reuss

These fossils are determined as Early to Middle Miocene (Te_5-Tf_2). The other limestone (g–2321), distributed in the eastern side of the Binuan River, yields the following larger foraminiferas identified as Early Miocene (Te_5).

Miogypsinoides dehaartii Van der Vlerk

Nephrolepidina sumatrensis (Brady)

Miogypsina miniacea

As the result of the above-described determinations of fossils, the Alava Formation is classified as of Early Miocene to Pliocene time. This formation distributed in the Chico and Saltan river basins is also considered to be Miocene to Pliocene age by existing data.

Geological Structure : This formation is distributed in the eastern and western wings of the Cordillera Central uplift, and shows distinct monoclinic structure dipping eastward in the eastern portion and westward in the western portion.

Relation to the Underlying Formation : The outcrop showing the unconforming between this formation and the underlying formation has not been observed. However, it is concluded that the Alave Formation rest unconformably upon the Mabaca Formation since there is obvious structural discordance between two formations and clastic rocks of this formation contain andesite fragments which are the same as the Mabaca Formation in lithology.

2–1–5 Quaternary Volcanic Rocks

Distribution : This rocks is restrictedly distributed within the southern portion of the survey area, that is, the widest distribution area is located around Mt. Masimus and Mt. Binulauan with characteristic topography, which are situated near Batong Buhay mine. Some of this rocks are narrowly exposed around Mt. Patoc and in the northern and western portion of Besao.

Thickness : Over 300 m.

Rock Facies : This rocks consist of dacitic volcanic rocks and andesitic ones.

The dacitic rocks, which are distributed around Batong Buhay mine and Mt. Patoc, are composed of light gray to grayish white dacitic welded tuff and light gray dacitic tuff. The former is widely exposed near Batong Buhay and it is generally soft and loose rock. The welded structure is not so intense. The latter is also insufficiently consolidated, and soft and loose. It shows partially weak welded structure. Occasionally this tuff is accompanied by tuff breccia layer containing essential breccia. Dacite lava has not been observed but the unpublish data on the Batong Buhay ore deposits suggest that it occurs near the mone.

The andesitic volcanic rocks which are found in the northern and western portions of Besao is composed mainly of brick red to dark gray andesite lava and its pyroclastic rocks. The lava contains coarse-grained hornblende and pyroxene as phenocryst, and the pyroclastic rocks seem to be plug.

Fossil and Age : No fossil yields in this rocks. There is no positive data to determine its age but on the basis of the distribution feature, occurrences and insufficient consolidation, these rocks can be classed as Quaternary.

Relation to the Underlying Formation : It is considered to be probably an unconformity.

2–1–6 Alluvium

This deposit is widely distributed around Solsona and the mouth of the Baay River, and also along the downstreams of the principal rivers, Chico, Apayao, Tineg, Baay and Binongan rivers. It consists of unconsolidated sands and gravels.

2–2 Intrusive Rocks

The intrusive rocks distributed in this project area are revealed as basic to acidic batholithic plutonic rocks, stocks and dykes of hypabyssal rocks related to the plutonic rocks and various dykes of doleritic to dacitic rocks. The plutonic rocks are distributed in the whole survey area excepting the Chico River basin, the southeastern part of the survey area, and frame of the Cordillera Central uplift zone. These rocks are lithologically diveided into three rock facies ; namely gabbro, quartz diorite and granodiorite. The hypabyssal rocks consist of diorite porphyry, quartz diorite porphyry and granophyre. Dolerite, andesite and dacite are observed as small-scale dyke rocks in this survey area.

1) Gabbro

Distribution and Occurrence : Gabbro is restrictedly distributed in the area from the Solsona River to the Palsuguan River, in the northwestern part of the survey area. In addition, two stocks of gabbro are narrowly exposed in the lower stream of the Malanas River. Around the Solsona River, this rock occurs as large-scale batholothic mass trending NE–SW from the middle reaches of the Solsona River to the lower reaches of the Borney River. In the Palsuguan River basin, some parts of this rock are exposed as small-scale fenster intruding into the Licuan Group Formation II.

Rock Facies : Generally, the rock is dark gray to dark-greenish gray, medium - to coarse-grained holocrystalline, but a part of it shows light-grayish white leucocratic gabbro facies. Plagioclase and pyroxene are observed as main rock-forming minerals and occasionally accompanied hornblende, olivine, biolite and a rare amount of quartz. Under the microscope, these rocks have an equigranular texture and show hornblende -gabbro facies, augite-hypersthene-hornblende-gabbro facies and olivine-augite-gabbro facies. Plagioclase is usually euhedral to subhedral and 70 – 90% An. Mafic minerals are subhedral to anhedral. Most of plagioclase and mafic minerals altered to sericite, chlorite and kaolinite.

2) Quartz diorite

Distribution and Occurrence : This rock is widely distributed in the whole survey area, from the southwestern end to the northern end of the area.

It occurs as a number of various-scale masses intruded into the Licuan Group, Tineg Formation and gabbro masses. However, most of these masses may be considered to be connected with each other in the shallow depth on the basis of their contacts which are dipping gently into the intruded rocks. As a whole it formed the batholith-shaped in a major-scale. Small-scale stock - and dyke-shaped bodies are also formed in places.

The remarkable distribution pattern of quartz diorite masses has not been observed but it can be roughly said that these masses are abundant in the northern and southern parts of the survey area and relatively poor in the central part. The general trend of these rocks seem to be NNE–SSW to N–S.

Rock Facies : Generally, this rock shows light-graish white to light-greenishi gray color. It is medium - to coarse-grained leucocratic holocrystalline rock with obvious equigranular texture, but in the marginal part its grain size becomes fine. Some parts of this rock show light-pinkish gray sue to its abundant K-content and fine-grained melanocratic facies.

Main rock-forming minerals are plagioclase, quartz and hornblende, accompanied by small amounts of K-feldspar, biotite, augite and hypersthene. Depending upon the combination and ratio of these minerals, this rock varies lithologically from granodioritic to diorite facies continuously, so that it is very difficult to classify the rock facies in detail.

Under the microscope, this rock show the equigranular and micrographic textures, and consists mainly of euhedral to subhedral plagioclase (50–70 % An), anhedral quartz and subhedral to anhedral hornblende, augite and lasser amount of K-feldspar. Some of plagioclase, hornblende and augite are altered to chlorite, sericite, calcite and kaolinite.

The alteration of this rock is generally weak and only chloritization and epidotization are sporadically observed, but the mass distributed along the lower stream of the Apayao River has been intensely silicified, sericitized and chloritized, in striking contrast to other quartz diorite masses. On the other hand, many minor joints and fractures are formed in the inner core, and also in the marginal part of most of the quartz diorite masses. Mineralization also occurs as network and/or dissemination along these fractures. This is the optium and most important rock for mineralization.

3) Granodiorite

Distribution and Occurrence : This rock is mainly distributed in the central portion of the survey area, which includes the middle reaches of the Ikmin Rivers and the middle to upper reaches of the Binongan River, and the southern part of Kabugao. A small-scale mass of this rock is also found near Bontoc. However, granodiorite is never found in the distribution area of gabbro.

This rock occurs as large-scale batholithic mass trending NNE–SSW. However, some small masses occur as stocks and/or dykes in the peripheral portion of the batholiths.

Rock Facies : This rock is medium - to fine-grained leucocratic holocrystalline rock showing light-grayish white to light-greenish gray color. But some parts of this rock show light-pinkish gray color due to a large amount of K-feldspar and gray to greenish gray due to abundant mafic minerals. Principal constituent minerals are quartz, plagioclase, biotite, hornblende, K-feldspar and augite. The granodiorite also has various rock facies in lithology from granodiorite to quartz monzonite, these facies gradually change like quartz diorite. The alterlation of this rock is also very weak and chloritization, epidotization and rarely sericitization are recognized in some parts of granodiorite.

Microscopically, this rock shows typical equigranular and micrographic textures, and major amounts of anhedral quartz, euhedral to subhedral plagioclase (50–50 % An) and subhedral to anhedral K-feldspar are observed as felsic minerals. Mafic minerals of this rock are subhedral to anhedral biotite, hornblende and augite. Plagioclase and mafic minerals are partially altered to sericite, chlorite, epidote and kaolinite.

In the same case as the quartz diorite, numerous minor fractures are developed in the inner portion of granodiorite mass and its marginal part with mineralization.

2–2–2 Hypabyssal Rocks

The rocks occur as stocks and dykes intruding the Licuan Group, Tineg Formation and plutonic rocks, and they are classified into diorite porphyry, quartz diorite porphyry and granophyre. All of them are closely related genetically to the plutonic rocks and considered to be the products formed by the multiple plutonic activity.

1) Diorite Porphyry

Distribution and Occurrence : This rock is limitedly exposed in the northern tributary of the downstream of the Layacan River as a dyke trending NE–SW and intruding the Tineg Formation. In other portion of the survey area, no diorite porphyry is found.

Rock Facies : This rock is greenish gray to light green fine - to medium-grained porphyritic rock with abundant phenocrysts of acicular hornblende and plagioclase. It is weakly altered in general but intense chloritization, epidotization and partially pyritization are recognized in its marginal parts. Under the microscope, this rock shows remarkable porphyritic texture and is composed mainly of coarse-grained euhedral plagioclase and lesser amount of euhedral hornblende. These minerals are altered to chlorite, epidote, sericite, calcite and secondary quartz.

2) Quartz Diorite Porphyry

Distribution and Occurrence : This rock is the most common rock facies of porphyritic rocks. It is distributed in the upstream of the Madongan River, the middle to upper streams of the Palsuguan River, the southern portion of Bucloc, the upper reaches of the Manikbel and Malibcong rivers, the lower streams of the Layacan River and around Butong Buhay mine along the Pacil River. This porphyry occurs as small-scale stocks and dykes intruding into the Licuan Group, Tineg Formation and the above-described plutonic rocks. The intrusive direction of these rocks is irregular but NE–SW or

NW–SE trends are relatively predominant.

Rock Facies : This porphyry is usually grayish white to gray, occasionally light green to light-greenish gray color, and it is a medium - to coarse-grained porphyritic rock accompanied by phenocrysts of quartz, plagioclase and little amounts of chloritized hornblende and pyroxene. This rock contains microscopically euhedral to subhedral plagioclase, anhedral quartz and euhedral to subhedral hornblende and augite as phenocrysts, but some occurred around Batong Buhay contain biotite. Groundmass consists of fine-grained quartz and plagioclase, rarely K-feldspar. These minerals are mostly altered to chlorite, epidote and sericite. This rock is also one of the most suitable rocks for the mineralization.

3) Granophyre

Distribution and Occurrence : This rock occurs as a small stock intruding the granodiorite mass in the direction of NNE–SSW in the middle stream of the Ikmin River ; and as a dyke intruding the Tineg Formation in the direction of NNE–SSW in the headwaters of the Anayan River.

Rock Facies : Both of the two intrusive bodies show the same lithologic feature, that is, they are pinkish gray coarse-grained leucocratic rocks consisting of plagioclase, quartz, K-feldspar and a rare amount of biotite. Under the microscope, the rock exposed in the middle stream of the Ikmin River is coarse-grained anhedral quartz, euhedral plagioclase (less than 10 % An), subhedral K-feldspar and a minor amount of fine-grained subhedral biotite. They form the typical micrographic texture.

The alteration of these rocks is very weak and rare chloritization is found in few parts of the rocks.

2–2–3 Dyke Rocks

In this survey area, numerous dykes intruding the Licuan Group, the Tineg Formation and the plutonic rocks are exposed in many places. These dyke rocks vary lithologically from doleritic to dacitic facies, but andesite and dacite are the most abundant. The direction of the intrusion of dykes is at random but some of them are controlled by faults and other structures. The scale of each dyke is extremely small, and most of them are not drawn on the geological map.

1) Dolerite

The dolerite occurs as dark green massive dykes in the downstream of the Binongan River and as a dark green sheet with 3 meters in thickness in the upper stream of the Anayan River. Chloritization and epidotization are partially recognized around the contact between this rock and the intruded rocks.

2) Andesite

This rock is the most common facies and it intruded the Licuan Group, Tineg Formation and plutonic rocks in many places. The andesite dykes are usually green to dark green massive aphanitic rocks since a few mafic minerals, such as pyroxene, are megascopically observed in some parts of this rock. In the Baren and Ikmin rivers this rock shows porphyritic facies with large phenocrysts of plagioclase and hornblende. The scale of dykes is a few meters in width. Alteration of this rock is very weak and only chloritization and epidotization are partially found in some dykes.

3) Dacite

A number of dacite dykes are distributed in this survey area. Remarkable dykes of dacite are exposed in the upper streams of the Manikbel and Tineg rivers, the southern portion of Bucloc, the lower streams of the Binongan and Layacan Rivers and around Batong Buhay mine. In the Tineg River, many dykes, 3–5 m (maximum 12m) in width, form a dyke swarm trending E–W in the quartz diorite.

This rock shows light-graish white to gray color and contains phenocrysts of plagioclase, quartz and hornblende. Mafic minerals are usually poor. The dacite dykes exposed in the Binongan River show porphyritic texture and contain large phenocrysts of quartz. Generally, these dykes are weakly altered but some dykes are highly chloritized and silicified.

2–3 Chemical Composition and Ages of Intrusive Rocks

2–3–1 Chemical Composition of Intrusive Rocks

The twenty three samples collected from the plutonic and hypabassal rocks distributed in the project area were analyzed to determine their chemical composition. The locations of samples are shown in Fig. II–2 and their analytical results are shown in Table A–2.

Table A–2 shows that the SiO_2 content of all samples range from 41.62% to 76.36% and thus belong to the basic to acidic rock facies but most samples belong to the intermediate facies. The Fe, Mg and Ca contents of the samples a-502 and b-2338 showing affinity to the acidic rock are in excellent contrast to that of g-512 and a-2306 to the basic rock, and these results prove that the former is a leucocratic rock and the latter is a melanocratic one containing abundant mafic minerals.

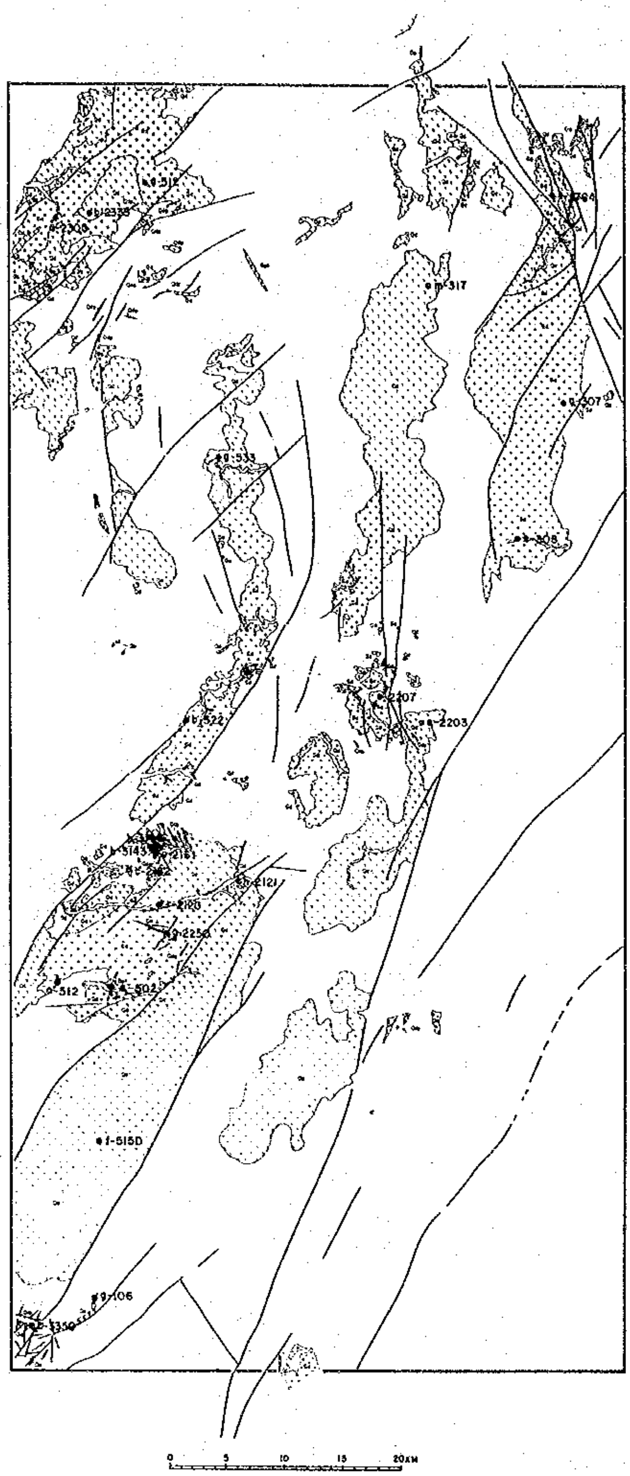
Fig. II–3 shows the relationship between each oxide and the differentiation index (D.I.) This figure shows the general feature of the magmatic differentiation of the calc-alkali rock series, that is, with the progress of the magmatic differentiation, SiO_2 value increases but FeO value decreases. This feature is proved by the M-F-A diagram showing the relation among MgO, Na_2O+K_2O and FeO+Fe_2O_3, as shown in Fig. II–4. In this diagram, FeO+Fe_2O_3 value continuously decreases with progress of the magmatic differentiation.

According to Fig. II–4, all samples trace the same magmatic differentiation process as that of the volcanic rocks of the calc-alkali rock series. From Fig. II–3 and Fig. II–4, it can be considered that g-512 and a-2306 are the early phase products of the magmatic differentiation process, most samples are the middle to late phase, and a-502 is the latest phase.

Normative constituents of each sample are plotted in the Or-Ab-An diagram, as shown in Fig. II–5. In this diagram, a certain trend was obviously recognized from the high anorthite-low orthoclase-albite zone to low anorthite-middle orthoclase-albite zone. However, two samples, b-2338 and e-2203, were plotted in the high albite zone. In can not be decided whether these two samples show the different trend or not. This diagram contains 2 data of the quartz diorite taken from the Agno Batholith and 8 data of quartz diorite porphyry, which is the hostrock of the Tawi Tawi porphyry copper ore deposit (ore reserve: 178 million tons, Cu content: 0.399%) located at Bokod, collected by the Northeastern Luzon survey. These samples trace the different trend from the rocks of this area and show the low concentration of alkali in the late phase of the differentiation.

Fig. II–6 shows the classification of plutonic rocks. Among 23 samples analyzed, a-502 sample is plotted in the granite zone, e-308 in quartz monzonite zone, e-308 in monzosyenite-monzonigabbro zone, a-2306 in gabbo and other 19 samples are plotted in granodiorite, tornalite, quartz monzosyenite and quartz diorite zones.

From the above-mentioned facts, the plutonic and hypabyssal rocks distributed in this project area are considered to have been formed from the same magma by the consecutive plutonic activity. Although the intrusive rocks show various rock facies from gabbro to granophyre, these variation of the facies can be considered to be caused by the different phase of the magmatic differentiation process.



LEGEND

● Rock Samples for K-Ar Dating and Chemical Analysis

Fig. II–2 Location Map of Rock Samples for Chemical Analysis and Dating

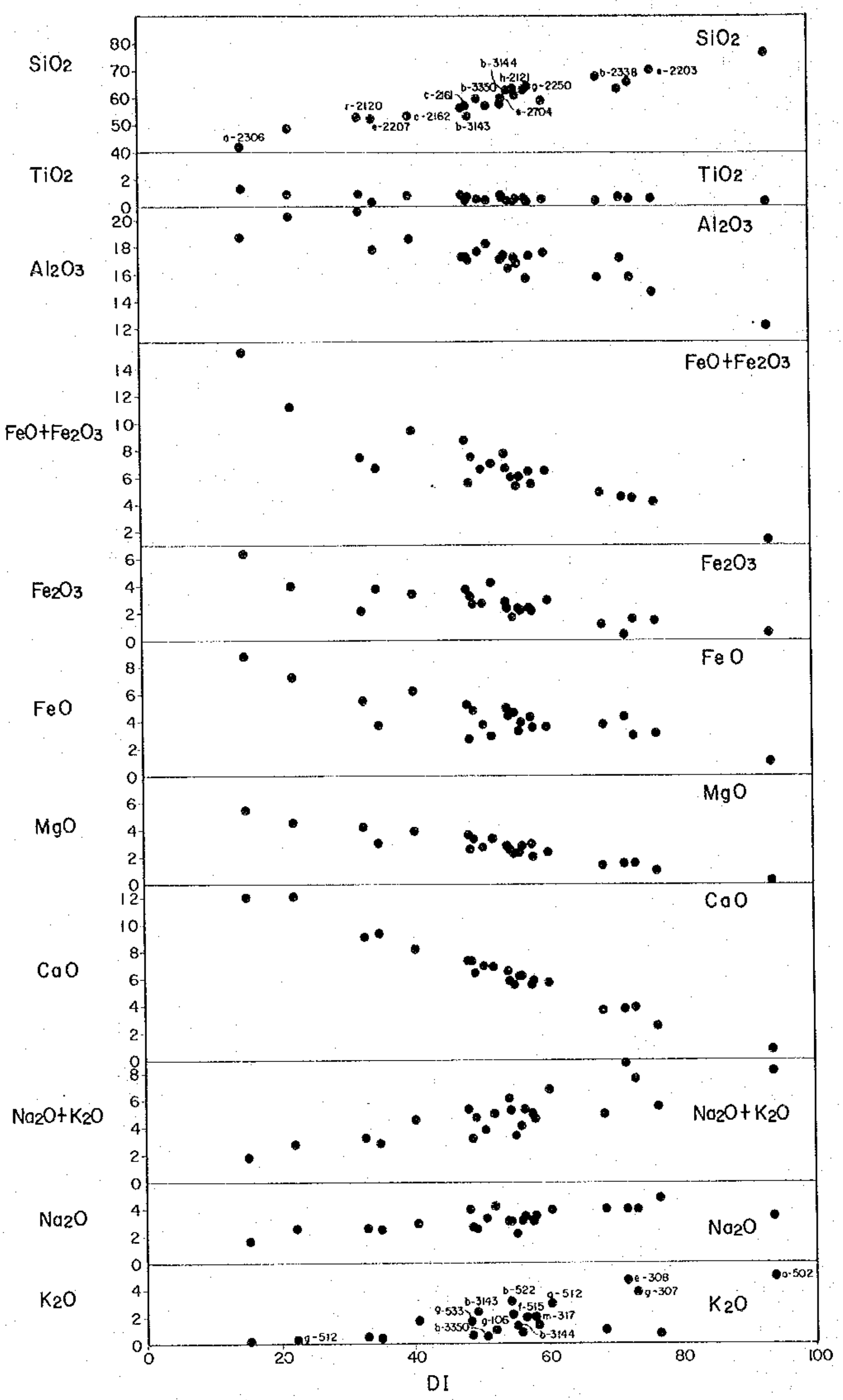


Fig. II–3 Variation Diagram of Intrusive Rocks

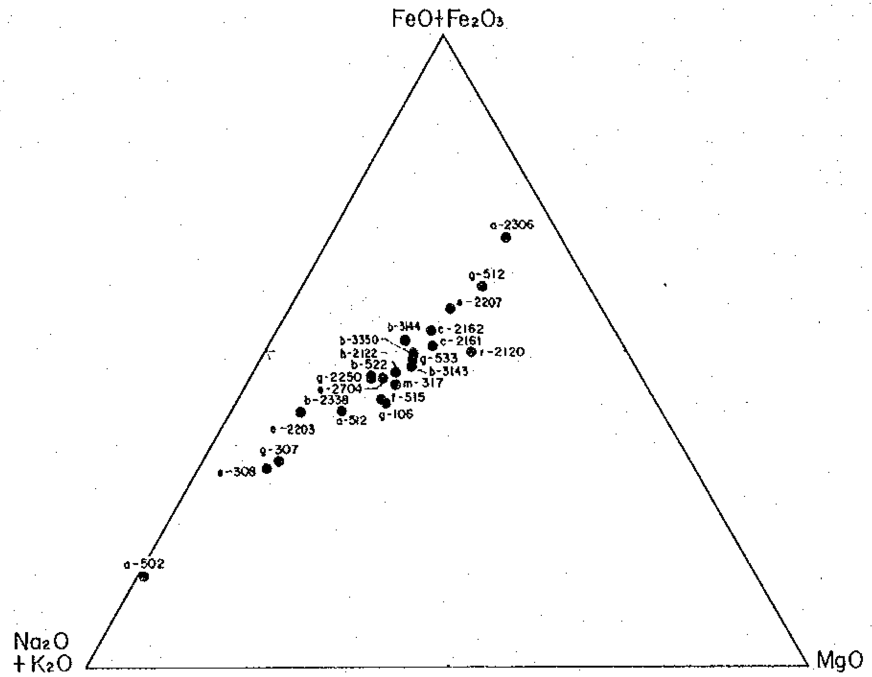


Fig. II-4 M-F-A Diagram of Intrusive Rocks

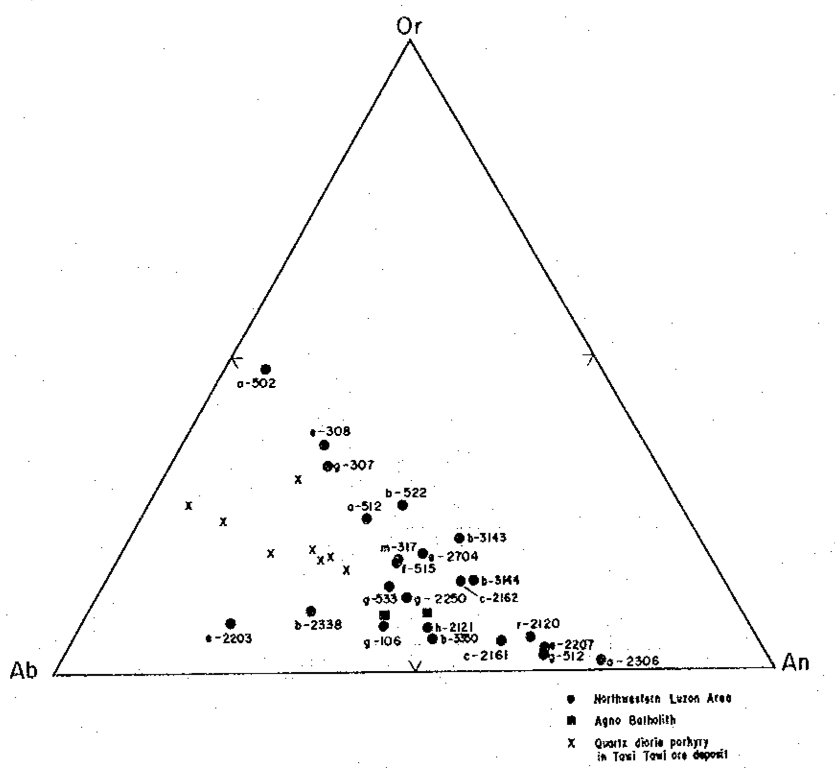


Fig. II-5 Normative Or-Ab-An Diagram of Intrusive Rocks

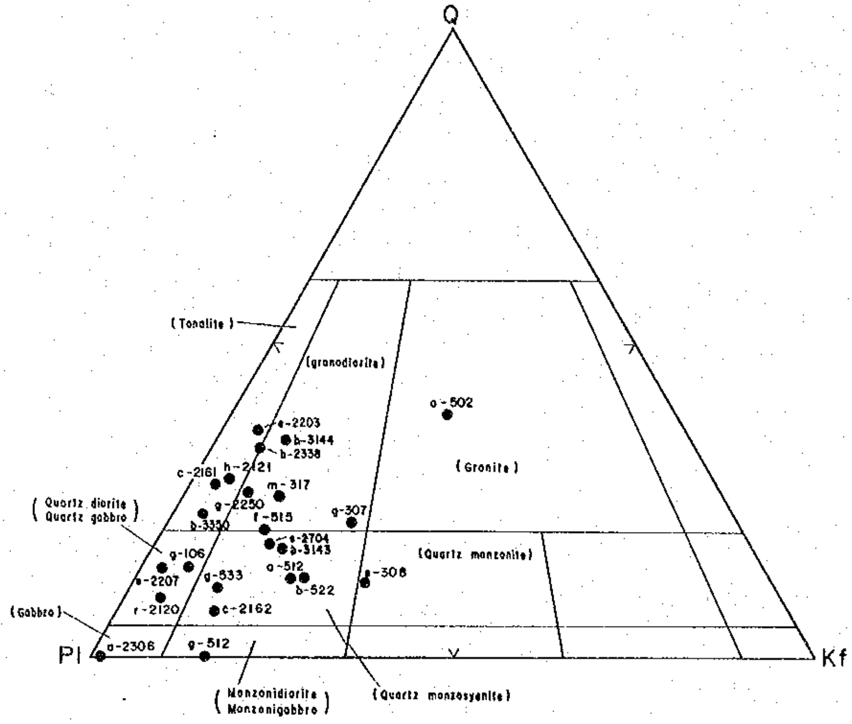


Fig. II–6 Normative Q-Kf-Pl Diagram of Intrusive Rocks

2–3–2 Ages of Intrusive Rocks

To know the intrusion ages of the intrusive rocks in this project area, absolute ages of 23 samples chemically analyzed were measured by K-Ar method, and the result of age determination for 20 samples were obtained as Table A-2. Three samples, g-106 (diorite porphyry), g-512 (gabbro) and a-2306 (gabbro), do not certain enough amount of K to determine thrie ages.

Table A-2 shows that their ages vary almost continuously from 26.3 m.y. to 9.8 m.y. From the viewpoint of rock facies, the results can be summarized as follows:

Quartz diorite (8 samples)	26.3 – 13.7 m.y.	26.3 – 15.9 m.y. (6)	Late Oligocen to Middle Miocen
		12.0 – 9.8 m.y. (2)	Middle Miocene
Granodiorite (6)	20.0 – 13.7 m.y.		Early to Middle Miocene
Quartz diorite porphyry (2)	15.4 – 12.6 m.y.		Middle Miocene
Granophyre (1)	12.6 m.y.		Middle Miocene
Dacite (3)	18.3 – 9.8 m.y.	18.3 m.y. (1)	Early Miocene
		10.5 – 9.8 m.y. (2)	Middle Miocene

From the above-stated ages of each rock facies, the sequence of intrusion is briefly considered to be that plutonic rocks → hypabyssal rocks → small-scale dykes in order of their decreasing age with excepting younger quartz diorites and older dacite. The older dacite dated as 18.3 m.y. intruded the granodiorite showing 20 to 18 m.y., and the quartz diorite showing the oldest age, 26.3 m.y., in this project area is exposed near the said dacite. This distribution feature is not inconsistent with the above-mentioned sequence of intrusion.

Although the activity of quartz diorite seems to have the two ranges which consist of the range from 26.3 to 15.9 m.y. and other one from 12.0 to 9.8 m.y., it is not clear whether or not there are two different-aged quartz diorite facies. Besides, the age of gabbro is considered to be before 23 m.y., as the gabbro is intruded by the quartz diorite being 23.0 m.y. in age while the age of the gabbro was not dated by K-Ar method.

2–4 Geological Structure and Geological History

The geological structure of the project area is characterized by large-scale batholith-like plutonic rocks extending north and south, and many faults. The principel trends of these structures are (1) N-S, (2) NE-SW and (3) NW-SE.

(1) N-S System Structure

The structure of this system is represented by the intrusion of plutonic rocks and N-S ∿ NNW-SSE faults. The emplacement of plutonic rocks reflects the structure of the basement rocks – probably Pre-Cretaceous crystalline schists, though there are no exposures in the survey area – which is the oldest structure in the area.

The faults of the N-S system, formed by the intrusion of plutonic rocks and uplift movements, developed in the central and the western parts and locally in the east of Kabugao where the faults cut the Alava Formation. This system agrees with the direction of the dacite dykes.

The N-S system structures in the central part of the Cordillera Central was emphasized by the intrusion of plutonic rocks and controlled the distribution of the Mabaca and Alava Formations.

(2) NE-SW System Structure

This system structure has two groups. One group is mainly observed in the northwestern part of the area and its scale is relatively small. However, this system seems to control the distribution of plutonic rocks. The other group is well developed in the center to the south of the area and is shown as large-scale faults. The period of its movement is considered to be post-intrusion and controls the intrusion of hypabyssal rocks and mineralization.

(3) NW-SW System Structure

The NW-SE system faults also consist of two kinds of faults. One is mainly distributed in the northern part of the Abra area and its scale is relatively small. The other is remarkably developed around the Kabugao and has a long strike-side extension. The period of the fault movement of major faults is younger than the other small faults. The major NW-SE system fault is the youngest in the project area.

There are no remarkable folding structures except wavy folds in the Licuan Group and Tineg Formation and an anticline with a long wave-length around the plutonic rocks.

Based on the above-mentioned geological structures, the distribution of each formation, the ages of the plutonic rocks, and from a viewpoint structural development, the geological history of this area can be summarized as follows:

The whole area of Northern Luzon including the survey area was mostly under the sea from the end of Cretaceous to Eocene time. Mainly basaltic (at first) and andesitic (later on) submarine volcanic activities occurred on a large scale and a thick pile of lava flows and pyroclastics accumulated – Licuan Group. The center of volcanic activities gradually moved from the southeast to the northwest of the area with the change of activities from basaltic to andesitic and the ocean floor began to upheave slowly from the southeast.

In the Oligocene time the sea retrogressed and dacitic lava flows and pyroclastic rocks produced by vigorous dacitic activities were lain with a few clastic rocks in a neritic environment -- Tineg Formation. The marine retrogression is thought to have continued during this time. The presence of welded tuff indicates that some parts of the ocean floor emerged above the sea. Coral limestone was locally formed at waning stages of volcanic activities.

In Latest Oligocene time, being controlled by the basement structures, plutonic rocks composed of gabbro – quartz diorite – granodiorite intruded as a large-scale batholith accompanying fault movements of a N-S system. In the central part of the area, the mountain range called "Ancestral Cordillera Central" after Durkee-Pederson (1961) was formed. Consequently the sedimentary basin was separated into the eastern and western basins by the Ancestral Cordillera Central, on both wings of which local andesitic igneous activities occurred along the N-S trending faults, and lava flows and pyroclastics were deposited – Mabaca Formation.

During the end of the Middle Miocene to Pliocene period a thick pile of molasse composed of sandstone, mudstone and conglomerate was continuously accumulated in the two sedimentary basins. At the fringe of the basins coral reef limestone was formed – Alava Formation.

On the other hand, plutonic activities occurred at the latest stage of Oligocene and ceased at the last stage of the Middle Miocene, showing rock-facies changes in response to magmatic differentiation. During this time porphyritic rocks were intruded and ore deposits were formed at their margins and partly in the rocks.

In Quaternary time local volcanic activities of dacite and andesite took place on a small scale with the result of deposition of lava flows and pyroclastic rocks – Quaternary Volcanic rocks.

3. ORE DEPOSITS

Geological and geochemical survey, as well as geophysical survey had disclosed the existence of a number of mineralized zones including two ore deposits, which are under constructing for development at present, in the project area. These mineralized zones are widely scattered from the northern to southern boundaries of this area, but most of the zones are concentrically distributed along the marginal part of plutonic intrusion mass and its vicinity, as shown in Fig. II–7. Although the mineralized zones can be divided into three types such as; dissemination-network, vein and skarn types, all of them are considered to be formed under almost same geological environment.

The details of principal mineralized zones and general features of mineralization observed in this project area are described hereafter. The several mineralized zones distributed in the Chico River basin were described on the basis of the data shared by BMG.

3–1 Mineralized Zones

1. Solsona Mineralized Zone

This mineralized zone is situated in the upstreams of the Solsona River. This zone covers a wide area of approximate 6km E-W and 4km N-S, and consists of eleven vein type mineralized outcrops and five dissemination type outcrops. Most of the veins type are pyrite-quartz veins occasionally accompanied with tiny magnetite grains, generally trend E-W and NNE-SSW, and have the maximum 10cm in width. There is exceptionally a pyrite-chalcopyrite vein (15cm in width) accompanied with a little sphalerite at the southeast end of this zone. The Cu enriched vein accompanies a silicified zone (1.0m in width) with pyrite dissemination. The richest part in the vein shows 19.90% Cu, 0.05% Zn, and 31.0 g/t Ag. These veins are concentrated in the marginal part of the gabbro masses. The mineralization of dissemination type is observed in the gabbro and quartz diorite masses. It consists of only pyrite, occasionally accompanied with small amounts of magetite.

As stated above, this zone has a large distribution area and a great number of mineralized outcrops. However, the scale of each outcrop and intensity of mineralization and alteration are entirely small and weak, and copper minerals are observed in only few veins.

2. Madongan Mineralized Zone

This mineralized zone consisting of three veins and four disseminated outcrops is situated in the uppermost streams of the Madongan River, and covers an area of 3km E-W

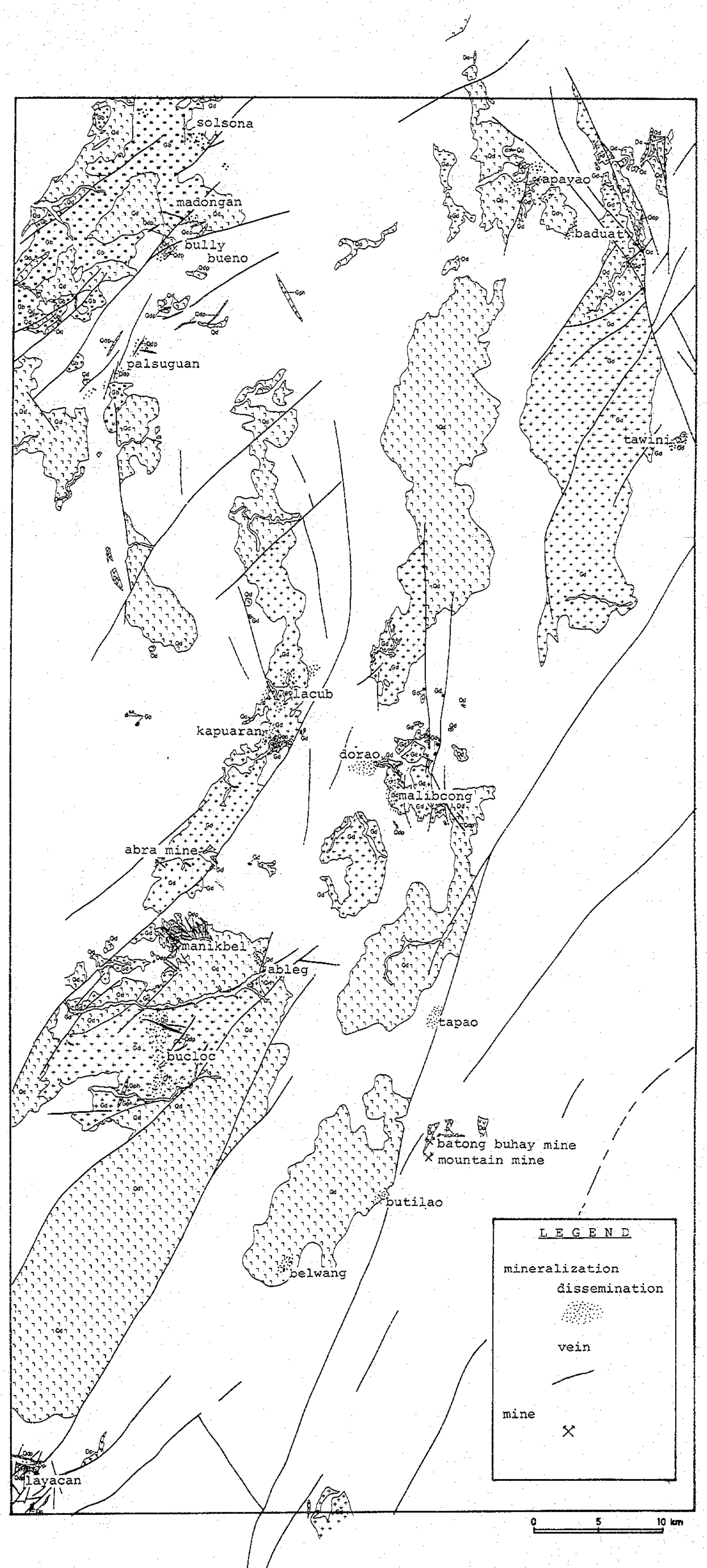


Fig. II–7 Distribtion Map of Mineralized Zone and 3.5km N-S. The outcrops of veins are distributed in gabbro and near its contact with quartz diorite. One of the veins is a networked zone (20cm in width) consisting of pyrite-bearing quartz veinlets, and trends NW-SE.

The other two are pyrite-quartz veins partly with a small amount of magnetite and chalcopyrite, and trend NE-SW and N-S. The disseminated outcrops are observed near the contact between the Licuan Group Formation II and quartz diorite, and in gabbro. It consists mainly of pyrite with a small amount of magetite and occasionally with rare amounts of chalcopyrite.

3. Bully Bueno Mineralized Zone

This mineralized zone is located 2 km south of the Madongan mineralized zone, at high elevation of 1,600 m above sea level. The provincial boundary between Ilocos Norte and Abra is situated 400 m to 600 m south of this mineralized zone. The road to this zone is not completed yet and it needs two days by the trail (34 km) along the ridge from Nueva Era of Ilocos Norte to this zone. The mining claim has been staked in an area including this mineralized zone by Tirad Minerals, Inc. and at present is under prospecting by Hercules Minerals and Oils, Inc..

The ore deposits consists of veins and network and are formed near the boundary between andesitic pyroclastic rocks of the Licuan Group Formation II and the stocks of quarz diorite porphyry intruding the Licuan Group. There are two large and small quartz diorite porphyry stocks, spacing about 1 km, and mineralization is recognized in both stocks, of which width is usually 30 cm to 50 cm, and occasionally, 1 m. The ore-forming minerals are composed of chalcopyrite, bornite and a small amount of chalcocite and plenty of malachite and azurite occur in outcrop. Gangue minerals are quartz and rare amount of barite. According to the data from BMG the analytical results of the samples taken from ten outcrops show the Cu contents ranged from 0.37% to 10.16%. From the results of the drilling exploration of more than sixty holes conducted by Hercules Minerals and Oils, Inc. until 1977, ore reserve of 6,470,000 ton (1.08% Cu) was estimated.

4. Palsuguan Mineralized Zone

This mineralized zone is composed of many outcrops which are distributed in the main stream and tributaries of the upper stream of the Palsuguan River, and this zone has an area of 5 km NE-SW and 2.5 km NW-SE.

Outcrops were divided into two groups of the northern group and southern group, from their distribution.

The northern group consists of vein and/or disseminated outcrops in andesite lava and its pyroclastic rocks of the Licuan Group Formation II. In this area, quartz diorite porphyry dike trending NE-SW which direction is well identical with the extension direction of the mineralized zone. Veins trending N-S are composed of quartz with pyrite and their widths are usually 30 cm to 5 cm. Copper mineral is absent. Disseminated outcrops consist of pyrite without copper mineral and their extension and intensity of mineralization are small and weak.

In the southern area, gabbro and quartz diorite masses are distributed along the fringe of the mineralized zone, which intruded into andesitic rocks of the Licuan Group Formation II, and vein disseminated outcrops were formed in the marginal parts of both masses and in andesitic rocks. Ore-forming minerals, width of vein and the extension of dissemination are similar to those of the northern group outcrops and no copper minerals were observed in both areas. Furthermore, there are no variable outcrops in spite of numerous ones.

As mentioned above, this mineralized zone has a wide area similar to the Solsona mineralized zone, but it is considered that this zone has low potential because of a small and narrow dimension of each outcrop composing mineralization zone, and rare copper minerals.

5. Apayao Mineralized Zone

This mineralized zone is located in an area of 4 km E-W and 5 km N-S near the junction of the Apayao and Dagara rivers. Disseminated zones of more than ten were observed in this zone. Most of them are distributed near the quartz diorite bodies intruding the Licuan Group, and some mineralized zones are distributed in the center of the body. Most of the disseminated zones have approximately 200 m to 500 m in a scale. It consists mainly of abundant pyrite as frequent film and occasional network, with little chalcopyrite. The quartz diorite in this zone is highly silicified and chloritized, compared with it in the other area.

6. Baduat Mineralized Zone

This mineralized zone is located northwest of Barrio Buduat situated 3.5 km to the south of Kabugao. It consists mainly of the three dissemination outcrops standing on a line trending E-W. The western outcrop consists mainly of pyrite dissemination with a little chalcopyrite. The central outcrop occurred in granodiorite is composed mainly of pyrite-chalcopyrite dissemination, with abundant malachite. The results of chemical analysis of ore sample obtained from the outcrop show 6.92% Cu, 6.47% S, 0.2 g/t Au and 65.5 g/t Ag.

The host rock is highly silicified and sericitized, and partly argillized. The mineralization of this outcrop is similar to it of the main part of the Malibcong mineralized zone. The eastern outcrop located near the quartz diorite porphyry dike consists mainly of pyrite dissemination, accompanied with small amounts of chalcopyrite, bornite and malachite.

7. Tawini Mineralized Zone

This mineralized zone is located in northwest of Barrio Tawini and occupies a small area of 1.6 km E-W and 2 km N-S. At present it is under the drilling exploration by Marcopper Mining Corporation. This zone shows characteristics of porphyry copper type, the mineralization is mainly observed in and near the quartz diorite stock, and consists mainly of chalcopyrite and pyrite with a small amount of bornite. Based on the results of drillings, it is clear that the quartz diorite stock has some apophyses and the mineralization is dominant in the margin of the stock and apolyses. The result of the chemical analysis of two ore samples obtained from the outcrops near the stock are as follows:

Cu %	W %	Au (g/t)	Ag (g/t)
1.97	0.12	0.8	1.1
0.43	1.83	0.5	2.0

Observating the ore sample taken from the western edge of the stock under the microscope, a lot of chalcopyrite grains containing tiny hematite grains are observed. The rim of chalcopyrite grain are partly replaced by covelline.

8. Lacub Mineralized Zone

This mineralized zone is located around Barrio Lacub and widely occupies an extended area of 8 km N-S and 2 km E-W in dimension. The zone consists of the following four subzones : (1) chalcopyrite and pyrite bearing networked-disseminated zone distributed in the northern portion of Lacub (main mineralized zone); (2) pyrite disseminated zone located in the eastern part of the main zone; (3) skarn type mineralized zone with pyrite distributed along the eastern ridge of the above-mentioned zone (2); and (4) pyrite disseminated zone widely extended in the southern part of Lacub.

The main mineralized zone (1) having an area of 2 km N-S and 0.6 km E-W in dimension lies 1 km north of Lacub and occurs as dissemination of pyrite and chalcopyrite with small amounts of bornite and chalcocite in intensely altered granodiorite mass. Remarkable malachite is found in surface of outcrops. Primary sulfide minerals occur usually as dissemination replaced mafic minerals of the hostrock and occasionally as network of quartz veinlets filling minor fractures and joints. The results of the chemical analysis of two lump samples taken from the outcrops situated at the southern margin of the zone are as follows:

Cu (%)	S (%)	Au (g/t)	Ag (g/t)
2.26	0.12	0.0	2.7
0.39	0.10	0.0	4.4

The specimen, under the microscope, large amounts of magnetite and secondary minerals are observed but primary copper mineral is not found. As alteration of host rock, intense silicification and sericitization are remarkably observed. Especially in the strongest altered zone, biotite is locally formed. From the forementioned mineral assembly, occurrence and alteration of the host rock, it can be said that this mineralized zone is a typical porphyry copper type of ore deposit although its scale is not so large. In addition, this zone had been prospected by Inco Mining Corporation and CDCP, but the results of that prospecting works could not be obtained.

The sub-zone (2) consisting of several number of pyrite disseminated outcrops with network of pyrite stringers lies 1 km each of the main mineralized zone and occurs discontinously in the weakly silicified granodiorite within 1.2 km along the creek. However, their mineralizations are generally weak and only a small amount of pyrite is observed as ore mineral in each outcrop.

The sub-zone (3) is distributed along the small ridge located at approximately 1 km east of the sub-zone (2). In that portion, the boundary between andesite lava of the Licuan Group Formation II and granodiorite mass extends with N-S direction, and two skarn type mineralized and altered zones accompanied by disseminated pyrite and a large amount hedenbergite are formed at intervals of around 400 m in andesite lava near the boundary. Extent of each mineralization is about 500 m in diameter. Minor amount of pyrite is observed as ore mineral but any copper minerals could not be found. Andesite lava is intensely silicified, chloritized and occasional epidote veinlets are observed.

The sub-zone (4) spreading 3 km NE-SW and 1.2 km NW-SE is located in the southern part of Lacub and consists of numerous mineralized outcrops distributed along the creek and its basin. Most outcrops occur in intensely silicified and sericitized granodiorite and andesitic volcanic rocks of the Licuan Group Formation II, especially remarkably developed near the contact of both rocks. Each outcrop consists mainly of disseminated pyrite and occasionally pyrite veinlets, but copper minerals can not be found.

As mentioned above, within the Lacub mineralized zone there are small but typical porphyry copper type ore deposits with widely spread disseminated zones of pyrite considered to be the halo of the deposits, therefore, this zone was chosen for the detailed survey area. However, the survey of Phase III could not be conducted because of peace and order situation problem.

9. Kapualan Mineralized Zone

This mineralized zone is distributed around Kapualan, on the middle stream of the Malanas River, and is adjacent to the south end of the Lacub mineralized zone. The area of this zone is approximately 1 sq.km and four mineralized outcrops are distributed in this narrow zone. These outcrops are formed in andesite lava of the Licuan Group Formation II and quartz diorite porphyry intruding granodiorite.

The outcrops in the andesite lava and granodiorite are composed of pyrite dissemination and highly silicified zone with disseminated pyrite. No copper minerals were observed. Two outcrops in quartz diorite porphyry stock consist of dissemination of pyrite with a small amount of chalcopyrite, and the central one is accompanied by predominant malachite stains on its surface. The lump ore sample taken from the central outcrop gave 1.68% Cu, 0.32% S and 11.1 g/t Ag, but copper mineralization can be observed only within 200 ∿ 300m along creek. Silicification and partial sericitization are host rock alterations and they are recognized only in highly mineralized parts. Generally mineralization and alteration in this zone are entirely weak and local in comparison with the Lacub mineralized zone.

10. Abra Mine

This mine is located 2 km west of Barrio Baay occupying the southern bank in the middle reaches of the Baay River. The mine had been operated for copper and gold and being mined 50 tons of crude ore per day (0.88% Cu, 3.8 g/t Au), but it was closed in 1980.

Ore deposits are formed as vein type deposits in marginal part of the granodiorite and consist principally of three veins called Pias, Nalbagan, and Patoc. The occurrences of the veins in the mine are as follows:

Name of Vein	Pias	Nalbagan	Patoc
Strike.dip	E-W, 70°S	N10°E, 70–80°W	N45°E, 80°SE
Vein width	1.2 – 2.2m		
Strike length	500 – 600m	800m	800 – 900m
Assay Cu	0.3 – 6.4%		
Au	2 – 8 g/t		
Ag	16 – 25 g/t		

The outcrop of Pias vein consists of chalcopyrite, galena and pyrite accompanied with clay and small amount of quartz and the poor mineralized vein is composed mainly of clay and quartz.

Alterations of host rock are recognized to be silicification and argillizations. The result of the chemical analysis of two lump samples take from Pias vein outcrop which contains mainly chalcopyrite, quartz rich sample and a lump sample of banded ore offered by the mine are as follows:

	Cu (%)	Pb (%)	Zn (%)	S (%)	Au (g/t)	Ag (g/t)
Cu rich ore (A)	11.34	0.55	0.34	28.07	11.1	122.1
Cu rich ore (B)	14.87	0.00	0.47	34.71	6.6	154.7
Quartz vein	0.02	0.00	0.01	2.20	0.2	0.7
Banded ore	0.73	6.81	4.36	37.04	42.1	266.0

The Cu rich ore (A) were observed under microscope. Description is as follows:

Minerals observed are pyrite, arsenopyrite, chalcopyrite, sphalerite and galena. Of four polished sections, a great deal of native gold were observed in two sections. Many irregular cracks are formed in pyrite and arsenopyrite and show a typical cataclastic texture, but the texture is not found in chalcopyrite, sphalerite and galena, so that, it only suggests that the vein has been deformed at the early stage of the mineralization. Native gold shows deep yellow color. Its occurrences were detected as inclusion in the thin galena veins filling the fractures of pyrite and arsenopyrite. Maximum grain size of native gold under the microscope was 200μ. Chalcopyrite was often found as isolated single grains in the gangue minerals, but was occasionally accompanied by rim of arsenopyrite in its marginal part. No silver mineral were found in the polished section.

11. Manikbel Mineralized Zone

This mineralized zone was one of the targets for the Phase III detailed survey, and the detailed geological, geochemical and geophysical surveys and drilling exploration were conducted.

The mineralized zone consists of dissemination-network type outcrops distributed in the Mamising Creek basin which is located at the northern portion of Ud-Udiao, vein type outcrops located at the western portion of Ud-Udiao and small-scale vein outcrops near the Nagasasan. Fig. II–8 shows the distribution of mineralized zones in the Mamising Creek.

The mineralized outcrops in the Mamising Creek occur as dissemination of pyrite with small amount of chalcopyrite and abundant secondary copper minerals such as malachite

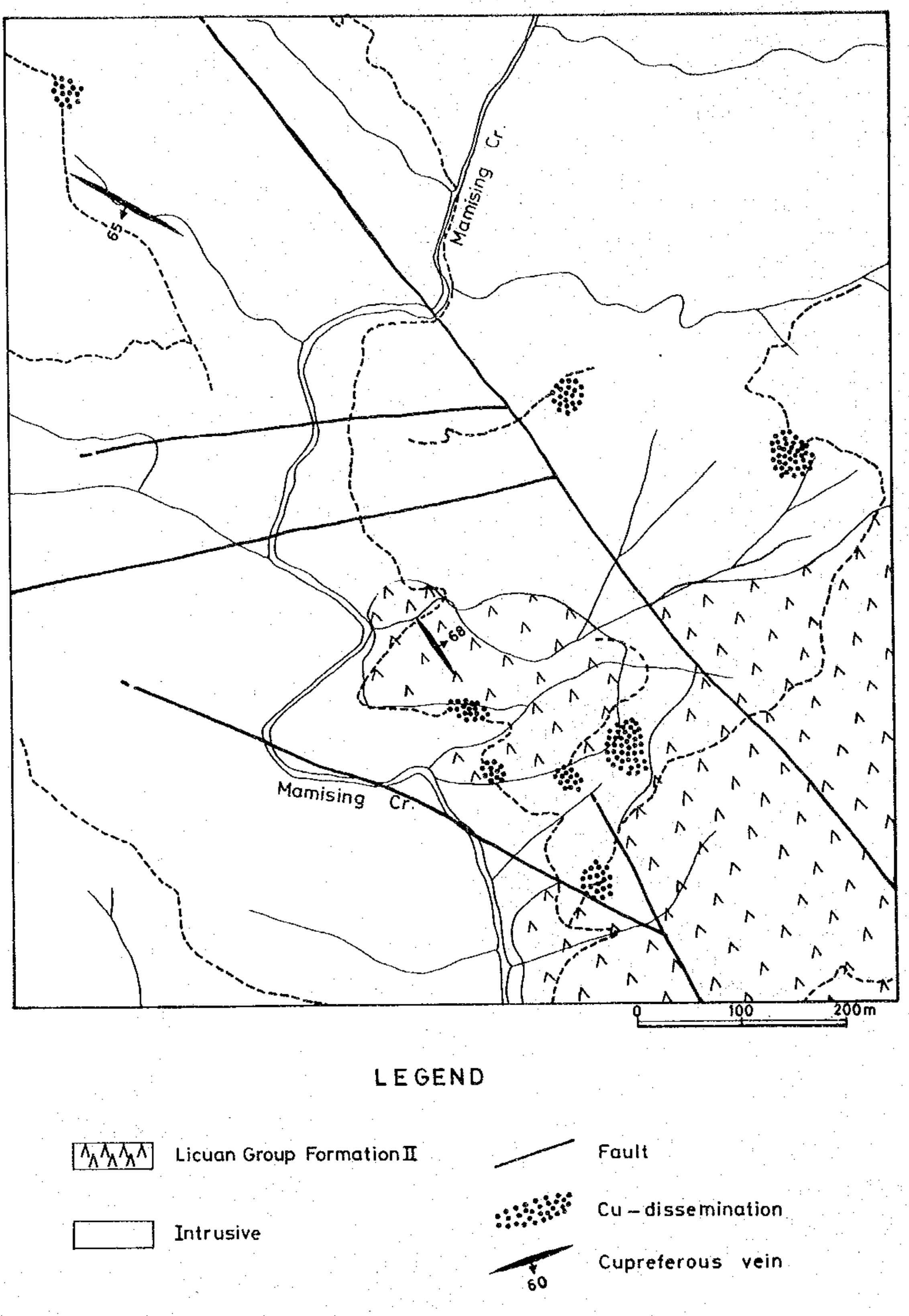


Fig. II–8 Distribution Map of Mineralized Outcrops in Manikbel Area and azurite in quartz diorite mass near the contact with andesite lava of the Licuan Group Formation II. In Phase III, the five samples collected from these outcrops were analyzed and their Cu and S contents ranged from 1.46% to 3.51% and 0.11% to 0.31%, respectively. The 20 samples of the Phase III surveys were also analyzed and 0.14% – 11.5% Cu and 0.03% – 5.38% S were obtained. Among these analytical results, the high grade samples for Cu showed low content of S, so that high Cu content is considered to be caused from the secondary copper minerals.

The lateral and vertical extensions of this mineralized zone were confirmed by the geophysical survey (IP method) and drilling exploration. From the result of the IP electric survey, high FE anomalous zone (more than 5% FE) extending towards depth were detected in the eastern periphery of the mineralized zone. The three holes were drilled in the IP anomalous zone to determine the IP anomalous zone and it was confirmed that pyrite dissemination with small amount of chalcopyrite was formed in granodiorite from 195.20 to 260.00 m depth of RPJ-1 hole. This is considered to be the extension of the mineralized zone though Cu content of the dissemination zone observed in RPJ-1 ranged from 0.2% to 0.3%.

Based on the above-mentioned results, it can be considered that the mineralized zone is formed as crust-shaped disseminated zone in the outermost part of the quartz diorite mass, and its primary ore minerals are pyrite and a small amount of chalcopyrite. The thickness of the zone may be less than 100 m.

The vein type mineralized zone located at west of Ud-Udiao consists of three chalcopyrite-pyrite-quartz veins and four thin pyrite-calcite-clay veins formed in andesite. Their general trend is ENE-WSW and E-W. The champion vein with 80 cm in width shows metal contents of 4.82% Cu, 5.30% S, 0.2 g/t Au and 38.6 g/t Au. Other two pyrite veins are observed in a adit drifted formerly by Marcopper Mining Corporation. These veins with 25 to 45 cm in width show the same nature and lesser grade of Cu content.

The veins distributed near Nagasasan occur in quartz diorite as pyrite-clay vein with 5 to 20 cm width. On the surface of the outcrops, abundant malachite are formed secondarily and their Cu content range from 1.32% to 2.98%.

The mineralized zone distributed in the Mamising Creek basin had been drilled with six holes by BMG in 1973 – 1974.

12. Ableg Mineralized Zone

This mineralized zone is located 1.5 km north of Ableg. This is composed mainly of networked zone in andesite lava of the Licuan Group Formation II and skarn type mineralized zone in the contact between granodiorite and limestone of the Licuan Group Formation II.

The former consists of three outcrops distributed along the creek discontinuously. Outcrop at the south end of the zone is newtork of veinlets containing pyrite, a small amount of chalcopyrite. This network strikes N40°W and dips 85°SW, and its maximum width is 1.0 m. Outcrop at the center is pyrite dissemination with a rare amount of chalcopyrite and its dimension is very small. In the upper stream, pyrite disseminated outcrop is formed along the creek between 1.0 km. Its extension is large but no copper mineral is observed.

The Cu and S contents of lump samples collected from each outcrop range 0.02% – 0.53% and 0.18% – 14.63%, respectively.

Outcrop of the skarn type mineralized zone is formed in limestone intruded by granodiorite. It is located near the sumit of the ridge, the west side of the above-mentioned network-dissemination outcrops. Limestone at the contact is intensely skarnized towards 4 m to 5 m from the contact with granodiorite, and garnet, hedenbergite, rhodonite and epidote occur. Granular chalcopyrite, pyrite and pyrrhotite are scattered in the zone where a plenty of garnet occurred. This outcrop extend about 50 m along the ridge. Metal contents of lump sample taken from the outcrop are 0.88% Cu, 0.26% S and 0.25% Mn.

In this mineralized zone, the mineralized outcrop of the skarn type shows an interesting Cu content, however, limestone is restrictedly distributed within about 50 m in diameter. In addition, the skarnized zone is also confined within 5 m from the contact. From these occurrences, this mineralized zone is considered to be small in dimension.

13. Bucloc Mineralized Zone

This mineralized zone is composed of the central part of the Bucloc and Boliney mineralized zones of the Phase I survey. It occupies the widest area in this project area, an area of 5 km E-W and 9 km N-S and contains a large number of mineralized outcrops. On the basis of their distribution feature, this zone can be divided into three groups : Group 1 – dissemination-veinlet group spread on the southern portion of Lamao; Group 2 – network-dissemination group at the divide between the Bucloc and Ikmin rivers; Group 3 – vein-dissemination group in the Ikmin River basin.

Group 1 : This group consists of three disseminations of pyrite and two pyrite-clay veinlets, and both are formed in granodiorite. Each dissemination contains a large amount of pyrite but copper minerals is absent. On a small ridge at 1 km southeast of Lamao, there are plenty of copper ores containing large amounts of malachite with minor amount of chalcopyrite and pyrite floats along the ridge within about 50 m. At that place, however, there are no exposures, so that it is not clear that those ores are floats or not. Metal contents of lump samples are 4.23% Cu, 1.02% S, 0.5 g/t Au and 1.8 g/t Ag.

Group 2 : Numerous outcrops belonging to this group occur as disseminations with network of veinlets containing pyrite in granodiorite and small dyke of quartz diorite porphyry trending NE-SW direction. Pyrite usually occurs as disseminations replaced mafic minerals and veinlets filling micro-fissures and minor sheared cracks. Ore mineral is only pyrite. The general trend of veinlets is NE-SW, and this direction is almost identical to the intrusive direction of quartz diorite porphyry dykes.

Most part of this zone were covered by the geophysical survey. In its central and northwestern portions, numerous number of pyrite veinlets are distributed. Chalcopyrite is occasionally associated with pyrite. Alterations of host rock are recognized to be intensive silicification, weak sericitization and partial argillization.

Group 3 : This group consists mainly of networks and disseminations containing chiefly pyrite. Several networked outcrops are remarkable on the upper reaches of the Ikmin River and disseminated ones are well developed on the middle reaches. Most networked outcrops are composed of quartz veinlets less than 3 cm in width and contain a major amount of pyrite. The disseminated outcrop at the northern bank of the middle stream contains a large amount of pyrite with lesser amount of chalcopyrite and the metal contents of a chip sample are 0.27% Cu and 0.26% S.

In the western basin of the middle stream of the Ikmin River, a lot of pyrite disseminated outcrops are distributed in granodiorite. These outcrops are equivalent to the main part of the Boliney mineralized zone of Phase I. According to the data from BMG, most of outcrops contain chalcopyrite, and Cu contents range from 0.11% to 6.20%.
In this mineralized part, the Phase I and II surveys could not be conducted because the inhabitants did not permit the implementation of the surveys.
However, this part had been ever explored by Marcopper Mining Corporation. According to a geologist of the company, high Cu anomalous zone of more than 1,000 ppm was detected in the basin of the Binulawan Creek, one of tributaries of the Ikmin River, and more than twenty holes were drilled. From the result of the drilling, the average grade of Cu were low although high grade Cu ores were observed in some holes.

From the results of the Phase II sruvey and the information from the company, it may be considered that the center of mineralization in the Bucloc mineralized zone is located in the Binulawan Creek basin. Many pyrite dissemination and the geochemical and geophysical anomalous zones can be considered to be the halo of the mineralization.

14. Layacan Mineralized Zone

The Layacan mineralized zone consists of numerous pyrite veins distributed along the main stream of the Balasian River and the lowest stream of the Kawayen Creek and some clayveins observed in the northern basin of the Segseg Creek.

Along the main stream of the Balasian River, more than ten pyrite-clayveins occur in basalt to basic andesite lava of the Licuan Group Formation I and stocks of quartz diorite porphyry intruding the lava. General trend of veins is N60°W and steeply dips north or south with various vein-widths ranged from 0.30 to 1.50 m. Many samples taken from all of veins were analyzed and their Cu content ranged from 0.01% to 0.21%, but some veins showed Au content of 1.3 – 12.2 g/t and Ag content of 5.6 – 18.6 g/t.

The veins exposed along the lowest stream of the Kawayen Creek occur in basic andesite lava near the contact with quartz diorite porphyry as shown in Fig. II–9. The widest vein is accompanied by chalcopyrite-bornite-pyrite streaks with 20 cm in width. This vein consists of, from hanging wall to foot wall, (1) pyrite and clay zone with 1.30 m in width, (2) high grade streaks of chalcopyrite-bornite-pyrite, 20 cm in width and (3) highly silicified zone with a thin streak of chalcopyrite-bornite-pyrite (1 – 2 cm width), 50 cm in width. The analytical results of each zone are as follows:

	Sampling width (m)	Au (g/t)	Ag (g/t)	Cu (%)	Pb (%)	Zn (%)
Zone (1)	1.30	0.1	6.4	0.04	–	–
Zone (2)	0.20	0.5	41.4	25.25	0.02	0.04
Zone (2)	lump	0.4	11.6	26.01	0.01	0.07
Zone (3)	0.50	0.0	0.8	0.20	0.00	0.00

Microscopic observation of lump ore taken from zone (2) showed that chalcopyrite altered to secondary copper sulfide such as bornite and digenite, although it was originally formed as primary mineral and that chalcopyrite could be observed in small amount only as a relic mineral after replacement. Pyrite occurred as an aggregate of fine to medium-grained crystals, interstices of which were filled by bornite and digenite.

The clayey veins silicified zones distributed in the Segseg Creek occur in basalt lava of the Licuan Group Formation I and dacite lava of the Tineg Formation. They contain poor

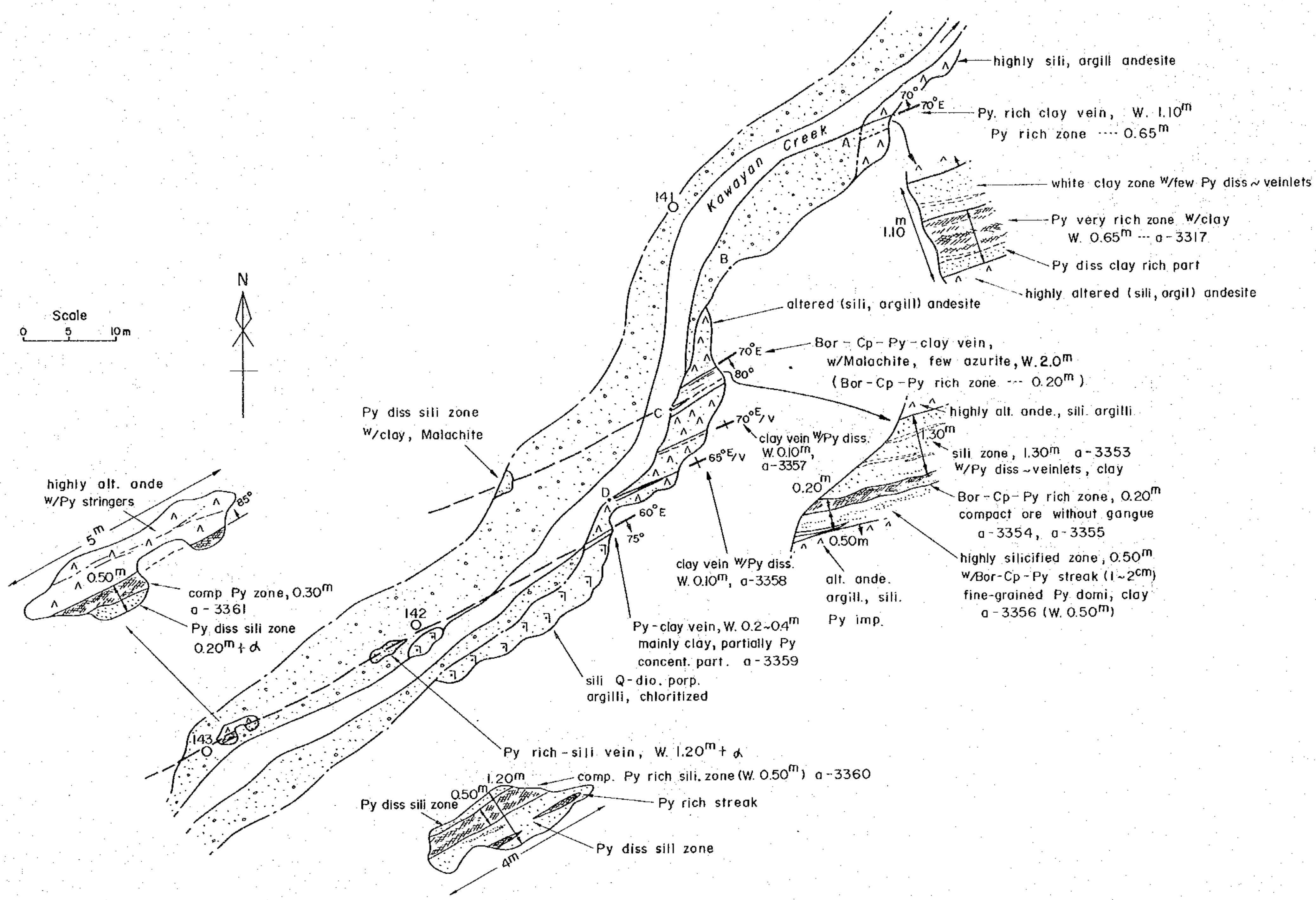


Fig. II–9 Distribution Map of Veins along Kawayen Creek in Layacan Area sulfide minerals with minor amount of gold and silver. At present they are unsystematically stoped by inhabitants.

15. Dorao Mineralized Zone

The Dorao mineralized zone spreading 1.5 km E-W and 0.5 km N-S is situated around Dorao, on the upper stream of the Binongan River, and consists of many outcrops distributed along the Binongan River. These outcrops occur mainly as disseminations of pyrite and occasionally very thin veinlets in the marginal parts of granodiorite intruding into andesite lava of the Licuan Group Formation II. Main ore mineral is pyrite and a small amount of chalcopyrite is partially observed. Intense silicification and local argillization are recognized at mineralized zones.

16. Malibcong Mineralized Zone

This mineralized zone which was newly discovered in Phase II is located at 4 km northeast of Barrio Malibcong and occupies an area of 2 km N-S x 0.8 km E-W. The zone consisting five mineralized outcrops are mainly formed around the contact between granodiorite mass and andesite lava of the Licuan Group Formation II. Among the five outcrops, three outcrops are formed in the peripheral parts of the mass and others in the andesite lava. Both rocks are intensely silicified and sericitized.

The outcrops in the mass are composed of disseminations of chalcopyrite and pyrite with a large amount of malachite and a small amount of azurite. Chalcopyrite and pyrite usually occur as replacement products of mafic minerals and thin veinlets filling microfractures and joints. Lump samples collected in two outcrops in the granodiorite mass show the following mineral contents:

Cu (%)	S (%)	Au (g/t)	Ag (g/t)
3.65	0.16	0.0	1.0
0.87	0.17	0.0	0.9

The outcrops in andesite lava are composed of dissemination of pyrite accompanied by a small amount of malachite and network (70 cm in width) of quartz veinlets with minor amounts of pyrite. The network strikes N26°W and dips 86°E. Both outcrops are accompanied by no copper minerals.

It can be considered that the Malibcong mineralized zone shows the same occurrence as the Lacub mineralized zone and its potentiality for copper mineralization equivalent to the Lacub one. Besides, this zone has never been prospected. Therefore, this mineralized zone was selected as the target of the Phase III survey, but the Phase III survey could not be conducted because of critical peace and order situation.

17. Tapao Mineralized Zone

This mineralized zone is located at 5 km south of Balbalasang and is formed in andestic rocks as pyrite dissemination. Five outcrops extend N60°E direction with maximum 1 km in width. Chalcopyrite is partially observed in the mineralized zone, however, grade of copper is not so high, showing 0.63% Cu in maximum. Geochemical anomalous zone (stream sediments) of Cu and Zn, 3.5 km x 1.5 km has been detected at 2 km south of this mineralized zone. According to the data of the Bureau of Mines, contents of Cu ranges 40 ppm to 1,200 ppm and Zn, 105 ppm to 350 ppm.

18. Batong Buhay Mine

The mine is located at Barrio Batong Buhay on the middle reaches of the Pasil River. At the preliminary survey for this project conducted in 1978, the mine was under test running and was producing 3,000 t/day (0.5% Cu, 3 g/t Au) of crude ore, and it was scheduled to be in full operation producing 21,000 t/day of crude ore from 1980. However, the mine is still under constructing at present.

The ore deposits occur in quartz diorite porphyry as stockwork and dissemination of sulfide minerals. The primary ore-forming minerals are composed mainly of chalcopyrite, pyrite and bornite with minor amount of native gold accompanied by network of quartz veinlets. As alteration of the host rock, silicification, sericitization and argillization are remarkably observed. According to ALMOGELA (1977), it is reported that ore reserve of the mine is 90 million tons (0.599% Cu).

19. Mountain Mine

The mine lies to the west adjoining to the Batong Buhay Mine and has already been explored by the Mountain Mine Incorporated. The ore deposits occurs in quartz diorite porphyry as stockwork, and five mineralized zones were confirmed in the area of 3 km x 3 km. Extension of the deposits shows N10° – 20°E trend. Ore minerals consist mainly of chalcopyrite, pyrite and bornite, and these minerals' occurrences are accompanied with thin quartz vein and as dissemination in the host rock. Copper grades taken from 37 test pit indicate 0.05 – 2.14% Cu, 12 samples from drilling cores 0.17 – 4.09% Cu and 11 samples from tunnel 0.21 – 1.60% Cu. Intensive silicification, sericitization and argillization are observed in and around the mineralized zone.

20. Butilao Mineralized Zone

According to a Bureau of Mines' survey, the mineralized zone ranging 900 m N-S and 400 m E-W is located at 7 km south of the Batong Buhay mine on the upper reaches of the Pasil River. It occurs as quartz veinlet network with pyrite, chalcopyrite and bornite along the boundary of quartz diorite and andesite which seems to belong to the Licuan Group Formation II. This mineralized zone has been explored by the Lepanto Mining Consolidated Inc. and estimated to have 30 million tons (Cu: 0.6%) of ore reserve. Silicification and partial kaolinitization were observed.

21. Belwang Mineralized Zone

This mineralized zone is located at 10 km southeast of the Butilao mineralized zone on the upper reaches of the Pasil River. This zone consists of two pyrite disseminated outcrops and four quartz veinlets network with pyrite dissemination and spread in the area of 1.5 km x 0.5 km. Four network zones are distributed showing NE-SW direction but the quartz veinlet shows N-S trend. Ore minerals consist of pyrite, chalcopyrite and bornite, and its grade shows 0.21 – 1.60% Cu. Host rocks, quartz diorite, are highly silicified.

Besides from the stated above, small-scale mineralized zones are locally recognized in the area of the Madongan, Sicapao, Tineg and Ikmin rivers. Some of them contain a small amount of copper minerals, however, the mineralization is generally very weak.

3–2 General Feature of Mineralization

The outline of each mineralized zone distributed in the project area is summarized as shown in Table II–3. Focusing on the geological environment in the formation of ore deposits, the following characteristics can be descrived:

1. The mineralized zones distributed in the surveyed area can be divided into three types, such as: (1) dissemination-network type; (2) vein type; (3) skarn type. Among them, the dissemination-network type mineralized zones are most distinguished and most of mineralized zones blong to this type. The vein type contains the Abra and Layacan mineralized zones, and the skarn type mineralized outcrops are observed in the Lacub and Ableg areas.

2. Most of the mineralized zones are formed in the plutonic and/or hypabyssal rocks and their peripheries as shown in Fig. II–7. It is evidently clear that the mineralized zones formed regardless of the intrusive rocks are extremely weak and small.

3. Main ore minerals in the network-dissemination type mineralized zone consist principally of pyrite and chalcopyrite with small amounts of bornite, chalcocite, molybdenite and magnetite, and rare amounts of galena and sphalerite in general.

On the other hand, the main component ore minerals in the vein type mineralized zone

Table II-3 Summary of Mineralized Zones

(1)

No.	Name	Location	Type	Scale	Hostrock	Mineral	Alteration	Occurrence	Remarks
1	Solsona	Upstreams of Solsona River	Diss, Netwk.	6.0 km x 4.0 km	Gabbro, Q-dio	Py, (Mag)	Sil, Epi	5 disseminated and 11 Q-veinlets networked outcrops are found in gabbro and Q-dio. Width of each vein is 1 ~ 3 cm (max. 10 cm). Main ore minerals are Py and Mag, but one veinlets contains Cp (19.90 % Cu).	
2	Madongan	Upstreams of Madongan River	Vein, Diss	3.0 km x 3.5 km	Gabbro, Q-dio, Q-dio -porp, Licuan F.II	Py, (Mag), (Cp)	Sil	3 Q-veins and 5 disseminated outcrops are distributed. Veins consisting of Py, (Mag) and (Cp) occur in gabbro and Q-dio. Their width are 10 ~ 30 cm. All of disseminated outcrops contain Py and Mag. No Cu minerals are found.	
3	Bully Bueno	Headwaters of Madongan River	Netwk. ~ diss	1.5 km x 0.5 km	Q-dio-por, Licuan F.II	Cp, Bor, Py Mal, Azu	Sil, Ser, Epi	Ore deposits consist mainly of network-shaped Q-veins containing Cp. Bor and Py in Q-dio-porp and its periphery. Generally vein width ranges 30 ~ 50 cm but occasionally 100 cm. Cu contents of 10 outcrops ranged 0.37 ~ 10.16 % on the basis of BMG report.	Under prospecting by Hercules Minerals and Oil Inc.
4	Palsuguan	Upper stream of Palsuguan River	Diss ~ Vein	5.0 km x 2.5 km	Licuan F.II, Q-dio	Py	Sil	Mineralized zone occurs as Py-Q-veinlets network with disseminated Py in Licuan F.II and marginal parts of Q-dio masses. This zone is accompanied by geochemical anomalous zones of Cu, but no Cu minerals are observed in outcrops.	
5	Apayao	4 km west of Kabugao	Diss	4.0 km x 5.0 km	Q-dio, Licuan F.II	Py, (Cp)	Sil, (Ser), (Arg)	This zone is composed of over 10 Py-disseminated outcrops around contact between Q-dio and Licuan F.II. Main ore mineral is Py but Cp is found in only one outcrop.	
6	Baduat	3.5 km south of Kabugao	Diss	3.0 km x 0.3 km	G-dio, Q-dio, Licuan F.II	Py, Cp, (Bor), Mal	Sil, Ser, Arg	Mineralized zone consists of 3 outcrops containing dissemination of Py, Cp and a rare amount of Bor. Outcrop in central part of this zone gave 6.92 % Cu, 6.47 % S and 65.5 g/t Ag.	
7	Tawini	Northwestern vicinity of Tawini	Diss	1.6 km x 2.0 km	Q-dio	Py, Cp, Mal, (Bor)	Sil, Arg, Ser	This ore deposit is formed in marginal part of Q-dio stock and its periphery, and it occurs as dissemination of Py, Cp and Bor with Q-veinlets. Two samples from this deposit show 0.43 % Cu and 1.97 % Cu.	Under prospecting by Marcopper Mining Corp.

Abbreviation

Diss : Dissemination
Netwk : Network
Licuan I : Licuan Group Formation I
Licuan II : Licuan Group Formation II

G-dio : Granodiorite
Q-dio : Quartz diorite
Q-dio-porp : Quartz diorite porphyry
Q : Quartz
Py : Pyrite
Cp : Chalcopyrite

Bor : Bornite
Cc : Chalcocite
Sph : Sphalerite
Pyh : Pyrrhotite
Mo : Molybdenite
Mag : Magnetite

Mal : Malachite
Azu : Azurite
Sil : Silicification
Arg : Argillization
Chl : Chloritization
Epi : Epidotization

Ser : Sericitization
Kao : Kaolinitization
Zeo : Zeolitization
Pyro : Pyrophillite
Dia : Diaspor

8	Lacub	Lacub and its vicinity	Diss ~ netwk	8 km x 2 km	G-dio, Licuan F.II	Cp, Py, Mal, (Bor), (Cc)	Sil, Ser, Arg. K-alteration	This zone is divided into 4 sub-zones. Main zone consists of dissemination of Py, Cp and Bor, and its Cu contents range 0.05 % to 2.87 %. Other 2 zones are composed of Py-disseminations and rest one is skarn.	Main zone had been prospected by Inco Mining Corp.
9	Kapuaran	3 km south of Lacub	Diss ~ Vein	1.0 km x 1.0 km	G-dio, Licuan F.II	Mal, Py	Sil, Ser.	This mineralized zone consists of 4 outcrops composed of dissemination of Py and Py-veinlets. One of them contains Mal and Cu content is 1.68 %.	
10	Abra mine	Western vicinity of Baay	Vein and Diss	0.8 km x 0.8 km	G-dio, Licuan F.II	Cp, Py, Sph	Sil, Arg	Ore deposit of Abra mine is composed of 3 principal veins with Cp, Py, Sph in marginal part of granodiorite. Cu contents ranged 0.73 ~ 14.87 %. Around Abra deposit, 4 disseminated outcrops of only Py are exposed.	This mine had been operated by Abra Mining Corp.
11	Manikbel	Northern vicinity of Ud-Udiao	Diss and Vein	2.0 km x 1.2 km	Q-dio, G-dio, Licuan F.II	Cp, Py, Mal, Azu	Sil, Ser, Arg, Zeo	Mineralized zones are mainly distributed in Mamising Creek and they occur as dissemination of Cp and Py with Mal and Azu. Cu contents of outcrops ranged 0.03 % ~ 11.15 %. Some vein type deposits are also found along Manikbel River, and their Cu contents ranged 0.16 % ~ 16.39 %.	Mineralized zone in Mamising River had been drilled by BMG in 1973–1974.
12	Ableg	Northern portion of Ableg	Skarn and Diss	1.5 km x 1.0 km	Q-dio, Licuan F.II	Py, Cp	Sil, Skarn mineral	Skarn deposit occurs in contact between Q-dio and limestone and consists of garnet, hedenbergite and other skarn minerals with Cp, Py, and Pyh. Py-disseminated outcrops with lesser Cu are found near skarn deposit.	
13	Bucloc	Southern portion of Bucloc	Diss ~ Netwk	5.0 km x 9.0 km	G-dio, Q-dio-porp, Licuan F.II	Py, (Cp), (Mal)	Sil, Ser, Arg	More than 20 outcrops are exposed in this zone, and they consist mainly of dissemination of abundant Py with minor amounts of Cp and Mal. Some of them occur as network of Q-veinlets with Py.	This had been prospected by Marcopper Mining Corp.
14	Layacan	Lower stream of Layacan River	Diss ~ Vein	2.0 km x 1.0 km	Q-dio-porp, Licuan F.I, Tineg F.	Py, Cp, Bor, (Mal), Au-minerals	Sil, Arg, Ser, Pyro, Dia	This mineralized zone consists of sulfide rich veins and gold one. The former is mainly distributed along Balasian River, and it is composed of Py and clay. But one vein contains abundant Cp and Bor. Gold veins are found along Segseg Creek. All of them are very thin and show low Au content.	Some of gold veins are stopped locally.

15	Dorao	Upper stream of Binongan River	Diss	1.5 km x 0.5 km	G-dio, Licuan F.II	Py, (Cp)	Sil, Arg	Many outcrops occur in contact between granodiorite and volcanic rocks of Licuan F.II as dissemination of Py accompanied by a minor amount of Cp.	
16	Malibcong	4 km east of Malibcong	Diss and Vein	0.8 km x 2.0 km	G-dio, Licuan F.II	Py, Cp, Mal	Sil, Ser, Arg	This mineralized zone consists of 4 disseminated outcrops. 3 of them occur in granodiorite and contain Py, Cp and Mal. Rest one is composed of only Py. This zone also contains one barren Q-veinlets networked outcrop.	
17	Tapao	5 km south of Balbalasang	Diss	1.0 km x 1.0 km	Licuan F.II	Py, (Cp)	Sil, Chl, Arg	Py-disseminated zones with minor amount of Cp occur along minor fractures and joints. Maximum Cu content of zones is 0.63 %.	Unsurveyed area. This had been prospected by Inco Mining Corp.
18	Batong Buhay mine	Batong Buhay, middle stream of Pasil River	Diss ~ Netwk	Ore reserve : 90 Mts, 0.599 % Cu	Q-dio-porp, Licuan F.II	Cp, Bor, Py	Sil, Ser, Arg	Ore deposits of this mine consist of dissemination of Cp, Bor and Py with network of Q-veinlets accompanied by Cp, Py, Bor and gold minerals. These deposits occur in quortz diorite porphyry and andesitic rocks of Licuan F.II	Unsurveyed area. Presently under constructing by Philex Mining Corp.
19	Mountain mine	Western vicinity of Batong Buhay mine	Stockwork	3.0 km x 4.0 km	Q-dio-porp, Licuan F.II	Py, Cp, Bor	Sil, Ser, Arg	Mineralized zones occur as dissemination of Cp, Py and Bor with networked Q-veinlets. General trend of zones is N10° ~ 20°E. Cu contents of 37 test pits, 12 drilling holes and 11 adits ranged 0.05 ~ 2.14 %, 0.17 ~ 4.09 % and 0.21 ~ 1.60 %, respectively.	Unsurvey area. Explored by Mountain Mine, Incorp.
20	Butilao	7 km south of Batong Buhay mine	Stockwork	0.9 km x 0.4 km Ore reserve : 30 Mts, 0.60 % Cu	Q-dio, Licuan F.II	Cp, Py, (Mal), (Mo)	Sil, Kao	Stockworked zone of Q-veinlets with Cp, Py and rare amount of Mo occur in contact between quartz diorite and andesitic rocks of Licuan F.II.	Unsurvey area. Explored by Lepanto Mining Corp.
21	Belwang	Upper stream of Pasil River	Diss, Netwk	1.5 km x 0.5 km	Q-dio	Py, (Cp), (Bor)	Sil	2 disseminated zones of Py and 4 networked zones of Py-Q veins are distributed in NE-SW direction. They occur in marginal part of quartz diorite mass. Cu contents ranged 0.21 ~ 1.60 %.	Unsurveyed area. Explored by Bengued Corp.

are pyrite, chalcopyrite, bornite, galena and sphalerite, and gangue minerals are generally quartz and calcite. Malachite and azurite are often observed in the oxidized parts of the mineralized zone as secondary minerals, supergene enrichment, however, have not been recognized in the area. The skarn type mineralized zone consists mainly of chalcopyrite, pyrite, pyrrhotite with abundant garnet, hedenbergite.

4. Alterations in and around the mineralized zone are commonly observed as silicification, sericitization and argillization, and the copper minerals, in most places, are contained in the intensely silicified zone. Chloritization and epidotization are also recognized in the altered zone with both alterations often found in the volcanic rocks near the mineralized zone. Besides, zeolites, pyrophillite, alunite and diaspor are the observed with the above-mentioned alteration minerals in some mineralized zones.

5. The mineralized zones formed in the plutonic and hypabyssal rocks in their peripheries are subdivided into four groups, such : (1) the central portion of the major-scale plutonic masses without the intrusion of porphyries; (2) the marginal portion of the major-scale masses; (3) the center to margin of the small-scale plutonic masses with remarkable porphyry intrusions; (4) the stocks of plutonic and hypabyssal rocks and their peripheries.

The first group contains the Bucloc and Caberuyan mineralized zones. The second group contains the Abra, Ableg, Solsona and Madongan mineralized zones. The third group contains the Lacub, Malibcong, Manikbel, Kapualan, Dorao, Apayao and Baduat mineralized zones. The last group contains the Palsuguan, Bully Bueno, Layacan, and Tawini mineralized zones.

On the other hand, the Lacub, Bucloc and Manikbel mineralized zones had been prospected. The Abra mineralized zone was also operated until in 1979. The Bully Bueno and Tawini mineralized zones are under prospecting at present. These five mineralized zones excluded the Bucloc belong to the third or fourth group. The detailed occurrence of the Bucloc mineralized zone is unknown because its mineralized part could not be investigated.

6. From the above-mentioned occurrence, it can be inductively said that the inner portion of the small-scale plutonic mass and stock of hypabyssal rocks and their peripheral zone are the most suitable place for the formation of ore deposits. The Batong Buhay porphyry ore deposits occur in the quartz diorite porphyry intruding in the vicinity of the quartz diorite mass.

7. In the Baguio Mineral District, it was clarified that the nine operating ore deposits occur the marginal parts of the large-scale quartz diorite mass (so-called Agno Batholihy) and its vicinities.

The above-stated geological environment for the mineralization in the project area is considered to be enclosed by that of the Baguio Mineral District.

8. On the genetic consideration of the mineralization in the project area, there are so many unknown facts on the formation of ore deposits. However, it would be considered in reference to the Manikbel mineralized zone surveyed in detail that the ore-forming process will be the following : intrusion of quartz diorite-granodiorite batholith → formation of tectonic fractures → preceding mineralization of pyrite → intrusion of quartz diorite porphyry → magnification and expansion of existing fractures → main mineralization of pyrite and chalcopyrite → intrusion of various dykes → succeeding mineralization of poor pyrite.

From this point of view, it could be said that some of mineralized zones in the area could be formed by the above-mentioned process.