NO. 1

REPUBLIC OF THE PHILIPPINES

DEPARTMENT OF NATURAL RESOURCES

BUREAU OF MINES

REPORT ON GEOLOGICAL SURVEY OF NORTHWESTERN LUZON

PHASE 1

SEP. 1979

METAL MINING AGENCY

JAPAN INTERNATIONAL COOPERATION AGENCY

GOVERNMENT OF JAPAN

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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 geological survey for mineral exploration in Northwestern Luzon, Philippines, and commissioned its implementation to Japan International Cooperation Agency. Considering its technical aspects, the agency sought collaboration of the Metal Mining Agency of Japan to accomplish the task within a period of three years.

As for this current year, a survey team was formed consisting of seven geologists headed by Mr. Hirofumi Taniguchi, staff of the Metal Mining Agency of Japan, and sent to the Philippines between January 14 and April 30, 1979 to conduct the first phase of the project. The survey had been accomplished under close cooperation with the Government of the Republic of the Philippines and its various authorities. This report hereby summarizes the results of the aforementioned undertaking.

We wish to express our heartfelt gratitude to the Government of the Republic of the Philippines and other authorities concerned for their kind cooperation and support extended to the Japanese survey team.

September 1979

Shinsaku Hogen
President
Japan International Cooperation Agency

Masayuki Nishiie
President
Metal Mining Agency of Japan

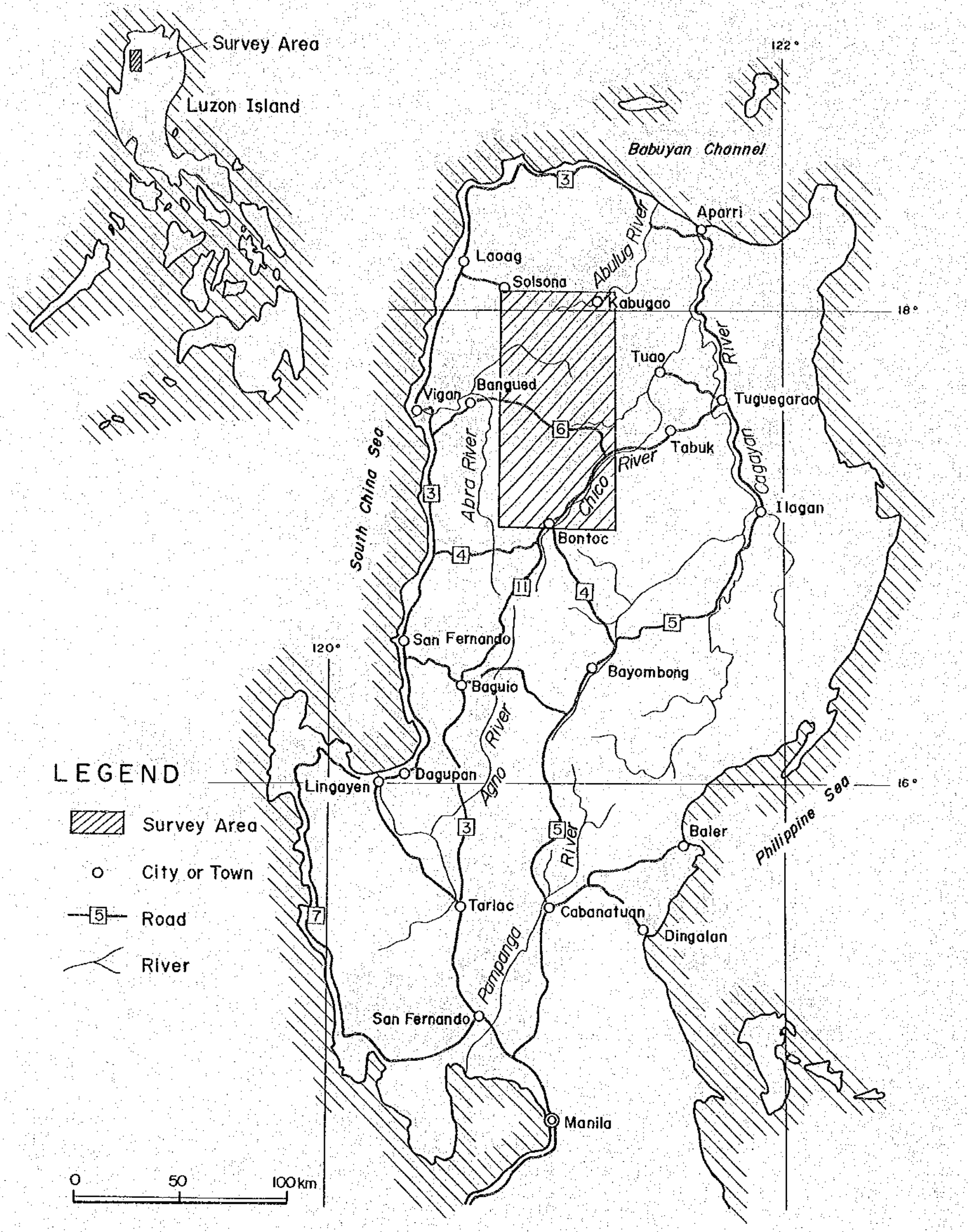

Fig. I Location Map of the Survey Area

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ABSTRACT

The phase I of the Co-operative Mineral Exploration Project in Northwestern Luzon, Philippines, consisting of Geological and Geochemical survey was conducted to delineate promising areas for ore deposits. Interpretation and clarification of the mutual relationship among the various geological criteria such as, stratigraphic classification, geological structure, igneous activity and mineralization were carefully done to achieve this purpose.

Based on the results of the geological survey, the undifferentiated volcanic and sedimentary rocks classed as the Cretaceous to Paleogene System (so-called KPg and UV) were divided into the Eocene basaltic-andesitic volcanic rocks and the Oligocene decitic volcanic rocks. This fact was established through the lithologic characteristic of the rock suites and newly found fossils.

Moreover, the plutonic rocks widely scattered in the survey area were divided into three rock facies, namely, gabbro, quartz diorite and granodiorite by microscopic observations, chemical analysis and K-Ar dating. These rock suites are arranged as large-scale masses trending north-south direction and in the order of their chemical composition, basic to acidic, from east to west. However, it was clarified that the lithologic differences of the plutonic rocks originated from the variation of the magmatic differentiation. On this premise, it can be considered that these three

types of rocks are the product of the same plutonic activity.

The result of the K-Ar dating revealed that the age of quartz diorite is 19.9 to 18.3 million years, granodiorite 16.2 to 13.7m.y., and granophyre which is one of the porphyries related to the plutonic rocks shows 12.6m.y. Consequently, the plutonic activity in this area ranges from the Early to Middle Miocene time.

It was also established that the characteristics of the plutonic rocks distributed in the survey area are exactly the same when compared to that of the plutonic rocks occurring in Baguio Mineral District. Considering this observation, it can be deduced that both rocks appear to be generated by the same magma.

The ore deposits distributed in the survey area can be generally classified as porphyry copper and vein type deposits. Eighteen mineralized zones including two ore deposits of operating mines were observed during the first phase of the survey. Most of these deposits were confirmed to be of the porphyry copper type. The mineralized zones occur in quartz diorite masses, stocks of quartz diorite porphyry related to the intrusion of quartz diorite, and in intruded rocks around the intrusive masses. Apparently these distributions confirmed the close relationship between the quartz dioritic rocks and the mineralization.

Furthermore, ten geochemical anomalous zones of Cu and Zn were detected in the area by geochemical survey for stream sediments, and most of them are superimposed on the mineralized zones.

Consequently the interrelation between the geochemical anomalous zones and the mineralized zones were also confirmed through their distribution features.

Judging from the results of the geological and geochemical surveys, the overlapped areas of mineralized and geochemical anomalous zones within the area of quartz dioritic rocks are the most promising for ore deposits. In Phase II, therefore, it is recommended that detailed geological, geochemical (for stream sediments and soil) and geophysical (IP and ground magnetic methods) surveys in the above-mentioned area be carried out to determine the nature of the mineralization.

GENERAL INFORMATION

1. INTRODUCTION

1-1 Preliminary Remarks

A Co-operative Mineral Exploration Project in the Republic of the Philippines had been conducted in Eastern Mindanao (1972 - 1974) and in Northeastern Luzon (1975 - 1977) by the Bureau of Mines, Philippines and the Metal Mining Agency of Japan. Through these two ventures, an extensive and enormous data on geology and ore deposits had been obtained. Moreover, these undertakings contributed effectively to the proper selection and improvement of the Bureau of Mines' projects.

Based on the above-mentioned beneficial results, the Bureau of Mines requested for another co-operative undertaking and selected northwestern part of Luzon Island as the third project. Although acknowledged as more promising one for mineral resources, only fragmentary surveys on geology and ore deposits had been carried out unsystematically on the area prior to its selection.

In response to this request, the Government of Japan dispatched a preliminary survey team headed by Mr. TAKEO KUROKO, Manager of the Overseas Department, Metal Mining Agency of Japan, on July 1978. The survey team conferred with the Bureau of Mines staff regarding the area to be surveyed and work program. After this deliberation, it was agreed upon to start the new project on January 1979. The context of this consultation for the first phase of the

Project are the following :

Project Name : Northwestern Luzon Project.

Survey Area : An area of approximately 6,000 km^2 bounded by 17° 05' and 18° 05' north latitudes, and 120° 45' and 121° 15' east longitudes (see Fig.1).

Program of Phase I : Geological, geochemical (for stream sediments) surveys and compilation of existing data for the whole area.

Prior to this venture, the Bureau of Mines carried out an airborne magnetic survey in the northwestern part of Luzon including the project area in 1978. The results of that investigation are being compiled and analyzed by Philippine geophysicists and Japanese exparts sent by Japan International Cooperation Agency. Those analytical data might be discussed in the next phase.

1-2 Details of Phase I Survey

1-2-1 Purposes of Survey

The purposes of the survey for Phase I in the Northwestern Luzon Project, Philippines were to elucidate the mutual relationship among various geological criteria such as; stratigraphy, geological structures, igneous activities and mineralizations through geological and geochemical (for stream sediments) reconnaissance surveys with compilation of existing data relevant to the whole project, and to delineate promising area of about 30 per cent (an area of approximately 1,800 km^2) of the initial area for detailed mineral resources investigation.

1-2-2 Outline of Survey

According to the work program and the above-mentioned purposes, the geological and geochemical surveys are intended to cover the whole project area. However, result of preparatory investigation preceding the survey proper conducted on January 1979 disclosed that peace and order situation in the southeastern part of the area is not feasible for fieldwork because of serious troubles that originated from the construction of hydroelectric dams at the Chico and Pasil rivers since last November.

For this reason, the Japanese survey team and the Bureau of Mines decided to exclude the unfeasible part having an area of 1,700 km^2 and to carry out the geological and geochemical surveys on the remaining 4,300 km^2 and increased the survey-route density of the original plan. The excluded part will be covered in Phase II or III if peace and order situation in that area be restored in the future.

Under these circumstances, the outline of the survey for phase I is shown in Table 1.

Table 1 Outline of Field Survey in Phase I

	Survey period	Area	Length of survey route	Number of samples
Preparatory survey	Jun. 14 ~ Feb.6, 24 days			
Geological reconnaissance survey	Feb. 7 ~ Apr. 14 67 days	4,300 Km^2	945 Km	164 pcs. of tested rock samples
Geochemical reconnaissance survey	Feb. 7 ~ Apr. 14 67 days	4,300 Km^2	945 Km	1,117 pcs. of geochemical samples
Compilation of existing data	Apr.15 ~ Apr.30 16 days	6,000 Km^2		

1-2-3 List of Member

The list of members engaged in the preliminary and the Phase I surveys are as follows:

1) Preliminary Survey Team

JUANITO C. FERNANDEZ	Bureau of Mines	TAKEO KUROKO Metal Mining Agency of Japan
FRANCISCO A. COMSTI	do	OKIHARU KANEISHI Agency of Natural Resources and Energy
OSCAR A. CRISPIN	do	KAZUHIKO MOROHOSHI M. M. A. J.
		KENJI SAWADA do

TAKECHIYO TAKATA
M. M. A. J.

YUTAKA HATANO
Japan International Cooperation Agency

HIROSHI FUCHIMOTO
M. M. A. J.

2) Phase I Survey Team

LEONARDO R. ANTONIO	B. O. M.	HIROFUMI TANIGUCHI	M. M. A. J.
EMIL T. AVILA	do	IKUHIRO HAYASHI	do
DONNO G. CUSTODIO	do	KENJI SAWADA	do
PABLITO ESCALADA	do	TADAYOSHI SEINO	do
JESSIE S. MIGUEL	do	ATSUSHI TAKEYAMA	do
EDWIN RILLON	do	TETSUO SATO	do
		YOSHIAKI SHIBATA	do

1-2-4 Analytical Works and Report

After completing the fieldworks, the survey results and compiled existing data were briefly discussed both by the Japanese and its Filipino counterparts in the Philippines. All rock samples for laboratory work and geochemical samples of stream sediments taken from the area were analyzed in Japan. Detailed analytical work and discussions concerning the results and the Phase II survey plans were carried out by Japanese members.

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

Likewise, the authors are indebted to Dr. EIKICHI NARITA of Geological Survey of Japan; Dr. TOSHINORI MATSUKUMA and Dr. SAKURO HONDA of Akita University; Dr. YOSHIO UEDA of Tohoku University; Dr. KUNITERU MATSUMARU of Saitama University; who provided instructive comments on igneous rocks, ore minerals, alteration age of plutonic rocks, and on larger foraminiferas, respectively. Their kind advice and suggestions are gratefully acknowledged.

1-3 Previous Works

The synthesized conception about the geology of the Philippine Island is shown in the 1:1,000,000 scale Geological Map of the Philippines which was compiled in 1963 by the Bureau of Mines based on the results of numerous geological investigations. From this map geologist can obtain a comprehensive knowledge on the regional geology of any area in the Philippines.

Concerning the geological investigations of Northern Luzon including the project area, COLBY el al, (1951) conducted a geological reconnaissance survey in Cagayan Valley and established the stratigraphy of the Neogene Tertiary rocks distributed in the area. DURKEE· PEDERSON (1961) also carried out a regional survey in Northern Luzon and mainly described the stratigraphy and the geological structures of Cagayan Valley basin. However, their investigations were confined to clarify the stratigraphy of the Neogene Tertiary unit for oil exploration, therefore, Pre-Neogene unit was retained as the undifferentiated "Basement Complex". In addition, FERNANDEZ and PULANCO (1964) were 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 referred by geologists as the most comprephensive write-up published concerning the geology of the area. In this report, the Pre-Neogene unit was divided 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 structures of the Philippines by F.GERVASIO (1967, 1971) and W.HASHIMOTO and T.SATO (1968, 1969, 1970) and Paleontological studies by H. HASHIMOTO (1938, 1970, 1975) are referred to in this report. These publications are very helpful in understanding the geological situations of Northern Luzon.

On the other hand, BRYNER (1969), MOTEGI (1975), ALMOGELA (1977) and GERVASIO (1977) were the previous workers who carried out the detailed studies on ore deposits in the Philippines. From their papers, various information on occurrences and nature of principal ore deposits can be obtained.

With regards to the project area, some unsystematic geological investigation were carried out by the Bureau of Mines and private mining companies. However, most of their survey results were unpublished. In view of this fact, few information on ore deposits was prepared by the Bureau of Mines and later referred to in the compilation of this report.

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2. GENERAL INFORMATION

2-1 Location and Accessibility

The project area is located in the northwestern part of Luzon Island as shown in Fig. 1. It covers an area of approximately 6,000 km^2 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 survey area covers most 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 Bangued, 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 fieldwork.

These cities and towns are very accessible owing to well-maintained roads from Manila. The main roads are the National Highway, Route 3, extending to the north end of Luzon along the western coastal line running through Vigan and Laoag City (408 and 486 km from Manila, respectively), Route 5 which is laid across the central part of Luzon and connected to Tuguegarao (482 km from Manila) Via Bayombong where the base camp of the North-eastern Luzon Project was settled, and Route 11 which is link to Route 5 at Tuguegarao via Baguio City, Bontoc (396 km from Manila) and Tabuk (120 km from Bontoc). In addition, domestic airline services are also available from Manila to Tuguegarao and Laoag City once a day.

From the foregoing statement, it is apparent that access to adjacent regions are rather easy. However, this condition is not available in the project area. Despite the approach provided by Route 6 and 11, accessibility is extremely poor owing to rugged mountainous topography. Route 6 linked to Route 3 and 11 surrounds the central portion of the project area via Bangued but passable only during the dry season. Some feeder roads connecting with the main routes are locally developed along the Abra and Chico rivers and some of its major tributaries, but in the central part of the area entirely covered by rugged topography, few trails are sporadically found. Besides, Route 11 and most of Route 6 are not accessible during the fieldwork due to the previously stated difficulties. These poor accessibilities and road conditions hindered the progress of the field 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 parallel 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 (see Fig. 2) 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 shows 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 high relief with many precipitous cliffs. Generally, the central part of the region is characterized mostly by high mountain ranges with an elevation of 1,800 - 2,500m and numerous peaks reaching over 2,000m above sea level can be found in these ranges, such as, Mt. Sicapao (2,352m), Mt. Manmanoc (2,064m), Mt. Malamot (2,078m), Mt. Sapocoy (2,455m), Mt. Cauitan (2,597m) the highest peak in the survey area, Mt. Mengmeng (2,305m) and Mt. Sipitan (2,127m) from north to south.

The project area is disected by two principal drainage system

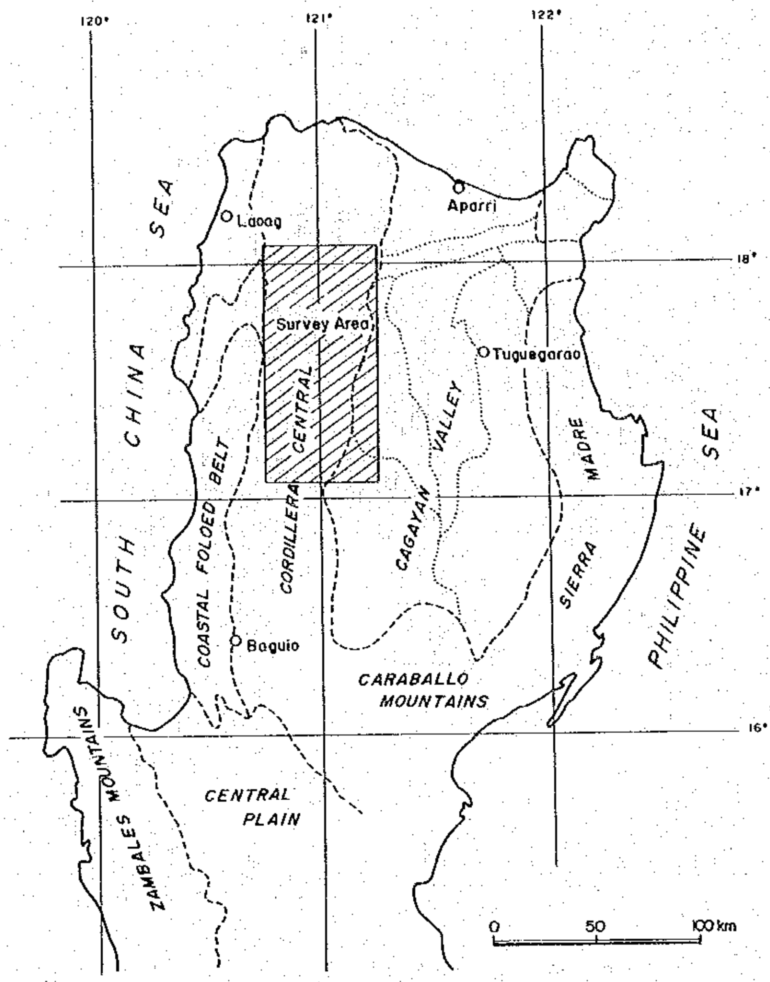

Fig. 2 Physiographic and Structural Provinces of Northern Luzon

flanking the eastern and western side of the Central Cordillera Mountains. On the east is Chico River, consisting of many branches mostly trending NE-SW direction and is one of the biggest tributaries of Cagayan River which debouched into the Babuyan Channel. The west side is drained by Abra River with branches trending E-W direction and debouched into the South China Sea. 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 hydro-electric dams, particularly at 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 3 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, Cordillea Central Mountains and its western lowlands have pronounced dry and wet season. The dry season lasts for 6 months from November to April and the rest of the year is wet. In Cagayan Valley, particularly the central part of the region, the climate is intermediate between the above-mentioned districts. It is rather dry from November to April. Nevertheless, dry and wet season in this region is not well pronounced.

Since the project area is located in the central portion of the

Cordillera Central, therefore, 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 2,000mm 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 5,000mm in some cases.

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.

3. GENERAL DISCUSSION

A great deal of new basic data on the stratigraphy, geological structure, igneous activity and mineralization were obtained by the Phase I survey. The principal data which may concern the future programme for this project survey will be chiefly discussed in this chapter.

3-1 Stratigraphic Classification

According to the previous works, the survey area consists mainly of the widely distributed undifferentiated volcanic rocks classed as the Cretaceous to Paleogene System (so-called KPg and UV), but no stratigraphic classification have been attempted so far to separate this units although the Neogene Tertiary rocks distributed in the western and eastern periphery of this area were classified by several previous workers. In Phase I, therefore, the stratigraphic classification for the undifferentiated volcanic unit was adopted as one of the most principal subjects of the survey.

In the consequence of the geological survey, the Pre-Neogene rocks were lithologically subdivided into basaltic to andesitic volcanic flows and pyroclastic rocks (the Licuan Group, Formation I and II) and dacitic flows and its pyroclastic rocks (the Tineg Formation). Based on the identified fossils collected in the area, the Licuan Group is determined as Late Eocene and the Tineg Formation as

Oligocene.

These rock facies and its corresponding geologic age are well correlated with the stratigraphy of the undifferentiated Cretaceous to Palaeogene System distributed in the Northeastern Luzon Project area, and it is considered that these classification may suggest the principle of the stratigraphy of that system.

On the contrary, the area of the Chico River basin which is has the widest distribution of the Licuan Group Formation I is unfeasible for field survey in this phase, hence observations for this formation is not always complete. Moreover, although the Licuan Group Formation II is lithologically delineated by the distribution ratio of lava and pyroclastic rocks in many survey routes and by change in facies of andesite lava, such as basaltic andesite, aphanitic andesite and porphyritic andesite, these characteristics can not be effectively used for detailed lithologic classification and structural analysis of this formation because of low density of survey route. The lithologic classification and structural analysis of the Licuan Group remained as one of the objects for further study.

3-2 Natures of Plutonic Rocks

In the survey area, large-scale plutonic rocks occuring like a batholith, stocks and/or dikes of porphyry genetically related to the aforementioned rock suites, intruded the Pre-Miocene rocks extensively. It is apparent that these rocks are closely related to the formation of ore deposits, especially porphyry copper type. To understand fully the nature of these rock suites, discussions and detailed analytical works such as microscopic observation of thin sections, chemical analysis of ten samples and K-Ar dating of eight samples were performed.

The following are the nature of the plutonic rocks distributed in the area.

1) The plutonic rocks occuring as two parallel masses and as two isolated bodies located on both flanks of two innermost masses are conspicuously distributed in the central and in the northern part of the area, respectively. These rock masses assumed a general trend N-S to NNE-SSW direction and seems to be formed as a batholith. Based on their occurrences, there is a possibility that at least two parallel masses are connected in shallow depth from the surface. It is assumed that the intrusion of the plutonic rocks were controlled by the structures of the Basement rocks, probably crystalline schist of Pre-Cretaceous time. Furthermore, it was observed that porphyries intruded the plutonic masses and the surrounding volcanic rocks as small stocks and dikes along fault structures.

2) Megascopic and microscopic observations of these plutonic rocks revealed various rock facies ranging from gabbroic to granitic type. However, based on the distribution and well-developed facies, these aforementioned rocks can be divided into three principal classifica-

tion namely, gabbro, quartz diorite and granodiorite. In consequence, the northwestern plutonic mass was deciphered as gabbro, the central masses as quartz diorite and the northeastern plutonic body as granodiorite. The variation in chemical composition of these rock suites can be deduced as basic in the west and acidic in the east.

The porphyries, on the other hand, can be lithologically subdivided into three facies, diorite porphyry, quartz diorite porphyry and granophyre. These rock suites are randomly distributed everywhere unlike the plutonic rocks.

3) The chemical analysis for the plutonic and hypabyssal rocks were carried out on ten samples, one from gabbro, five from quartz diorite, two from granodiorite and two from hypabyssal rocks. The differentiation index values (D.I.) of the analyzed samples show four groups; D.I. 22 (one sample), D.I. 48-60 (five samples), D.I. 72-73 (two samples) and D.I. 94 (one sample) (see Table I-3). The normative mineral (wt%) are also calculated based on the analytical data obtained from the chemical analysis. On the other hand, the M.F.A. diagram revealed that plotted results of the chemical analysis on the samples assumed a common trend. These facts suggest that the plutonic and hypabyssal rocks are magmatic differentiation of the same magma. Therefore, gabbro can be classified as the product of the early phase of magmatic differentiation, quartz diorite, diorite porphyry

and quartz diorite porphyry during the middle phase and granodiorite and granophyre on the last phase. Considering therefore the foregoing statements, it can be conceptualized that during the progress of the magmatic differentiation, the plutonic activity shifted its main field from west to east of the survey area.

4) K-Ar dating on ten samples, the same rock types used for the chemical analysis, was performed to determine the age of plutonic and hypabyssal rocks. From these ten samples, eight was determined to have ages ranging from 9.8 to 19.9 million years. In view of the insufficient amount of K-content on the remaining two samples, their ages can not be obtained. From the quartz diorite mass, one sample shows 9.8m.y. while four samples exhibited 18.3 to 19.9m.y. On the other hand, two samples from the granodiorite shows 13.7 to 16.2m.y. The granophyre with one sample show 12.6m.y. From these ages, with the exception of the quartz diorite giving 9.8m.y. in age the intrusion sequence of the plutonic rocks as obtained from the analysis of the chemical composition was proven.

5) In the Northeastern Luzon Project, likewise the chemical analysis and K-Ar dating had been carried out to determine the chemical composition and the age of the Agno Batholith which is composed mainly of quartz dioritic rocks. This intrusive mass is located in the Baguio Mineral District, the most productive area for mineral resources in the Cordillera Central.

When the analytical data of the Agno Batholith was compared to that of the survey area, the chemical composition and nature of the quartz diorite in both areas perfectly coincided.

Likewise, the age of Agno Batholith which was determined to be 17.9±0.9m.y. tallied with the age of the quartz diorite in the survey area.

Considering the above-mentioned facts, this would suggest that the plutonic rocks in both areas are the products generated by the same plutonic activity.

6) The preceding observations unfold the nature of the plutonic rocks exposed in the survey area. However, the age of quartz diorite dated as 9.8m.y. remained as the unresolved subject in the first phase. Although it showed the same occurrence and characteristics with the rest of the plutonic rocks by megascopic and microscopic observations and chemical composition, the geological time gap of about 10m.y. between the two kinds of quartz diorite, is too long to be considered and conclude that both belongs to the same intrusive mass. The ambiguity of these findings warrant additional K-Ar dating and detailed observation on the quartz diorite rocks.

3-3 Relation between Mineralized Zones and Geological Structures

In Phase I, the distribution of numerous ore deposits and mineralized zones in the survey area was revealed by geological survey and compilation of existing data. It was found out that eighteen mineralized zones including the two operating mines show high potentialities for ore deposits. Correlating these findings to the geology of the area, it was deciphered that these principal mineralized zones occur in close relation to the following rock suites; quartz diorite mass and intruded rocks (fourteen mineralized zones), quartz diorite porphyry (two), gabbro mass and its adjacent rocks (one) and volcanic rocks (one). Since the quartz diorite porphyry had been considered a product of the intrusion of quartz diorite, it can be deduced that most of the mineralized zones are closely associated to quartz dioritic rocks. These findings, therefore, clarified the predominant lithologic control of the mineralization (see PL.I-3).

In addition, the survey area is characterized by predominant structures trending N-S and NE-SW directions. The N-S structures are considered the oldest in the area, and are represented by the intrusive direction of the plutonic rocks and some faults. The NE-SW structures on the other hand, are manifested as big faults apparently the youngest in the area. However, there is a possibility that these structure system also originated from the intrusion of the plutonic rocks.

Analysis regarding the implication of these system of structures to mineralization revealed that the mineralized zones and their comprising veinlet system have a general trend same as that of the

N-S and NE-SW structures. It was also determined that the distribution of the mineralized zones and the intrusive rocks are controlled by the N-S structural system.

Since the purpose of the Phase I survey was to detect the regional distribution of mineralized zone in extensively unsurveyed areas, detail observations on the mineralized zones was sacrificed to achieve the goal. Therefore, the details of every mineralized zone such as structural control can not be presented.

However, for the whole area, it can be concluded that the mineralized zones deciphered were controlled by the N-S and NE-SW structural system.

3-4 Relation between Mineralized Zones and Geochemical Anomalous Zones.

The geochemical reconnaissance stream sediments survey for Cu and Zn was carried out in collaboration with geological survey in an area of 4,300 km^2. Most of the tributaries of principal rivers with the exception of its main stream, were sampled to obtain an information in wide scale.

From this survey, ten anomalous zones for Cu and Zn chiefly distributed in the plutonic rocks and their peripheral zones were detected.

Considering the relationship between these geochemical anomalous zones and mineralized zones, it is clarified that 6 anomalous zones are superimposed mostly in some parts of the mineralized zones while 4 other anomalous zones are accompanied by local disseminations of pyrite with small quantity of chalocopyrite or weak pyritizations (refer to PL. II-3). Therefore, as far as the distribution of both zones is concerned, clear interrelation can be recognized between the geochemical anomalous zones and the mineralized zones. These observations and results once again confirmed the usefulness of geochemical stream sediments survey and justify the effectiveness of the prospecting method in delineating mineralized and/or promising area for ore deposit.

On the contrary, there are some mineralized zones without the presence of geochemical anomalies, hence it is premature to conclude that without geochemical anomaly no mineralized zone will be observed. A good example is the case of ore deposits with very narrow mineralization haloes such as vein type ores. It will be very difficult to detect the geochemical anomaly suggesting the existence of mineralized zone in this type of deposit if the geochemical survey is conducted with low density of survey routes.

Although there is no doubt that geochemical survey can be used as a criterion to delineate promising area, the survey area for the next phase should be decided after sufficient geological and metallogenic discussion concerning the area having no geochemical anomalies were done.

3-5 Summary

Focusing on the mutual relationship among the plutonic rocks, the mineralized zones and the geochemical anomalous zones, the facts mentioned above will be summarized as follows:

The plutonic rocks distributed in the survey area are divided broadly into three facies, namely gabbro, quartz diorite and granodiorite, considered to be generated from the difference of the same magmatic differentiation process and to be the products of the same plutonic activity. The plutonic rocks are also accompanied by the intrusion of diorite porphyry, quartz diorite porphyry and granophyre intruding into the plutonic masses and their peripheral portion as stocks and dikes.

On the other hand, most of the mineralized zones occurring in this area are located in the plutonic masses and its periphery. It has been clarified that the mineralization is closely related genetically to the plutonic and hypabyssal rocks.

The following are the outline of the mutual relationship among the plutonic rocks.

1. Gabbro: The product of the earliest phase of the magmatic differentiation. The age is undetermined (intruded by quartz diorite). This rock is practically accompanied by small-scale porphyry copper type mineralized zones and one geochemical anomalous zone.
2. Quartz diorite: The product of the middle phase. The age

ranges from 18.3m.y. to 19.9m.y. (4 samples) and 9.8m.y. (1 sample). The former can be correlated with the 17.9±0.9 m.y. of the Agno Batholith. Most of the porphyry copper type and vein type mineralized zones distributed in the area occur in this intrusive mass, especially in its marginal part exemplified by the ore deposits of the Abra mine. Six anomalous zones are also distributed around the mass.

3. Granodiorite: The product of the late phase. The age ranges 13.7m.y. to 16.2m.y. Three mineralized outcrops were observed in this intrusive mass, but they are localized and small. One anomalous zone was found in the eastern periphery of this mass.

4. Diorite porphyry: This occurs as dike. The age is unknown. This dike is accompanied by porphyry copper type with disseminations of pyrite and rare amount of chalcopyrite in highly altered parts. The anomalous zone accompanying quartz diorite covers this dike.

5. Quartz diorite porphyry: This occurs as stocks and dikes. The age is undetermined (quartz diorite is intruded by this rock). The ore deposits of the Batong Buhay and Mountain mines occur in this stock, and this is very important as the host rock of large-scale porphyry copper deposits. The dikes is also accompanied by local mineralized zones. Some anomalous zones accompanying the plutonic masses cover these

stocks and dikes.

6. Granophyre: The last phase of the magmatic differentiation. This is found as a stock, and the age is determined as 12.6 m.y. No mineralization is observed.

4. CONCLUSION AND RECOMMENDATION

4-1 Conclusion

This year being the first phase of the Project, the geological and the geochemical stream sediments surveys were conducted to delineate promising area of approximately 30 percent of the initial area, an area of about 6,000km^2, for ore deposit. This goal was achieved through the systematic interpretation of the mutual relationship among the stratigraphy, geological structure, igneous activity and mineralization. Based on these survey results and analytical studies, the following conclusions were deciphred.

1. The widely distributed undifferentiated volcanic rocks classed as the Cretaceous to Paleogene System (KPg and UV) were divided into the Eocene basaltic to andesitic volcanic rocks and the Oligocene dacitic volcanics based on their lithologic differences and determinations of fossils collected. Through clarifications of their distributions, lithologic features and structures, the stratigraphy of the survey area has been established.
2. The principal structures prevailing over the survey area are the N-S, NW-SE and NE-SW systems in descending order. Among them, the most significant structure is the N-S system controlling the intrusive direction of the plutonic rocks.
3. The large scale-plutonic rocks have been intruded into the Eocene and Oligocene units, occurring as four paralleled masses

trending N-S direction, reflecting the N-S structural systems.

Lithologically the plutonic rocks show gabbroic to granitic facies, but it has been clarified that this change of facies are due to the variation of the same magmatic differentiation process. The main facies are gabbro, quartz diorite and granodiorite that are distributed in the area following the same sequence from west to east. Result of K-Ar dating revealed that quartz diorite ranges from 19.9m.y. to 18.3m.y. with the exception of the quartz diorite with 9.8m.y., while granodiorite shows 16.2m.y. to 13.7m.y.

4. Diorite porphyry, quartz diorite porphyry and granophyre occur as a stock and dike in the plutonic masses and their periphery. These rocks originates from the magma that formed the plutonic rocks. Granophyre shows 12.6m.y.

5. Numerous porphyry copper type mineralized zones and few vein type mineralizations are observed mainly in the quartz diorite and quartz diorite porphyry and their peripheral portion. Some quartz diorite porphyry stocks are accompanied by large-scale porphyry copper deposits such as the Batong Buhay mine. These stocks are very significant for the host rock.

From the foregoing fact, it is evident that the mineralized zones are closely related to the quartz dioritic rocks. Consequently, areas intruded by quartz dioritic rocks with mineralized zones are promising area for detailed survey.

6. From the result of the geochemical survey, 10 geochemical

anomalous zones of Cu and Zn were detected. Most of the anomalous zones are concentrically distributed in the area of quartz dioritic rocks and superimposed on the mineralized zones.

Consequently, the close association between the quartz dioritic rocks and the mineralized zones is confirmed by the results of the geochemical survey. It has also proved that geochemical stream sediments survey is one of the most effective prospecting methods in delineating more promising areas from unsuerveyed area.

7. Based on the above-mentioned survey results, the four areas (an area of 1,800 km^2 in total) are selected as the more promising area for ore deposits (refer to Fig. 3).

4-2 Recommendation

As stated above, the geology of the project area consists mainly of the Pre-Neogene Tertiary rocks and the Miocene plutonic rocks intruding into the former rocks. Numerous ore deposits and mineralized zones are distributed in this area. These geological environment is very similar to the Baguio Mineral district located in the southern part of the area, therefore, it is anticipated that some mineable ore deposits may be found in this project area.

The promising areas for ore deposits delineated by the first phase survey are mainly the quartz diorite area, which is companied by a great deal of mineralized zones and are mostly covered by geochemical anomalous zones of Cu and Zn.

In Phase II, on attempt to resolve the distribution feature of the plutonic rocks, the extentions of mineralized and geochemical anomalous zones and the detailed nature of each mineralized zone will be conducted through the semi-detailed and detailed geological and geochemical (for stream sediments and soil) surveys. Geophysical survey (IP method and ground magnetic surveys) to confirm the vertical continuation of the plutonic and mineralized zones will be introduced.

Moreover the lithologic classification of the plutonic rocks, the distribution of quartz diorite porphyry which is often accompanied by large-scale porphyry copper deposits and the detailed lithologic classification of the Pre-Neogene units must be reexamined by geological survey because these objects were not sufficiently clarified in the Phase I survey.

Furthermore the airborne magnetic survey results will be correlated with the results of the ground magnetic survey. If possible, geological and geochemical surveys for the unsurveyed area in Phase I will be incorporated in Phase II.

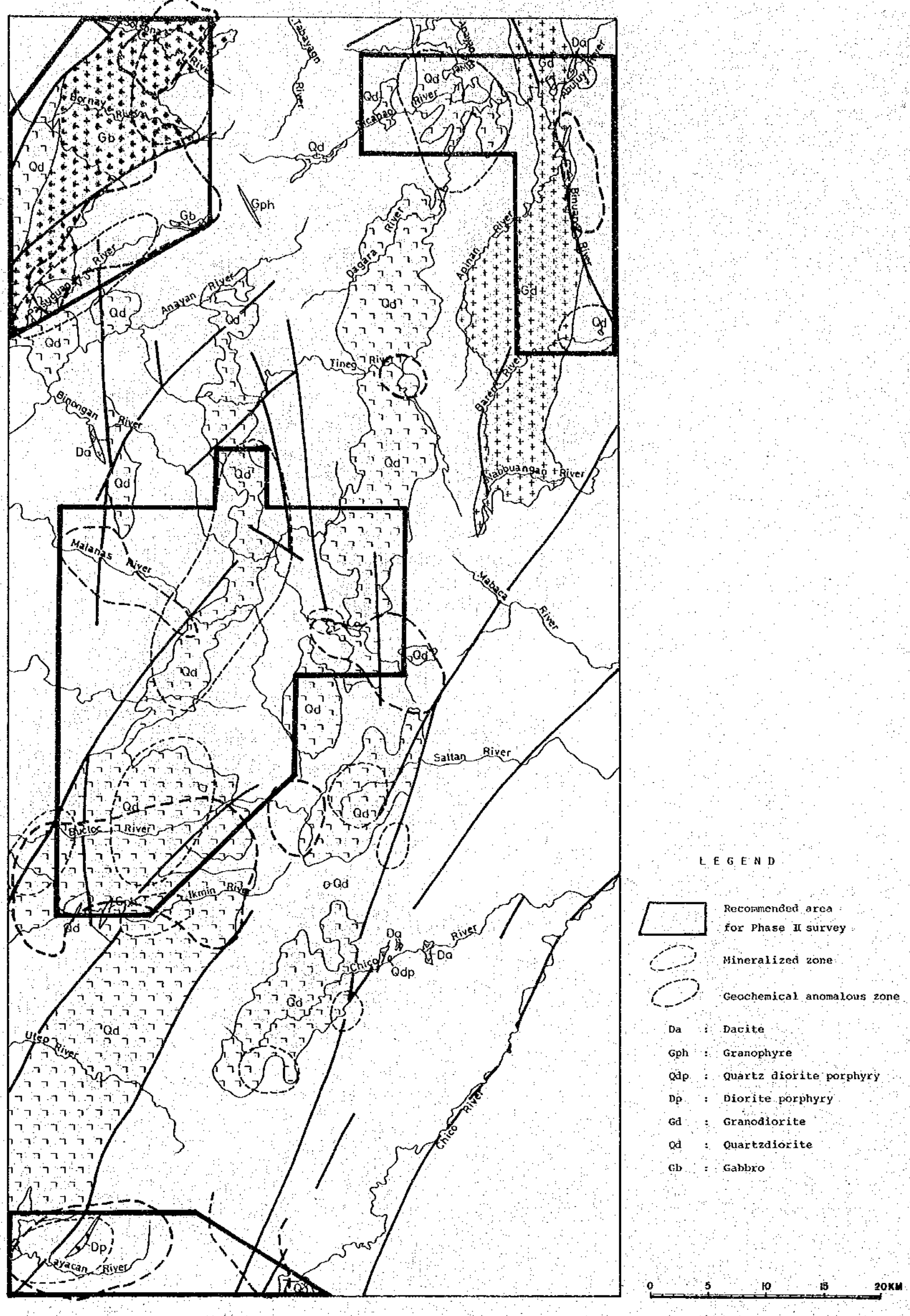

Fig. 3 Recommended Area for Phase II Survey

PART I
GEOLOGICAL SURVEY

1. General Remarks

According to the Phase I survey results and existing data and geological maps, the survey area consists mainly of

Post-Cretaceous rocks overlying the Pre-Cretaceous basement rocks exposed discontinuously along the eastern shore line. These Post-Cretaceous rocks can be subdivided into the same belts as the topography, that is, from the east to the west, 1) Sierra Madre uplifted zone, 2) Cagayan subsided zone, 3) Cordillera Central uplifted zone and 4) Coastal Folded Belt.

The Sierra Madre uplifted zone is composed mainly of the basement rocks, the Cretaceous to Oligocene volcanic rocks, and the Late Eocene to Oligocene granitic rocks (49m.y. to 27m.y.) which have been intruded into the volcanic rocks along their anticlinal axes. The lesser Neogene rocks are sporadically distributed in the wings of the uplifted zone.

The Cagayan subsided zone is circumscribed in part by both the Sierra Madre and Cordillera uplifted zones, and it has been formed in the relatively subsiding basin caused by the two uplifted zones. In this zone, the Neogene sedimentary rocks accumulated thickly, overlying the Eocene to Oligocene volcanic rocks. The prominent igneous activities are observed in the southern periphery of this zone, and in that place the alkaline plutonic rocks have been intruded into the volcanic rocks during the Late Oligocene to Early

Miocene time (25 - 17m.y.).

The Cordillera Central uplifted zone consists mainly of the Eocene to Early Miocene volcanic rocks which are later in geologic time as compared to the Sierra Madre, and the Post-Middle Miocene sedimentary rocks. They have been intruded by the Early to Middle Miocene quartz dioritic rocks (20 - 9m.y.) along their anticlinal axes.

The Coastal Folded Belt is composed of intensely folded clastic rocks classified as of Neogene time.

Among these four geological subdivisions, especially between the Sierra Madre and the Cordillera Central, there are some prominent differences in the geotectonic process and the nature of the plutonic activity. These differences may be considered to have been caused by the two subduction zones on both sides of Northern Luzon.

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. For example, in the Sierra Madre uplifted zone, no workable ore deposits have been found although some small-scale deposits are confirmed. On the contrary, most of workable deposits are situated in the Cordillera Central uplifted zone. A particularly great number of these ore deposits are concentrically distributed in the Baguio district and form the Baguio Mineral

District. In the Cagayan Valley subsided zone, no metallic deposits have been found because of no igneous activity, but in the southern end of the zone few deposits such as the Cordon porphyry copper type ore deposit 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, Lepanto, Suyoc and Abra ; (3) Contact metasomatic type : Thanksgiving and Lammin. Of these deposits, the Batong Buhay and the Abra mines are located in the survey area.

The above-mentioned deposits, particularly the porphyry copper type deposits, are genetically related to stocks and dikes of dioritic porphyries intruded into plutonic masses and their peripheral volcanic rocks along stractural lines, like a fault. 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 Northeastern Luzon survey results. As already stated, therefore, the maldistribution of deposits is considered to be caused by the lithologic and the environmental differences of the plutonic rocks and its intrusion field.

From the geological and structural features, the geological environment of the survey area may be regarded as similar to that of the Baguio Mineral District. The details of the geology and ore deposits will be described in the next chapter with these points as background.