2. Geology

2-1 General Statement

The survey area consists of the Post-Cretaceous volcanic rocks, normal sedimentary rocks and plutonic 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 determination of some newly collected fossils by this phase 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 Fig.I-1.

The plutonic rocks distributed in the area were also subdivided broadly into three facies: gabbro, quartz diorite and granodiorite. Their ages were determined as of Early to Middle Miocene time (19.9 - 9.8m.y.) by K-Ar dating.

The stratigraphy, geological structure and igneous activity in this survey area are summarized in Table I-1. The formation names used in this report are newly given on the basis of the place or river name of each type locality.

Table I-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 60km to the south and it is so far from the present survey area. However, the

Northeastern Luzon Project area was selected as the object of the correlation because it covered the Cordillera Central uplifted zone and the undifferentiated Cretaceous to Paleogene units have been stratigraphically classified in detail. The stratigraphy of the Cagayan Valley (West) by DURKEE· PEDERSON (1961) includes the area around the Mabaca River basin located 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.

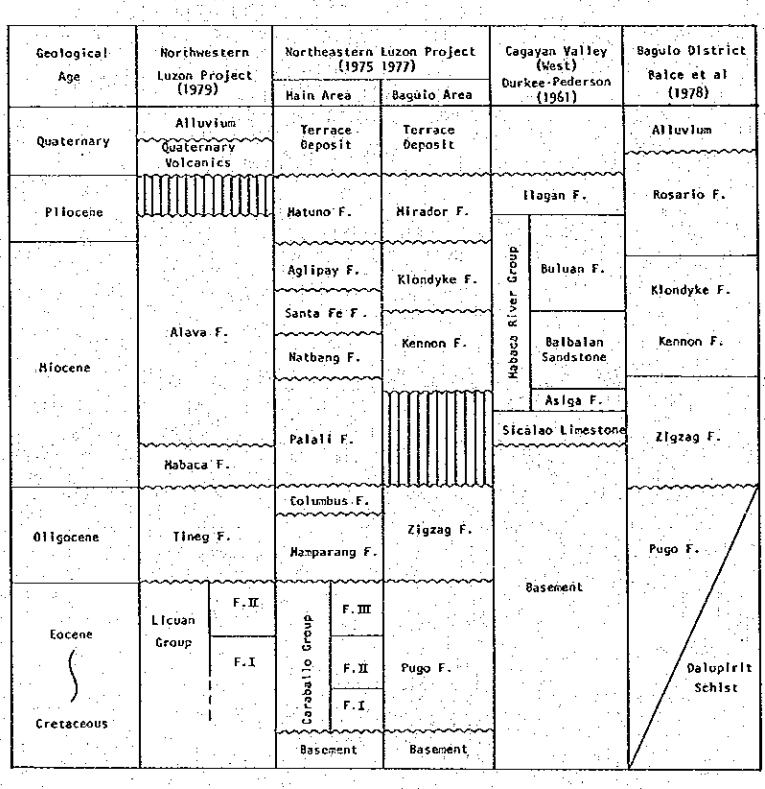


Table I - 2 Stratigraphic Correlation in Northern Luzon

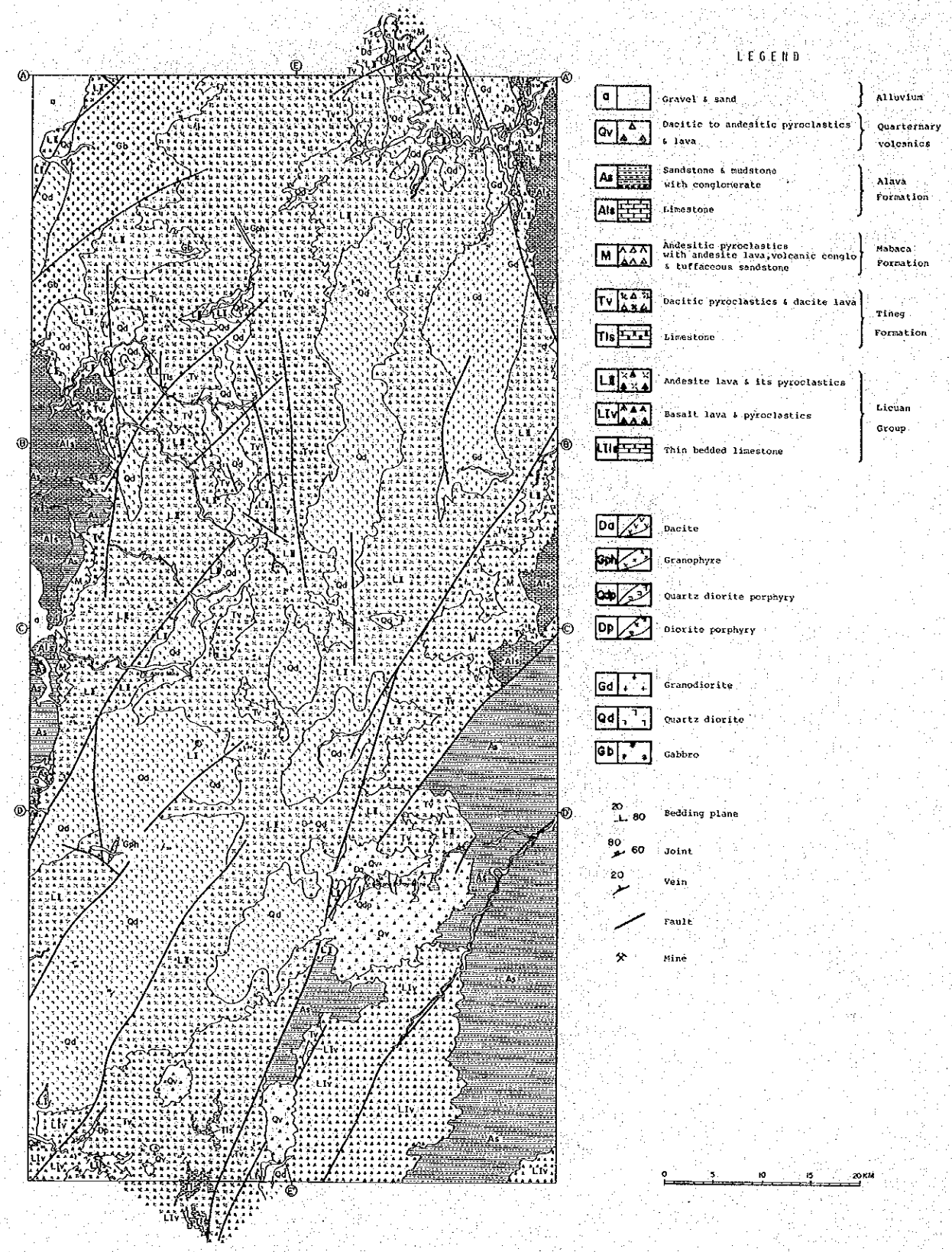
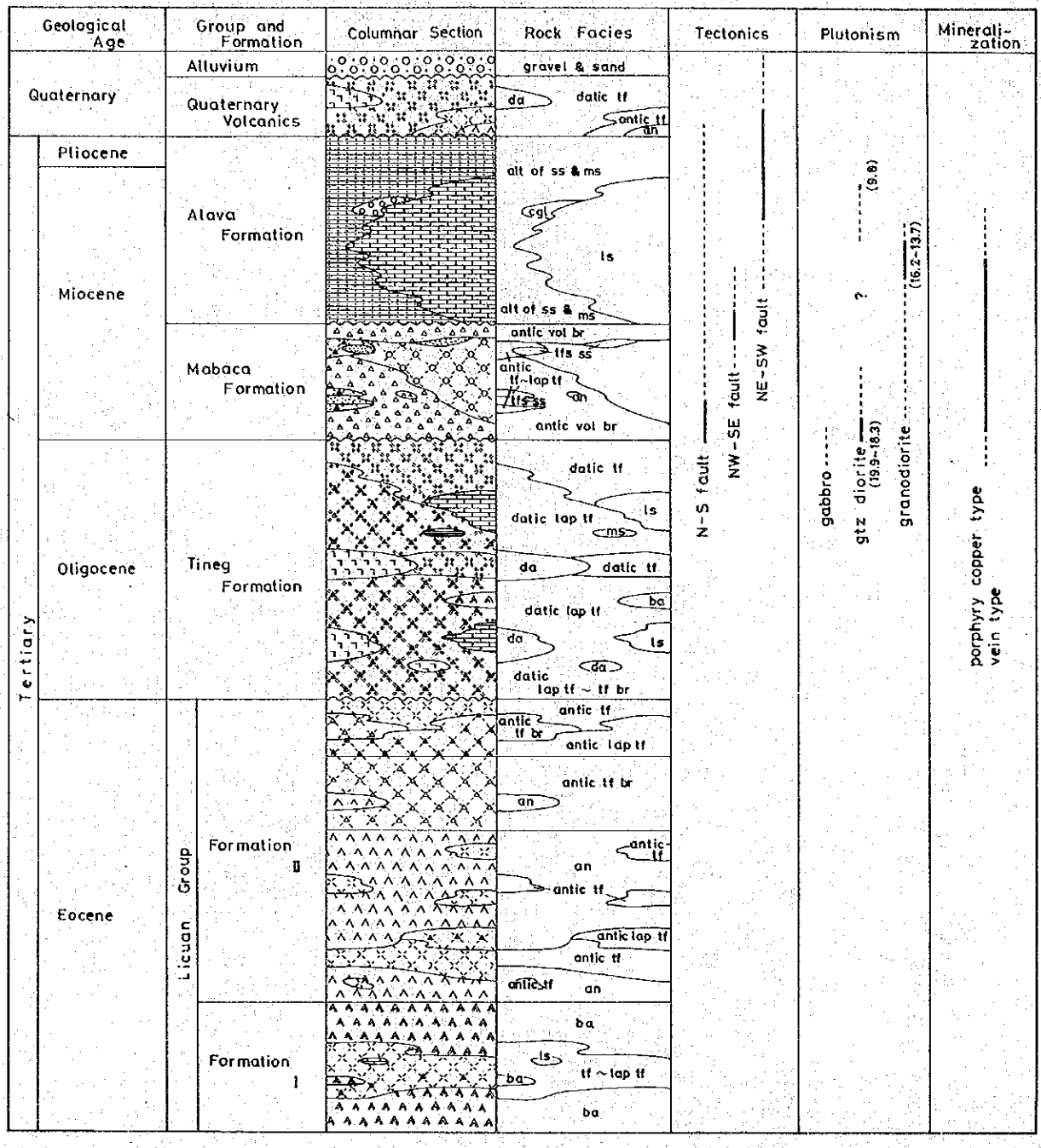


Fig. I - 1 Geological Map of Survey Area

Table I - 1 Generalized Stratigraphy in Northwestern Luzon



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

The Licuan Group was divided into two formation. One is the Formation I, consisting of basaltic lavas and pyroclastic rocks. The other is the Formation II, consisting mainly of andesitic pyroclastic rocks and lavas. Formation I and II can be lithologically correlated to the Caraballo Group Formations II and III in the Northeastern Luzon area, respectively. The Caraballo Group Formation I and the basements are not distributed in this area. In the Cagayan Valley and Baguio areas, the classification of the Pre-Neogene unit has not been attempted, so that the Licuan Group Formation I and II are correlative in part to the basement in the Cagayan Valley area and the Pugo Formation in the Baguio District.

The Tineg Formation is composed mainly of dacitic pyroclastic rocks and lavas, accompanied by lenticular limestone yielding the index fossils of Oligocene age. It differs from the Mamparang Formation that is characterized by alkaline rocks in lithology, but which has been classified as of Oligocene time by the determination of fossils. The Columbus Formation, in addition, also consists of limestone containing the Oligocene fossils. The Tineg Formation can be considered to be in the same horizon as the Mamparang and Columbus Formations in geological time.

The Zigzag Formation, which is accompanied by dacitic rocks according to BALCE, may seem to be similar to the Mamparang and Columbus Formations in lithology, and by the results of the Northeastern Luzon survey it has been assinged to Oligocene. However,

BALCE has classified it as of Early Miocene time. The results are conflicting, and the geological age of the Zigzag Formation should be redetermined in the future. In the Cagayan Valley area, the Tineg Formation is correlated to a part of the basement in lithology and age.

The Mabaca Formation, determined as Early Miocene, is the product of local andesitic volcanic activity. It seems to be lithologically correlated with the Zigzag Formation, but the age of the Zigzag Formation is not clear as stated above. On the other hand, this formation differes with the lithology of the Palali Formation. From the above, the Mabaca Formation can not be correlated with other formations and its distribution may be confirmed within the survey area and/or its periphery. In the Cagayan Valley area, the Tineg Formation is also correlated to a part of the basement.

The Alava Formation, which consists of limestone and clastic rocks, are classed as Early Miocene to Pliocene and correlated with the Neogene rocks of the Post-Natbang Formation in the Northeastern Luzon area and the Kennon Formation in the Baguio District. In the Cagayan Valley area, the Alava Formation is equivalent to the Sicalao limestone and the Mabaca River Group. The Ilagan Formation in that area is not distributed in this survey area.

The above mentions the outline of stratigraphic correlations on the basis of previous data, but some problems are still remain on the details of these correlations. In the future, these problems

should be discussed from a regional viewpoint within the concept of geotectonic history.

2-2 Stratigraphy

2-2-1 Licuan Group

The Licuan Group is the most widely distributed in the survey area and it consists mainly of andesitic pyroclastic rocks and lavas, but basalt lavas are remarkably dominant in the southern part of the area. Consequently, the Group was divided into two formations. 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 vinicity of Bontoc and in the middle to lower streams of the Layacan River located in the western portion of Besao. In addition, 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. But from field

observations, it may be estimated to be over 1,200m in thickness.

Rock Facies : This formation is composed mainly of basalt lavas accompanied by pyroclastic rocks intercalating lenticular limestone.

The basalt lavas 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 the lavas but occasionally massive basalt lavas with columnar joints, a few meters in thickness, are alternately intercalated with basaltic pillow lavas. These lavas have been highly chloritized and epidotized.

The pyroclastic rocks consist of green- to dark green-colored 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. Lapilli tuff contains dark green to dark brown basalt and andesite fragments and thinly elongated andesitic pumices. Volcanic ejectas of tuff breccia are mostly basalt.

In the middle reaches of the Layacan River, light-greenish gray 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. The microscopic observations of the basalt lava are as follows:

Basalt (e-119)

Texutre : Amygdaloidal texture.

Phenocryst : Plagioclass and augite

Plagioclase is euhedral to subhedral, 0.1 to 1mm in diameter, albitized. Augite is subhedral to anhedral, medium amount.

Groundmass : Plagioclase, orthopyroxene, opague minerals. Plagioclase is short columnar, about 1mm in diameter. All minerals are abundant.

Alteration mineral : Chlorite, epidote, calcite, secondary quartz and zeolite.

Fossil and Age : The limestone (g-106) 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 show the Priabonian stage in Europe and are determined as Late Eocene (Tb).

Geological Structure : Noticeable structures have not been found because this formation is composed mainly 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 toward NW to NNW as a whole.

(2) Formation II

Distribution : The Formation II is distributed the widest in the

survey area, from the distribution area of the Formation I to the north end of the survey area.

Thickness : It is considered to be more than 2,300 meters.

Rock Facies : In contrast to the Formation I, this formation is composed mostly of andesite lavas and andesitic pyroclastic rocks. As a rule, lavas are abundant in the lower part and pyroclastic rocks 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, the andesite lavas are partially divided into three rock facies: basaltic, aphanitic and porphyritic facies. The basaltic andesite facies is well exposed in the Utep River, which is in the southern part of the area, and in the vicinity of Barrio Kabugao in the northern part of this survey area. It shows a predominant amygdaloidal texture and a pillow structure. The aphanitic andesite facies is the most common one. It is a compact and massive rock, but flow and brecciated structures are found in the Bucloc and Malanas rivers. The porphyritic andesite facies is sporadically distributed in the upper stream of the Lingas River, the middle stream of the Baay River and along the Route 6. This facies is characterized by large phenocrysts of plagioclase, usually massive but partially auto-brecciated. Besides, basaltic andesite lavas are occasionally associated with the basalt lava.

The above-mentioned classification, however, is not

necessarily strict, and frequently 2 or 3 facies coexist with each other. Consequently, this lithologic classification could not be generalized by this phase survey. Intense chloritization and local epidotization are observed in all of the facies.

The pyroclastic rocks occur as thick deposits overlying the andesite lavas and as interbeds in the lavas, but both have the same lithologic feature. These pyroclastic rocks are composed of light green to dark green or dark-greenish gray consolidated tuff, lapilli tuff and tuff breccia. 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 - 80cm units in thickness. The lapilli tuff, the most common rock facies, is usually massive and contains angular or subangular essential lapillies of andesite and basalt, and also occasionally accidental breccias of mudstone and thinly elongated pumices. The tuff breccia is composed mainly of angular or subangular andesitic to basaltic volcanic ejectas, 5 - 10cm in diameter. In the downstream of the Baay River, it is accompanied with layer of volcanic breccia consisting of dacitic volcanic ejectas characterized by phenocrysts of bipyramidal quartz. Bedding of both breccia beds are not distinct and commonly massive. Generally, these pyroclastic rocks have been intensely chloritized

and epidotized. Moreover, silicification and pyritization are superimposed on the above-mentioned alterations around the contact of these rocks and plutonic rocks. Bleached pyroclastic rocks show pale green to light gray color.

There is no distinct rule on the distribution of lavas and pyroclastic rocks is not clear because the pyroclastic rocks are interbedded with lavas, and some lavas are also interbedded with thick pyroclastic rocks. However, it is considered to be the general tendency that the lavas are chiefly exposed in the area from the Utep River to Kabugao via Barrio Licuan, and the pyroclastic rocks have a wide distribution in the northern part of it. This tendency, as well as the lithologic classification of the andesite, is subjective so that it is necessary to clarify the rules and to attempt to subdivide the Licuan Group Formation II in detail by the Phase II survey. The microscopic feature of main rocks are as follows:

Andesite (a-519)

Texture : Porphyritic and hyalopilitic textures.

Phenocryst : Plagioclase and augite.

Plagioclase is euhedral, 0.1 - 3mm across, medium amount, 50 - 70%An. Augite is subhedral, less than 1mm in diameter, in small amounts and altered to chlorite and calcite.

Groundmass : Plagioclase, opaque minerals and glass.

Plagioclase is subhedral, very fine-grained and altered to chlorite, epidote and calcite. Glass is also altered.

Alteration mineral : Chlorite, epidote, calcite and kaolinite.

Altered andesite (e-304)

Texture : Porphyritic and hyalopilitic textures.

Phenocryst : Plagioclase.

It is euhedral, 0.1 - 2mm in diameter and highly altered to chlorite and sericite.

Groundmass : Opaque minerals.

Alteration mineral : Secondary quartz, chlorite, sericite, calcite, kaolinite and silicates.

A large amount of secondary quartz and chlorite occur as alteration products of plagioclase and mafic minerals. This rock is strongly altered.

Andesitic tuff (f-501)

Texture : Pyroclastic texture.

Fragment of mineral : Plagioclase.

Matrix : Plagioclase.

Alteration mineral : Chlorite, calcite, secondary quartz and silicates.

Fossil and Age : This formation yields no fossil. The age of this

formation may be considered to be Early Eocene on the basis of the ages of the underlying and overlying formations, though the positive data for determinations of the age have not been obtained by this phase survey.

Geological Structure : The structure of this formation has been complicated by the intrusion of plutonic rocks and many 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 is not observed in the field. As already stated, however, the Formation I and II can be correlated the Formation II and III of the Caraballo Group and they show conformable relations. Therefore, based on that relation, it can be considered that the Licuan Group Formation I is conformably overlain by the Formation II.

2-2-2 Tineg Formation

Distribution : The Formation is mainly exposed in the area from Sagada to the upper stream of the Layacan River, the middle to upper stream of the Saltan River, the middle reaches of the Mabaca River, and the portion from the northern part of Barrio Licuan to the north end of the survey area. In addition, it is

also narrowly distributed in the downstream of the Malanas River and the headwaters of the Baay River.

Thickness : More than 1,500m.

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

The dacitic pyroclastic rocks consist chiefly of pale green to dark green, occasionally greenish gray tuff, lapilli tuff and tuff breccia. Relatively, tuff is abundant at the upper part and tuff breccia in the lower part. The tuff is well-bedded, highly indurated, fine- or coarse-grained rock, and contains wholly quartz grains. In addition, it often alternates with layers of mudstone and lapilli tuff. In the upper reaches of the Tineg River, a slump bed of fine tuff, 2 -3m in thickness, is observed in lapilli tuff. The lapilli tuff, which is the main constituent of this formation, is composed of dacite, rhyolite and lesser amount of andesite lapillis, and generally contains thinly elongated light green pumice. A large amount of quartz grains are found in its matrix. Some parts of this rock show the welded texture and they suggest to be terrestrical deposits. Usually this rock is massive but partly shows bedding. The tuff breccia is composed mainly of angular or subangular dacite, rhyolitic and andesitic volcanic ejectas, and often contained thinly elongated pumices and

a large amount of quartz grains in its matrix. The maximum diameter of ejectas is about 10cm. In the western portion of Bontoc and the downstream of the Binongan River, layers of volcanic breccia consisting chiefly of dacite blocks are observed and the layer in western part of Bontoc contains pebbles of granodiorite.

The dacite lavas occur as thin beds intercalated with the dacitic lapilli tuff but the lava in the Tineg River measures up to 150m thick. These lavas are usually pale green to light-greenish gray, porous and massive, with no flow structure but partly brecciated.

The basaltic lava is observed at the upper stream of the Mabaca River as thin bed associated with the dacitic lapilli tuff. It is dark green aphanitic rock with predominant pillow structure.

The sandstone and mudstone beds occur in Sagada, the upper reaches of the Mabaca River and the Apayao River. In Sagada, pale green to greenish gray, well-bedded, coarse-grained, tuffaceous sandstone bed is observed under the limestone. It contains a great deal of fragments of fossils but the index fossil has not been found. In the upper stream of the Mabaca River, a dark green calcareous mudstone bed alternating with dacitic tuff is observed. Well-bedded calcareous sandstone and mudstone beds also occur in the upper stream of the Apayao River.

The limestone is exposed in and around Sagada as thick

sequences. In the middle reaches of the Baliwanan River, which is located in the northern position of Kabugao, and the upper reaches of the Tineg River, the limestone occurs as thin beds intercalated with dacitic lapilli tuff. The limestone in Sagada occurs as three large bodies but among them two bodies exposed at Barrio Sagada and its northern vicinity seem to be in the same horizon. Both limestone bodies are milky white to light-grayish white, massive in general, but weak bedding is observed in some outcrops. The other one, which is exposed in the Malitep Creek, southern part of Barrio Sagada, is light gray to yellowish gray, massive and it is considered to be in the horizon below the above-mentioned two bodies. The limestone distributed in the Baliwanan River occur as two thin beds in dacitic lapilli tuff associated with mudstone. It is light gray, well-bedded, muddy limestone and each bed is a few meters in thickness. In the upper reaches of the Tineg River, grayish white well-bedded limestone, 2m thick, occurs as thin bed intercalated with dacitic lapilli tuff.

Following are the microscopic features of the two main rocks.

Dacitic tuff (f-318)

Texture : Pyroclastic texture.

Fragment of mineral : Plagioclase and quartz.

Plagioclase is subhedral to anhedral, 0.1 - 1mm

in diameter. Quartz is anhedral and 0.1 - 1mm across.

Matrix : A small amount of plagioclase

Alteration mineral : Sericite, chlorite, calcite, secondary quartz and kaolinite.

Dacite (g-529)

Texture : Porphyrytic texture.

Phenocryst : Quartz, plagioclase and augite.

Quartz is very small amount. Plagioclase is subhedral, 1 - 3mm across. Augite is subhedral, 0.1 - 1mm across and altered to chlorite and other minerals.

Groundmass : Plagioclase and opague minerals.

Plagioclase is subhedral and fine-grained (less than 1mm in diameter).

Alteration mineral : Chlorite, sericite, epidote, secondary quartz and silicates.

Fossil and Age : The limestone taken from Barrio Sagada yields the following larger foraminiferas.

Eulepidina formosa (Schlumberger)

Nephrolepidina sumatrensis (Brady)

These fossils indicate Early Oligocene time (Te_4). In addition, the other limestone collected from the Malitep Creek yields the

index fossils of Late Oligocene, shown as follows.

Eulepidina favosa Cushman

Nummulite fichteli (Michelotti)

On the other hand, the following larger foraminiferas were discovered from the limestone taken from the upper stream of the Tineg River.

Eulepidina formosa (Schlumberger)

E. gibossa Yabe

Nephrolepidina sumatrensis (Brady)

They indicate Late Oligocene time (Te_4), and this horizon can be doubtlessly correlated with the Sagada's limestone. Based on these results, the age of the Tineg Formation has been determined as Oligocene.

Geological Structure : Generally, this formation has relatively distinct bedding but it has been disturbed and complicated by many faults and intrusion of plutonic rocks so that prominent structures could not be observed. The formation exposed along the Saltan River shows the monoclinic structure tilting gently to the east, and in the portion from Barrio Licuan to the northern part of the survey area it shows the same structure tilting to the west. These structures are discordant with the structures of the underlying formations.

Relation to the Underlying Formation : This formation occurs in fault contact with the Licuan Group Formation II. The relation is not

clear but it may be considered to be unconformable because of the structural discordance between both formations.

HASHIMOTO (1975), moreover, reported the yield of some leading fossils of the Eocene time from thin limestone lenses intercalated with pyroclastic rocks distributed along the Route 11 and the Sagada Road. These limestone lenses could not be confirmed by this survey, and according to the survey results the Tineg Formation is widely distributed around those localities. Therefore the said pyroclastic rocks may be considered to be the Licuan Group exposed narrowly as a small fensters in the distribution area of the Tineg Formation.

2-2-3 Mabaca Formation

Distribution : The formation has been considered to be the product of the local andesitic volcanism. Its distribution areas are confined in the middle stream of the Saltan River, the middle to lower stream of the Mabaca River, the Apayao River and the portion from the downstream of the Bucloc River to the Malanas River.

Thickness : Less than 1,000m.

Rock Facies : This formation consists of andesitic volcanic breccia and volcanic conglomerate with thin layers of andesitic pyroclastic rocks, andesite lava and mudstone.

The andesitic volcanic breccia show dark brown to blackish gray color in the Mabaca River, dark green to dark-reddish gray in

the Apayao River and light green to light-yellowish gray in the Route 6, but no difference in lithology is recognized among them. They are composed mainly of angular to subangular porous and loose andesitic volcanic ejectas with large amount of hornblende phenocrysts. In the Apayao River, fragments of limestone and bedded tuff are partially contained. Matrix of this rock consists of poorly-sorted fine-grained andesitic fragments with sand. The volcanic conglomerate is observed in the Mabaca River, and it consists of rounded pebble- to cobble-sized andesite fragments. It is lithologically the same as the ejecta of volcanic breccia, but it gradually changes to volcanic breccia or coexists with that rock. The consolidation of the volcanic breccia and volcanic conglomelate 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. This lava and the volcanic breccia seem to be the products of the same volcanic activity.

The tuffaceous sandstone and mudstone occur as a thin layer in

volcanic breccia and it shows light gray colored. It is well-bedded. The alteration of this formation is very weak as compared to the Tineg Formation and the Licuan Group, and only chloritization and epidotization are observed as replacements of mafic minerals under the microscope.

The microscopic features of andesite lava are as follows:

Andesite (b-313)

Texture : Porphyritic and spherulitic textures.

Phenocryst : Plagioclase, hornblende, augite and opaque minerals. Plagioclase is euhedral and 1 - 5mm across. Hornblende is euhedral and 1 - 3mm across. Augite is subhedral and 0.1 - 1mm across. All minerals are less in amount.

Groundmass : Plagioclase and glass. Plagioclase is euhedral, lath-shaped and shows flow texture.

Alteration mineral : Chlorite, sericite, calcite and epidote.

Fossil and Age : No fossil was found in this formation. The age of this formation seems 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 the semi-basin structure plunging to the northeast is recognized as local

structure in the Apayao River. 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 because of the discontinuous distribution of this formation. However, the prominent differences in the nature of volcanic activity and the structural discordance between the two formations suggest an unconformable relation.

2-2-4 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 area from Barrio Lias, which is located on the east of Bontoc, to the downstream of the Mabaca River and eastern part of Kabugao. In the western part, it is observed from the lower reaches of the Bucloc River to the junction of the Tineg and the Binongan rivers. The area from Lias to the Saltan River, which has the widest distribution, was mapped using existing data due to the unfeasibility of conduction field works during this phase.

Thickness : More than 800 m.

Rock Facies : This formation consists of thick limestone and clastic rocks occuring in its upper and lower parts, and is characterized

by the lack of volcanic rocks.

The limestone is widely exposed along the road from Barrio Dolores, the suburbs of Bangued, to Barrio Alava. In this portion, this rock is light cream, occationally light-brick red reefal limestone, and well-bedded in 20 - 30cm unit in thickness. The limestone distributed in the Mabaca River and eastern part of Kabugao show the same lithology as the Alava Road' limestone.

The clastic rocks consist of sandstone and alternation of sandstone and mudstone below the limestone, and of conglomerate, sandstone and alternation of sandstone and mudstone above it. The lower sandstone is pale green, pooly-sorted calcareous and contains a great deal of fossil fragments. Bedding is very weak and often massive. The alternation of sandstone and mudstone is exposed in the lower stream of the Bucloc River and it occurs as fine-unit alternation of light gray arkose sandstone and gray mudstone. Among the clastic rocks which occur above the limestone, the conglomerate, about 5m thick, consists of rounded pebbles of dacite, rhyolite, andesite and acidic tuff, and its matrix is calcareous. Limestone fragments is not observed. The sandstone layer consists mainly of light yellow, well-bedded, fine- to coarse-grained calcareous sandstone and a dark green medium-grained massive one. The mudstone shows gray color and well-developed bedding. These sandstone and mudstone contain large amount of smaller faraminiferas. In the Mabaca

River, alternated bed of grayish white coarse-grained calcareous sandstone and gray mudstone is exposed. The sandstone is unsufficiently sorted and contains fragments of fossils. The mudstone also contains black carboniferous materials.

Alteration is not recognized in this formation.

Fossil and Age : The limestone samples from the Alava Road yields the following larger foraminiferas:

Miogypsina dehaartii Van der Vlerk

M. thecidaeformi Rutten

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

Globorolaria tumida (Brady)

It indicates the Late Miocene age (N17-N18), but other samples suggest a possibility of Pliocene age. On the other hand, this formation distributed from Lias to the Saltan River is considered to be Miocene to Pliocene by existing data.

Based on the above-mentioned facts, the Alava Formation is determined as of Early Miocene to Pliocene time.

Geological Structure : This formation shows clear monoclinic structure dipping eastward in the eastern portion and westward in the western portion.

Relation to the Underlying Formation : The outcrop showing the unconformity between this formation and the Mabaca Formation has not been observed but clastic rocks of this formation contain

andesite fragments which are lithlogically the same as the Mabaca Formation. Moreover, the Mabaca Formation dips 30° - 40° east in the Mabaca River while the limestone of this formation dips about 20° east, and generally there is structural discordance between the two formations. Therefore, it is concluded that the Alava Formation rest unconformably upon the Mabaca Formation.

2-2-5 Quarternary Volcanic Rocks

Distribution : These rocks consist of dacitic volcanic rocks and andesitic ones. Dacitic volcanic rocks are distributed in the middle to upper reaches of the Pasil River, especially around Mt. Masimus and Mt. Binulauan, which are located in the southern part of the Pasil River, with characteristic topography. Some of this rock type are narrowly exposed around Mt. Patoc. The andesitic rock is distributed in the northern to western portion of Besao with narrow exposures.

Thickness : About 300m or more.

Rock Facies : The dacitic rocks consist of light gray to grayish white dacitic welded tuff and light gray dacitic tuff. The former is mainly exposed around the Pasil River basin, and according to the preliminary survey in 1978, it is porous and loose rock, characterized by weak but widely spread welded structure. The latter is found around Mt. Patoc and it is also loose rock, partially showing weak welded structure, and intercalated with thin

tuff breccia layer containing essential breccias.

Dacite lava has not been observed but the unpublish data of the Batong Buhay mine suggest that it occurs near the mine.

The andesitic rocks are brick red to dark gray andesite with coarse-grained hornblende and pyroxene phenocrysts. These rocks occur as plugs in Besao and its northern vicinity, Barrio Agawa, and as lavas around Mt. Sipitan.

The microscopic feature of the rock exposed along the Pasil River are as follows.

Dacitic welded tuff (p-121)

Texture : Welded structure.

Fragment of mineral : Quartz, plagioclase, hornblende and opaque minerals.

Quartz is 0.1 - 1mm across and medium amount.

Plagioclase is 0.1 - 0.5mm across in large amount.

Hornblende is 0.1 - 0.5mm across and medium amount.

All of fragments are not altered.

Matrix : Glass.

Fossil and Age : Fossil is not found in this rock. There is no positive data to determine as its age but on the basis of the distribution feature, its occurrence and very weak consolidation, these rocks can be classed as Quaternary.

Relation to the underlying Formation : It is considered to be probably

an unconformity.

2-2-6 Alluvium

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

2-3 Intrusive Rocks

The intrusive rocks distributed in this survey area are found as basic to acidic batholithic plutonic rocks, stocks and/or dikes of hypabyssal rocks related to the plutonic rocks and various dikes of doleritic to dacitic rocks.

2-3-1 Plutonic Rocks

The plutonic rocks vary in lithology, from gabbroic to granitic facies, but are broadly divided into three principal rock facies based on their distribution features and representative facies. These are: gabbro, quartz diorite and granodiorite. This lithologic classification, however, is not necessarily strict because of the coexistence of two or three facies and the very complicated facies-change.

1) Gabbro Group

Distribution : This group occurs as large-scale mass trending

NNE-SSW, which intruded the Licuan Group Formation II and the Tineg Formation, in the northwestern part of the survey area from the Solsona to Palsuguan rivers via the Madongan River. In addition, a part of this group is narrowly exposed in the uppermost stream of the Palsuguan River as small-scale fenster along the river.

Rock Facies : Usually the rock is megascopically dark gray to dark-greenish gray, medium- to coarse-grained holocrystalline, but a part of it shows light-grayish white leucocratic gabbro facies. Under the microscope, these rocks have an equigranular texture and show hornblende-gabbro, augite-hypersthene-hornblende-gabbro and olivine-augite-gabbro facies. In many cases, a small amount of quartz is present. However, it is very difficult to distinguish and divide each facies individually in the field that all of them are described here collectively. The typical samples show the following features under the microscope:

Augite-hypersthene-hornblende-gabbro(g-512)

Texture : Equigranular texture.

Forming mineral : Plagioclase, augite, hypersthene, hornblende, biotitie and opaque minerals.

Plagioclase is subhedral, 0.1 - 1mm across, 70 - 90% An, abundant amount. Augite is subhedral, 0.1 - 0.3mm across, medium amount.

Hypersthene is also subhedral, 0.1 - 1mm across, small amount and altered to chlorite.

Hornblende is anhedral, 0.1 - 2mm across and mostly altered to chlorite. Biotite is anhedral, less than 1mm across and in very small amount.

Alteration mineral : Chlorite and kaolinite.

Hornblende-gabbro (g-539)

Texture : Ophitic texture.

Forming mineral : Plagioclase, hornblende, quartz and opaque minerals.

Plagioclase is euhedral to subhedral, 0.1 - 1mm across, abundant, 70 - 90% An and altered to sericite and calcite. Hornblende is anhedral, 0.1 - 1mm across and mostly altered to chlorite. Quartz is anhedral and in rare amounts.

Alteration mineral : Chlorite, sericite, calcite and kaolinite.

2) Quartz Diorite Group

This group is the most predominant among the plutonic rocks distributed in the survey area. It was intruded into the central part of the Cordillera Central as a large-scale batholith-shaped mass trending N-S and formed the frame of the Cordillera Central.

Distribution : This rock group is discontinuously exposed as two

parallel great masses, trending N-S or NNE-SSW. The eastern mass is distributed in the lower stream of the Apayao River, the middle stream of the Dagara River, each upper part of the Tineg-Binongan-Saltan rivers and the upper reaches of the Pasil River. The western mass is distributed from the upper reaches of the Anayan River to the lower reaches of the Layacan River via each middle reaches of the Tineg, Binongan and Malanas rivers; the middle to upper stream of the Baay River; and each middle stream of the Bucloc, Ikmin and Utep rivers. This distribution of the quartz diorites seems to have resulted from the regional differences in erosion and the various dislocation by faults after intrusion of the plutonic rocks. This seems to be so because these two parallel masses may be considered to be connected with each other in shallow depth from the surface on the basis of the contact dipping gently between the mass and intruded rocks. Besides, other small masses are found in the western to southern portion of the gabbro mass and in the southern part of Bontoc.

Rock Facies : Generally this rock shows light-grayish white to light-greenish gray color. It is medium- to coarse-grained leucocratic holocrystalline rock, but in the marginal part its grain size becomes fine. Some rock types, however, show partly light-pinkish gray due to its abundant K-content and fine-grained melanocratic facies.

Main rock-forming minerals are plagioclase, quartz, and

hornblende, with small amounts of K-feldspar, biotite, augite and hypersthene. The quartz diorite group varies lithologically, from grantic to quartz diorite facies, depending upon the combination and ratio of the minerals. The granitic facies consists mainly of quartz, plagioclase and biotite. The quartz diorite facies consists of the minerals; plagioclase, hornblende and the pyroxene group. Of the two, the quartz diorite facies is the more common. These facies-changes are frequently observed in the same outcrop as gradual changes without clear boundaries. As such, when the granodiorite facies is observed in several parts of the quartz diorite, they are lumped together as quartz diorite group in accordance with the most prominent facies. The detailed investigation on the plutonic rocks, including its lithologic classification, is one of the most important subject of the next phase survey.

The alteration of this group is generally weak and only chloritization and epidotization are sporadically observed, but the mass distributed along the Apayao River has been strongly silified, sericitized and chloritized, in strike contrast to other quartz diorite masses.

The representative samples show the following features under the microscope:

Biotite-hornblende-augite-quartz diorite (f-549)

Texture : Equigranular texture.

Forming mineral : Plagioclase, quartz, K-feldspar, biotite, hornblende, augite and opaque minerals.

Plagioclase is euhedral, 0.1 - 5mm across abundant, 50 - 70% An and altered to sericite. Quartz is anhedral, less than 1mm in diameter and in little amounts. K-feldspar is also anhedral and in little amounts. Biotite is anhedral, less than 1mm across, in little amounts and chloritized. Mornblende is subhedral, 0.1 - 1mm across, strongly chloritized. Augite is subhedral, 0.1 - 1mm across and in little amounts.

Alteration mineral : Chlorite, sericite, calcite, epidote and secondary quartz.

Hornblende-quartz diorite (g-544)

Texture : Equigranular texture.

Forming mineral : Quartz, plagioclase, hornblende and opaque minerals.

Quartz is anhedral, 1 - 5mm across and medium amount. Plagioclase is subhedral, 1 - 5mm across, abundant and partially altered to sericite. Hornblende is subhedral to anhedral, 1 - 5mm across, medium amount and weakly chloritized. These minerals are

coarse-grained in general.

Alteration mineral : Chlorite, sericite and kaolinite.

Alteration is weak.

Hornblende-granodiorite (a-512)

Texture : Equigranular and micrographic textures.

Forming mineral : Plagioclase, quartz, hornblende and opaque minerals.

Plagioclase is subhedral to anhedral, 0.1 - 5mm across, abundant, 30 - 50% An. Quartz is anhedral, 0.1 - 1mm across, in little amounts and fresh. Hornblende is subhedral to anhedral, 0.1 - 5mm across, in little amounts and weakly altered to chlorite.

Alteration mineral : Chlorite, sericite and calcite. Each mineral occurs in little amounts.

Granite (m-533)

Texture : Equigranular and micrographic textures.

Forming mineral : Plagioclase, K-feldspar and quartz.

All minerals are 1 - 5mm in diameter and plagioclase is euhedral and abundant, K-feldspar and quartz are anhedral and common. Some plagioclase crystals are altered to albite.

Alteration mineral : Small amounts of albite, sericite and silicates.

On the other hand, many minor fractures are formed in each quartz diorite mass, especially in its marginal portion, and mineralization occurs as network and/or dissemination along these fractures. This is the optimum and most important rock for mineralization.

3) Granodiorite Group

Distribution : This group is distributed in the northeastern part of the survey area from the northern portion of Kabugao to the middle to upper stream of the Nabbuangan River via the middle to lower reaches of the Apinan River and the middle reaches of the Baren River. It forms a large-scale mass pallarel to the quartz diorite masses.

Rock facies : The rocks of this group show generally light-grayish white to light-greenish gray color, and medium- to coarse-grained leucocratic holocrystalline texture. However, in some parts of this rock, gray to greenish gray color is shown, with abundant mafic minerals.

Main forming minerals are plagioclase, quartz, hornblende, biotite and K-feldspar. Lithologically the rocks can be divided into granodiorite consisting of biotite, hornblende and K-feldspar and quartz diorite consisting mainly of plagioclase, quartz and mafic minerals. The granodiorite facies is remarkably predominant. In the upper stream of the Nabbuangan River, however,

light-pinkish gray quartz monzonite is found and it is abundant in K-feldspar. This group has also various rock facies and these facies gradually change like in the quartz diorite group. The granodiorite of this group is abundant in biotite and poor in K-feldspar as compared with the one in quartz diorite group.

The alteration of this group is also very weak and chloritization, epidotization and rarely sericitization are recognized in some parts of this group.

Following are microscopic features of the typical rocks of this group.

Biotite-hornblende-granodiorite (g-307)

Texture : Equigranular texture.

Forming mineral : Quartz, plagioclase, K-feldspar, biotite and opaque minerals.

Quartz is anhedral, 0.1 - 1mm across, abundant and fresh. Plagioclase is subhedral, 0.1 - 3mm across, abundant, 30 - 50% An and partially altered to sericite. K-feldspar is anhedral, less than 1mm in diameter and in little amounts. Biotite is medium amount, subhedral to anhedral and less than 1mm across. Hornblende is also anhedral, 0.1 - 2mm across and weakly chloritized.

Alteration mineral : Chlorite, sericite and kaolinite.

Biotite-hornblende-augite-quartz monzonite (e-308)

Texture : Equigranular texture.

Forming mineral : Plagioclase, quartz, K-feldspar, biotite, hornblende, augite and opaque minerals.

Plagioclase is euhedral to subhedral, 0.1 - 1mm across, abundant and 10 - 30% An. Quartz is anhedral, 0.1 - 1mm across, in little amounts. K-feldspar is medium amount, subhedral to anhedral, and 0.1 - 2mm across. Biotote and hornblende are subhedral, 0.1 - 1mm across and in little amounts. Augite is anhedral, less than 0.1mm across and also a minor occurence.

Alteration mineral : Chlorite, sericite and kaolinite.

2-3-2 Hypabyssal Rocks

The rocks occur as stocks and dikes 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 to the plutonic rocks and considered to be the products formed by the sequent plutonic activity.

1) Diorite Porphyry

Distribution : This rock is exposed in the northern tributary of the Layacan River as a dike trending NE-SW and intruding the

Licuan Group Formation I and the Tineg Formation.

Rock Facies : This porphyry is greenish gray fine- to medium-grained porphyritic rock with abundant phenocrysts of acicular hornblende and plagioclase. It is generally weakly altered but strong chloritization and epidotization are observed in its marginal parts. In addition, pyrite-bearing mineralization occur in some highly altered parts of this rock.

The results of microscopic observations are as follows:

Hornblende-diorite porphyry (g-106)

Texture : Porphyritic texture.

Forming mineral : Plagioclase, hornblende and opaque minerals. Plagioclase is euhedral, 1 - 5mm across, abundant and 50 - 70% An. Hornblende is euhedral to subhedral, 0.3 - 3mm across and in little amounts. Both are highly altered.

Alteration minerals : Chlorite, epidote, sericite, calcite, kaolinite and secondary quartz.

2) Quartz Diorite Porphyry

Distribution : This rock occurs as stocks and dikes intruding the Licuan Group Formation II, the Tineg Formation and the plutonic rocks in the Batong Buhay mine, the mouth of the Apinan River, the Lingas River and the Palsuguan River.

Rock Facies : This porphyry is usually grayish white to gray, but shows light-greenish gray color in the Lingas and Palsuguan rivers. It is a medium- to coarse-grained porphyritic rock with phenocrysts of quartz, plagioclase and chloritized hornblende and pyroxene. The quartz diorote porphyry which occurs in the Batong Buhay mine is the main hostrock of its ore deposits and it has been strongly silicified and chloritized, so that it is very difficult to distinguish the original rock. Some other rocks of this type are also accompanied by mineralized zones.

Under the microscope the rock in the Batong Buhay mine shows the following features:

Altered biotite-hornblende-quartz diorite porphyry (p-117(a), this sample was collected in the preliminary survey in 1978).

Texture : Porphyritic texuture.

Forming mineral : Plagioclase, quartz, biotite and hornblende.

Plagioclase is euhedral to subhedral, 1 - 5mm across, abundant, 45% An and highly altered to sericite.

Quartz is anhedral, 1 - 5mm across and abundant.

Biotite is subhedral, 1 - 2mm across, in little amount and mostly altered to chlorite. Honblende is euhedral to subhedral, 1 - 3mm across, in little amount and completely altered to chlorite.

Alteration mineral : Chlorite, epidote, sericite and secondary quartz.

3) Granophyre

Distribution : This rock occurs as a small stock intruding the quartz diorite mass in the direction of NNE-SSW in the middle stream of the Ikmin River; as a dike intruding the Tineg Formation in the direction of NNW-SSE in the uppermost reaches of the Anayan River; and, as smaller dikes trending NNE-SSW in the quartz diorite mass at the downstream of the Bucloc River.

Rock Facies : All of them show the same lithologic feature, that is, they are pinkish gray, coarse-grained, leucocratic rocks consisting of plagioclase, quartz and K-feldspar. Usually these rocks are holocrystalline but, in the Anayan River, porphyritic texture is very prominent. Mafic minerals are generally very few except for a few biotites. Very weak alteration, in the form of chloritization, occurs in this rock. The microscopic features of this rock exposed in the middle stream of the Ikmin River are as follows:

Biotite - granophyre (a-502)

Texture : Micrographic texture.

Forming mineral : Quartz, plagioclase, K-feldspar and biotite. Quartz is anhedral, 0.1 - 5mm across and abundant. Plagioclase is euhedral, 0.1 - 1mm across, abundant and less than 10% of An. K-feldspar and biotite are subhedral, 0.1 - 1mm across and in

little amounts. Some of the biotite crystals are partly altered to chlorite.

Alteration mineral : Chlorite and kaolinite.

2-3-2 Dike Rocks

In this survey area, many dikes intruding the Licuan Group, the Tineg Formation and the plutonic rocks are distributed in many places. These dike rocks vary lithologically from doleritic to dacitic facies, but andesite and dacite are the most abundant. The direction of the intrusion of dikes is at random but some of them are controlled by faults or other structures.

1) Dolerite

The dolerite occurs as dark green massive dikes 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 found around the contact between this rock and the intruded rocks.

2) Andesite

This rock is the most abundant facies and it occurs as green to dark green, occasionally greenish gray, massive dikes intruding the Licuan Group, Tineg Formation and the plutonic rocks with the exception of the granodiorite. Megascopically pyroxene phenocrysts

are recognized in some dikes but most of them are generally aphanitic. In the Baren and Ikmin rivers, this rock shows porphyritic facies with large phenocrysts of plagioclase and hornblende. The scale of dike is a few meters in width and its direction of intrusion is very varied. Alteration of this rock is very weak as a whole and only chloritization and epidotization are partly observed in some dikes.

3) Dacite

This rock occurs as dikes in the Abulug River which is located at the eastern portion of Kabugao, the Apayao River, the downstream of the Binongan River, the upper stream of the Tineg River and around the Batong Buhay mine. These dikes intruded the Licuan Group, Tineg Formation, granodiorite and quartz diorite groups. All of these dikes contain quartz and plagioclase as phenocrysts and some of them contain lesser amount of hornblende. Alteration is very weak in general but strong silicification and pyritization are observed in the dike exposed in the Binongan River. The direction of the dikes are at random, but in the upper stream of the Tineg River, many dikes, 3 - 5m (maximum 12m) in width, form a dike swarm trending E-W in the quartz diorite. Here, pyrite disseminated zone is formed in quartz diorite but no mineralized zone is observed in the dacite dikes.

2-4 Chemical Compositions of Plutonic Rocks

The ten samples collected from the plutonic and hypabyssal rocks were analyzed to determine their chemical composition and the results have been interpreted together with the two data (N-16, N-76) of the quartz diorite taken from the Agno Batholith by the Northeastern Luzon survey. The location of samples obtained from gabbro (1), quartz diorite (5), granodiorite (2), diorite porphyry (1) and granophyre (1) are shown in Fig. I - 2.

Table I-3 shows the analytical results of the 10 samples and the normative mineral (wt%) composition calculated from these results. This table shows that the SiO_2 content of most samples range from 55% to 65% and thus belong to the intermediate rock type. Samples a-503 and g-512 show affinity to the acidic and the basic rocks respectively. The Fe, Mg and Ca contents of the sample a-502 is in excellent contrast to that of g-502, and these results prove that the former is a leucocratic rock and the latter is a melanocratic one with abundant mafic minerals. Moreover, K_2O content of both samples are very poor.

The relationship between each oxide and the differentiation index (D.I.) is shown in Fig. I - 3. The D.I. values of 8 samples, except those of g-512 (gabbro, showing the early phase of the magmatic differentiation) and a-512 (granophyre, the latest phase) are divided into two groups, one is from 48 to 60 and the other is 72 - 73. The former group includes 5 samples of quartz diorite

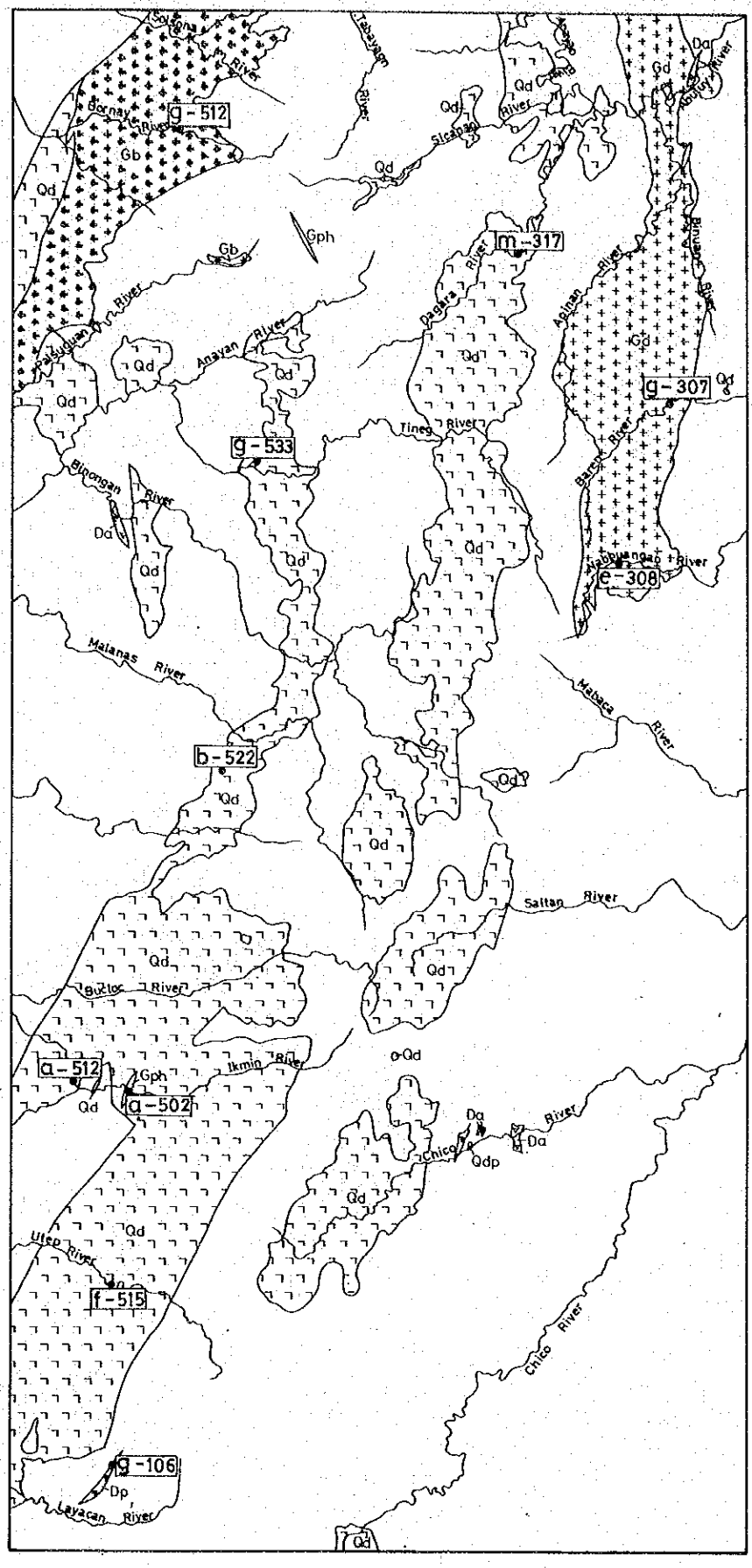


Fig. I - 2 Location Map of Rock Samples for Chemical Analysis and Dating

Table I - 3 Chemical Composition of the Plutonic Rocks

	Sample No.	g - 106	e - 308	g - 307	m - 317	g - 512	a - 502	g - 533	b - 522	a - 512	f - 515
	Location	Layacan R.	Nabbuangan R.	Baren R.	Dagara R.	Madongan R.	Ikmin R.	Tineg R.	Route 6	Ikmin R.	Utep R.
	Rock Name	dio-por	qtz-monz	gra-dio	qtz-dio	au-hy-hb gab	gph	qtz-dio	gra-dio	gra-dio	qtz-dio
Chemical composition	SiO_2 %	56.67	62.73	65.43	62.95	48.01	76.36	56.08	57.39	59.01	61.22
	TiO_2	0.48	0.53	0.51	0.51	0.81	0.13	0.71	0.73	0.49	0.51
	Al_2O_3	18.17	17.03	15.74	15.60	20.21	12.07	17.22	17.10	17.55	16.74
	Fe_2O_3	4.19	0.32	1.52	2.28	3.94	0.48	3.59	2.83	2.83	2.08
	FeO	2.84	4.24	2.87	4.20	7.19	0.93	5.07	4.92	3.56	3.95
	MnO	0.14	0.10	0.10	0.14	0.17	0.02	0.17	0.13	0.10	0.14
	MgO	3.31	1.39	1.39	2.92	4.46	0.09	3.61	2.73	2.31	2.77
	CaO	6.81	3.62	3.77	5.55	12.07	0.70	7.19	6.52	5.64	6.12
	Na_2O	4.07	3.96	3.70	3.10	2.43	3.22	3.68	3.09	3.77	3.33
	K_2O	0.88	4.65	3.77	1.80	0.24	4.82	1.53	3.04	2.94	1.90
	P_2O_5	0.26	0.23	0.21	0.13	0.07	0.05	0.23	0.35	0.24	0.16
	CO_2	0.40	—	—	—	—	—	—	0.18	—	—
	$H_2O(+)$	1.41	0.39	0.08	0.38	0.10	0.25	0.52	0.80	0.93	0.50
	$H_2O(-)$	0.22	0.22	0.14	0.06	0.16	0.10	0.12	0.08	0.08	0.12
	Total	99.85	99.41	99.23	99.62	99.86	99.22	99.72	99.87	99.45	99.54
CIPW norm	Q	11.6	10.1	18.7	20.5		37.2	8.2	9.7	10.3	16.3
	C						0.3				
	or	5.0	27.3	22.3	10.6	1.7	28.4	8.9	17.8	17.3	11.1
	ab	34.6	33.6	31.5	26.2	20.4	27.3	30.9	26.2	32.0	28.3
	an	28.6	15.0	15.0	23.4	43.4	3.3	26.1	23.9	22.3	25.0
	di wo	0.3	0.5	1.2	1.4	6.9		3.3	2.3	1.7	1.9
	di en	0.3	0.2	0.6	0.8	3.7		1.9	1.2	1.0	1.0
	di fs		0.4	0.6	0.6	2.9		1.1	1.0	0.6	0.7
	hy en	8.0	3.2	2.8	6.5	7.2	0.2	7.2	5.6	4.7	5.9
	hy fs	1.3	6.3	2.7	4.7	5.7	1.1	4.2	4.6	2.9	4.3
	ol fo					0.2					
	ol fa					0.2					
	mt	6.0	0.5	2.3	3.2	5.8	0.7	5.1	4.2	4.2	3.0
	il	0.9	1.1	0.9	0.9	1.5	0.3	1.4	1.4	0.9	0.9
	ap	0.7	0.7	0.3	0.3			0.7	0.7	0.7	0.3
	cc	0.9							0.4		
	Total	98.2	98.9	98.9	99.1	99.6	98.8	99.0	99.0	98.6	98.7
	Q+or+ab	51.2	71.0	72.5	57.3	22.1	92.9	48.0	53.7	59.6	55.7
	D.I.	52.1	71.8	73.3	57.8	22.2	94.0	48.5	54.2	60.4	56.4

Abbreviation; dio-por:diorite porphyry qtz-monz:quartz monzonite gab:gabbro
qtz-dio:quartz diorite gra-dio:granodiorite gph:granophyre

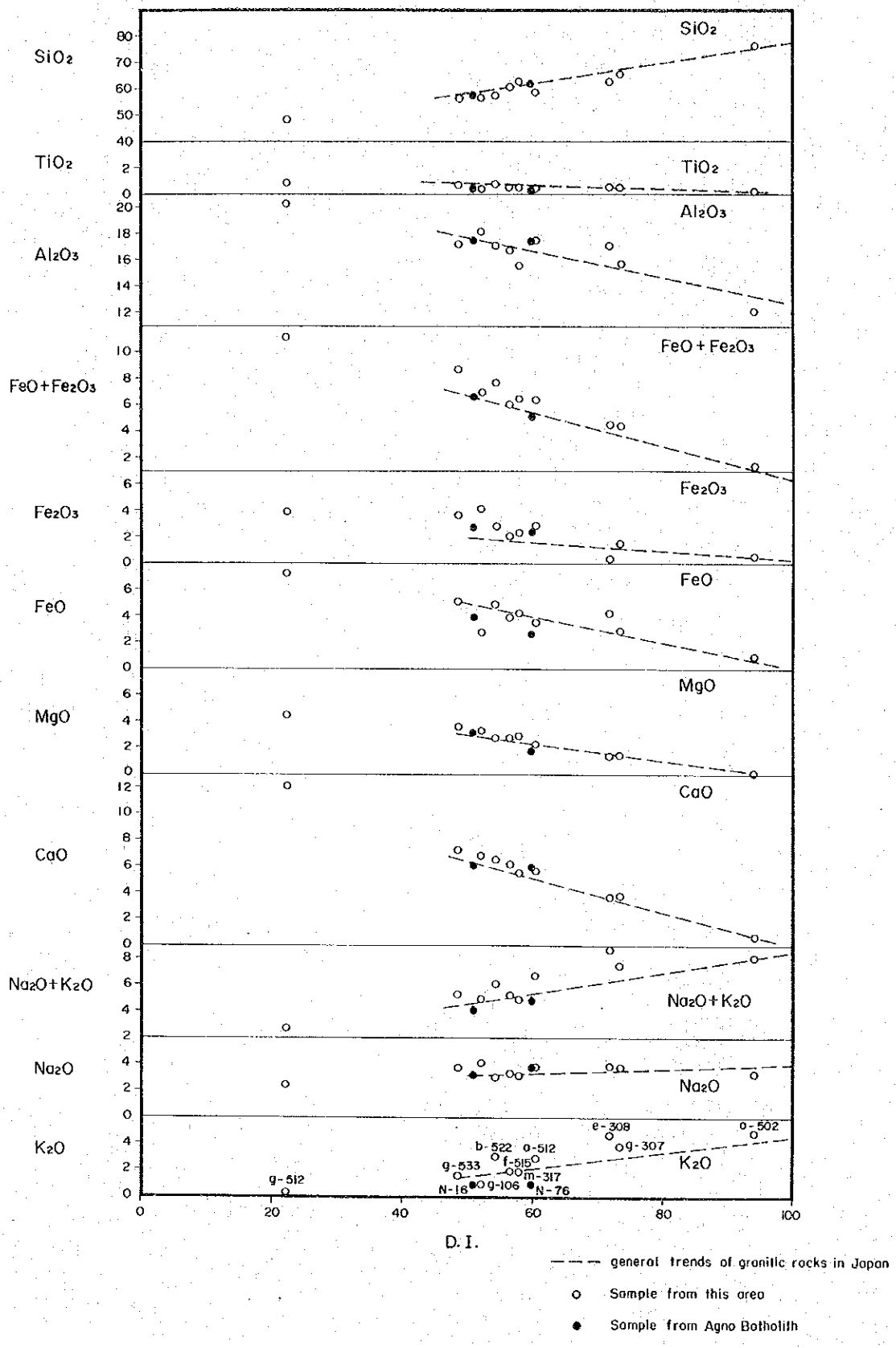


Fig. I - 3 Variation Diagram of Plutonic Rocks

and 1 sample of diorite porphyry, and the latter includes 2 samples of granodiorite. Each oxide shows a linear trend and they are very similar to the average value of the Japanese granitic rocks (ARAMAKI et al, 1972) with the exception of Fe_2O_3 and K_2O. The two samples from the Agno Batholith belong to the quartz diorite group and show the same nature as the quartz diorite from this survey area.

Normative constituents of each sample are plotted in the Q-Kf-Pl diagram, as shown in Fig. I - 4. In this diagram, a-502 sample is plotted in the portion with high contents of quartz and K-feldspar (granite zone), g-512 is plotted in the portion with no quartz and high plagioclase (monzonidiorite-monzonigabbro zone) and the other samples, including 2 samples of the Agno Batholith, are plotted in the quartz monzonite, granodiorite, tonalite and quartz diorite zones.

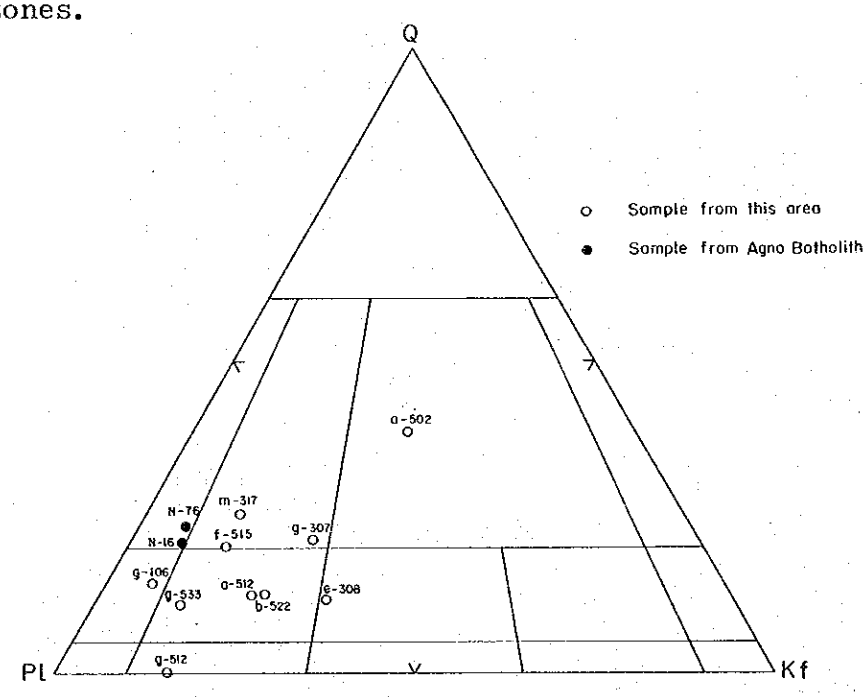


Fig. I - 4 Normative Q-Kf-Pl Diagram of Plutonic Rocks

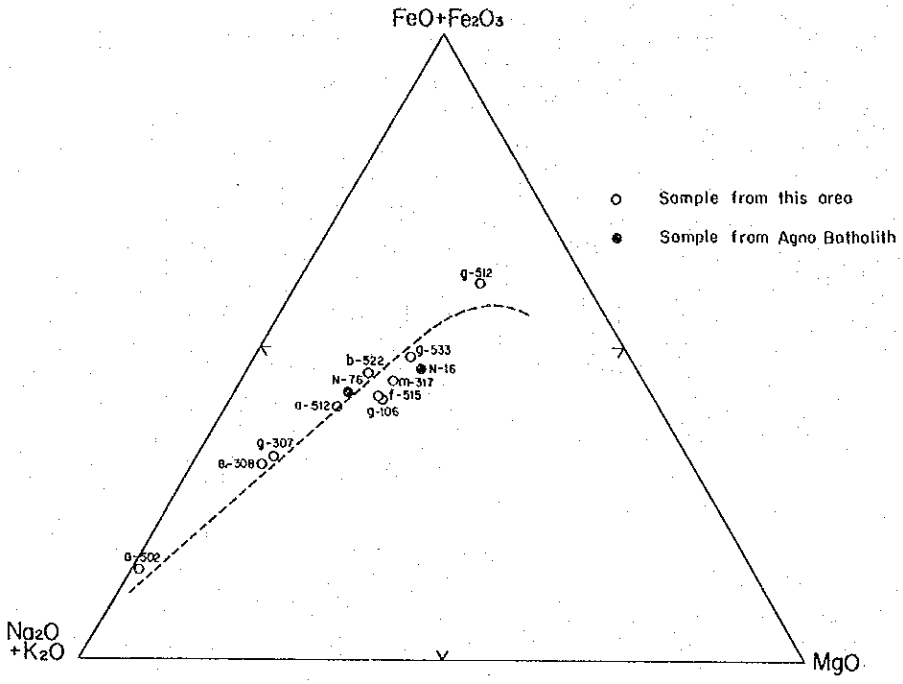


Fig. I - 5 M. F. A. Diagram of Plutonic Rocks

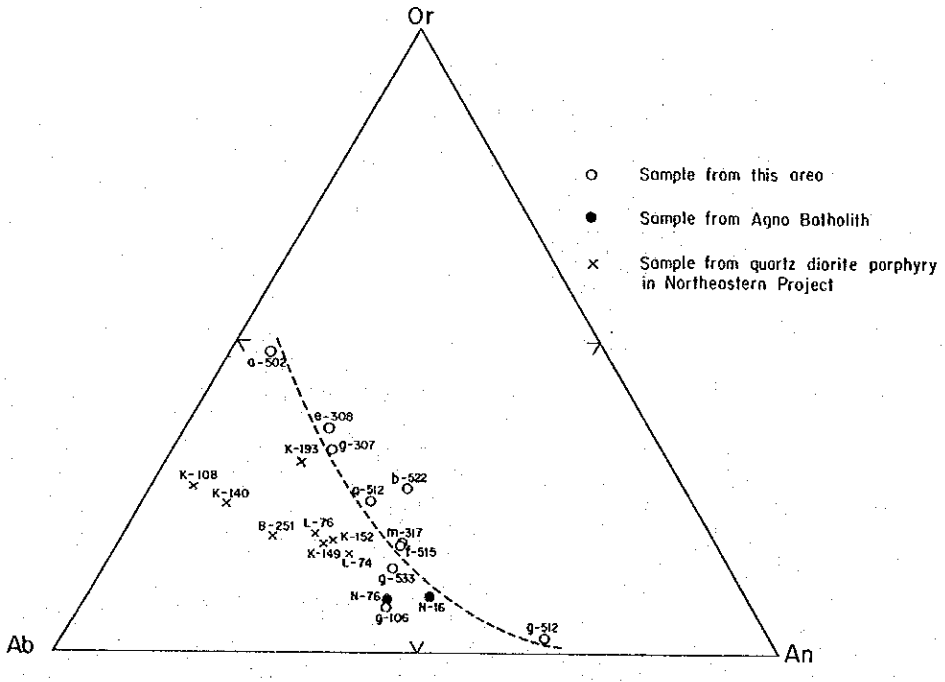


Fig. I - 6 Normative Or-Ab-An Diagram of Plutonic Rocks

According to the M-F-A diagram (Fig.I-5), all samples trace the same magmatic differentiation process as that of the volcanic rocks of the calc-alkali rock series. That is, it can be considered that g-512 is the early phase product of the magmatic differentiation process, g-533, m-317, b-522, a-512, f-515, g-106, N-16 and N-76 are the middle phase, g-307 and e-308 are the late phase and a-502 is the latest phase.

In the normative Or-Ab-An diagram shown as Fig. I - 6, a certain trend was obviously recognized between the high anorthite-low orthclase zone and the low anorthite-high orthoclase zone. This diagram contains 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.

From the above-mentioned facts, the plutonic rocks distributed in the survey area are considered to have been formed from the same magma by the consecutive plutonic activity. Considering the sample localities, the gabbro mass occurs as the early phase product of the differentiation process in the area from the Solsona River to the Palsuguan River; the quartz diorite masses exposed in the central part of the area occur as the middle phase product; the late phase product is the granodiorite mass distributed in the eastern portion of

the quartz diorite masses; and, the latest phase product occurs as the granophyre intruding the quartz diorite. The Agno Batholith which shows the same nature as the quartz diorite in this area is considered to be the middle phase product caused from the same plutonic activity. The quartz diorite porphyries which occur as the hostrock of the Tawi Tawi ore deposit have been considered to have originated from the magma forming the Agno Batholith, and they may suggest to have the different natures in the magmatic differentiation process. Only a few porphyritic rocks were observed by this phase survey so that the data on those rocks were not sufficient. The detailed studies on the plutonic and hypabyssal rocks and the clarification of the relationship between these rocks and mineralization should be conducted in the next phase survey.

2-5 Ages of Plutonic Rocks

To know the intrusion ages of the plutonic rocks in the survey area, absolute ages of 10 samples chemically analyzed were measured by K-Ar method (cf Fig.I-2). Two samples, g-106 (diorite porphyry) and g-512 (gabbro), do not certain enough amounts of K to determine their ages. The results of the other samples are shown in Table I-4.

The table shows that their ages vary almost continuously from 9.8m.y.-19.9m.y. From the viewpoint of rock masses, the quartz diorite mass (5 samples) can be classified into two groups, 9.8m.y. (1 sample) and 18.3 - 19.9m.y. (4 samples). The granodiorite

Table I - 4 Results of K-Ar Dating

Sample No.	Rock Name	Mineral	Sample wt(gr.)	K%	$^{40}Ar^{R}$ / ^{40}K	Air Contamination %	Age (m.y.)
e-308	Quartz monzonite	Mafic	1.0170	1.37	0.000946	60.55	16.2
g-307	Granodiorite	Mafic	1.2000	3.11	0.000803	56.06	13.7
m-317	Quartz diorite	Mafic	1.2291	3.11	0.001168	46.73	19.9
a-502	Granophyre	Salic	1.1405	3.66	0.000744	59.57	12.6
a-512	Granodiorite	Salic	1.1267	3.24	0.001079	67.92	18.4
b-522	Granodiorite	Salic	1.0264	3.26	0.001070	55.02	18.3
f-515	Quartz diorite	Mafic	1.0080	2.46	0.000574	58.58	9.8
g-533	Quartz diorite	Salic	1.0940	1.57	0.001084	42.80	18.5
g-106*	Diorite porphyry	-	-	-	-	-	-
g-512*	Gabbro	-	-	-	-	-	-

Remarks ; $\lambda e = 0.581 \times 10^{-10}$ year^{-1} $^{40}K/K = 0.0001167$

$\lambda\beta = 4.962 \times 10^{-10}$ year^{-1} $^{40}Ar^{R}$: radiogenic argon 40

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

mass (2 samples) is 13.7 - 16.2m.y. and the granophyre (1 sample) is 12.6m.y. These variable ages indicate some clear time differences among their intrusions. Although it is still a matter of estimation because of no data on gabbro, these differences are considered to show each stage in the magmatic differentiation already stated in the paragraph on chemical composition; early phase — gabbro ; middle phase— quartz diorite ; later phase— granodiorite ; latest phase — granophyre. The youngest quartz diorite tested is from the mass which widely occupies the south western part of the area and has megascopically almost the same rock facies as those of quartz diorite distributed in the northern area. Besides, there are no clear field evidences that the youngest quartz diorite intrudes into other quartz diorite masses so that it would be natural to think that the two groups — 9.8m.y. and 18.3 19.9m.y. — vary continuously. However, the time difference of about 10m.y. between them is too large to consider that they have been produced by the same igneous activity. A review of these problems, including rock facies classification, will be needed in future.

The age of the Agno Batholith, determined to be 17.9 ± 0.9 m.y. by the survey of Northeastern Luzon, corresponds to the age of 18.3 - 19.9m.y. of the quartz diorite in this area. Thus, it is clear that there are similarities between them not only in chemical composition but also in age. WOLFE (1972) reported the ages of dioritic rocks distributed in the southeast and south of Baguio as

14.8±0.8m.y. and 9.8±1.0m.y. From the rough sketch and rock types, the former age may be the Agno Batholith and the latter age, the quartz diorite distributed along the Kennon Road, though it is not so sure because he did not describe sampling sites and occurrences.

2-6 Alteration

The alterations observed in the area are regional alterations commonly observed in the lavas and pyroclastic rocks of the Licuan Group and Tineg Formation, alteration accompanied with plutonic rock intrusion and alteration accompanied with mineralization. These alterations frequently overlap each other, which leads to difficulty of distinguishing each other.

Generally speaking from field and microscopic observations, chloritization and silicification with epidotization, sericitization and albitization are remarkable in the Licuan Group; chloritization, silicification and carbonitization with sericitization, epidotization and albitization, in the Tineg Formation. In the Mabaca Formation alterations become generally weak and chloritization, montmorillonitization, silicification and sericitization are locally recognized. No alteration can be found in the Alava Formation and Quaternary volcanic rocks.

Near the contacts between the plutonic rocks and intruded rocks, silicification and epidotization are noticeable. Gossans of pyrite

and limonite and partial hornfels are also recognized at the contact.

The wide alteration of silicification, sericitization and local pyritization observed along the Route 11, southwest of Bontoc, and in the east of Sagada, is possibly a hydrothermal alteration accompanied with a hot spring process.

In this survey X-ray diffractive analyses were carried out on 11 samples as shown in Table A-3, most of which are strongly altered rocks with mineralization. Their results, therefore, will be described in the chapter of ore deposits with hostrock alteration.

2-7 Geological Structure and Geological History

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

(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 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 dikes.

It is an interesting fact that 3 hot springs gush out along the N-S fault running through Barrio Alava and its extension fault with the same trend, suggesting the structural control over the spring locations.

(2) NW-SE System Structure

This system, being in the same direction as the Philippine Fault which bounds the south of the Cordillera Central Mountain Range, does not control the major structure in the area but is exposed on a small-scale at 3 places — the downstream of the Solsona River, middle reaches of the Binongan River and downstream of the Ikmin River.

As cutting the N-S system faults and being cut by the NE-SW system to be described later, this system can be estimated to be oldest one after the N-S structures.

(3) NE-SW System Structure

This system, developed mainly in the center to the south of the area, is shown as a large-scale fault with a long strike-side extension. As this fault cuts the above-mentioned N-S and NW-SE systems and traverses the Alava Formation, it is the newest fault. It possibly started to be formed latently at the time of plutonic rocks intrusion, because the extension of the diorite porphyry in a branch of the Layacan River and granophyre in middle reaches of

the Ikmin River belongs to this system.

The Northeastern Luzon survey pointed out in the Baguio Mineral District the development of faults of this system, some of which has had much influence on the ore-formation. It is possible that these faults are shear fractures formed by compression caused by the plutonic rocks intrusion with a N-S system or secondary faults accompanied with the Philippine Fault movement. 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 occured 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 Early Miocene 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 acumulated 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 early stage of Middle Miocene time and ceased at the last stage of the same period, 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— Quaternerly Volcanic rocks.

3. ORE DEPOSITS

3-1 General Statement

Geological and geochemical survey, as well as compilation of the existing data provided by the Bureau of Mines had disclosed the existence of a number of mineralized zones in the survey area, in addition to the two operating copper mines (Batong Buhay and Abra mines): Of these mineralized zones, some have been investigated and explored in detail by the Bureau of Mines and other mining enterprises in order to evaluate ore reserve. The rest of the mineralized zones, however, have been neglected without detailed investigation due to topographic difficulties.

General features of the ore deposits and mineralized zones throughout the whole survey area are as follows:

1) Mineralized zone is roughly classified into two types, that is, network-dissemination type and vein type. Most mineralized zones including the Batong Buhay mine belong to the former, and a few mineralized ones including the Abra mine to the latter.
2) The distribution of mineralized zones is shown in Fig.1-7 and this indicate clearly that most of mineralized zones appear to occur in plutonic rocks, especially at their marginal or adjacent parts. Based on this fact, it can be said that mineralization is closely related to plutonic activity.

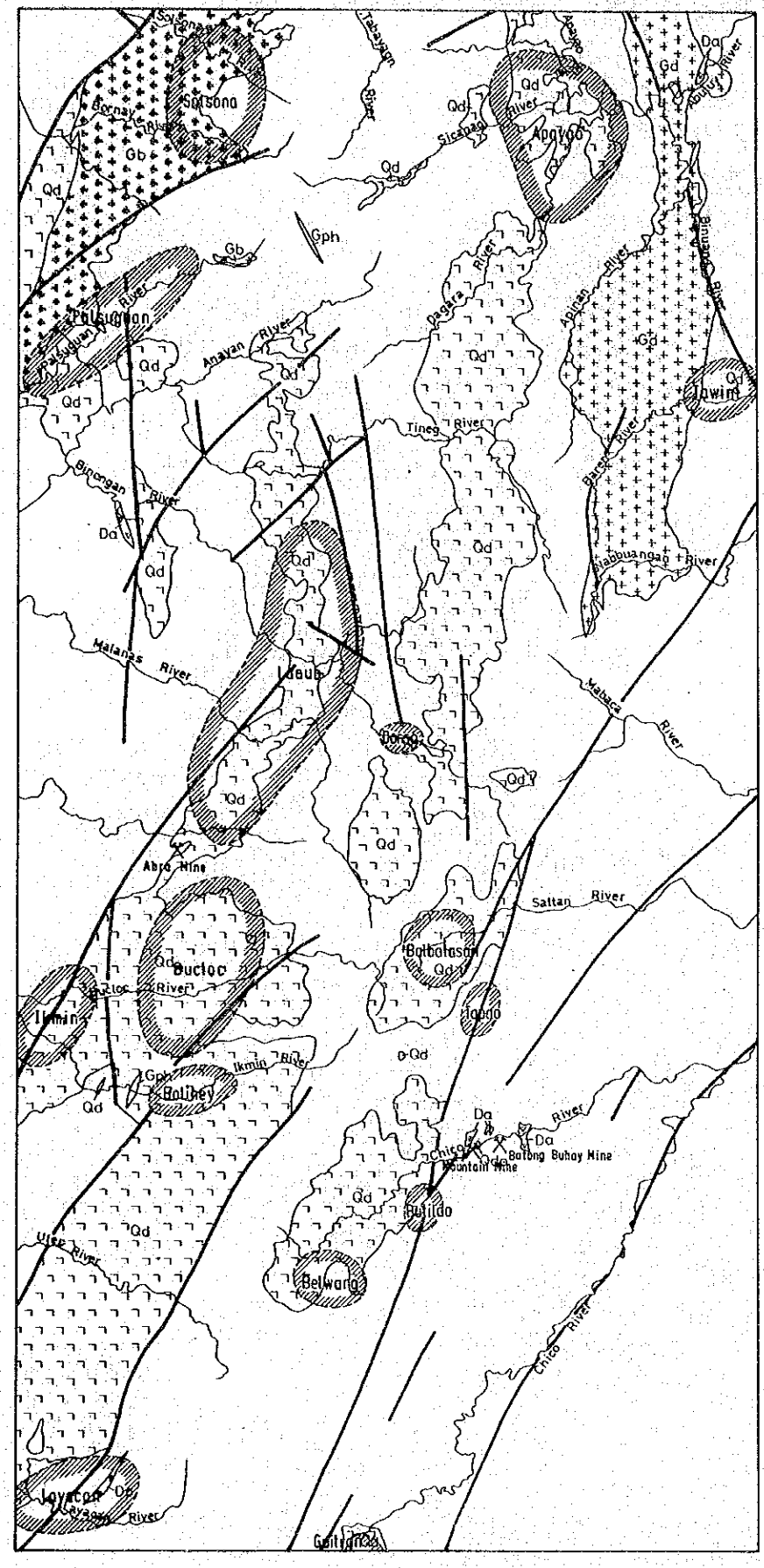


Fig. I - 7 Distribution Map of Mineralized Zones

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 are pyrite, chalcopyrite, bornite, galena and sphalerite, and as 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.

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.

5) The Batong Buhay mine, which is represented as a typical network-dissemination type deposit in the area is a porphyry copper deposit occuring in the stock of quartz diorite porphyry intruded into the volcanic rocks near the plutonic mass. Considering that the stock of porphyry is caused by the plutonic activity, it can be concluded that the mineralization is genetically related closely to the plutoni activity.

6) At present, it is impossible to make detailed discussion on each mineralized zone due to lack of enough investigation of the area yet. Considering the distribution and occurrences of the mineralized zones and the relation between ore deposits and their host rocks, it could be thought that the most favorable sites for mineralization could be the fractured zones produced by intrusion of plutonic rocks or by the cooling process of intrusive masses.

7) On the genetic consideration of the mineralization in the area, there are so many unknown facts on the formation of ore deposits, as can be seen at the Batong Buhay ore deposit, it would be considered that the ore forming process will be the following; intrusion of plutonic rock → intrusion of hypabyssal rock → ore deposits formation in or around the rocks stated above. This ore deposit forming pattern is the same as that suggested by ALMOGELA (1977) and at the survey results of the Northeastern Luzon Project in the Baguio Mineral District. 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.

8) Mineable vein type deposits located in the Baguio Mineral District occurred in the plutonic rocks. The Abra mine, for example, which is one of vein type deposits in the survey area is also formed in quartz diorite. In such a way that most of vein type deposits in the area take the same feature with those in the Baguio Mineral District.

9) The period of the ore formation has not been revealed because K-Ar dating were limitedly conducted to determined the age of the plutonic and hypabyssal rocks, so that it could be merely said that mineralization occurred at the post-plutonic activities. In the Baguio Mineral District, the ore formation period has been considered to be 3 - 6m.y. on the basis of the determination of the host rocks by K-Ar dating.

3-2 Mineralized Zones

Based on the results conducted by this phase survey and referring to the data shared by the Bureau of Mines, detailed descriptions regarding principal mineralized zones in the area are summarized belows.

In the discussions, several number of mineralized zones which are scattered at a narrow area and, which have the same features genetically, have been treated and described together as one mineralized zone.

1. Solsona Mineralized Zone

This mineralized zone is located on the upper reaches of Solsona and Madongan rivers, consisting of three veins and three disseminated zones.

The vein situated on the Solsona River occurs along the fracture zone with one meter of silicification in gabbro showing N65°E strike and 70°S dip. Ore minerals consist of chalcopyrite

and pyrite, and vein appears as a narrow one about 0.15m in width. However, a lump sample taken from the enriched part showed 19.9% in copper and 31.0g/t in silver (m-601).

In the polished section, major amount of chalcopyrite and grayish secondary copper minerals which cut the primary chalcopyrite in network-shaped texture have been observed and also a small amount of sphalerite have been identified in the section. The vein located at the Madongan River occurs on a small fracture zone in gabbro consisting of magnetite-quartz-vein about 10 - 30cm in width. It contains small amounts of chalcopyrite and pyrite partially showing low grade of copper. Under the microscope, mainly chalcopyrite and pyrite accompanied with quartz are observed. Other minerals of germanite-melnicovite-pyrite-marcasite aggregate are also detected under the microscope. This aggregate seems to be produced under a low temperature condition and is thought to occur as secondary minerals. Rare amount of sphalerite is also observable. The direction of the veins generally shows N35° E and N60° W trends. In the adjacent host rock of the veins, intensive epidotization occurs and many epidote veins are commonly observed.

The small disseminated zone which consists of pyrite only as ore minerals have been recognized in gabbro and in its adjacent dacitic tuff of the Tineg Formation.

Furthermore, at a tributary on the south bank of the upper reaches of the Madongan River, there is a porphyry copper deposit

under exploration by the Hercules Mineral Co. However, details are not available.

2. Palsuguan Mineralized Zone

The mineralized zone is located on the middle to upper reaches of the Palsuguan River and is classified as network-dissemination type. This zone which is located on the middle reaches of the river occurs along its main stream extending 2.5km in quartz diorite with disseminated pyrite accompanied fine quartz veinlets. Pyrite, main component of the zone, appears to be accompanied quartz veinlets trending N10°W - N10°E. In the host rock, pyrite is usually observed, with occasionally minor amounts of chalcopyrite and magnetite. Silicification and argillization are remarkable alteration. The mineralization located on the upper reaches of the river develops as pyrite disseminated type in the andesite flow of the Licuan Group Formation II and extends about 1.5km along the river. In the disseminated zone, there are four quartz diorite porphyry dikes in the Licuan Group and these dikes are also mineralized.

From this, it is considered that the mineralization is closely related with the intrusion of these dikes.

Alteration of the host rocks, which are andesite lava and quartz diorite porphyry, are observed to be mainly silicification.

3. Apayao Mineralized Zone

The mineralized zone spreads along the Apayao River and its branches, which is on the west of Kabugao, and on the mouth of

Sicapao and the Dagara rivers, and occur as pyrite dissemination deposits. Alteration of the host rocks, which are quartz diorite and andesite of the Licuan Group Formation II, seems to be silicification, chloritization, and partial sericitization.

The mineralized outcrop occurred at the entrance of the Dagara River extending about 2km along the river. However, copper mineralization was not observed except small amount of pyrite.

Disseminated zone located at the entrance of the Sicapao River extends 1km along the river. Only disseminated pyrite has been observed in the field, however, minor amount of chalcopyrite could be detected under the microscope.

The result of chemical analysis of the sample in polished section is as follows:

0.00% Cu, 2.02% S, 0.0g/t Au and 0.1g/t Ag.

Mineralized outcrops exposed along the main stream of the Apayao River does not produce any copper minerals, and the amount of pyrite is the same as that of the Dagara and Sicapao rivers. That is, as mineralization spreads in a wide area, it becomes weaker. Silicification, sericitization, chloritization and epidotization are generally observed as alteration.

4. Tawini Mineralized Zone

This mineralized zone is located at the mouth of the Baren River near the northwestern part of Barrio Tawini, and is under exploration by the Marcopper Mining Corp. imploring geochemical

soil survey and trenching.

According to the information from the Marcopper Mining geologists, the ore deposits is porphyry copper type accompanied with alaskite, but the scale and occurrence of the deposits are not yet clear.

At the mouth of the Baren River, a small stock of quartz diorite and geochemical anomalous zone are detected. Accordingly, it would be recommended to conduct the next phase survey to the area.

5. Lacub Mineralized Zone

This mineralized zone is distributed from Barrio Lacub on the middle stream of the Binongan River to Barrio Licuan on the middle stream of the Malanas River occupying the widest zone in the survey area of 23km N-S and 6km E-W.

The mineralization seems to be network-dissemination type occurring in a long and narrow quartz diorite mass trending NNE-SSW and in andestic rocks belonging to the Licuan Group Formation II. This mineralized zone could be divided into 7 groups. Copper content analysis and other pertinent data are provided by the Bureau of Mines.

Group 1 : This is located north of Barrio Lacub and is 2km x 6km in dimension. Seven outcrops are found in the area and each outcrop contains chalcopyrite, pyrite and small amount of bornite and chalcocite with quartz veinlets.

Copper grade ranges from 0.05% to 2.87%.

Group 2 : This mineralized zone is distributed within an area of 4km x 1km in dimension at 6km north of Lacub in the marginal portions of diorite, and consists of five outcrops. Each outcrop shows dissemination of pyrite and chalcopyrite with quartz veinlet network. Copper grade ranges from 0.06 - 1.01%.

Group 3 : This is located 3km east of Lacub and consists of three small outcrops. The host rock is andesite, which belong to the Licuan Group Formation II. Outcrop shows disseminated pyrite and occasionally contains small amount of chalcopyrite. Copper grade ranges 0.07% to 0.10%.

Group 4 : Mineralization develops in quartz diorite as disseminated type at 3km south of Lacub. The scale of mineralized zone is 1km N-S and 0.5km E-W. Constituent minerals of this group are pyrite, chalcopyrite and malachite, and contains 0.06% to 11.98% copper.

Group 5 : This is located at 2km north of Barrio Len-neng and is developed in andesite as disseminated type deposits with mineralization spreading in the area of 2km N-S and 0.8km E-W. Minerals are mainly pyrite and small amount of chalcopyrite. Malachite as secondary mineral is also found. Copper grade ranges from 0.05% to 1.54%.

Group 6: The mineralized zone develops at the southwestern part

of Licuan and occupies 1.5km x 0.5km in dimension. Disseminated pyrite and chalcopyrite in the andesite and fissure-filling chalcopyrite and pyrite with quartz micro-veinlets in the quartz diorite are found. Occasionally, small amount of bornite and in some part, sphalerite and galena are recognized. The grade of elements are 0.4 - 0.96% Cu, 0.55 - 2.76% Pb and 0.94 - 4.46% Zn.

Group 7 : This is located at the 5km south of Licuan occupying 1km x 1km in dimension and consists of four outcrops. Each mineralized zone is formed as network of quartz veinlets containing pyrite and rare amounts of chalcopyrite and bornite. Copper grade ranges 0.08% to 1.06%. A part of this mineralized zone is distributed around Route 6 (This data had been distingushed on this phase survey).

6. Abra Mine

This mine is located 2km west of Barrio Baay occupying the southern bank in the middle reaches of the Baay River. At present the mine produces mainly copper and gold and being mined 50 tons of crude ore per day (0.88% Cu, 3.8g/t Au).

Ore deposits are formed as vein type deposits in marginal part of the quartz diorite 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 - 8g/t		
Ag	16 - 25g/t		

The outcrop of Pias vein observed during the survey period of this year, 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 argillization. The result of the chemical analysis of two lump samples take from Pias vein outcrop which contains mainly chalcopyrite [a-529(a), a-529(b)], quartz rich sample [a-529(c)], and a lump sample [a-530] offered by the mine are as follows:

Sample No.	Cu(%)	Pb(%)	Zn(%)	S(%)	Au(g/t)	Ag(g/t)
a - 529(a)	11.34	0.55	0.34	28.07	11.1	122.1
a - 529(b)	14.87	0.00	0.47	34.71	6.6	154.7
a - 529(c)	0.02	0.00	0.01	2.20	0.2	0.7
a - 530	0.73	6.81	4.36	37.04	42.1	266.0

Except for the quartz sample (a-529(c)), the three samples were all observed under the microscope. Descriptions are as follows:

a-529(a) : 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 this 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 and considering from the color, it is thought that Au content would be over 90%. 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. Besides stated above, arsenopyrite occurs as zoned inclusion in gangue mineral. No silver mineral were found in the polished section, which might be included in galena.

a-529(b) : Constituent minerals are pyrite, chalcopyrite, marcasite,

arsenopyrite and magnetite. Among these minerals, pyrite, marcasite and arsenopyrite are considered to be oxidized from pyrrhotite. Cataclastic texture has been recognized in pyrite, and cracks were filled with chalcopyrite. No galena and native gold were detected in this section. Analysis of the samples shows high grade of silver, but no silver mineral and galena were found. Accordingly, occurrence of silver is unclear.

a-530 : Main component minerals of the sample are chalcopyrite, sphalerite and pyrite. Chalcopyrite are present as irregular grains and as veinlets filling the numerous fractures occuerring in sphalerite and pyrite. Considering the Au contents of the sample, native gold is expected to be found, but none was observed, so with the silver minerals.

7. Dorao Mineralized Zone

This mineralized zone is located near Barrio Dorao in the upper reaches of the Binongan River and extends 1km along the main stream. Minerals consist mainly of pyrite and partial chalcopyrite, but the latter is seldom observed.

A hand specimen of copper ore offered by an inhabitant of Barrio Mataragan, situated in the north of Dorao, contains a great deal of bornite and it suggests the existence of a copper ore deposit. Under the microscope, plenty of primary bornite are formed in the

specimen with secondary covelline forming as rim of bornite.

8. Bucloc Mineralized Zone

This mineralized zone spreads from the middle reaches of the Bucloc River to the middle reaches of the Manikbel River. The mineralized zone is grouped into three zones, such as the Bucloc River basin, the Caberuyan area and the Manikbel River basin.

(1) Bucloc River Basin

This is located near Barrio Bucloc and its southern part, and classified as network-dissemination type. There are six mineralized zones in the area of 4km N-S and 2km E-W. The biggest one among the six spreads 1.8km and 0.6km E-W. Each mineralized zone occurs as networks of quartz veinlets along the fractures of quartz diorite. Chalcopyrite and pyrite are commonly found throughout the zone, and rare amount of bornite are observed with malachite and covelline are formed as secondary minerals. In the network zone, dissemination of pyrite and chalcopyrite is also recognized. Copper grade is ranging 0.07 - 2.59% (data from Bureau of Mines).

(2) Caberuyan Area

This mineralized zone occurs at Barrio Caberuyan, 5km east from Bucloc, and shows N10°E strike, 55°W dip and consists of three quartz veins, each vein is 10 - 20cm in width, in a 2m width sheared zone. Malachite is partly observed in the vein. The best one among them contains 2.68% Cu, 0.63% S and 4.0g/t Ag.

It seems that high grade copper contributes to the existence of malachite. Under microscope, small amounts of chalcopyrite replaced by secondary copper mineral are observed.

(3) Manikbel River Basin

This mineralized zone is located near UD-Udiao on the middle reaches of the Manikbel River and spreads 4km N-S and 1.5km E-W, and consists of 9 outcrops showing network-dissemination type. The three disseminated outcrops are found in the area and contain pyrite, chalcopyrite and small amount of bornite. Extension of the zone shows N25° - 35° E trend, copper grade ranges 0.17% to 4.55%. Six network zones are found in the area and contain pyrite and chalcopyrite with a small amount of bornite, galena and sphalerite in thin quartz vein. Cu grade ranges 0.41% to 3.17% (data from Bureau of Mines).

9. Ikmin Mineralized Zone

This mineralized zone is located downstream of the Ikmin River and the Bucloc River. Pyrite disseminated outcrops are found at four places in this zone, and two of four outcrops occur in quartz diorite and other two in andestic pyroclastic rocks of the Licuan Group Formation II. A small amount of pyrite is only observed and mineralization itself is generally weak. A few quartz veins is observed in some parts of the zone, but pyrite is very little. Silicification and argillization are remarkable alteration.

10. Boliney Mineralized Zone

This is located on the north bank on the middle reaches of the Ikmin River and is distributed in the area of 8km E-W x 2km N-S with 8 outcrops of pyrite dissemination. Ore minerals consist of pyrite, chalcopyrite and a small amounts of bornite and magnetite. Copper grade indicates from 0.11% to 6.20%. This mineralization zone has been claimed by the Binulawan Mining Association because of the exploration permit, so that, it was impossible to get geochemical samples. However, there is a highly altered zone about 10km in width in quartz diorite at about 10km west of Barrio Danac along the main stream of the Ikmin River, but the copper content is very low.

11. Balbalasang Mineralized Zone

Network and disseminated mineralized zones are observed at 3km west of Barrio Balbalasang along the upper reaches of the Saltan River. There are two mineralized outcrops occupying 50m x 20m at a distance of 1km. Extension of mineralized zone show N-S and N70°E direction, respectively. Ore minerals consist of pyrite and chalcopyrite, and network of fine quartz veinlets is also accompanied by pyrite dissemination. Occasionally, small amount of bornite is observed. Copper grade shows 0.01% to 0.26%. The geochemical anomalous zone has been detected by the Bureau of Mines at 3km south of this mineralized zone.

12. Tapao Mineralized zone

This mineralized zone is located at 5km south of Balbalasang

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

13. Batong Buhay Mine

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

14. 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 3km x 3km. 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 (date from Bureau of Mines).

15. Butilao Mineralized Zone

According to a Bureau of Mines' survey, the mineralized zone ranging 900m N-S and 400m E-W is located at 7km 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.

16. Belwang Mineralized Zone

This mineralized zone is located at 10km 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 1.5km x 0.5km. 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 (data from the Bureau of Mines).

17. Layacan Mineralized Zone

This mineralized zone belongs to the dissemination type with accompanying Cu-rich vein and is located to the west of Bontoc on the lower streams of the Layacan River and its tributaries. The mineralized zone located on the lower streams of the river occurs in basalt lavas, which belong to the Licuan Group Formation I, as pyrite dissemination and develops 2.5km along the main stream. N-S extension of the deposits seems to be 1.7km on the basis of the information from the inhabitants. Intensive silicification and chloritization are commonly formed as host rock alteration with a strongly silicified zone with in 2.5m in the central part and there is the vein about 20cm in width consisting of bornite, chalcopyrite and pyrite treanding N70° E and dipping 80° S.

Fig. I-8 shows the occurrence of this vein. Chemical analysis of the samples taken from enriched portion of the vein is as follows:

Cu : 32.76%, Pb : 0.02%, Zn : 0.38%, S : 30.42%,

Au : 0.6g/t, Ag : 88.9g/t.

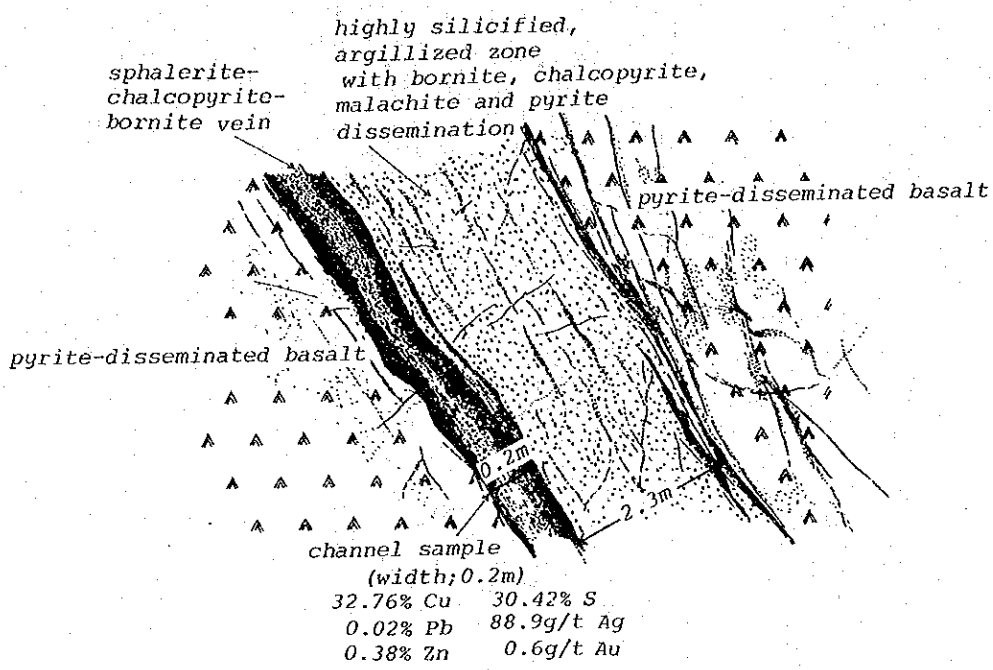


Fig. I - 8 Sketch of Vein in Layacan Mineralized Zone

On the enriched copper specimen, under the microscope, large amounts of bornite, pyrite, tennantite and minor amounts of chalcopyrite and sphalerite are observed. The mineralized zone located at the tributary of the Layacan River occurs in diorite porphyry as pyrite dissemination. This zone consists of four narrow disseminated zones and are exposed discontinuously along the Licuan Group Formation I showing NE-SW trend. Fine quartz veinlets are partially observed with little amounts of pyrite but no chalcopyrite is contained.

18. Guitron Mineralized Zone

The mineralized zone is located at 2.5km south of Bontoc and is classified as pyrite disseminated quartz veinlets network

type. No copper minerals are found in megascopical observation, but minor amounts of molybdenite accompanied with iron oxide minerals are identified under the microscope.

19. Other Mineralized Zone

Aside from the stated above, small-scale mineralized zone are locally recognized in the area of the Madongan River, the Sicapao River, southern part of Kabugao and the upstreams of the Tineg River. In some parts of these areas, minor amount of chalcopyrite is observed, however, the mineralizations are generally very weak.

Table I - 5 Summary of Mineralized Zones

Name	Location	Type	Scale	Hostrock	Mineral	Alteration	Occurence	Remarks
Solsona	Upstream of Salsona and Madongan Rivers	Vein	wd. 3~30cm	Gabbro	Cp,Py,Q,Mag	Sil ,Epi	Veins occur along fractured and joints in gabbro mass with Py dissemination occasionally. Most enriched vein (w.d.15cm, N65°E/70°S) contents 19.9%Cu, 19.31%S and 31g/t Ag.	
		Diss.	very small	Gabbro & Tineg F.	Py		Local Py dissemination along minor fractures and joints. Forming mineral is only Py.	
Palsuguan	Middle to upper stream of Palsuguan River	Stockwork	2.5km along river	Quartz diorite	Py,(Cp),(Mag) Q	Sil ,Arg	This zone located in middle part occure as dissemination of Py and network of quartz veinlets with minor amounts of Cp and Mag in fractured and highly altered quartz diorite.	
		Diss.	1.5km along river	Q-dio porp.& Licuan Group F.II	Py		Py dissemination occures in small dikes of quartz diorite porphyry intruding andesite lava of Licuan Group F.II .	
Apayao	Western part of Kabugao	Diss.	Max.2km along river	Quartz diorite and Licuan Group F.II	Py	Sil ,chl , (Ser),(Epi)	Many mineralized outcrops occur in highly silicified quartz diorite and andesite of Licuan Group F.II . Py dissemination is not so strong.	
Tawini	Vicinity of Tawini	Diss. ?	?	?	Py,Cp		Under prospecting by Marcopper Mining Corp.(geochemical soil survey and trenching) Details are unknown.	Marcopper area
Lacub	Vicinity of Lacub	Stockwork	7 outcrops in 2km x 0.6km	Quartz diorite	Py,Cp,(Bor) (Cc),(Mal),Q	Sil	Each outcrop consists of Py dissemination with Py-Cp-(Bor)-(Cc)-Q veinlets Quartz diorite is often fractured.Cu contents ranged from 0.05% to 2.87%.	Inco Mining Corp. area
	Northern part of Lacub	Stockwork	5 outcrops in 4km x 1km	Quartz diorite	Py,Cp,Q	Sil	Outcrops occur as dissemination with Q veinlet of Py and Cp in marginal part of quartz diorite. Cu values range from 0.06% to 1.01%.	
	3km east of Lacub	Diss.	3 small outcrop in 1km(N-S) x 0.5km(E-W)	Licuan Group F.II	Py		Dissemination of Py and minor amounts of Cp. Cu values ranged 0.07~0.10%.	
	3km south of Lacub	Diss.		Quartz diorite	Py,Cp,Mal		Py and Cp disseminated zone with Mal stain. Cu contents ranged 0.06% to 11.98%.	
	2km north of Len-neng	Diss.	2km(N-S) x 0.8km(E-W)	Licuan Group F.II	Py,Cp,Mal		Py and Cp disseminated zone with Mal stain. Cu contents ranged 0.05% to 1.54%.	
	Western part of Licuan	Diss.	1.5km(N-S)x0.5km(E-W)	Licuan Group F.II & Quartz diorite	Py,Cp,(Bor), Ga,Sph	Sil ,Arg	This zone occurs as dissemination and cavity-filling of Py,Cp and minor amounts of Bor in andesite of Licuan Group near the contact of quartz diorite. Metal contents are 0.40~0.96%Cu, 0.55~2.76%Pb, 0.94~4.46%Zn and 0.35g/t Ag.	Capcapo Cu area
	Southern part of Licuan	Network	4 small zones	Quartz diorite	Py,Cp,(Bor), Q	Sil	This zone consists of 4 small networked zones of Py-Cp-(Bor)-Q veinlets occured along joints and fractures. Cu values ranged from 0.08% to 1.06%.	Rizal Mining Corp.
Abra Mine	2km west of Baay	Vein	3 veins ranged from 550m to 900m	Quartz diorite	Cp,Ga,Sph,Py, Q	Sil ,Arg	Operating mine. Production of crude ore is about 50t/day (0.88%Cu and 3.8g/t Au). Pias vein : E-W/70°S, Wd.1.2~2.2m, strike length 550~600m, metal contents 0.3~6.4% Cu(max.20%), 2~8g/t Au, 16~25g/t Ag (in enriched part). Nalbagan vein : N10°E/70° 80°W, strike length is 800m (?). Patoc vein : N45°E/80°SE, length may be 800~900m. 3 chip samples taken from enriched part of Pias and patoc veins gave 0.73~14.87%Cu, 6.6~42.1g/t Au and 122.1~266.0 Ag.	
Dorao	9km SE of Lacub	Diss.	1km along river	Quartz diorite	Py,(Cp)	Sil	Widely spreaded Py disseminated zone in silicified quartz diorite.	
Bucloc	Middle stream of Manikbel River	Diss. and network	4km(N-S)x1.5km(E-W)	Quartz diorite	Py,Cp,(Ga), (Sph),(Mol), (Mal),Q	Sil ,Ser Arg	9 mineralized outcrops are distributed in this zone(3 disseminated zones and 6 networks). Cp,(Bor) and (Mal) occur in Py disseminated zones trending to N25°~35°E with 0.17~4.55%Cu. Qveinlets with Cp, Py,(Ga),(Sph) and (Mol) occurs as network, Cu contents ranged from 0.41% to 3.17%.	UD-Udiao Mining Co. area
	Southern vicinity of Bucloc	Stockwork	4km(N-S)x2km(E-W)	Quartz diorite	Py,Cp,(Bor), (Mal),(Azu), Q	Sil ,Ser	This zone consists of 6 stockworked zones along fractured and brecciated zones. Quartz veinlets contains Cp, Py and minor amount Bor. Cu contents ranged 0.09% to 2.95%.	Lamao-Bucloc Mining Co. area
	Caberuyan	Vein	Vein width 10~20cm	Quartz diorite	Py,(Mal),Q		3 Py-Q veinlets with Mal stain occur along fractures. Cu and S contents are 2.68% and 0.63%.	

Abbreviation; Diss :Dissemination
Q-dio porp:Quartz diorite porphyry

Py : Pyrite Cp : Chalcopyrite Bor: Bornite Cc : Chalcocite Ga : Galena Sph: Sphalerite

Mal : Malachite Azu : Azurite Mag : Magnetite Q : Quartz Mol : Molybdenite

Sil : Silicification Ser : Sericitization Arg : Argillization Chl : Chloritization Epi : Epidotization Kal : Kaolinitization

Name	location	Type	Scale	Hostrock	Mineral	Alteration	Occurence	Remarks
Ikmin	Lower part of Bucloc and Ikmin Rivers	Diss.	Width:20~40m Length:100~500m	Quartz diorite Licuan Group F.II	Py,Mal	Sil ,Arg	Highly silicified zone with Py dissemination and Mal stain. Occasionally Py-Q veinlets occur as network in silicified zone. Dissemination is not so strong.	
Boliney	Midstream of Ikmin River	Diss.	8 mineralized outcrops in area of 3km x 2km	Quartz diorite	Py,Cp,(Bor) (Mag)	Sil ,Ser Arg	Py dissemination with minor amounts of Cp and Bor occured along fractures and joints in quartz diorite. Cu contents of outcrops ranged from 0.11% to 6.20%.	Binulawan Mining Association area
	1.5km west of Danac	Diss.	Width 10m (max)	Quartz diorite	Py	Sil ,Ser	Highly altered zone with dissemination of Py. Cu content is only 0.01%.	
Balbalasang	3km west of Balbalasang	Network	2 zones in 1km.Each zone is 50m x 20m	Quartz diorite	Py,Cp,(Bor), Q	Sil.,Ser.	Py-Cp-Q veinlets networked zones with minor amount of Bor. Their general trends are N70°E and N-S. Cu contents ranged from 0.01% to 0.26%. Geochemical anomalies of Cu are obtained at 3km south of this zone.	Lepanto Consolidated Mining Corp.
Tapao	5km south of Balbalasang	Diss.	5 outcrops within 1km	Andesitic rocks (Licuan Group F.II)	Py,(Cp)	Sil.,Chl. Arg.	Py disseminated zones with minor amount of Cp occur along fractures. General trend of zones is N60°E. Max. Cu content is 0.63%. In over 2km south of this zone, geochemical anomalous zone of Cu was detected by Lepanto Consolidated Mining Corp.	Inco Mining Corp.
Batong Buhay Mine	Batong Buhay, middle stream of Pasil River	Diss. and Network	? Ore reserve: 90,000,000t,0.599%Cu	Q-dio porp. & andesitic rocks (Licuan Group F.II)	Cp,Bor,Py,Q	Sil ,Ser Arg	Under test operating. Production of crude ore is 3000t/day(0.5%Cu,3g/t Au). In 1980, production will be increased to 21,000t/day. Ore deposits consist of dissemination of Cp, Bor and Py, and network of Q veinlets with Cp,Py,Bor and gold minerals occuring in quartz diorite porphyry and andesitic rocks intruded by quartz diorite porphyry.	
Mountain Mine	Western vicinity of Batong Buhay Mine	Stockwork	5 mineralized zones in area of 3km x 4km	Q-dio porp. & andesitic rocks (Licuan Group F.II)	Py,Cp,Bor,Q	Sil ,Ser Arg	Explored ore deposits by Mountain Mine, Incorporated. Mineralized zones occur as dissemination of Cp, Py and Bor with Q veinlets. General trend of zones is approximately N10°~20°E. Cu contents ranged 0.05~2.14%(37 test pits), 0.17~4.09%(12 drilling cores) and 0.21~1.60% (11 adits).	
Butilao	Upstream of Pasil River, 7km southeast of Batong Buhay	Stockwork	900m(N-S)x 400m(E-W) Ore reserve: 30,000,000t,0.60%Cu	Quartz diorite & andesitic rocks (Licuan Group F.II)	Cp,Py,(Mal) (Mol) Q	Sil ,Kao	Explored ore deposits by Lepanto Consolidated Mining Corp. Cp-Py-Q veinlets with minor amount of Mol occur as stockwork trending N-S in contact between quartz diorite and Licuan Group F.II.	
Belwang	Uppermost stream of Pasil River	Diss. and network	6 mineralized zones in area of 1.5km x 0.5km	Quartz diorite	Py,(Cp),(Bor) Q	Sil	2 disseminated zones of Py and 4 networked zone of Py-Q veinlets trending N-S are distributed in NE-SW direction. Networked zones occur along fractures in quartz diorite. Cu content ranged 0.21~1.60%.	Bengued Consolidated Incorp.area
Layacan	Lower part of Layacan River	Diss.	2.5km(N-S)? x 1.7km (E-W)	Licuan Group F.I	Py	Sil ,Chl	Silicified and chloritized zone with Py dissemination. Occasionally Py Occurs as film-shaped.	
		Vein	Width 2.5m	Licuan Group F.I	Cp,Bor,Py,(Q)	Sil	Cp, Bor and Py bearing strongly silicified zone(wd.2.5m) with highly enriched Cp-Bor-Py-(Q)vein (wd.20cm) in Py disseminated silicified zone. Strike and dip are N70°E and 80°S. Chip sample taken from vein gave 32.76% Cu and 88.9g/t Ag.	
	5km east of above zone	Diss.	4 small zones	Diorite porphyry & Licuan Group F.II	Py		Local Py disseminated zone with quartz veinlets occured in contact of diorite porphyry and basalt of Licuan Group F. I.	
Guitron	2.5km south of Bontoc at Guitron River	Stockwork	1,000m x 500m	Quartz diorite	Py,Q		Q veinlets networked zone with disseminated Py.	

Abbreviation; Diss :Dissemination
Q-dio porp:Quartz diorite porphyry

Py : Pyrite
Cp : Chalcopyrite
Bor: Bornite
Cc : Chalcocite
Ga : Galena
Sph: Sphalerite

Mal : Malachite
Azu : Azurite
Mag : Magnetite
Q : Quartz
Mol : Molybdenite

Sil : Silicification
Ser : Sericitization
Arg : Argillization
Chl : Chloritization
Epi : Epidotization
Kal : Kaolinitization