# REPORT
# ON
# THE COOPERATIVE MINERAL EXPLORATION
# IN
# THE CATANDUANES AREA, THE REPUBLIC OF THE PHILIPPINES

## PHASE II

MARCH, 1995

JAPAN INTERNATIONAL COOPERATION AGENCY
METAL MINING AGENCY OF JAPAN

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METAL MINING AGENCY OF JAPAN

# PREFACE

In response to the request of the Government of the Republic of the Philippines, the Japanese Government decided to conduct a Mineral Exploration in the Catanduanes Area and entrusted the survey to the Japan International Cooperation Agency (JICA) and the Metal Mining Agency of Japan (MMAJ).

The JICA and MMAJ sent to the Republic of the Philippines a survey team headed by Mr. Takehiro Sakimoto from July 23 to October 2, 1994.

The team exchanged views with the officials concerned of the Government of the Republic of the Philippines and conducted field surveys in the Catanduanes area. After the team returned to Japan, further studies were made and the present report has been prepared.

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

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

January, 1995

Kimio Fujita

Kimio Fujita
President
Japan International Cooperation Agency

Takashi Ishikawa

Takashi Ishikawa
President
Metal Mining Agency of Japan

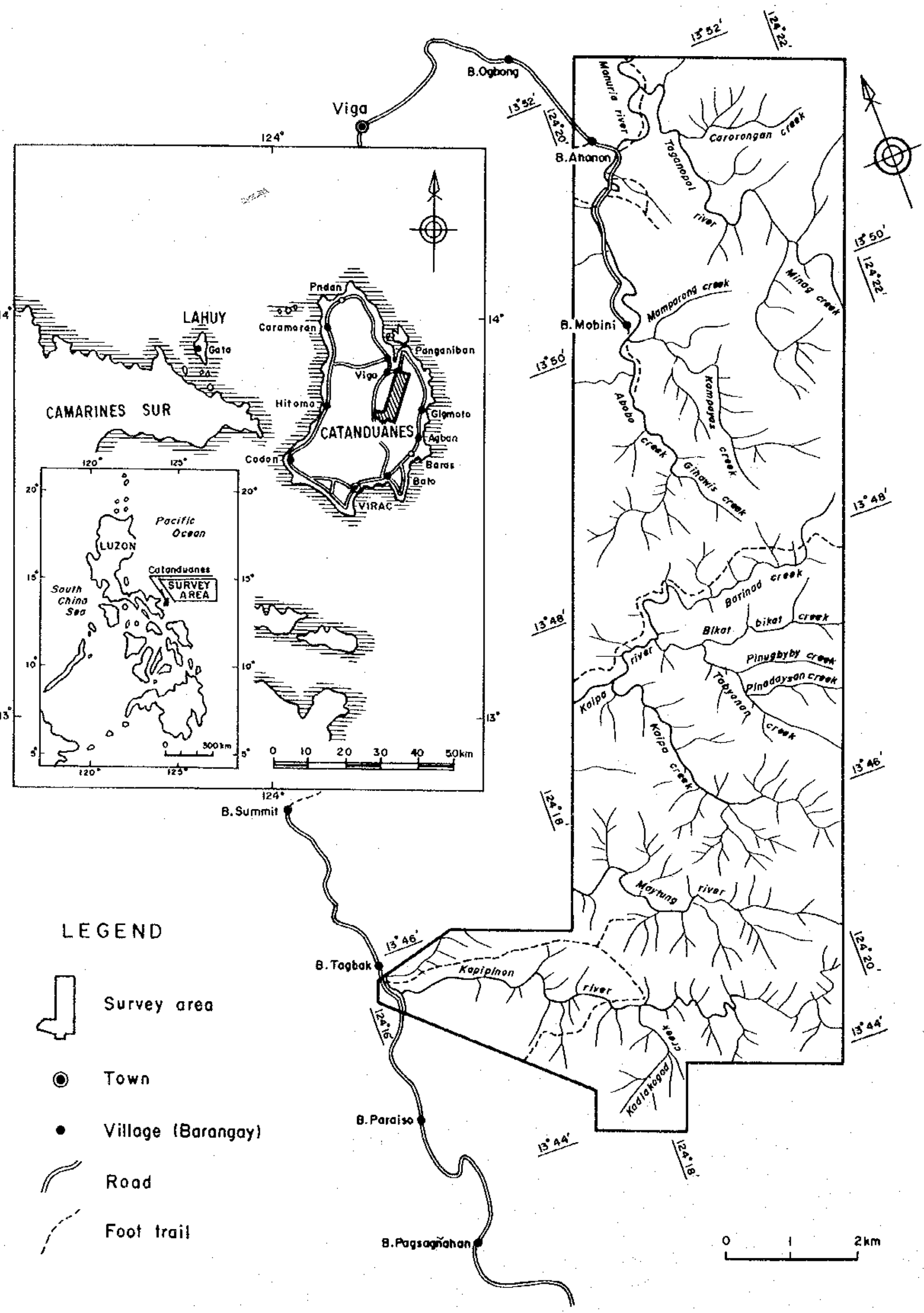


**Fig. 1 Location Map of the Survey Area**

# Summary

This survey corresponds to the Second phase of the Cooperative Mineral Exploration in the Catanduanes Area, Republic of the Philippines. The objective of the survey is to evaluate the potential of gold and copper in the area.

As the results of the survey, primary gold indications were found to be accompanied with quartz veins. The results are as follows:

The Geology is composed of Cretaceous Catanduanes Formation (graywacke and green-schist ) and Eocene Payo Formation (sandstone, limestone and volcanic rocks), Cretaceous Intrusives (gabbro) and Oligocene Batalay Intrusives. Mineralization is divided into the following groups; (1)quartz vein (gold), (2)silicified zone, (3)placer gold, (4)native copper and (5)others.

Probably mineralization is directly or indirectly related to the Batalay Intrusives. Among them, quartz veins and placer gold are the important types of the mineralization. There are two kinds of quartz veins. One is the segregation veins which are formed during dynamo-metamorphism by faulting. The other is hydrothermal quartz veins. Gold-bearing quartz veins are hydrothermal in origin. In the northern part of the survey area, there are many big floats of quartz veins, but both types are not distinguishable in floats from each other. Silicified zone is noted at about 20 localities. Some of them possibly show the surface indication of the deep-seated intrusive rocks and/or mineralization.

Native copper is found in the small cracks within gabbro of Cretaceous Intrusives and nearby graywacke. But the scale and grade of them are poorl.

Others denote network quartz veinlets in weathered graywacke and so on.

As the results of geological and geochemical surveys disclose, the following areas were picked up as promising;

1) **Carorongan Mineral Occurrence:** This is located in the northernmost survey area and in the east part of Ananon. Geology is composed of green-schist of the Catanduanes Formation. Mineralization is in the form of gold-bearing silicified veins, clay veins and silicified zone. The width of the silicified vein is 0.7 to 2 meters. Maximum gold grade were 65.19g/t in the silicified veins (W=5m) and 10.33g/t in the clay veins (W=30cm). Silicified and mineralized zone probably extends to 100m by 200m in size.

As the result of geological and geochemical surveys disclose, the mineralized zone extends over the survey area for this year. This area has a good indication in the geochemical survey and a promising primary gold deposit is expected to exist.

2) **Taganopol Mineral Occurrence:** This is situated in the southeastern part of Carorongan Mineral Occurrence. Quartz vein of 50cm wide are noted in green-schist of the Catanduanes Formation. This quartz vein accompanies pyrite and maximum gold grade was 10.33g/t (W=50cm). Soil and vegetation cover concealed the continuation of the vein. The geochemical anomaly area is rather small and continuity is rather poor, but bigger scale is expected underneath.

3) **Ananon North Area:** This is located in the east of Ananon. The geology is composed of green-schist and Quaternary sediments. There are many of quartz veins along the Taganopol river. There are about 20 pits for placer gold along the river. Gold grains of 4mm in maximum size were recognized in the pit through panning. The gold content is high in stream sediments along this river and potential of placer gold is expected to be large.

4) **Kadlakogod Area:** This is located in the south of the survey area. There is a silicified and argillized zone in the Kadlakogod creek caused by andesite porphyry of Batalay Intrusives. There are many pits for placer gold in the lower reaches of the intrusive rock. Through panning of Quaternary sediments, a gold nugget with 7mm in maximum size was recognized. The surrounding area has possibility of containing placer gold.

5) **Kampayas Area:** This is located in the southeast of Mabini. Small diorite body of Batalay Intrusives was found in the upper stream of the Kampayas river. The sedimentary rocks surrounding the diorite were subjected to silicification and

argillization.

In this river area, gold content is high in stream sediments and primary gold deposit related with diorite is expected to exist.

The survey result of this year indicates that the high potential area for gold may quite probably extend to the eastern area of this survey area. The results of the reconnaissance survey of last year had picked up the promising geochemical anomaly areas in the eastern extension area. Accordingly, in addition to the promising area as above mentioned, we can expect a high potential area in the eastern extension of the survey area for this year to Siemil.

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# Part Ⅰ GENERAL REMARKS

# PART I GENERAL REMARKS

## Chapter 1 Introduction

### 1-1 Background and Objective

The Republic of the Philippines is one of the major mineral producing countries in Southeast Asia, and her production in 1990 is eighth for gold and eleventh for copper in the world. Ore reserves for both metals, however, are sixth and ninth respectively in the world. It means that she has large amounts of undeveloped resources.

The areas mapped geologically in the scale of 1 to 50,000 in this country are 130,000km$^2$, 43% of the total land area. (ref. Resources Information Center of Metal Mining Agency of Japan, 1992) It indicates that she has possibility for new findings in accordance with progress of geological mapping and exploration activities.

The economical environment for mining in the Philippines in these years has been very severe, e.g. low metal prices, low mining grades, exhausting ore reserves, and natural disasters, and the amounts of gold and copper production tend to go down. Under these circumstances, the Government of the Philippines requested the Government of Japan to execute cooperative mineral resources exploration projects for acquisition of new mineral resources.

In response to the request, the Japanese government dispatched a preliminary survey mission to the Philippines, and discussed this matter with the relevant organization of the Philippines. Finally, both sides reached an agreement, and the Japanese representatives, the Japan International Cooperation Agency (JICA) and the Metal Mining Agency of Japan (MMAJ), and the Philippines representatives, the Mines and Geo-Science Bureau (MGB), Department of Environment and Natural Resources, Philippines, entered into an agreement on July 21, 1993. Based on this agreement, a three-year program of the Cooperative Mineral Resources Exploration in the Catanduanes Area, northeast offshore islands of the Bicol Peninsula was programmed to be conducted from 1993. This year is the Second phase survey.

The objective of this project is to discover new ore deposits of gold, copper, and other useful minerals by means of clarification of the geology, geological structure, mineralization, and geochemical characteristics in the area and integrated interpretation of these data.

### 1-2 Conclusions and Recommendations of the First Phase Survey

#### 1-2-1 Conclusions of First Phase Survey

The First phase survey was intended to pick up the high potential areas of ore deposits in Catanduanes island (1,550km$^2$) and Lahuy island (20km$^2$). In Catanduanes island, whole of the island was the subject of the geological survey including stream sediments geochemical survey. In Lahuy island, the detailed geological survey was carried out in the area of 2km$^2$ and the soil geochemical survey was done in the area of 16km$^2$. Following are the conclusions:

**(1) Catanduanes Island**

The survey resulted in picking up Carorongan Area, East of Bato City Area, Dugui Too Area and East of the Bato River Area as the promising.

**(i) Carorongan Area:** Batalay Intrusives was not found, however, geochemical anomaly areas of many elements were found overlapped in this area. In the Tinaga river, east of Carorongan Area, geochemical anomalies of gold and other elements were overlapping.

**(ii) East of Bato City Area:** Diorite belonging to Batalay Intrusives has the widest distribution in this area in Catanduanes island, which was surrounded by minor intrusions and many mineral indications. The most notable copper bearing quartz veins in the island was found in Agban Area, the northeastern part of the survey area.

**(iii) Dugui Too Area:** The strongest geochemical anomaly of gold in the island was recognized in this area. The small diorite stocks belonging to Batalay Intrusives are recognized. The stocks and the nearby sedimentary rocks underwent hydrothermal alterations. There are many placer gold indications in this area. Mineral indications of weak skarnization with pyrite in Hikming Area and Danicop Area are presumably related with that of Dugui Too Area.

**(iv) East of the Bato River Area:** Gold mineralization was not found in the reconnaissance geological survey. But geochemical anomalies of gold and other elements were found scattered.

**(2) Lahuy Island**

**(i) Detailed survey area:** Remarkable mineralization was confirmed in Gata. As the results of principal component analysis, mineralization of gold, silver, copper, lead and zinc was made clear.

**(ii) Reconnaissance area:** The geochemical survey resulted in picking up the anomaly areas in three parts e.g., the eastern part of Gata, the southwestern part of Gogon and southern end of the island. As the results of geological survey disclose, it was found that the detailed survey area of Gata was uplifted by the fault and the upper part was already eroded out and the deeper geology is presented at the surface compared with the eastern reconnaissance area. Therefore it is possible that there is the potential mineral deposit deep under the geochemical anomalies of three parts. However, analytical values are generally low and contrast among them are weak. So, these anomalies do not suggest the existence of the workable deposit at least in the shallow part.

### 1-2-2 Proposal of First Phase Survey

**(1) Catanduanes Island**

**(i) Carorongan Area:** In the area geochemical anomaly areas about various elements and a great number of quartz floats are distributed. Also along the Tinaga river in the east of this area, geochemical anomalies were found. Therefore it is required to conduct a detailed geological survey in this area for the purpose of establishing the control and scale of the mineral veins and how valuable metals exist. Also it is effective in pinpointing the potential area to carry out a soil geochemical survey over an area including the Taganopol river and the Carorongan creek.

**(ii) East of Bato City Area:** In this area diorite bodies are extensively distributed and around it such mineral occurrences as San Pedro, Libjo, Aroyao and Tilod are scattered. Conducting a detailed geological survey around the diorite bodies and disclosing the characters between individual mineral occurrences and the mineralization control are indispensable in finding the characters of the mineralization in this island. Also carrying out a detailed geological survey is desired over an area surrounding Agban.

**(iii) Dugui Too Area:** The actual conditions of the mineral deposits should be made clear by making a detailed geological survey over an area including Hikming and Danicop which are adjacent to this area as the center.

**(iv) East of the Bato River Area:** This area has not been surveyed practically as far as mineral deposit survey is concerned. There is a possibility of finding a new mineral occurrence by carrying out a concentrated detailed geological survey.

**(2) Lahuy Island**

**(i) Detailed Survey:** It may involve many difficulties to develop ore in this area because the ore horizon are below sea level and sea water infiltration poses a problem.

**(ii) Reconnaissance Survey:** Promising deposit of commercial importance is hardly expected at the shallow depth from surface in this reconnaissance survey area.

Accordingly, we may conclude that further exploration is discouraged in this island.

## 1-3 Outline of the Second Phase Survey

### 1-3-1 Survey Area

Catanduanes island is a fig-shaped island which covers a total land area of 1,550km$^2$. It is the easternmost island of the Bicol area which lies at geographic coordinate 124° 16' to 124° 22'E longitudes and 13° 44' to 13° 52'N latitudes (Fig. 1).

It is affected by storm due to typhoons which occur during the rainy months of september to january.

The second phase of the survey was focused at Carorongan area since results of reconnaissance survey of the last year picked up anomaly zones which might turn out to be a primary or secondary deposit of gold and copper.

Initially the survey area was 60km$^2$ (4km by 15km) but a promising area of 6km$^2$ was extended southward and finally total area covered 66km$^2$. The survey area originates from the municipality of Viga to southwest of San Miguel area (Pagsagnahan). This area is accessible through a principal road running in North-South direction interconnecting the capital town of Virac with the municipality of Viga.

The survey team has encountered poor accessibility necessitating the group to set up fly-camping in eight places excluding lodging at Viga, Ananon and Virac.

### 1-3-2 Objective of the Survey

The objective of the survey is to find new deposits through clarifying the settings of geology and mineralization. It also intends to transfer the technology to the Government of the Republic of the Philippines through the survey.

### 1-3-3 Contents of the Survey

Detailed geological survey was conducted in order to delineate the potential of the areas to be subjected for stream sediments surveys. Soil geochemical surveys were also carried out in two potential areas at Carorongan and Taganopol in about a 250m by 300m area in a grid pattern.

Table 1 shows the contents of the survey and related experiments .

Table 1 Content of Works

| Content | Item | Quantity |
|---|---|---|
| Geological Survey (Detailed Survey) | ① Polished thin section | 44 pcs |
| | ② X-ray powder diffraction analysis | 106 pcs |
| | ③ K-Ar dating of igneous rock | 6 pcs |
| | ④ Chemical analysis | |
| | 1) Rock | 42 pcs |
| | $SiO_2$,$Al_2O_3$,CaO,FeO,$Fe_2O_3$,$K_2O$,MgO,MnO, $Na_2O$,$P_2O_5$,$TiO_2$,$H_2O$,LOI,Au,Ag,As,Cu,Hg,Mo, Pb,S,Sb,Zn | |
| | 2) REE | 11 pcs |
| | Ba,Ce,Dy,Er,Eu,Gd,Ho,La,Lu,Nb,Nd,Pr,Rb,Sm,Sr, Tb,Tm,Y,Yb,Zr | |
| | 3) Ore | 241 pcs |
| | Au,Ag,As,Cu,Hg,Mo,Pb,S,Sb,Zn,Fe | |
| | ⑤ Mesurment of Homogenization Temparature | 31 pcs |
| | ⑥ Mesurment of resistibity and polarization | 31 pcs |
| Chemical survey (Detailed survey) | Chemical analysis | |
| | 1)Stream sediment | 882 pcs |
| | Au,Ag,As,Cu,Hg,Mo,Pb,S,Sb,Zn,Fe | |
| | 2)Soil | 921 pcs |
| | Au,Ag,As,Cu,Hg,Mo,Pb,S,Sb,Zn,Fe | |

### 1-3-4 Members of the Survey Team

Japan

Planning and Coordination

| | |
|---|---|
| Jiro Oosako | MMAJ |
| Toyo Miyauchi | MMAJ |
| Nobuyasu Nishikawa | MMAJ |
| Testuo Suzuki | MMAJ, Manila |

Geological and Geochemical Surveys

| | |
|---|---|
| Takehiro Sakimoto | Nittetsu Mining Consultants Co., Ltd. |
| Hiroyuki Takahata | do. |
| Yasunori Ito | do. |
| Hirohisa Horiuchi | do. |
| Shoichi Machida | do. |

Philippines

Planning and Coordination

| | |
|---|---|
| Joel D. Muyco | MGB |
| Salvador G. Martin | do. |
| Edwin G. Domingo | do. |
| Romeo L. Almeda | do. |

Geological and Geochemical Surveys

| | |
|---|---|
| Alvin M. Matos | MGB |
| Dr. Sevillo D. David Jr. | do. |
| Emmanuel Santos | do. |
| Brian Esber | do. |
| Diosdado R. Dizon | do. |

### 1-3-5 Period of the Survey

From July 18, 1994 to January 31, 1995

# Chapter 2 Geography

## 2-1 Location and Access

The survey area is situated in the eastern part of Catanduanes island. The area lies at geographic coordinate 124° 02' to 124° 25' E longitudes and 13° 31' to 14° 06' N latitudes.

To reach Catanduanes island, it takes about one hour from Manila to Legazpi by plane, another one hour from Legazpi to Tabaco by car, and four hours from Tabaco to Virac, the capital town of Catanduanes, by ferry boat. Flight service from Manila to Virac is available once a day, and from Legazpi to Virac three flights a week.

The Provincial Government is active for development of road systems in the island, and the system is good condition at present. There exist an around-island road and cross-island in the island. The survey area is accessible through a principal road running in North-South direction interconnecting Virac and Viga. Within the survey area, only a car road from Viga runs to Mabini through Ananon at the northwestern part of the area.

## 2-2 Topography

The topography is largely divided into the north area and south area by a ridge running in the East-West direction between the Guihawis creek and the Barinad creek, showing a conspicuous difference in topography.

The north area is characterized by a ridge oriented in the North-South direction. Rivers run north between the mountainous land parallel with these mountains or changing their directions sharply. In the northwest part of the area rivers are wide; Alluvium is developed, and a number of short tributaries are found. However, most of the area is formed of narrow rivers and creeks, and relatively gentle mountainsides. The topography of tributaries is steep and many small waterfalls are distributed.

In the south area water systems are oriented in a North-South and East-West directions running parallel with the strike of Catanduanes Formation. They are developed in a rectangular fashion. The rivers form deep V-shaped creeks, and there are many waterfalls. The rivers and creeks wind their ways through narrow basins. Mountainous are generally of steep topography with sharp ridges.

# Chapter 3 Existing Geological Information

## 3-1 Previous Works

Philippine Bureau of Mines, now Philippine Bureau of Mines and Geo-sciences (MGB), has been active in preliminary surveys for mineral occurrences in Catanduanes island. At the early stage of the program, Capistrano (1951a, 1952b and 1952) described coal, manganese, and marble occurrences in the island. Crispin et al. (1955) also described coal resources in the Panganiban area, contemporaneously showed a stratigraphic succession in the island. Then, Miranda and Vargas (1967) performed detailed geological surveys in the whole area of the island, and established the stratigraphic succession. They also described mineral occurrences for coal, copper, gold, manganese, heavy sands, clay, etc. in the island, and show their geological maps covering the whole island area. MGB (1982a) noted their geological map and mineral occurrences in the island based on the Miranda and Vargas report (1967). MGB (1982b) described the geology and mineral occurrences of the island in comparison with surrounding area, based on the prior mentioned reports.

Geological maps, 1 to 50,000 in scale, MGB, 1983 (a, b, c, d, e, f and g) covering the survey area are available. These maps are revised from the maps of Miranda and Vargas (1967). Several papers published by MGB Legazpi branch office describe other mineral occurrences; Angeles and Teodoro (1980, 1983) and Teodoro et al. (1988).

Rangin et al. (1988), in his report of Bicol district, described the result of age determination made on the intrusive rocks of Catanduanes island.

David Jr. (1994) stated that the area of Caramoan Peninsula and Catanduanes island was developed by tectonic upheavals during Pre-Tertiary period originating from the eastern mobile belt of the Philippines as described by the stratigraphy, geochemistry, age and geological structure of Catanduanes island.

JICA and MMAJ conducted (1994) geological and geochemical surveys over the whole of Catanduanes island and Lahuy island.

## 3-2 Geology and Mineral Deposits

The geology consists of Catanduanes Formation, Cretaceous Intrusives, Payo Formation, Batalay Intrusives and Alluvium. Catanduanes Formation is in a complex structure distributed over a wide extent of the survey area.

The survey area is divided into three Areas, Northern, Central and Southern by East-West faults and Northwestern-Southeastern faults. The Northern Area consists of green-schist of the lowest part of Catanduanes Formation covered by volcanic rocks of Payo Formation lying unconformably.

The Central Area is composed of massive graywacke of Catanduanes Formation and small body of gabbro and dolerite intruded into Catanduanes Formation. The Southern Area is composed of bedded graywacke and basaltic andesite lavas.

The Cretaceous Intrusives consists of gabbro and dolerite which were intruded into Catanduanes Formation in the form of sill and small rock bodies. Batalay Intrusives consists of diorite bodies intruded into Catanduanes Formation in Oligocene. Mineralization has been associated with Batalay Intrusives. Au deposits have been encountered in the survey area.

## 3-3 Mining History of the Survey Area

Though Catanduanes island is separated to some extent form the Philippine Fault, it is an area which underwent relatively active igneous activity related to the Palaeogene which is considered to be associated with the gold and copper occurrences of the Caramoan Peninsula, suggesting a high potentiality of gold and copper mineralization. In addition to gold and copper, many mineral occurrences including heavy mineral sand, manganese, coal, limestone, phosphate and clay are known, and prospecting activities have been made relatively actively.

Mining was made in a small scale in some of the mineral occurrences, but no large-scale mining have been carried out. The mineral occurrences where the small-scale mining activities were made are those of gold and copper, including Agban, Carorongan and Dugui Too, but there is no mine under operation.

The mineral deposits (mineral occurrences) in the survey area are of gold alone; they are classified into primary one (gold-bearing quartz veins and silicified veins) and secondary ones (placer gold deposits). The primary deposit is in Carorongan and the secondary ones are an placer gold deposits in the east of Ananon and in the Kadlakogod creek. All these three deposits were prospected mostly before World War II ; at present only Kadlakogod placer gold is mined in a small scale.

Fig.11 shows the locations of the mineral occurrences and indications.

# Chapter 4 Comprehensive Discussion

## 4-1 Geochemical Anomaly and Mineralization

As the results of analyzing the samples of stream sediments, the maximum and mean values are respectively found to be 15,980ppb and 288.7ppb with Au, 88ppm and 4.3ppm with As, 18ppm and 3.3ppm with Sb, 776ppm and 130.7ppm with Cu, 26ppm and 5.0ppm with Pb, and 218ppm and 99.4ppm with Zn. When the mean values of these elements are compared with content of the earth crust i.e. Clarke number (Levinson, 1974), the former is 72.2 times in Au, 2.4 times in As, 17 times in Sb, 2.4 times in Cu, 0.4 times in Pb, and 1.4 times in Zn larger than the latter, indicating that Au mineralization is preeminent.

The principal component analysis was made by dividing the survey area into Area A (mainly of green-schist) and Area B (mainly of graywacke) by taking Ogbong Fault as the boundary.

In Area A mineralization related with gold was expressed in the First principal component while in Area B the same mineralization was presented in the Second, Forth and Fifth principal components. Comprehensively interpretating these factors a large area extending from the upper reaches of the Taganopol river to the Kampayas creek was selected as an area with conspicuously high marks meaning an area with a high gold mineralization potential. In addition, an area extending from the lower reaches of the Barinad creek in Area B to the middle reaches of the Tabyonan creek and an area near a point where the Maytung river and a fault in the East-West direction intersect each other presented high marks though the scale was small. Around the later area with high marks there are a fault and silicified zone.

In the Taganopol river basin many big floats of quartz veins are distributed, and along the upper reaches of this river there is a silicified zone accompanied with pyrite. In the Kampayas creek there are small rock bodies of Batalay Intrusives which are presumed to have been genetically related with gold mineralization, and around the rock bodies silicification and pyrite dissemination are recognized.

In addition, first principal component in Area B showed high anomalies in the Barinad creek. This component indicates the factors of rock (gabbro) and sulfide which might also be accompanied with gold mineralization. Copper bearing sulfide would be changed into native copper in the secondary process.

The individual elements have their own anomaly areas, but they do not indicate the elements individual mineralization. They are found near gold anomaly areas and around silicification zones and faults in relation with gold mineralization.

Existence of intrusive rocks and/or related mineralization surmised in the gold anomaly areas, particularly in the deep parts of the underground around the silicified zones. The gold anomaly areas presented on the surface in some of silicified zones are presumed to express the tops of the mineralization.

According to the soil geochemical survey, a remarkable anomaly area suggesting gold mineralization was extracted in Carorongan Mineral Occurrence. In this anomaly area mineralization and alteration zones have been found by geological survey. The results of both surveys are harmonious with each other.

## 4-2 Promising Area

As the results of geological and geochemical surveys disclose, the following areas were picked up as hopeful;

**Carorongan Mineral Occurrence:** it is located in the northernmost survey area and in the east part of Ananon. Geology is composed of green-schist of the Catanduanes Formation. Mineralization is in the form of gold-bearing silicified veins, clay veins and silicified veins. Width of the silicified vein is 0.7 to 2 meters. Maximum gold grade were 65.19g/t in the silicified vein (W=5m) and 10.33g/t in the clay vein (W=30cm). In silicified zone, it probably extends 100m by 200m in size.

As the result of geological and geochemical surveys disclose, the mineralized zone extends over the survey area of this year. This area has good indication in geochemical survey and promising primary gold deposit is expected to exist.

**Taganopol Mineral Occurrence:** it is situated in the southeastern part of Carorongan Mineral Occurrence. Quartz vein of 50cm wide are noted in green-schist of the Catanduanes Formation. This quartz vein accompanies pyrite and maximum gold grade was 10.33g/t (W=50cm). Soil and vegetation cover concealed the continuation of the vein. Geochemical anomaly area is rather small and continuity is rather poor, but bigger scale is expected underneath.

**Ananon North Area:** it is located in the east of Ananon. Geology is composed of green-schist and Quaternary sediments. There are many of quartz veins along the Taganopol river. There are about 20 pits for placer gold along the river. Maximum 4mm of gold grain was recognized in the pit through panning. Gold content is high in stream sediments along this river and potential of placer gold is expected to be large.

**Kadlakogod Area:** it is located in the south of the survey area. There is silicified and argillized zone in the Kadlakogod creek caused by andesite porphyry of Batalay Intrusives. There are many pits for placer gold in the lower reaches of the intrusive rock. Through panning of Quaternary sediments, maximum scale of 7mm gold nugget was recognized. The surrounding area has possibility to contain placer gold.

**Kampayas Area:** it is located in the southeast of Mabini. Small diorite body of Batalay Intrusives was found in the upper stream of the Kampayas river. The sedimentary rocks surrounding the diorite were subjected to silicification and argillization.

In this river area, gold content is high in stream sediments and primary gold deposit related with diorite is expected to exist.

The survey result of this year indicates that the high potential area for gold may quite possibly extend to the eastern area of this survey area. The results of the reconnaissance survey of last year had picked up the hopeful geochemical anomaly areas in the eastern extension area. Accordingly, in addition to the promising area above mentioned, we can expect high potential area in the eastern extension area for this yers to Sicmil.

# Chapter 5 Conclusion and Recommendations

## 5-1 Conclusion

(1) The geology of the survey area is composed of Cretaceous Catanduanes Formation (graywacke, green-schist and andesitic lavas), Eocene Payo Formation (sandstone, limestone and volcanic rocks), Cretaceous Intrusives (gabbro and dolerite), Oligocene Batalay Intrusives (diorite, andesite porphyry and aplite) and Alluvium.

The Batalay Intrusives occur as small intrusive bodies in the survey area.

(2) The geological structure is characterized by northwest-southeast trending faults and folding and east-west trending faults. In the northeastern part of the survey area, the Catanduanes Formation underwent dynamo-metamorphism by faults and the graywacke has been metamorphosed into green-schist during Eocene time.

(3) Except for the segregation quartz veins, the important mineralization and pyritization are also associated with the Batalay Intrusives. The Catanduanes Formation underwent metamorphism in parts, alteration and mineralization, but the overlying Payo Formation underwent none of them.

(4) The mineralization is divided into the following groups; (i) quartz vein (Au), (ii) silicified zone, (iii) placer gold, (iv) native copper and (v) others. Among them, the most important types are gold bearing quartz vein and placer gold. There are two kinds of quartz vein: one is the segregation veins and the other is hydrothermal ones which are associated with gold mineralization. Many floats of quartz veins are distributed in the Taganopol river basin but both types are not distinguishable in floats. Silicified zone is noted at about 20 localities. All of them underwent medium to weak silicification and weak pyritization. Some of them are probably showing the surface indications of the deep-seated intrusion and / or related mineralization.

Placer gold are noted in the eastern part of Ananon and in the Kadlakogod creek. Gold grain is observed in Quaternary sediments through panning.

Native copper is found in the small cracks within gabbro of Cretaceous Intrusives and nearby graywacke in the Barinad creek. But the scale is small and the copper grade is very low.

Others denote network quartz veinlets in weathered graywacke and so on.

As the results of geological and geochemical surveys disclose, the following areas were picked up as hopeful;

**Carorongan Mineral Occurrence:** it is located in the northernmost survey area and in the east part of Ananon. Geology is composed of green-schist of the Catanduanes Formation. Mineralization is in the form of gold-bearing silicified veins, clay veins and silicified veins. Width of the silicified vein is 0.7 to 2 meters. Maximum gold grade were 65.19g/t in the silicified vein (W=5m) and 10.33g/t in the clay vein (W=30cm). In silicified zone, it probably extends 100m by 200m in size.

As the result of geological and geochemical surveys disclose, the mineralized zone extends over the survey area of this year. This area has good indication in geochemical survey and promising primary gold deposit is expected to exist.

**Taganopol Mineral Occurrence:** it is situated in the southeastern part of Carorongan Mineral Occurrence. Quartz vein of 50cm wide are noted in green-schist of the Catanduanes Formation. This quartz vein accompanies pyrite and maximum gold grade was 10.33g/t (W=50cm). Soil and vegetation cover concealed the continuation of the vein. Geochemical anomaly area is rather small and continuity is rather poor, but bigger scale is expected underneath.

**Ananon North Area:** it is located in the east of Ananon. Geology is composed of green-schist and Quaternary sediments. There are many of quartz veins along the Taganopol river. There are about 20 pits for placer gold along the river. Maximum 4mm of gold grain was recognized in the pit through panning. Gold content is high in stream sediments along this river and potential of placer gold is expected to be large.

**Kadlakogod Area:** it is located in the south of the survey area. There is silicified and argillized zone in the Kadlakogod creek caused by andesite porphyry of Batalay Intrusives. There are many pits for placer gold in the lower reaches of the intrusive rock. Through panning of Quaternary sediments, maximum scale of 7mm gold nugget was recognized. The surrounding area has possibility to contain placer gold.

**Kampayas Area:** it is located in the southeast of Mabini. Small diorite body of Batalay Intrusives was found in the upper stream of the Kampayas river. The sedimentary rocks surrounding the diorite were subjected to silicification and argillization.

In this river area, gold content is high in stream sediments and primary gold deposit related with diorite is expected to exist.

The survey result of this year indicates that the high potential area for gold may quite possibly extend to the eastern area of this survey area. The results of the reconnaissance survey of last year had picked up the hopeful geochemical anomaly areas in the eastern extension area. Accordingly, in addition to the promising area above mentioned, we can expect high potential area in the eastern extension area for this year to Sicmil.

## 5-2 Recommendations for the Third Phase Survey

**(1) Carorongan Mineral Occurrence:** Mineralized zone was found out to extend outside of the Second phase target area. Accordingly, it is recommended that a detailed geological survey and soil geochemical survey be conducted in the northern and southern extension of last year's target area.

For the mineralized, silicified and clay veins, it is recommended that drilling be conducted to clarify the character and degree of mineralization.

(2) **Taganopol Mineral Occurrence:** it is recommended that test pitting and trenching be conducted to confirm the vein extension.

(3) **Ananon North Area:** it is recommend that test pitting be conducted to know the grade and scale of placer gold.

(4) **Kadlakogod Area:** it is recommend that test pitting be conducted to know the grade and scale of placer gold.

(5) **Kampayas Area:** it is recommended that detailed geological survey and soil geochemical surveys be carried out to delineate geological settings of mineralization and to find primary gold deposit. If the results of the survey is hopeful, drilling surveys will be recommended to clarify the mineralization.

In addition, it is proposed that detailed geological survey and stream sediments geochemical survey be extended in the eastern extension of high gold concentration area of the second phase survey.

# PART II DETAIL DESCRIPTION

# PART II DETAILED DESCRIPTION

## Chapter 1 General Geology

### 1-1 Outline of Geology and Geological Structure

David Jr. (1994) regarding Catanduanes island and the Caramoan Peninsula in the east of Luzon near this island, divided the geological structure of these districts into three geological units by Hilawan Fault and Minas Fault. As far as Catanduanes island is concerned, he divided the structure into North-Central Catanduanes Structural Unit for the part of north from Hilawan Fault and Southern Catanduanes Zone in Median Structural Unit for the part of south from the same fault. The survey area for this phase is included in North-Central Catanduanes Structural Unit.

The geological structure of the survey area is characterized by the preceding Northwest-Southeast oriented faults and folding and East-West oriented faults running across them. The survey area is divided into the three Areas of Northern Area, Central Area and Southern Area by geology and structure.

The Northwest-Southeast oriented faults are found in the northern and southern areas. In the Central Area folding structure with Northwest-Southeast trending axes is found conspicuously. This folding structure continues to the southern area, but is cut by East-West oriented faults and becomes unclear gradually.

The geology of the survey area, enumerated from the lower part, Cretaceous Catanduanes Formation (graywacke, conglomerate, green-schist and lava), Cretaceous Intrusives (gabbro and dolerite), Eocene Payo Formation (sandstone, conglomerate, limestone and volcanic rocks), Oligocene Batalay Intrusives (dioritic rocks) and Alluvium. Fig.2 shows the geological map of the survey area, and Fig.3 shows the schematic geological column.

#### 1-1-1 Northern Area

The northern boundary of the survey area is north limit, and Ogbong Fault in Northwest-Southeast direction which passes near Ananon is the south limit.

The area is distributed with green-schist of lower unit of Catanduanes Formation and Payo Formation covering them in unconformity, forming relatively gentle mountains land.

The green-schist is formed by dynamo-metamorphism owing to fault movement. Segregation quartz veins in the form of numerous thin veins or lenses are found on schistosity planes of schist or along joints running in parallel with them.

The bottom of Payo Formation is formed of basaltic lava and pyroclastic rocks of the same kind, which are collectively distributed in the northeast end of the survey area. This formation covers the green-schist of

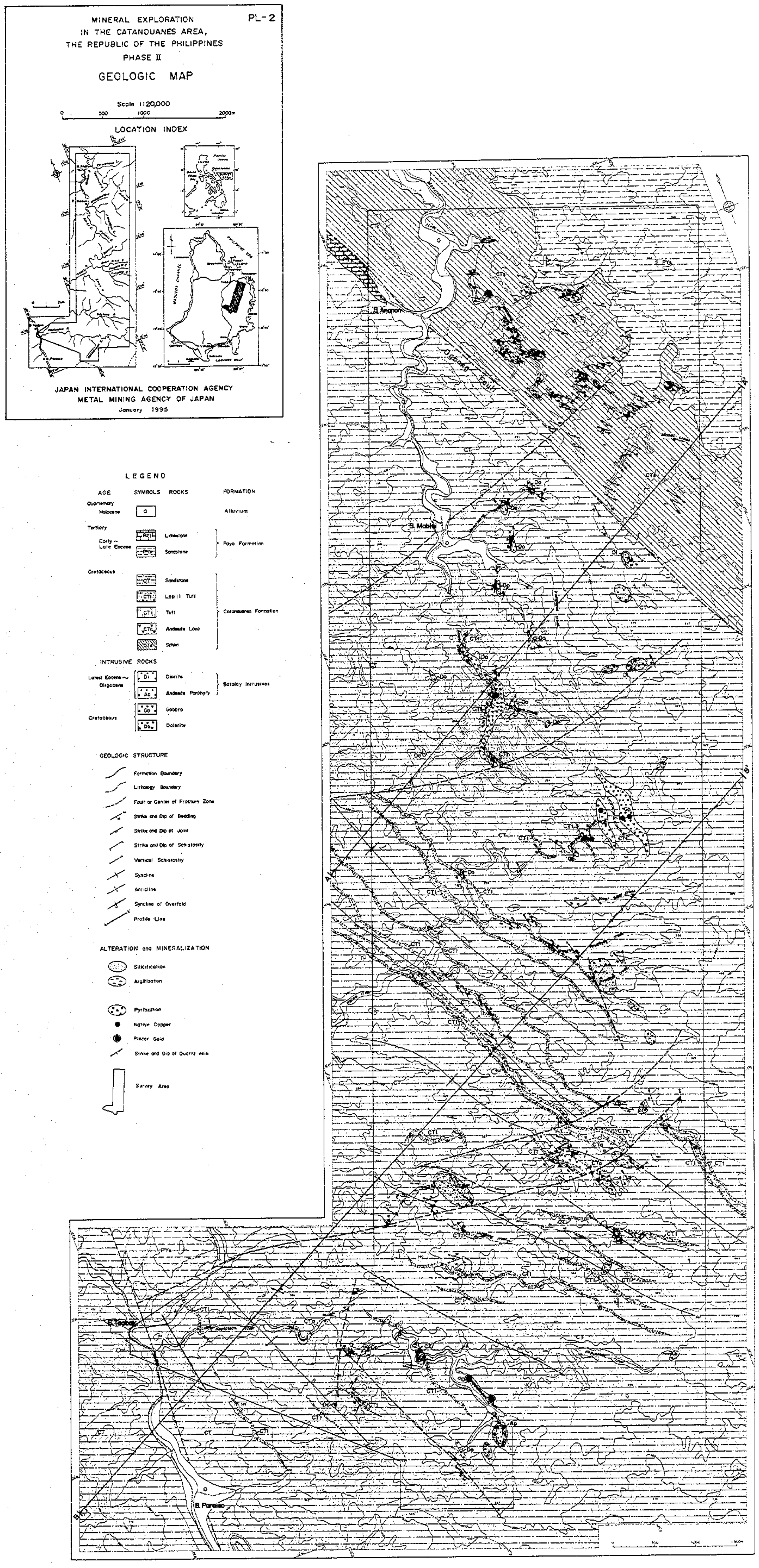


Fig. 2 Geologic Map of the Survey Area

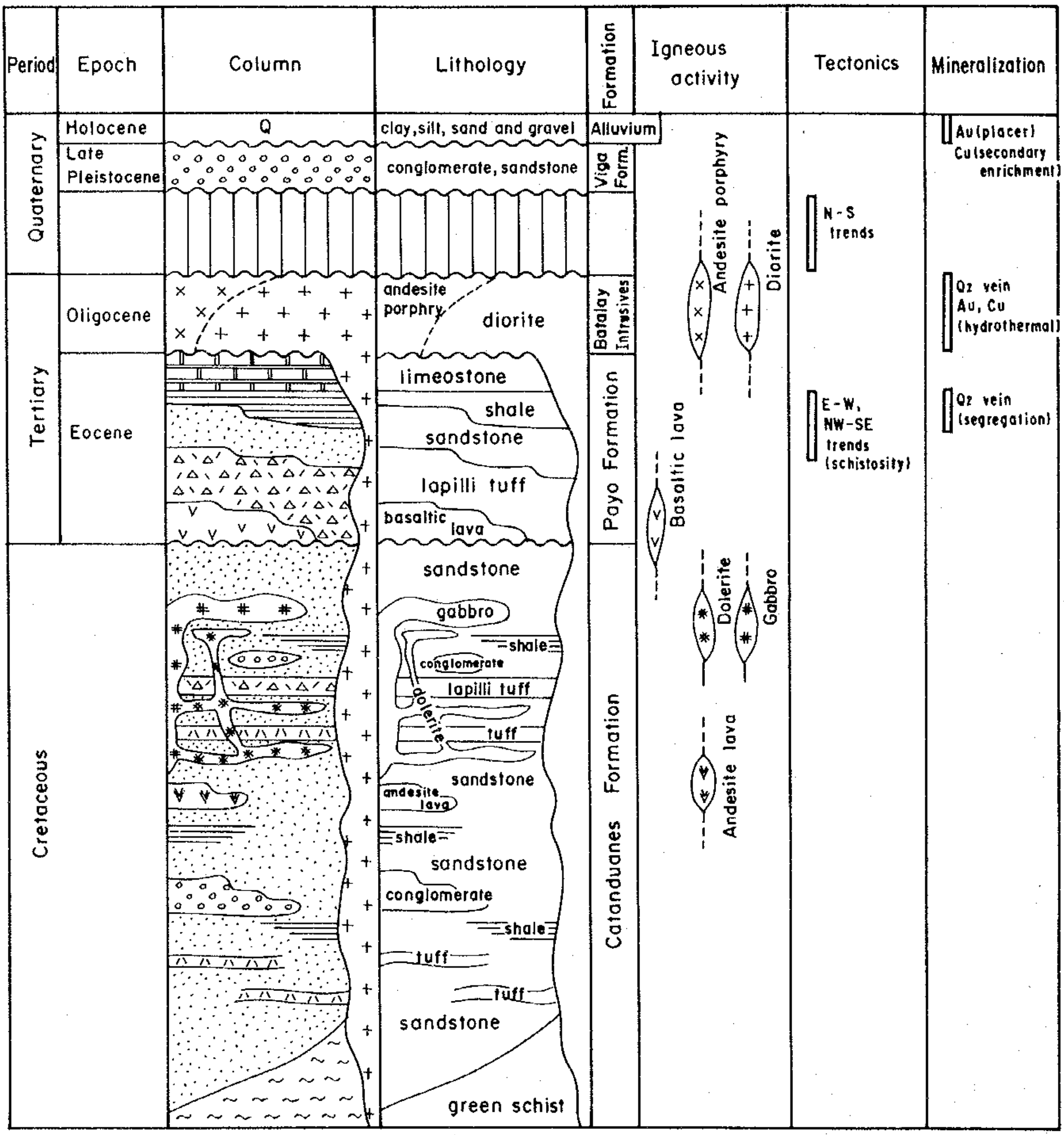



**Fig. 3 Schematic Geologic Column of the Survey Area**

Catanduanes Formation and dips gently toward northeast.

### 1-1-2 Central Area

The central area is bounded by northern area and Ogbong Fault, and its south limit is the Tabyonan creek.

This area is extensively distributed with green to greenish gray graywacke of Catanduanes Formation, and limestone belonging in the upper Payo Formation is seen in the northwesternmost part.

Catanduanes Formation is composed of medium to coarse grain graywacke with unclear bedding, originating from basic rocks. Compared with the southern area, there are few thin layers of fine grained tuff and lapilli tuff, and generally the bedding is unclear.

This Formation has been intruded by Cretaceous Intrusives and Batalay Intrusives. In this area too, in some places there are parts that have turned slightly into green-schist and parts that have changed into green-schist, and segregation quartz veins are seen in the vicinities of them, but such extents grow weak as one is more off to the south from Ogbong Fault.

The limestone of Payo Formation is found near Ananon in the northwest part of this area. It is white and is in unconformable contact with Catanduanes Formation.

### 1-1-3 Southern Area

The southern area is a portion to the south of the Tabyonan creek.

Extensively distributed with Catanduanes Formation, this area is characterized by greenish gray graywacke with clear graded bedding, thin layers of fine grained tuff, lapilli tuff and basic lava.

The greenish gray graywacke is originated from basaltic rocks and is formed of fine to coarse grained graywacke.

Anticlines and syncline in a Northwest-Southeast direction appear repeatedly, and in some parts overfolding is noted. Also thin reddish brown seams of acidic tuff and dark greenish basic lapilli tuff constitutes very characteristic features in the greenish gray graywacke. In the southernmost part Batalay Intrusives is distributed.

Payo Formation is distributed near Tagbak in the southwestrnmost part of the southern area; it is formed of graywacke, andesitic pyroclastic rocks and tuffceous sandstone, covering Catanduanes Formation in unconformity.

## 1-2 Detailed Description of the Geology

### 1-2-1 Catanduanes Formation

Meck (1938) stated that part of this formation was Agban Phyllites, but later Capistrano (1951a) regarded it as fine grained strata of Cabugao Sub-graywacke, belonging in the Pre-Tertiary. However, Miranda and Vargas (1967) redefined this formation as Catanduanes Formation on the ground that Agban Phyllites were part of this formation and that this formation including Agban Phyllites and Cabugao Sub-graywacke were able to be classified stratigraphically.

On the other hand though no fossil has been discovered, Miranda and Vargas (1967), making the correlation of this formation with Mansalay Formation of Mindoro island (Teves et al., 1949), asserted that it belonged to the Jurassic. MGB (1981) said that it was of the pre-Cretaceous, preceding Yop Formation. David Jr. (1994), mentioning the fact that this formation is in interfingering relation with Yop Formation, asserted that it belonged to the upper Cretaceous. About its thickness, Miranda and Vargas (1967) said that the formation was about 3,000m thick.

Catanduanes Formation is most extensively distributed over the survey area, its area occupancy rate reaching about 90%. This Formation, being the lowest formation in the survey area, consists of green-schist in the northern area and of sedimentary rocks and basaltic andesite lava in the central and southern areas.

Catanduanes Formation in the northern and central areas is divided by the sheared zone. This zone has a width of about 50m, the biggest one in the survey area. There runs the Oco river on the fault sheared zone at a point about 2km to the east of Viga, and from the name of a small Barangay this sheared zone has been named Ogbong Fault. In an area where green-schist is distributed, plural faults are inferred to run geographycally in parallel with Ogbong Fault, but they are not marked on the geological map.

The green-schist is exposed well along the Taganopol river and its tributaries. The green-schist can been seen over a width of about 500m northeastward from Ogbong Fault. These rocks are originally formed of graywacke having mainly basaltic composition. Generally these rocks are fine grained, compact and hard, presenting the appearance of being schistose, bedded and phyllitic. The rocks are formed of feldspar, epidote, chlorite, anthrophyllite, and amphibole. Some of the green-schist contains epidote and garnet. The schistosity is developed in the direction in parallel with the fault. Also quartz and feldspar congregate and form milky white lenses or small veins in parallel with the schistosity. This segregation quartz veins, are formed during metamorphism. Generally their vein width is 1m to 2 cm, coming up to 30cm in some parts, but their continuity is poor and the length is only 1m to 3m.

The distribution of the green-schist is closely related with the fault, and the schistosity is parallel to it. So that it is considered that the activities of Ogbong Fault have strongly affected the formation of this schist. With the boundary of Ogbong Fault, the green-schist is contiguous to the sedimentary rocks of Catanduanes Formation. These sedimentary rocks are mainly formed of graywacke and mudstone; and conglomerate, tuff, tuff breccia, and basic lava lie between the rocks. The graywacke is usually hard, and graded bedding appears well in the southern area; it has altered into chlorite and epidote, appearing greenish gray. The mudstone, appearing greenish gray to black, presenting alternation of strata as it lies between the graywacke.

In the course of the survey in this phase, round pebbles containing many small pebbles of basalt and andesite, the size of medium to fine pebbles, were found in the basins of the Kapipihan river in the south area and of the Maytung river in the central area.

Also thin strata of reddish brown fine-grained acidic tuff with the stratum thickness of about 1 to 2m and strata of basaltic tuff breccia with the stratum thickness of about 10 to 20m are distributed along a number of rivers including the basin of the Kaipa creek and the Barinad creek. These rocks of tuff present very characteristic lithofacies in the graywacke, and can be used as key strata in making geological survey.

Regarding the lithofacies of the graywacke, acidic tuff and green-schist , microscopic observation was made. The graywacke is mostly of medium to coarse grains; fragments of rock are largely classified into andesitic material (AR-036, DR-021, ER-046, ER-119, FR-035) and basaltic one (ER-171).

In the sand grains, the fragments of quartz, feldspar and a small amount of amphibole crystals are found. As altered minerals, a large amount of chlorite and trace amount of idiomorphic epidote were recognized. In the matrix sericite and calcite which were originated secondarily and thin veins of the same quality are seen in great numbers. Also in many samples original texture is unclear (DR-012, ER-046, ER-171). In X-ray powder diffraction analysis, montmorillonite and sericite were detected (FR-035).

The rock fragments of the acidic tuff are formed of extremely fine-grained quartz, feldspar and amphibole under microscope (ER-061, ER-104, ER-118). As altered minerals sericite, chlorite, epidote, montmorillonite, prehnite, and laumontite in a small vein form were found. In X-ray powder diffraction analysis montmorillonite was detected (FR-104).

The lapilli tuff (AR-101) contains a large amount of basaltic small rock fragments of angular to subangular form. As primary minerals feldspar, amphibole and common pyroxene were recognized under a microscope. As altered minerals, a large amount of calcite, a medium to small amount of chlorite, sericite and quartz were found.

The green-schist has remarkably undergone silicification and argillization. As altered minerals X-ray powder diffraction analysis has detected a medium to large amount of sericite, calcite, chlorite (ER-005, ER-160), and montmorillonite (ER-005).

### 1-2-2 Payo Formation

Miranda and Vargas (1967) named the lowest formation of the Tertiary which are extensively exposed on this island Payo Formation, and determined the age as the Eocene of the Palaeogene; he divided it, from the lower position, into the three members of Cabugao Sub-Graywacke Member, Hitoma-Payo Coal Measure and Sipi Limestone Member.

Miranda et al. (1967) said that all these members were formed of such sedimentary rocks as sandstone, siltstone, coal measures and limestone. On the other hand, David Jr. (1994) asserted that, since this formation was in an interfinger relation with Catanduanes Formation, it was characterized by such volcanic rock, volcaniclastic material, and sedimentary rocks as fine to coarse-grained andesitic sandstone, andesitic lava, pillow lava and shallow sea limestone.

The positions where Payo Formation has been confirmed in this survey areas are the vicinity of Ananon to the southeast of Viga, the upper reaches of the Carorongan creek, and the Tagbak situated at the southwest of the survey area, and the areas of this distribution are all limited to small scopes. Payo Formation in the survey area is composed of andesite to basaltic lava, clastic rocks of the same quality, and lapilli tuff at the lower position and of sandstone, shale, and limestone at the upper position. Also in the vicinities of Viga the unconformity relation between this formation and Viga Formation which belongs to the Pleistocene lying above was observed (MMAJ, 1993).

Regarding the thickness of this Payo Formation, Meek (1938) estimated it to be 1,500m at the northeast of Catanduanes island, which is the type locality, but David Jr. (1994) said that it was more than 3,000m.

### 1-2-3 Alluvium

Alluviums develop along principal rivers; they are formed of unsolidified pebbles, sand, silt and clay.

The main areas where Alluviums develop are the area along the Manuria river which runs in the east of Ananon from the south to north, the lowest reaches of the Taganopol river which is a tributary of the said river, the area along the Kapipihan river in the southern most part of the area, and the area along the Bato river which flows to the south in the east of Tagbak.

There are a great variety of pebbles, formed of sandstone, green-schist , diorite, dolerite, lapilli tuff, silicified rock, and others.

In this survey, along the lower reaches of the Taganopol river and the Kadlakogod creek which is a tributary of the Kapipihan river, the existence of alluvial gold deposits was confirmed.

### 1-2-4 Intrusives

**(1) Cretaceous Intrusives:** These are intrusive rocks discovered anew in the central of the survey area by the geological survey of this phase.

According to K-Ar method age measurement, these rocks were found to be belonging in the Cretaceous, ranging from 82.85±2.6Ma (ER-120) to 95.35±5.7Ma (HR-028).

These rocks are distributed on a large scale in the basin of the Abobo creek, in nearly the middle of the survey area, which flows from the south to north and also in the basin of the Barinad creek. The rocks is formed of gabbro and chlorite. These rocks have not caused thermal metamorphism, hydrothermal alteration or skarnization to their surroundings. They have undergone turning into chlorite and epidote and appear greenish gray like the graywacke of Catanduanes Formation. Outdoors they can hardly be distinguished from Batalay Intrusives in the field.

Under a microscope a large to medium amount of feldspar, biotite, amphibole, and diopside as primary minerals, and tremolite, actinolite, sericite, chlorite, epidote, calcite, feldspar and quartz as secondary minerals have been recognized. As ore minerals a medium amount of chalcopyrite, and small amounts of pyrite, sphalerite, bornite and chalcocite have been found (ER-120, HR-028).

A result of the chemical analysis of these rocks indicated that the content of $SiO_2$ was 46.40% (ER-120) and 45.80% (HR-028), (Table 2).

**(2) Batalay Intrusives:** Miranda and Vargas (1967) indicated that the intrusives distributed in the neighborhood Bato in the south of Catanduanes island were diversified in the aspects of composition and texture, such as diorite, andesite and dacite, and called them Batalay Intrusives collectively.

These rocks, in terms of lithology, are formed of medium to coarse grained hornblende biotite diorite, biotite granodiorite, hornblende porphyry (andesite), andesitic basalt and aplite; these are distributed as a number of small intrusives bodies centering around the south of this island. Miranda and Vargas (1967) asserted that these rock caused thermal metamorphism to the rocks subjected to the intrusion, producing gold and sulfide deposits of this island. Main alteration found in the rocks subjected to the intrusion are silicification, pyrite dissemination, and argillization.

To the east of Bato, which is the type locality, these rocks are extensively distributed on a scale of 6.5 kilometers in the North-South direction and 1.5 kilometers in the East-West direction. Such gold and copper mineral occurrences as Agban, Vinticayan point, Tilod, San Pedro, Libjo, Aroyao and San Miguel are considered to have been generated in relations with these intrusives (Miranda and Vargas, 1967).

In the survey area in this phase the distribution of Batalay Intrusives were confirmed as small rock bodies at two places, a place in the upper reaches of the Kampayas creek in the central part of the area and another place in the upper reaches of the Kapipihan creek in the southernmost part of the area.

In the Kampayas creek small rock bodies of diorite (FR-028) are distributed on a scale of 120 meters in the North-South direction and 100 meters in the East-West direction. These rocks have undergone alteration of silicification, pyrite dissemination, and argillization. According to X-ray powder diffraction analysis of clay, large amounts of epidote and sericite were detected.

Under a microscope, as primary minerals, large amounts of quartz, plagioclase and amphibole, and a small amount of diopside were found. As altered minerals chlorite, epidote, calcite and sericite were observed. As ore minerals a medium amount of chalcopyrite, small amounts of pyrite and sphalerite were found. In parts of remarkable alteration the paragenesis of pyrite and chalcopyrite was seen. In rare cases chalcopyrite and sphalerite in the form of very small grains are contained in pyrite.

In the Kadlakogod creek andesite porphyry (AR-099) is distributed. The scale of the distribution of the rock bodies is about 100meters in the North-South direction and about 50 meters in the East-West direction. Surrounding these rocks silicification was observed, and in the downstream floats of silicified rocks were seen (Fig.18). Also in the surroundings of the intrusive rocks one can see an argillization, though on a small scale. In the X-ray powder diffraction analysis test of samples from altered zone, large to medium amounts of feldspar and quartz, small amounts of chlorite, sericite, laumontite (FR-058), and pyrite (BR-003), and trace amounts of montmorillonite (BR-004) and pyrophyllite (BR-003) were detected.

In the survey of this phase, K-Ar dating was conducted of two samples of Batalay Intrusives (Table 6). Their absolute age ranges from 32.9±2.0Ma to 34.2±1.1Ma, which indicates the age of the middle of the Oligocene of the Tertiary, which is in harmony with the age indicated by Miranda and Vargas (1967) from stratigraphic relations.

## 1-3 Chemistry of Igneous Rocks

The igneous rocks distributed in the survey area are andesitic lava in Catanduanes Formation dolerite and gabbro of the Cretaceous Intrusives, and diorite and andesite porphyry of the Batalay Intrusives. In this survey the representative samples of these rocks were subjected to the chemical analysis of major composition, trace elements and rare earth elements. For trace element analysis,11 elements of Au, Ag, Cu, Hg, Mo, Pb, S, Sb, Pb, Fe were subjected to analysis. For the rare earth elements, 20 elements of Ba, Ce, Dy, Er, Eu, Gd, Ho, La, Lu Nb, Nd, Pr, Rb, Sm, Sr, Tb, Tm, Y, Yb and Zr were subjected to analysis.

### 1-3-1 Major Composition

Table 2 shows the composition of the major compositions of the igneous rocks and the result of norm calculation. In the following shown are TAS diagram, Harker diagram, ACF diagram, MFA diagram, QPA diagram and an-ab-or diagram as Fig.4 to Fig. 9 respectively.

The kinds of rocks in the figures are shown in the following; (1) Andesite lava in Catanduanes Formation (3 samples), (2) Dolerite of Cretaceous Intrusives (19 samples), (3) Gabbro of Cretaceous Intrusives (8 samples), (4) Diorite and andesite porphyry of Batalay Intrusives (3 samples), (5) Aplite of Batalay Intrusives (2 samples).

**(1) Andesite Lava in Catanduanes Formation:** In the naked eye these rocks are formed basalt to

## Table 2 Chemical and Normative Compositions of Igneous Rocks (1)

| | AR-045 | ER-054 | ER-097 | ER-122 | FR-064 | CR-015 | CR-016 | CR-021 | DR-016 | DR-017 |
|---|---|---|---|---|---|---|---|---|---|---|
| ROCK TYPE | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 2 |
| ROCK NAME | basa.and | basa.and | basa.and | basalt | basalt | dolerite | dolerite | dolerite | dolerite | dolerite |
| SiO2 | 55.10 | 52.70 | 51.90 | 48.60 | 46.20 | 48.00 | 48.30 | 51.00 | 49.00 | 47.20 |
| TiO2 | 0.69 | 1.10 | 1.04 | 0.97 | 0.99 | 1.01 | 1.09 | 0.95 | 1.11 | 0.86 |
| Al2O3 | 15.87 | 17.53 | 19.03 | 16.54 | 17.07 | 17.28 | 17.08 | 18.24 | 15.95 | 18.77 |
| Fe2O3 | 7.10 | 9.62 | 8.43 | 11.39 | 10.15 | 11.94 | 12.58 | 9.31 | 12.85 | 10.90 |
| MnO | 0.13 | 0.21 | 0.16 | 0.23 | 0.17 | 0.22 | 0.21 | 0.15 | 0.24 | 0.19 |
| MgO | 3.32 | 3.41 | 2.40 | 4.07 | 4.68 | 4.75 | 4.68 | 2.96 | 5.13 | 4.23 |
| CaO | 6.09 | 6.78 | 6.96 | 8.91 | 9.99 | 8.26 | 7.39 | 8.12 | 6.80 | 8.55 |
| Na2O | 3.09 | 4.29 | 4.34 | 3.21 | 3.35 | 3.12 | 2.71 | 3.55 | 3.21 | 3.63 |
| K2O | 2.62 | 2.10 | 2.45 | 0.78 | 1.15 | 2.97 | 3.80 | 0.73 | 3.64 | 2.99 |
| P2O5 | 0.08 | 0.19 | 0.28 | 0.27 | 0.24 | 0.31 | 0.32 | 0.20 | 0.39 | 0.27 |
| LOI | 6.49 | 3.18 | 3.36 | 4.05 | 7.06 | 2.69 | 2.69 | 5.72 | 2.68 | 3.20 |
| TOTAL | 100.58 | 101.11 | 100.35 | 99.02 | 101.05 | 100.55 | 100.85 | 100.93 | 101.00 | 100.79 |
| FeO | 4.83 | 5.72 | 4.76 | 5.33 | 7.00 | 6.90 | 6.59 | 6.58 | 6.88 | 5.69 |
| H2O+ | 3.15 | 3.30 | 3.56 | 4.25 | 3.84 | 3.00 | 2.65 | 4.62 | 2.81 | 3.54 |
| H2O- | 0.29 | 0.30 | 0.24 | 0.34 | 0.64 | 0.28 | 0.49 | 0.36 | 0.60 | 0.31 |
| OUT OF VOLATILE COMPONENT | | | | | | | | | | |
| SiO2 | 55.08 | 52.45 | 51.99 | 49.38 | 46.08 | 48.11 | 48.24 | 50.90 | 48.89 | 47.12 |
| TiO2 | 0.69 | 1.09 | 1.04 | 0.99 | 0.99 | 1.01 | 1.09 | 0.95 | 1.11 | 0.86 |
| Al2O3 | 15.86 | 17.45 | 19.06 | 16.80 | 17.02 | 17.32 | 17.06 | 18.20 | 15.91 | 18.74 |
| Fe2O3 | 1.73 | 3.24 | 3.15 | 5.56 | 2.36 | 4.28 | 5.25 | 2.00 | 5.19 | 4.57 |
| FeO | 4.83 | 5.69 | 4.77 | 5.42 | 6.98 | 6.92 | 6.58 | 6.57 | 6.86 | 5.68 |
| MnO | 0.13 | 0.21 | 0.16 | 0.23 | 0.17 | 0.22 | 0.21 | 0.15 | 0.24 | 0.19 |
| MgO | 3.32 | 3.39 | 2.40 | 4.13 | 4.67 | 4.76 | 4.67 | 2.95 | 5.12 | 4.22 |
| CaO | 6.09 | 6.75 | 6.97 | 9.05 | 9.96 | 8.28 | 7.38 | 8.10 | 6.78 | 8.54 |
| Na2O | 3.09 | 4.27 | 4.35 | 3.26 | 3.34 | 3.13 | 2.71 | 3.54 | 3.20 | 3.62 |
| K2O | 2.62 | 2.09 | 2.45 | 0.79 | 1.15 | 2.98 | 3.80 | 0.73 | 3.63 | 2.99 |
| P2O5 | 0.08 | 0.19 | 0.28 | 0.27 | 0.24 | 0.31 | 0.32 | 0.20 | 0.39 | 0.27 |
| LOI | 6.49 | 3.17 | 3.37 | 4.11 | 7.04 | 2.70 | 2.69 | 5.71 | 2.67 | 3.19 |
| C. I. P. W. NORM | | | | | | | | | | |
| Q | 8.06 | 0.00 | 0.00 | 3.79 | 0.00 | 0.00 | 0.00 | 3.74 | 0.00 | 0.00 |
| C | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| or | 15.48 | 12.35 | 14.48 | 4.67 | 6.80 | 17.61 | 22.46 | 4.31 | 21.45 | 17.67 |
| ab | 26.15 | 36.13 | 36.81 | 27.59 | 24.04 | 21.82 | 21.46 | 29.95 | 24.77 | 21.24 |
| an | 21.67 | 22.27 | 25.24 | 28.87 | 28.05 | 24.41 | 23.16 | 31.61 | 18.33 | 26.05 |
| ne | 0.00 | 0.00 | 0.00 | 0.00 | 2.28 | 2.53 | 0.80 | 0.00 | 1.25 | 5.09 |
| di | 3.90 | 4.93 | 3.64 | 8.49 | 9.48 | 7.56 | 6.25 | 2.91 | 7.03 | 0.58 |
| hd | 2.69 | 3.24 | 2.52 | 2.99 | 6.79 | 4.40 | 2.97 | 3.15 | 3.33 | 0.27 |
| wo | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 5.64 |
| en | 6.46 | 5.92 | 2.31 | 6.35 | 0.00 | 0.00 | 0.00 | 6.00 | 0.00 | 0.00 |
| fs | 5.11 | 4.46 | 1.83 | 2.56 | 0.00 | 0.00 | 0.00 | 7.45 | 0.00 | 0.00 |
| fo | 0.00 | 0.17 | 1.39 | 0.00 | 5.07 | 5.85 | 6.12 | 0.00 | 6.65 | 7.18 |
| fa | 0.00 | 0.14 | 1.21 | 0.00 | 4.59 | 4.30 | 3.67 | 0.00 | 3.98 | 4.20 |
| mt | 2.51 | 4.70 | 4.57 | 8.06 | 3.42 | 6.20 | 7.61 | 2.90 | 7.52 | 6.63 |
| ht | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| il | 1.31 | 2.07 | 1.97 | 1.88 | 1.88 | 1.92 | 2.07 | 1.80 | 2.11 | 1.63 |
| ru | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| ap | 0.19 | 0.44 | 0.65 | 0.63 | 0.56 | 0.72 | 0.74 | 0.46 | 0.90 | 0.63 |
| TOTAL | 93.53 | 96.82 | 96.62 | 95.88 | 92.96 | 97.32 | 97.31 | 94.28 | 97.32 | 96.81 |
| salic-total | 71.36 | 70.75 | 76.53 | 64.92 | 61.17 | 66.37 | 67.88 | 69.61 | 65.80 | 70.05 |
| femic-total | 22.17 | 26.07 | 20.09 | 30.96 | 31.79 | 30.95 | 29.43 | 24.67 | 31.52 | 26.76 |
| D.I. | 49.69 | 48.48 | 51.29 | 36.05 | 30.84 | 39.43 | 43.92 | 38.00 | 46.22 | 38.91 |
| S.I. | 21.54 | 18.48 | 14.31 | 22.23 | 25.56 | 22.01 | 20.79 | 18.95 | 21.79 | 20.47 |
| FeO*/MgO | 1.92 | 2.54 | 3.16 | 2.52 | 1.95 | 2.26 | 2.42 | 2.83 | 2.25 | 2.32 |
| Na2O+K2O | 5.71 | 6.36 | 6.80 | 4.05 | 4.49 | 6.10 | 6.50 | 4.27 | 6.83 | 6.61 |

[ Legend ] D.I.: differentiation index S.I.: solidification index * total Fe as FeO
C.I.P.W. NORM : W.Cross,J.P.Iddings,L.V.Pirsson and H.S.Washington(1902)

## Table 2 Chemical and Normative Compositions of Igneous Rocks (2)

| | ER-012 | ER-022 | ER-024 | ER-142 | ER-145 | ER-167 | ER-170 | FR-021 | FR-023 | GR-016 |
|---|---|---|---|---|---|---|---|---|---|---|
| ROCK TYPE | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| ROCK NAME | dolerite | dolerite | dolerite | dolerite | dolerite | dolerite | dolerite | dolerite | dolerite | dolerite |
| SiO2 | 48.90 | 41.20 | 48.70 | 52.00 | 51.30 | 50.00 | 47.20 | 50.20 | 46.00 | 47.30 |
| TiO2 | 0.57 | 0.37 | 0.95 | 0.94 | 1.07 | 0.85 | 1.03 | 1.08 | 0.79 | 1.05 |
| Al2O3 | 16.01 | 17.20 | 16.39 | 17.68 | 17.59 | 17.09 | 16.94 | 15.86 | 19.47 | 18.26 |
| Fe2O3 | 6.94 | 7.93 | 11.39 | 9.55 | 10.66 | 10.32 | 11.84 | 12.26 | 9.37 | 12.01 |
| MnO | 0.12 | 0.08 | 0.20 | 0.19 | 0.21 | 0.15 | 0.23 | 0.23 | 0.16 | 0.21 |
| MgO | 8.28 | 1.54 | 4.09 | 4.21 | 3.73 | 3.69 | 4.57 | 4.63 | 3.29 | 4.66 |
| CaO | 7.82 | 22.88 | 10.18 | 6.42 | 6.75 | 9.36 | 8.91 | 6.65 | 12.14 | 7.76 |
| Na2O | 3.19 | 0.54 | 3.62 | 3.80 | 5.17 | 4.40 | 3.37 | 3.77 | 3.35 | 2.71 |
| K2O | 2.38 | 0.04 | 0.75 | 2.17 | 0.87 | 0.28 | 2.65 | 3.03 | 1.01 | 3.30 |
| P2O5 | 0.11 | 0.08 | 0.22 | 0.32 | 0.39 | 0.27 | 0.44 | 0.38 | 0.22 | 0.31 |
| LOI | 5.56 | 5.91 | 3.71 | 3.95 | 3.05 | 3.78 | 3.50 | 2.87 | 5.03 | 3.14 |
| TOTAL | 99.88 | 97.77 | 100.20 | 101.23 | 100.79 | 100.19 | 100.68 | 100.96 | 100.83 | 100.71 |
| FeO | 4.47 | 1.40 | 6.41 | 6.05 | 6.49 | 3.98 | 6.32 | 7.01 | 3.89 | 5.93 |
| H2O+ | 3.72 | 4.60 | 3.33 | 3.79 | 3.01 | 3.67 | 3.54 | 2.65 | 4.00 | 3.32 |
| H2O- | 0.32 | 0.13 | 0.25 | 0.46 | 0.34 | 0.51 | 0.47 | 0.47 | 0.38 | 0.37 |
| OUT OF VOLATILE COMPONENT | | | | | | | | | | |
| SiO2 | 49.21 | 42.21 | 48.95 | 51.71 | 51.26 | 50.13 | 47.21 | 50.11 | 45.82 | 47.28 |
| TiO2 | 0.57 | 0.38 | 0.95 | 0.93 | 1.07 | 0.85 | 1.03 | 1.08 | 0.79 | 1.05 |
| Al2O3 | 16.11 | 17.62 | 16.47 | 17.58 | 17.58 | 17.13 | 16.94 | 15.83 | 19.39 | 18.25 |
| Fe2O3 | 1.98 | 6.53 | 4.29 | 2.81 | 3.45 | 5.91 | 4.82 | 4.46 | 5.03 | 5.42 |
| FeO | 4.50 | 1.43 | 6.44 | 6.02 | 6.49 | 3.99 | 6.32 | 7.00 | 3.87 | 5.93 |
| MnO | 0.12 | 0.08 | 0.20 | 0.19 | 0.21 | 0.15 | 0.23 | 0.23 | 0.16 | 0.21 |
| MgO | 8.33 | 1.58 | 4.11 | 4.19 | 3.73 | 3.70 | 4.57 | 4.62 | 3.28 | 4.66 |
| CaO | 7.87 | 23.44 | 10.23 | 6.38 | 6.75 | 9.38 | 8.91 | 6.64 | 12.09 | 7.76 |
| Na2O | 3.21 | 0.55 | 3.64 | 3.78 | 5.17 | 4.41 | 3.37 | 3.76 | 3.34 | 2.71 |
| K2O | 2.39 | 0.04 | 0.75 | 2.16 | 0.87 | 0.28 | 2.65 | 3.02 | 1.01 | 3.30 |
| P2O5 | 0.11 | 0.08 | 0.22 | 0.32 | 0.39 | 0.27 | 0.44 | 0.38 | 0.22 | 0.31 |
| LOI | 5.59 | 6.05 | 3.73 | 3.93 | 3.05 | 3.79 | 3.50 | 2.86 | 5.01 | 3.14 |
| C. I. P. W. NORM | | | | | | | | | | |
| Q | 0.00 | 1.68 | 0.00 | 0.07 | 0.00 | 1.98 | 0.00 | 0.00 | 0.00 | 0.00 |
| C | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| or | 14.12 | 0.24 | 4.43 | 12.76 | 5.14 | 1.65 | 15.66 | 17.85 | 5.97 | 19.50 |
| ab | 24.96 | 4.65 | 30.80 | 31.99 | 43.75 | 37.32 | 21.76 | 31.19 | 24.51 | 21.69 |
| an | 22.49 | 45.49 | 26.39 | 24.62 | 22.19 | 26.12 | 23.27 | 17.40 | 34.93 | 27.89 |
| ne | 1.19 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 3.66 | 0.34 | 2.03 | 0.67 |
| di | 10.13 | 8.49 | 11.69 | 2.48 | 4.18 | 13.09 | 8.89 | 6.70 | 7.14 | 5.02 |
| hd | 2.52 | 0.00 | 7.05 | 1.56 | 3.01 | 1.63 | 4.32 | 3.97 | 1.48 | 1.91 |
| wo | 0.00 | 24.79 | 0.00 | 0.00 | 0.00 | 0.00 | 0.75 | 0.00 | 5.34 | 0.00 |
| en | 0.00 | 0.00 | 3.08 | 9.29 | 1.86 | 3.15 | 0.00 | 0.00 | 0.00 | 0.00 |
| fs | 0.00 | 0.00 | 2.13 | 6.72 | 1.54 | 0.45 | 0.00 | 0.00 | 0.00 | 0.00 |
| fo | 11.25 | 0.00 | 1.22 | 0.00 | 3.85 | 0.00 | 5.09 | 5.89 | 3.41 | 6.50 |
| fa | 3.53 | 0.00 | 0.93 | 0.00 | 3.51 | 0.00 | 3.13 | 4.40 | 0.89 | 3.13 |
| mt | 2.87 | 3.77 | 6.22 | 4.07 | 5.00 | 8.57 | 6.99 | 6.47 | 7.29 | 7.86 |
| ht | 0.00 | 3.93 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| il | 1.08 | 0.72 | 1.80 | 1.77 | 2.03 | 1.61 | 1.96 | 2.05 | 1.50 | 1.99 |
| ru | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| ap | 0.25 | 0.19 | 0.51 | 0.74 | 0.90 | 0.63 | 1.02 | 0.88 | 0.51 | 0.72 |
| TOTAL | 94.39 | 93.95 | 96.25 | 96.07 | 96.96 | 96.20 | 96.50 | 97.14 | 95.00 | 96.88 |
| salic-total | 62.76 | 52.06 | 61.62 | 69.44 | 71.08 | 67.07 | 64.35 | 66.78 | 67.44 | 69.75 |
| femic-total | 31.63 | 41.89 | 34.63 | 26.63 | 25.88 | 29.13 | 32.15 | 30.36 | 27.56 | 27.13 |
| D.I. | 39.08 | 6.57 | 35.23 | 44.82 | 48.89 | 40.95 | 37.42 | 49.04 | 30.48 | 41.19 |
| S.I. | 41.21 | 16.65 | 21.86 | 22.42 | 19.26 | 20.90 | 21.51 | 20.61 | 20.46 | 21.70 |
| FeO*/MgO | 0.75 | 4.63 | 2.51 | 2.04 | 2.57 | 2.52 | 2.33 | 2.38 | 2.56 | 2.32 |
| Na2O+K2O | 5.60 | 0.59 | 4.39 | 5.94 | 6.04 | 4.69 | 6.02 | 6.79 | 4.34 | 6.01 |

[ Legend ] D.I.: differentiation index S.I.: solidification index * total Fe as FeO

## Table 2 Chemical and Normative Compositions of Igneous Rocks (3)

| | HR-031 | KR-013 | AR-015 | AR-029 | BR-007 | CR-019 | ER-120 | ER-121 | HR-028 | HR-037 |
|---|---|---|---|---|---|---|---|---|---|---|
| ROCK TYPE | 2 | 2 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| ROCK NAME | dolerite | and dike | gabbro | gabbro | sil.gabbr | gabbro | gabbro | gabro | gabbro | gabbro |
| SiO2 | 48.30 | 54.60 | 48.20 | 47.10 | 56.20 | 48.50 | 46.40 | 46.00 | 45.80 | 47.30 |
| TiO2 | 0.97 | 1.08 | 1.06 | 0.94 | 0.71 | 0.65 | 1.11 | 0.91 | 1.11 | 1.01 |
| Al2O3 | 19.94 | 17.23 | 16.48 | 17.78 | 15.26 | 15.56 | 17.10 | 19.45 | 17.06 | 18.34 |
| Fe2O3 | 11.05 | 8.11 | 12.68 | 11.57 | 6.25 | 7.29 | 12.90 | 11.52 | 12.93 | 11.63 |
| MnO | 0.19 | 0.19 | 0.20 | 0.18 | 0.14 | 0.14 | 0.21 | 0.20 | 0.18 | 0.18 |
| MgO | 4.39 | 3.23 | 5.45 | 4.95 | 1.84 | 2.49 | 5.09 | 4.35 | 5.23 | 4.80 |
| CaO | 6.72 | 7.64 | 8.69 | 10.27 | 7.05 | 15.50 | 8.00 | 8.92 | 10.95 | 9.26 |
| Na2O | 3.60 | 3.57 | 3.00 | 2.57 | 4.46 | 3.29 | 3.56 | 3.30 | 2.80 | 3.07 |
| K2O | 2.47 | 3.35 | 2.40 | 1.02 | 2.28 | 0.57 | 2.56 | 2.45 | 1.13 | 1.49 |
| P2O5 | 0.23 | 0.57 | 0.10 | 0.10 | 0.40 | 0.19 | 0.26 | 0.29 | 0.13 | 0.13 |
| LOI | 3.07 | 1.22 | 2.80 | 3.55 | 5.69 | 7.02 | 2.69 | 3.18 | 2.88 | 3.13 |
| TOTAL | 100.93 | 100.79 | 101.06 | 100.03 | 100.28 | 101.20 | 99.88 | 100.57 | 100.20 | 100.34 |
| FeO | 5.71 | 3.42 | 7.05 | 5.93 | 4.50 | 1.81 | 7.32 | 5.86 | 6.24 | 5.91 |
| H2O+ | 3.12 | 0.96 | 3.14 | 3.31 | 2.18 | 1.47 | 2.81 | 3.09 | 2.68 | 3.20 |
| H2O- | 0.57 | 0.18 | 0.26 | 0.60 | 0.21 | 0.18 | 0.42 | 0.61 | 0.32 | 0.45 |
| OUT OF VOLATILE COMPONENT | | | | | | | | | | |
| SiO2 | 48.16 | 54.38 | 48.07 | 47.40 | 56.32 | 48.02 | 46.84 | 46.04 | 46.03 | 47.45 |
| TiO2 | 0.97 | 1.08 | 1.06 | 0.95 | 0.71 | 0.64 | 1.12 | 0.91 | 1.12 | 1.01 |
| Al2O3 | 19.88 | 17.16 | 16.43 | 17.89 | 15.29 | 15.41 | 17.26 | 19.47 | 17.14 | 18.40 |
| Fe2O3 | 4.69 | 4.29 | 4.84 | 5.01 | 1.25 | 5.23 | 4.81 | 5.01 | 6.03 | 5.08 |
| FeO | 5.69 | 3.41 | 7.03 | 5.97 | 4.51 | 1.79 | 7.39 | 5.86 | 6.27 | 5.93 |
| MnO | 0.19 | 0.19 | 0.20 | 0.18 | 0.14 | 0.14 | 0.21 | 0.20 | 0.18 | 0.18 |
| MgO | 4.38 | 3.22 | 5.43 | 4.98 | 1.84 | 2.47 | 5.14 | 4.35 | 5.26 | 4.82 |
| CaO | 6.70 | 7.61 | 8.67 | 10.34 | 7.07 | 15.35 | 8.08 | 8.93 | 11.00 | 9.29 |
| Na2O | 3.59 | 3.56 | 2.99 | 2.59 | 4.47 | 3.26 | 3.59 | 3.30 | 2.81 | 3.08 |
| K2O | 2.46 | 3.34 | 2.39 | 1.03 | 2.29 | 0.56 | 2.58 | 2.45 | 1.14 | 1.49 |
| P2O5 | 0.23 | 0.57 | 0.10 | 0.10 | 0.40 | 0.19 | 0.26 | 0.29 | 0.13 | 0.13 |
| LOI | 3.06 | 1.22 | 2.79 | 3.57 | 5.70 | 6.95 | 2.72 | 3.18 | 2.89 | 3.14 |
| C. I. P. W. NORM | | | | | | | | | | |
| Q | 0.00 | 3.62 | 0.00 | 0.11 | 0.00 | 1.58 | 0.00 | 0.00 | 0.00 | 0.00 |
| C | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| or | 14.54 | 19.74 | 14.12 | 6.09 | 16.75 | 3.51 | 15.25 | 14.48 | 6.74 | 8.81 |
| ab | 29.88 | 30.12 | 24.03 | 21.92 | 23.83 | 29.00 | 20.97 | 19.86 | 22.75 | 26.06 |
| an | 30.86 | 20.98 | 24.35 | 34.15 | 23.27 | 27.09 | 23.36 | 31.08 | 30.79 | 31.98 |
| ne | 0.27 | 0.00 | 0.69 | 0.00 | 0.74 | 0.00 | 5.10 | 4.37 | 0.55 | 0.00 |
| di | 0.50 | 9.05 | 9.85 | 9.56 | 9.85 | 13.94 | 6.68 | 4.16 | 13.82 | 7.70 |
| hd | 0.21 | 1.27 | 4.78 | 3.76 | 1.12 | 0.00 | 3.70 | 1.84 | 4.61 | 3.00 |
| wo | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 13.55 | 0.96 | 1.64 | 0.00 | 0.00 |
| en | 0.00 | 3.82 | 0.00 | 7.97 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.27 |
| fs | 0.00 | 0.61 | 0.00 | 3.59 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.01 |
| fo | 7.48 | 0.00 | 6.28 | 0.00 | 4.71 | 0.00 | 6.80 | 6.24 | 4.69 | 4.32 |
| fa | 4.03 | 0.00 | 3.85 | 0.00 | 0.68 | 0.00 | 4.76 | 3.49 | 1.98 | 2.12 |
| mt | 6.80 | 6.22 | 7.02 | 7.26 | 16.52 | 4.59 | 6.97 | 7.26 | 8.74 | 7.36 |
| ht | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 4.43 | 0.00 | 0.00 | 0.00 | 0.00 |
| il | 1.84 | 2.05 | 2.01 | 1.80 | 1.83 | 1.29 | 2.13 | 1.73 | 2.13 | 1.92 |
| ru | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| ap | 0.53 | 1.32 | 0.23 | 0.23 | 0.69 | 0.46 | 0.60 | 0.67 | 0.30 | 0.30 |
| TOTAL | 96.94 | 98.80 | 97.21 | 96.44 | 99.99 | 99.44 | 97.28 | 96.82 | 97.10 | 96.85 |
| salic-total | 75.55 | 74.46 | 63.19 | 62.27 | 64.59 | 61.18 | 64.68 | 69.79 | 60.83 | 66.85 |
| femic-total | 21.39 | 24.34 | 34.02 | 34.17 | 35.40 | 38.26 | 32.60 | 27.03 | 36.27 | 30.00 |
| D.I. | 44.42 | 53.48 | 38.15 | 28.12 | 40.58 | 34.09 | 36.22 | 34.34 | 29.49 | 34.87 |
| S.I. | 21.52 | 18.51 | 24.48 | 26.12 | 12.95 | 19.29 | 22.30 | 21.25 | 25.15 | 24.21 |
| FeO*/MgO | 2.26 | 2.26 | 2.09 | 2.10 | 3.06 | 2.63 | 2.28 | 2.38 | 2.23 | 2.18 |
| Na2O+K2O | 6.05 | 6.89 | 5.38 | 3.61 | 6.75 | 3.82 | 6.18 | 5.75 | 3.95 | 4.57 |

[ Legend ] D.I.: differentiation index S.I.: solidification index * total Fe as FeO

## Table 2 Chemical and Normative Compositions of Igneous Rocks (4)

| | AR-099 | FR-028 | FR-052 | CR-027 | ER-111 |
|---|---|---|---|---|---|
| ROCK TYPE | 4 | 4 | 4 | 5 | 5 |
| ROCK NAME | and.porp | diorite | diorite | aplite | aplite |
| SiO2 | 61.20 | 51.90 | 53.60 | 70.60 | 73.40 |
| TiO2 | 0.42 | 0.87 | 0.82 | 0.13 | 0.08 |
| Al2O3 | 18.64 | 19.06 | 18.27 | 16.52 | 14.92 |
| Fe2O3 | 4.72 | 8.15 | 8.14 | 1.27 | 1.05 |
| MnO | 0.11 | 0.13 | 0.13 | 0.08 | 0.04 |
| MgO | 2.24 | 3.88 | 4.18 | 0.49 | 0.40 |
| CaO | 4.63 | 6.43 | 7.19 | 0.43 | 1.36 |
| Na2O | 5.07 | 3.96 | 4.35 | 4.77 | 5.26 |
| K2O | 0.74 | 2.37 | 1.25 | 3.07 | 2.77 |
| P2O5 | 0.10 | 0.24 | 0.17 | 0.06 | 0.07 |
| LOI | 2.36 | 2.89 | 2.60 | 1.86 | 1.08 |
| TOTAL | 100.23 | 99.88 | 100.70 | 99.28 | 100.43 |
| FeO | 1.72 | 4.67 | 3.60 | 0.33 | 0.40 |
| H2O+ | 2.15 | 3.00 | 2.50 | 1.30 | 0.55 |
| H2O- | 0.44 | 0.31 | 0.28 | 0.30 | 0.08 |
| | OUT OF VOLATILE COMPONENT | | | | |
| SiO2 | 61.18 | 52.23 | 53.44 | 71.14 | 73.11 |
| TiO2 | 0.42 | 0.88 | 0.82 | 0.13 | 0.08 |
| Al2O3 | 18.63 | 19.18 | 18.22 | 16.65 | 14.86 |
| Fe2O3 | 2.81 | 2.98 | 4.13 | 0.91 | 0.61 |
| FeO | 1.72 | 4.70 | 3.59 | 0.33 | 0.40 |
| MnO | 0.11 | 0.13 | 0.13 | 0.08 | 0.04 |
| MgO | 2.24 | 3.90 | 4.17 | 0.49 | 0.40 |
| CaO | 4.63 | 6.47 | 7.17 | 0.43 | 1.35 |
| Na2O | 5.07 | 3.99 | 4.34 | 4.81 | 5.24 |
| K2O | 0.74 | 2.39 | 1.25 | 3.09 | 2.76 |
| P2O5 | 0.10 | 0.24 | 0.17 | 0.06 | 0.07 |
| LOI | 2.36 | 2.91 | 2.59 | 1.87 | 1.08 |
| | C. I. P. W. NORM | | | | |
| Q | 15.72 | 0.00 | 3.08 | 29.85 | 28.70 |
| C | 1.31 | 0.00 | 0.00 | 4.75 | 0.97 |
| or | 4.37 | 14.12 | 7.39 | 18.26 | 16.31 |
| ab | 42.90 | 33.76 | 36.72 | 40.70 | 44.34 |
| an | 22.32 | 27.37 | 26.54 | 1.74 | 6.24 |
| ne | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| di | 0.00 | 1.77 | 5.35 | 0.00 | 0.00 |
| hd | 0.00 | 0.79 | 0.93 | 0.00 | 0.00 |
| wo | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| en | 5.58 | 7.20 | 7.91 | 1.22 | 1.00 |
| fs | 0.35 | 3.68 | 1.57 | 0.00 | 0.17 |
| fo | 0.00 | 1.18 | 0.00 | 0.00 | 0.00 |
| fa | 0.00 | 0.66 | 0.00 | 0.00 | 0.00 |
| mt | 4.07 | 4.32 | 5.99 | 0.95 | 0.88 |
| ht | 0.00 | 0.00 | 0.00 | 0.26 | 0.00 |
| il | 0.80 | 1.67 | 1.56 | 0.25 | 0.15 |
| ru | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| ap | 0.23 | 0.56 | 0.39 | 0.14 | 0.16 |
| TOTAL | 97.65 | 97.08 | 97.43 | 98.12 | 98.92 |
| salic-total | 86.62 | 75.25 | 73.73 | 95.30 | 96.56 |
| femic-total | 11.03 | 21.83 | 23.70 | 2.82 | 2.36 |
| D.I. | 62.99 | 47.88 | 47.19 | 88.81 | 89.35 |
| S.I. | 18.21 | 22.12 | 24.44 | 5.17 | 4.26 |
| FeO*/MgO | 1.90 | 1.89 | 1.75 | 2.33 | 2.37 |
| Na2O+K2O | 5.81 | 6.37 | 5.58 | 7.90 | 8.00 |

[ Legend ] D.I.: differentiation index S.I.: solidification index * total Fe as FeO

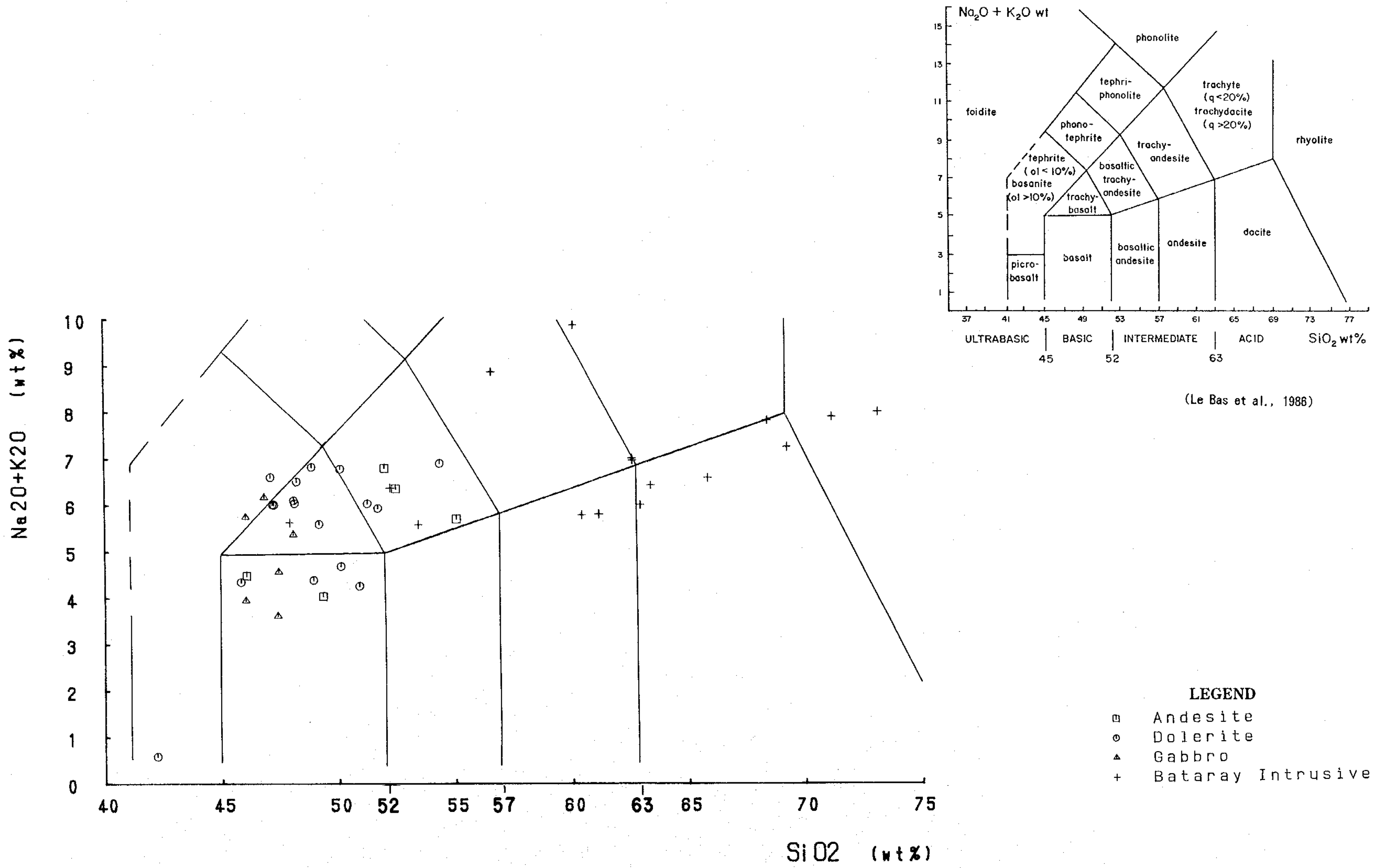



**Fig. 4 TAS Diagram**

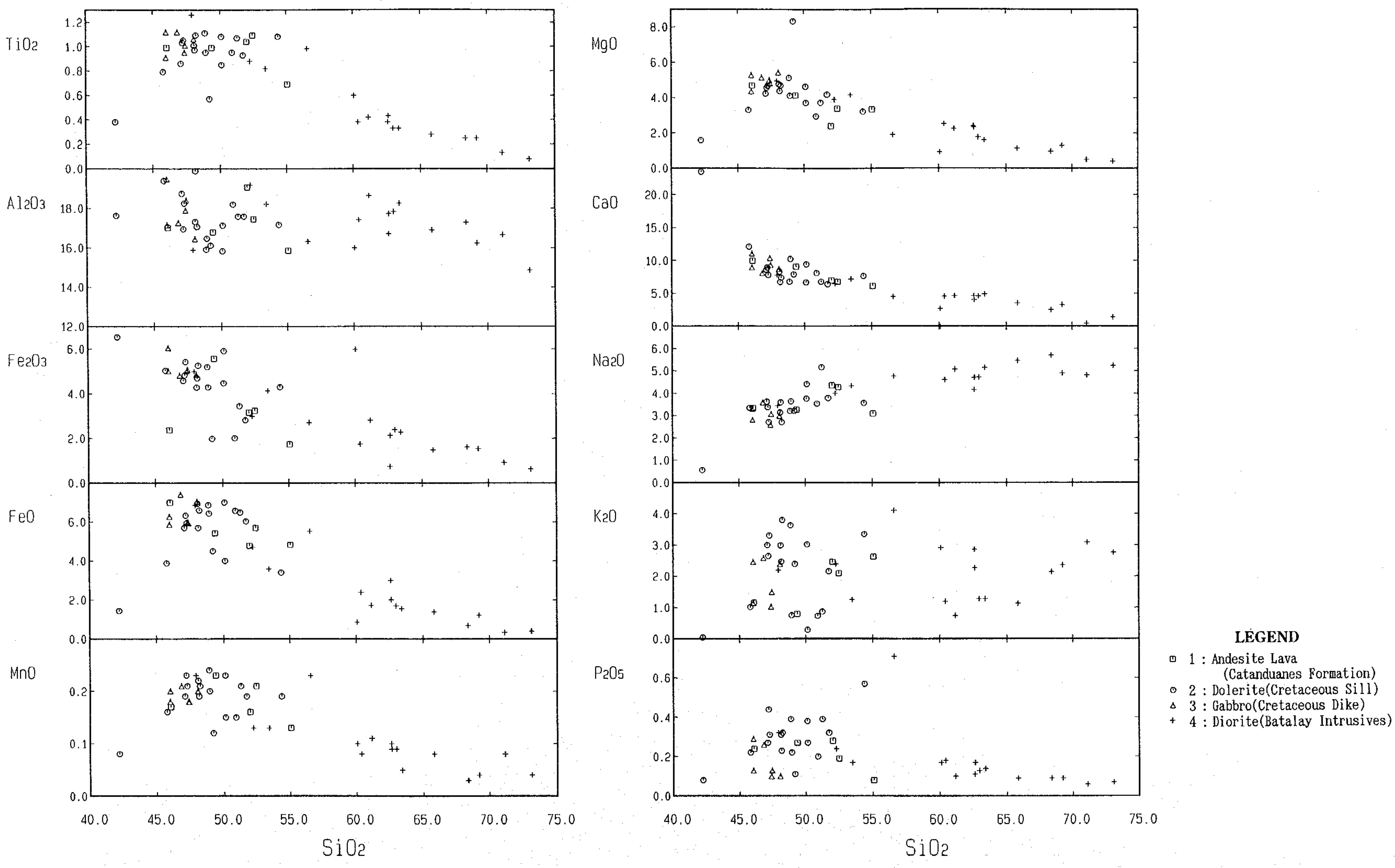
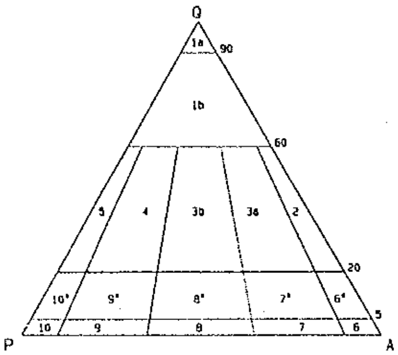



**Fig. 5 Harker Diagram**




Classification of granitic rocks (IUGS, 1973)

Q – quartz ; A – alkali feldspar (including microcline, orthoclase, sanidine, anorthoclase, and perthites (including their plagioclase components), and plagioclase An-0·5} ; P – plagioclase other than An-0-5 ; F – feldspathoids (leucite and pseudoleucite, nepheline, sodalite, nosean, houyne, cancrinite, analcime, etc.

1a, quartzolite (silexite) ; 1b, quartz-rich granitoids ; 2, alkali-feldspar granite ; 3, granite ; 4, granodiorite ; 5, tonalite ; 6*, quartz alkali-feldspar syenite ; 7*, quartz syenite ; 8*, quartz monzonite ; 9*, quartz monzodiorite/quartz monzogabbro ; 10*, quartz diorite/quartz gabbro/quartz anorthosite ; 6, alkali-feldspar syenite ; 7, syenite ; 8, monzonite ; 9, monzodiorite/monzogabbro ; 10, diorite/gabbro/anorthosite

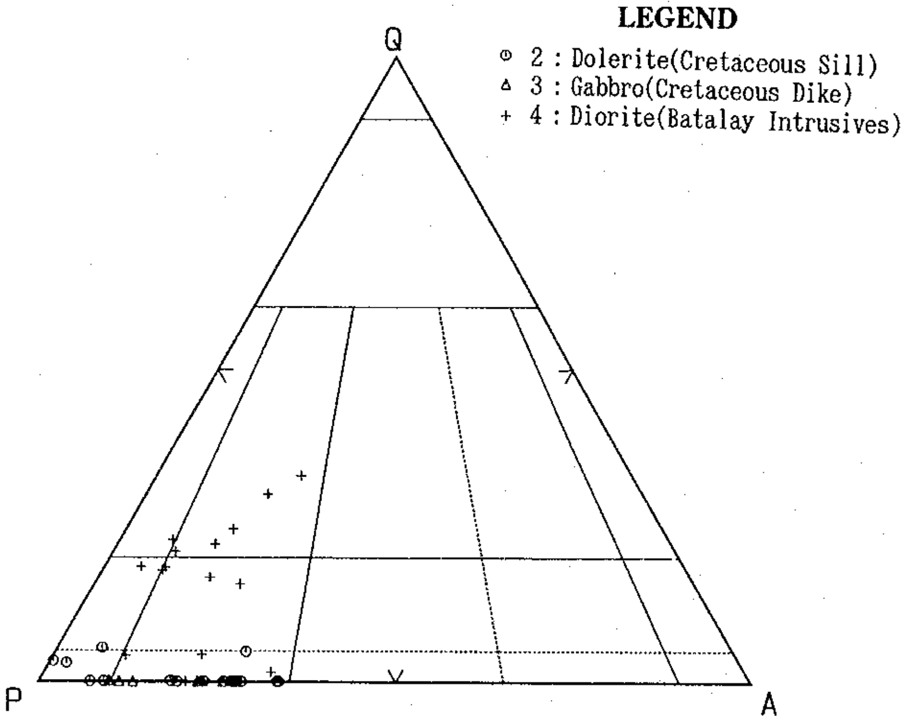



**Fig. 6 QAP Diagram**

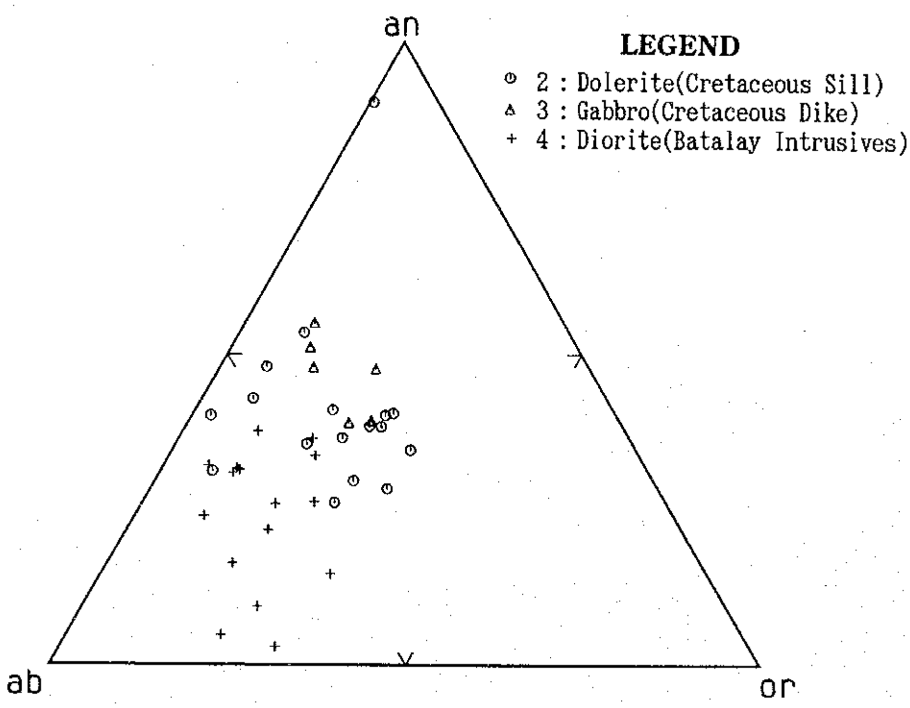



**Fig. 7 an-ab-or Diagram**

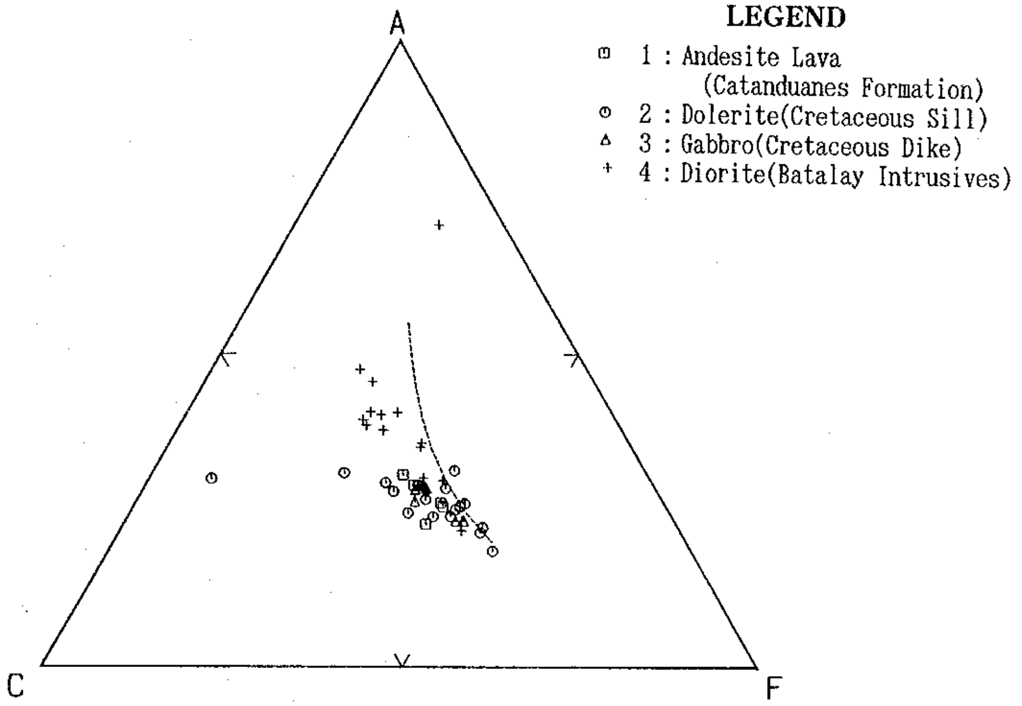



**Fig. 8 ACF Diagram**

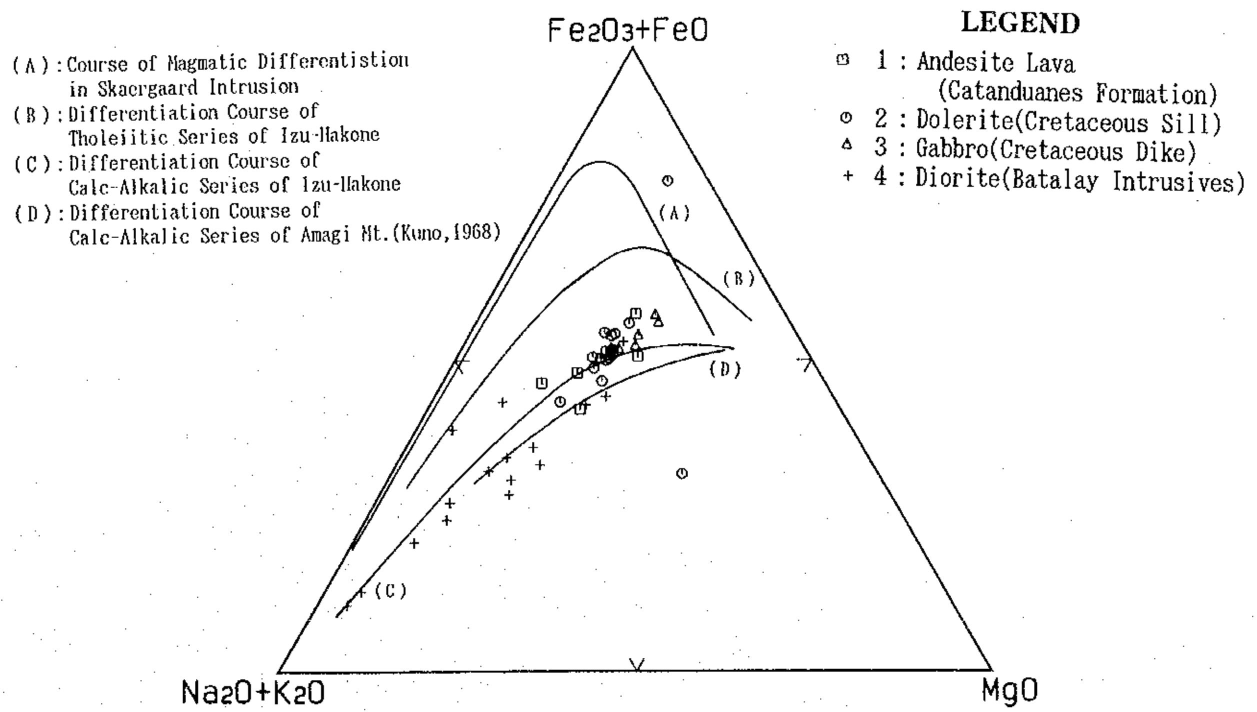



**Fig. 9 MFA Diagram**

basaltic andesite. The content of $SiO_2$ in these rocks ranges from 46.20% to 55.10%. The TAS diagram indicates the category of basalt to basaltic andesite. The Harker diagram indicates comparatively coherent distribution, meaning low extent of divergence. In the AFM diagram too, distribution is seen in a collective narrow area in the calc-alkali series. In the ACF diagram, classification into I type is found. These rocks present the character of the island-arc trench system.

**(2) Cretaceous Intrusives:** These rocks are formed of gabbro and dolerite. The content of $SiO_2$ in the gabbro ranges from 41.20% to 54.60%, while the same content in the dolerite from 45.80% to 53.60%. In the TAS diagram, the gabbro and dolerite is in the category of gabbro to gabbroic diorite. According to QAP diagram, the gabbro is plotted in the area of monzonite gabbro, while the dolerite in the area of gabbro to monzonite gabbro. According to the Harker diagram, as compared with Batalay Intrusives, these rocks indicate narrow distribution, meaning that the extent of differenciation is low. In the MFA diagram, the rocks indicate a differenciation trend practically in the calc-alkali series, but are distributed in a narrow area like the Harker diagram. In the ACF diagram, the rocks are classified into I type. They present the character of the island-arc trench system.

**(3) Batalay Intrusives:** These rocks are formed of andesite porphyry, diorite and aplite. The content of $SiO_2$ is between 51.91% and 73.40%. In the TAS diagram, the rocks are in the area of gabbroic diorite to granite. From the QAP diagram, they are classified into quartz diorite to monzodiorite to granodiorite. The Harker diagram indicates that as the content of $SiO_2$ increases the contents of other components decrease or increase, showing a series of differenciation trends. In the MFA diagram too, the rocks indicate a differenciation course in the calc-alkali series in the island-arc system. In the ACF diagram, they are classified I type.

### 1-3-2 Trace Element

For the igneous rocks 28 samples were subjected to trace element analysis. Table 3 shows the results of analysis. The number of rock kinds in the Table are the same as Table 2. In calculating the mean values, for samples whose values were below the detection limit values, the values of the half of the detection limit values were used.

Since only one sample of As, three samples of Pb, five samples of Sb, and 18 samples of Mo surpassed the detection limit values, these elements were removed from the objects of study.

The highest analysis values for the elements were 17ppb of Au and 0.6ppm of Ag in dolerite, 832ppm of Cu in basalt lava, 108ppm of Zn in andesite, and 0.186% of S in dolerite. Table 4 shows the mean content values. A value surpassing the detection limit value in As was 200ppm of one sample (BOR-007) of silicified rock taken from the upper reaches of the Taganopol river. According to Table 4 the contents of trace elements are different between Cretaceous Intrusives and Batalay Intrusives. One the other hand the andesite lava and the Cretaceous Intrusives indicate similar content values.

### 1-3-3 Rare Earth Elements (REE)

Rare earth element analysis was made for four samples of gabbro, four samples of dolerite of the Cretaceous Intrusives, two samples of diorite and one sample of aplite of the Batalay Intrusives, totaling 11 samples. The results of the analysis is shown in Table 5. Also the analysis values were standardized according to the chondrite composition (Thompson et al., 1984, but only Eu according to Taylor and McLennan, 1985) and shown in Fig. 10, REE pattern diagram.

According to Fig.10, the gabbro and dolerite of the Cretaceous Intrusives differ to some extent in the content values but indicate the same pattern. Batalay Intrusives indicate the same pattern except for aplite (FR-028). All the rocks present the pattern of decreasing on the right hand side, which means igneous activity in the island-arc. As for Eu there is no negative abnormality in all the samples.

The results from the survey of this phase are harmonious with the results about Batalay Intrusives by David Jr. (1994).

### 1-3-4 K-Ar Dating

Age measurement by K-Ar method was made on six samples of igneous rock of Catanduanes island.

The samples were those of dolerite (DR-016) and gabbro (ER-120, HR-028) of Cretaceous Intrusives, andesite porphyry (AR-099) and diorite (FR-028) of Batalay Intrusives, and andesite from the outside of the survey area (KT-013). The samples were very carefully selected aiming at taking the least altered material, but microscopic observation revealed that they have alteration of chlorite, sericite and epidote to medium to strong degrees. The result is show in Table 6.

The result of the age measurement showed that the age of the samples of the Cretaceous intrusive rocks, ER-120 and HR-028 ranged from 82.9±2.6Ma to 95.4±5.7Ma indicating the later period of the Cretaceous. Sample DR-016 indicated the age of 48.5±1.1Ma which is in the age of the middle of the Eocene. From considering the geological conditions and microscopic observation, this sample is considered to be the rock intruded in the Cretaceous being later rejuvenated owing to alteration. Samples AR-099 and FR-028 showed the values ranging from 32.9±2.0Ma to 34.2±Ma, meaning the middle of the Oligocene. This age accords well with the one Miranda and Vargas indicated from the stratigraphic relations for Batalay Intrusives. Also it is in accordance with the period of intrusion as indicated by David Jr. (1994).

The constants were, according to Steiger and Jaeger (1977), set as follows:

$$\lambda e = 0.581 \times 10^{-10}/Y,\ \lambda \beta = 4.962 \times 10^{-10}/Y.$$

## Table 3 Trace Element Analysis of Igneous Rocks

| Sample No. | Rock Type | Rock Name | Au ppb | Ag ppm | As ppm | Cu ppm | Mo ppm | Pb ppm | S % | Sb ppm | Zn ppm |
|---|---|---|---|---|---|---|---|---|---|---|---|
| AR-045 | 1 | basaltic andesite | 4 | <0.2 | < 2 | 92 | < 1 | < 2 | 0.014 | < 2 | 68 |
| ER-054 | 1 | basaltic andesite | 3 | 0.4 | < 2 | 210 | 1 | < 2 | 0.014 | 2 | 92 |
| ER-097 | 1 | basaltic andesite | 1 | 0.4 | < 2 | 196 | 2 | < 2 | 0.021 | < 2 | 96 |
| ER-122 | 1 | basalt | 3 | 0.4 | < 2 | 832 | 2 | < 2 | 0.014 | < 2 | 148 |
| FR-064 | 1 | basalt | < 1 | 0.2 | < 2 | 106 | < 1 | < 2 | 0.03 | < 2 | 102 |
| CR-015 | 2 | dolerite | 5 | 0.4 | < 2 | 231 | 1 | < 2 | 0.021 | < 2 | 82 |
| CR-016 | 2 | dolerite | 6 | 0.4 | < 2 | 270 | 1 | < 2 | 0.026 | < 2 | 90 |
| CR-021 | 2 | dolerite | 1 | 0.2 | < 2 | 136 | < 1 | < 2 | 0.186 | < 2 | 102 |
| DR-016 | 2 | dolerite | 4 | 0.4 | < 2 | 281 | 1 | < 2 | 0.017 | < 2 | 96 |
| DR-017 | 2 | dolerite | 2 | 0.4 | < 2 | 190 | < 1 | < 2 | 0.012 | < 2 | 94 |
| ER-012 | 2 | dolerite | < 1 | <0.2 | < 2 | 96 | < 1 | < 2 | 0.091 | < 2 | 52 |
| ER-022 | 2 | dolerite | 1 | <0.2 | < 2 | 91 | < 1 | < 2 | 0.01 | < 2 | 102 |
| ER-024 | 2 | dolerite | 17 | 0.6 | < 2 | 243 | < 1 | < 2 | 0.012 | < 2 | 96 |
| ER-142 | 2 | dolerite | 1 | 0.2 | < 2 | 115 | < 1 | < 2 | 0.142 | < 2 | 96 |
| ER-145 | 2 | dolerite | 4 | 0.4 | < 2 | 259 | 2 | < 2 | 0.039 | < 2 | 102 |
| ER-167 | 2 | dolerite | < 1 | 0.4 | < 2 | 135 | < 1 | < 2 | 0.018 | < 2 | 88 |
| ER-170 | 2 | dolerite | 4 | 0.4 | < 2 | 274 | 2 | < 2 | 0.036 | < 2 | 100 |
| FR-021 | 2 | dolerite | 3 | 0.4 | < 2 | 253 | 2 | < 2 | 0.012 | < 2 | 92 |
| FR-023 | 2 | dolerite | 2 | 0.4 | < 2 | 190 | < 1 | < 2 | 0.012 | < 2 | 88 |
| GR-016 | 2 | dolerite | 4 | 0.2 | < 2 | 220 | < 1 | < 2 | 0.021 | < 2 | 94 |
| HR-031 | 2 | dolerite | 3 | 0.2 | < 2 | 198 | 1 | < 2 | 0.012 | < 2 | 76 |
| KR-013 | 2 | andesite | 5 | <0.2 | < 2 | 469 | 1 | 2 | 0.011 | < 2 | 108 |
| AR-015 | 3 | gabbro | 8 | 0.4 | < 2 | 183 | < 1 | < 2 | 0.03 | 4 | 80 |
| AR-029 | 3 | gabbro | 8 | 0.2 | < 2 | 316 | < 1 | < 2 | 0.01 | < 2 | 76 |
| BR-007 | 3 | siliceous gabbro | 1 | <0.2 | 200 | 132 | 1 | < 2 | 0.051 | < 2 | 96 |
| CR-019 | 3 | gabbro | 1 | <0.2 | < 2 | 6 | < 1 | < 2 | 0.376 | < 2 | 64 |
| ER-120 | 3 | gabbro | 4 | 0.2 | < 2 | 231 | 2 | < 2 | 0.017 | < 2 | 90 |
| ER-121 | 3 | gabbro | 4 | 0.2 | < 2 | 185 | < 1 | < 2 | 0.018 | < 2 | 84 |
| HR-028 | 3 | gabbro | 3 | 0.2 | < 2 | 205 | 1 | < 2 | 0.015 | < 2 | 86 |
| HR-037 | 3 | gabbro | 3 | 0.2 | < 2 | 171 | < 1 | 2 | 0.01 | 2 | 78 |
| AR-099 | 4 | andesite porphyry | < 1 | 0.2 | < 2 | 48 | < 1 | < 2 | 0.001 | 2 | 48 |
| FR-028 | 4 | diorite | < 1 | 0.2 | < 2 | 135 | 1 | < 2 | 0.017 | < 2 | 76 |
| FR-052 | 4 | diorite | < 1 | <0.2 | < 2 | 113 | < 1 | < 2 | 0.02 | < 2 | 62 |
| CR-027 | 5 | aplite | < 1 | <0.2 | < 2 | < 1 | < 1 | 6 | 0.005 | < 2 | 26 |
| ER-111 | 5 | aplite | < 1 | <0.2 | < 2 | 13 | < 1 | < 2 | 0.009 | 4 | 28 |

## Table 4 Average of Trace Element Analysis of Igneous Rocks

| | | Number | | Au ppm | Ag ppm | Cu ppm | Zn ppm | S % |
|---|---|---|---|---|---|---|---|---|
| Andesite lava | | 3 | | 3 | 0.2 | 343 | 106 | 0.019 |
| Cretaceous Intrusives: gabbro | | 9 | | 4 | 0.2 | 171 | 80 | 0.060 |
| : dolerite | | 19 | | 4 | 0.3 | 214 | 87 | 0.020 |
| | Total | 28 | Avg. | 4 | 0.3 | 200 | 84 | 0.030 |
| Batalay Intrusives: diorite | | 2 | | 0.5 | 0.2 | 92 | 62 | 0.007 |
| : aplite | | 2 | | 0.5 | 0.1 | 7 | 27 | 0.009 |
| | Total | 4 | Avg. | 0.5 | 0.2 | 49 | 45 | 0.008 |

## Table 5 Rare Earth Element Analysis of Igneous Rocks

| Sample No. | | ER-097 | DR-016 | ER-142 | KR-013 | AR-015 | AR-029 | ER-120 | HR-028 | AR-099 | FR-028 | ER-111 | CT-12 (*1) | CT-16C (*1) | CT-16D (*1) | OIB (*2) | コンドライト (*3) | コンドライト (*4) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Rock Type | | 1 | 2 | 2 | 2 | 3 | 3 | 3 | 3 | 4 | 4 | 5 | | | | | | |
| Ba | ppm | 220 | 680 | 70 | 240 | 160 | 50 | 140 | 150 | 260 | 220 | 660 | 415 | 310 | 247 | 150 | 6.9 | — |
| Ce | ppm | 69 | 61 | 36 | 60 | 34 | 26 | 25 | 25 | 22 | 29 | 22 | 30 | 21 | 23 | 35.5 | 0.865 | 0.957 |
| Dy | ppm | 5.1 | 4.4 | 3.4 | 4.9 | 3.4 | 2.9 | 2.9 | 3 | 2.1 | 3.3 | 0.9 | — | — | — | — | — | — |
| Er | ppm | 2.5 | 1.9 | 1.3 | 1.9 | 1.5 | 1.5 | 1.3 | 1.3 | 1.1 | 1.7 | 0.3 | — | — | — | — | — | — |
| Eu | ppm | 1.8 | 2.2 | 1.6 | 2 | 1.5 | 1.3 | 1.2 | 1.3 | 0.9 | 1.1 | 0.6 | 0.85 | 0.75 | 0.8 | 1.88 | — | 0.087 |
| Gd | ppm | 4.4 | 4.7 | 3.3 | 4.9 | 3 | 2.5 | 2.5 | 2.7 | 1.9 | 2.5 | 1.1 | — | — | — | — | — | — |
| Ho | ppm | 1.2 | 0.9 | 0.8 | 1 | 0.8 | 0.6 | 0.6 | 0.7 | 0.4 | 0.7 | 0.2 | — | — | — | — | — | — |
| La | ppm | 18 | 24 | 12 | 22 | 12 | 9 | 8 | 9 | 9 | 11 | 9 | 13.1 | 10 | 9.9 | 13.4 | 0.328 | 0.367 |
| Lu | ppm | 0.4 | 0.2 | 0.3 | 0.4 | 0.3 | 0.2 | 0.2 | 0.2 | 0.2 | 0.3 | <0.1 | — | — | — | — | — | — |
| Nb | ppm | 12 | 5 | 7 | 6 | 5 | 5 | 5 | 4 | 3 | 5 | 8 | 2.6 | 1.95 | 3.55 | 17 | 0.35 | — |
| Nd | ppm | 19 | 28 | 16 | 25 | 18 | 12 | 11 | 12 | 11 | 11 | 8 | 15 | 11 | 13 | 10 | 0.63 | 0.711 |
| Pr | ppm | 5.9 | 7.1 | 4.4 | 7.5 | 3.9 | 3.4 | 3.1 | 3.4 | 2.8 | 3.5 | 2.2 | — | — | — | — | — | — |
| Rb | ppm | 22 | 43 | 6 | 29 | 24 | 4 | 49 | 18 | 15 | 11 | 70 | 32 | 21 | 17.5 | 9.2 | 0.35 | — |
| Sm | ppm | 5.2 | 5.6 | 4.5 | 6 | 3.8 | 3.6 | 3 | 3.6 | 2 | 3.2 | 1.2 | — | — | — | — | — | — |
| Sr | ppm | 500 | 1300 | 690 | 1050 | 750 | 350 | 550 | 750 | 790 | 800 | 430 | 766 | 760 | 750 | 371 | 11.8 | — |
| Tb | ppm | 0.8 | 0.8 | 0.6 | 0.8 | 0.6 | 0.4 | 0.5 | 0.5 | 0.4 | 0.5 | 0.2 | — | — | — | — | — | — |
| Tm | ppm | 0.5 | 0.3 | 0.3 | 0.3 | 0.3 | 0.2 | 0.2 | 0.2 | 0.2 | 0.3 | 0.1 | — | — | — | — | — | — |
| Y | ppm | 32 | 24 | 24 | 30 | 18 | 16 | 18 | 19 | 12 | 24 | 7 | 10.5 | 11.3 | 13.5 | 25 | 2 | 2.25 |
| Yb | ppm | 2.9 | 1.8 | 1.9 | 2.5 | 1.8 | 1.3 | 1.4 | 1.6 | 1.2 | 1.9 | 0.4 | 1 | 0.95 | 1.15 | 1.98 | 0.22 | 0.248 |
| Zr | ppm | 181 | 137 | 111 | 160 | 104 | 79 | 81 | 86 | 115 | 119 | 81 | 25 | 32 | 59 | 115 | 6.84 | — |
| Sr/Y | | 15.6 | 54.2 | 28.8 | 35.0 | 41.7 | 21.9 | 30.6 | 39.5 | 65.8 | 33.3 | 61.4 | 73.0 | 67.3 | 55.6 | 14.8 | 5.9 | — |

*1:David Jr.(1994); *2:Willson(1989); *3:Thompson R.N. et al.(1984); *4:Taylor and McLennan(1985)

OIB: Ocean island basalt

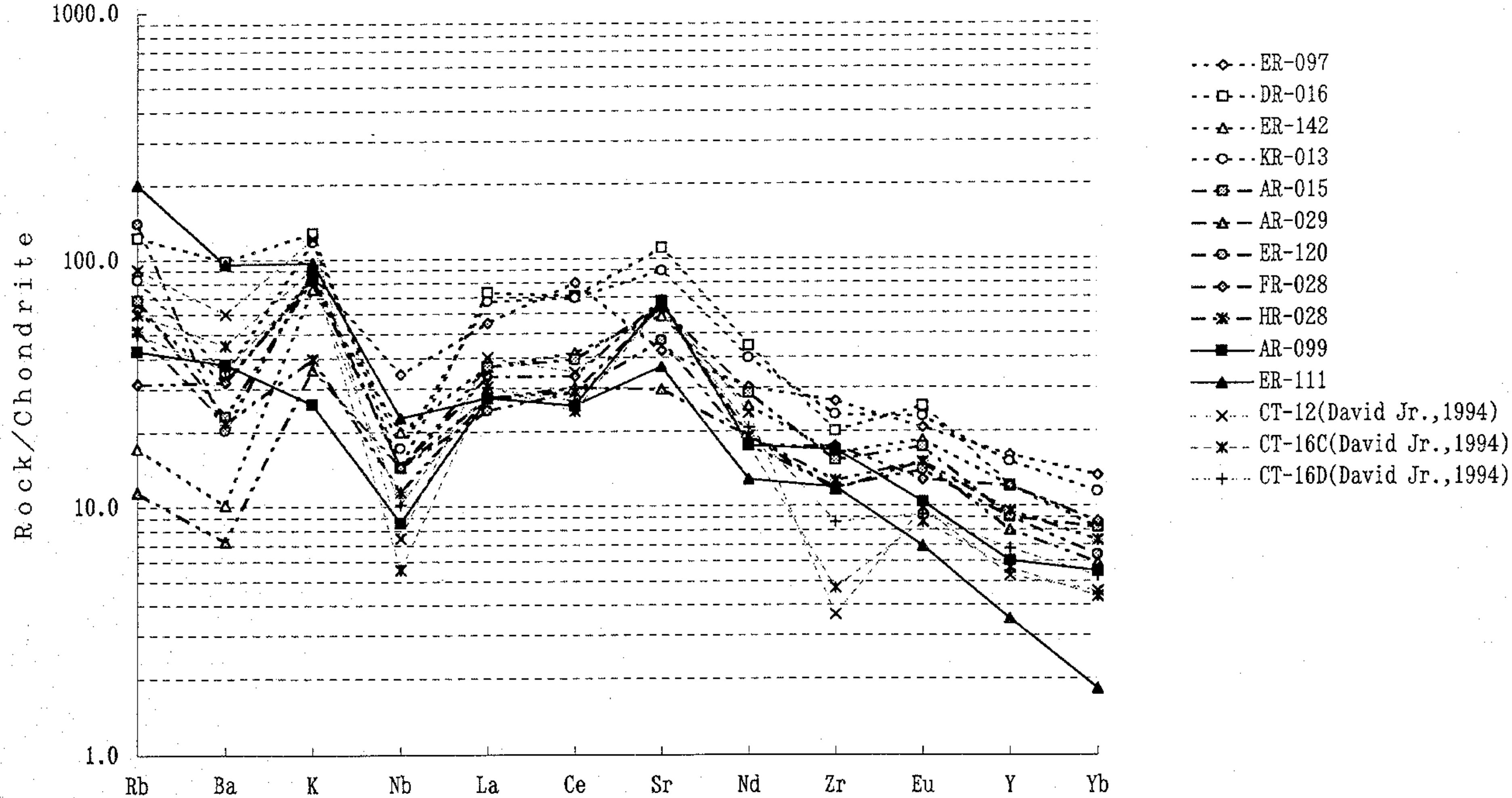



**Fig. 10 Spidergram (REE pattern)**

## Table 6 K-Ar Dating of Igneous Rocks

| Sample No. | Rock Type | Sample Locality (latitude , longitude) | POTASSIUM (K wt%) | Rad. $^{40}Ar$ ($10^{-8}$ cc/g) | K-Ar AGE (Ma) | AIR CONT. (%) | Average of K-Ar Age (Ma) |
|---|---|---|---|---|---|---|---|
| AR-099 | Andesite porphyry | Kadlakogod creek (N 13° 44′ 19″ ,E 124° 18′ 16″ ) | 0.54±0.03 | 68.7±0.9<br>69.2±1.0 | 32.8±2.0<br>33.0±2.0 | 23.0<br>22.4 | 32.9±2.0 |
| DR-016 | Dolerite | Gihawis creek (N 13° 48′ 52″ ,E 124° 19′ 55″ ) | 2.89±0.06 | 553±6.0<br>550±6.0 | 48.6±1.1<br>48.4±1.1 | 6.3<br>6.2 | 48.5±1.1 |
| ER-120 | Gabbro | Barinad creek (N 13° 47′ 53″ ,E 124° 20′ 17″ ) | 1.47±0.04 | 481±5.0<br>483±5.0 | 82.7±2.6<br>83.0±2.6 | 8.7<br>7.2 | 82.9±2.6 |
| FR-028 | Diorite | Up stream of The Taganopol river (N 13° 49′ 30″ ,E 124° 21′ 06″ ) | 1.16±0.04 | 157±2.0<br>153±2.0 | 34.6±1.1<br>33.8±1.1 | 17.6<br>16.2 | 34.2±1.1 |
| HR-028 | Gabbro | Branch of Barinad creek (N 13° 47′ 43″ ,E 124° 19′ 58″ ) | 0.89±0.05 | 328±4.0<br>344±4.0 | 93.2±5.5<br>97.5±5.8 | 10.1<br>12.3 | 95.4±5.7 |
| KR-013 | Andesite dike | 1.5km southeast of Pagsagnahan Point (N 13° 43′ 08″ ,E 124° 16′ 38″ ) | 2.48±0.05 | 379±5.0<br>380±5.0 | 39.0±0.9<br>39.1±0.9 | 13.4<br>13.6 | 39.1±0.9 |

* Dating was done on bulk samples by Mitsubishi Material Co.,Ltd. Central Laboratory.
* Decay Constant(after Steiger and Jaeger,1977):

$\lambda e = 0.581 \times 10^{-10}/yr$

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

* $^{40}K$ content in K : $^{40}K/K = 0.01167$ atom %
* Error estimation was done after Nagao et al.(1984)

The existence rate of 40K in K was set at 40K/K=0.01167 atom%. The estimation of measurement errors was based on Nagao et al. (1984).

## 1-4 Mineral Deposits and Mineralization

In the First phase survey, covering the whole island, reconnaissance was made at 17 gold and copper occurrences and seven places of clay zones.

The survey area for this phase is the area including Carorongan Mineral Occurrence by the geological and geochemical surveys in the first phase survey and was reported as having the highest gold content of 21.59g/t by Miranda and Vargas (1967).

As the result of detailed geological survey the following mineralization and mineral occurrences were found; (1) Quartz veins: Ananon South Area, Carorongan Mineral Occurrence, and Taganopol Mineral Occurrence, (2) Silicification zones: Pinadaysan Area, Maytung Area and Kaipa Area, (3) Alluvial gold deposits: Ananon North Area and Kadlakogod Area, (4) Native copper: Barinad Area, (5) Others: Kampayas Area, Tagbak Area and Pagsagnahan Area

The location map of the mineral occurrences in the survey area is shown as Fig.11 and the result of the analysis as Attached Table 2.

The analysis of the ore was made for the eight elements of Au, Ag, Cu, Fe, Mo, Pb, Zn and S. The employed methods of analysis were; method of neutron radio activation for Au, method of high-frequency furnace combustion for S, and ICP-AES Method for the remaining six elements. The detection limit values were: 0.001 oz/t for Au, 2ppm for Ag, 0.01% for Fe, and 0.001% for the remaining five elements.

### 1-4-1 Quartz Vein

Quartz veins occur in the green-schist unit of Catanduanes Formation and floats of quartz veins are scattered mainly at the area of green-schist and its periphery. These are divided into two; segregation quartz veins, and hydrothermal veins.

**Segregation quartz veins:** these veins are formed through dynamo-metamorphic processes. They occur mainly in the green-schist and show milky white color and it is generally embedded parallel to the schistosity of the green-schist. The width of veins are generally 1-5cm (occasionally 25cm), and extensions are 0.5-3m. No alterations were observed.

**Hydrothermal quartz veins:** three areas were found out to produce hydrothermal quartz veins. They are; Ananon South Area, Carorongan Mineral Occurrence and Taganopol Mineral Occurrence.

In these areas silicification and weak argillization and pyritization are observed. Width of veins are 0.5-1.0m and extension may be approximately 30m maximum.

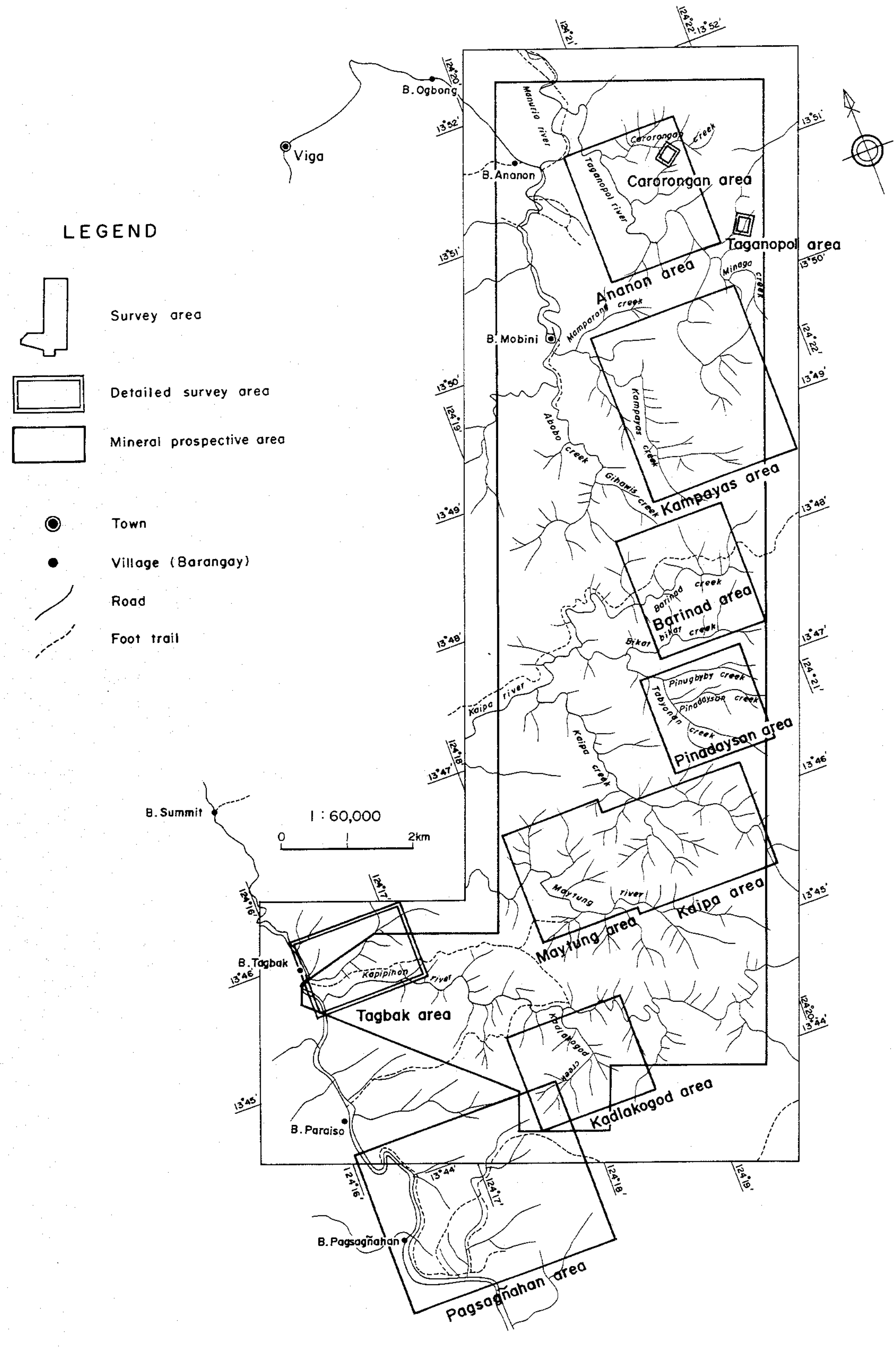



Fig. 11 Location Map of the Mineral Occurrences in the Survey Area

They are composed of pyrite bearing quartz and silicified veins. Along the Taganopol river, big quartz floats ranging 0.3-1.0m (maximum 2.5m) are distributed. Expect for these three areas, clear hydrothermal quartz veins were not observed. However, some floats scattered at these areas could be of hydrothremal origin.

**(1) Ananon South Area:** This area covers the Taganopol river and its tributaries except the Carorongan Mineral Occurrence. Route map of this area is shown in Fig.12.

Geology consists mainly of green-schist and partly volcanic rocks of Payo Formation at northeastern corner. Milky colored quartz veins i.e. segregation quartz veins were embedded in green-schist. Strike and dip of their quartz veins are parallel to the scistosity showing N20° -40° W, 70° -90° E. Width of veins are 1-5cm (occasionally 25cm) and extension are 0.5-3m. There quartz veins do not accompany hydrothermal alteration and pyrite, and they don't show gold content.

At the junction between the Taganopol river and one of its tributary quartz veins impregnated by pyrite (EOR-013, 014) are located. Wall rocks are silicified and pyritized. Strike and dip of veins are N35° -45° W, 40° -60° W. Width are 8-20cm, and extension is 1-2m. Au content of samples EOR-013 and EOR-014 are 0.31g/t and <0.03g/t respectively. These quartz veins are presumably hydrothermal in origin because they contains pyrite and gold and an adjacent quartz veins contain pyrite and wall rocks are pyritized and silicified.

**(2) Carorongan Mineral Occurrence:** This area was selected as promising through first phase survey. This year we carried out detailed geological survey and soil geochemical survey. This area has been probably explored by Aurora Mining Company and Virmagold in 1930 to 1945.

This occurrence is located about 1.5km east of Ananon and situated in the Carorongan creek. It takes about two hours to reach this occurrence on foot through mountain trails. In the southwestern part of this silicified vein, topography is steep with many small waterfalls and geology consists of silicified rocks. On the contrary, in the northeastern part of silicified vein, the topography is gentle and outcrop is traced about 25m eastward. Sampling and survey point of last year (BCOR-014, BCOR-014-1) is in the southern end Fig.14. Geology consists of green-schist of Catanduanes Formation and volcanic rocks of Payo Formation. The former underwent mineralization and alteration but the latter did not. Mineral indication are composed of silicified veins, silicified zone, clay veins, and floats of quartz. Gold is mostly found in silicified and clay veins. Some gold are contained in silicified zones and trace amounts are indicated in floats of quartz.

Alteration consists of silicification, argillization and weak pyritization. Au extension of mineralized zone is oriented in a Northwestern-Southeastern direction having a distance 50-100m width and 200m length. Center of mineralization is located at silicified vein with pyrite impregnation and clay veins with pyrite. Hanging wall side is silicified with some pyrite. This silicified vein is possibly mineralized along a strike-slip

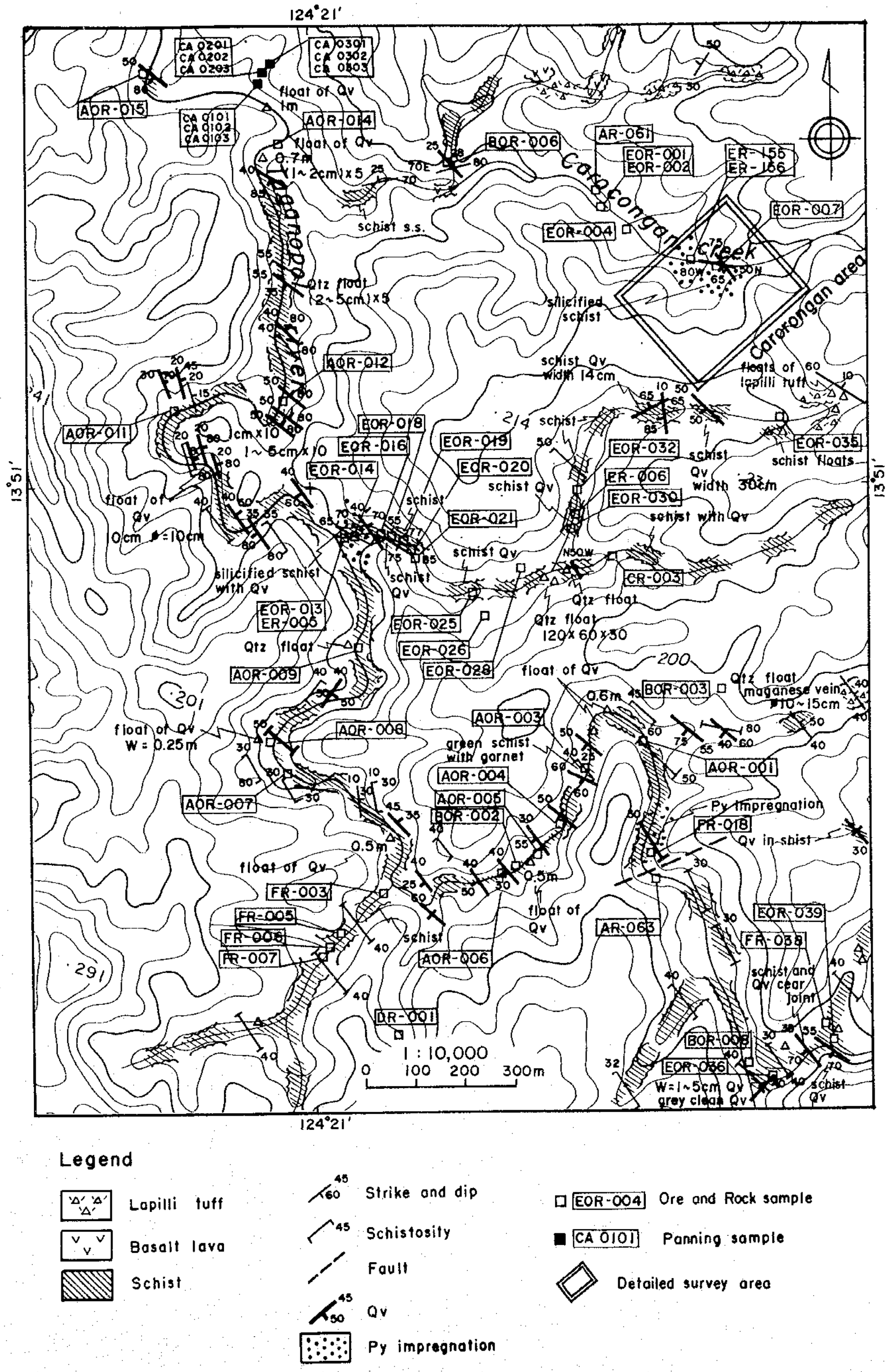



**Fig. 12 Route Map of the Ananon Area**

## Table 7 Assay Results of the Ananon South Area

| Sample No. | Sample Type | Width (cm) | Au g/t | Ag ppm | Cu % | Pb % | Zn % |
|---|---|---|---|---|---|---|---|
| AOR-001 | Qv flt | φ 40 | <0.03 | <2 | 0.001 | 0.003 | 0.004 |
| AOR-003 | Qv flt | φ 100 | <0.03 | <2 | 0.001 | 0.004 | 0.003 |
| AOR-004 | Qv flt | φ 10 | <0.03 | <2 | <0.001 | 0.001 | 0.001 |
| AOR-005 | Qv flt & limo | φ 20 | <0.03 | <2 | 0.010 | <0.001 | 0.006 |
| AOR-006 | Qv flt | φ 15 | <0.03 | <2 | 0.002 | <0.001 | 0.001 |
| AOR-007 | Qv flt | φ 60 | <0.03 | <2 | <0.001 | 0.001 | 0.001 |
| AOR-008 | Qv flt | φ 250 | <0.03 | <2 | <0.001 | 0.001 | 0.001 |
| AOR-009 | Qv flt | φ 20 | <0.03 | <2 | <0.001 | 0.001 | <0.001 |
| AOR-010 | Qv flt | φ 2 | <0.03 | <2 | 0.002 | 0.001 | 0.003 |
| AOR-011 | Qv flt | φ 10 | <0.03 | <2 | <0.001 | 0.002 | 0.002 |
| AOR-012 | Qv flt | φ 150 | <0.03 | <2 | <0.001 | 0.002 | <0.001 |
| AOR-013 | Qv flt | φ 5 | <0.03 | <2 | <0.001 | 0.002 | <0.001 |
| AOR-014 | Qv flt | φ 3 | <0.03 | <2 | <0.001 | 0.001 | 0.001 |
| AOR-015 | Qv flt | φ 2 | <0.03 | <2 | <0.001 | 0.001 | <0.001 |
| AR-061 | sil sch with Py | 5 | 2.27 | <2 | 0.005 | 0.002 | 0.004 |
| AR-063 | Qv in sch,flt | 4 | <0.03 | <2 | <0.001 | 0.002 | 0.001 |
| BOR-002 | Qv in shear zone | 10 | <0.03 | <2 | <0.001 | 0.002 | 0.001 |
| BOR-003 | Qv with Mn | 10 | <0.03 | <2 | <0.001 | 0.002 | 0.002 |
| BOR-006 | Qv in Payo form | 3max | <0.03 | <2 | 0.006 | <0.001 | 0.007 |
| BOR-008 | Qv flt | φ 10 | <0.03 | <2 | <0.001 | 0.001 | <0.001 |
| CR-003 | Qv in sch | 5 | <0.03 | <2 | 0.005 | 0.001 | 0.004 |
| DR-001 | Py,Ch in sch | 3 | <0.03 | <2 | 0.012 | 0.003 | 0.010 |
| EOR-001 | Qv in sch | 3 | <0.03 | <2 | 0.001 | 0.001 | 0.001 |
| EOR-002 | Qv in sch | 3 | <0.03 | <2 | 0.011 | 0.002 | 0.006 |
| EOR-004 | Qv flt | φ 70 | 3.83 | <2 | <0.001 | 0.003 | 0.002 |
| EOR-007 | Qv in sch | 6 | 0.09 | <2 | 0.005 | <0.001 | 0.002 |
| EOR-013 | Qv in sch | 12 | 0.31 | <2 | 0.001 | 0.003 | 0.003 |
| EOR-014 | Qv in sil sch | 20max | <0.03 | <2 | 0.002 | 0.001 | 0.002 |
| EOR-016 | Qv in sil sch | 2 | <0.03 | <2 | 0.002 | 0.002 | 0.002 |
| EOR-018 | Qv in sch | 5max | <0.03 | <2 | 0.006 | 0.002 | 0.006 |
| EOR-019 | Qvlet in sch | 2 | <0.03 | <2 | 0.004 | 0.003 | 0.005 |
| EOR-020 | Qvlet in sch | 1.5max | <0.03 | <2 | <0.001 | 0.002 | 0.002 |
| EOR-021 | Qv in sch | 12max | <0.03 | <2 | 0.001 | 0.002 | 0.002 |
| EOR-025 | Qv in sch | 8max | <0.03 | <2 | 0.001 | 0.001 | 0.002 |
| EOR-026 | Qv in sch | 3max | <0.03 | <2 | 0.002 | 0.002 | 0.003 |
| EOR-028 | Qv in sch | 6max | <0.03 | <2 | 0.005 | 0.004 | 0.003 |
| EOR-030 | Qv in sch | 2max | <0.03 | <2 | 0.002 | 0.002 | 0.002 |
| EOR-032 | Qv in sch | 6 | <0.03 | <2 | 0.008 | 0.003 | 0.006 |
| EOR-035 | Qv in sch | 30max | 2.43 | <2 | 0.003 | 0.003 | 0.003 |
| EOR-036 | Qv,Ep in sch | 2 | <0.03 | <2 | 0.001 | 0.002 | 0.002 |
| EOR-039 | Qvlet in sch | 2 | <0.03 | <2 | 0.004 | 0.003 | 0.006 |
| ER-005 | sil sch with Py | 5 | 0.06 | 2 | 0.012 | 0.004 | 0.015 |
| ER-006 | sil sch,Py flt | φ 10 | <0.03 | 4 | 0.020 | 0.006 | 0.009 |
| ER-155 | Qv in sil sch | 0.5 | 0.12 | <2 | 0.009 | 0.004 | 0.008 |
| ER-156 | limo in sch,flt | 0.5 | 0.68 | <2 | 0.035 | 0.006 | 0.013 |
| FR-003 | milky Qv in sch | 3 | <0.03 | <2 | 0.008 | 0.003 | 0.005 |
| FR-005 | milky Qv flt | hs | <0.03 | <2 | 0.003 | 0.003 | 0.002 |
| FR-006 | milky Qv | hs | <0.03 | <2 | 0.001 | 0.003 | 0.003 |
| FR-007 | milky Qv in sch | 4 | <0.03 | <2 | <0.001 | 0.003 | <0.001 |
| FR-018 | Qv,Py in sch | 4 | 0.06 | <2 | 0.019 | 0.003 | 0.014 |
| FR-038 | Qv flt with Py | 15 | 0.03 | <2 | <0.001 | 0.002 | 0.002 |

[Abbreviations] Qv:quartz vein, Qvlet:quartz veinlet, flt:float,
sil:siliceous, sch:schist, Py:pyrite, Mn:manganese, Ch:chlorite
limo:limonite, form:formation, hs:hand specimen

fault in green-schist. Mineralization could probably extend eastward wherein topography is gentle but due to concealment brought about by the overlying Payo Formation, we cannot deduce the mineralization extension. Hydrothermal solution may come up through the strike-slip fault and altered the abjacent hanging wall side.

Silicified veins are located at two points separated 25m apart. The west vein strikes N40° W and dips 40° W and width of vein is 2.0m. The east vein is observed in small outcrop about 1m high and 4m long. The east vein consist of silicified vein with pyrite. Trend of this vein is N60° W and dip 35° W, and its present width is 70cm. This is possibly due to erosion which destroyed original vein. Trace of the vein is concealed by Quaternary sediments but inferred to be continuous as indicated by its nearly same direction and character of mineralization and alteration is similar.

The west silicified vein is in contact with clay veins and at 8m distance at its footwall side, clay veins are disposed, all of which contain gold.

Silicified zone has some pyrite impregnation and does not show schistosity where silicification is strong. Occasionally quartz veinlets measuring several millimeters to 2cm are observed in silicified zone. This small veins hardly accompany pyrite, but it contains Au (BCOR-014, 0.68g/t of Au; JICA and MMAJ,1994). So this small veins are hydrothermal in origin.

Floats of quartz veins are distributed at the southeastern part of the silicified veins. Biggest float is 1.0m in size. These floats are milky white and without pyrite, and they are similar to floats encountered at the Taganopol river.

As the result of X-ray powder diffraction analysis, medium to small amounts of feldspar, quartz, sericite, chlorite and trace amount of montmorillonite were detected in the clay samples (ER-003, ER-004).

Under the microscope, large amounts of pyrite, small amount of chalcocite, chalcopyrite, sphalerite, magnetite and hematite in silicified vein (EP-160), and medium amount of pyrite and small amount of limonite are detected in silicified vein (EOR-010).

Results of ore analysis are shown in Table 8. Element other than Au is traceable. A 2m thick vein of the west vein was samples in 3 parts (EOR-008, ER-157, ER-160, Au content is 3.27 g/t, 0.87g/t, 0.75g/t, respectively) and average grade is 1.29g/t Au. One hand specimen 5cm wide inside in this vein (EOR-010) contains 65.19g/t Au. On the contrary, gold content of the east vein (ER-165) is 2.46g/t Au. Clay veins, samples EOR-003, EOR-004, EOR-009, EOR-163 show respectively 2.3g/t, 1.71g/t, 10.70g/t, 0.81g/t of gold. Silicified rock shows 0.62g/t (EOR-011). Float of quartz vein (ER-156) show 0.68g/t Au. Homogenization temperature of quartz (ER-164) was not measured because inclusions were too small to measure.

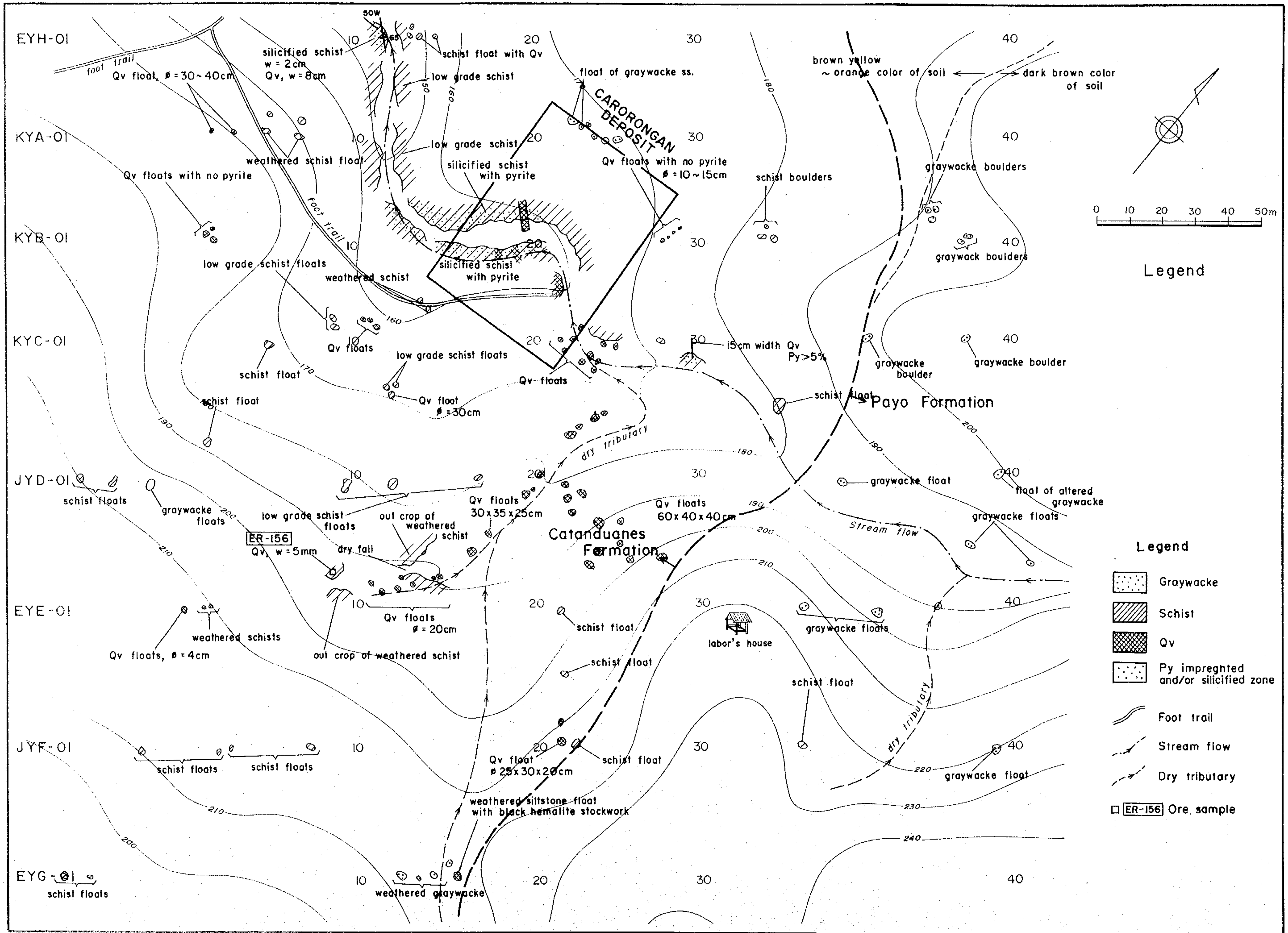
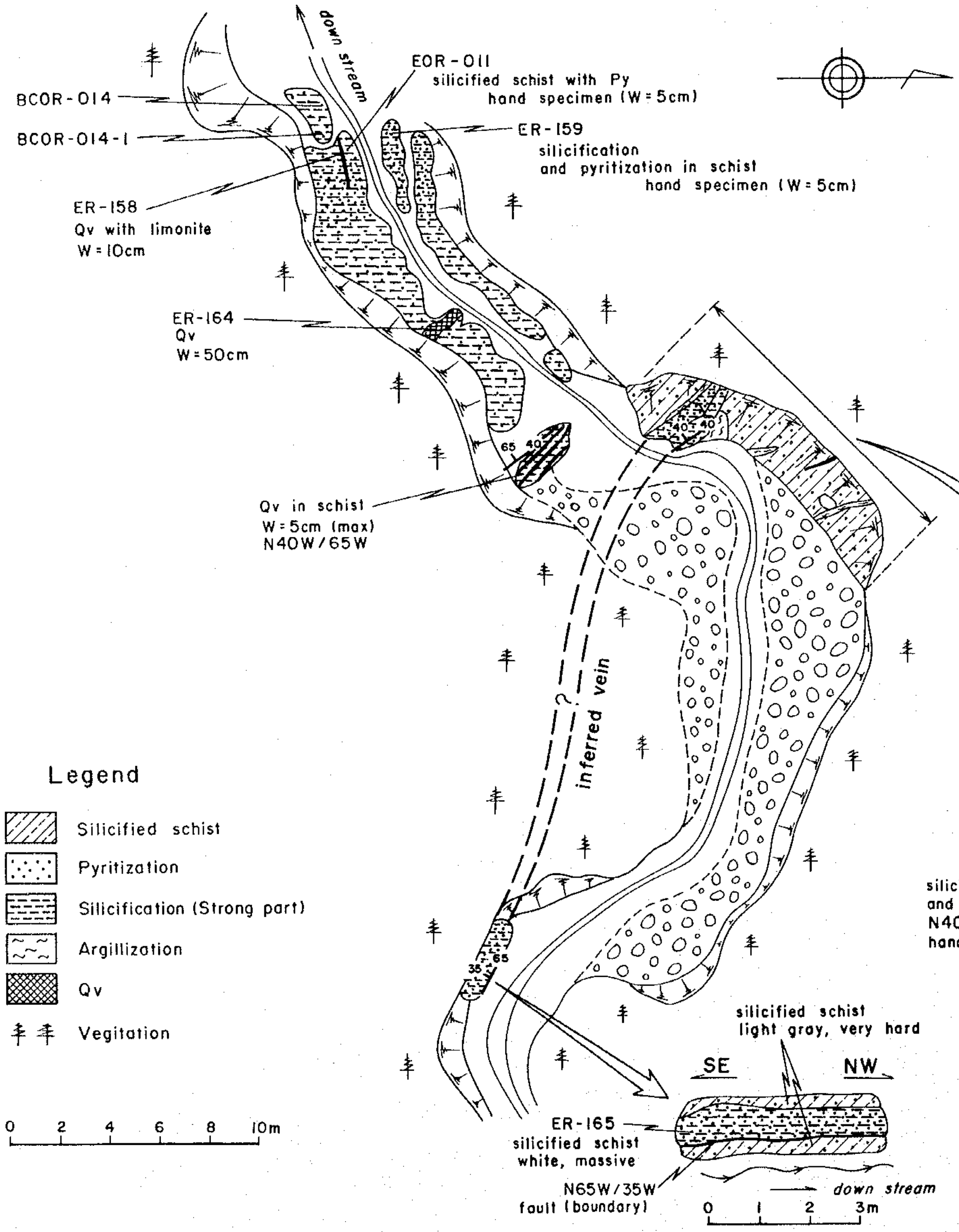
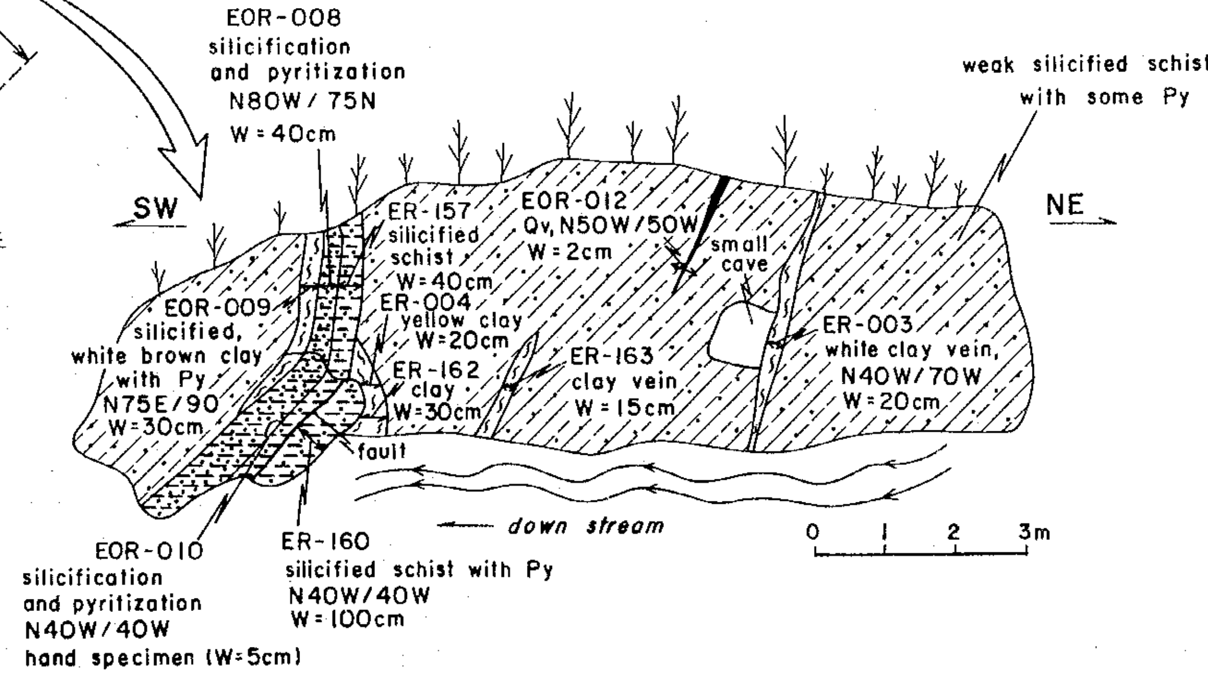



Fig. 13 Route Map of the Carorongan Mineral Occurrence




| Sample No. | Sample Type | Width (cm) | Au g/t | Ag ppm | Cu % | Pb % | Zn % |
|---|---|---|---|---|---|---|---|
| EOR-011 | sil sch with Py | hs 5 | 0.62 | <2 | 0.012 | 0.002 | 0.011 |
| ER-158 | Qv with limonite | 10 | 1.65 | <2 | 0.015 | 0.003 | 0.009 |
| ER-159 | sil sch with Py | hs 5 | 1.09 | <2 | 0.014 | 0.005 | 0.011 |
| ER-164 | Qv with sil sch | 50 | 0.19 | <2 | <0.001 | 0.003 | 0.006 |
| ER-165 | sil sch with Py | 50 | 2.46 | <2 | 0.005 | 0.007 | 0.006 |
| BCOR-014* | sil sch with Py | hs 10 | 1.71 | <2 | 0.009 | <0.001 | 0.035 |
| BCOR-014-1* | Qvlts | hs 5 | 0.68 | <2 | 0.008 | <0.001 | 0.074 |

sil:siliceous, sch:schist, Qvlts:quartz veinlets, alt:alteration,
Py:pyrite, hs:hand specimen *:MMAJ(1994)




| Sample No. | Sample Type | Width (cm) | Au g/t | Ag ppm | Cu % | Pb % | Zn % |
|---|---|---|---|---|---|---|---|
| EOR-008 | sil & Py | 40 | 3.27 | <2 | 0.004 | 0.003 | 0.008 |
| EOR-009 | sil,Py & clay | 30 | 10.70 | <2 | 0.006 | 0.001 | 0.006 |
| EOR-010 | sil,many Py | hs 5 | 65.19 | <2 | 0.001 | 0.002 | 0.003 |
| EOR-012 | small Qv | 2 | 0.65 | <2 | 0.004 | 0.001 | 0.004 |
| ER-003 | white clay vein | 20 | 2.30 | <2 | 0.030 | 0.004 | 0.010 |
| ER-004 | yellow clay | 20 | 1.71 | <2 | 0.018 | 0.002 | 0.015 |
| ER-157 | sil sch with Py | 40 | 0.87 | <2 | 0.002 | 0.002 | 0.002 |
| ER-160 | sil sch with Py | 100 | 0.75 | <2 | 0.016 | 0.005 | 0.009 |
| ER-162 | yellow clay | 30 | 0.65 | <2 | 0.022 | 0.006 | 0.023 |
| ER-163 | clay vein | 15 | 0.81 | <2 | 0.012 | 0.004 | 0.019 |

**Fig. 14 Sketch of the Carorongan Mineral Occurrence**

**Table 8 Assay Results of the Carorongan Mineral Occurrence**

| Sample No. | Sample Type | Width (cm) | Au g/t | Ag ppm | Cu % | Pb % | Zn % |
|---|---|---|---|---|---|---|---|
| EOR-008 | sil & Py | 40 | 3.27 | <2 | 0.004 | 0.003 | 0.008 |
| EOR-009 | sil,Py & clay | 30 | 10.70 | <2 | 0.006 | 0.001 | 0.006 |
| EOR-010 | sil,many Py | hs 5 | 65.19 | <2 | 0.001 | 0.002 | 0.003 |
| EOR-011 | sil sch with Py | hs 5 | 0.62 | <2 | 0.012 | 0.002 | 0.011 |
| EOR-012 | small Qv | 2 | 0.65 | <2 | 0.004 | 0.001 | 0.004 |
| ER-003 | white clay vein | 20 | 2.30 | <2 | 0.030 | 0.004 | 0.010 |
| ER-004 | yellow clay | 20 | 1.71 | <2 | 0.018 | 0.002 | 0.015 |
| ER-157 | sil sch with Py | 40 | 0.87 | <2 | 0.002 | 0.002 | 0.002 |
| ER-158 | Qv with limonite | 10 | 1.65 | <2 | 0.015 | 0.003 | 0.009 |
| ER-159 | sil sch with Py | hs 5 | 1.09 | <2 | 0.014 | 0.005 | 0.011 |
| ER-160 | sil sch with Py | 100 | 0.75 | <2 | 0.016 | 0.005 | 0.009 |
| ER-162 | yellow clay | 30 | 0.65 | <2 | 0.022 | 0.006 | 0.023 |
| ER-163 | clay vein | 15 | 0.81 | <2 | 0.012 | 0.004 | 0.019 |
| ER-164 | Qv with sil sch | 50 | 0.19 | <2 | <0.001 | 0.003 | 0.006 |
| ER-165 | sil sch with Py | 50 | 2.46 | <2 | 0.005 | 0.007 | 0.006 |

[Abbreviations] sil:siliceous, Py:pyrite, sch:schist, Qv:quartz vein, hs:hand specimen

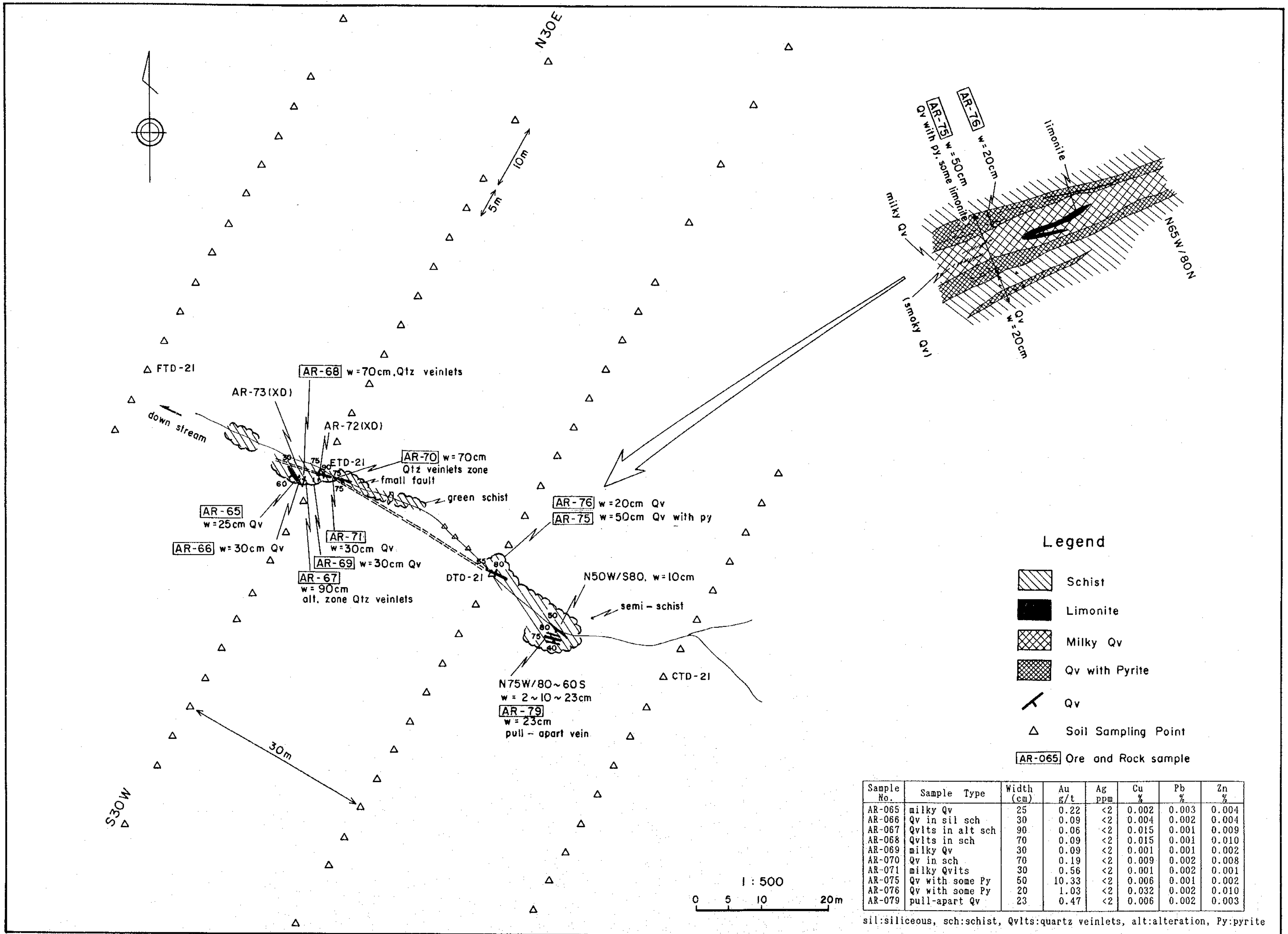
**(3) Taganopol Mineral Occurrence:** The occurrence is located in 3km southeast of Ananon. It takes 3.5 hours along the Taganopol river from Ananon and 2 hours along the mountain trail from Mabini on foot to reach there.

The occurrence is situated in the tributary of the Taganopol river. Many outcrops are distributed along the tributary below the occurrence. However except the creek, outcrops are very rare in the surrounding hill.

Geology consists of green-schist of Catanduanes Formation so long as the outcrops are concerned. The schist is sporadically underwent silicification and is accompanied with the segregation quartz veins in places. Floats of massive barren milky quartz veins are scattered in the creek and they are 10-50cm in size.

The outcrops of quartz veins are located at two points separated 30m apart. As shown in Fig.15, the east vein strikes N65° W and dips 80° N and width of the vein is 50cm and extends 2.5m. The central part of vein is essentially composed of massive, hard milky white quartz vein without pyrite, though it has some limonite and smoky quartz partly. Both sides of the central part consist of pyrite bearing quartz veins and they are considerably easy to be broken compared with central part. The pyrite is coarse and is 1-5mm in size.

The west veins are composed of several quartz veins and veinlets surrounded by brownish white clay. The west veins are composed of milky white fine grained quartz veins. They are hard and do not accompany pyrite within them. Quartz veins are irregularly oriented, but the main vein (AR-071) strikes N75° W and




| Sample No. | Sample Type | Width (cm) | Au g/t | Ag ppm | Cu % | Pb % | Zn % |
|---|---|---|---|---|---|---|---|
| AR-065 | milky Qv | 25 | 0.22 | <2 | 0.002 | 0.003 | 0.004 |
| AR-066 | Qv in sil sch | 30 | 0.09 | <2 | 0.004 | 0.002 | 0.004 |
| AR-067 | Qvlts in alt sch | 90 | 0.06 | <2 | 0.015 | 0.001 | 0.009 |
| AR-068 | Qvlts in sch | 70 | 0.09 | <2 | 0.015 | 0.001 | 0.010 |
| AR-069 | milky Qv | 30 | 0.09 | <2 | 0.001 | 0.001 | 0.002 |
| AR-070 | Qv in sch | 70 | 0.19 | <2 | 0.009 | 0.002 | 0.008 |
| AR-071 | milky Qvlts | 30 | 0.56 | <2 | 0.001 | 0.002 | 0.001 |
| AR-075 | Qv with some Py | 50 | 10.33 | <2 | 0.006 | 0.001 | 0.002 |
| AR-076 | Qv with some Py | 20 | 1.03 | <2 | 0.032 | 0.002 | 0.010 |
| AR-079 | pull-apart Qv | 23 | 0.47 | <2 | 0.006 | 0.002 | 0.003 |

sil:siliceous, sch:schist, Qvlts:quartz veinlets, alt:alteration, Py:pyrite

**Fig. 15 Sketch of the Taganopol Mineral Occurrence**

dips 90° and width of vein is 30cm. The veinlets are composed of quartz veins with the width of 1-10mm, and they from a veinlets zone of 70cm wide.

The trace of both veins are concealed by Quaternary sediments, but inferred to be continuous as indicated by its nearly same direction.

As the result of X-ray powder diffraction analysis, large amount of feldspar, medium amount of quartz, small amount of chlorite, sericite and kaolinite, and trace amount of montmorillonite were detected in the white clay (AR-073). Large amount of feldspar, medium amount of quartz, chlorite and calcite, small amount of montmorillonite, sericite and pyrite were detected in the silicified green-schist (ER-005).

Results of ore analysis are shown in Table 9. Contents of gold are 1.03g/t (AR-075) and 10.33g/t (AR-076) in the east vein, and 0.56g/t in the main vein (AR-071) and 0.19g/t in the quartz veinlets zone (AR-070) of the west veins.

**Table 9 Assay Results of the Taganopol Mineral Occurrence**

| Sample No. | Sample Type | Width (cm) | Au g/t | Ag ppm | Cu % | Pb % | Zn % |
|---|---|---|---|---|---|---|---|
| AR-065 | milky Qv | 25 | 0.22 | <2 | 0.002 | 0.003 | 0.004 |
| AR-066 | Qv in sil sch | 30 | 0.09 | <2 | 0.004 | 0.002 | 0.004 |
| AR-067 | Qvlts in alt sch | 90 | 0.06 | <2 | 0.015 | 0.001 | 0.009 |
| AR-068 | Qvlts in sch | 70 | 0.09 | <2 | 0.015 | 0.001 | 0.010 |
| AR-069 | milky Qv | 30 | 0.09 | <2 | 0.001 | 0.001 | 0.002 |
| AR-070 | Qv in sch | 70 | 0.19 | <2 | 0.009 | 0.002 | 0.008 |
| AR-071 | milky Qvlts | 70 | 0.56 | <2 | 0.001 | 0.002 | 0.001 |
| AR-075 | Qv with some Py | 50 | 10.33 | <2 | 0.006 | 0.001 | 0.002 |
| AR-076 | Qv with some Py | 20 | 1.03 | <2 | 0.032 | 0.002 | 0.010 |
| AR-079 | pull-apart Qv | 23 | 0.47 | <2 | 0.006 | 0.002 | 0.003 |

[Abbreviations] Qv:quartz vein, Qvlts:quartz veinlets, sil:siliceous, sch:schist, Py:pyrite

Judging from the above data, these quartz veins are different from the segregation quartz veins in size, content of gold, an existence of alteration, homogenization temperature. Then these veins are judged to be hydrothermal origin.

Many quartz floats are found in the lower reaches of the hydrothermal quartz veins. Expect for the vicinity of the veins, most floats are composed of white milky, hard, massive quartz veins without pyrite. It is inferred that both sides of the central part of the vein were broken and disintegrated into small fragments and pyrite bearing parts were disappeared when the vein floats were rolling downward from the original places and were in the weathering process. Accordingly, it is estimated that many big floats of barren milky quartz veins along the Taganopol river and its tributary may contain hydrothermal origin just like the case here.

### 1-4-2 Silicified Zone

The silicified zones are distributed in the central and southern parts of the survey area.

The zones are generally 150m by 200m in dimensions except one whose ones is 300m by 600m. The rocks of the zone is gray to pale greenish gray in color and they are hard because of medium to weak silicification. The original rock of the zone is mainly graywacke. Small amount of pyrite and occasionally small veins of quartz and/or calcite are observed in the zones. It can be inferred that there is plutonic intrusion deep underneath the silicified zone and the silicification represents the surface indications of the intrusion and/or related mineralization in some of them.

**(1) Pinadaysan Area:** This area is located in the central part of the survey area. The upper reaches of the Tabyonan creek and its tributaries i.e. the Pinadaysan and the Pinugbyby creeks are included in this area (Fig.16)

The geology is composed of graywacke with red brown thin layers of acidic tuff.

At the intersection between the Tabyonan creek and the Pinadaysan creek, the rocks are sheared by the Northeast-Southwest trending faults. The width of the sheared zone is about 100m. The rocks of the sheared zone is highly chloritized, silicified and pyritized. Milky quartz veins with 1cm wide are observed occasionally in this sheared zone.

As the result of X-ray powder diffraction analysis, large amount of quartz and feldspar, medium amount of chlorite and calcite, small amount of sericite were detected in the clay from the sheared zone (ER-112). Small amount of interstratified mineral (chlorite /montmorillonite), chlorite, sericite and quartz were detected in the weakly altered graywacke (JR-019).

Aplite dike with 5m wide is intruded into graywacke along North-South oriented fault and surrounding rocks are subjected to silicification and weak pyritization. Under the microscope, the aplite (ER-111) underwent sericitization.

Results of ore analysis is shown in Table 10 and all elements are traceable.

**Table 10 Assay Results of the Pinadaysan Area**

| Sample No. | Sample Type | Width (cm) | Au g/t | Ag ppm | Cu % | Pb % | Zn % |
|---|---|---|---|---|---|---|---|
| AR-040 | Qv in sil ss | 3 | <0.03 | <2 | 0.011 | 0.003 | 0.009 |
| AR-044 | Py in sil ss | hs | <0.03 | <2 | 0.014 | 0.002 | 0.010 |
| ER-105 | Qv & Ep in ss | 10 | <0.03 | <2 | 0.005 | 0.003 | 0.006 |
| ER-108 | Qv & Ep in clay | hs | <0.03 | <2 | 0.029 | 0.003 | 0.010 |
| ER-110 | Qv &Py in sil ss | 15 | <0.03 | <2 | 0.012 | 0.004 | 0.010 |
| JR-022 | sil ss with Py | hs | <0.03 | 4 | 0.010 | 0.002 | 0.010 |

[Abbreviations] sil:siliceous, ss:sandstone, Qv:quartz vein, Py:pyrite, Ep,epidote, hs:hand specimen

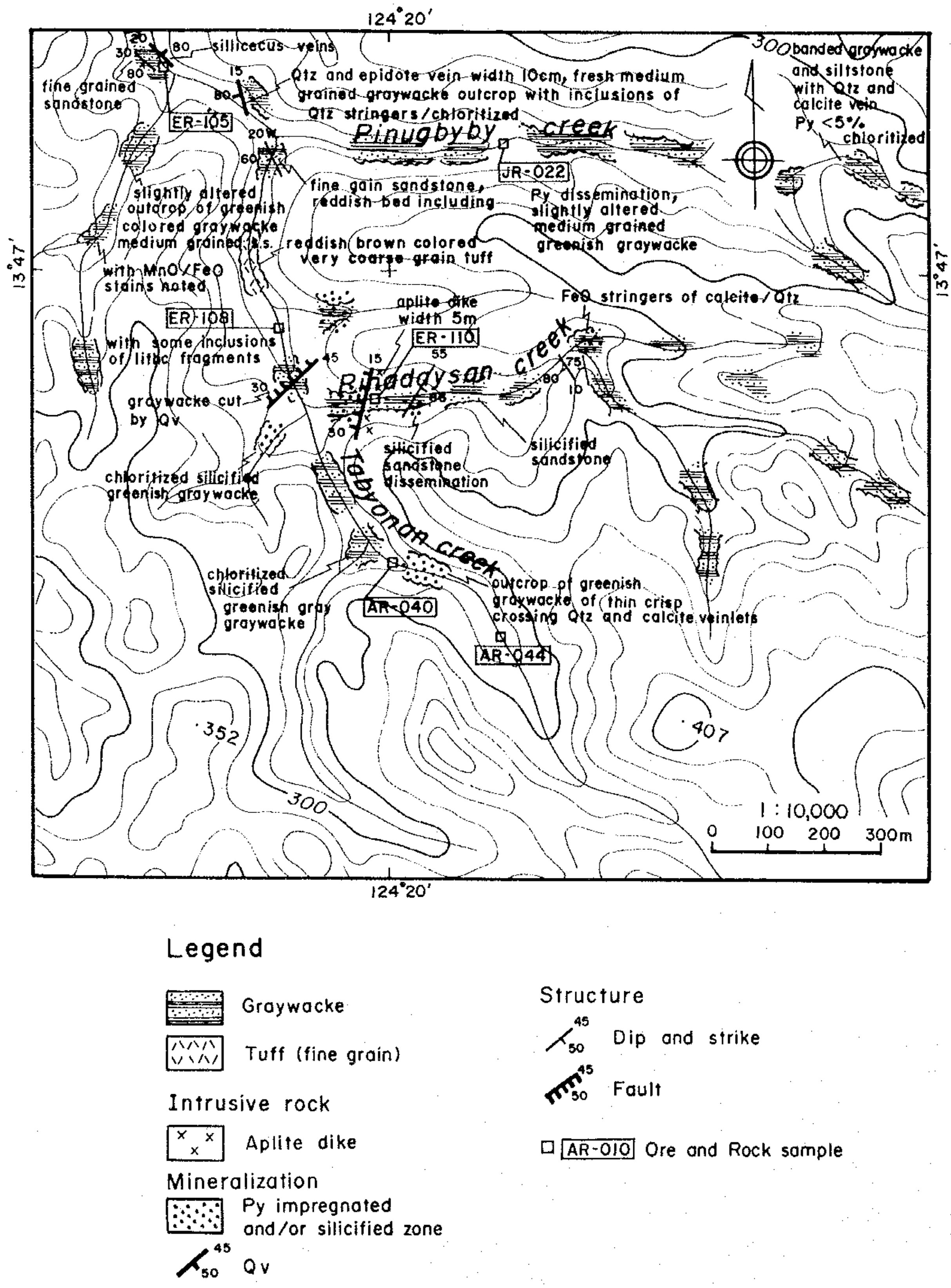



Fig. 16 Route Map of the Pinadaysan Area

**(2) Maytung Area:** The area is located in the southern part of the survey area. At the middle and lower part of the Maytung river, the East-West trending fault intersects the river. The river meanders in the vicinity of the intersections.

The geology consists of graywacke with clear graded bedding and overturn folding is observed by noted bedding in the middle reaches of the river.

Silicified zone is about 300m by 600m in dimensions. In the zone, graywacke underwent silicification and some pyritization. Outside the map of Fig 17, two small silicified zones are distributed in the upper reaches of the river. Following is the explanation on the largest silicified zone with the dimension of 300m by 600m.

As the results of X-ray powder diffraction analysis, medium amount of quartz, small amount of chlorite, sericite and epidote were detected in silicified vein (ER-042). Large amount of quartz, medium amount of chlorite, sericite and prehnite were detected in silicified graywacke (EOR-068). Beside the minerals mentioned above, large to small amounts of calcite was detected in silicified graywacke (EOR-064~EOR-067).

Under the microscope, Large amount of quartz, chlorite and sericite, medium to small amounts of epidote and calcite were detected as the altered minerals in coarse graywacke (ER-046). As the ore minerals, trace amount of chalcocite, bornite, chalcopyrite and pyrite were identified. Concerning copper minerals, such mineral assemblages as chalcopyrite-bornite and bornite- chalcocite were noted, but chalcopyrite-chalcocite assemblage was not recognized .

The results of ore analysis of the silicified zone is shown in Table 11. Contents of elements are very low.

**Table 11 Assay Results of the Maytung Area**

| Sample No. | Sample Type | Width (cm) | Au g/t | Ag ppm | Cu % | Pb % | Zn % |
|---|---|---|---|---|---|---|---|
| EOR-060 | Qv in sil ss | 6max | <0.03 | <2 | 0.004 | 0.003 | 0.006 |
| EOR-061 | sil ss& Qv,Py,Ca | 1 | <0.03 | <2 | 0.007 | 0.002 | 0.007 |
| EOR-064 | sil ss flt&Qv,Py | 2 | <0.03 | <2 | 0.023 | 0.004 | 0.012 |
| EOR-065 | sil ss & Qv,Py | 1 | <0.03 | <2 | 0.013 | 0.004 | 0.010 |
| EOR-068 | sil ss & Qv,Py | 1 | <0.03 | <2 | 0.014 | 0.002 | 0.012 |
| EOR-069 | sil ss & Qv,Py | 1 | <0.03 | <2 | 0.023 | 0.002 | 0.013 |
| EOR-071 | sil ss flt&Qv,Py | 5 | <0.03 | <2 | 0.002 | 0.002 | 0.004 |
| EOR-074 | Qv in ss | 2 | <0.03 | <2 | 0.006 | 0.003 | 0.008 |
| ER-032 | sil ss | 1 | <0.03 | 4 | 0.010 | 0.003 | 0.009 |
| ER-039 | sil ss & Ep | 1 | <0.03 | <2 | 0.009 | 0.002 | 0.009 |
| ER-042 | sil vein | 7 | <0.03 | <2 | 0.002 | 0.005 | 0.002 |
| GR-002 | sil ss with Py | hs | <0.03 | <2 | 0.011 | 0.003 | 0.009 |

[Abbreviations] Qv:quartz vein, sil:siliceous, ss:sandstone, flt:float, Py:pyrite, Ca:calcite, Ep,epidote, hs:hand specimen

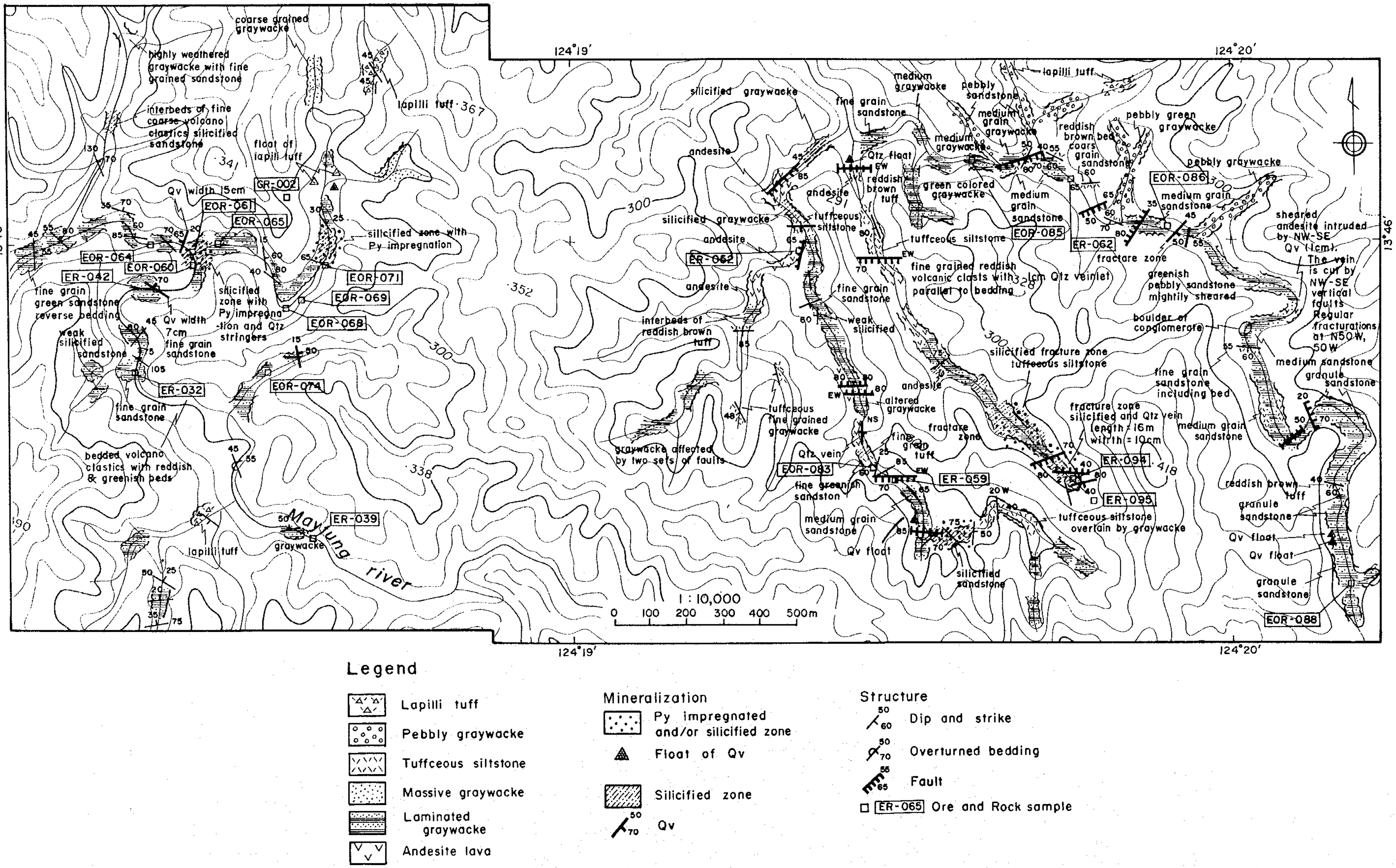



**Fig. 17 Route Map of the Maytung Area and Kaipa Area**

(3) **Kaipa Area:** Silicified zones are located in the upper reaches of the Kaipa river. The geology consists of graywacke with clear bedding, acidic tuff, lapilli tuff and lavas of basaltic to andesitic composition.

Two faults extending East-West direction occur. Two silicified zones and one argillized zone are located in vicinity of the southern fault. The dimensions of these zone are 300m by 150m in the silicified zones and 150m by 100m in the argillized zone. The argillized zone is located in the accessory sheared zone between two major faults.

At the points about 80m south from the silicified zone, a hydrothermal (?) quartz vein (ER-095) cut the segregation veins which are parallel to the bedding of graywacke. The vein is 40cm wide and 16m long.

As the results of X-ray powder diffraction analysis, large amount of quartz and feldspar, medium to small amounts of calcite, chlorite, sericite (EOR-083, ER-090~ER-094), small amount of pyrite (EOR-093,094), small amount of montmorillonite (ER-092) and small amount of interstratified mineral (chl/mont, EOR-090) were detected.

Large amount of quartz, medium amount of prehnite, and small amount of kaolinite and pyrophyllite were detected in clay from the argillized zone (EOR-086).

Under the microscope, medium amount of magnetite and maghemite, trace amount of chalcocite, bornite and chalcopyrite (EOR-054), small amount of chalcopyrite and trace amount of bornite and sphalerite (ER-097) were detected in the basaltic andesite nearby the silicified zones. These ore minerals may have directly or indirectly related with the silicified and argillized zones.

Table 12 show the results of ore analysis. The contents of elements are traceable.

**Table 12 Assay Results of the Kaipa Area**

| Sample No. | Sample Type | Width (cm) | Au g/t | Ag ppm | Cu % | Pb % | Zn % |
|---|---|---|---|---|---|---|---|
| EOR-083 | clay vein | 35 | <0.03 | <2 | 0.019 | 0.003 | 0.011 |
| EOR-085 | sil ss flt | 25 | <0.O3 | <2 | 0.001 | 0.005 | 0.001 |
| EOR-086 | Qv in clay vein | 6~30 | <0.03 | <2 | 0.006 | 0.002 | 0.004 |
| EOR-088 | milky Qv flt | 20 | <0.03 | <2 | 0.021 | 0.004 | 0.011 |
| ER-052 | sil ss with Py | hs | <0.03 | <2 | 0.013 | 0.003 | 0.010 |
| ER-059 | sil ss & many Py | hs | <0.03 | <2 | 0.016 | 0.004 | 0.011 |
| ER-062 | sil ss flt &Py | hs | <0.03 | <2 | 0.013 | 0.003 | 0.010 |
| ER-094 | sil ss with Py | hs | <0.03 | <2 | 0.009 | 0.004 | 0.009 |
| ER-095 | Qv in sch(l=16m) | 40 | <0.03 | 2 | 0.008 | 0.004 | 0.006 |

[Abbreviations] sil:siliceous, Qv:quartz vein, sch:schist, flt:float, Py:pyrite, hs:hand specimen