# REPORT
# ON
# THE COOPERATIVE MINERAL EXPLORATION

# GEOLOGICAL ASSESSMENT OF CHROMITE, BASE METALS, PLATINUM AND RELATED PRECIOUS METAL OCCURRENCES IN SOUTH CENTRAL PALAWAN, THE REPUBLIC OF PHILIPPINES

## CONSOLIDATED REPORT

MARCH 1993

JAPAN INTERNATIONAL COOPERATION AGANCY
METAL MINING AGENCY OF JAPAN

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# PREFACE

The Government of Japan, in response to the request of the Government of the Republic of the Philippines, decided to conduct the mineral exploration project in South Central Palawan and Northeastern Panay and entrusted the survey to the Japan International Cooperation Agency (JICA) and the Metal Mining Agency of Japan (MMAJ).

The survey was carried out for two years from September,1990 to February,1992 and was brought to completion with the cooperation of the Government of the Republic of the Philippines,in particular,the Mines and Geosciences Bureau,Department of Environment and Natural Resources.

This final report summarized the results of Phase 1 and Phase 2 survey in the South Central Palawan.

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.

February, 1993

Kensuke Yanagiya
President
Japan International Cooperation Agency

Takashi Ishikawa
President
Metal Mining Agency of Japan

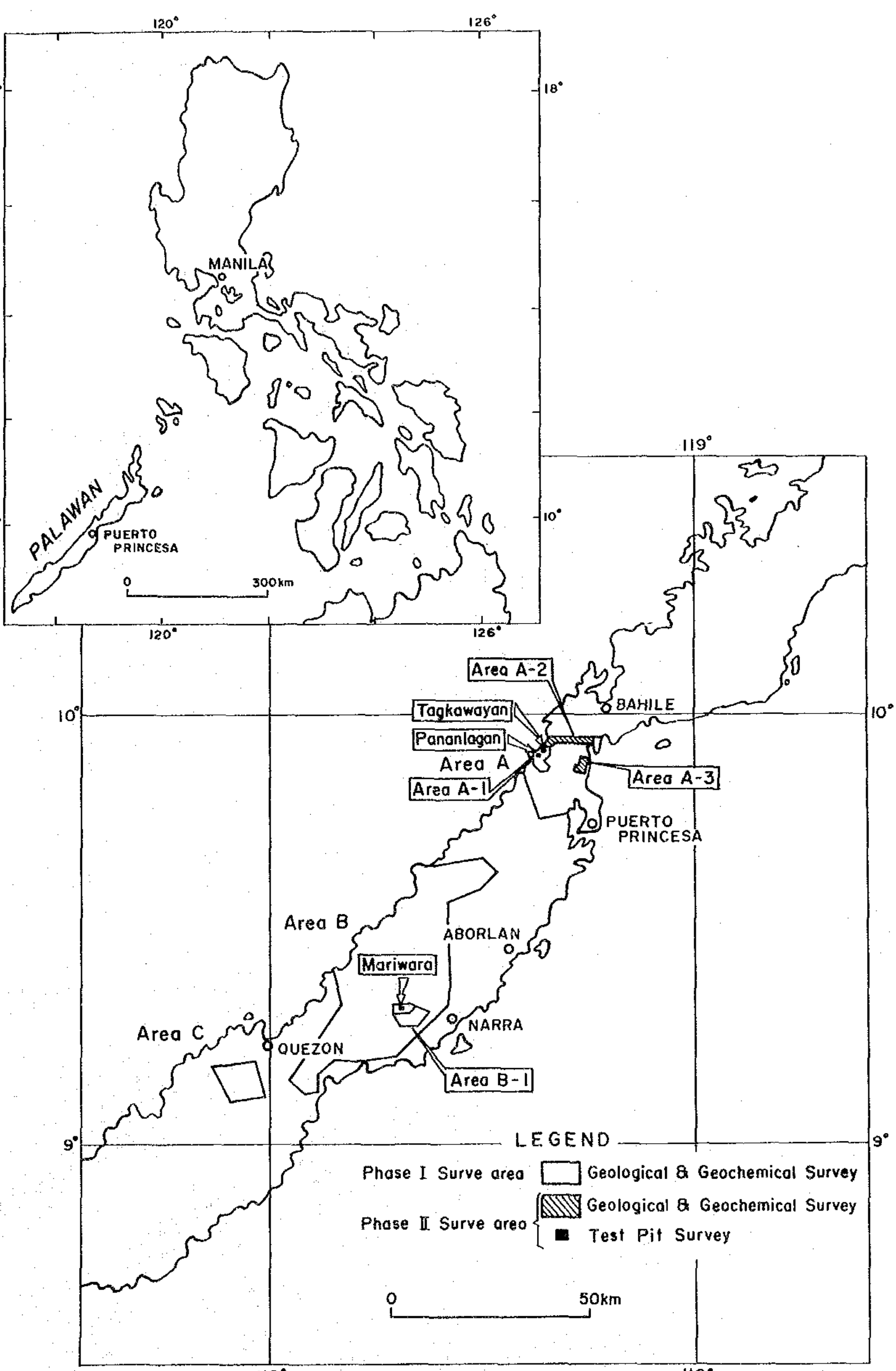



Fig. 1 Location map of the survey area

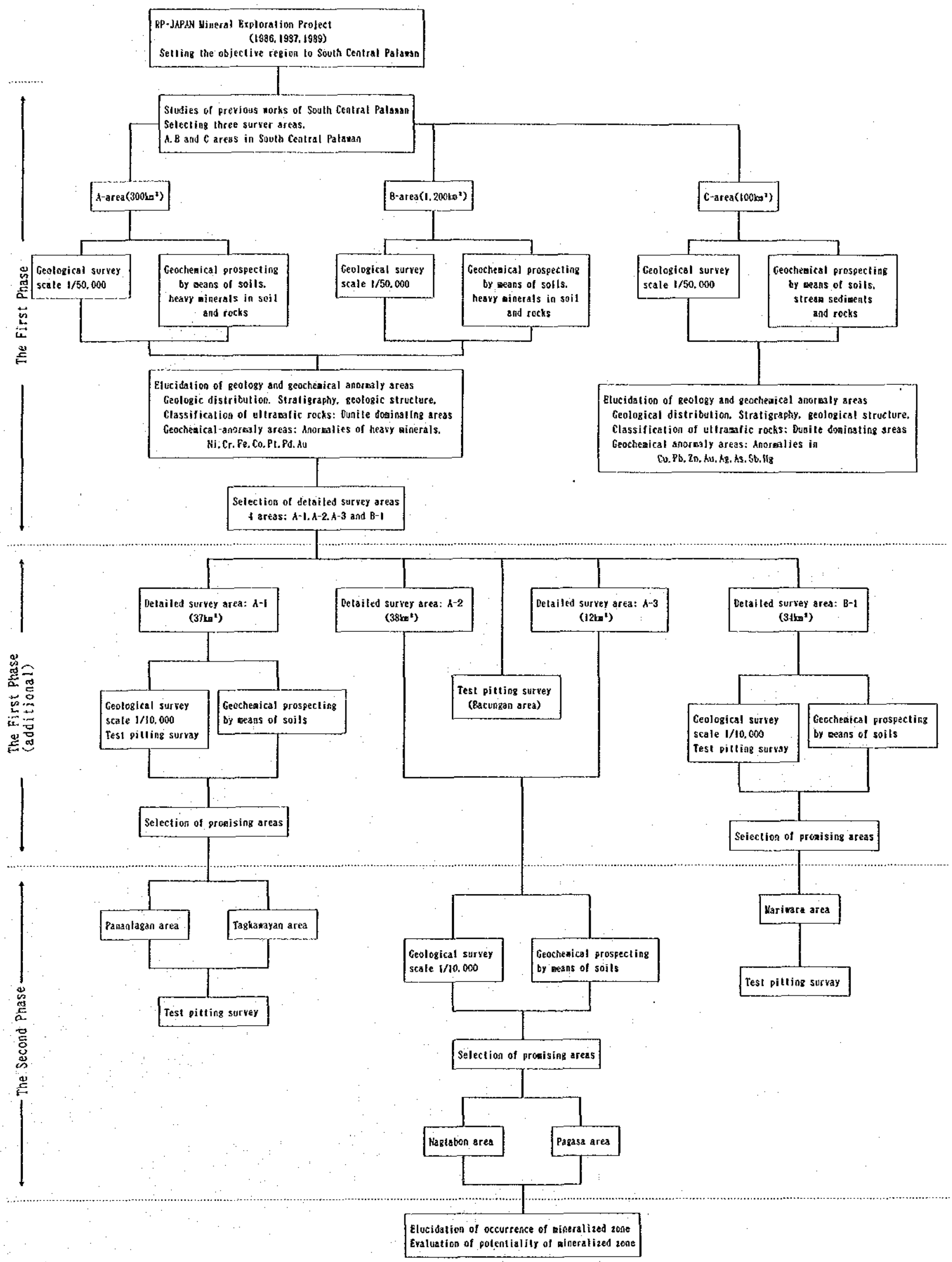



Fig. 2 Flow chart of the Exploration Program

# SUMMARY

The RP-JAPAN Mineral Exploration Project was conducted in the Republic of the Philippines from 1984 to 1989. After evaluating the result of these survey, the Cooperative Mineral Exploration Project has been conducted in South Central Palawan. The survey consists of Phase 1 geological and geochemical survey at A-area,B-area and C-area in South Central Palawan, additional Phase 1 survey at detailed survey area A-1 and B-1 selected from A-area and B-area each, and Phase 2 survey in detailed survey area A-1,A-2,A-3 and B-1.

The survey areas are underlain by the ultramafic rocks consisting mainly of hartzburgite,dunite and pyroxinite in which chromite and nickel mineral showings are contained.

Most of the chromite mineral showings in A-area are distributed in detailed survey area A-1,A-2 and A-3 which were selected after result of geological and geochemical survey in A-area. All of the chromite mineral showings exist in the diapir like dunite tectonite body shaped as intrusive rocks within hartzburgite region.

Important chromite mineral showings are distributed at Sun Chromite area,Macasaet area,Pananlagan river area ,and Tagkawayan area in area A-1, Nagtabon No.1 to No.6 deposits and Maranat deposit in area A-2, and Pagasa 1 to 4 deposits in area A-3. No extension of mineral showings were recognized at Pananlagan area and Tagkawayan area in area A-1, though test pitting survey was conducted near the chromite occurrences.

Nickel laterite occurs at north of Bacungan in area A-2, but no commercial mineral showing was found even by test pitting survey.

Important chromite mineral showings are at nearby Long Point and vicinity of Berong in west coast of B-area. Only one operating mine,Norsophil mine,is in west side of B-area. Those mineral showings in B-area occur within diapir like dunite tectonite body in hartzburgite same as those in A-area.

On the other hand, dunite body which is distributed in detailed survey area B-1 is of cumulate type. No sign was recognized indicating the existence of commercial chromite mineral showings, though test pitting survey was conducted within this cumulate type dunite body in which chromite dissemination is recognized. No nickel mineral showing was found, though test pitting survey was conducted within nickel laterite region in B-area.

Survey was conducted in C-area expecting the sulfide deposits associated to green rocks, but there was neither sulfide deposit nor chromite deposit.

Nagtabon No.1 deposit in area A-2 and Pagasa 1 deposit in area A-3 are larger ones compared to other mineral showings in the survey area. It may be possible to expect the tonnage of 2,000t at Nagtabon No.1 deposit and tonnage of 20,000 to 40,000t in Pagasa 1 deposit as chromite. That is,it may be possible to expect about 200,000t of crude ore grade of 20 to 25%$Cr_2O_3$.

Norsophil mine, only one operating chromite mine in South Central Palawan, has several deposits. Each unit deposit consist of crude ore tonnage of 200,000 to 500,000t,grade 20 to25%$Cr_2O_3$.Thinking the scale of this Norsophil mine and present market price of chromite ore,it may be pretty difficult to get commercial deposit at present in Pagasa 1 area,even if further exploration be conducted, because Pagasa 1 deposit consists of only one unit deposit .

But thinking of possibility of increase of chromite market price in future, it is preferable to conduct the drilling survey at Nagtabon No.1 deposit and Pagasa 1 deposit to clarify the occurrence of the deposits underground.

# CONTENTS

## Figures

## Tables

# PART I GENERAL REMARKS

# Chapter 1 Introduction

## 1-1 Objective of the survey and survey areas

The Cooperative Mineral Exploration Project in South Central Palawan has been conducted based on the Implementing Arrangement between the Government of the Philippines through the Mines and Geosciences Bureau(MGB) and the Government of Japan through the Japan International Cooperation Agency(JICA), together with the Metal Mining Agency of Japan(MMAJ). The Implementing Arrangement was signed on July 5, 1990 and the project was officially titled as "Geological Assessment of Chromite, Base Metals, Platinum and related precious Metal Occurrences in South Central Palawan and Northeastern Panay".

Preceding the survey, the RP-JAPAN Mineral Explration Project was conducted in the Republic of the Philippines from 1985 to 1989. After evaliating the result of these surveys, South Central Palawan and North Eastern Panay were selected as the target areas of the Cooperative Mineral Exploration Project.

The South Central Palawan has high potentiality about the mineral resources such as chromite,nikel and other minerals that are associated with ophiolite. So the survey areas were set within the ophiolite region.

The objective of this survey is to delineate the type of mineralization present such as Ni, Cr, and other minerals to identify promising areas by clarifying the geological setting,and to recognize the mode of occurrence of the mineral deposits through geological and geochemical explorations.

This program consists of geological and geochemical explorations in South Cetral Parawan. The Phase 1 survey was conducted in the area A, B and C from October to Deceiver, 1990, and the additional Phase 1 program in the detailed survey area A-1 and B-1 from January to February, 1991. The Phase 2 survey was conducted in the detailed survey areas above mentioned from September to November, 1991.

## 1-2 Contents of the survey

1) Geological and Geochemical Survey

The survey was done using topological maps on the scale of 1:10,000, which were enlarged from its original 1:50,000. Most of survey routes were set up along streams. The length of the survey route lines is 100 km in total. The results were recorded on the enlarged 1:10,000 route maps. Samples were taken for laboratory studies and geochemical investigations.

The survey for detailed survey area A-1 was conducted using maps on the scale of 1:10,000, which were enlarged from its original 1:50,000 scale maps. Survey routes were set up for main stream lines and ridges. On each survey route, simple topographic surveys using a compass and tape were conducted. Results were recorded on the route maps on a scale of 1:5,000, and then transcribed to 1:10,000 scale map.

2) Pit Survey

The Phase 1 pit survey was conducted in some important places, where mineral occurrences crop out.

Thirty-four test pits were dug in detailed survey area A-1 and 11 pits in the north of Bacungan. In the area A-1, 13 pits were dug in the laterite zone, the rest of pits were dug to examine the extension of chromite occurrences. The pits in the north of Bacungan were to confirm the existence of nickel occurrences.

The pits are approximately 1m x 1m in size, 1.2 to 3.0m deep. But the pit in the north of Bacungan is 5m deep. They were dug by hands using shovels, iron staffs, ropes, and pulleys.

Soil profiles of the pits were sketched on the scale of 1:50. Samples were taken from each soil horizons or every one meter. The sketches and the result of chemical analyses of the pits are shown in Appendix 5.

The Phase 2 test pitting survey was conducted in the area A-1 and B-1, mainly operated with the rectangular grid system. The direction of survey lines was decided to cross the general geologic trend, the spacing between survey lines was 100 meters, and the interval between pits was ranging from 20 to 25 meters. Each test pit was sunk downward until basement by hand.

Contents of the survey and their quantities held in the A, B, and C areas, and detailed survey areas A-1 and B-1 are shown in Table 1 and 2.

## 1-3 Members of survey team

(1) Survey Planning and Negotiation

| JAPAN | PHILIPPINES |
|---|---|
| Yoichi Yamaguchi (MMAJ) | Joel D. Muyco (MGB, Director) |
| Norio Nakano (Ministry of Foreign Affairs) | Salvador Martin (MGB) |
| Hajime Ikeda (JICA) | Edwin G. Domingo (MGB) |
| Koichi Koyama (MMAJ) | Romeo L. Almeda (MGB) |
| Yoshitaka Hosoi (MMAJ) | Noel V. Ferrer (MGB) |
| Yuji Kajitani (Manila Office) | |
| Kenzo Masuda (MMAJ) | |

(2) Field Survey Team

**1) Phase 1 survey**

i) A, B, and C areas

Period of Field Survey from January 30 to April 18, 1991 (79 days)

Personnel of Field Work

| | JAPAN | PHILIPPINES |
|---|---|---|
| * Team Leader, Coordinator | Akio Shida | Romeo L. Almeda |
| * A-area | Hideaki Nabeshima | Noel V. Ferrer |
| | Junichi Maeno | Benjamin Cadawan Jr. |
| | | Joselito Velasquez |
| * B-area (Eastern Part) | Yasunori Ito | Rogel Santos |
| | Minoru Nonoguchi | Oliver Relova |
| | | Noel Ariel Cruz |
| * B-area (Western Part) and C-area | Tuyoshi Yamada | Eugenio Esguera |
| | Fumitaka Yoshimura | Ronald Miranda |
| | Shigeyuki Yamasawa | Reinhold Salas |

| | | |
|---|---|---|
| | | Emmanuel Cruz |

ii) Detailed Survey Area A-1 and B-1
Period of Field Survey from October 21 to December 9, 1990 (50 days)
Personnel of Field Work

| | JAPAN | PHILIPPINES |
|---|---|---|
| * Team Leader, Coordinator | Akio Shida | Romeo L. Almeda |
| * Detailed Survey Area A-1 | Itoshi Kono | Noel L. Ferrer |
| | Makoto Miyoshi | Joselito Velasquez |
| | | Emmanuel Santos |
| | | Oliver Relova |
| * Detailed Survey Area B-1 | Yasunori Ito | Antonio N. Apostol |
| | | Rogel Santos |
| | | Ronaldo Mirando |
| | | Reinhold Salas |

**2) Phase 2 survey**
Period of Field Survey from September 9 to November 8, 1991 (61 days)
Personnel of field work

| | JAPAN | PHILIPPINES |
|---|---|---|
| * Team Leader | Akio Shida | Noer V. Ferrer |
| | Yasunori Ito | Antonio N. Apostol Jr. |
| | Makoto Miyoshi | Ronaldo Miranda |
| | | Joselito Velasquez |
| | | Emmanuel Santos |
| | | Jimmy Crisoloso |
| | | Eleazar Mantaring |

Table 1 Contents of the survey

| | Name of Area | | Contents (Geological & Geochemical Survey) | | | |
|---|---|---|---|---|---|---|
| | | | Area | Route Length | Test Pit | Number of Geochemical Samples |
| PHASE I | A-area | | 300 $km^2$ | 117 km | — | Soil Samples : 1,040 pcs<br>Semi-Quantitative Analysis of Chromite : 2,546 pcs<br>Rock Samples : 210 pcs |
| PHASE I | B-area | | 1,200 $km^2$ | 441 km | — | |
| PHASE I | C-area | | 100 $km^2$ | 105 km | — | Soil Samples : 210 pcs<br>Rock Samples : 44 pcs |
| PHASE I (addition) | Area A-1 | | 37 $km^2$ | 88 km | 30 points | Soil Samples : 1,569 pcs<br>Rock Samples : 84 pcs |
| PHASE I (addition) | Area B-1 | a | 19 $km^2$ | 44 km | 30 points | Soil Samples : 1,355 pcs<br>Rock Samples : 82 pcs |
| PHASE I (addition) | Area B-1 | b | 15 $km^2$ | 55 km | | |
| PHASE II | Area A-1 | | — | — | 102 points | Soil Samples : 204 pcs |
| PHASE II | Area A-2 | | 50 $km^2$ | 106 km | — | Soil Samples : 443 pcs |
| PHASE II | Area A-3 | | | | | Soil Samples : 104 pcs |
| PHASE II | Area B-1 | | — | — | 100 points | Soil Samples : 200 pcs |

Table 2 Laboratory Examinations

| | Name of Area | Examination Items | Quantity |
|---|---|---|---|
| PHASE I | A-area and B-area | Preparation of thin section<br>Preparation of polished thin section<br>EPMA quantitative analysis<br>Chemical analysis<br>1 Whole rock analysis ($SiO_2$,$TiO_2$,$Al_2O_3$,$Fe_2O_3$,FeO,MnO,MgO,CaO,$Na_2O$,$K_2O$,$P_2O_5$,LOI)<br>2 Geochemical analysis<br>soil sample (Pt,Pd,Au,Ni,Cr,Fe,Co)<br>soil sample (Cu,Pb,Zn,Au,Ag,As,Sb,Hg)<br>rock sample (Pt,Pd,Au,Ni,Cr,Fe,Co)<br>3 Ore analysis (Cr,Fe,Al,Mg,Si)<br>X-ray diffraction examination | 60 pcs<br>15 pcs<br>10 pcs<br><br>60 pcs<br><br>1,040 pcs<br>101 pcs<br>210 pcs<br>10 pcs<br>50 pcs |
| PHASE I | C-area | Preparation of thin section<br>Chemical analysis<br>1 Whole rock analysis ($SiO_2$,$TiO_2$,$Al_2O_3$,$Fe_2O_3$,FeO,MnO,MgO,CaO,$Na_2O$,$K_2O$,$P_2O_5$,LOI)<br>2 Geochemical analysis<br>soil sample (Cu,Pb,Zn,Au,Ag,As,Sb,Hg)<br>heavy minaral sand (Au,Ag)<br>X-ray diffraction examination | 21 pcs<br><br>21 pcs<br><br>210 pcs<br>44 pcs<br>11 pcs |
| PHASE I (addition) | Area A-1 | Preparation of thin section<br>Preparation of polished thin section<br>EPMA quantitative analysis<br>Chemical analysis<br>1 Whole rock analysis ($SiO_2$,$TiO_2$,$Al_2O_3$,$Fe_2O_3$,FeO,MnO,MgO,CaO,$Na_2O$,$K_2O$,$P_2O_5$,LOI)<br>2 Geochemical analysis<br>soil sample (Pt,Pd,Au,Ni,Cr,Fe,Co)<br>rock sample (Pt,Pd,Au,Ni,Cr,Fe,Co) | 53 pcs<br>18 pcs<br>10 pcs<br><br>32 pcs<br><br>1,569 pcs<br>84 pcs |
| PHASE I (addition) | Aera B-1 | Preparation of thin section<br>Preparation of polished thin section<br>EPMA quantitative analysis<br>Chemical analysis<br>1 Whole rock analysis ($SiO_2$,$TiO_2$,$Al_2O_3$,$Fe_2O_3$,FeO,MnO,MgO,CaO,$Na_2O$,$K_2O$,$P_2O_5$,LOI)<br>2 Geochemical analysis<br>soil sample (Pt,Pd,Au,Ni,Cr,Fe,Co)<br>rock sample (Pt,Pd,Au,Ni,Cr,Fe,Co) | 52 pcs<br>12 pcs<br>10 pcs<br><br>22 pcs<br><br>1,355 pcs<br>82 pcs |
| PHASE II | Area A-1<br>Area A-2<br>Area A-3<br>and<br>Area B-1 | Preparation of thin section<br>Preparation of polished thin section<br>EPMA quantitative analysis<br>Chemical analysis<br>1 Geochemical analysis<br>soil sample (Pt,Pd,Au,Ni,Cr,Fe,Co)<br>2 Ore sample ($Cr_2O_3$,$Fe_2O_3$,$Al_2O_3$,$SiO_2$,Ni) | 14 pcs<br>16 pcs<br>10 pcs<br><br><br>951 pcs<br>33 pcs |

# Chapter 2 Existing Geological Information of Survey Area

## 2-1 Previous works

The Palawan Island is a long and narrow island, located in the southwest of Philippine archipelago. Palawan has the potentiality of the deposits associated with ophiolite, hydrothermal deposit and vein type deposits. As for chromite deposits, it appears that many private companies explored during 1970's to early 1980's, but very little has been reported about their results. The geology and mineral deposits of the Philippines Archipelago are summarized by Bureau of Mines and Geo-Sciences (1982, 1986). The regional geology and mineral deposits of Palawan Island are stated in these reports.

The stratigraphy, geological structures, and mineral deposits in Central Palawan are described and interpreted the tectonic evolution of Palawan Island by UNDP (1985). The Geologic Map of the Bacungan Quadrangle (BMG-UNDP, 1986) was published based on UNDP's survey results.

JICA-MMAJ conducted the RP-JAPAN Mineral Exploration Project at several areas in Philippines during five years from 1984 to 1988, and the regional geological survey and geochemical exploration were conducted in the whole areas of Palawan Island. The stratigraphy, geological structure, and mineral showings in Palawan Island were described by JICA-MMAJ (1987, 1988) and at the same time the geochemical anomalies were delineated in their reports. The geological survey and geochemical prospecting were conducted as the Phase 5 of the RP-JAPAN Project in the South Central Palawan that was extracted by the regional survey (JICA-MMAJ, 1989).

UNRFNRE (1990) conducted the precise geological survey and geochemical exploration in the west coast area of Palawan to identify economically minable deposits of metallurgical-grade chromite. They described the geochemical anomalies and mineral showings

## 2-2 General geology and ore deposit

**1) General geology**

South Palawan is thought to be constructed by the northwestward thrust movements of overlying ophiolite to the north Palawan block during the formation of the South China Sea and the Sulu Sea. North Palawan block is a micro-continent drifted away from East Asia during the formation of the South China Sea Basin. North Palawan and South Palawan were bordered by Sabang Fault. North Palawan mainly consists of continental metamorphic rocks, whereas South

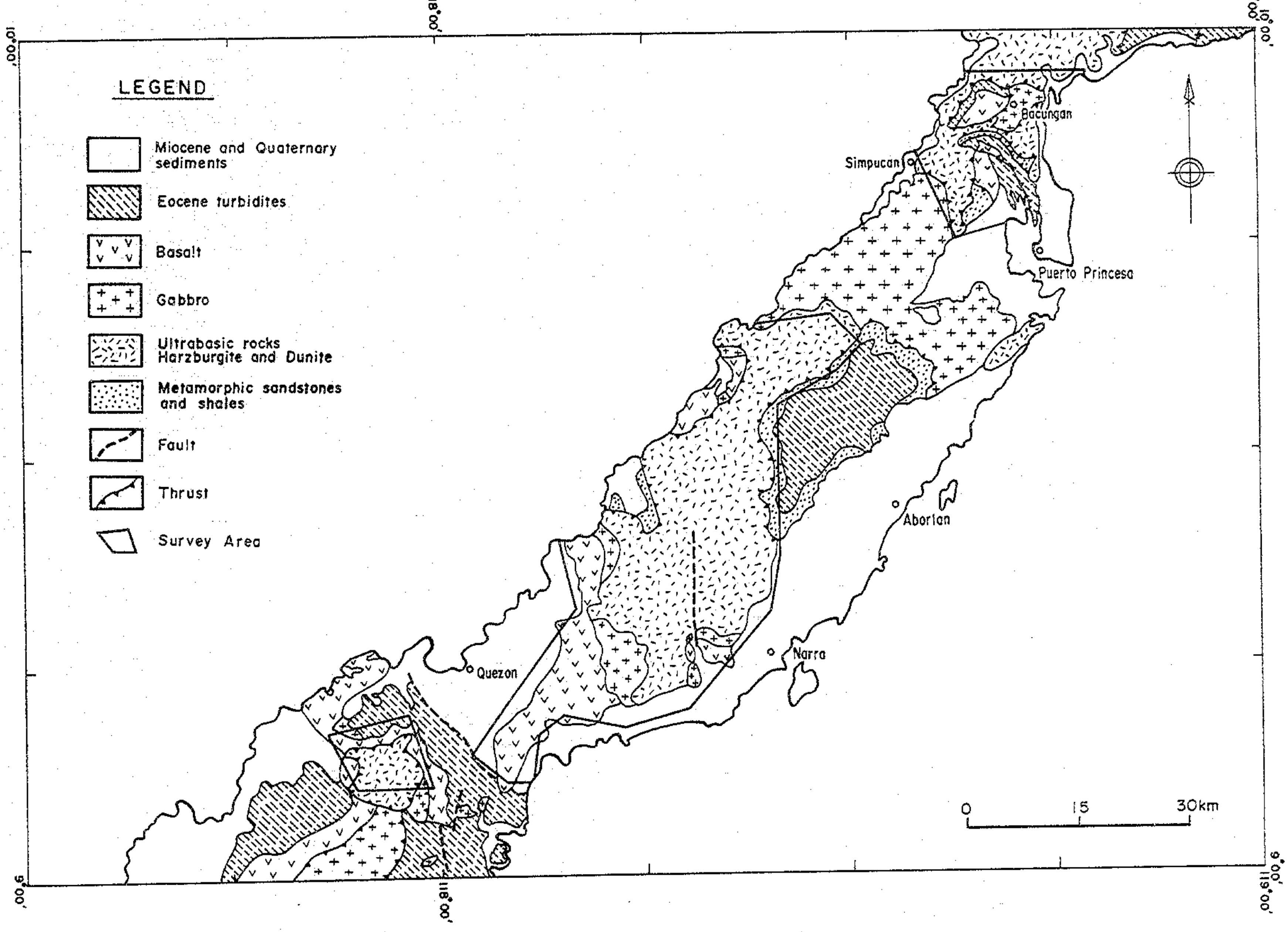



Fig. 4 Simplified geologic map of South Central Palawan

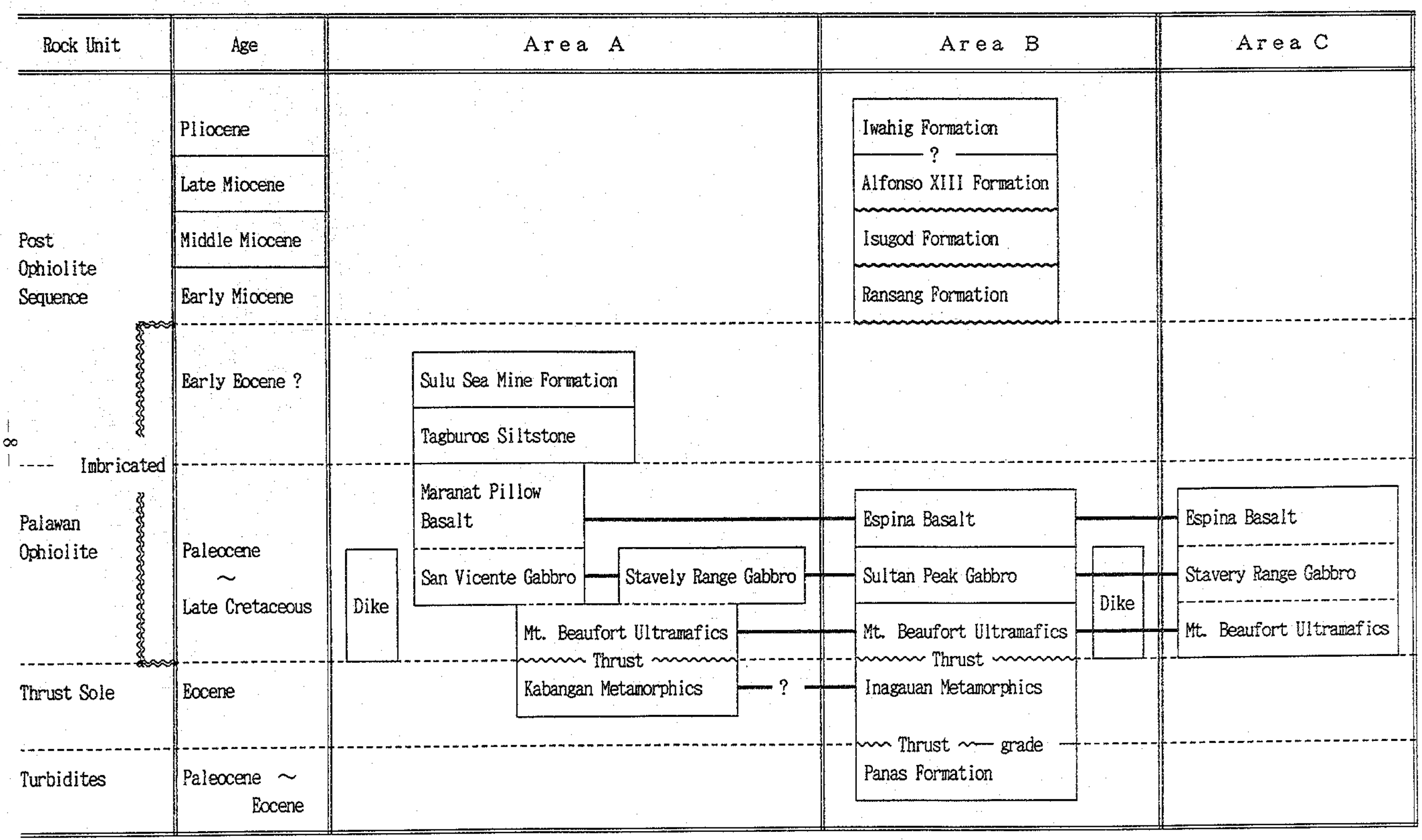



Fig. 5 Columnar section of the survey area

Palawan basic rocks of ophiolite.

Palawan Ophiolite, from the base upward, is composed of Mt. Beaufort Ultramafics, the Stavely Range Gabbro and the Sultan Peak Gabbro, and the Espina Basalt. The Inagauan Metamorphics are distributed at the thrust sole. The upper part of Inagauan Metamorphics consists mainly of amphibolite, whereas the lower part consists of pelitic and psammitic schist, metamorphosed turbidites.

**2) Ore deposit**

A chromite mine and a nickel mine are actively operated in South Central Palawan.

Ore deposits in Palawan Island are orthomagmatic and placer chromite deposit, nickeliferous laterite deposit, massive sulfide deposit, hydrothermal mercury deposit and vein type antimony deposit. In particular, Palawan Island is known to produce metallurgical-grade chromite ore of high chromium content.

Chromite deposits mainly occur in dunite tectonite and cumulate dunite in this area as podiform type, which consist of compact massive and disseminated type ore. Chromite bodies have irregular shape and vary markedly in thickness ranging from several ten centimeters to several meters as the result of the deformation of peridotite body by the large scale thrust movement.

Nickeliferous laterite is recognized in peridotite area of gentle topography2-2 General geology.

# Chapter 3 Situation of Survey Area

## 3-1 Location and access

Palawan Island is situated on the Southwestern end of the Philippine Archipelago. It faces the Sulu Sea to the east and the South China Sea to the west.

The Area A is situated in the south western part of the island, stretching from the east coast to the west coast, between the latitude of 9°45'N and 9°57'N. The detailed survey area A-1 is situated in the southwestern portion of the A-area, west side of the backbone mountains, from Simpucan to the south of Bluff Point. Puerto Princes, the capital city of the Province of Palawan, is situated to the south of the survey area, on the east coast.

There is a paved road running from Puerto Princesa to the east coast of the survey area. There is also an unpaved road running from Bacungan to Nagtabon Beach on the west coast. But on this road, there are steep slopes in bad conditions, thus making it difficult to drive except for jeeps. There is also a road which runs down to the south from Iwahig (to the south of Puerto

Princesa) to Simpucan (the southern edge of the survey area) through Napsan (on the west coast). The road is badly in need of reparation, and further more, there is a need to cross several large rivers like Iwahig River, thus making it sometimes difficult to cross during the rainy season.

Simpucan is the south edge of area A-1 by the west coast and about 80 kilometers from Puerto Princesa City. A paved national highway runs through the east coast. An unpaved road branches at Iwahig and leads to Simpucan by way of Napsan at the west coast. As this rough road crosses some large rivers as Iwahig River, it is sometimes impossible to cross the deep rivers in rainy season. The daily passenger jeepny service is available between Puerto Princesa City and Napsan, and it takes about 3 hours and a half even in good road condition from Puerto Princesa City to Simpucan.

There are no roads along the west coast from Nagtabon Beach (northern edge of the survey area) to Simpucan through Bluff Point, so all traveling must be done on foot or by using bancha boats.

Area A-2 is about 20 kilometers north of Puerto Princesa City. A national highway leads from Puerto Princesa City to the eastern part of area A-2 by way of Bacungan. An unpaved road branches from Bacungan crossing the backbone range and leads to Nagtabon Beach by the west coast. Since this road is rough and partly very steep, four-wheel drive car is needed to get to the west coast. It takes about 30 minutes from Puerto Princesa City to Bacungan, and about another 30 minutes from Bacungan to Nagtabon Beach by car.

Area A-3 is along the national highway and about 15 kilometers north of Puerto Princesa City. It takes about 20 minutes from Puerto Princesa City to area A-3 by car.

The B-area is situated at the south central part of Palawan Island to the southeast of Puerto Princesa, the capital city of the Province of Palawan. It is extended from the east coast to the west coast, and between 9°07'N and 9°40'N in latitude. The area is falls under two jurisdiction; its eastern half under Narra province and its western half under Quezon province.

The sub-camp in Narra, which was set up for the survey in the southwestern B-area, is accessible from Puerto Princesa by highway, and it takes two hours by car. This highway leads to Rio Tuba, the southern end of this island. A branch of this road from Aboabo leads to Quezon, located on the west coast. From Quezon to the southwestern B-area, the road is not completed in some parts.

On the other, no vehicle roads run in the west coast. So we arrived the western part of survey area by small boat (bancha) from Quezon and from coast on foot.

The detailed survey area B-1 is located in the southeastern B-area. It is 10km northwest of Narra, and on the southwest of the Norsophil Mine (ex-Trident Mine). It is accessible by car from Narra to the survey area, but no vehicle road exists within the area. An unpaved road leads from Narra to Mariwara, the south edge of area B-1. It takes about 10 minutes from Narra to

Mariwara. The test pitting site is about one hour's walk from Mariwara.

The C-area is situated in the southern part of Central Palawan, southwest of Quezon in the west coast.

A paved road runs from Puerto Princesa to Aboabo through Narra, along the east coast. From Aboabo to Quezon, there is an unpaved road which diverts from the paved road. It is 120 km from Puerto Princesa to Aboabo, and 20 km from Aboabo to Quezon. Bus services are available several times a day from Puerto Princesa to Quezon.

An unpaved road runs from Quezon to Lamacan, in the north end of the C-area.

## 3-2 Topography

Generally the lithofacies decide the topography in South Central Palawan. The ultramafic rock's area forms very steep, whereas gabbro, basalt and sedimentary rocks' area forms gentle hill.

In the A area, backbone range runs parallel to the shore line, which divides the survey area into two, the east side and the west side. The west side is very steep, while the deeply dissected east side forms gentle hill.

Steep and rugged mountains, centering Victoria Peak, are dominant in B area, because Ultramafic rock is widely distributed in backbone range. Mountains are approached very near to west coast, whereas flat alluvial land occupies along east coast. The southern half of area B-1 where deeply weathered gabbro and basalt are distributed shows gentle topography. The northern half is very rigid because of ultramafic rock's area.

The backbone range in Central Palawan becomes low at the road that runs from Aboabo to Quezon. From the Pulute Range, located in the southwest of this road, southern Palawan backbone range runs southward. The C-area is situated to the north of the backbone mountains nearby the Pulute Range. The area shows rugged topography.

All the drainage in this area flow toward north from the Pulute Range, and reach into the South China Sea.

## 3-3 Climate and vegetation

The survey area belongs to the tropics, and season is divided into the wet season and dry season. Generally the dry season starts in December and ends in May. The wet season starts in June and ends in November. Annual rainfall in South Central Palawan is about 2,700 millimeters. In the end of dry season, April and May, small rivers dry out and serious lack of

water occurs in Puerto Princesa City.

Virgin forests are found at deep mountains. It mainly consists of latifoliate trees. Sccondary forests, consisting of small tree and bush, are found around the village. They have mainly made by slash and burn. Rice fields occupy the lowland along small streams and rivers near the east coast. There are many orchards and pastures in the hills along the east coast. Colonies of mangrove are observed along the east coast.

## 3-4 General information

Puerto Princesa City, where the base camp was settled, is the capital city of Province of Palawan, and almost equipment is available within the city. Electricity and water are supplied in Puerto Princesa City and other main towns.

Flatlands along the big rivers are studded with villages. Only a few persons live in the deep mountains, but many trails exist in the mountain for charcoal and lumber making and resin sampling.

Main industry of the area is agriculture and fishery. Rice, coconut, cashew, and fruit are produced in Palawan.

# Chapter 4 Conclusion and Recommendations

## 4-1 Conclusions

**(1) Geological survey and geochemical prospecting in A-area and area A-1**

1) The A-area is underlain by the Palawan Ophiolite, Kabangan Metamorphics, Tagburos Siltstone, and Sulu Sea Mine Formation.

2) Mineral occurrences observed in the A-area are of chrome and nickel, and both are restricted in the Mt. Beaufort Ultramafics.

3) Most of the chromite occurrences are in dunite-tectonite intruded into harzburgite. Principal chromite occurrences have been found by the detailed survey in area A-1, which was selected based on the results of the initial geological and geochemical survey in the A-area. The mineral showings are distributed in the San Chromite area, Macasaet area, Upper Pananlagan, Lower Pananlagan, Tagkawayan, and Tagminatay.

4) Laterite is distributed in Bacungan, and has a potential for nickel resources.

5) Evaluation of volume ratios of heavy minerals obtained by panning of soil samples has revealed the following high concentration areas of heavy minerals; the area north of Tagburos, the surrounding area of Bacungan, the northwestern area, and the area along the west coast.

6) The results of the soil geochemical survey for seven elements, Pt, Pd, Au, Ni, Cr, Fe, and Co, have revealed following the anomalous areas; the area north of Tagburos, the area north to northwest of Bacungan, and the area from the Malinao River to Tagminatay along the west coast.

7) The results of the above mentioned surveys lead to the selection of following potential areas in the A-area; the area north of Tagburos, the area from the north of Bacungan to the west coast, the area from the Malinao River to Tagminatay.

8) The detailed survey area A-1, the area from the Malinao River to Tagminatay, was selected from three geochemical anomaly areas which were found by the initial geochemical survey in the A-area. The results of the detailed geological survey clarified occurrences of dunite bodies and mineral showings.

9) The results of the detailed geochemical survey in area A-1 lead to the selection of following potential areas for chrome ores; area containing the Pananlagan mineral showings, area from the Tagkawayan mineral showings to the Tagminatay area.

**(2) Geological survey and geochemical prospecting in area A-2**

1) Area A-2 is mainly underlain by the nappe of ultramafic complex, consisting of harzburgite, dunite and pyroxenite.

2) Large dunite tectonites are distributed in southwest of Mt. Airey and the vicinity of Nagtabon

Pass.

3) Almost chromite deposits occur in the dunite tectonite around Nagtabon Pass. Ore bodies consist of massive and disseminated types' chromite ores, which vary markedly in width. The scale of occurrences is small except the Nagtabon No. 1 deposit.

4) The disseminated type's ore is well-exposed in the Nagtabon No. 1 deposit, and massive ore was once mined. Though subsurface occurrence is not clear, the volume of 2,000 tons as chromite is estimated only from the disseminated type's ores near surface.

5) From soil geochemical prospecting, the chromium anomalies were detected scatteringly at places in the area. They don't seem to be coincide with the distribution of dunite tectonite and ore deposits. Therefore promising areas for chromite deposits could not define only by this result. An anomaly zone of platinum related elements is distributed along a small river to the north of Maranat, where some sample shows more than 100 ppb of both platinum and palladium. Nickel and iron anomalies overlap the area in the north of Bacungan, south of Mt. Airey and north of Maranat. These areas have potential for nickeliferous laterite.

**(3) Geological survey and geochemical prospecting in area A-3**

1) Area A-3 is mainly underlain by ultramafic complex, consisting of harzburgite, dunite and pyroxenite.

2) Dunite tectonite is distributed around 291m peak in the central portion of the area. Pagasa 1, 2 and 4 deposit are located in this dunite tectonite.

3) Many massive and disseminated ores crop out in Pagasa 1 deposit. The mineralized zone covers at least 150 x 150 meters. Though it is difficult to estimate the volume of ore only by surface survey, 40 to 60 thousand tons of chromite is thought to be estimated.

4) The disseminated and massive chromite ore bodies occur in Pagasa 2 and 4 deposits. Massive chromite ore body usually does not extend so much and vary markedly in width.

5) As the results of soil geochemical prospecting, chromium anomalies are recognized in the area south of Pagasa 1 and south of Pagasa 2, and these areas are thought to be promising for chromite deposit.

The anomalies of platinum related elements are distributed in the area south of Pagasa 1, from Pagasa 2 to Pagasa 4, and west of national highway.

**(4) Test pitting survey in area A-1**

1) Extension of massive chromite ore body in lower Pananlagan was not confirmed by this survey.

2) Test pits revealed that geochemical anomaly along the branch of the Pananlagan River was a false anomaly by secondary concentration of chromite.

3) Extension of disseminated chromite ore body at lower old working in upper Pananlagan is confirmed to extend to the pit 10 meters apart. Another chromite band parallel to this ore body was also recognized in another pit.
4) Outcrop of massive chromite ore was newly discovered near the upper old working in upper Pananlagan. The ore body strikes N45°W, dips 40°NE, and extends more than 7 meters in length and 2 meters in width. The analysis shows 49.00% $Cr_2O_3$. No other ore body was found around this area.
5) Two small old workings were found in Tagkawayan area, and the analysis of a stock shows 35.30% $Cr_2O_3$. The dunite is almost barren in this area. No other mineral showing was found.

**(5) Geological survey and geochemical prospecting in B-area and area B-1**

1) The B-area is underlain by the Palawan Ophiolite, Inagauan Metamorphics, and Panas Formation.
2) Mineral occurrences observed in the B-area are of chrome and nickel, and they are restricted in the *Mt. Beaufort Ultramafics.*
3) Two kinds of chrome occurrences exist in the area. One is associated with cumulate dunite close to layered gabbro, and the other is associated with dunite tectonite in harzburgite. The former is typical in the mineral showings in the basin of the Malinao River, and the latter is typical in the mineral showings within the Norsophil Mine and in the Berong area in the west coast.
4) The results of interpretation of the chromite components obtained by EPMA analysis have revealed that the chrome grade of the chromite from the transitional zone to the cumulate dunite is lower than those from the dunite tectonite.
5) Evaluation of volume ratios of heavy minerals obtained by panning from soil samples has revealed the following high concentration areas of heavy minerals; the area within the Norsophil Mine, the upper stream area of the Malasgao River, the basin of the Malinao River, the surrounding area of Long Point, and Berong area.
6) The results of the soil geochemical survey for seven elements, Pt, Pd, Au, Ni, Cr, Fe, and Co, have revealed that geochemical anomalies are overlapping in the same areas of the heavy mineral anomalies.
7) The results of the above mentioned surveys lead the selection of following five potential areas in the B-area; the upper stream area of the Malasgao river, the area within the Norsophil Mine, and the upper stream area of the Malinao River, --in the east coast; the surrounding area of the Long Point, and Berong area, --in the west coast.
8) The detailed survey area B-1, the upper stream area of the Malinao River, was selected from geochemical anomaly areas which were found by the initial geochemical survey in the B-area.

The results of the detailed geological survey revealed the existence of the transitional zones of gabbro and peridotite, and clarified mineral occurrences in dunite bodies.

9) The results of the detailed geochemical survey in area B-1 lead the selection of the northwestern portion of area B-1 as a promising area for chrome ores.

**(6) Test pitting survey in area B-1**

1) Chromite mineralization was recognized at 13 pits in the Mariwara area.

2) Massive chromite was discovered at NG034 pit in the central portion of the area. The analysis of this ore shows 26.70% $Cr_2O_3$. Contents of platinum related elements are also high around this pit. The bottom samples of pit show Pt; 1,600 ppb, Pd; 3,400 ppb at NG034 and Pt 1,200 ppb, Pd 740 ppb at NG100.

3) Other mineralized zones consist of disseminated chromite and thin chromite band, but the grade is low.

4) Floats of massive chromite ore and leopard type nodular ore were found in the branch of Marinao River. The analysis shows 30.50% $Cr_2O_3$.

**(7) Geological survey and geochemical prospecting in C-area**

(1) Harzburgite is thrust over the Espina Basalt and the Sultan Peak Gabbro in the C-area.

(2) Potential for Cyprus type sulphide ores was previously expected in this area. The survey results, however, indicate that the distribution area of basaltic rocks is small and no mineral indication exists.

(3) No promising area was detected from the geochemical survey.

## 4-2 Recommendation for the future

Many chromite occurrences are distributed in South Central Palawan. The evaluation of the Phase 1 and Phase 2 result has led that the Nagtabon No. 1 deposit in area A-2 and the Pagasa 1 deposit in area A-3 have potential for the chromite deposit.

It is difficult to estimate the volume of ore only by surface survey,nevertheless, it may be possible to expect the tonnage of 2,000t at Nagtabon No.1 deposit and tonnage of 20,000 to 40,000t in Pagasa 1 deposit as chromite. That is, it may be possible to expect about 200,000t of crude ore grade of 20 to 25%$Cr_2O_3$ in Pagasa 1 deposit.

Norsophil mine, only one operating chromite mine in South Central Palawan, consists of several unit deposits. Each unit deposit has crude ore tonnage of 200,000 to 500,000t,grade of 20 to 25 % $Cr_2O_3$. Thinking the scale of this Norsophil mine and present market price of chromite ore, it may be pretty difficult to get the commercial deposit at present in Pagasa 1 area, even if further exploration be conducted, because Pagasa 1 deposit consists of only one unit deposit .

But thinking of possibility of increase of chromite market price in future, it is preferable to conduct the drilling survey at Nagtabon No.1 deposit and Pagasa 1 deposit to clarify the occurrence of the deposits underground.

In the Cooperative Mineral Exploration Program, geological survey and geochemical prospecting were conducted in both stage of phase 1 regional survey and phase 2 detailed survey. Geochemical prospecting in regional survey stage was effective to select the promising areas. Especially, the survey of heavy mineral contents in soil samples was very effective to select the promising areas in early stage of regional field survey. Nevertheless, it was pretty difficult to narrow down the promising areas only by geochemical prospecting in detailed survey stage. That is, it was difficult to select the geochemical anomaly areas which directly indicate the existence of chromite deposit, because the detailed survey areas were already anomaly areas selected by regional geochemical survey. Precise geological survey must be effective in detailed survey stage to clarify the distribution of chromite occurrences in dunite body.

Survey program for podiform type chromite deposits had better be like this;

i) regional survey stage: geological survey and geochemical prospecting including survey of heavy mineral contents in soil samples

ii) detailed survey stage: detailed geological survey, searching for the chromite outcrops and test pitting survey

iii) stage of exploration of the deposit: test pitting survey, trenching survey and drilling survey

# PART II REGIONAL DISCUSSION

# Chapter 1 A-area and detailed survey area A-1,A-2 and A-3

## 1-1 Geology

### 1-1-1 Outline of geology

1) A-area

The A-area is underlain by the Palawan Ophiolite, the Kabangan Metamorphics, the Tagburos Siltstone, and the Sulu Sea Mine Formation(Fig.6 and 7).

The Palawan Ophiolite is extensively distributed in this survey area, and is composed of the Mt. Beaufort Ultramafics, the San Vicente Gabbro, the Stavely Range Gabbro, and the Maranat Pillow Basalt. They were cut by several thrust faults during the emplacement of the ophiolite, and imbricated each other. The geological structure of the area is therefore very complicated, and the formations are situated upside-down in many places.

The Kabangan Metamorphics are in contact with the bottom of the Mt. Beaufort Ultramafics. The Kabangan Metamorphics is restricted in distribution, and possibly resulted from the dynamic metamorphism at the ophiolite sole.

In the A-area, two large scale windows, the Bacungan Window and the Iratag Window, exist. They resulted from the erosion of the Mt. Beaufort Ultramafics thrust over as a nappe. In these windows, the Maranat Pillow Basalt which is the uppermost part of the ophiolite, Tagburos Siltstone, and Sulu Sea Mine Formation are distributed. They are conformably overlie each other, and are referred to the Bacungan River Group (UNDP, 1985). The Tagburos Siltstone and Sulu Sea Mine Formation are probably deposited during the ophiolite thrust movement on the ocean floor and fore arc basin.

2) Detailed survey area A-1

Detailed survey area A-1 is situated along the west coast of the A-area, and is largely underlain by the Stavely Range Gabbro and the Mt. Beaufort Ultramafics(Fig.8 and 9).

The Stavely Range Gabbro is distributed in the southern edge and western part of the survey area, and assumably is thrust fault contact with the Mt. Beaufort Ultramafics. Banded structure is well observed in the gabbro. The Gabbro mass consists of gabbro, olivine gabbro and troctolite.

The Mt. Beaufort Ultramafics is dominantly distributed in this area, and consists mainly of harzburgite. Dunite tectonites occur in dike shape or alternatively of various sizes in the harzburgite. Chromite deposits are embedded in dunite bodies. Pyroxenite (websterite) crops out in the western area.

In the northern area, phyllitic red chert of the Sulu Mine Formation is exposed as small-scale windows.

Pyroxenite, fine grained gabbro, porphyrite, plagioclase- hornblende pegmatite intruded into the ultramafic rocks and gabbro.

3) Detailed survey area A-2

The area A-2 is mainly composed of nappe of Mt. Beaufort Ultramafics. The Mt. Beaufort Ultramafics been thrust over gabbro San Vicente Gabbro at east side of the area, and Sulu Sea Mine Formation at west side of the area. Inagauan Metamorphics, which consists of

quartz schist, are distributed at near Maranat (Fig.10).

The Mt. Beaufort Ultramafics is composed of harzburgite, dunite and pyroxenite. Dunite bodies are distributed within this harzburgite as diapir-like bodies. Dunite sometimes occurs alternated with harzburgite and pyroxenite.

The dikes of pyroxenite, fine grained gabbro, porphyrite and plagioclase-hornblende pegmatite intrude into the ultramafic rocks at places.

4) Detailed survey area A-3

Geology of area A-3 is almost the same as that of area A-2. Area A-3 mainly consists of Mt. Beaufort Ultramafics. San Vicente Gabbro is distributed in west and north of the area thrust by the Mt. Beaufort Ultramafics(Fig.11). The Mt. Beaufort Ultramafics consists mainly of harzburgite, and contains some dunite and pyroxenite. The ultramafic complex forms the steep slopes and cliffs, whereas the gabbro forms gentle hills. The Inagauan Metamorphics occur in thrust fault contact with the ultramafics near the east coast.

### 1-1-2 Detailed geology

1) Kabangan Metamorphics

The Kabangan Metamorphics consist of amphibolite, greenschist, sandstone, and phyllitic schist, and are distributed in the northern and southern edges of the Bacungan window, which is situated in the middle stream area of the Bacungan River, and in the northern and eastern edges, and along the southwestern edge of the Iratag Window, which is situated to the west of Tagburos. The scale of the each body is smaller than 300m wide.

It is believed that they have formed along the thrust fault during the emplacement of the ophiolite suite. The psammitic to pelitic metamorphic rocks are probably metamorphosed from turbidite, similar to the Panas Formation distributed in southern Palawan.

2) Mt. Beaufort Ultramafics

The Mt. Beaufort Ultramafics are the ultramafic complex body, which is the main constituent of the Palawan Ophiolite. It is largely distributed in the southern area, from the area nearby Mt. Beaufort to the north as a nappe. It mainly consists of slightly serpentinized harzburgite, accompanied with dunite, and pyroxenite. In the middle stream area of the Bacungan River and the area west of Tagburos, the Mt. Beaufort Ultramafics have been eroded, resulting in forming the Bacungan Window and Iratag Window.

The harzburgite, which consists of several millimeters to 2 cm of olivine and orthopyroxene, differs in color between the weathered parts and the fresh parts. It is brown to pale brown in the weathered parts, and dark grayish green to black in the fresh parts. By microscopic observation generally it was altered, orthopyroxene to bustite and olivine to serpentine. Chromespinel (chromite) is accompanied as an accessory mineral. The orientation of the orthopyroxene is well observed in the weathered facies.

Many dunite diapir-like bodies intruded into the harzburgite in spindle to irregular shapes at a scale of several meters to several hundred meters. They are usually yellowish brown to brown in color in the weathered facies, and dark green to olive in color in the fresh facies. They are also slightly altered to serpentine shown a mesh texture under the microscope, which is identified as

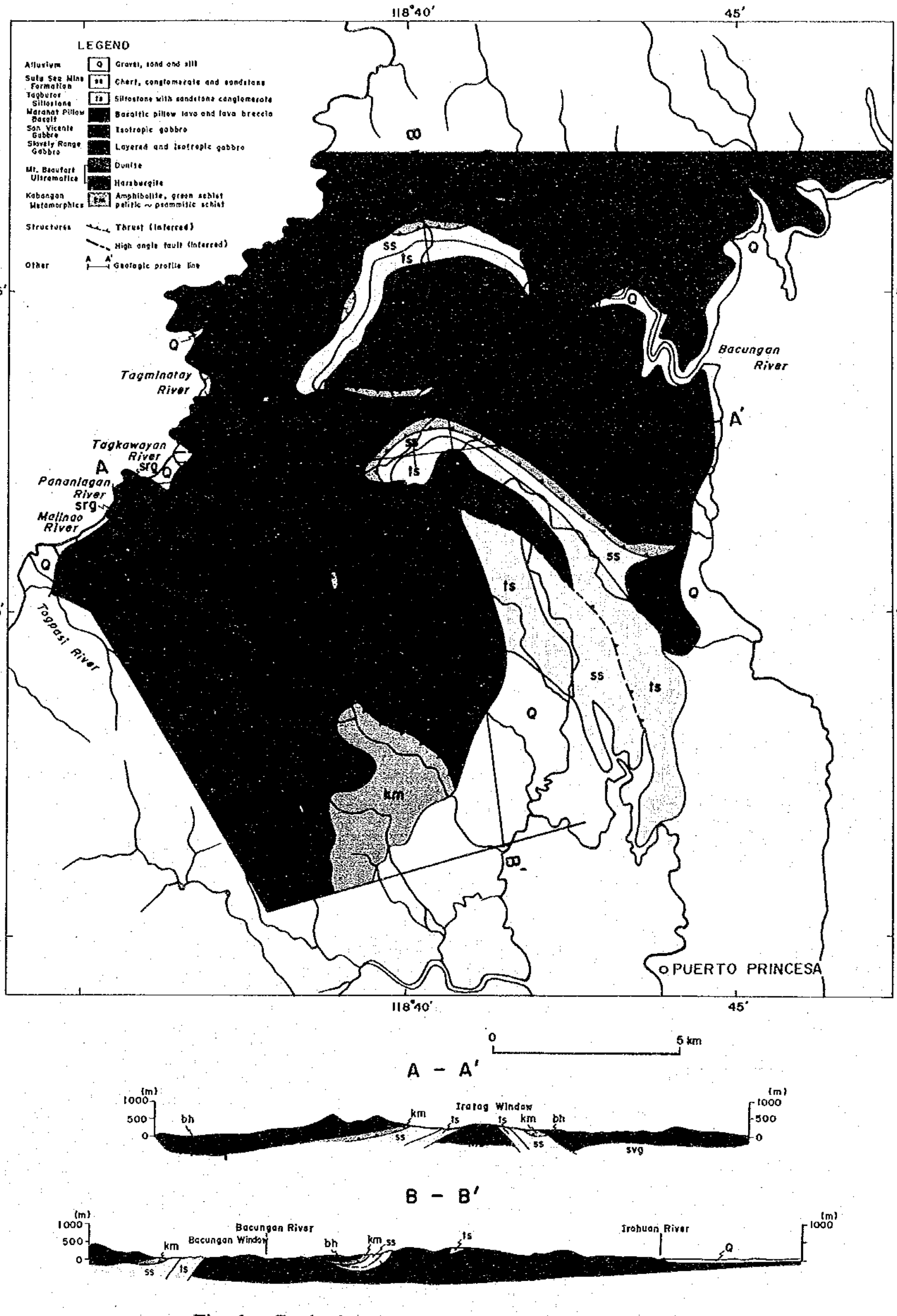



Fig. 6 Geologic map and profile in A-area

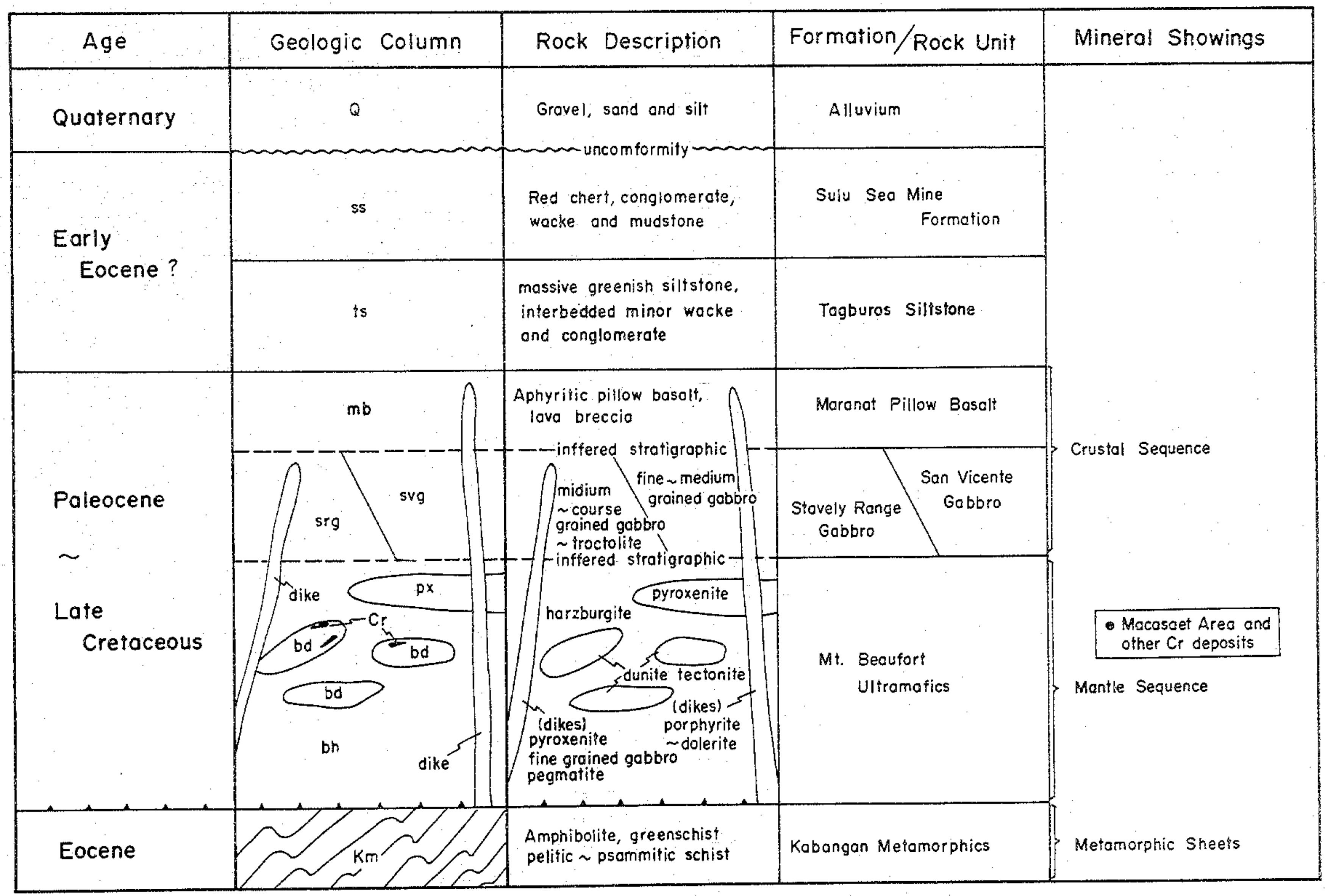



Fig. 7 Schematic geologic column in A-area & B-area

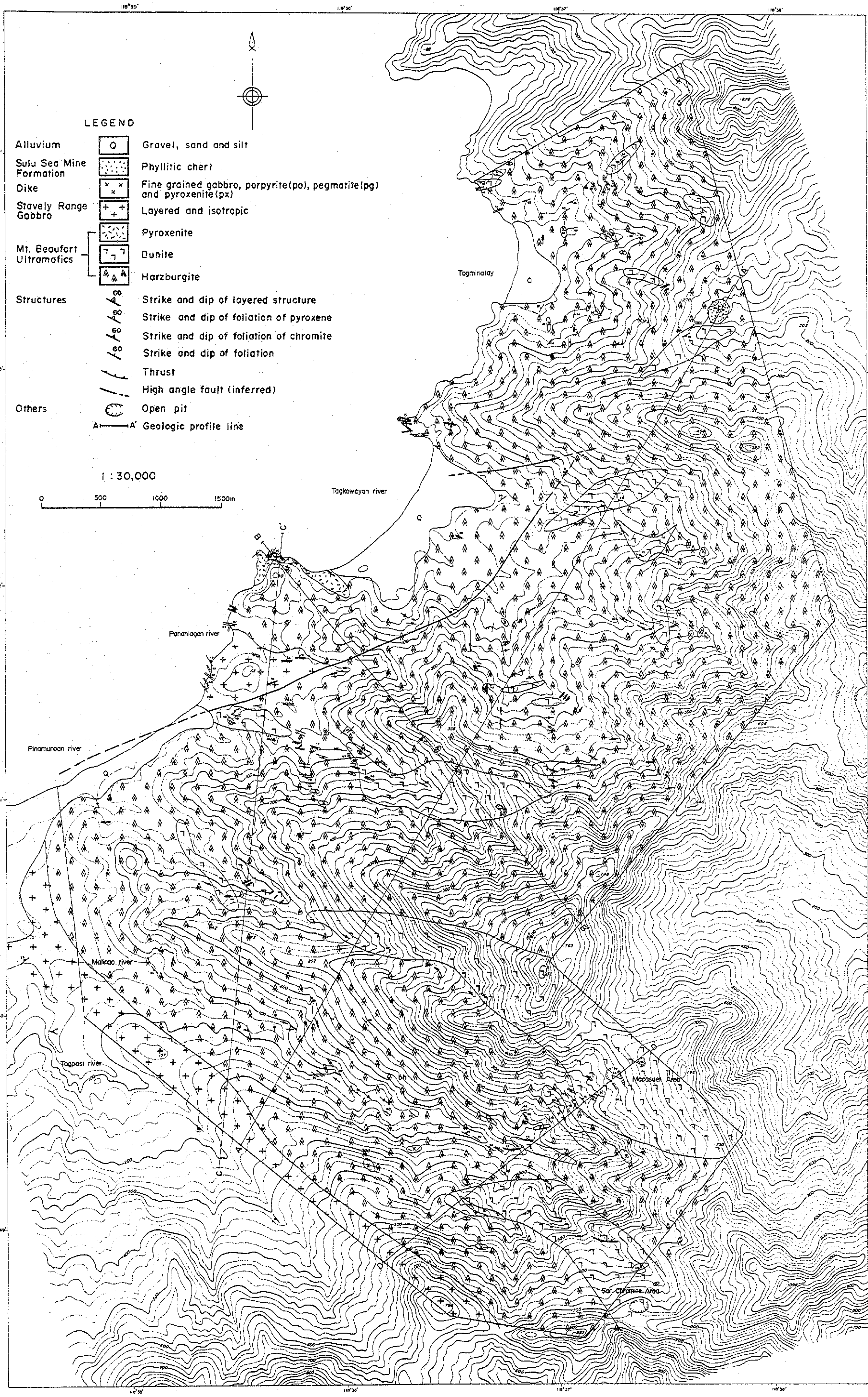



Fig. 8 Geologic map in area A-1

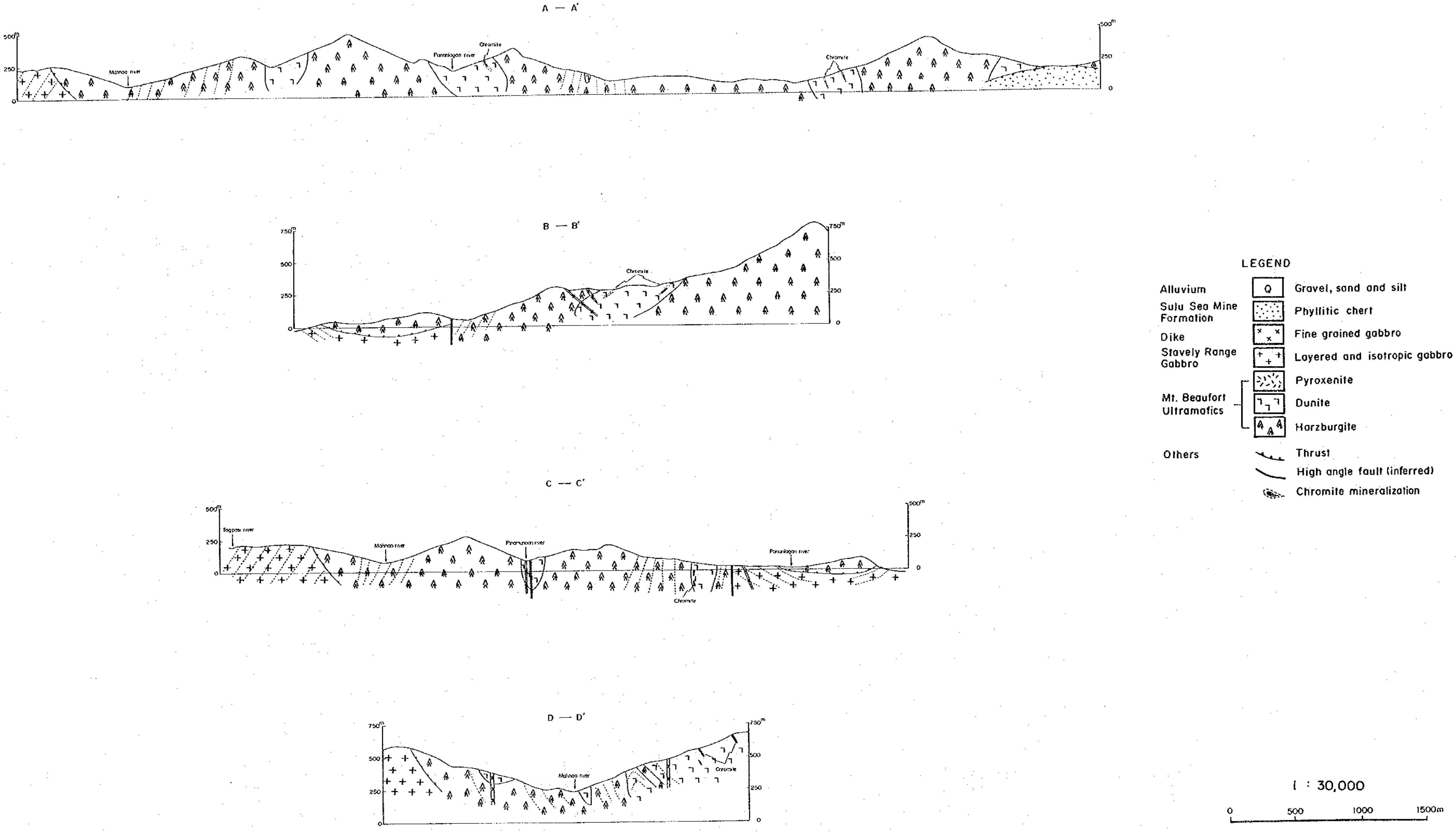



Fig. 9 Geologic profile in area A-1

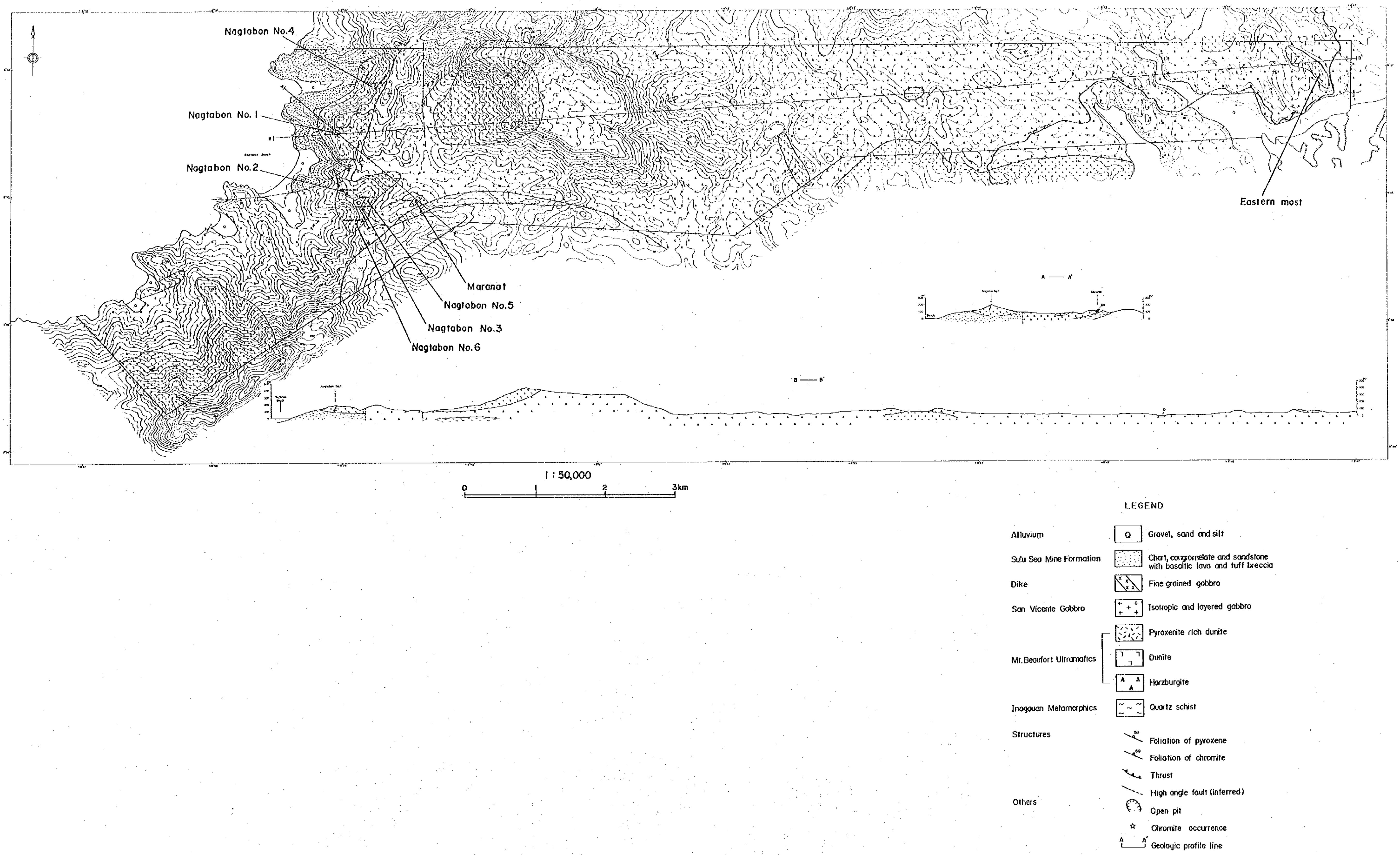



Fig.10 Geologic map and profile in area A-2

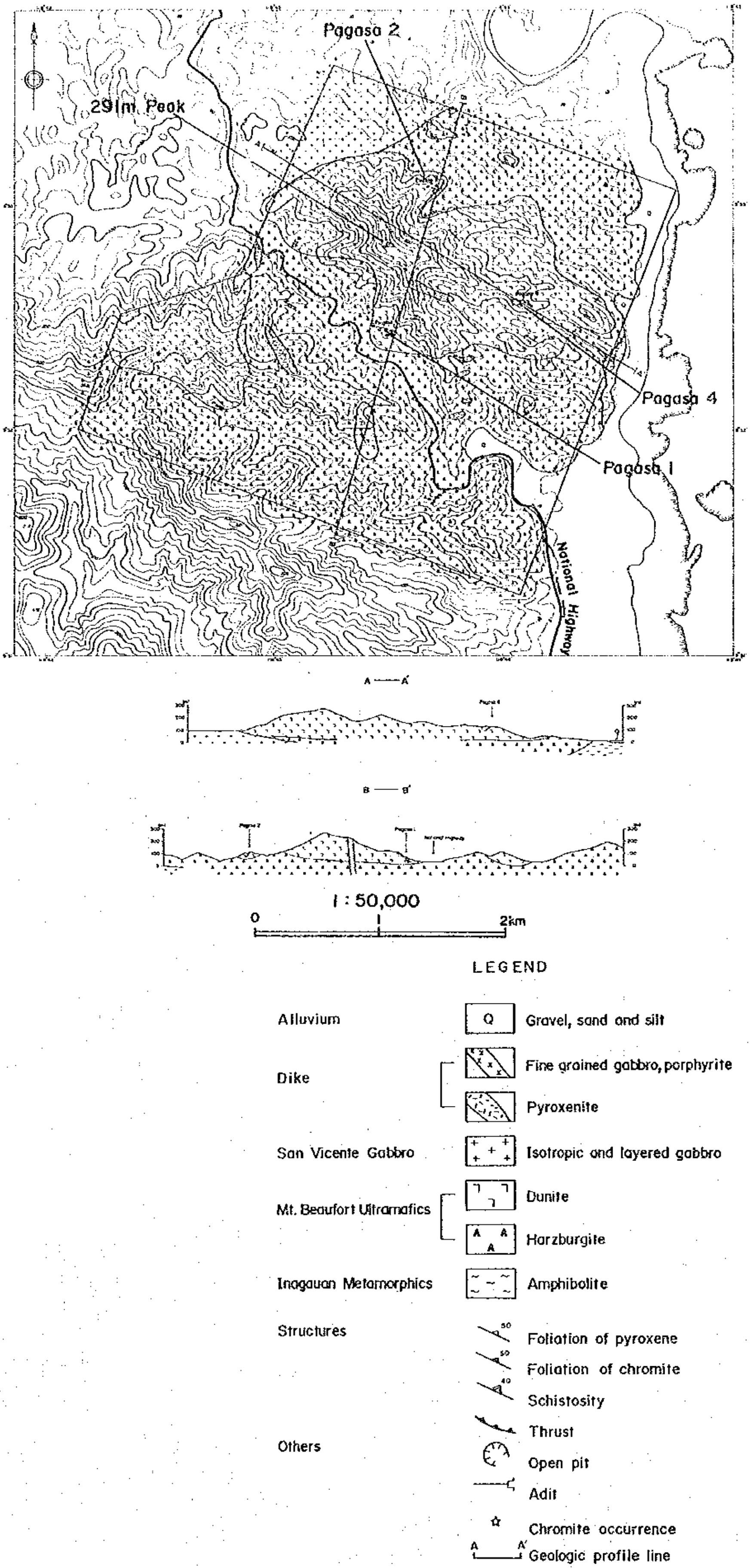



Fig.11 Geologic map and profile in area A-3

antigorite by X-ray diffraction. The boundary between the dunite and harzburgite often comes across slightly diagonally with the orientation of the orthopyroxene in the harzburgite, but the dunite bodies generally stretch in the direction of the texture of harzburgite. Chromite grains are commonly observed megascopically in the dunite, and orientate. The direction of intrusives is in some cases parallel to the orientation of minerals, chromite seams, and lenses.

In detailed survey area A-1, pyroxenite (websterite) is distributed in a layered shape in the harzburgite.

3) Stavely Range Gabbro

The Stavely Range Gabbro is distributed in the area to the southwest of the Malinao River and the Balsahan River in the southwestern margin of the A-area. It consists of medium to coarse grained gabbro, and is accompanied by olivine gabbro and troctolite.

Banded structure is not significant in the south part of the survey area, but well observed in the western survey area. The structure is due to the difference of grain size and volume ratio of colored minerals. At the Tagpasi River, it strikes NW-SE and dips to the north. In the downstream area of the Pananlagan River, it strikes N-S, dips to the east. On the downstream area of the Pananlagan River, alternated layers of pyroxene-plagioclase gabbro, amphibole gabbro and troctolite are found.

4) San Vicente Gabbro

The San Vicente Gabbro is distributed at Bacungan, along the national highway running from Puerto Princesa to the north, and the area centered by San Vicente. This gabbro mass distribution area shows very gentle and low hills because of intense weathering. The rock facies are of fine to medium grained pyroxene-plagioclase gabbro, and layered and banded structures due to the different volume ratio of colored minerals are unclear.

The Mt. Beaufort Ultramafics were thrust over this gabbro mass, and this gabbro mass is thrust over the Maranat Pillow Basalt. It is assumed that this gabbro mass is correlative with the Sultan Peak Gabbro distributed in southern Palawan.

5) Maranat Pillow Basalt

The Maranat Pillow Basalt mainly consisting of pillow lava and basaltic tuff breccia, is distributed in the area centered by the Maranat Creek in the Bacungan Window and the area centered by the Irawan River in the Iratag Window.

The Basalt distributed in the Bacungan Window consists of aphyric or non-amygdaloidal basalt, and has commonly undergone chloritization.

The Basalt distributed in the Iratag Window consisting of the same types of basalt as seen in the Bacungan Window has in some places thin layers of mudstone, several meters to several tens of meters thick.

It is believed that the Maranat Pillow Basalt is correlative with the Espina Basalt extensively distributed in southern Palawan. The San Vicente Gabbro and harzburgite are thrust over this rock, and is conformably overlain by the Tagburos Siltstone.

6) Dikes

Many of dikes of fine grained gabbro, dolerite, porphyrite, pyroxenite, and pegmatite intruded

into the Mt. Beaufort Ultramafics, the Stavely Range Gabbro, the San Vicente Gabbro, and the Maranat Pillow Basalt.

The fine grained gabbro to dolerite and porphyrite are light gray to dark gray hard rocks, and distributed in many places. They are 1 to 10 cm wide, and the orientation of dikes varies sporadically.

The pyroxenite dikes intruded into the Mt. Beaufort Ultramafics and the Stavely Range Gabbro, particularly in detailed survey area A-1 in the west coast. They are greenish green to dark greenish gray in color, and 0.1 to 1 m in wide. The pyroxenites are websterite or olivine websterite, and its crystals are equigranular and 5 to 7 mm in size.

The pegmatite consists of large crystals of hornblende and plagioclase crystals, which are several centimeters in size, and intruded into the Mt. Beaufort Ultramafics and Stavely Range Gabbro as dikes with about 1 m wide.

7) Tagburos Siltstone

The Tagburos Siltstone is distributed in the northern part of the Bacungan Window, the Bacungan River area in the Iratag Window, and the Iratag River area.

In the Bacungan Window, it consists of massive green siltstone and fine grained sandstone, and intercalates sandstone layers. In the Iratag Window, it consists of massive green siltstone, and intercalates sandstone and conglomerate layers.

It has conformable contacts with the underlying Maranat Pillow Basalt and overlying Sulu Sea Mine Formation.

8) Sulu Sea Mine Formation

The Sulu Sea Mine Formation is distributed in the northern Bacungan Window and eastern Iratag Window, and consists of alternated layers of red chert, ferruginous siliceous rock, conglomerate, sandstone, and mudstone. In the northern part of detailed survey area A-1, phyllitic red chert is distributed in harzburgite in a small scale as window.

It conformably overlies the underlying Tagburos Siltstone.

### 1-1-3 Geological structure

The geological structure of the A-area has resulted from the emplacement of the ophiolite, which was generated on the ocean floor during the Late Cretaceous to Paleocene age. It appears that the thrust movement occurred in Late Eocene to Early Paleocene.

1) Thrust fault

The thrust fault situated at the bottom of the Mt. Beaufort Ultramafics or Kabangan Metamorphics is the lowest angle one in this area. These rocks are commonly distributed as a nappe due to the almost horizontal thrust fault.

Because the bottom of the Ultramafics is confined by the thrust fault, windows of various sizes have been formed in eroded parts of the Ultramafics. The largest windows are in the areas nearby Bacungan and Iratag. These are known as the Bacungan Window and Iratag Window (UNDP, 1985). Near the thrust fault, harzburgite is extensively serpentinized, and in some places even mylonitized.

Also in this area, there are thrust faults, which resulted from imbricated thrust movement of the ophiolite to the northern Palawan Block. They are in between the San Vicente Gabbro and Maranat Pillow Basalt, and the Maranat Pillow Basalt and Tagburos Siltstone.

2) High angle fault

A high angle fault is observed along the west coast, extending ENE to WSW. It cuts harzburgite and gabbro, and appears a right lateral fault in the geological map of the area.

### 1-1-4 Ore deposits and mineral showings

The most important ore deposits in the A-area are of chromite associated with the peridotite. It is presumed that chromium is concentrated by partial melting of the mantle. On the other hand, nickel laterite occurrences resulted from weathering of the peridotite are also distributed in this area. A mercury mine is situated near Tagburos, where research for gold is presently being conducted by Atlas Cons..

As for chromite showings, a detailed survey was conducted in area A-1,A-2 and A-3, where they have a high potential, and revealed its distribution. The test pit survey was conducted to confirm the scale of the chromite showings.

As for nickel occurrences, the results of the survey revealed distribution zones of laterite in the harzburgite area of the Bacungan area in the northern A-area and detailed survey area in the west coast. In these areas, a test pit survey was conducted to confirm their mode of occurrences. Details on each mineral showings are as follows.

1) Chromite deposits and showings

(1) Detailed survey area A-1

In the detailed survey area A-1, situated on the west coast of the A-area, chromite outcrops and floats are seen in more than 10 locations. These are divided into three regions; i) the San Chromite Area, Macasaet Area in the southwestern area, ii) Upper Pananlagan and Lower Pananlagan in the middle area, iii) Tagkawayan and Tagminatay in the northern area. Fig.12 shows the location of the mineral showings and test pits.

There is no operating mine in this area, but there are old workings of open pit operation in the Macasaet Area and San Chromite Area. They are of fairly large scale. In Upper and Lower Pananlagan, there are smaller old workings of open pit mining. No old working exists in the Tagkawayan River area and Tagminatay area, but some floats of chromite ore are found at several spots.

i) Macasaet area

This area is situated in the upstream area of the Malinao River, in the northeastern area, and occupies an area of 500 m south to north and 400 m east to west. An open pit working extending 500 to 200 m and eight outcrops of massive chromite ore having various sizes are observed. A road comes from Iraan, and it goes to the San Chromite area. This area is situated in the largest

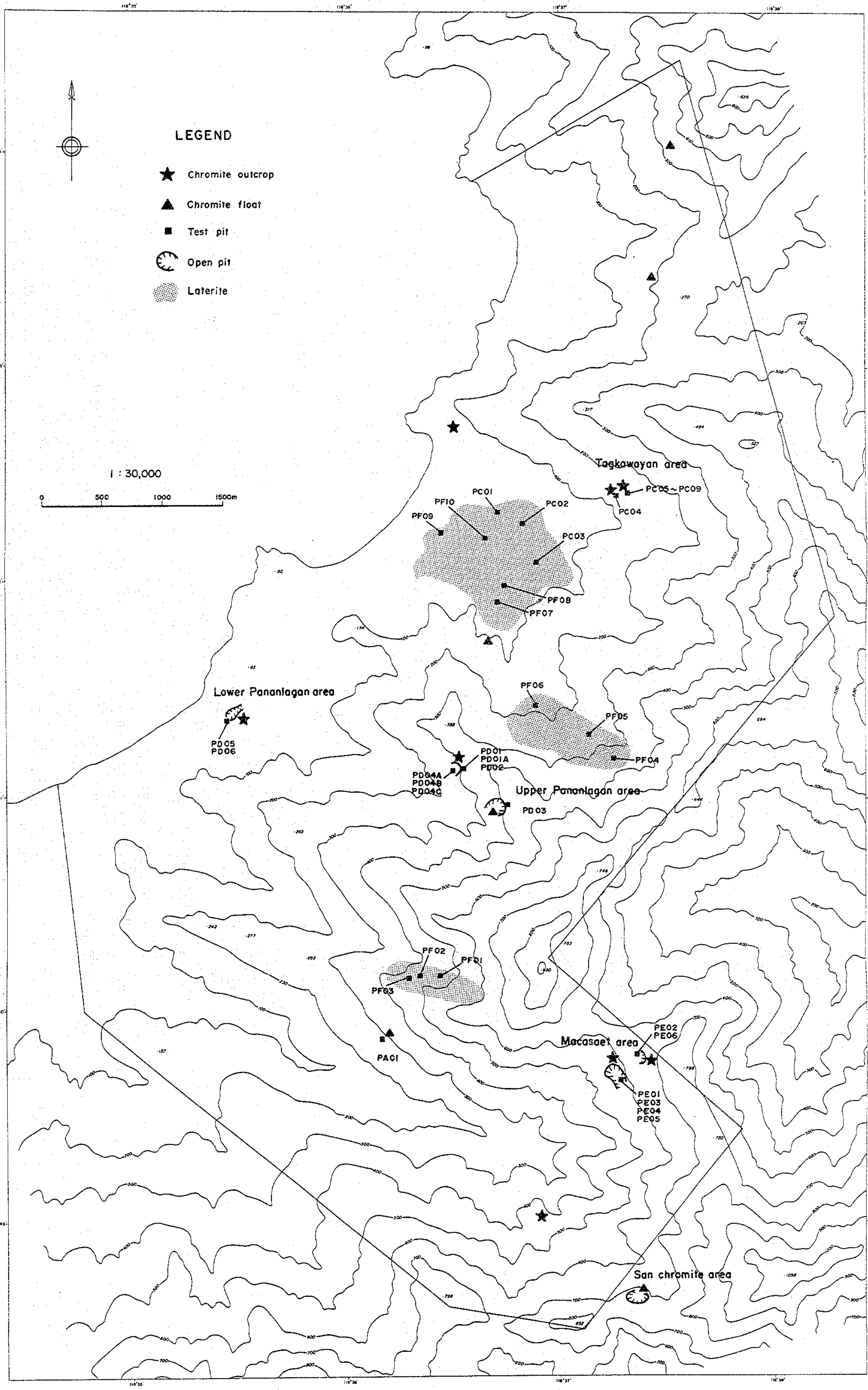



Fig.12 Location of mineral showings and test pits in area A-1

dunite tectonite body in area A-1. The dunite hosts extensive dissemination of chromite.

The old working of open pit mining was presumably performed by means of machines in large-scale. It is said that an underground mining was also partially applied. Benguet performed a prospecting program consisting of geological and soil geochemical surveys, and the results revealed the distribution of the chromite boulders. The company followed up those results by a test pit survey.

The ore deposits confirmed by above mentioned surveys are 1 to 2m wide, and extend as long as 60m. Beside the largest ore body, 150 tons of high grade massive ores are stocked. Each ore body mainly consists of massive ores, accompanied with nodular ores (Leopard type) in some cases. The ore bodies extend NNW-NW to SSE-SE, and dip 50° to 60° east. The test pit survey consisting of six pits was performed in phase 1 survey, and revealed chromitite outcrop at the test pit PE01.

ii) San Chromite area

An old working of open pit mining exists in the uppermost part of the Malinao River, southeastern end of the area A-1. The working is 200m east to west and 200m north to south in size. The working zone is underlain by dunite disseminated by chromite. At present, no ore outcrop is seen, but some floats of massive ore are scattered there. Judging from those evidences, this area used be mined for massive ore as well as the Macasaet area.

An lense of massive ore crops out on the ridge north of this open pit, traceable to 20m long with 1m wide. Several tons of ore is stocked there.

iii) Lower Pananlagan area

This zone is situated in the downstream area of the Pananlagan River, and contains three chromitite outcrops. The largest outcrop is seen in an old working of open pit mining, 40m x 20m in size (Fig. 14). Several chromite lenses in spindle shape are observed in the direction of N80°W, dipping 60° to 80° west in weathered dunite. Chromite disseminated ores surround the massive ores. A test pit survey was performed at four sites to follow the extension of the ore bodies, but no chromitites were found.

iv) Upper Pananlagan area

On the northern slope of the Pananlagan River, two workings of open pit mining exist. One in the downstream side is of small size, only 20m x 10m, with approximately 10m wide. Disseminated chromite ores extend from east to west. A test pit survey consisting of six pits was performed in this zone, and revealed the extension of the chromite ores.

The other one in the upstream side is approximately 200m x 50m in size. The slope has generally collapsed and no chromite ore outcrop was found. But some boulders of massive chromite ore are observed in the collapsed material. Several tons of massive ore stock is seen in the area. One test pit was dug at the topmost working, but no chromite ore was found.

v) Tagkawayan area

In two places in the tributary of the Tagkawayan River, dunite layers containing disseminated chromite in 3m wide exist. The direction of the chrome dissemination is N70°E-E to S70°W-W, dipping 60° to 70° to the north. In the downstream and upstream areas of the tributary, many

floats of massive chromite ore are scattered, but no outcrop is found. On the west slope, a small amount of chromite ore stock exists, suggesting small scale mining was previously conducted there. The test pit survey was performed at nine sites in the area. Dunite disseminated by chromite were observed at every pit, but no outcrop of the ore was found.

In the tributary south of the Tagkawayan River, boulders of massive chromitite were found but no chromitite outcrop were discovered.

vi) Tagminatay area

Floats of chromite ore are scattered along the old forest road running from the Tagkawayan River area to Tagminatay. When the road was under construction, an outcrop of chromite ore in spindle shape, 30cm x 6m in size, was found in weathered harzburgite. The ore outcrop however thinned out in a short, then was covered by soil again.

Many floats of massive chromite ore were found in the northern tributary in the Tagminatay area, no outcrop however was found. Dunite is distributed around this area.

(2) Detailed survey area A-2

The most important ore deposits of the area A-2 are of chromite deposits. The chromite deposits are mainly distributed around the Nagtabon Pass (Fig.10). No operating mines are found in area A-2, but it seems that the exploration was conducted vigorously by private companies in later half of 1970's. These chromite deposits are grouped in Maranat deposit and Nagtabon deposits. Most of these deposits are small in scale except Nagtabon No. 1 deposit. Nagtabon No. 1 deposit is rather large in scale, though it consists mainly of disseminated chromite ore on the surface. It may be able to be mined depend on the subsurface occurrence. Precise descriptions of each deposit are as follows.

i) Maranat deposit

There is an old working on the gentle ridge south of Maranat Village. Vegetation is grass and small trees around the working.

Chromite ore occurs in small weathered dunite body. Thrust fault is found 200 meters east of the deposits. Quartz schist crops out as window in the ultramafics on the upper part of the ridge. It is supposed that the bottom of the ultramafics is shallow, some ten meters, in this area.

There are two open cuts. Chromite ore was mined from upper open cut. Massive chromite ore body of 3 meters wide still remains in weathered dunite. It trends N10°E and dips 60°E. About 15 meters of trench-like old working extends to this direction, and no chromite ore crops out in the lower open cut 40 meters apart. From these it may be inferred that the length of ore body was about 15 meters and pinched out. About 200 tons of massive chromite ore are stocked in the lower old cut. Residents referred that Golden Island Co. Ltd. mined surface float ore and subsurface ore body. They stopped mining at January 1977 because they ran short of budget, and meanwhile they shipped twice the same amount of stocked ore. This means that about 600 tons of massive ore was mined from this deposit.

Though the extension below the surface is not clear, the Maranat deposit might have been podiform in shape with about 1,000 tons of massive ore at the thought of the thin thickness of the ultramafic rocks, a small dunite body and only one ore body.

The ore sample from this ore body seemed to be very high grade, but the ore shows 26.50

% of $Cr_2O_3$ and rich in aluminum. It is classified into refractory grade ore.

ii) Nagtabon No. 1 deposit

An old working is situated to the 450 meters north of Nagtabon Pass (Fig. 13). A good road, passable by car, leads from the Pass to the working. The east side of the working to Bacungan consists of gentle hills, whereas the west side of the working forms steep cliffs.

This deposit occurs in serpentinized dunite and consists mainly of disseminated chromite ore. This area was stripped along the ridge extending about 70 meters. The disseminated chromite ore body is being able to pursue for 40 meters. The outcrop is 7.5 meters in width at the lowest part, but it is separated into 3 or 4 ore strings at the upper part on the ridge. Each string consists of disseminated type ore with 1.5 meter in width. The lowest part of the outcrop consists of close spaced chromite bands ranging from 1 to 40 cm in width. The average chromite content is megascopically about 30 %. Six channel samples of the lowest part of the outcrop shows 12.59% $Cr_2O_3$ average. The microprobe analysis of chromite is obtained about 53.4 % $Cr_2O_3$, hence the chromite content of ore is estimated about 24 %.

Residents referred that massive ore was mined at first, but mined out already. Only floats of massive ore are recognized now. Underground mining was not operated. There is no data about the occurrence of subsurface massive chromite ore body.

The tonnage of massive chromite ore is not clear, but as far as disseminated ore is concerned, this deposit can be estimated the tonnage about 2,000 tons as chromite by presuming the extension of ore body 10 meters downward and 24% of chromite content.

iii) Nagtabon No. 2 deposit

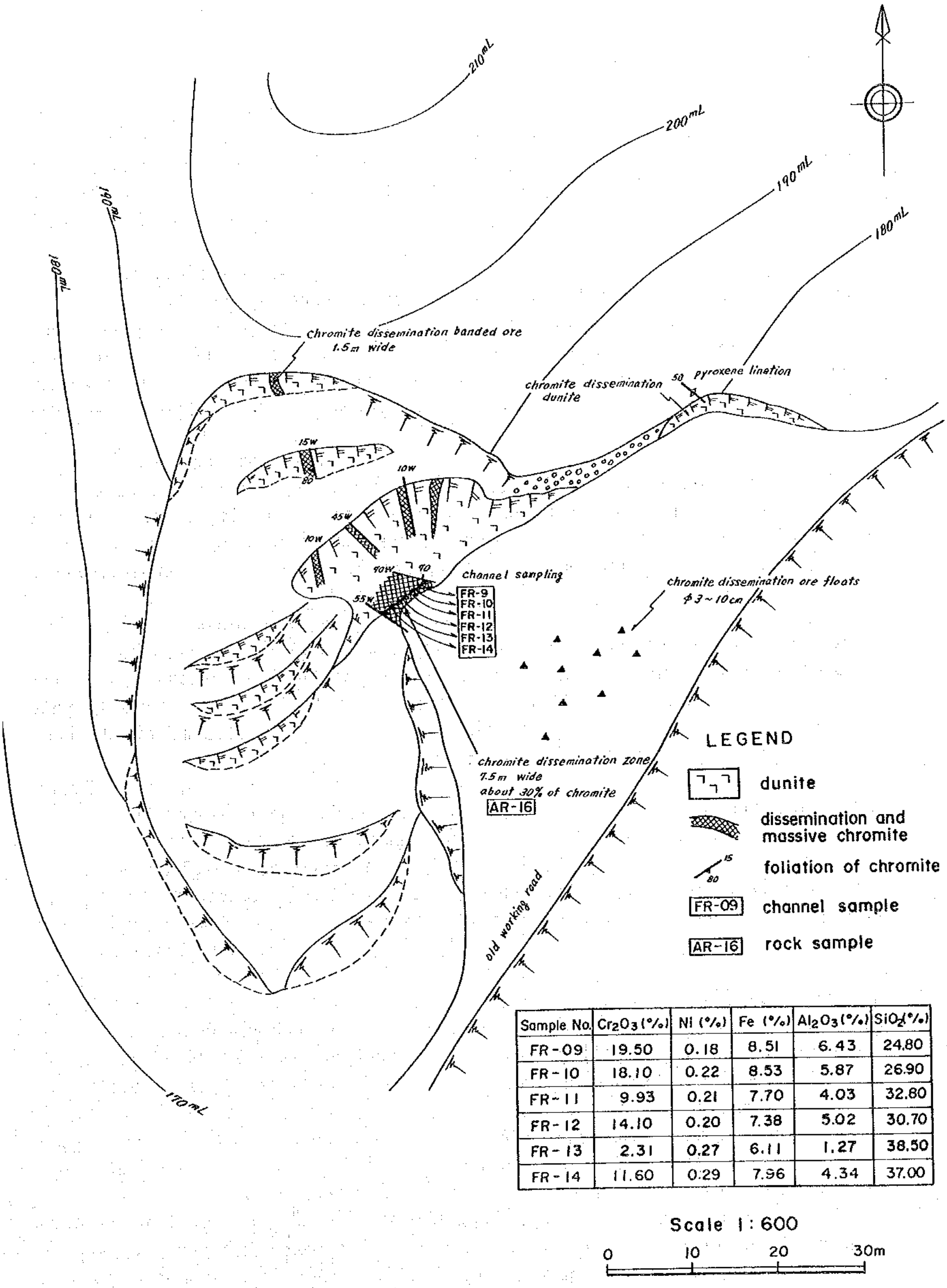
Two old mine roads run southward from Nagtabon Pass. One road is the east side of ridge, and the other is the west of ridge. Former one leads to Nagtabon No. 2 deposit , which is 500 meters south of Nagtabon Pass and situated in the bed of a small stream flowing eastward. Vegetation is thicket around the working.

The ore body consists of massive chromite extending 6 meters, trending N35°E and dipping 65°W. The maximum width is 70 centimeters. The analytical result of chromite ore is 38.40 % $Cr_2O_3$. The ore body occurs in serpentinized dunite that is strongly fractured. The ore body is stretched to the direction of shear N10°E, and divided into echelon veins.

About 20 tons of massive chromite ore are stocked in the working. The analytical result of ore sample shows 37.80% $Cr_2O_3$. This deposit can be calculated about 200 tons of tonnage as chromite, presuming 10 meters extension of ore body from the top downward, hence this ore body is very small in scale.

iv) Nagtabon No. 3 deposit

The old mine road of the west side of ridge leads southward from Nagtabon Pass to an old working, which is 500 meters south of Nagtabon Pass and 50 x 50 meters in scale (Fig. 12). Serpentinized dunite crops out in the working, but no outcrops of chromite ore are found. About 30 tons of massive chromite ores are stocked in the working. The analysis of ore sample from this stock pile shows 39.60% $Cr_2O_3$. A small amount of disseminated ore is also found in the stocked ores; therefore the ore body is presumed a lens-like massive ore body same as Nagtabon No. 2 deposit. The width of lens must be at least 60 centimeters, because maximum size of




| Sample No. | $Cr_2O_3$ (%) | Ni (%) | Fe (%) | $Al_2O_3$ (%) | $SiO_2$ (%) |
|---|---|---|---|---|---|
| FR-09 | 19.50 | 0.18 | 8.51 | 6.43 | 24.80 |
| FR-10 | 18.10 | 0.22 | 8.53 | 5.87 | 26.90 |
| FR-11 | 9.93 | 0.21 | 7.70 | 4.03 | 32.80 |
| FR-12 | 14.10 | 0.20 | 7.38 | 5.02 | 30.70 |
| FR-13 | 2.31 | 0.27 | 6.11 | 1.27 | 38.50 |
| FR-14 | 11.60 | 0.29 | 7.96 | 4.34 | 37.00 |

Fig.13 Map of the Nagtabon No.1 old working

stocked ore exceeds 60 cm in diameter.

The scale of ore deposit is difficult to presume, because there is no outcrop and working site was put into disorder. The tonnage of deposit is presumed to be 1,000 tons as chromite, thinking the size of working here is bigger than that of Nagtabon No. 2 deposit, but smaller than that of Nagtabon No. 1 deposit.

v) Nagtabon No. 4 mineral showing

A small massive chromite ore body occurs in weathered dunite on the road cutting to the north of Nagtabon No. 1 deposit. This ore body is 70 cm wide and 6 meters long. Chromium oxide content of this ore is 47.2 %. There is no other ore body around here. The ore body consists of massive chromite ores, and this deposit can be calculated the tonnage ranging from 200 to 300 metric tons presuming the extension of ore body 10 meters downward.

vi) Nagtabon No. 5 mineral showing

A small trench, 1 meter wide and 2 meters long, is found at northeast of Nagtabon No. 3 deposit. Small massive chromite ore ranging in diameter from some centimeters to 10 centimeters is scattered around the trench. Analysis of sample shows 33.50%$Cr_2O_3$.The weathered dunite is cropped out in the trench,but no outcrop of chromite was discovered.

vii) Nagtabon No. 6 mineral showing

This mineral showing is 200 meters south of Nagtabon No. 3 deposit. Floats of disseminated chromite ore are scattered in the trench which is 1.5 meters wide and 4 meters long. Chromium oxide content of these floats is 31.80 %. The maximum size of ore is 40 centimeters in diameter.

viii) Other mineral showings

A very small chromite pod occurs in a small dunite body at the easternmost part of the survey area. It consists of massive chromite ore. About 1 metric ton of chromite ore is stocked around this pod. Chromium oxide content of this ore is 41.20%.

Some chromite bands are scattered in the dunite bodies distributed around Nagtabon Pass and south of Mt. Airey. These chromite bands consist of one to several bands ranging in width from several to 10 centimeters.

(3) Detailed survey area A-3

The main mineral deposits are chromite deposits in this area. Most of them occur in a dunite body distributed in the central portion of the area (Fig.11). These deposits were explored by private company, Country Mineral Resources Corporation, during later half of 1970's. Since the name of claim was "Pagasa", they named the possible areas Pagasa 1 to Pagasa 5. It seems that Pagasa 3 and Pagasa 5 was only possible areas of chromite deposit by the result of geochemical prospecting, and no ore bodies were recognized in this survey.

Mining and exploration might have been operated in Pagasa 1, 2 and 4. Several old mine roads lead to these areas. The dunite is well-exposed due to the lack of soil because of rigid topography, in addition, construction of mine road and stripping made cropped out chromite ores. In particular, many outcrops of massive chromite ore occur in Pagasa 1 area and promising

area is rather large. For this reason Pagasa 1 deposit may be possible to estimate several ten thousand tons as chromite.

i) Pagasa 1 deposit

An old mine road branches northeastward off the national highway along the ridge and leads to Pagasa 1 area, where the mineralized area covers more than 150 x 150 meters and more than 10 outcrops of massive and disseminated chromite ore occur in dunite, along this mine road (Fig.14). Vegetation is small trees around here, but soil is very thin and many boulders piled up upper part of the ridge.

The dunite has been sheared in the direction of E-W. This dunite is distributed from 50 meters' level to the upper part of the ridge, hence chromite deposit might be also limited above 50 meters' level. Chromite lenses and bands trend generally E-W, dip steeply southward, and they are ranging in width from several ten centimeters to 2 meters. They consist of close spaced chromite stringers ranging in width from several millimeters to 2 centimeters. Chromium oxide content of channel samples shows 16.50%, 12.70%, 46.80%, and 46.70%. The electron microprobe studies show that chromite in this deposit contains about 60 % $Cr_2O_3$. On the basis of this result, chromite content of the channel samples is calculated 30 to 80 %.

It is rather difficult to calculate the volume of the deposits based on only surface survey. On the basis of the assumptions of the 150 x 150 meters promising area, the extension of deposit 10 meters downward, 20 to 30 % ore existence and 30 % of chromite content, it may be inferred that the weight of chromite is 40 to 60 thousand tons.

ii) Pagasa 2 deposit

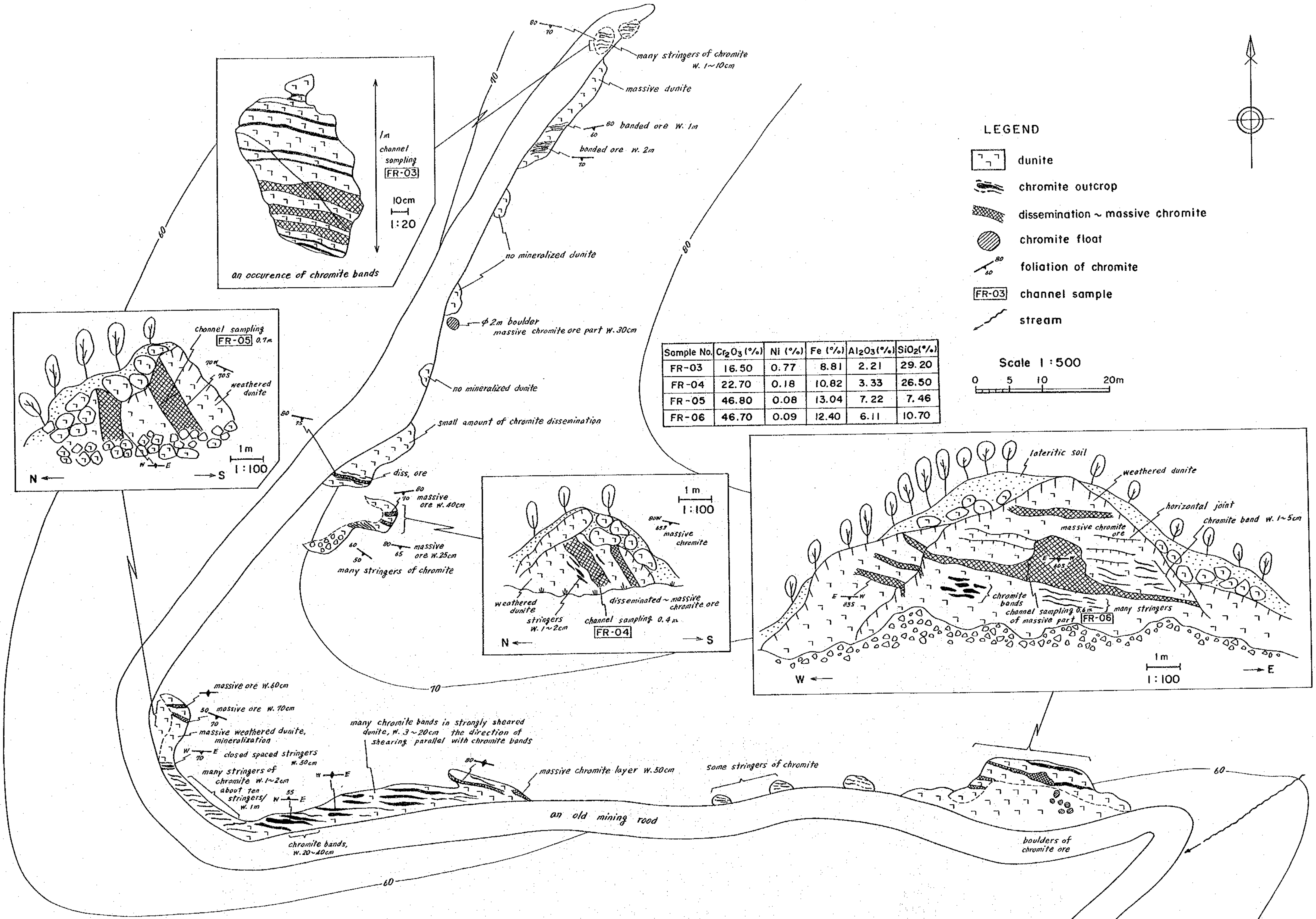
The old mine road runs eastward in the north of the area. The old subsurface mining site is situated at the end of this road. Vegetation is tall grasses and shrubs around here.

Chromite band and disseminated ore occur in chromite disseminated dunite around the adit, especially at southern part. They strike N80°W, dip steeply northwest. The level adit is about 35 meter long, and connected with another inclined adit at the heading. The trend of level adit coincides with that of chromite bands. Small floats of massive chromite ores scatter around the entrance of the adit, and the analysis of this shows 49.00 % $Cr_2O_3$. Another ore (BR-07) collected from a stock near the entrance shows 46.60 %. Though residents said that massive chromite ore body exposed 1.5 meters wide in the adit, the chromite ore is not found in the adit now because the surface of the adit is wholly covered by rock powder. Width of the level adit is almost regular, whereas that of inclined adit is irregular, thereby it seems that mining was operated at the inclined adit. Small breccias of oxidized massive chromite ore are found extending to N80°W at the entrance of the inclined adit. The grade of this ore is 51.30 % $Cr_2O_3$.

It is very difficult to estimate the volume of deposit, because outcrops of chromite ore are scarce and occurrence of chromite body is not clear under the adit level. The deposit might be small in scale, because only one massive ore body has been mined in small scale and a small amount of chromite bands is observed on the surface.

iii) Pagasa 4 deposit

An old working of open pit mining is situated at the ridge extending to east from 291m peak that is east of national highway. Residents said that massive chromite ores were mined




| Sample No. | $Cr_2O_3$ (%) | Ni (%) | Fe (%) | $Al_2O_3$ (%) | $SiO_2$ (%) |
|---|---|---|---|---|---|
| FR-03 | 16.50 | 0.77 | 8.81 | 2.21 | 29.20 |
| FR-04 | 22.70 | 0.18 | 10.82 | 3.33 | 26.50 |
| FR-05 | 46.80 | 0.08 | 13.04 | 7.22 | 7.46 |
| FR-06 | 46.70 | 0.09 | 12.40 | 6.11 | 10.70 |

Fig.14 Map of the Pagasa 1 old working

around area A-3 and transported to east coast. From the location of this deposit, it may be inferred that the ore was mined at this deposit and was shipped.

Lenses and dissemination type chromite ore occur in weathered dunite. Stripping was conducted in a wide scale around the deposit area about 140 meters east to west and 70 meters north to south. Outcrop of massive chromite ore is found at central portion of the working and it consists of chromite lens ranging in width from 0.6 to 1.2 meter. The lens strikes N70°E, and dips 60°E. The analysis of 1.2 meter's channel sample from this lens shows 30.90 % $Cr_2O_3$. This lens pinches out both sides of cutting, and this chromite lens seems to be completely mined.

There are other 3 or 4 small outcrops in the working. Each outcrop strikes N70 to 80°E, and dips 50°E. They are ranging in width from 0.3 to 2 meters, and consist of 1 to 5 centimeters close spaced chromite bands.

iv) Other mineral showings

Several chromite bands ranging in width from 1 to 5 centimeters occur on the ridge between Pagasa 1 and Pagasa 2. Each band is a small scale disseminated one and spaces apart. There is scarce potentiality for chromite deposit.

Outcrop of massive chromite ore in width several ten centimeters occur in the westernmost part of the area. Considering the small scale of this dunite tectonite, it hardly seems possible to find other deposits. The analysis of this ore shows 11.70% $Cr_2O_3$.

(2) Nickel occurrences

Nickel laterite is distributed in the area near Bacungan in the northern A-area, as well as the upstream area of the Pinamonoan River and basin of the Tagkawayan River in the west coast. The test pit survey was conducted in these areas.

i) Bacungan area

Eleven test pits were dug in this area. Fig. 15 shows the locations of the test pits and the distribution of laterite.

Lateritization in this area is intense. Laterite layers are more than 4.5m to 6.5m in thick at the nine pits out of eleven, and about 1m at the rest two pits, which reached to the basement rocks. About the half of the pits did not reach to the basement yet. The results of the assay have revealed that the grade of nickel content was 0.5 to 1%, showing poor grade as nickel ore. Also the results has indicated that the grade of iron was higher than 40% except two pits, BC-01 and BC-02. It means that the bottoms of those pits are still in residual laterite. Because the nickel is concentrated in the underlying peridotite (saprolite), almost all pits dug this time presumably do not reach nickel concentrated layers.

Grade of chrome shows higher than 2% at every pit, over 6% in some cases, which indicates high potentiality for the chromite deposits.

ii) West coast

Because laterite was found in the upstream area of the Pinamunoan River and the Tagkawayan River, the test pit survey consisting 13 pits was conducted in three areas. Fig. 12 shows the locations of the test pits. Weathered crusts of peridotite in the west coast are not thick compared with the Bacungan area, because of its steep topography.

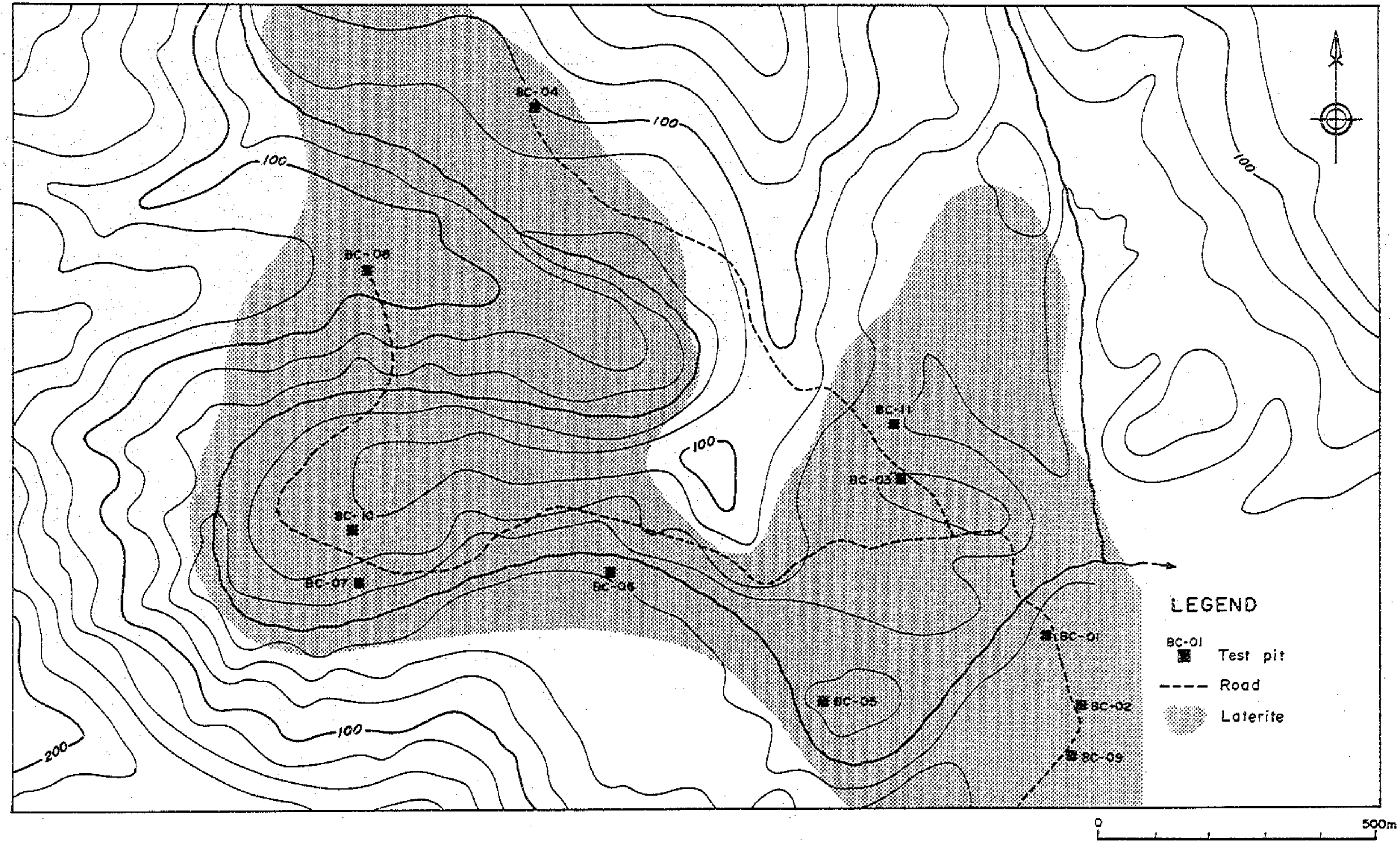



Fig.15 Location map of test pits BC01 to BC11 in Bacungan area

Three test pits were dug in the upstream area of the Pinamunoan River. They reached to altered peridotite zones, however did not show any high assay results for nickel, 0.5 to 0.7%.

The test pits dug in the downstream area of the Tagkawayan River reached to the basement except one pit, PF10. The nickel grade is 0.5 to 1.0% at test pit PC02 and PC03, and 0.4% at the rest of pits.

A test pit survey consisting of three pits was conducted in the upstream area of the Tagkawayan River. The nickel grades show higher than 0.7%, except at PF05 which was dug into a weathered zone of fine-grained gabbro. The grade is particularly high at PF06, 1.9% at the zone 3m to 4m deep and 2.7% at the zone 4m to 5m deep.

## 1-2 Geochemical Survey

### 1-2-1 Soil geochemistry in A-area

1) Sampling

Soil geochemical survey was conducted in combination with geological mapping at the scale of 1:10,000. As chromite ore deposits in ultramafic rocks are the most important in this area, each sampling site along streams were predetermined in ultramafic rocks' area on the map.

Soil from B horizon had been taken from opposite banks at points above the highest water level of the stream. The heavy mineral sand was collected from 5 kilograms of soil by panning and checked the weight per 1 kilogram's soil. About 1 kilogram of soil samples from right and left banks was mixed for chemical analysis sample.

Collected soil samples were air-dried and screened with an 80 mesh sieve. About 100 g of -80 mesh fraction of each dried sample was taken and divided into halves. One half was used for chemical analyses in the PETROLAB in Philippines while the other half was used for analyses in Chemex Labs. Ltd. in Canada.

2) Pathfinder elements and chemical analyses.

Chromite deposits associated with ultramafic rocks are known to exist in this area. As these ore deposits are associated with ophiolite complexes, seven elements were selected as pathfinder elements because of the high possibility of concentration: platinum (Pt), palladium (Pd), gold (Au), nickel (Ni), chromium (Cr), iron (Fe) and cobalt (Co).

The elements of Ni, Cr, Fe and Co were analyzed in PETROLAB while Pt, Pd and Au analyses were done in Chemex Labs. Ltd.

3) Data analyses

The method of basic statistical analysis and principal components analysis were used in this survey.

The combined data of A-area and B-area were used for data processing, and same statistic values and anomalous values were used for geochemical analysis in A-area and B-area, because both of areas are mainly underlain by the Mt. Beaufort Ultramafics.

There is no one-to-one correspondence between the weight of heavy mineral sand and chemical data of soil samples. The average weight of heavy mineral sand from right and left bank soil was used for the calculation of correlation coefficients and principal components analysis.

(i) Statistical analysis

It is known that normal and lognormal distribution models are of great importance in processing geochemical data. In particular, the distribution of minor elements in geochemistry shows close resemblance to that of the lognormal law as long as the accuracy of analyses is enough. Accordingly the logarithmic transformation of raw data was done before the data were analyzed. The raw values for Pt, Pd and Au have below-detection-limit. If the value of the raw data is below-detection-limit, half of the detection limit value is used in data processing.

The maximum value, minimum value, median, mean value(m) and standard deviation($\sigma$) are shown in Table 3.

Table 3 Basic statistic quantities of soil samples in A-area and B-area

| | | | linear | | logarithmic | | |
|---|---|---|---|---|---|---|---|
| element | range | median | mean | std. dev. | mean | $10^{\wedge}$mean | std. dev. |
| Pt (ppb) | 2.5 - 120 | 2.5 | 6.5 | 13.9 | 0.540 | 3.5 | 0.351 |
| Pd (ppb) | 1 - 120 | 4 | 8.7 | 13.5 | 0.613 | 4.1 | 0.527 |
| Au (ppb) | 1 - 130 | 1 | 2.2 | 5.3 | 0.153 | 1.4 | 0.308 |
| Ni (ppm) | 28 - 16100 | 2690 | 2773.3 | 1964.4 | 3.261 | 1823.3 | 0.509 |
| Cr (ppm) | 100 - 324000 | 14000 | 17121.7 | 18206.2 | 3.998 | 9948.9 | 0.576 |
| Fe (%) | 2.8 - 53.4 | 10.5 | 13.3 | 9.0 | 1.043 | 11.0 | 0.254 |
| Co (ppm) | 17 - 1900 | 236 | 277.2 | 208.6 | 2.309 | 203.7 | 0.368 |

(ii) Element content map

The content of each element is classed by mean value and standard deviation, and plotted on the element content map (Fig. 16 to Fig. 19).

Threshold for classifying background and anomalous values about Ni, Cr, Fe, Co and Pd is decided taking into consideration the cumulative probability curves, mean value(m) and standard deviation($\sigma$).

(iii) Distribution of anomalous area

On the basis of the above-mentioned thresholds, anomalous values of each element are shown in element content map. The results are as follows:

Heavy mineral sand in soil(Fig.20):The anomaly areas are distributed in the north area of Tagburos, around Bacungan, the northeast part of A-area, and the area along west coast.
Cr: The anomaly areas are distributed in the north area of Tagburos, the area around Bacungan, and the area along west coast.
Co: The anomaly areas are distributed in the north area of Bacungan and along west coast.

(iv) Principal components analysis

The aim of principal components analysis (PCA) is to represent the large number of elements in the original data by smaller number of "factor". The covariance matrix obtained from standardized ((raw value - mean)/(standard deviation)) data set is equal with correlation coefficients matrix. We have used the correlation matrix as initial matrix for this principal components analysis.

According to the factor loading matrix, elements can be divided into 2 groups. Ni, Cr, Fe and Co have strong positive loading on component 1. Pt, Pd and Au have strong negative loading on component 2.

These results mean that the samples with high scores on component 1 are generally enriched in Ni, Cr, Fe and Co and the sample with negative scores on component 2 are enriched in Pt, Pd and Au compared with the other samples.

The component 1 scores of more than $m+1\sigma$ and the component 2 scores of less than $m-\sigma$ area were picked up for anomaly.

The anomaly areas of component 1 are distributed in the north area of Tagburos, the north area of Bacungan, and the area from Malinao River to Tagminatay. The anomaly areas of components 2 are almost overlapped with that of component 1.

4) Results of soil geochemistry

Interpretation map (Fig.32) shows the anomaly areas of principal component 1 summarizing the content of Ni, Cr, Fe and Co, component 2 summarizing the content of Pt, Pd and Au, the anomaly areas of heavy mineral sand in soil, and the distribution of ultramafic rocks.

The promising areas overlapping with several anomaly areas are shown as follows:

1. The area from Malinao River to Tagminatay
2. The area from the north of Bacungan to west coast
3. The area on the north of Tagburos

## 1-2-2 Soil geochemistry in detailed survey area A-1

The A-1 anomalous area is the area from Malinao River to Tagminatay along the west coast, located in the west part of A-area. This area was followed up with detailed geologic mapping and close spaced soil sampling designed along spurs and ridges.

1) Sampling and chemical analysis

Soil geochemical survey was conducted in combination with geological mapping at a scale of 1:5,000. Sampling method in area A-1 was almost the same with that of A-area.

Same elements as A-area were selected as pathfinder elements.

2) Data analyses

The method of basic statistical analysis and principal components analysis were used in this survey.

(i) Statistical analysis

The range, median, mean and standard deviation($\sigma$) are shown in Table 4. Area A-1 is the anomaly area of A-area, so medians and mean values of all elements are higher than the values calculated from A-area and B-area data set.

Table 4 Basic statistic quantities of soil samples in area A-1

| | | | linear | | logarithmic | | |
|---|---|---|---|---|---|---|---|
| element | range | median | mean | std. dev. | mean | 10^mean | std. dev. |
| Pt(ppb) | 2.5 - 320 | 25 | 29.7 | 25.8 | 1.331 | 21.4 | 0.382 |
| Pd(ppb) | 1 - 650 | 12 | 18.2 | 25.1 | 1.067 | 11.7 | 0.421 |
| Au(ppb) | 1 - 270 | 1 | 4.5 | 12.0 | 0.314 | 2.1 | 0.447 |
| Ni(ppm) | 2 - 17200 | 3200 | 3657.7 | 2653.7 | 3.396 | 2489.8 | 0.485 |
| Cr(ppm) | 140 - 71000 | 19000 | 20336.2 | 11429.0 | 4.195 | 15669.2 | 0.403 |
| Fe(%) | 3.0 - 55.0 | 16.8 | 18.0 | 7.9 | 1.212 | 16.3 | 0.199 |
| Co(ppm) | 4 - 1890 | 390 | 453.9 | 271.0 | 2.557 | 361.0 | 0.343 |

(ii) Element content map

The content of each sample is classed by mean value and standard deviation, and plotted on the element content map (Fig.21 to Fig.24).

Area A-1 is one of the anomaly areas in A-area, therefore we can't apply the same threshold with A-area and B-area to this area A-1. New threshold for area A-1 is considered mean value (m) and standard deviation (σ), and the point of m+1.0σ was adopted as threshold.

On the basis of the above-mentioned thresholds, anomalous values of each element are shown in element content map. The results are as follows:

Ni: The content in the northern half of area A-1 is higher than that of southern half. The high content areas are the area from the upper stream of Pananlagan River to the middle-upper stream of Tagkawayan, and the area in the north of Tagminatay.
Cr: The content in the northern half of area A-1 is higher than that of southern half. The anomaly areas are the middle of area A-1, and the area from Pananlagan to Tagkawayan. The anomaly area from Pananlagan to Tagkawayan is concerned with Pananlagan and Tagkawayan mineral showings. Though the rather high content area exists around Macasaet area, which are significant mineral showings in area A-1, no remarkable anomaly is obtained.
Fe: The content in the northern half of area A-1 is higher than that of southern half. Remarkable high content area was detected from Tagkawayan River to Tagminatay.
Co: The content in the southern half of area A-1 is low. The high content areas are distributed as follows; the area from Pananlagan mineral showings to the upper stream of Tagkawayan, and the south part of Tagminatay.

(iii) Principal components analysis

According to the factor loading matrix, the elements can be divided into 2 groups. Ni, Cr, Fe and Co have strong positive loading on component 1. Pt, Pd and Au have strong positive loading on component 2.

These results mean that the samples with high scores on component 1 are generally enriched in Ni, Cr, Fe and Co and the sample with positive scores on component 2 are enriched in Pt, Pd and Au compared with the other samples.

The component 1 scores of more than m+1σ and the component 2 scores of more than m+σ area were picked up as anomalous area.

The high scores areas of component 1 are distributed in the area from the upper stream of Pananlagan River to the upper part of Tagkawayan and the area on the south of Tagminatay. These areas contain Pananlagan and Tagkawayan mineral showings. The anomalous areas of

components 2 are distributed in the upper stream of Malinao River, the basin of Pananlagan River, the upper part of Pananlagan River and the area from Tagkawayan mineral showings to Tagmintay.

3) Results of soil geochemistry

Interpretation map (Fig.33) shows the anomaly areas of principal component 1, which summarizes the content of Ni, Cr, Fe and Co, and component 2, which summarizes the content of Pt, Pd and Au, and the distribution of dunite. The promising areas overlapping with several anomaly are shown as follows:

1. The area around Pananlagan mineral showings
2. The area from Tagkawayan mineral showings to the southern part of Tagminatay

The high content of Fe in soil indicates the development of residual lateritic soil. Perhaps the high contents of Fe and Ni mean the distribution of nickel laterite. The upper stream of Tagkawayan and the north part of Tagminatay have the potential of nickel lateritic soil.

### 1-2-3 Soil geochemistry in detailed survey area A-2 and A-3

1) Data analyses

The combined data of area A-2 and A-3 were used for data processing, because both of the areas are mainly underlain by the same Mt. Beaufort Ultramafics and the distance from area A-2 to area A-3 is very short.

The logarithmic transformation of raw data was done before the data processing. Some raw values for Pt, Pd and Au are below-detection-limit. If the value of raw data is below-detection-limit, half of the detection limit value is used for processing.

The range, median, mean value and standard deviation are shown in Table 5.

The content of each element is classed by mean value and standard deviation, and plotted on the element content map (Fig. 15 to Fig. 18). Anomalous values are also shown on the element content map. Because of comparing the soil geochemistry of area A-2 and A-3 with the result of the area A-1 soil geochemical survey in Phase 1, the same thresholds with the values of area A-1 soil geochemical survey are used in this survey.

Table 5 Basic statistic quantities of soil samples in area A-2 and A-3

| Basic statistic quantity (A-2 & A-3) | | | | linear | | logarithmic | | |
|---|---|---|---|---|---|---|---|---|
| element | range | (*) | median | mean | std. dev | mean | $10^{mean}$ | std. dev |
| Pt(ppb) | <5 - 290 | 31 | 25 | 39.1 | 35.5 | 1.429 | 26.9 | 0.406 |
| Pd(ppb) | <2 - 260 | 64 | 14 | 24.8 | 32.2 | 1.102 | 12.7 | 0.556 |
| Au(ppb) | <2 - 66 | 205 | 4 | 7.2 | 9.3 | 0.563 | 3.7 | 0.512 |
| Ni(ppm) | 13 - 15000 | 0 | 4600 | 4428.3 | 2590.9 | 3.476 | 2990.4 | 0.563 |
| Cr(ppm) | 200 - 162000 | 0 | 14000 | 15612.4 | 13671.8 | 4.041 | 10979.1 | 0.444 |
| Fe( % ) | 2.5 - 57.0 | 0 | 18.6 | 21.3 | 11.5 | 1.266 | 18.4 | 0.242 |
| Co(ppm) | 10 - 1640 | 0 | 430 | 427.5 | 219.0 | 2.545 | 350.9 | 0.326 |

(*) The number of the below-detection-limit samples. n=547

2) Geochemical pattern

i) detailed survey area A-2

The Ni, Cr, Co and Fe contents in soil are relatively high in the area distributed ultramafic rocks whereas very low in the metamorphic rocks and gabbro area. But contents exhibit variations not only due to the different kind host rocks but also between the different parts of the same area distributed ultramafic rocks. The content variations of these elements are due to influence of secondary enrichment and leaching by relating the weathering process, in particular, the nickeriferous laterite forming processes.

The high Fe areas exist around Bacungan and the North of Maranat. From the rock geochemical survey of Phase 1 survey, the Fe contents in peridotites of Mt. Beaufort Ultramafics fall within the range of 4 to 5 %, whereas the Fe contents in some of soil samples are more than 50 %. The residual laterite zone of nickeriferous laterite is formed by leaching of silica and enrichment of iron, cobalt and chromium during weathering process. The residual laterite, from the top downward, consists of iron crust zone, pisolites zone, and plastic laterite. The residual laterite shows characteristically high content of iron. The anomalous zone of iron may suggest the presence of nickeliferous laterite deposits.

The geochemical anomalies of nickel, more than 7,700 ppm, occur to the north of Bacungan, south of Mt. Airey and north of Maranat. They overlap with the anomalies of Fe. The anomalous values of Cr are detected to the south of Mt. Airey, north of Maranat and north of Nagtabon Pass. The anomalies of Co are distributed in the Southwest of Mt. Airey and the north portion of Maranat.

ii) Detailed survey area A-3

It appears from the soil geochemical survey that chromite deposit is only potential in this area, because nickel and cobalt content are low in soil. The dunite tectonite in area A-3 is distributed in high elevation to the east of national highway. Since almost all chromite deposits occur in dunite tectonites in Palawan, the dunite tectonite has a potential for chromite ore. Because of this, it can be stated that the areas of high chromium content in soil within this dunite body are delineated as high potential area for chromite deposits; thereby the areas around Pagasa 1 and south of Pagasa 2 are promising areas for chromite deposits.

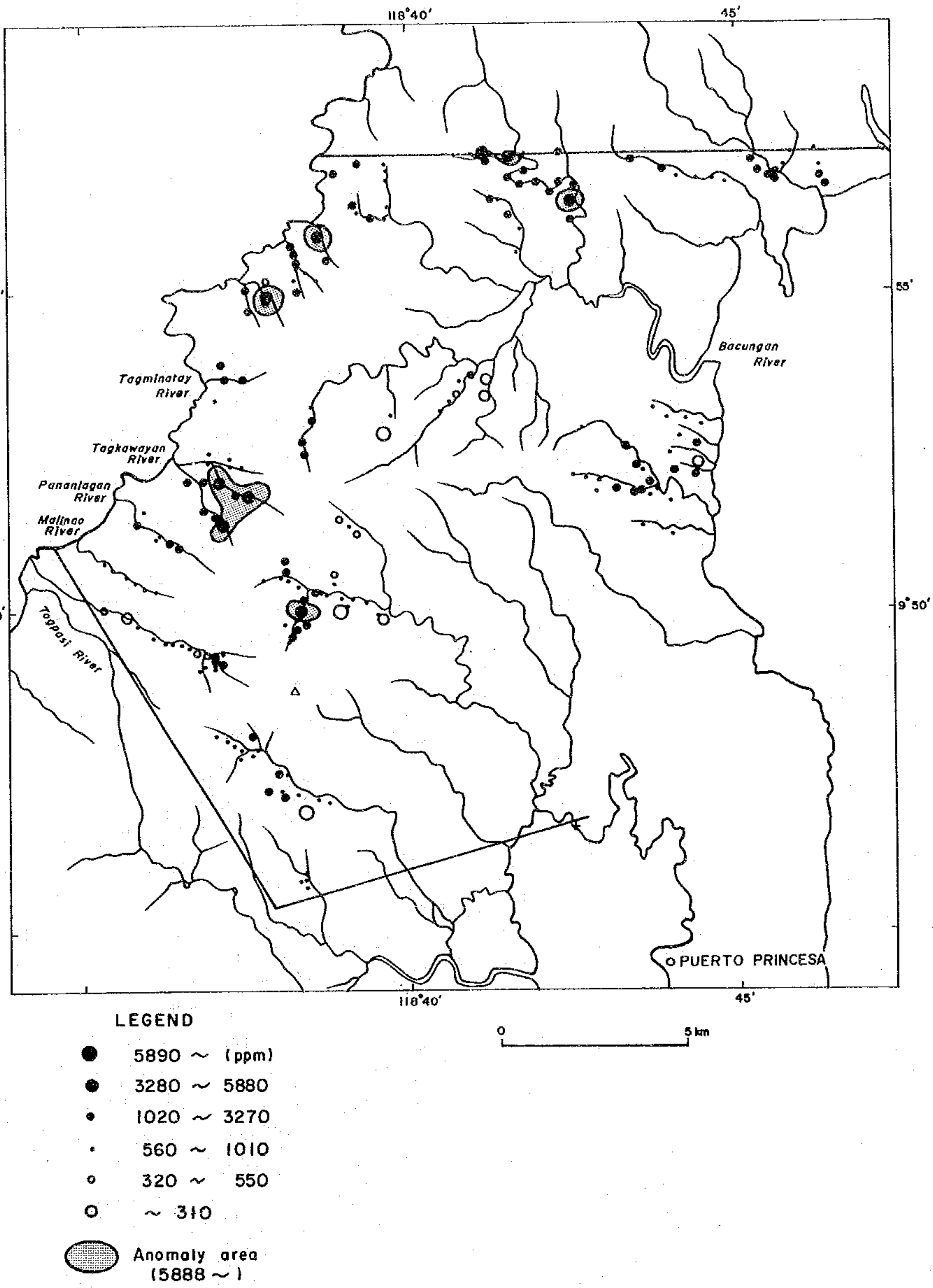



Fig.16 Ni content of soil samples in A-area

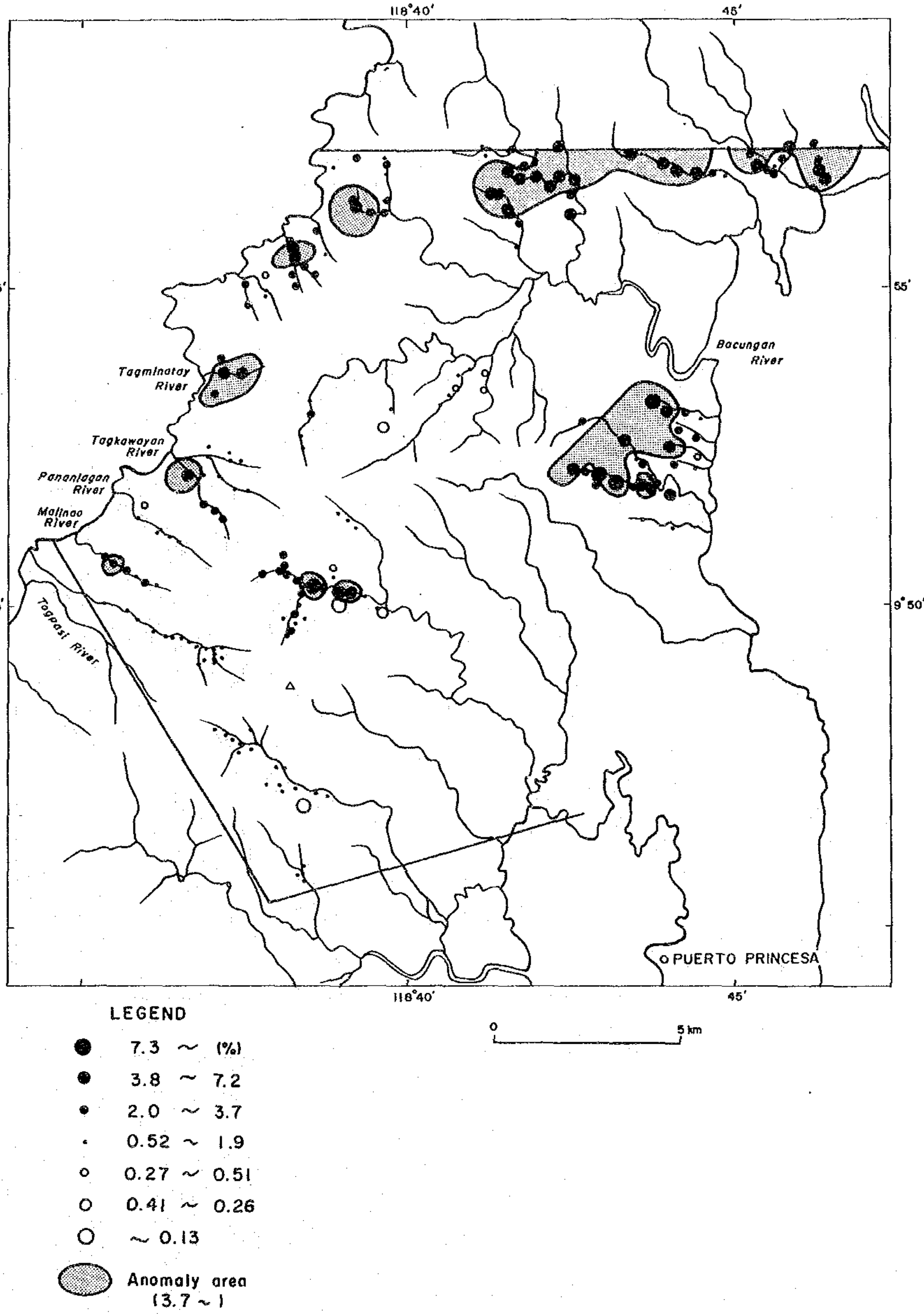



Fig.17 Cr content of soil samples in A-area

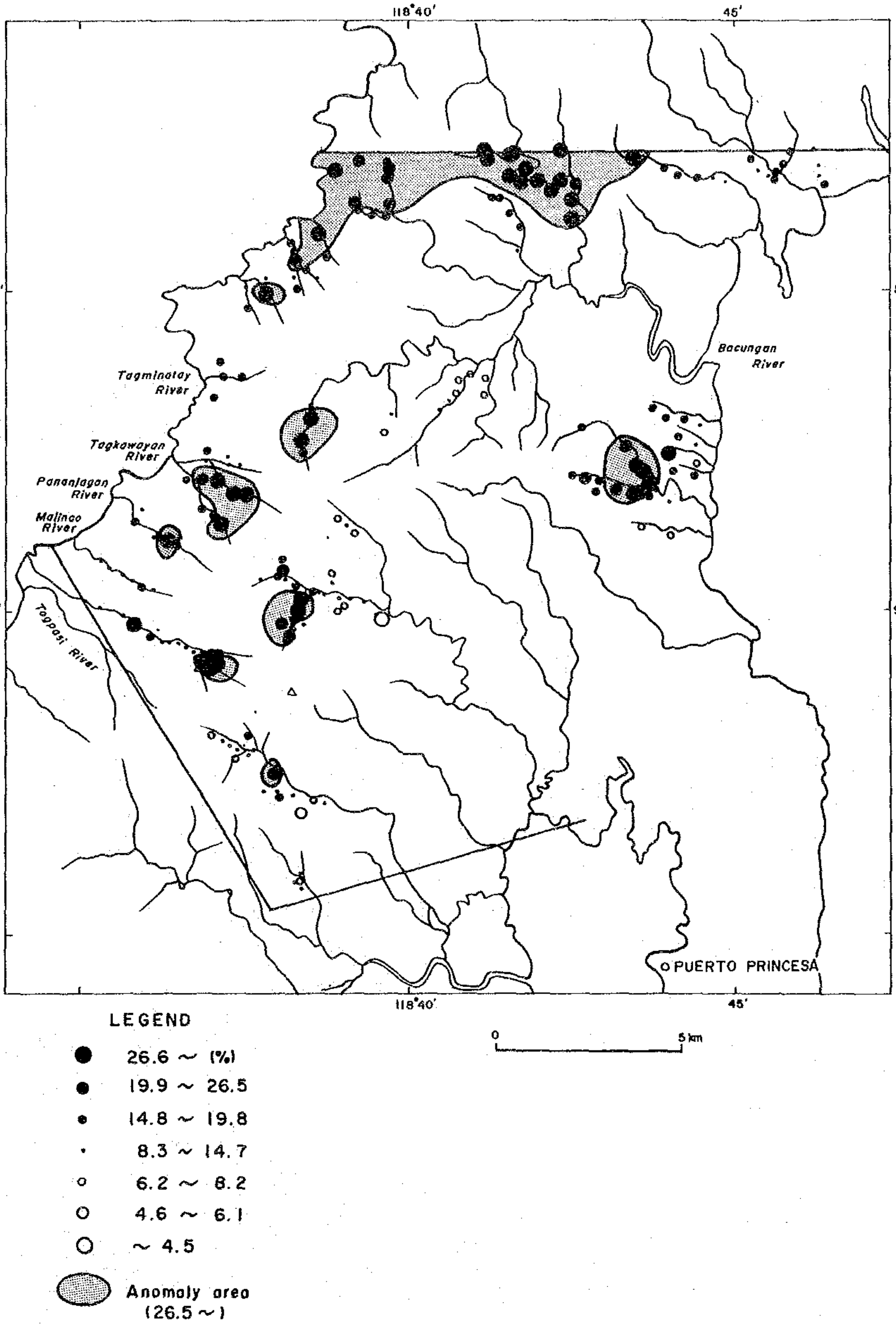



Fig.18 Fe content of soil samples in A-area

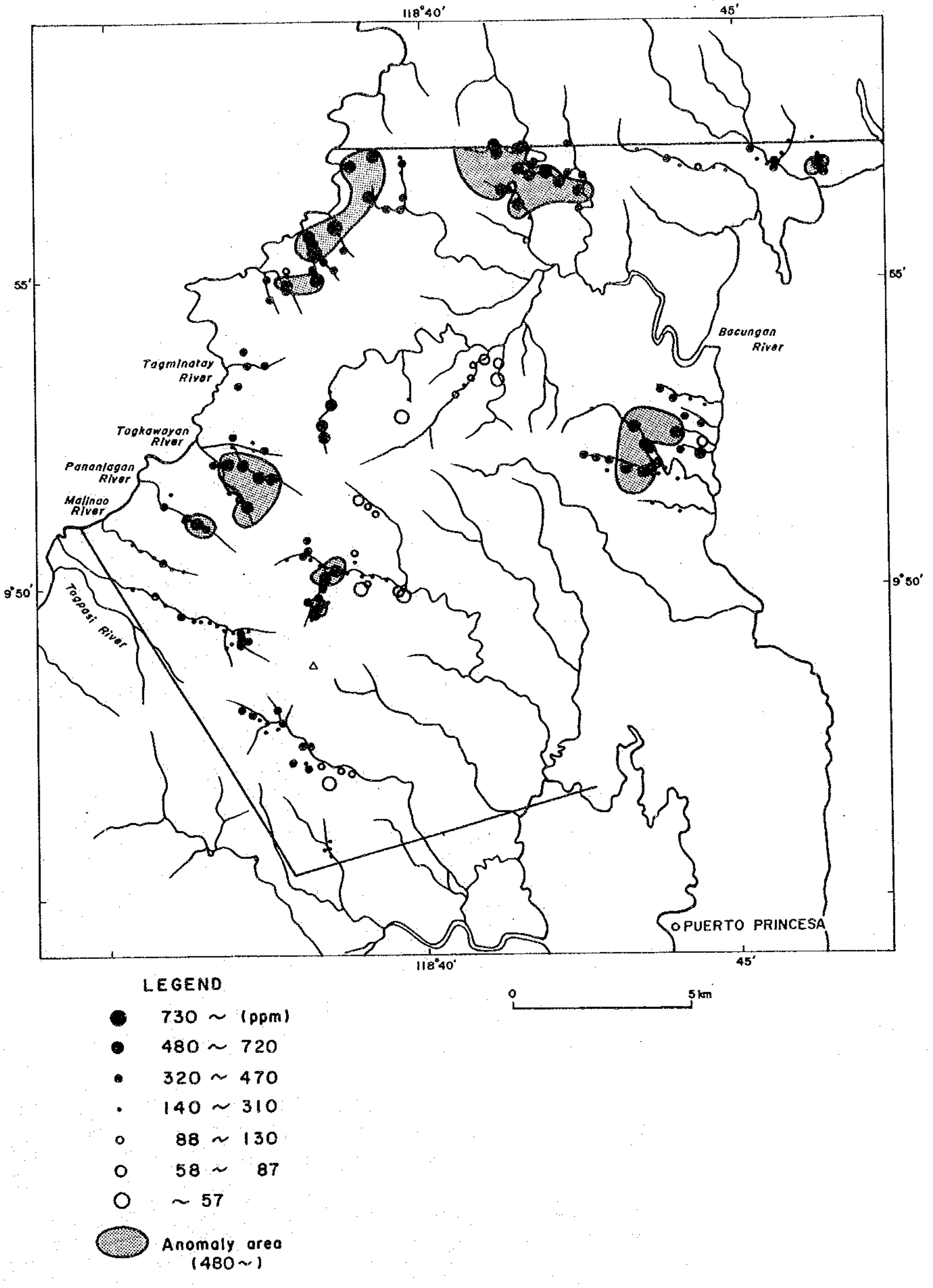
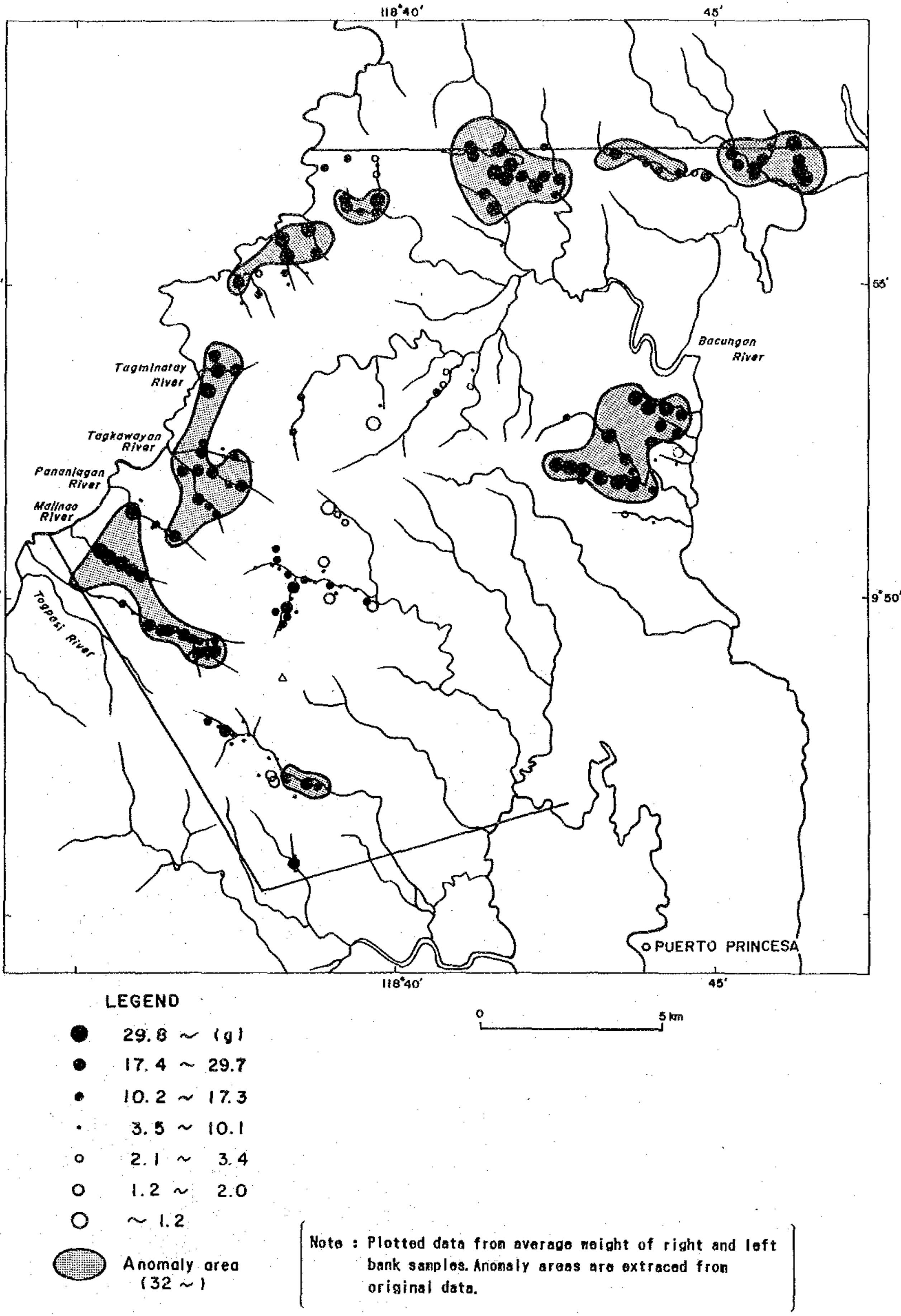



Fig.19 Co content of soil samples in A-area




Note : Plotted data from average weight of right and left bank samples. Anomaly areas are extraced from original data.

Fig.20 Heavy mineral content of soil samples in A-area