REPORT ON THE MINERAL EXPLORATION

MINERAL DEPOSITS AND TECTONICS OF TWO CONTRASTING GEOLOGIC ENVIRONMENTS IN THE REPUBLIC OF THE PHILIPPINES

PHASE III (PartIII)

PALAWAN I～VI AREA
WEST NEGROS AREA

MARCH 1987

JAPAN INTERNATIONAL COOPERATION AGENCY
METAL MINING AGENCY OF JAPAN

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Preface

In response to the request of the Government of the Republic of the Philippines, the Japanese Government decided to conduct a survey on the potential of mineral resources in the eastern Luzon, Visayas and Palawan Project and entrusted the survey to the Japan International Cooperation Agency (J.I.C.A.) and the Metal Mining Agency of Japan (M.M.A.J.).

In its third fiscal year, the J.I.C.A. and the M.M.A.J. sent to the Republic of the Philippines three teams in order to survey Northern Sierra Madre Area, Cebu Panay Romblon Area and Palawan V.VI., Western Negros Area from May, 1986 to March, 1987.

The survey works were carried out on geological, geochemical Surveys and spot investigation for mineral showings according to schedule with great cooperation of the Philippine autholities concerned, especially the Bureau of Mines and Geo-Sciences (BMG), Ministry of Natural Resources.

This report was compiled with the data on various chemical testings, statistical treatment, microscopic observation and fossil identification, which had been performed after the field work.
This volume (Part III) consists of survey details and results of synthetic analysis in Palawan and Negros Area.

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 my deep appreciation to the officials concerned of the Government of the Republic of the Philippines for their close cooperation to the team.

March, 1987

Keisuke Arita

President
Japan International Cooperation Agency

Junichiro Sato

President
Metal Mining Agency of Japan

Summary

This survey was carried out as the second year fieldwork as per Implementing Agreement concluded last 26th of Stptember, 1984.

This report summarizes results of field survey and results of the statistical treatment of the microchemical analysis data on Palawan I, II, III and IV Areas, (Total Area: 5,890 Km^2) and the actual survey conditions for Palawan V, VI and Western Negros Area (Total Area: 7,240 Km^2).

The following items are clear after synthesizing all these results;

1) The survey area is divided by the tectonic line called Ulugan Bay fault, which passes through the central part of Palawan Island from north to south, into northeastern part and southwestern part. The basement of northeastern part consists of Pre-Permian crystalline schist and sedimentary rocks of Permian, Triassic and Jurassic Systems are sedimented with gentle wavelike fold. At the southwestern part, the basement consists of Cretaceous crystalline schist and ophiolite intensely deformed by faulting and folding. These lithlogical unit appear to belong to the province that has been suggested to more intense stress.

2) Known mineralizations are divided into Ni and Cr mineralized zones associated with the ophiolite blocks and Hg, Cu, Zn, As and Sb mineralizated zones brought about post-Miocene mineralization.

3) The results of microchemical analysis for 10 elements of the geochemical samples were treated statistically. Univariate analysis method for the south-western part and univariate plus multivariate analysis method for the north-eastern part were applied to extract the anomalous values.

4) The extracted anomalous zones indicative of strong mineralization which strongly corresponds to the known mineralization, geologic and tectonic setting of the area are as follows.

   1 Ni, Cr and Co anomalous zones accumulated around in the harzburgite body at the southwestern part.

   2 Hg, Cu, Mn and Sb anomalous zones accumulated in the harzburgite at the distribution area of upper formation and its surroundings north of Puerto Pricesa, (UNDP area).

   3 Cu, Zn, Sb, Hg, Sn and W anomalous zones consisting of many high and middle anomalous values accumulated in the semischist north of Taradungan 20 kms east-northeast of Roxas.

   4 Cu, Pb, Zn and Hg anomalous zones accumulated in Babuyan River turbidite east of Ulugan Bay fault, northwest of Stripe Peak, (UNDP area).

   5 Pb, Zn, Sb, As and Hg anomalous zones are observed in the Tumarbong semischist north of Barton at north coast.

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1. INTRODUCTION

1. Introduction

1-1 Background and Objectives of the Survey

1-1-1 Background and Particulars

Pursuant to the Implementing Arrangement (IA) entered into between the Government of the Philippines through the Bureau of Mines and Geo-Sciences and the Government of Japan through the Japan International Cooperation Agency (JICA) and the Metal Mining Agency of Japan (MMAJ) signed on September 26, 1984.
The second phase of the project (Fiscal Year 1985), fieldworks were carried out in Masbate, Northern Leyte, Southern Leyte, Dinagat-Siargao Island Group and Palawan.
This report particularly embodies the geological and geochemical surveys conducted in Palawan from Jan. 13, 1986 to Feb. 28, 1986. (Fig. 1)

1-1-2 Objectives of the Survey

The objectives of the present survey consist of the preparation of a mineral inventory map and of the selection of mineral potential areas, by means of statistical analysis of the results of chemical assays, combined with other laboratory tests and examinations on the various samples collected during the geochemical and geological surveys of the Palawan Area, Republic of the Philippines. Existing geological data from this area were also considered in the preparation of this report.

1-2 Contents of the Survey

1-2-1 Fieldwork

As for the fieldwork, stream sediment samples were collected at a rate of one sample per 1 - 2 km^2 along the drainage systems in the survey areas.
At the same time, PH value and electric conductivity of the stream water at sampling points were measured. Heavy mineral samples were collected by panning at junctions or mouths of the main drainage systems. In conjunction with the foregoing geochemical survey, mapping and investigation of geological structures and known mineral showings in these areas were carried out.

The details of the collected samples are as follows:

1) Palawan I (Taytay) Area (Ref. Fig. 2)

- Survey Area	1,310 km^2
- Stream sediment samples	640
- Duplicate samples	10
- Heavy mineral samples	40
- Spot survey points	33
- Samples for petrographical thin sections	20 (of which 10 were for identification)
- Samples for polished ore sections	10 (of which 5 were for identification)

- Whole rock analysis samples 5
- Ore assay samples 10
  (of which 5 were for assay)
- X-ray diffraction analysis samples 10
- K-Ar dating samples 3
  (of which 2 were for dating)
- Palaeontological samples 10

2) Palawan II (Roxas) Area (Ref. Fig. 3)

- Survey Area 2,080 km^2
- Stream sediment samples 1,050
- Duplicate samples 20
- Heavy mineral samples 80
- Spot survey points 6
- Samples for petrographical thin sections 20
  (of which 10 were for identification)
- Samples for polished ore sections 10
  (of which 5 were for identification)
- Whole rock analysis samples 5
- Ore assay samples 10
  (of which 5 were for assay)
- X-ray diffraction analysis samples 10
- K-Ar dating samples 3
  (of which 2 were for dating)
- Palaeontological samples 10

3) Palawan III (Puerto) Area (Ref. Fig. 4)

- Survey Area 1,330 km^2
- Steam sediment samples 842
- Duplicate samples 29
- Heavy mineral samples 50
- Spot survey points 3
- Spot survey panning samples 9
- Samples for petrographical thin sections 15
  (of which 10 were for identification)
- Samples for polished ore sections 20
  (of which 10 for identification)

- Whole rock analysis samples	5
- Ore assay samples	20
- X-ray diffraction analysis samples	10
- K-Ar dating samples	2
- Palaeontological samples	5

4) Palawan IV (Narra) Area (Ref. Fig. 5)

- Survey Area	1,170 km^2
- Stream sediment samples	864
- Duplicate samples	18
- Heavy mineral samples	50
- Spot survey points	10
- Spot survey panning points	30
- Samples for petrographical thin sections	15
	(of which 10 were for identification)
- Samples for polished ore sections	
	(of which 10 were for identification)
- Whole rock analysis samples	5
- Ore assay samples	20
- K-Ar dating samples	2
- Palaeontological samples	5

5) Palawan V (Busuanga) Area (Ref. Fig. 6)

- Survey Area	1,260 km^2
- Stream sediment samples	630
- Duplicate samples	12
- Heavy mineral samples	50
- Spot survey points	3
- Sample for petrographical thin section	10
- Sample for polished ore section	5
- Whole rock analysis samples	5
- Ore assay samples	5
- X-Ray diffraction samples	5
- K-Ar dating samples	2
- Palaeontological samples	5

6) Palawan VI (Quezon - Rio Tuba) Area (Ref. Fig. 5)

- Survey Area	3,580 km^2
- Stream sediment samples	2,148
- Duplicate samples	40
- Heavy mineral samples	145
- Spot survey point	8
- Sample for petrographical thin section	20
- Sample for polished ore section	15
- Whole rock analysis samples	10
- Ore assay samples	15
- X-ray diffraction samples	10
- K-Ar dating samples	5
- Palaeontological samples	10

7) Western Negros Area (Ref. Fig. 7)

- Survey area	2,400 km^2
- Stream sediment samples	1,100
- Duplicate samples	20
- Heavy mineral samples	100
- Spot survey point	8
- Sample for petrographical thin section	20
- Sample for polished ore section	15
- X-ray diffraction samples	10
- K-Ar dating samples	5
- Paleontological samples	10

1-2-2 Synthetic Analysis

After accomplishment of the fieldwork, analysis of stream sediment samples and heavy mineral samples, statistical treatment of the results of said analysis, observations of thin and polished sections, X-ray diffraction testing, whole rock analysis, ore assay, micro-fossils identification as well as K-Ar dating were performed. The objectives of the survey are; to prepare the mineral inventory map; and to select the mineral potential area by analyzing synthetically the results of these operations.

As for UNDP surveyed area of middle parts of Palawan Is, the geological maps and raw data stream sediments analysis were submitted through the kindness of of Dr. A.H.G. Mitchel, Chief Technical Adviser, UNDP and used on synthetic analysis.

On the synthetic analysis for the Palawan V, VI area and Western Negros area, the details of that will show in next phase volume.

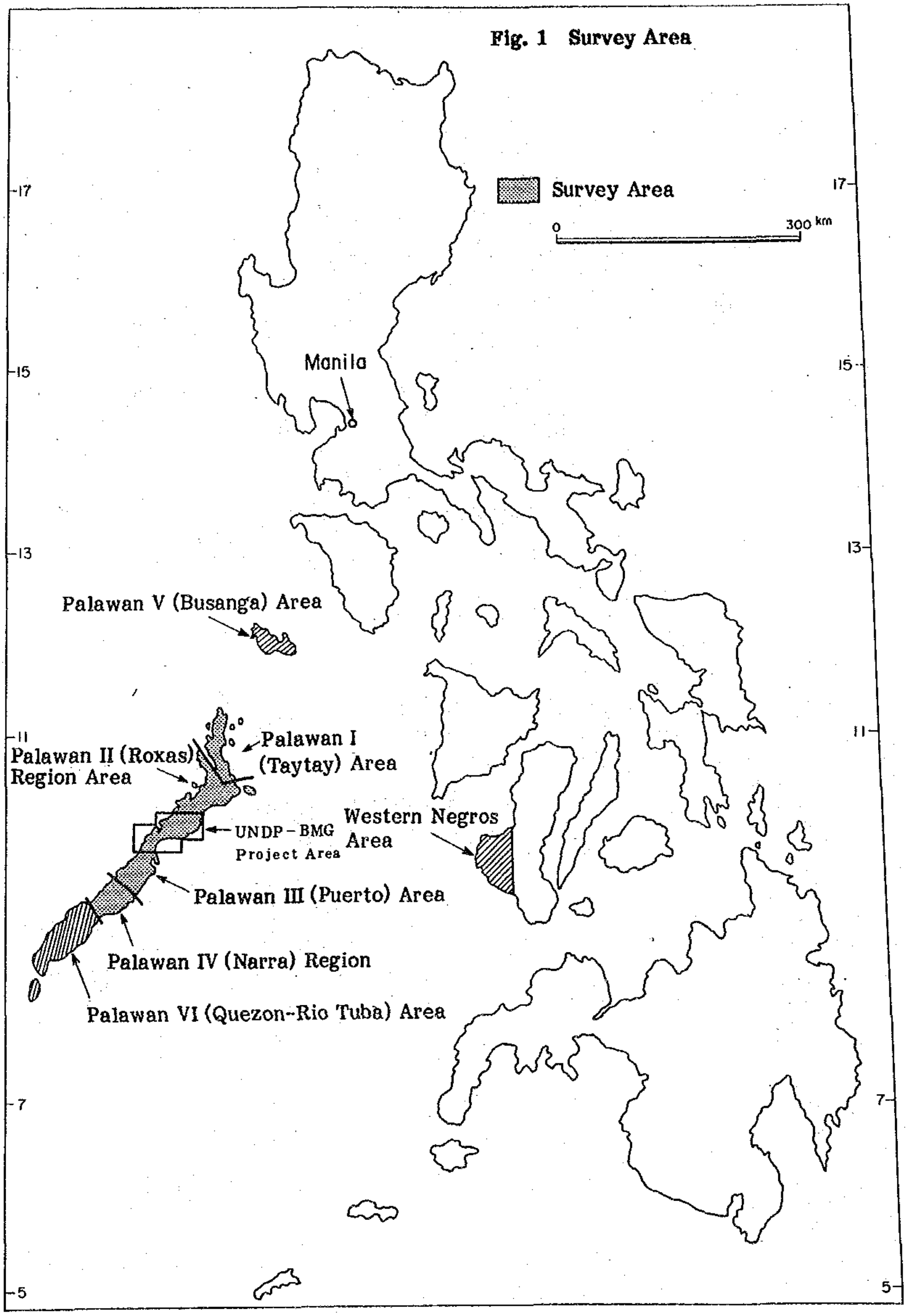


Fig. 1 Survey Area
Survey Area
0
300 km
Manila
Palawan V (Busanga) Area
Palawan I
(Taytay) Area
Palawan II (Roxas)
Region Area
UNDP-BMG
Project Area
Western Negros
Area
Palawan III (Puerto) Area
Palawan IV (Narra) Region
Palawan VI (Quezon-Rio Tuba) Area
17
15
13
11
7
5

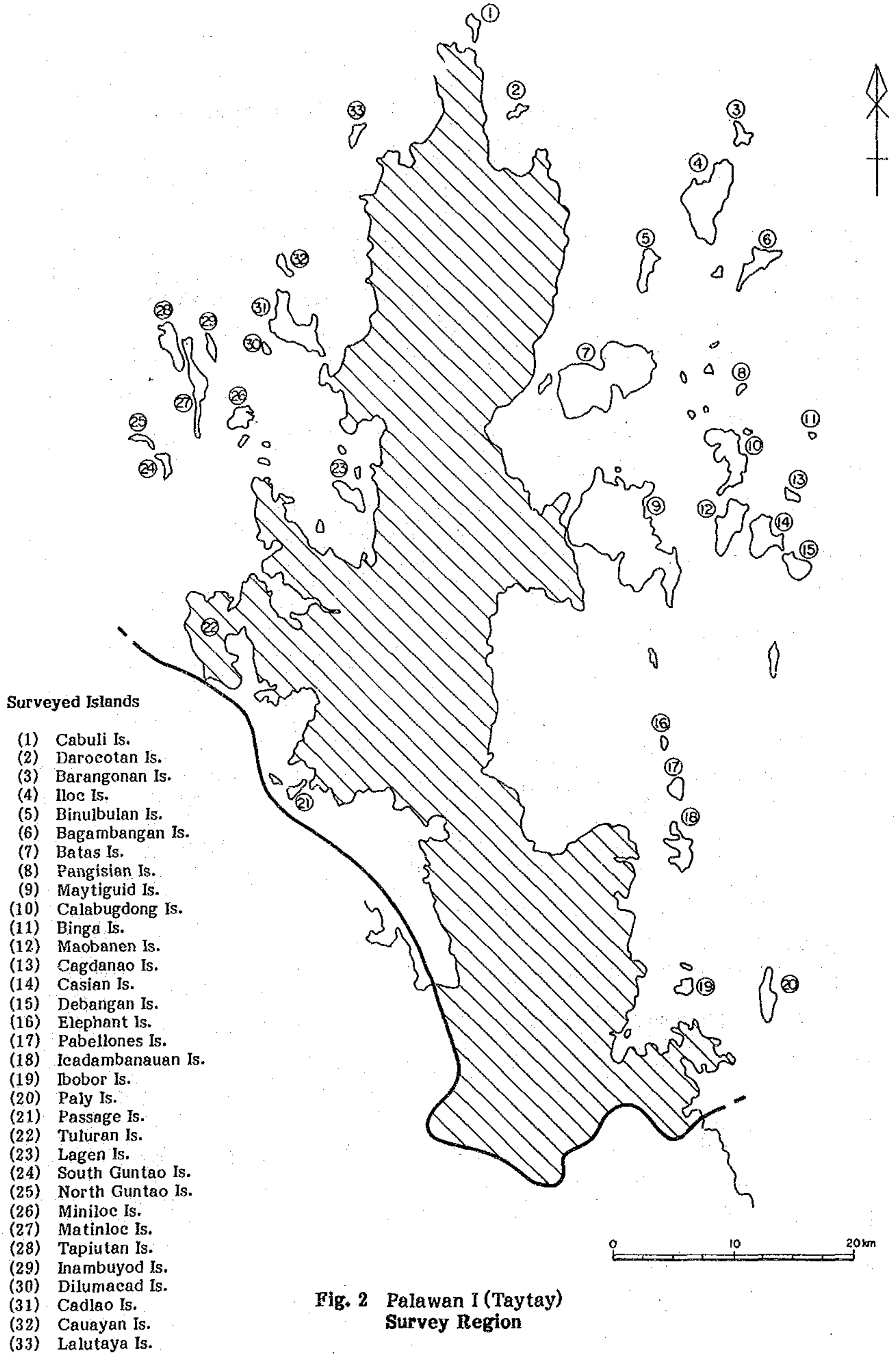


Fig. 2 Palawan I (Taytay) Survey Region

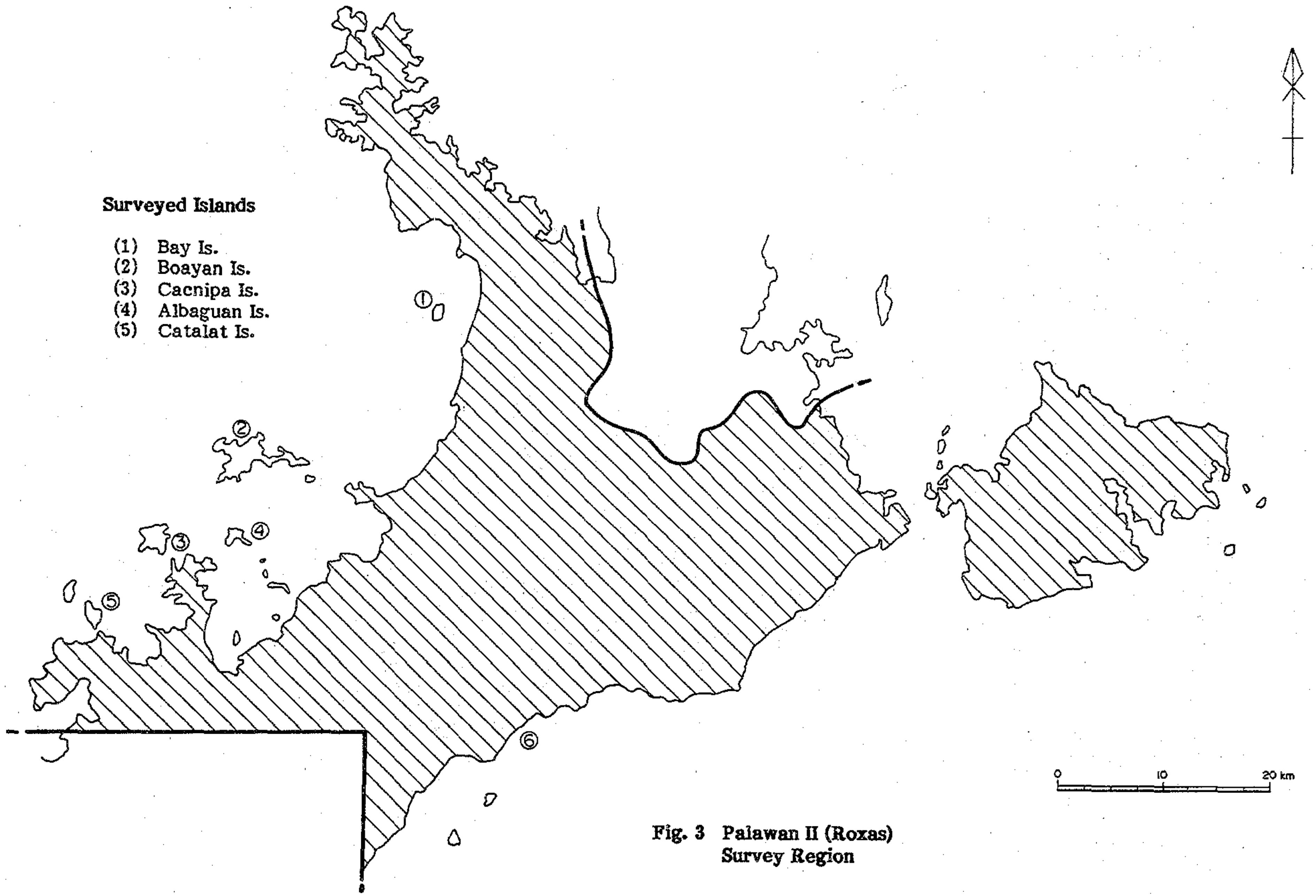


Fig. 3 Palawan II (Roxas)
Survey Region

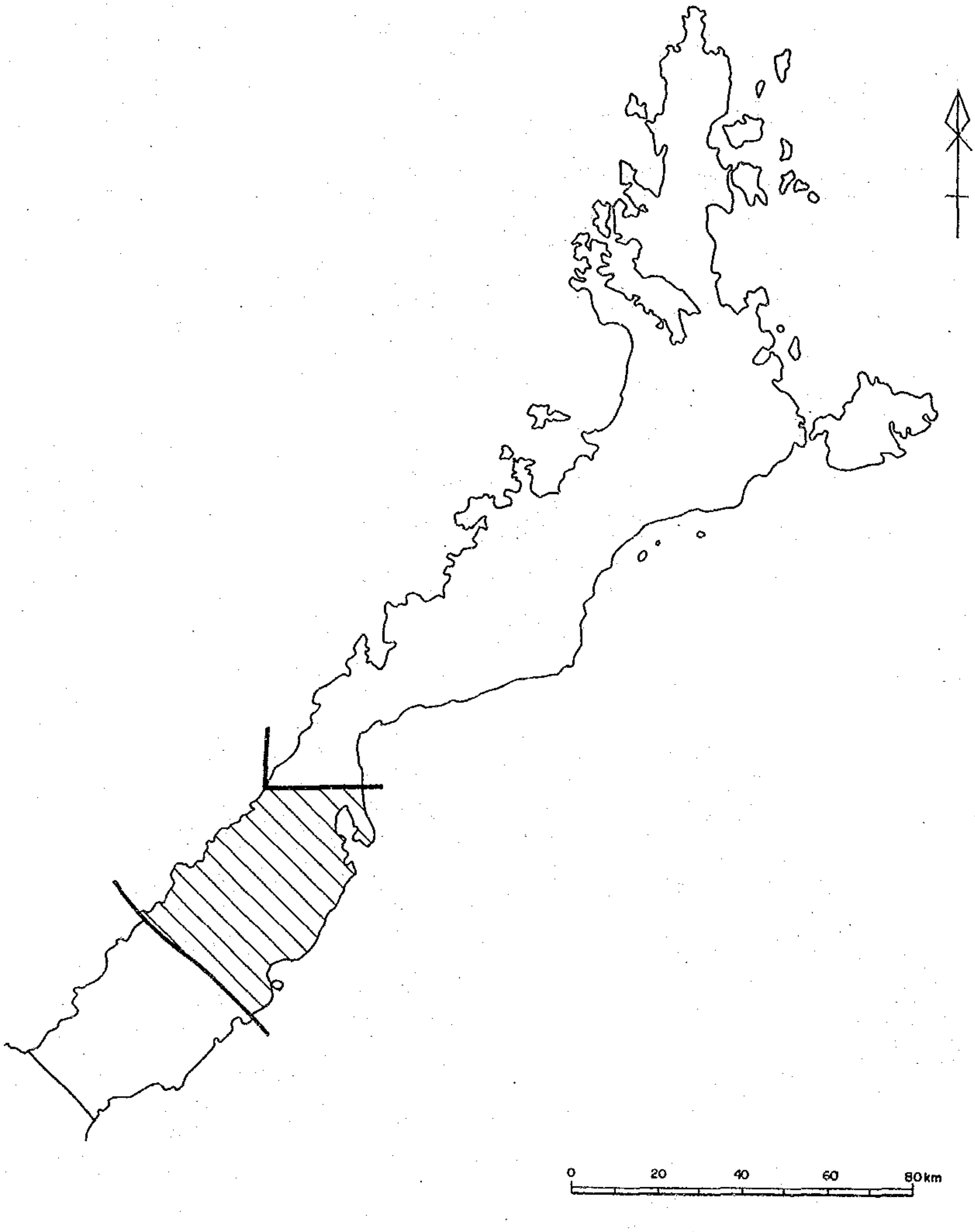


Fig. 4 Palawan III (Puerto)
Survey Region

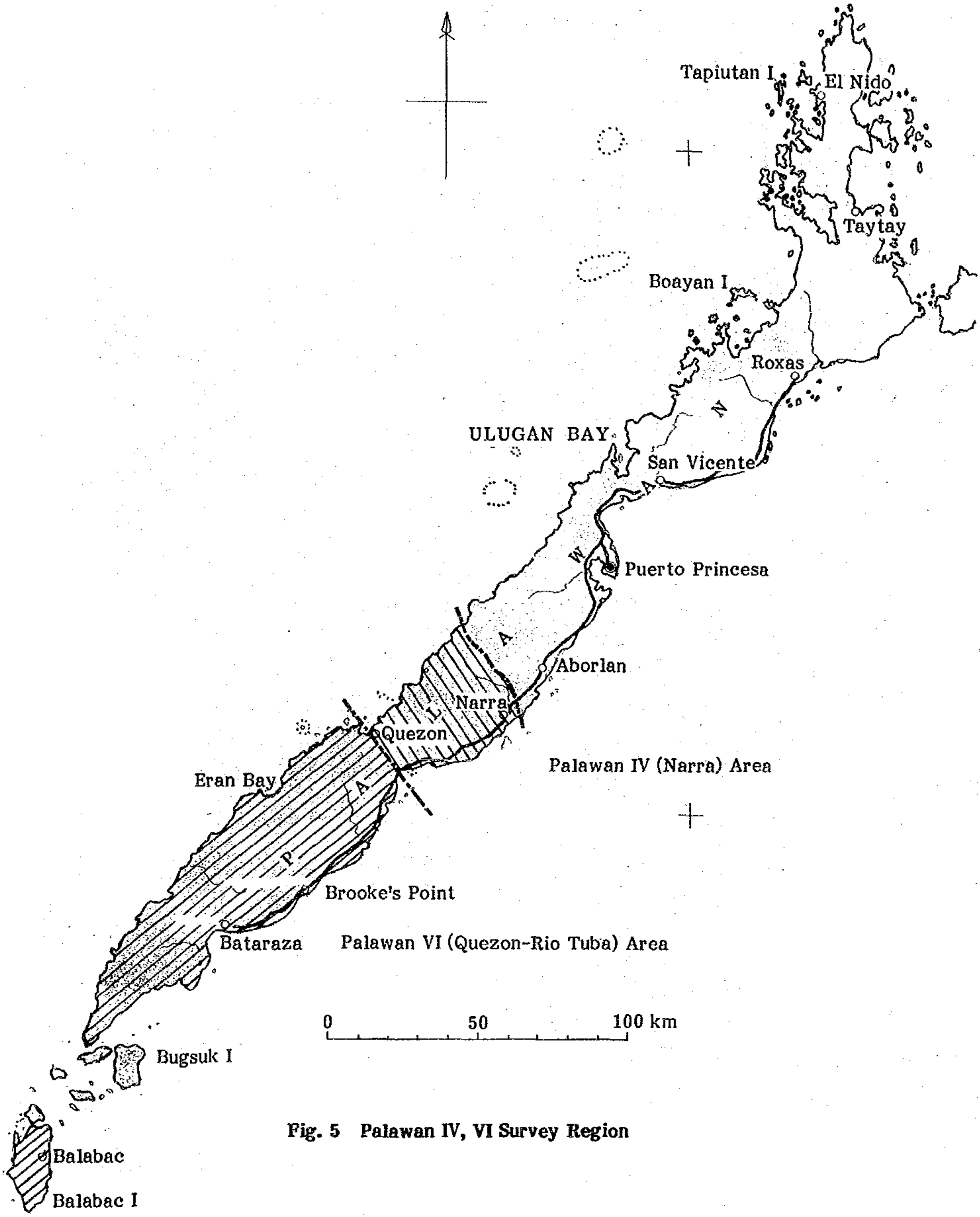


Fig. 5 Palawan IV, VI Survey Region

Fig-6 Palawan V (Busuanga)
Survey Region

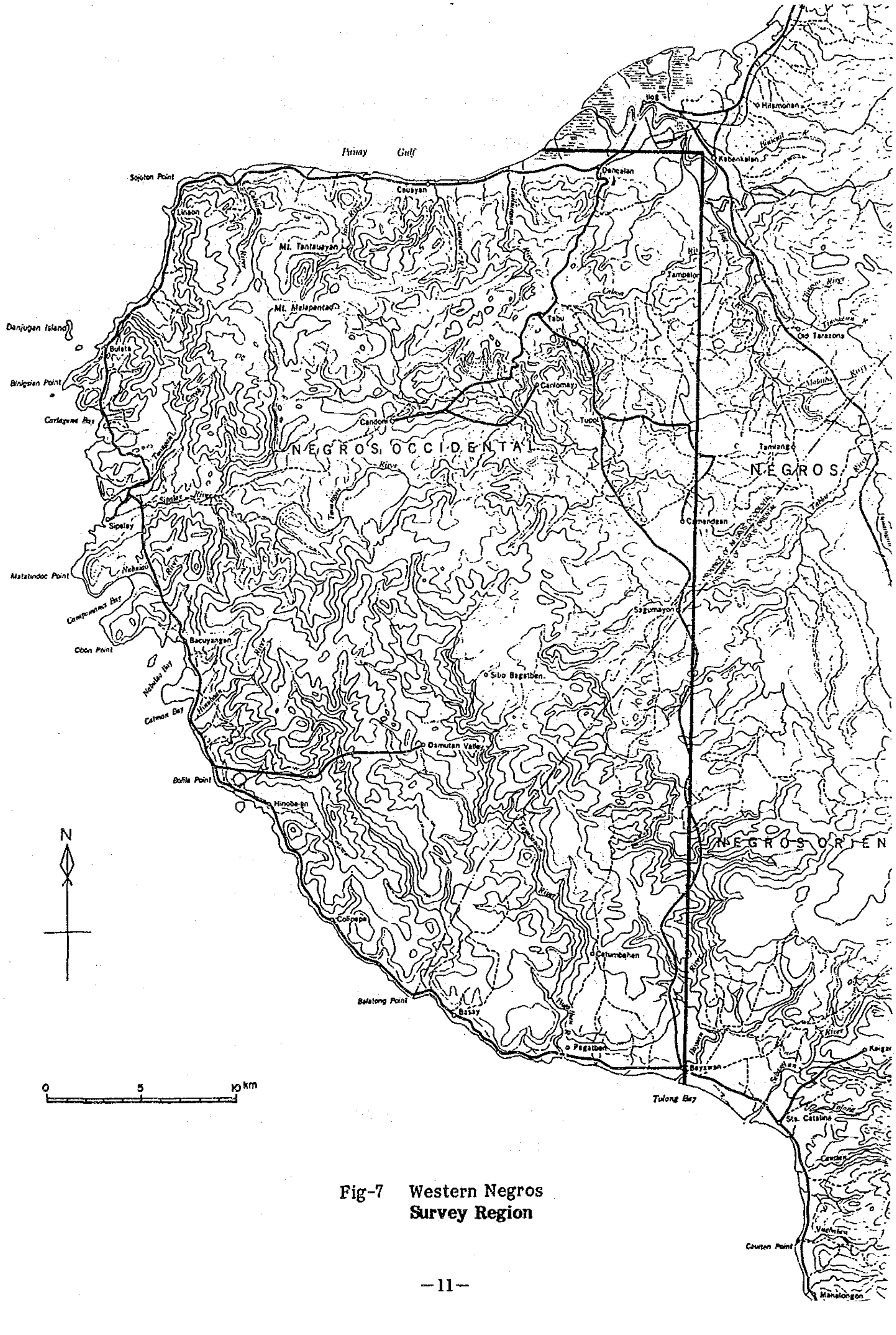


Fig-7 Western Negros
Survey Region

1-3 Composition of Members and Itinerary of the Survey Mission

1-3-1 Composition of the Survey Mission

The members of the Japanese party and the Philippine party who participated in planning the survey program, in negotiations and in fieldwork were as follows:

A. Planning of the Survey Program and Negotiations

Japanese panel:

Makoto Ishida	MMAJ
Seiichi Ishida	id
Michihisa Shimoda	id
Jiro Osako	id
Yoshitaka Hosoi	id
Natsumi Kamiya	id
Yasuo Endo	id

Philippine panel

Juanito C. Fernandez	BMG
Benjamin A. Gonzales	id
Guillermo R. Balce	id
Romeo L. Almeda	id
Noel V. Ferrer	id

B. Members of Survey Mission

Japanese party:

Project Manager: Akira Yatsuji	OMRD

Palawan I (Taytay) Area

Leader:	Katsuji Fukumoto	Mitsui Mineral Development Eng. Co., Ltd.
	Yuukichi Tagami	id.
	Keishi Nakajima	id.

Palawan II (Roxas) Area

Leader:	Shinichi Doi	Mitsui Mineral Development Eng. Co., Ltd.
	Minoru Kamezawa	id.
	Ryohei Otsubo	id.

Palawan III (Puerto) Area

Leader:	Akio Shida	Nittetsu Mining Consultants Co., Ltd.
	Hiromitsu Nozawa	id.
	Koji Uchiyama	id.

Palawan IV (Narra) Area

Leader:	Hiroshi Fuchimoto	Bishimetal Exploration Co., Ltd.
	Hiroshi Takahashi	id.
	Shinji Naito	id.

Palawan V (Busuanga) Area

Leader:	Akio Shida	Nittetsu Mining Consultant Co., Ltd.
	Kozo Uchiyama	"
	Tatsuaki Nakatsuka	"

Palawan VI (Quezon - Rio Tuba) Area

Leader:	Kazuyoshi Masubuchi	Dowa Engineering Co., Ltd.
	Shigehisa Fujiwara	"
	Yukio Kinryu	"
	Makoto Takeda	"
	Hiroshi Miyamoto	"
	Junichi Ishikawa	"

Western Negros Area

Leader:	Hideo Kuroda	Bishimetal Exploration Co., Ltd.
	Hiroo Nakane	
	Mitsutaka Banba	

Chemical Analyst

Taiichi Yamamoto	OMRD

Preparation of the complete report

Yoshikazu Okubo	OMRD

Philippine party:

Project Manager	:	Romeo L. Almeda	BMG
Assistant Manager	:	Noel V. Ferrer	id
Analysis Manager	:	Edwin G. Domingo	id

Palawan I (Taytay) Area

Leader	:	A. Cabantog	BMG
Sub-leader		F. Zepeda	id
Sub-leader		E. Mantaring	id

Palawan II (Roxas) Area

Leader	:	P. Rovillos Jr.	BMG
Sub-leader		F. Sajona	id
Sub-leader		E. Malaca	id

Palawan III (Puerto) Area

Leader	:	W. Diegor	BMG
Sub-leader		B. Cadawan	id
Sub-leader		E. Esguerra	id

Palawan IV (Narra) Area

Leader	:	A. Matos	BMG
Sub-leader		L. Morales	id
Sub-leader		U. Palaganas	id

Palawan V (Busanga) Area — BMG

Leader	:	O. Pineda	"
Sub-leader		B. Cadawan	"
Sub-leader		F. Zepeda	"

Palawan VI (Quezon - Rio Tuba) Area — BMG

Leader	:	A. Cabantog	"
Sub-leader		M. Aurelio	"
Sub-leader		G. Revilla	"

West Negros Area

Leader	:	P. Rovillos	BMG
Sub-leader		E. Rillon	"
Sub-leader		E. Santos	"

C. Composition of the fieldwork party

One field party was composed of one Japanese geologist and 3 BMG geologists, and 3 such parties were assigned to each survey area. Furthermore, one geologic aide was assigned for each area to take charge of the drying and sieving of samples and in coordinating material supplier.

D. Treatment disposal of chemical analysis

In this survey, microchemical analysis of 3,473 stream sediment samples including duplicates (10 elements analysed for each sample) and 220 heavy mineral samples (3 elements analyzed) were conducted. This endeavor was accomplished by means of atomic absorption spectrometry (AAS) before the end of May at PETROLAB (one of the BMG GSD sections in charge of laboratory analysis).

As in the preceeding year, for the purpose of increasing the analyzing capacity, one Japanese chemical analyst was assigned to check the above operations and supply necessary materials. (From early June, he had transferred the technique of treatment for the new donated AAS equipment).

1-3-2 Itinerary of the Survey

The fieldwork was conducted on the Palawan I - IV area for a period of 47 days starting from January 13, 1986 until Feburary 28, 1986 (as described already in the Second Year Report).

The corresponding laboratory operations were performed from the middle of March 1986 towards the end of May.

The details of itinerary are shown in the Table-1-1 below.

On the Palawan V, VI and Western Negros areas, fieldwork schedule is as shown in Table-1-2.

Table-1-1 Schedule of Fieldwork and Synthetic Analysis on the Palawan I - IV Areas

	1986 Jan.	Feb.	Mar.	Apr.	May	July
Preliminary meeting & data arrangement at BMG	13 - 18	25 - 28			14 - 16	17 - 21
Fieldwork	19	- 24				
Chemical analysis at PETROLAB			15—	———	—31	
	1986 May	Jun.	Jul.	Aug.		
Synthetic Analysis	14— Indoor Testing	—13; 14— Statistical Treatment	—16	Report Making 22——30		

Table-1-2 Schedule of Fieldwork on the Palawan V, VI and Western Negros Area

	1987 Feb.	Mar.
Preliminary meeting and data arrangement at BMG	9——12	10——13
Fieldwork	13——	——9

2. GENERAL DESCRIPTION OF PHYSIOGRAPHY, GEOLOGY AND MINERAL DEPOSITS

2. General Description of Physiography, Geology and Mineral Deposit in the Survey Area

2-1 Physiography and Geology

The survey area belongs to the so-called "stable or aseismic belt", or the Palawan Physiographic Province, which has not significant seismic activity. This Physiographic Province is bounded at its northwest side by the Palawan trough which is considered to be an extinct subduction trench. The northern part and the central part are divided by the "Ulugan" Bay Fault assumed to run in a north-south direction and passing through slightly to the east of the middle of the Island.

The northern part of the Physiographic Province includes the northern half of Palawan Island, the Busuanga Islands and Cuyo Island; ridges having a northeastern trend are found throughout this Province. South of the line connecting Dumaran Island with Imuruan Bay, Paleozoic formations of Carboniferous to Permian are distributed, which are regionally metamorphosed up to low grade green schist facies. North of this line, the geosynclinal sediments of Triassic and Jurassic are widely distributed and overlaine with unconformity by shale, sandstone and others of the Permian period as exposed at the eastern part of El Nido. Jurassic granodiorite penetrated through these Paleozoic formations and geosynclinal sediments. As for the Tertiary sedimentary rocks, turbidite and limestone cover the Palaeozoic and Mesozoic formations and are exposed at the seacoast; further, Quaternary volcanic rocks are observed overlying Mesozoic formations at the northern part of Calavag, middle eastern part of the said area. The above mentioned Paleozoic and Mesozoic formations may be considered geosynclinal sediments associated with the Palawan continental block.

In contrast with the northern part of this Physiographic Province, at the central portion of Palawan, ophiolitic rocks which are extended towards the south-west and intensively occur; and in its southern part, this Province is covered by arkose - quartzite clastics and limestone belonging to Paleogene system as well as thin sedimentary rocks belonging to Neogene system. Ophiolite rocks are intensively transformed and within the stratigraphically lower and thrust up harzburgite formations, the higher level pillow basalts are exposed in tectonic windows and are associated with Cretaceous units (northern Puerto Princesa). As these preceding cases show, over thrust structures are observable in many places in Palawan.

2-2 Geological Structures (Ref. PL1-1·1-2 geological map and section)

Caramay schists, believed to be the oldest formation in the survey area, are exposed as *part of a horst within the Tumarbong semi-schist in northern Tintitan (UNDP Survey* Area) on the east coast of northern Palawan and at Pagdanan Range situated north-west of Northern Tintitan. The Caramay schists in the northern portion is in fault contact with the surrounding semi-schist, whereas in the western part, it is in a reverse fault contact. These exposures found near the anticlinal part of the semi-schist suggest a close relationship between folding and thrusting movement. The same type of reverse fault is observed at Boayan Islands situated on the west coast of Northern Palawan, where eastern Paleozoic formations are thrusted over the Paleogene Babuyan River Turbidite. At the east of Babuyan located on the southeast coast of Central Palawan, the Tumarbong semi-schist is in reverse fault contact with the west side of the Babuyan River Turbidite. The contact runs in a north-south direction. On the west, a harzburgite unit belonging to the ophiolite block is thrusted over the Babuyan River Turbidite. The Sagasa Pt. tectonic complex (Miocene - Cretaceous) is observed randomly marking the contact between

Northern Palawan and South Central Palawan. The Ulugan fault is considered to be covered so far as observed on the surface, by the harzburgite which is in a possible low angle thrust. This low angle thrusting of the harzburgite is observed in the area where the Cretaceous system is exposed through a window and also at the western area of Panacan.

To summarize, in Northern Palawan, the geosynclinal sediments associated with the continental block and belonging to the Paleozoic - Mesozoic group are composed of folded and uplifted rocks; on the other hand, in South·Central Palawan, west of Ulugan Bay Fault, the lithology is dominated by intensively transformed ophiolitoc rocks of Cretaceous - Paleogene Age, Limestone, sandstone and pelitic conglomerate belonging to the Neogene system and covering the ophiolite rocks unconformably are exposed at northern Aborlan on the east coast and at eastern Quezon on the west coast. There exists an opinion that these formations constituting the Middle·Southern Palawan were formed in the middle of the Sulu Sea and were translated to the present site along Ulugan Bay Fault (Hashimoto 1970). According to this, it may be interpreted that the intense deformation and thrusting in the ophiolite would be due to lateral stresses along a north-west direction.

Ulugan Bay Fault is, at present, not recognizable being covered by rock bodies thrust up in a low angle; however, the UNDP Report referred to Hamilton's descriptions (1979) that upright or steep lineaments in a north-south direction are observed parallel with that of the elongation of Rita Island at Ulugan Bay.

2-3 Ore Deposits

The mineralization between the northeastern part and the southwestern part of Palawan Island are remarkably different because the former consists principally of geosynclinal sediments while the latter is made up of Cretaceous ophiolitic rocks.

In northeastern Palawan silica sand derived from the Paleogene system and sedimentary manganese ore deposit in small scale belonging to the Paleozoic group, are merely observed sporadically; additional survey will be necessary for the disseminated ore deposit of chromite with serpentinite at Paly Island, east of Calanay; on the other hand, in the southwestern part of Palawan Island, various Cr and Ni deposits (partially lateritized) associated with ophiolite rocks are known to exist, and north of Aboabo in the southern end of the survey area, phosphate deposits (Guano type) are also known to exist. Cr deposits are mainly orthomagmatic ones and are related to the dunite within harzburgite. As for Ni deposits, some of them exist in lateritized wall rocks which were secondarily enriched, but other deposits are of the orthomagmatic type.

3. RESULTS OF GEOLOGICAL SURVEYS AND INVESTIGATION OF ORE DEPOSITS

3. Results of Geological Survey and Investigation of Ore Deposits

3-1 Geology and Ore Deposits of the Northeastern Area of Palawan (Ref. PL1-1)

3-1-1 General Summary

The survey area corresponding to the north-eastern part of Palawan belongs, from an administrative point of view, to Region IV, Palawan Province and is situated about 500 km south-west of Metro Manila (cf. Fig. 1).

Transportation to the survey area from Manila is as follows: from Manila to Puerto Princesa, the capital of Palawan Province, air flight service is available and a highway (road) runs from Puerto Princesa to Roxas and Taytay which are located in the center of survey areas. Between Roxas and Taytay, the road conditions are very poor and only a four wheel drive vehicle is practical. After a rainfall, the road is often not passable because of its muddy condition. North of Taytay, the road is passable for a four wheel drive vehicle only as far as Pancol which is 15 km north-west of Taytay. Other transportation means on land are either by foot or by water buffalo and a banca boat is practicable for transportation on the sea.

	regular flight (1/day)		by car		by car	
Manila	→ 1 hr. 10 min.	Puerto Princesa	→ 3 hrs.	Roxas	→ 4 hrs.	Taytay

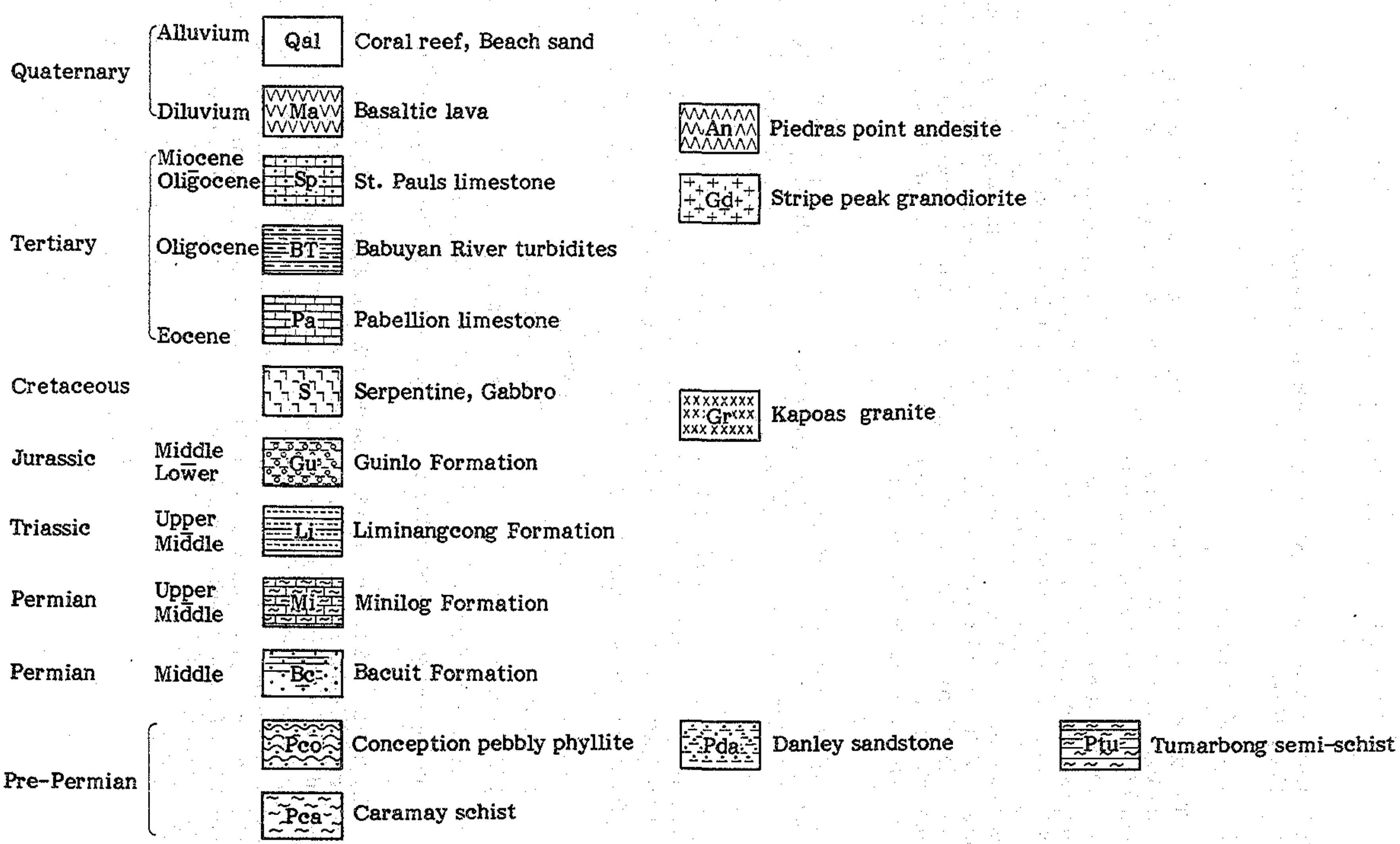
The survey area is located in the northeastern part of Palawan Island and, as administrative division, corresponds to Roxas District, San Vincent District, Dumaian District, Araceli District, Bacuit District and Taytay District.

The geographic situation is as follows:

Area :	3,390 km^2
Elevation :	0 m - 1,013 m
Highest peak :	Mt. Copoas (1,013 m)
Average temperature :	about 27° centigrade
Average annual precipitation :	about 2,000 mm (UNDP Report 1985)

The climate belongs to a typical monsoon climatic zone of the western Pacific, where dry season (November - April) and rainy season (May - October) are clearly observed, and May and June are typhoon months. Coral reefs are abundant on the east coast, and the inland areas are covered with virgin forest. The area is infected with malaria. Rice growing is practiced only on the plains along the coast and inland, coconut palms and cashew nuts are cultivated by slash and burn method; in villages along the coast, small-scale fishing for self consumption is practiced. Electricity is available only at city areas such as Roxas.

Fig. 8 Stratigraphy of the Northeastern Palawan Area



Details of Each Formation in the Northeastern Palawan Area

Qal (Alluvium)	Unconsolidated deposits of gravel, sand, clay and organic materials along flood plains of major drainage system. Beach sands and corals are also included.
Ma (Manguao volcanics)	Chiefly composed of dark gray, fine grained and porous basaltic lavas (Manguao volcanics); K-Ar - dating result show 0.5 ± 0.3 M.y. age.
BT (Babuyan River turbidites)	Chiefly composed of white to pale gray colored graywacke sandstone, parallel laminar alternation of sandstone, shale and calcareous sandstone; Main strike is EW to NE-SW, generally dipping 50^{o} - 60^{o} S.
Pa (Pabellion limestone)	Chiefly composed of dark gray, massive limestone; Well developed bedding plans sometimes observed.
Gu (Guinlo Formation)	Chiefly composed of sandstone and interbedded conglomerate. Sandstone exhibit white to pale gray color and cross-beddings observed in places; Conglomerate contain sorted pebbles of chert and quartzite.
Li (Liminangcong Formation)	Chiefly composed of red and white chert. Black slate, sandstone, shale and lenticular limestone are interbedded in places.
Mi (Minilog Formation)	Chiefly composed of black and pale gray massive limestone, partially crystalline limestone and marble; Bedding plane are visible in places. Exposed parts show steep criffs in places.
Bc (Bacuit Formation)	Composed of well folded alternation of sandstone and slate.
Pda (Danley sandstone)	Chiefly composed of nearly non-metamorphosed, hard silicious sandstone interbedded with the Tumarbong semi-schist.

Ptu (Tumarbong semi-schist)	Composed of well-folded phyllite, black slate and pelitic semi-schist, the schistosity plane coincided to bedding plane.
Grx (Kapoas granitic rocks)	Areas of distribution include north-western Pancol; south-western Mabini, north-western Silaltan and Kapoas Peninsula, south-western Mabini samples composed of small amount hornblend and altered biotite, parthite, plagioclase and quartz. Biotite are altered to chlorite and prehnite, sericite and epidote are recognized in feldsper. Samples of Kapoas Peninsula composed of biotite, quartz and plagioclase relatively fine equigranular holo-crystalline rock, alternation are not observed. The results of K-Ar dating of these samples will describe later on.
Sp (serpentine)	Composed of dark green colored serpentinized peridotite and serpentinite distributed at the eastcoast of Paly Is. Chromite dissemination observed in the east side of this Is. Some asbestos veinlet observed in places of strong serpenitization.

3-1-2 Stratigraphy

The geology of the north-eastern part of Palawan consists of basement rocks (Pca, Ptu, Pco, Pda) composed mainly of schists and semi-chist belonging to the Palaeozoic group of uncertain period and of sedimentary rocks of the Mesozoic group (Gu, Li) and Palaeogene system (Pa, Bt) which cover, in unconformity, the above mentioned basement rocks.

Basement rocks are distributed at the area centering around Roxas and extending from Dumaran Island in the east to Babuyan in the south-west, in repeating the folding with an axis in a direction mainly NE - SW.

In the northern area, Mesozoic group is widely distributed around Malampaya Sound, in convering, in unconformity, Palaeozoic group of uncertainable period, and in the southern area, Babuyan River Formations considered as Eocene series cover directly and in unconformity Palaeozoic group.

At the northern end of Palawan Island, Bacuit Formations and Minilog Formations, which are considered as Permian system, are exposed more than 20 km in a south-north direction, and are covered partially by Mesozoic group and Eocene series; however, as the part in contact with the Palaeozoic group of uncertain period was not observed, the relation between these two formations is not clear.

As for intrussive rocks, the diorite, which had intruded into Mesozoic group and Permian system, and which is estimated to be dated from the end of the Mesozoic period, is recognized in numerous places, distributed with northern Mesozoic group. In the area extending from Cleopatra Needle Peak to the west side of Stripe Peak and corresponding to the eastern part of UNDP survey area, the quartz diorite had intruded into Babuyan River Formations and estimated as that of the Eocene system.

At Paly Island situated 20 km offshore east of Calauag Bay in the northern area, the serpentinite, is exposed which intrusion is estimated to date late Mesozoic, and is partially accompanied by chromite dissemination. As the latest formations, the volcanic rocks belonging to Diluvium are widely distributed, covering Mesozoic group of the northern part of the Calauag Bay.

The succession of each of the above mentioned formations is shown in the schematic geological column. (Fig. 8)

Descriptions for each geological unit are given as follows:

o Caramay Schist Formation; Pca

This formation is composed of dark gray to gray graphite schist, mica schist and quartzite, situated at the lowest position of the Palaeozoic group of uncertain period. In the present survey area, this formation is exposed, in a belt shape, west-north-west of Tumarbong and south of Alemanguan. Also in the UNDP survey area, extensive exposure is recognized north of Tintitan on the south-eastern coast. The schistosities of this formation show generally in a east-west strike, but the strike varies occasionally in a northeast-southwest or in a northwest-southeast direction; its inclination measures 40^{o} - 70^{o} towards north. On the northern side of these exposed area, this formation seems to thrust up upon the upper Conception conglomerate and phyllite bed in overthrusting structure, and this assumption may be backed up by many drug foldings, but such outcrop, that might indicate directly relation between the upper and the lower, could not find out.

o Conception Conglomeratic Phyllite Formation; Pco

The formation which was named by UNDP survey as Conception conglomeratic phyllite formation belonging to the Palaeozoic group of uncertain period, is classified in the uncertain 3 formation groups in the present survey, and the conglomeratic phyllite formation situated at the lowest position is defined, in a narrow sense, as Conception conglomeratic phyllite formation. This formation consists of gray to pale brown coloured slate, pelitic semi-schist, phyllite and partially quartzite put between these beds. A certain portion of this formation became conglomeratic phyllite, occasionally retaining its mud ball relic of the original rock. The formations are exposed in the west part of Danleg and in the middle southern part of Dumaran Island; the strike of schistosities runs mainly in a northeast-southwest direction and the inclination measures 20° to 30° towards north-west or south-east; a folding structure declining towards the south-west is observed. Segregated quartz veins crossing with schistose planes in a oblique or normal angle are often observed.

o Danleg Sandstone Formation; Pda

This means the formation classified from sandstones in the middle bed of the Conception conglomeratic phyllite formation (belonging to Palaeozoic group of uncertain period) in the UNDP survey. This formation is composed almost entirely of unmetamorphosed medium grained quartz sandstone and is exposed, in a belt shape more than 20 km long in the south-western part of Danleg and in the southern part of Alemanguan.

The formation in the south-western part of Danleg is accompanied by Conception conglomeratic phyllite formation and elongates in a northeast-southwest direction; its inclination measures 20° to 55° towards north-west or south-east. The formation at the southern part of Alemanguan has in a northwest-southeast strike.

o Tumarbong Semi-Schist Formation: Ptu

This formation is named for the uppermost formation of Conception conglomeratic phyllite formation (unknown Palaeozoic) in the UNDP survey, and consists of quartz semi-schist, psammitic semischist and quartzite, and partially changed to sandstone. This formation is distributed in the main part of the Tumarbong Quadrangle and in the southern part of the Alemanguan Quadrangle, and occupied main part of unknown Palaeozoic in the survey area. Several folding axes running generally in NNW-SSE directions are observed.

o Bacuit Formation: Bt

This formation correlates to middle and lower Permian as analyzed the by BMG (1982) and alternates between sandstone and slate, remarkably folded, and is distributed in the northern area from El Nido on the northern most Palawan Is., in the western area from Cadlao Is., and in Casian Is.

Folding axes show NE direction in the southern area and an E-W direction in the western Cadlao Is., granodiorite of the latest Mesozoic intruded in this formation.

o Minilog Formation: Mi

This formation correlates to the middle and upper Permian and consists of black and grayish white limestone that shows generally massive facies but partially bedded structure and partially marbled. This limestone is distributed in the small islands group situated to the west of Bacuit and to the north of Liminangcong. Out crops of this limestone used to show steep cliffs and well developed caves which have been formed by rivers and rain water.

On the result of X-ray diffraction, abundant dolomite was identified in this formation (Sample No. NJR-62 in Bacuit Quadrangle)

o Liminangcong Formation: L

This formation correlates to the middle and upper Triassic as analyzed by the BMG (1982) and is composed of mainly red and white cherts, intercalated black slate, sandstond, shale and limestone lenses, and is remarkably folded. The unit order of foldings is from several ten centimeters to several kilometers. On the inland, steep ranges have been formed by erosion.

This formation is widely distributed in the north in the area from the south-western part of Calauag to the north-eastern islands.

o Guinlo Formation: Gu

This formation correlates to the lower and middle jurassic as analyzed by the BMG (1982), and is composed mainly of sandstone intercalated conglomarate.

The sandstone is fine to coarse grained and shows white to grayish white coloured massive facies and has well developed cross bedding. Conglomerate included the pebbles of quartz and chert.

This formation is distributed in the area of northern Palawan Is., that is, the area around Malampaya Sound, the eastern area from Mabini and Maytignid Is.

o Pabellion Limestone Formation: Pa

This formation correlates to the Eocene according to the BMG (1982), and is composed of dark gray massive limestone and partially observed well developed bedding planes. This formation is distributed on Pabellion Is., Mayteguid Is. and others located in the northeastern part of the survey area, and is also observed in a small exposure covering the Permian and Jurassic in the northern part of Palawan Is. This rock from Pabellion Is. contains many fossils of Foraminifera (Nummulites). Generally, it is observed that well developed limestone caverns have been formed by rain water and river water erosion.

Fossil identification results.

The fossil specimen of this formation at Calabugdong Is. identified as Nummulites by Dr. M. Okamula; Department of Geology, Faculity of Science, Kochi University. This Foraminifera indicates middle Eocene.

o Babuyan River Turbidite Formation: BT

This formation correlates to the Eocene according to the survey by the UNDP (1985) and is, composed of white to pale gray coloured greywacke sandstone, alternation of sandstone and shale with remarkable paralle lamina and calcareous sandstone. It is distributed around the north coast of Barton and Bumaran Is. covering the Palaeozoic Group in discordance. Sandstone shows massive facies and is observed with partial unclear bedding plane. In the alternation parts of sandstone, siltstone and shale, parallel lamina, having a size of several millimeters to several centimeters, are observed.

The strike of this formation runs mainly in an east-west direction and northeast-southwest direction and the dip is inclined 50 to 60 degrees to the south. In Dumaran Is., the strike of this formation runs chiefly in a northwest-southeast direction and the dip is inclined 40 to 45 degrees to the northeast.

o Manguao Volcanic Rocks: Ma

This volcanic rock is basalt lava belonging to the Diluvium. Quaternary and is distributed around Mangnao lake located at the south of Taytay, covering the area along rivers and topographic low land. This basalt consists of olivine phenocrysts and dark gray coloured fine ground mass, and is porous.

Microscopic observation results. (NB004)

Phenocryst

Olivine; -2 mm automorphic crystals observed in granular and short columnar texture. Some crystals are sharp in direction along C axis.
Ortho-pyroxene showed -1.5 mm automorphic and short columnar texture.

Groundmass; Needle shape plagioclase crystals occupied the greater part of groundmass, granular ortho-pyroxene crystals observed among such plagioclase. Some automorphic opaque mineral and glass are observed.

3-1-3 Intrusive Rocks

Granodiorite: Gd

These rocks consist of pale grey coloured massive granodiorite and microdiorite. These diorites have a generally holocrystalline texture in which there are remarkably observed phenocrysts of plagioclase, quartz, biotite and amphibole. These rocks are distributed around the west coast of San Miguel and in the western area from San Miguel, north western area from Pancol, south-western area from Mabini and around Darocotam Bay situated at the northern end of this area. In the diorite distributed in the area southwest from Mabini, there are observed weak chloritization and pyrite dissemination. The age of intrusion was estimated by BMG (1982) to be of the later Jurassic but the result of age determination by the K-Ar method, performed in the present survey, has proved as follows.

Microscopic observation results. (NF492386)

This rock is holocrystalline and equi-granular granite and consist of small amount hornblend and altered biotite parthite, plagioclase and quartz.

Biotite is chloritized and prehnitized, sericite and epidote are recognized in feldsper.

K-Ar dating result showed 36.0 $\pm$ 1.8 M.y. (early Oligocene). This age may be indicated to alternation age.

Serpentinite: S

These rocks consist of dark green coloured serpentinized peridotite and serpentinite and clastic structure is observed in them. In these rocks that are exposed along the east coast of central Paly Is., disseminated chromite minerals are included. These rocks intruded along the thrust fault cutting Tumarbong semi schist.

The age of intrusion of these rocks is estimated to be Cretaceous according to the study of BMG (1982).

Microscopic observation results. (NB11)

This rock is serpentinized peridotite. Automorphic olivine assembrage have altered to serpentine. Clino-pyrocene has allotriomorphic to olivine and observed in ubiquitous. Sometimes automorphic granular chromite s observed.

3-1-4 Geological Structure

According to the opinion of the former geologists, it was considered that there are folding axes of the direction of NNW-SSE and NW-SE in the areas of Palaeozoic to lower Mesozoic group.

In the results of this survey, it becomes clear that the folding axes in the directions from NNE-SSW to NE-SW, exist predominantly and also the axes of E-W and NW-SE directions and that these axes cause the geological structure to be complex because of their alternative overlapping.

In particular, older formations than Liminangcong Formation, estimated as Triassic are remarkably folded. Contrasting these phenomena, the foldings in the Guinlo Formation, that are considered to be of the Jurassic, are mainly wavy foldings of lower than 50 degrees in inclination.

There are many faults running in a mainly N-S and NW-SE direction, but thrusts have NE-SW strike, this is influence of the large scale over thrust movement in the south-western area of Palawan Is.

3-1-5 Results of Mineral Showing Survey

A mineral showing survey was performed in north-eastern Palawan Is. together with the geochemical survey. Besides this survey, the geology, mineralization and alteration were checked in the small 38 islands around northern Palawan Is.

The results of these surveys and the chemical analysis of samples are shown in Tab.2. In these islands, only small bedded manganese deposits in the Palaeozoic group, pyrite dissemination in diorite and silica sand deposit derived from sandstone of Eocene are observed, but no large mineralization and/or alteration are observed. As for the surveys in the small islands, there is confirmed chromite dissemination in ultramafic rock existing on Paley island. Assay of 4 samples of Paley Is. showed as follows.

Ni 0.23 - 0.20%   Cr 1.72 - 0.25%

Table-2 Assay for Silica Sand Samples

Sample No.	SiO_2 (%)	Al_2O_3 (%)	Fe_2O_3 (%)	MgO (%)	CaO (%)	Identified minerals by X-ray diffraction
4 Vulcan-1	96.91	1.01	0.54	0.07	0.06	Quartz (abundant) Plagioclase, K-feldspar (rare)
5 Vulcan-2	96.08	1.05	0.59	0.06	0.04	"
6 Vulcan-3	97.43	0.87	0.56	0.07	0.06	"
7 Vulcan-4	98.47	0.55	0.32	0.03	0.05	Quartz (abundant) K-feldspar (small)
8 Ninbay-1	98.59	0.56	0.40	0.02	0.07	Quartz (abundant) K-feldspar (small)
8 Ninbay-2	97.38	0.76	0.32	0.03	0.15	Quartz (abundant) K-feldspar (small) Sericite (rare)
9 Ninbay-3	98.24	0.47	0.32	0.02	0.07	Quartz (abundant) Plagioclase (small) K-feldspar (rare)

3-1-6 Mineralization of UNDP Survey Area

UNDP survey area in north-eastern Palawan are Caruray, Caramay, Nasuedan, Tintitan and Babuyan Quadrangles situated north-eastern Puerto Princesa City. In these area, antimon anormalies are observed around Lasgas in Tintitan Quadrangle and around Tugbuan in Babuyan Quadrangle, and mercury anomalies are found out around Tugbuan in Babuyan Quadrangle. These anomalies are accompanied to mineralization which carried out post period of Neogene fault movement. UNDP Report (1985) recommend further exploration to these anomalies.

3-2 Geology and Ore Deposits of the South-Western Area of Palawan (Ref. PL1-2)

3-2-1 General Summary

The survey area corresponding to the south-western part of Palawan island belongs, from an administrative point of view, to Region IV, Palawan Province and is situated 600 km south-west of the capital, Manila. (cf. Fig. 1)

Transportation to the survey area from Manila is as follows: From Manila to Puerto Princesa, the capital of Palawan Province, air service is available and highway (road) runs from there to Quezon, the western end of the survey area passing through the south-eastern coast.

The road condition from Puerto Princesa to the north-western coast and from Quezon to the west-nothern coast is in bad and passage is difficult in the rainy season. For access to places where road along the seacoast is not equiped, banca boat is utilized.

Manila → (regular air line; 1 flight a day; 1 Hour ten minites) → Puerto Princesa → (4 hours; by car) → Quezon

As an administrative division, the survey area corresponds to Puerto Princesa city, Quezon district and Narra district.

The geographic situation is as follows:

Area :	2,500 km^2
Elevation :	0 - 1,798 m
Highest peak :	Victoria Peaks (1,798 m)
Average temperature :	27^{o} centigrade
Average annual precipitation :	2,700 mm

The survey area belongs to the tropical monsoon zone.

Rainy season is from June to November and dry season is from December to May, but on the eastern side of the central range the seasonal change is not so clear as on the western side of the range.

On the east coast, generally, coral reefs are well developed and there are many swamps where mangrove are plentiful grow well. There are rice fields developed near the swamps, but they are rare in the west coast area. Topography is generally steep and in the central range where ultramafic rocks are distributed, the creeks beds are deeply eroded and have water falls in places. In the south-western part of the central range, limestones are partially distributed and cliffs and dolines characteristic of limestone areas can be observed.

Main industry are agriculture located in east coast plane and fishery around Puerto Princesa.

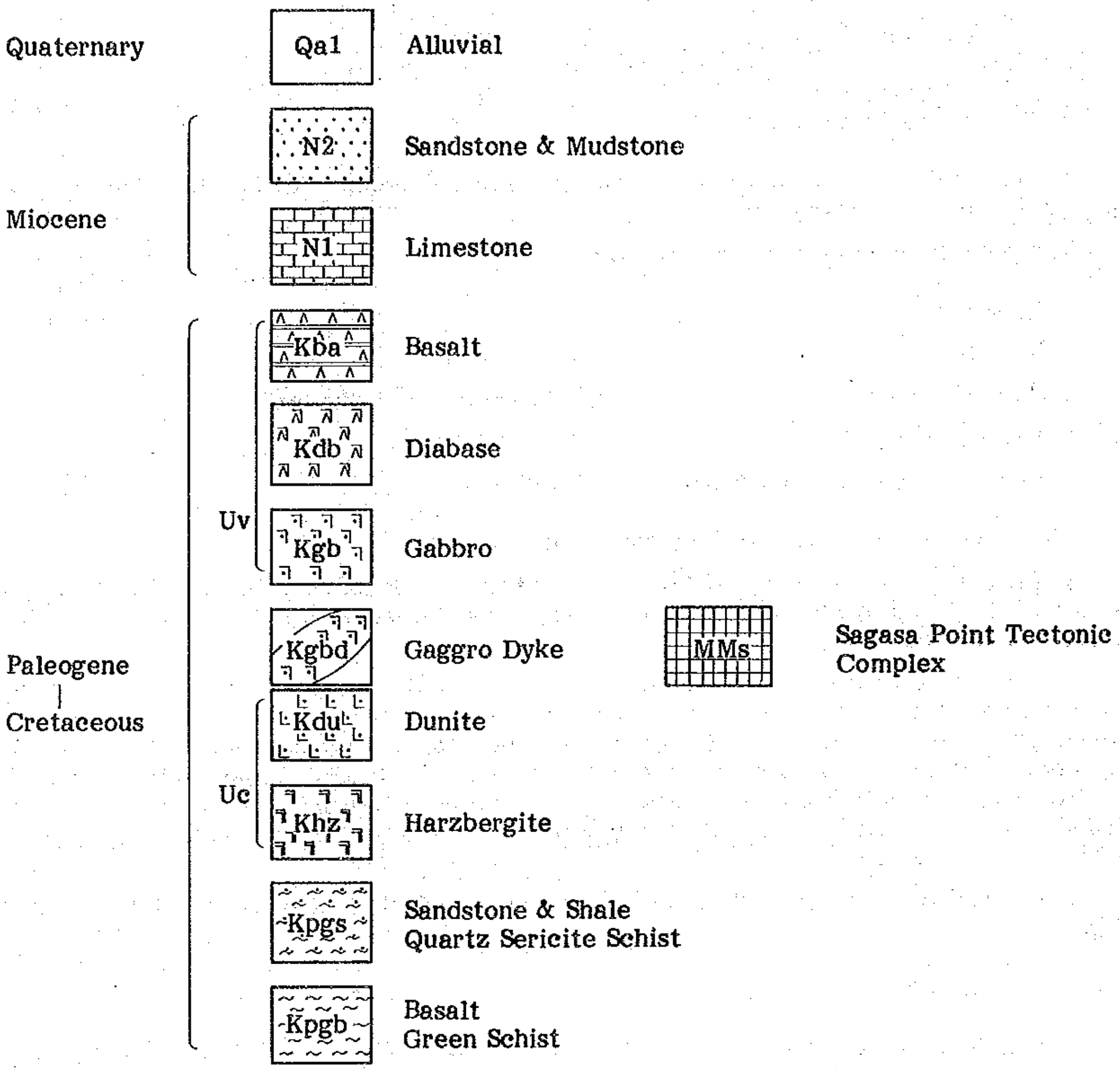
3-2-2 Stratigraphy

The geology of south-western Palawan island consists of Formation (Kpg) belonging to the Mesozoic group (Cretaceous?), upper and lower ophiolite rock formation (UV,UC), Neogene system and intrusive rocks. The Formation (kpg) is basement and composed of green schist, sericite quartz schist, sandstone, shale, basalt lava and amphibole schist. lower ophiolite rock formation (UC) is thrust up upon the above basement and is composed of harzburgite and massive gabbro.

Upper ophiolite rock formation (UV) is composed of sheetlike diabase and pillow basalt. It is distributed around the above lower ophiolite formation (UC) and is thrust up by harzburgite formation in the northern and southern parts of survey area.

Neogene system is the Formation (N1) composed of limestone and calcareous siltstone in southwestern area, distributed on a UC Formation and UV Formation in discordant. Also, mudstone accompanied with calcareous sandstone and conglomerate (N2) is observed in the south-western and north-eastern areas.

Fig. 9 Schematic Columnar Section of South-Western Palawan Area



Details of Each Formation in South-Western Palawan

Qal (alluvial)	Unconsolidated deposits of gravel, sand, clay and organic materials along flood plains of major drainage system. Beachsand and corals are also included. This formation developed broad area in south-east coast.
N_2 (sandstone & mudstone formation)	Chiefly composed of alternation of calcareous sand and mud and interbedded conglomerate, conglomerate contained sandstone, madstone and basalt half rounded pebble, matrix is calcareous.
N_1 (limestone formation)	Chiefly composed of massive limestone and calcareous siltstone, this formation contained molluscs fossil in places well developed in southern part of the area
Kba (upper ophiolite basalt lava)	Occupied upper part of upper ophiolite formation, chiefly *composed of dark gray color basalt lava, pillow structure are* visible in places.
Kdb (upper ophiolite diabase)	Dark green to dark gray colored appearance, observed as dyke rock at the boundary *of basaltic rocks and gabbroic rocks.* This formation seems to correspond to sheet complex of ophiolite body.
Kgb (upper ophiolite gabbro)	Occupied lower part of upper ophiolite formation, chiefly shown medium and coarse grained equigranular massive appearance.
Kgbd (gabbro dyke)	Intruded in lower ophiolite formation in places, this dykes showed medium to fine equigranular appearance and marginal facies changed to diabasic appearance.
Kdu (lower ophiolite *dunite*)	Strong serpentinized and showed greasy luster distributed in harzburgite, accompanied to lenticular or disseminated chromite in places.

Khz (lower ophiolite harzburgite)

Composed main part of lower ophiolite formation, showed dark green color by influence of serpentinization, augite phenocrysts of strip shape are visible and veinlets of assumed prehnite observed in places. The lower portion contact to Kpg Formation showed visible schistosity and metamorphosed to amphibolite in places.

Kpgs
Kpgb

Chiefly composed of shale, sandstone and red chart, and interbedded thin layer of basaltic lava. This formation increased metamophism grade, according as approached to lower ophiolite formation, namely sedimentary rocks changed to sericite-quartz schist, basic volcanic rocks changed to green-schist, and hornblend-schist observed at the boundary to harzburgite.

MMs (Sagasa Point tectonic complex)

This tectonic complex occured along fault between ophiolite formation and Babuyan River Formation. Chiefly composed tectonic melange of above mentioned formations and basalts and quartzites at promontory in Ulugan Bay.

As intrusive rocks, diabase, gabbro and pyroxenite as dykes are observed in the area of ultramafic rocks and gabbro dykes are also observed in the massive gabbro body of the northern part of the survey area.

The stratification of each above formation is shown in the schematic geological column (Fig. 9).

The descriptions of each geological unit are as follows:

Mesozoic Formation (Kpg)

These consist mainly of shale, sandstone and red chert intercalated with thin layers of basalt lava (Kpgb). These rocks are distributed in the area around Moorson Point, the western part of Aborlan on the west coast and the northern and western parts of Irahuan in the north. These rocks gradually change to higher metamorphosed rocks in accordance with the proximity of harzburgite (Khz) belonging to the UC Formation situated at the upper part than the Formation (Kpg). That is, sedimentary rocks are metamorphosed to sericite quartz schist and bassic volcanic rocks are metamorphosed to green schists and changed to amphibole schist near the contact between harzburgite and these sedimentary rocks. These phenomena would indicate that the metamorphic temperature increased in accordance with the proximity of the upper situated harzburgite. The age of these rocks are considered by BMG (1982) to be from the Cretaceous to Palaeocene.

Microscopic observation results.

CN06 (located near Malasgao River); chart; aggregation of fine grain quartz (0.02 - 0.05 mm) penetrated 0.06 mm width quartz veinlet and 0.06 - 0.3 mm calcite veinlet. Dust like opaque minerals which assumed hematite are abundant. CJ004MA; This rock is hornblend schist with granoblastic texture which consist of hornblend, epidote and plagioclase.

Ophiolite rocks

Lower ophiolite body (UC). These consist of harzburgite (Khz) intercalated with dunite lenses in the upper part of this rock body and small gabbro dykes (Kgbd) and small pyroxenite dykes (Kpxd) are observed in this rock body. Harzburgite alters to serpentinite, is a dark green colour and has phenocrysts (1 - 10 mm) of frame like pyroxenes and well developed white veinlets considered often to be as prehnite. In this body, a well developed schistose structure is observed in the basal part that is in contact with the lower situated Kpg Formation. This rock is metamorphosed to amphibolite near the point of contact between them. At Birong on the western side, melange enveloping the lower situated Kpg Formation is observed.

Dunite is remarkable in serpentinitization and showing oily and fat luster. In this dunite and harzburgite near this dunite, lenticular and disseminated chromite deposits are frequently observed.

This rock body thrusts of through the above described Kpg Formation with a low angle of 20° - 30° degrees. These facts are confirmed in the middle stream of Malasgao River and Birong. In the contact between both formations, there is observed melange and thermal metamorphism considered to be the results of dynamic metamorphism.

Microscopic observation results.

CE012 - 013 MA.PT; This rock is serpentinite well developed mesh texture, recognized granular olivine and big granular clinopyroxene as relict minerals, it's original rock is assumed harzburgite. (G048 MA.PT; This rock is serpentinite well developed mesh texture, recognized granular olivine and opaque mineral as relict, its original rock is assumed dunite.

On the results of X-ray diffraction test of this sample, Brucite and Serpentine were identified.

Age determination results.

Upper Ophiolite body: UV

This rock is distributed around the Lower Ophiolite Body in the northern part, southern part and western part of the survey area, and is composed of gabbro (Kgb), diabase (Kd), and basalt (Kba).

Gabbro has generally granule, medium to coarse grained with and massive facies. In the lower part, troctolite is rarely observed that include scarcely pyroxene phenocryst. In the eastern area around Batanbatan, many gabbro boulders are observed at the river side, which have a foliated structure, but the outcrop from which these boulders were derived were not found out. Basalt, dark gray in colour is predominant pillow structure. Each block shows a flat like elliptical shape and is 30 cm to 80 cm in size. Around each block, hematites crystalized and filled in cabifies zeolite are frequently observed.

Diabase is a dark green to dark gray colour, distributed as the dykes near the contact of gabbro and basalt. These dykes correspond to the sheet complex generally observed in iphiolite bodies. In the geological map (PL.), as this zone is key-bed means the category of diabase includes a transitional zone which is not dominant in the dykes.

It is considered that this ophiolite body would be in fault relation (thrust fault) to lower ophiolite (UC). To determine the age of this ophiolite, a sample was taken from this body and analyzed by the K-Ar method. Its result is as follows:

Age determination result.

Ref. APPENDIX-4 Sample No. CO052286, CA034MA.PT.AD. and CJ056AD

Microscopic observation results.

Sample No. CL063 Ma.PT Locality, 3 km Northern part of Inagauan River; This sample is alkali gabbro which consist of plagioclase, titaniferous pyroxene with hypidiomorphic texture, nepheline is observed at inter grain of plagioclase.

Sample No. CS028R locality near Narra; This rock is augite basalt having intersertal texture which consist of phenocrysts of granular-short column augite and columnar plagioclase (labradorite) and ground mass which composed fine grain of augite, magnetite and glass, zeolite is observed as cavity filling.

N1 Formation

N1 Formation is composed of massive limestone and calcareous siltstone, frequently including shell fossils. This formation is distributed comparatively widely around Aboabo, southern part of Quezon, to be spots and small scales and covering the basalt of upper ophiolite in discordance. The BGM (1982) concluded that the sedimentary age of this formation is from early Miocene to middle Miocene.

Fossil identification results.

CJ021PL; The limestone sample of this formation at 7 km SSW of Richman Mine, is determinated by nannoplankton as upper Oligocene[1].

N2 Formation

N2 Formation is mainly composed of alternation of calcareous sandstone and calcareous mudstone, intercalated with conglomerate and sandstone bearing nodules.

This formation is distributed in the western part of Inagauan situated in the eastern region of the survey area, in the north and in the south-west side from Birong to Quezon.

The alternating layers of calcareous sandstone and calcareous mudstone have a thickness from 1 cm to 15 cm and bear microfossils.

Conglomerate is composed subrounded pebbles of ultramafic rock, gabbro and basalt and partly observed beding plane horizontal to low dipping.

This formation covers the N1 Formation, gabbro and basalt of upper ophiolite in discordance, and is corresponded by BGM (1982) to upper Miocene series.

Fossil identification results.

Hexacoralia specimen (CG044A·B) is collected along the north-east coast of this formation, but identification is impossible because of incomplate specimen.

3-2-3 Intrusive Rocks

Diabase, Gabbro and Pyroxinite

These rocks are observed as dyke rocks in the upper and lower ophiolite bodies and are dominantly distributed in the range along the north-western coast.

Microscopic observation result.

Sample No. CA023 Ma, Locality, Richman Mine site; This rock is diabase, in which granular clinopyroxene and opaque minerals are observed around columnar plagioclase phenocryst. Plagioclase and clinopyroxene in groundmass are partially chloritized.

3-2-4 Geological Structure

In this area, there is the thrust accompanied by the subduction of oceanplate. In accordance with this thrust, ophiolite bodies which would belong to Cretaceous are thrust up through the basement of Cretaceous to Palaeogene sedimentary rocks. Ophiolite bodies are composed by two beds of which the lower bed is constituted of harzburgite and the upper bed is (constituted) from gabbro and basalt, showing a NE-SW direction and extending to 90 km in length.

In south-western area, thrust fault shows N-S strike and a low inclination to the west.

(1) According to Dr. N. Okada, Geo-Sciences Department, Science Faculity, Yamagata University

In the area from north most part to UNDP survey are, there is observed the peculiar window structure that complexed Cretaceous series and upper ophiolite body expose in the area of 7 km east-west and 15 km north-south, under lower ophiolite body that over thrust upon Cretaceous and upper ophiolite.

N1 Formation and N2 Formation of Neogene system cover these formations and ophiolite bodies in discordance. Folding structures are observed in the basement, ophiolite bodies and the Tertiary system and show folding axes of a NE-SW direction.

Except for the low angle thrust fault, there is nearly a vertical fault in a NE-SW direction and elongate 20 km length to the north of Mt. Aborlan. This vertical fault forms the northern limit of the basement rocks.

Synthesizing the these descriptions, the thrust fault was formed in the time of the Palaeocene to the Miocene, that is, the period before the N1 Formation and after the formation of the basement rocks. Judging from the fact that the formation jets younger as it goes from east to west in the south-western part of the survey area, it is considered the upheaval of the western part continued tilting until the N2 Formation.

Compared with these phenomena in the south-western part, in the northern part of the survey area there is observed the window structure that throughout wavely folded upper ophiolite formation exposes partially under lower ophiolite formation which over thrust upon upper ophiolite formation.

3-2-5 Results of Mineral Showing Survey

In this area, survey was carried out on the following 13 showings. (Ref. Appendix 12)

Number	Name of mineral showing	Kind of mineralization
1	Atlas Mine	Laterite, chromite
2	Richman Mine	Chromite massive deposit
3	Boyo Mine	do
4	Ramarao	Ni-laterite, chromite
5	Berong	do
6	Ibatong	do
7	Malasgao	do
8	Bethlehem	do
9	Bethlehem West	do
10	Olympic	do
11	Santa Monica	do
12	Trident	Chromite
13	Aboabo	Guano type phosphate deposit

1. Atlas Mine

This mine is situated at a point 5 km southwest from Long Point, on the northwest coast.

Ore deposit is composed of conglomeratic chromite in laterite, and mining operation started at the end of 1985.

From this mine, 1,147 tons of ore were produced and sent during one month to Quezon by shipment.

Ore deposit is impregnated within serpentinite altered from ultramafic rock.

Table 3 Assay Results of Pit wall samples (Ref. Appendix 7-3)

Sample No.	SiO_2 (%)	Cr_2O_3 (%)	T·Fe (%)	MgO (%)	Al_2O_3 (%)	Total (%)
CA007	0.4	53.1	10.3	13.7	17.4	94.9
CA008	0.4	51.0	11.0	13.1	17.0	92.5
CA009A	0.6	47.1	11.7	12.6	19.2	91.2
CA009B	0.2	54.3	9.5	14.5	16.5	95.0

X-Ray Diffraction

Sample No.	Identified minerals	Locality	Kind of sample
CA008	Chromite	Atlas mine	Laterite

2. Richman Mine

This mine is situated at a point 4 km southeast of the Atlas Mine. Ore deposit is massive chromite deposit in peridotite, showing a Leopard type dissemination and closely related to diabase dyke.

Assay Results of Pit wall samples (Ref. Appendix 7-3)

Sample No.	SiO_2 (%)	Cr_2O_3 (%)	T·Fe (%)	MgO (%)	Al_2O_3 (%)	Total (%)
CA010	16.6	28.1	7.4	26.3	13.1	91.5
CA012	6.0	40.8	8.5	20.8	19.4	95.5
CA013	13.8	32.2	7.3	23.9	15.8	93.0
CA016	12.0	33.3	8.0	23.4	15.2	91.9
CA020	13.1	32.8	7.5	24.0	15.3	92.7
CA021	4.3	48.8	8.6	18.8	14.9	95.4
CA022	12.9	33.5	7.8	23.8	14.4	92.4

X-Ray Diffraction

Sample No.	Identified minerals	Locality	Kind of sample
CA016	Serpentine (medium) chromite (abundant)	Richman mine	Ore
CA019	Montmorillonite (not clear) Serpentine (abundant)	"	Serpentine

3. Boyo Mine

This mine is located at a point 2 km south from Aniphahan, on the northwest coast and is now operated by 7 persons. Ore deposit is massive chromite deposit impregnated within peridotite and gabbro. When surveying, ore could not be observed because the open pit had collapsed because of a landslide.

Assay Results of Pit wall samples (Ref. Appendix 10•11)

Sample No.	SiO_2 (%)	Cr_2O_3 (%)	T•Fe (%)	MgO (%)	Al_2O_3 (%)	Total (%)	
CA028A	2.1	50.5	9.6	16.4	15.6	94.2	
CA028B	5.3	46.6	9.4	18.1	14.5	93.9	
CA030A	18.0	34.0	9.4	17.3	11.4	90.1	
CA030B	44.8	1.1	3.1	25.4	8.8	83.2	Assay for Amphybolite
CA031A	3.7	48.3	9.8	17.2	15.0	94.0	
CA031B	5.8	45.8	9.1	19.0	14.4	94.1	

X-Ray Diffraction

Sample No.	Identified minerals	Locality	Kind of sample
CA030B	Chlorite (medium) Amphibole (abundant)	Boyo Mine	Country Rock

4. Romarao

This mineral showing is located between Berong and Moorsom Point on the west coast. There is wholly distributed harzburgite in mineralized area. Lateritization is widely observed and the thickness of laterite is shallow (3 m) depth.

The saprolite (decomposed part of serpentinite) development under laterite is not enough and in this part garnierite is not observed.

Two points of chromite mineralization were found. These mineralizations are observed to be impregnated in a lenticular shape within dunite intercalated in harzburgite. The sizes of the mineralization are 0.4 - 1.5 m in thickness and 6 m in length. The chromite shows massive and disseminated feature. (Ref. Appendix 7-4)

Ore assay

Sample No.	SiO_2 (%)	Fe_2O_3 (%)	FeO (%)	Al_2O_3 (%)	MgO (%)	NiO (%)	Cr_2O_3 (%)	Kind of ore
CX21786	-	-	11.24	10.76	22.19	0.22	41.08	Chromite
CS054MA	40.71	12.87	-	1.03	27.49	0.64	-	Ni-Laterite

5. Berong

This mineral showing is situated to the north of Berong on the west coast and in this showing area laterite and chromite are observed. Laterite derived from harzburgite is widely distributed in this area. Bench cut mining was performed along the ridge in the middle of Berong River. In the bench cut part the thickness of laterite is about 3 m and that of saprolite is over 3 m. Garnierite is contained in saprolite. Chromite mineralization is observed at the upper stream of Berong River. In the trench performed at chromite mineralization, there is a concentrated chromite dissemination zone impregnated within dunite of about 5 m thickness intercalated in harzburgite. This dissemination zone shows 1.5 m to 2 m in thickness. (Ref. Appendix 7-4)

Ore assay

Sample No.	SiO_2 (%)	Fe_2O_3 (%)	FeO (%)	Al_2O_3 (%)	MgO (%)	NiO (%)	Cr_2O_3 (%)	Kind of ore
CX21486	—	—	11.81	19.57	18.85	0.23	42.60	Chromite
CS043MA	33.60	27.75	-	2.03	16.37	0.26	-	Ni-Laterite
CS044MA	40.23	7.06	-	0.36	33.67	3.28	-	"

X-Ray diffraction

Sample No.	Identified mineral	Kind of ore
CS045MA	Sericite (not clear) Antigorite (abundant)	Garnierite

6. Inbatong

This mineral showing corresponds to the northwest extension of the Berong showing.

In this area, it was confirmed that the thickness of laterite was over 2 m. In the small creek near the laterite deposit, chromite dissemination occured within dunite intercalated in harzburgite is observed. (Ref. Appendix 7-4)

Ore assay

Sample No.	SiO_2 (%)	Fe_2O_3 (%)	Al_2O_3 (%)	MgO (%)	NiO (%)	Kind of ore
CP01S3	1.00	66.51	7.19	1.02	0.80	Ni-Laterite
CP04S3	0.91	67.44	8.17	1.54	0.79	

7. Malasgao

This mineral showing is situated at a point 15 km north of Panacan, that is, in the middle of the Malasgao River. In this showing, there is laterite derived from harzburgite which is distributed in an area of 2.5 km^2 (1.5 km north-south x 1.5 km east-west). In a old test pit, the thickness of laterite is over 2 m. (Ref. Appendix 7-4)

Ore assay;

Sample No.	SiO_2 (%)	Fe_2O_3 (%)	Al_2O_3 (%)	MgO (%)	NiO (%)	Kind of ore
CPT1-1(4)	12.12	56.73	7.82	2.33	1.09	Ni-Laterite

8. Bethelehem

This mineral showing is located at a point 10 km west from Panacan, that is, the upper Malinao River.

Laterite derived from harzburgite is distributed in a area of 7 km^2 (3.5 km north-south x 2 km east-west) and on the low land of 200 m to 600 m from sealevel. In this area, laterite development is not good in depth, beause of steep topography and its thickness estimated to maximum of 5 m. There is also observed a small outcrop of chromite dissemination in harzburgite. (Ref. Appendix 7-4)

Ore assay;

Sample No.	SiO_2 (%)	Fe_2O_3 (%)	Al_2O_3 (%)	MgO (%)	NiO (%)	Kind of ore
CS011MA	10.25	54.62	6.89	3.93	1.66	Ni-Laterite

X-Ray diffraction;

Sample No.	Identified minerals	Kind of ore
CS012MA	Plagioclase (medium) Antigorite (abundant)	Garnierite

9. Bethelehem West

This mineral showing is situated at the middle stream of Batanbatan River, west of the Bethelehem Mine.

Laterite derived from harzburgite is distributed in a area of 3 km^2 (2 km north-south x 1.5 km east-west). The thickness of laterite is up to 5 m on the ridge, but not well developed because of the steep topography. (Ref. Appendix 7-4)

Ore assay;

Sample No.	SiO_2 (%)	Fe_2O_3 (%)	Al_2O_3 (%)	MgO (%)	NiO (%)	Kind of ore
CS018MA	9.89	61.84	6.00	3.72	1.09	Ni-Laterite

10. Olympic

This mineral showing is situated on the west slope of Mt. Calategas, which is located 15 km southwest from Panacan. Laterite derived from harzburgite is distributed in an area of 2.5 km^2 (1.5 km north-south x 1.5 km east-west).

In some parts of this showing area, small scale exploration and mining operations were carried out by the Olympic Co. in the 1970's. Laterite (7 m thickness) and saprolite (over 2 m thickness) are well developed and contained garnierite. And irregular and lenticular chromite of 30 cm thickness was also observed. (Ref. Appendix 7-4)

Ore assay

Sample No.	SiO_2 (%)	Fe_2O_3 (%)	FeO (%)	Al_2O_3 (%)	MgO (%)	NiO (%)	Cr_2O_3 (%)	Kind of ore
CS020MA			13.06	14.46	17.08	0.11	47.94	Chromite
CS022MA	11.50	60.27	-	7.69	1.01	1.27	-	Ni-Laterite
CS023MA	17.25	57.24	-	5.03	1.88	1.43	-	
CS024MA	48.22	11.85	-	0.93	20.50	4.92	-	Saprolite

X-Ray diffraction

Sample No.	Identified mineral	Kind of ore
CS025MA	Sericite (not clear) Antigorite (medium) Quartz (abundant)	Garnierite

11. Santa Monica

This mineral showing is situated at a point 5 km west of the Olympic mineral showing.

Laterite derived from harzburgite is distributed in an area of 2 km north-south and 1 km east-west and developed to a depth of 15 m. And there is also a chromite dissemination zone of 6 m width. Drilling exploration was said to have been performed formerly in this chromite mineralization but the depth continuation of the mineralized zone was not confirmed. (Ref. Appendix 7-4)

Ore assay

Sample No.	SiO_2 (%)	Fe_2O_3 (%)	Al_2O_3 (%)	MgO (%)	NiO (%)	Kind of ore
CS033MA	6.19	64.54	5.15	1.53	1.64	Ni-Laterite

12. Trident

This mineral showing is situated at a point 7 km to 10 km northwest from Panacan. In 1978 TRIDENT MINING & INDUSTRIAL CORP. commenced a mining operation and produced about 100,000 t of chromite concentration 1 (CrO grade: 46 - 48%), but stopped operation in 1982, because TRIDENT M.I. CORP. was fell into management difficulties. During the time of operation, it is said, two milling plants (Processing capacity; 250 t/month and 500 t/month) were fully operated. But, now these plants are becoming ruins.

Ore deposit is massive and disseminated chromite deposit occured in the dunite which is stretched to the northwest-southeast direction.

Four open pits of 50 m to 100 m in diameter were observed. One of the pits is in Area 1 and the other pits are in Area 5. The ore deposit was almost mined out and could not be observed in whole aspects.

According to features of ore remained slightly in the walls of open pits, it could be estimated to be as followings:

Area 1

There exists a massive chromite deposit laid within the fault (strike: N90°E, dip: 30°S) developed in harzburgite. Its thickest part measures about 1 m. The open pit is, now, filled up with water.

Area 5

There exists a massive or disseminated chromite deposit impregnated within dunite. On the west wall of a open pit in the eastern extremity, massive ore bodies of 0.5 m to 2 m in thickness are observed being ranged in few banded structure within the dissemination zone of 9 m in width. The dunite is scarcely altered.

This ore body was dislocated to west because of the fault (strike: N20°E and dip: 20°S) and the second pit might have mined this part of ore body. The strike and the dip of ore body run in 40°W and 75°N, corresponding to the direction of dunite elongation.

Area 6

In various places, massive or fine grained chromites (chromite sand) are observed mixed with weathered soil derived from dunite and harzburgite.

In this area, trenching by bulldozer was performed once, but promising ore zone could not be found.

According to the aspects of open pit and what former employees told on the mine, scale of a unit ore body would be estimated as to be several thousand tons to severl ten thousand tons. (Ref. Appendix 7-4)

Ore assay;

Sample No.	FeO (%)	Al_2O_3 (%)	MgO (%)	NiO (%)	Cr_2O_3 (%)	Locality	Kind of ore
CN13	13.60	4.80	19.62	0.18	44.81	Area 5	Chromite
CN15	8.63	3.51	25.15	0.32	32.84	Area 5	
CN17	13.04	16.72	15.82	0.18	48.95	Area 1	

13. Aboabo

This mineral showing is situated on the south slope of Mt. Buod Mainat 5 km north from Aboabo. In this area, guano type phosphate deposits are observed in the limestone of N1 Formation. The strongly weathered part of this phosphate deposit was, mined, in older age. (Ref. Appendix 5-4)

X-Ray Diffraction

Sample No.	Identified minerals	Kind of ore
CT01S12	Calcite (abundant)	Aboabo limestone
CT02S12	Crandallite (abundant)	Guano type phosphate ore

3-2-6 Mineralization of UNDP Survey Area

UNDP survey area in south-western Palwan are Kadangon Beach and Bacungan Quadrangles located northern Puerto Princesa City.

Geological structure of this area have characterized over thrust structure of lower ophiolite formation and upper ophiolite formation exposed as window style. Chromite ore accompanied of the upper ophiolite formation in places and stratified manganese deposits have found out in Palaeogene sediments, many Cu, Zn, Hg anomalies are also found out in this window style upper ophiolite region. UNDP Report (1985) recommended further exploration to these regions.

4. GEOCHEMICAL SURVEY

4. Geochemical Survey

4-1 Survey Method

Geochemical survey was undertaken mainly to analyze the microchemical contents of the elements of stream sediments and heavy mineral samples. Sampling error was checked by taking duplicate samples from the same place of original sampling point at approximately every 50 stream sediment samples collected.

All geochemical samples were analyzed by the Bureau of Mines and Geo-Sciences analytical laboratory (herein after called PETROLAB) by atomic absorption method.

Processing of geochemical data was done by Overseas Mineral Resources Development Co., Ltd. (herein after called OMRD). Analyzing method is univariate analysis in whole area and multivariate analysis (Factor analysis) in Taytay and Roxas Area.

4-1-1 Sampling Location

Sampling was carried out along active channels of streams by the same method used at the Southern Sierra Madre·Polillo Area, the Bohol·Siquihol Area on 1984. The density of sampling is approximately one stream sediment sample for every one to two square kms. Sampling points are pre-determined in a 1/50,000 scale prior to the start of the survey.

4-1-2 Sampling Method

Samples collected are wet sieved by using stainless sieve to 30 mesh fraction in situ by which they amounted to about 500 grams. They are washed thoughly to remove dirt and clay fractions before they are placed in a properly marked water resistant kraft paper bag. An accompanying data seet card (Fig.-10) is filled up to record observations like location, grid coordinates, features of the stream, PH, Eh, topography etc. Samples are transported to basecamp for drying and sieving to -80 mesh.

Heavy mineral samples are collected using wooden pans at pre-determined sampling points. About 20 grams of heavy mineral fractions are collected from each point and are placed in a plastic tube. This samples are sent to the laboratory through basecamp. Similar to stream sediments, a corresponding data sheet form is filled up to decribe the place where the sample is taken. Stream sediment samples are transported to each base camp, are sun-dried and are sieved to -80 mesh by stainless sieve. Samples are put in remarked kraft paper bags and are sent to PETROLAB.

4-1-3 Method of Indoor Testing

1) Adjustment method of analitical samples

   Stream sediment and heavy mineral samples sent to PETROLAB are divided into 20 grams for analytical samples and the rest amount for spare samples. In the analytical laboratory, 1 gram of stream sediment sample and 10 grams of heavy mineral sample are weighed AAS. Excess samples are stored for further use.

Fig. 10 Field Data Sheet of Geochemical Prospecting

AREA:

SAMPLE NO.	SAMPLE TYPE	EASTING	NORTHING	STREAM Ord.	STREAM Width-m	STREAM Depth cm	STREAM Flow	STREAM PH	STREAM EH	BANK Type	BANK Ht-m	SEDIMENT OR SOIL SIZE	ORGANIC MATTER	PRECIPITATE
1 5	6	7 10	11 14	15	16 17	18 20	21	22 23	24 25	26	27 28	29	30	31

CONTAMINATION	MINERALIZATION	ALTERATION	ROCK TYPE	OTHER SAMPLES
32	33	34	35 36	37

REMARKS:

CODES:

Cols.1-5 Sample number.

Col.6 Sample type. Enter one of the following codes:
- 1-stream sediments
- 2-soil
- 3-rock
- 4-heavy mineral concentrate (note original concentrate panned under REMARKS column)
- 5-duplicate sample (corresponding to preceeding sample number)

Cols.7-14 Coordinates.

Col.15 Stream order.

Cols.16-17 Stream width(m). Enter width of active channel;(enter 99 if > 99).

Cols.18-20 Water depth (cm).

Col.21 Flow. Enter one of the following codes:
- 0-dry
- 1-stagnant
- 2-slow
- 3-moderate
- 4-fast
- 5-artificial

Cols.22-23 PH. Leave blank if not recorded: if measurement is 6.4 enter 64.

Cols.24-25 Conductivity ($\mu s / cm$)

Col.26 Bank type:
- 1-colluvial
- 2-alluvial
- 3-scree
- 4-bedrock
- 5-colluvial and bedrock

Cols.27-28 Bank height(m).

Col.29 Sediment or soil size. Record grain size of material sampled (whether sediment or soil) using one of following codes:
- 1-coarse
- 2-medium (sandy)
- 3-fine (silty)
- 4-clayey

Col.30 Organic matter. Note presence and amount (abundant, moderate, minor). Use code 1 if present and 0 if absent.

Col.31 Precipitates. Note precipitates present, using codes:
- 0-absent or not detected
- 1-iron (red or brown stains)
- 2-manganese (black stains)
- 3-sulphur (yellow stains)
- 4-carbonate
- 5-other (specify)

Col.32 Contamination. Note presence and type. Use code 1 if present and 0 if absent.

Col.33 Mineralization. Note presence and type (sketch on reverse). Use code 1 if present and 0 if absent.

Col.34 Alteration. Note presence and type. Use code 1 if present and 0 if absent.

Cols.35-36 Rock type. Use one of the codes given on the reverse.

Col.37 Other samples. Note other samples collected at the same site. Use one of the following codes:
- 0-none
- 1-stream sediment
- 2-soil
- 3-rock
- 4-heavy mineral concentrate
- 5-duplicate
- 6-several types (specify)

Remarks. Enter any other pertinent information about the sampling locality

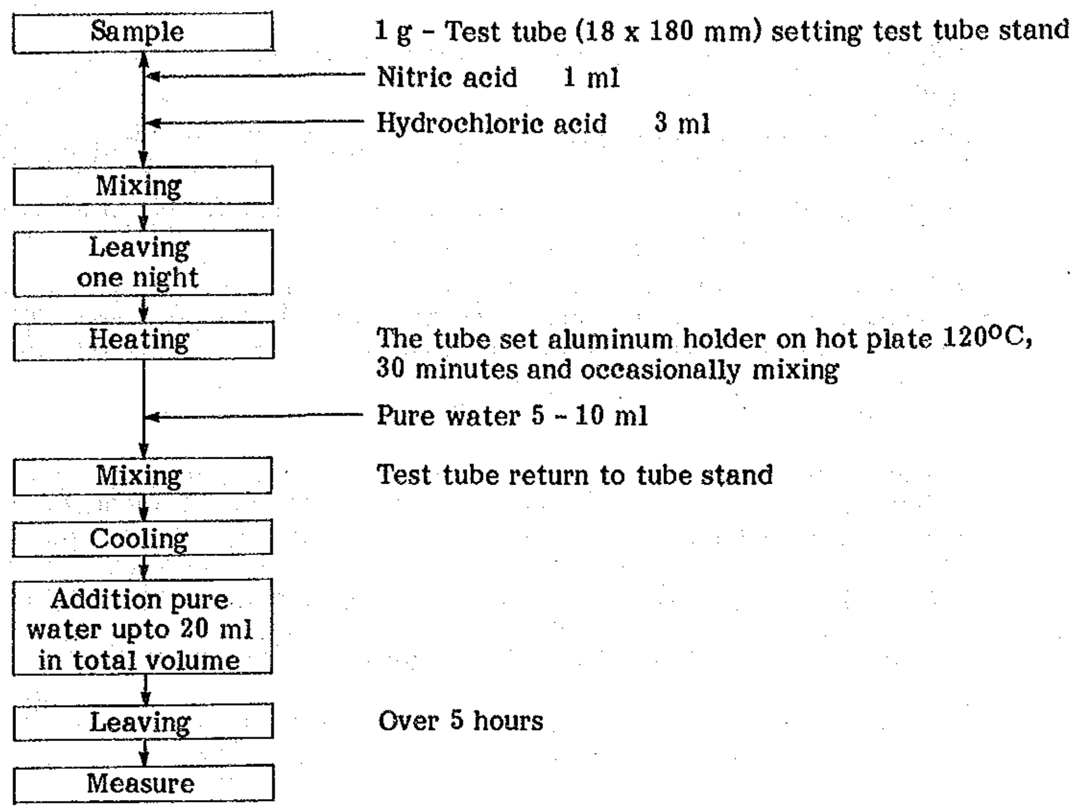


Fig.11 Flow Chart of Stream Sediment Preparation

Table 4 Microchemical Analytical Method on Stream Sediments (AAS)

Element	Measuring Method	Flame	Wave Length (mm)
Ag	Direct Atomic Absorption	Air-C_2H_2	328.1
Cu	"	"	324.7
Mn	"	"	403.3
Pb	"	"	217.0
Zn	"	"	213.7
Mo	"	N_2O-C_2H_2	313.0
Hg	Reduction Vapor-AAS	Flameless	253.7
As	Hydration-AAS	"	197.4

2) Microchemical analytical method (Foot note 1)

Weighed samples are analyzed by atomic absorption method according to the attached flow chart (Fig. 9).

Elements analyzed are Ag, Cu, Pb, Zn, As, Hg, Mo, Sn, W, Sb (10) in Palawan I, II Areas and Ag, Cu, Pb, Zn, Co, Mn, Ni, Cr, As (10) in Palawan III, IV Areas.

Heavy mineral samples are analyzed for Au, Ag and Ga (3) in all Areas. The detection limits of those elements are shown in Table 5.

In PETROLAB, 4 sets of atomic absorption spectrometer are utilized. 3 sets are made by Varian Tectron Co. (one of which is flameless type model GTA-95 while other two AS-1475) and 1 set is made by Shimadzu which used as test operation.

(Foot note 1)

This method is a direct aqua-regina extraction from - 80 mesh samples unless further grinding, therefore, some amount of indication elements which are included in quartz grain etc., have the possibility to remain after extraction. Geochemical survey requires not only absolute contents but comparable value in each samples, so such convenience method is accepted in geochemical survey.

Table 5 Detection Limit of AAS of Laboratory

(Unit: ppm)

Laboratory	Cu	Pb	Zn	Ag	Ni	Co	Mn	As	Hg	Mo
PETROLAB	2	10	2	1	3	3	50	0.5	0.04	2

3) The method of statistical analysis for geochemical results

The statistical analysis for geochemical results are applied each in the Northeastern Palawan Area and the Southwestern Palawan Area by univariate analytical method to each population group using the procedure of C. Lepeltier (1969), because of that Palawan Island is divided into the two lithological provinces - the Northeastern Area consisted of mainly sedimentary rocks and the Southwestern Area consisted of ophiolite. Its boundary is the eastern edge of ophiolite distributed over east side of Ulugan Bay. On the Northeastern Area, multivariate analytical method was applied moreover and the same method will be applied on the Southwestern Area after the survey for its southwestern neighboring area.

Computer was used for calculation. Procedure of analysis are as follows.

<u>Previous Procedure of data</u>

1 Determination of lithological population

Country rocks which predominate in sampling were divided into different lithological populations in reference to tendency of microchemical component of the rocks (generally 8 - 12 population in one area).

2 Making data file

Data file were made on sample number, analytical results in each lithological population and elements.

3 Checking dispersion for results of microchemical analysis between original and duplicate samples.

Univariate Analysis

1 The resulting data were rearranged in the order of value in each population and element.

2 Mean, threshold, standard deviation, maximum, minimum, dispersion etc., statistical values were calculated.

3 Histograms for each population and elements were made.

4 Logarithmic data tables were made for each population and elements.

5 95% level student (t), and Snedecor (F) certification for dispersion of data were carried out between different population. If data dispersion range among some populations were the same, these populations were consolidated.

6 Drawing cumulative frequency curve for each population and elements.

7 Making the list to pick up anomalous data.

8 Correlative coefficients between all populations and elements were calculated.

Multivariate Analysis (Factor Analysis) (Foot note 2)

1 Determination of Factor and Inference of Factor Loadings.

2 Calculation of Factor Scores.

3 Drawing distribution maps of Factor Scores.

(Foot note 2)

Factor analysis has been developed as the statistical method to condense many various informations to small amount of potential factors and applied to broad field at the same sense of other multivariate analysis methods in recent days. This method has some similarity to principal component analysis method, but the purpose of former method is to explain correlation of various informations by using potential factors (in this case mineralizations). On the other hand, the later is to explain dispersion of various informations by using small number of principal components.

4-2 Geochemical Survey in the Northeastern Palawan Area

4-2-1 Basic Statistical Data

1) Statistical data for each lithological code

Stream sediments in the Northeastern Palawan Area are divided into following 10 populations (lithological code) according to the geochemical feature of country rocks.

Lithological Code	Contents	Sample Number
BM	Upper volcanics	11
PA	Pabellion limestone	10
BT	Babuyan River Turbidite	809
GU	Guinlo Formation	54
LI	Liminancong Formation	411
BA	Bacuit Formation	173
PT	Tumarbong Semi-Schist	1,215
PC	Conception Pebbly Phyllite	494
SP	Serpentinite	2
GD	Granodiorite	61
	Total	3,240
	Duplicate samples	30

Statistical data for each lithological code are shown in following tables. (These values are calculated by logarithmic base and transferred to natural values.)

Lithotogical code ; BM Upper volcanics

Number of Samples 11 (Unit; ppm except Sb, Hg)

	Cu	Pb	Zn	Ag	Mo	Sb (ppb)	As	Hg (ppb)	Sn	W	Remarks
$\bar{x}$	7.4	5.0	7.3	0.5	1.0	29.9	0.55	32.6	0.53	1.5	
1 δ value	19.6	-	18.1	-	-	44.4	1.51	64.6	0.66	-	
1.5 δ value	31.8	-	28.5	-	-	54.1	2.48	91.0	0.73	-	This value estimate as threshold
2 δ value	51.6	-	45.0	-	-	65.9	4.08	128.1	0.81	-	
Maximum	23.0	5.0	45.0	0.5	1.0	68.0	3.30	94.0	1.00	1.5	
Minimum	1.0	5.0	2.0	0.5	1.0	25.0	0.25	20.0	0.50	1.5	

Lithological code ; PA Pabellion Limestone

Number of Samples 10 (Unit ; ppm except Sb, Hg)

	Cu	Pb	Zn	Ag	Mo	Sb (ppb)	As	Hg (ppb)	Sn	W	Remarks
$\bar{x}$	11.4	5.0	45.7	0.5	1.0	242.0	5.5	32.4	0.5	1.5	
1 δ value	23.8	-	80.7	-	-	526.6	10.6	74.7	-	-	
1.5 δ value	34.3	-	107.3	-	-	776.6	14.6	113.4	-	-	This value estimate as threshold
2 δ value	49.5	-	142.5	-	-	1,145.4	20.3	172.2	-	-	
Maximum	20.0	5.0	70.0	0.5	1.0	430.0	11.0	85.0	0.5	1.5	
Minimum	5.0	5.0	24.0	0.5	1.0	100.0	3.0	20.0	0.5	1.5	

Lithological code ; BT Turbidite

Number of Samples 809 (Unit ; ppm except Sb, Hg)

	Cu	Pb	Zn	Ag	Mo	Sb (ppb)	As	Hg (ppb)	Sn	W	Remarks
$\bar{x}$	8.2	7.8	31.2	0.5	1.0	89.5	2.8	50.1	0.50	1.57	
1 δ value	17.8	12.4	77.5	0.515	-	230.9	6.2	110.2	0.53	1.85	
1.5 δ value	26.2	15.7	122.1	0.523	-	370.9	9.2	163.4	0.55	2.01	This value estimate as threshold
2 δ value	38.4	19.8	192.4	0.530	-	595.7	13.6	242.3	0.57	2.19	
Maximum	59.0	23.0	122.0	1.00	1.0	2,400.0	49.0	5,600.0	1.00	3.00	
Minimum	1.0	5.0	1.0	0.50	1.0	25.0	0.25	20.0	0.50	1.50	

Lithological code ; Gu Guinlo Formation

Number of Samples 54 (Unit ; ppm except Sb, Hg)

	Cu	Pb	Zn	Ag	Mo	Sb (ppb)	As	Hg (ppb)	Sn	W	Remarks
$\bar{x}$	8.3	5.9	33.3	0.5	1.0	204.0	6.7	20.8	0.51	1.68	
1 δ value	14.1	8.2	60.9	-	-	434.5	13.1	25.3	0.56	2.22	
1.5 δ value	18.4	9.8	82.3	-	-	633.4	18.3	28.0	0.58	2.55	This value estimate as threshold
2 δ value	23.9	11.6	111.4	-	-	923.4	25.6	30.9	0.61	2.93	
Maximum	24.0	16.0	70.0	0.5	1.0	770.0	34.0	29.0	1.0	5.0	
Minimum	2.0	5.0	4.0	0.5	1.0	25.0	0.8	20.0	0.5	1.5	

Lithological code ; LI Liminancong Formation

Number of Samples 411 (Unit ; ppm except Sb, Hg)

	Cu	Pb	Zn	Ag	Mo	Sb (ppb)	As	Hg (ppb)	Sn	W	Remarks
$\bar{x}$	10.8	5.4	30.9	0.5	1.0	81.5	3.30	29.7	0.52	1.56	
1 δ value	21.8	6.8	68.3	-	-	213.1	8.09	67.0	0.62	1.85	
1.5 δ value	30.9	7.6	101.5	-	-	344.6	12.68	100.6	0.68	2.01	This value estimate as threshold
2 δ value	43.9	8.5	150.9	-	-	557.3	19.86	151.0	0.75	2.19	
Maximum	65.0	17.0	116.0	0.5	1.0	980.0	200.00	20,000.0	2.00	5.00	
Minimum	1.0	3.0	1.0	0.5	1.0	95.0	0.25	20.0	0.50	1.5	

Lithological code ; BA Bacuit Formation

Number of Samples 173 (Unit ; ppm except Sb, Hg)

	Cu	Pb	Zn	Ag	Mo	Sb (ppb)	As	Hg (ppb)	Sn	W	Remarks
$\bar{x}$	8.0	7.0	34.3	0.5	1.0	161.7	7.22	20.7	0.55	1.74	
1 δ value	15.2	10.9	65.1	-	-	381.6	18.14	25.0	0.74	2.48	
1.5 δ value	20.9	13.6	89.7	-	-	586.3	28.75	27.5	0.86	2.96	This value estimate as threshold
2 δ value	28.8	17.0	123.5	-	-	900.7	45.57	30.2	1.01	3.53	
Maximum	21.0	21.0	95.0	0.5	1.0	1,000.0	110.00	110.0	3.00	8.00	
Minimum	1.0	5.0	2.0	0.5	1.0	25.0	0.25	20.0	0.50	1.50	

Lithological code ; PT Tumarbong Semi-Schist

Number of Samples 1215 (Unit ; ppm except Sb, Hg)

	Cu	Pb	Zn	Ag	Mo	Sb (ppb)	As	Hg (ppb)	Sn	W	Remarks
$\bar{x}$	6.4	5.8	20.7	0.50	1.0	100.9	3.4	22.2	0.53	1.61	
1 δ value	12.3	8.3	42.8	0.52	-	248.5	8.9	35.4	0.73	2.18	
1.5 δ value	17.2	9.9	61.5	0.54	-	390.1	14.4	44.6	0.85	2.53	This value estimate as threshold
2 δ value	23.9	12.8	88.4	0.57	-	612.3	23.4	56.3	0.99	2.95	
Maximum	72.0	44.0	115.0	2.00	1.0	1,700.0	150	12,000.0	13.00	250.00	
Minimum	1.0	5.0	1.0	0.50	1.0	25.0	0.25	20.0	0.50	1.5	

Lithological code ; PC Conception Peblly Phyllite

Number of Samples 494 (Unit ; ppm except Sb, Hg)

	Cu	Pb	Zn	Ag	Mo	Sb (ppb)	As	Hg (ppb)	Sn	W	Remarks
$\bar{x}$	5.7	6.7	15.5	0.5	1.0	131.7	4.1	24.6	0.51	1.52	
1 δ value	12.8	10.4	35.9	-	-	288.2	12.5	57.0	0.65	1.66	
1.5 δ value	19.2	12.8	54.4	-	-	426.4	21.9	75.0	0.73	1.74	This value estimate as threshold
2 δ value	28.7	15.9	82.7	-	-	630.7	38.5	101.0	0.82	1.81	
Maximum	16.0	16.0	54.0	0.5	1.0	480.0	30.0	260.0	3.00	3.00	
Minimum	1.0	5.0	1.0	0.5	1.0	25.0	0.25	20.0	0.50	1.50	

Lithological code ; SP Serpentinite

Number of Samples 2 (Unit ; ppm except Sb, Hg)

	Cu	Pb	Zn	Ag	Mo	Sb (ppb)	As	Hg (ppb)	Sn	W	Remarks
$\bar{x}$	8.9	5.0	62.6	0.5	1.0	25.0	0.25	20.0	0.50	1.50	
1 δ value	10.5	-	73.3	-	-	-	-	-	-	-	
1.5 δ value	11.3	-	79.3	-	-	-	-	-	-	-	This value estimate as threshold
2 δ value	12.3	-	85.4	-	-	-	-	-	-	-	
Maximum	10.0	5.0	70.0	0.5	1.0	25.0	0.25	20.0	0.50	1.50	
Minimum	8.0	5.0	56.0	0.5	1.0	25.0	0.25	20.0	0.50	1.50	

Lithological code ; GD Granodiorite

Number of Samples 61 (Unit ; ppm except Sb, Hg)

	Cu	Pb	Zn	Ag	Mo	Sb (ppb)	As	Hg (ppb)	Sn	W	Remarks
$\bar{x}$	5.5	5.8	26.2	0.5	1.0	82.5	2.4	25.4	1.01	2.11	
1 δ value	11.5	8.1	45.4	-	-	204.1	9.0	38.3	2.88	3.44	
1.5 δ value	16.5	9.5	59.7	-	-	321.1	17.6	47.0	4.86	4.40	This value estimate as threshold
2 δ value	23.8	11.1	78.5	-	-	505.0	34.3	57.8	8.20	5.62	
Maximum	16.0	12.0	57.0	5.0	1.0	440.0	17.0	72.0	25.0	8.00	
Minimum	1.0	5.0	5.0	5.0	1.0	25.0	0.25	20.0	0.50	1.50	

2) Histogram

Frequency dispersion histograms for each detective element in each lithological code are made by logarithmic scale with 1/2 standard deviation unit as shown in Appendix-8.

Each histogram features for each element are as follows.

Cu; Histogram of copper for each lithological code shows normal logarithmic dispersion. High grade side dispersion is not enough, especially this tendency is strong in codes BT, BA, PT, PC.

Pb; Pb content is almostly under the detection limit. Extreme accumulation of dispersion is observed at 5 ppm which is assumed grade of detection contact. Pb histogram does not show normal logarithmic dispersion. Maximum content of 44 ppm is included in code PT.

Zn; Generally high grade side dispersion is not enough. All histograms are not of normal logarithmic dispersion, especially this tendency is strong in codes BT, LI, BA, PT.

Ag; Ag content is almostly under the detection limit. Extreme accumulation of dispersion is observed at 0.5 ppm which is assumed grade of detection content. Ag histogram does not show normal logarithmic dispersion. Maximum content of 2 ppm is included in code PT.

Mo; All samples are under detection limit. To analyze statistically is impossible.

Sb; About 20% of samples are under detection limit. Extreme accumulation of dispersion is observed at 25 ppb which is assumed grade of detection content. Other histograms shows generally normal logarithmic dispersion. In codes GU, LI, PC, dispersions are not enough in high grade part. Sb has a maximum value of 2,400 ppm in code BT.

As; About 3% of samples are under detection limit. Other histograms shows almost normal logarithmic dispersion. Some excess dispersions are seen in high grade part. This means that these rocks have a uniform of arsenic content. This tendency is strong in codes BT, GU, LI, BA, PT. The maximum content of 200 ppm is included in code LI.

Hg; About 70% of samples are under detection limit. Other histograms shows excess dispersions slightly in high grade part. Maximum value of 12,000 ppb is included in code PT.

Sn; About 94% of samples are under detection limit. Maximum value of 13 ppm is included in code PT.

W; About 90% of samples are under detection limit. Maximum value of 250 ppm is included in code PT.

3) Cumulative frequency

Cumulative frequency curves corresponding to the above mentioned histograms are shown in Appendix-8. They have a transition point between mean value +0.5 σ to mean value +2 σ in many codes. This justifies an estimation mean of +1.5 σ value as threshold value.

The feature of the curve for each element is as follows.

Cu; On code PT, transition point is observed at mean +2 σ value. The codes BT, GU, LI are located at mean +1.5 σ value. Transition point is observed at mean +1 σ value on codes BA, GD.

Pb; 80% of samples are almostly under detection limit. Transition point of the curve is not clear. On codes BT, PT, PC, transition point is observed at mean +1.5 σ value.

Zn; Generally high grade side dispersion is not enough. Transition point is not clear. On code PT, transition point is observed at mean +2 σ value. On code LI, this is located at mean +1.5 σ value. Transition point is observed at mean +1 σ value on code BA.

Ag; The greater part of Ag content of samples is almostly under detection limit. Transition point is not observed.

Mo; Mo content of all samples is under detection limit. Transition point is not observed.

Sb; On codes BT, LI, PC, transition point is observed at mean +2 σ value. The codes GU, BA are located at mean +1.5 σ value. On code GD, transition point is observed at mean +1 σ value.

As; On codes BT, LI, BA, PT, PC, transition point is observed at mean +1.5 σ value. The codes GU, GD are located at mean +1 σ value.

Hg; About 70% of samples are under detection limit. Transition point is not clear. On code BT, transition point is observed at mean +2 σ value. The code LI is located at mean +1.5 σ value.

Sn; 90% of samples are under detection limit. Transition point is not clear. On codes BA, PT, transition point is observed at mean +2 σ value.

W; 90% of samples are under detection limit. Transition point is not clear. On code PT, transition point is observed at mean +2 σ value. The code BA is located at mean +1.5 σ value.

4) Correlation coefficient

Correlation coefficient between elements for all samples in the Northeastern Palawan Area is shown in Table 6.

High correlation is observed between Cu and Pb·Zn·As, Pb and Zn, Zn and As, Sb and As. Low correlation is observed between Cu, Pb, Zn and Hg, Sn and W.

The correlation coefficient table between elements in each lithological code are shown in Appendix.

Table 6 Correlation Coefficient between Each Element in the Northeastern Palawan Area

Sample ; 3,240

	Cu	Pb	Zn	Ag	Sb	As	Hg	Sn	W
Cu	1.0000								
Pb	0.4143	1.0000							
Zn	0.8276	0.3865	1.0000						
Ag	0.128	0.0003	0.0094	1.0000					
Sb	0.1416	0.1317	0.0880	0.0096	1.0000				
As	0.4217	0.2461	0.3995	0.0281	0.4330	1.0000			
Hg	0.2762	0.2048	0.2802	-0.139	0.0658	0.0185	1.0000		
Sn	-0.0058	-0.157	0.0154	0.0464	0.0180	0.0117	-0.0255	1.0000	
W	0.0452	0.0495	0.0431	-0.0063	0.0536	0.1085	-0.0304	0.1038	1.0000

5) Multivariate analysis (Factor analysis)

Multivariate analysis for the Northeastern Area was carried out on the common detective elements (Cu, Pb, Zn, Ag, Sb, As, Hg) between the samples collected at this time and those collected by UNDP survey on 1981.

i) Determination of Factor Number

The relationships between detective elements and factors extracted by factor analysis of the geochemical results for stream sediment in the Northeastern Area are shown in Table 7 as factor loadings.

Factor		Elements
1st Factor (F1)	;	Cu, Pb, Zn, Hg
2nd Factor (F2)	;	Sb, As

These factors are used for the analysis of the detected elements with the exception of Mo, Sn, W. Contents are almostly under the detection limit. Factor contribution of 1st to 2nd factor is 54%.