REPORT ON THE MINERAL EXPLORATION
IN THE REPUBLIC OF THE PHILIPPINES

PHASE III (Part I)

MARCH 1987

REPORT ON THE MINERAL EXPLORATION

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

PHASE III (Part I)

NORTHERN SIERRA MADRE AREA

MARCH 1987

JAPAN INTERNATIONAL COOPERATION AGENCY
METAL MINING AGENCY OF JAPAN

No. 56

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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 I) consists of survey details and results of synthetic analysis in the Northern Sierra Madre 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 third year fieldwork per Implementing Arrangement concluded last 26th of September, 1984.

This report summarizes the results of the field survey and of the statistical analysis on microchemical analysis data on the Northern Sierra Madre Area.

The following items are clear after synthesizing all these results;

1) The survey area is divided by the Northern Sierra Madre Mountain Range into the east tectonic region and the west tectonic region.

   Basement in the former consists of Paleocene sediments with steep dipping intrafolial fold and pre-Tertiary ophiolite, basaltic lava, chert in fault contact at its east side. In the east coast, these are covered unconformaly by Oligocene, Pliocene and Pleistocene sediments. On the contrary, basement in the latter passes through the intrusive zone of quartzdiorite exposed intermittently over an areas extent of 140 kms NS and 10 kms EW in Paleocene sediments at the west side of the range.

2) Known mineralizations are as follows; Orthomagmatic chromite deposit, bedded cupriferous sulphide deposit and bedded manganese deposit related to pre-Tertiary ophiolite, basalt and chert. epithermal veins into and around quartzdiorite intruded into Eocene sediments, and weathering residual deposits in Neogene.

3) Statistical treatment of results of microchemical analysis for 11 elements was conducted and anomalous values were delineated through the univariate analysis method.

4) Extracted anomalous zones which are assumed to relate to strong mineralizations that closely corresponds to the geology, tectonics and known mineralizations are as follows:

   1 Around Dimakawal mineral showing near the range in the southernmost part of the survey area, polymetallic anomalous zone of Cu, Pb, Zn, As, Hg and Mn.

   2 Around Bicobian mineral showing associated with the basalts and chert 20 kms N of Palanan, anomalous zone of Cu, Zn and Mn.

   3 Cr, Co and Ni anomalous zone associated with the faults that passed between the Paleocene and pre-Tertiary rock unit in the southern part of Divilican Bay

   4 Anomalous zone of Cu, Zn, As and Hg in Pliocene rock unit 7 kms NE of Manuri in the eastern part of the southernmost survey area

   5 Cu, Pb, Zn, As, and Mo anomalous zones accompanied with quartzdiorite 10 kms W of Bolos Cove in the northeast coast of the survey area.

The relationship between the anomalous zones and the known mineral showings are shown in Attached Plate 5.

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1. INTRODUCTION

1. Introduction

1-1 Background and Objective 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 third phase of the project (Fiscal year 1986)was carried out in the Northern Sierra Madre.

This report particularly embodies the geological and geochemical surveys conducted in the Northern Sierra Madre from May 14, '86 to July 24, '86.

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 assay, combined with other laboratory test and examinations of the various samples collected in the geological and geochemical survey of the Northern Sierra Madre 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

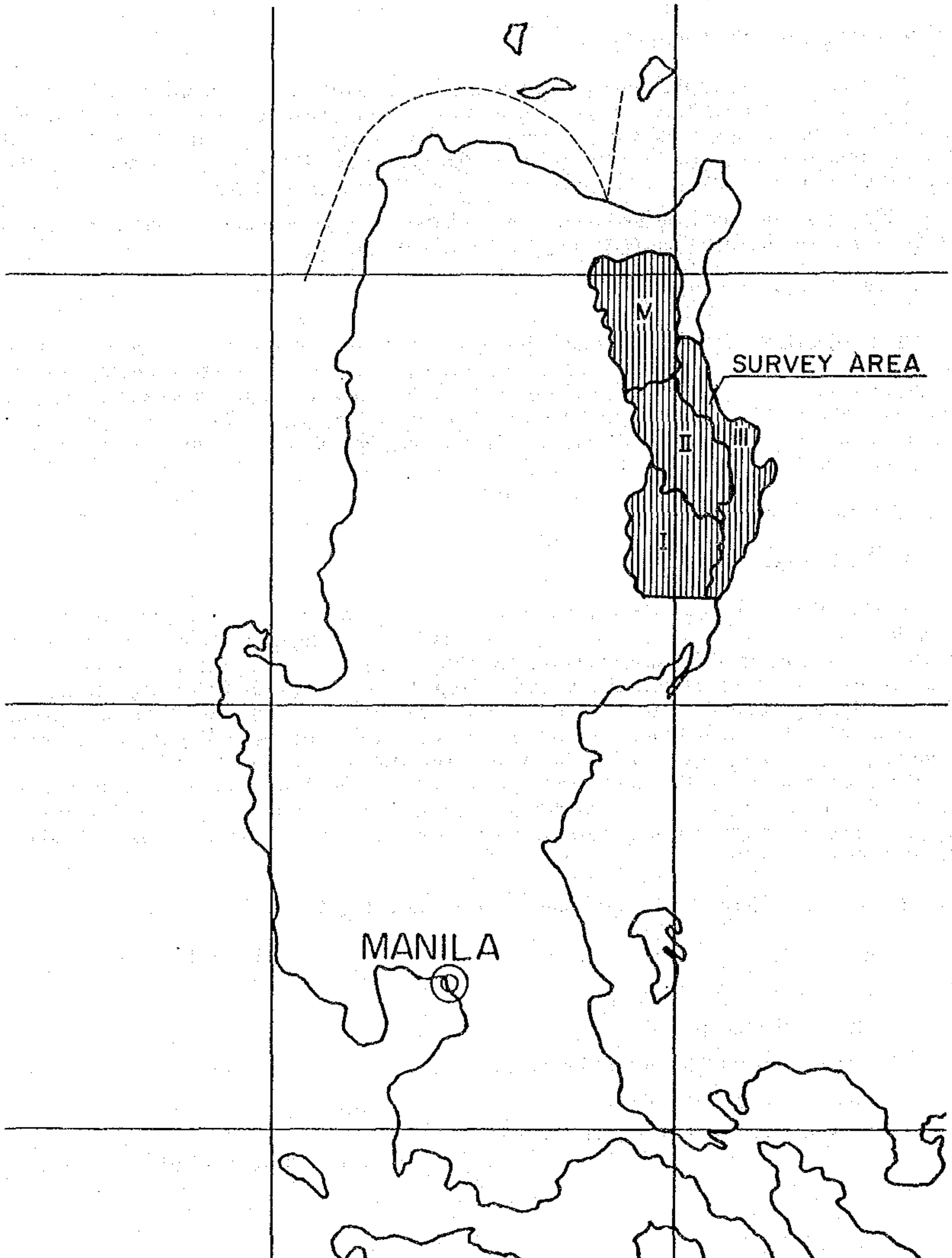
1-2-1 Field Work

During the fieldwork, stream sediments samples were collected at the rate of one samples per 1 - 2 km^2 along the drainage systems in the survey areas, and micro chemical analysis of these samples were executed for Cu, Pb, Zn, Co, Ni, Ag, As, Hg, Cr and Mn on the east coast of the Northern Sierra Madre Area (Palanan), as well as for Cu, Pb, Zn, Ag, Co, Ni, Mn, Mo, As and Hg on the east side of the Cagayan Valley Area (Cauayan, Ilagan, Tuguegarao) 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. The heavy mineral samples were analyzed for Au, Ag and Ga. In conjunction with the foregoing geochemical survey mapping and investigation of geological structures and known mineral showings in these areas were carried out.

1) Northern Sierra Madre I (Cauayan) Area. (Ref. Fig. 1)

Survey Area	2,600 km^2
Stream Sediment Samples	1,338
Duplicated Samples	25
Heavy Mineral Samples by Panning	104
Spot Investigation Points	11
Samples for Petrographical analysis	22 (of which 10 were for identification)

Fig-1 LOCATION MAP OF THE SURVEY AREA



Samples for Polished Ore Section	15 (of which 10 were for identification)
Samples for Whole Rock Analysis	13 (of which 10 were for analysis)
Samples for Ore Assay	15 (of which 10 were for analysis)
Samples for X-ray Diffraction Analysis	13 (of which 10 were for analysis)
Samples for K-Ar Dating	6 (of which 2 were for dating)
Samples for Palaeontological	11 (of which 10 were for identification)
Samples for Identification of Heavy Mineral	10

2) Northern Sierra Madre II (Ilagan) Area. (Ref. Fig. 1)

Survey Area	2,033 km^2
Stream Sediment Samples	1,001
Duplicated Samples	29
Heavy Mineral Samples by Panning	86
Spot Investigation Points	8
Samples for Petrographical Thin Section	20 (of which 10 were for identification)
Samples for Polished ore Section	15 (of which 10 were for identification)
Samples for Whole Rock Analysis	10
Samples for Ore Assay	15 (of which 10 were for identification)
Samples for X-ray Diffraction Analysis	10
Samples for K-Ar Dating	5 (of which 2 were for dating)
Samples for Palaeontological	10
Samples for Identification of Heavy Mineral	10

3) Northern Sierra Madre III (Palanan) Area. (Ref. Fig. 1)

Survey Area	2,170 km^2
Stream Sediment Samples	1,395
Duplicated Samples	25
Heavy Mineral Samples for Panning	90
Spot Investigation Points	15

Samples for Petrographical Thin Section	20
Samples for Polished Ore Section	20
Samples for Whole Rock Analysis	10
Samples for Ore Assay	20
Samples for X-ray Diffraction Analysis	5 (of which 2 were for dating)
Samples for Palaeontological	10
Samples for Identification of Heavy Mineral	10

4) Northern Sierra Madre IV (Tuguegarao) Area. (Ref. Fig. 1)

Survey Area	2,555 km^2
Stream Sediment Samples	1,263
Duplicated Samples	25
Heavy Mineral Samples by Panning	90
Spot Investigation Points	4
Samples for Petrographical Samples	20 (of which 10 were identification)
Samples for Polished Ore Sections	12 (of which 5 were for identification)
Samples for Whole Rock Analysis	10 (of which 5 were for analysis)
Samples for Ore Assay	12 (of which 5 were for assay)
Samples for X-ray Diffraction Analysis	10
Samples for K-Ar Dating	5 (of which 2 were for dating)
Samples for Palaeontological	5 (of which 5 were for identification)
Samples for Identification of Heavy Mineral	10

1-2-2 Synthetic Analysis

After accomplishment of the field work, analysis of stream sediment samples and heavy mineral samples, statistical treatment of the result of said analysis, microscopic observation of thin and polish sections, X-ray diffraction testing, whole rock analysis, ore assay, micro fossil identification as well as K-Ar dating were performed. The objective of the survey, that are; to prepare the mineral inventory map and to select the mineral potential area, was pursued by analysing synthetically the results of these operations.

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

1-3-1 Composition of the Survey Mission

Member of the Japanese Party and Philippine Party who participate in planning the survey program, in negotiations and in field work were as follows;

A. Planning of the Survey Program and Negotiations

Japanese Panel;

Hiiroshi Ishii	MITI
Takeshi Izumi	MMAJ
Makoto Ishida	MMAJ
Michihisa Shimoda	MMAJ
Jiro Osako	MMAJ
Yasuo Endo	MMAJ

Philippine Panel;

Benjamin A. Gonzales	BMG
Guillermo R. Balce	BMG
Romeo M. Luis	BMG
Edwin G. Domingo	BMG
Romeo L. Almeda	BMG
Noel V. Ferrer	BMG

B. Members of Survey Mission

Japanese Party

Project Manager; Yoshikazu Okubo, Akira Yatsuji OMRD

Northern Sierra Madre I (Cauayan) Area

Leader	Takashi Isaka	Nikko Exploration and Development Co., Ltd.
	Tetsuo Sato	
	Yoshihiro Kikuchi	

Northern Sierra Madre II (Ilagan) Area

Leader	Akio Shida	Nittetsu Mining Consultant Co., Ltd.
	Hiroshi Yoshida	
	Koji Uchiyama	

Northern Sierra Madre III (Palanan) Area

Leader	Takeo Fukasawa	Bishimetal Exploration Co., Ltd.
	Yoshinori Tsukuma	
	Takehiro Koseki	

Northern Sierra Madre IV (Tuguegarao) Area

Leader	Kazuyoshi Masubuchi	Dowa Engineering Co., Ltd.
	Shigehisa Fujiwara	
	Soichiro Tanaka	
Chemical Analyst		
	Taiichi Yamamoto	OMRD
Preparation of the Complete Report		
	Yoshikazu Okubo	

Philippine Party;

Project Manager; Romeo L. Almeda	BMG Geologist
Assistant Manager; Noel V. Ferrer	BMG Geologist
Chemical Analysis	
Manager; Edwin G. Domingo	BMG Geologist
Northern Sierra Madre I (Cauayan) Area	
Leader; O. Pineda	BMG Geologist
Sub-Leader; F. Zepeda	BMG Geologist
Sub-Leader; E. Mantaring	BMG Geologist
Northern Sierra Madre II (Ilagan) Area	
Leader; A. Matos	BMG Geologist
Sub-Leader; E. Malaca	BMG Geologist
Sub-Leader; L. Morales	BMG Geologist
Northern Sierra Madre III (Palanan) Area	
Leader; A. Cabantog	BMG Geologist
Sub-Leader; W. Diegor	BMG Geologist
Sub-Leader; U. Paraganas	BMG Geologist
Northern Sierra Madre IV (Tuguegarao) Area	
Leader; P. Rovillos Jr.	BMG Geologist
Sub-Leader: B. Cadawan	BMG Geologist
Sub-Leader; N. Quiwa	BMG Geologist

In addition to the above mentioned, some 30 other geologists of the BMG participated in the field work.

C. Composition of the field work party

One field work party was composed of one Japanese geologist and 3 BMG geologists, and 3 such parties were assigned to each survey area. Further, one geologic aide was assigned for each area at the base camp to take charge of the drying and sieving of samples and supply coodination.

D. Treatment disposal of chemical analysis

In the field work of the present survey on the areas, it was necessary to conduct micro analysis operation on 5,101 stream sediment samples including duplicates anayzed for each elements and for 370 heavy mineral samples (3 elements analyzed); This endeavor was accomplished by means of atomic absorption spectrometry (AAS) before the end of October at PETROLAB, (one of BMG sections in charge of analyzing). One Japanese chemist charge in full designation until Oct. 3, for the purpose to checking micro-chemical analysis and supply the necessary materials.

1-3-2 Itinerary of the Survey

The fieldwork was conducted for a period of 69 days starting from May 14, 1986 until July 22, 1986.

The analysis operations were performed from middle of August until end of October in 1986.

The details of the itinerary are shown in the table-1 below;

Table-1 Schedule of field work and synthetic analysis on the Northern Sierra Madre I-IV Areas

	May	Jun	July	Aug.	Sept.	Oct.	Nov.	Dec.
Preliminary meeting & Data arrangement at BMG.	5/14- 5/19		7/17- 7/22					
Field work	5/20 ----	--------	-- 7/16					
Chemical analysis at PETROLAB				Analysis Term 8/1 ----	------- 9/4 --	---- 10/3	10/30 Analysis Specialist	
Synthetic Analysis	Nov.	Dec.	'87 Jan.	Feb.				
	11/1 ----	--------	--------	---- 2/28				

2. GENERAL DESCRIPTION OF PHYSIOGRAPHY, GEOLOGY AND MINERAL DEPOSITS IN THE SURVEY AREA

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

2-1 Physiography and Geology

The Survey Area is contained entirely in the so-called "Philippine Mobil Belt" which belongs to the Eastern Physiographic Province and has been divided into two regions as Eastern Geological Belt and Western Geological Belt. Northern Sierra Madre Mountain Range locate at boundary of these belts.

Eastern Geologic Belt has for it basement which conform of ophiolite formation in east coast and deep marine clastic sediments from Cretaceous to Palaeocene contacted with unconformity west side of ophiolite formation.

These basement formation were penetrated by dioritic rocks and hornblende andesite in northern and eastern parts which intruded at late Oligocene. Neogene Formation which consists of shallow clastic sediment and limestone distribute partially in northern and eastern parts of the Eastern Geologic Belt with unconforminty to former formations.

The Western Geologic Belt basement is conformed by deep marine basaltic clastic sediments at Cretaceous to Palaeocene Period, which covered partially by Eocene clastic sediments.

Dioritic rocks intruded in these formation with irregular shape which has general elongation south to north.

Neogene formations overlie on these Palaeogene formations with unconformity in west side and northern part of the Western Geologic Belt, at northern part of Tuguegarao Palaeogene Formation shows curved in shape to the east side according to the basin structure around Bagao.

Topographic Feature shows corresponding significance to these country formations, namely, Neogene Formation distributed area in eastern and western parts of Survey Area show gentry declined hill like topography on the contraly Palaeogene and dioritic rocks distributed area in central parts of Survey Area show steep topography, these area contain Northern Sierra Madre Mountain Range (highest peak 1,804 m), including many cliffs and water falls. (Ref. Fig. 6 Identified Columnar Section.)

2-2 Geological Structure

As above mentioned, the Northern Sierra Madre Area has been constructed by the deep marine sediments in Cretaceous to Palaeocene and dioritic rocks intruded at late Oligocene in basement units, these basement formations uplifted and formed Northern Sierra Madre Mountain Range.

Neogene Formations consist of volcanic clastics, limestone and shallow to deep marine sediments are located in the Northeastern and Western parts of the basement with unconformity, and Isabela ultramafic rocks (ophiolites) consist of harzburgite gabbro and basalt, etc. underlie below the deep marine clastic sediments (Cretaceous to Palaeocene) with unconformity.

According to A.S. Zanoria et al. (1984), the uplifting of the Northern Sierra Madre Mountain Range occurred in the late Eocene, in present survey , all K-Ar age determination samples of dioritic rocks have indicated from the middle Oligocene to early Miocene origin.

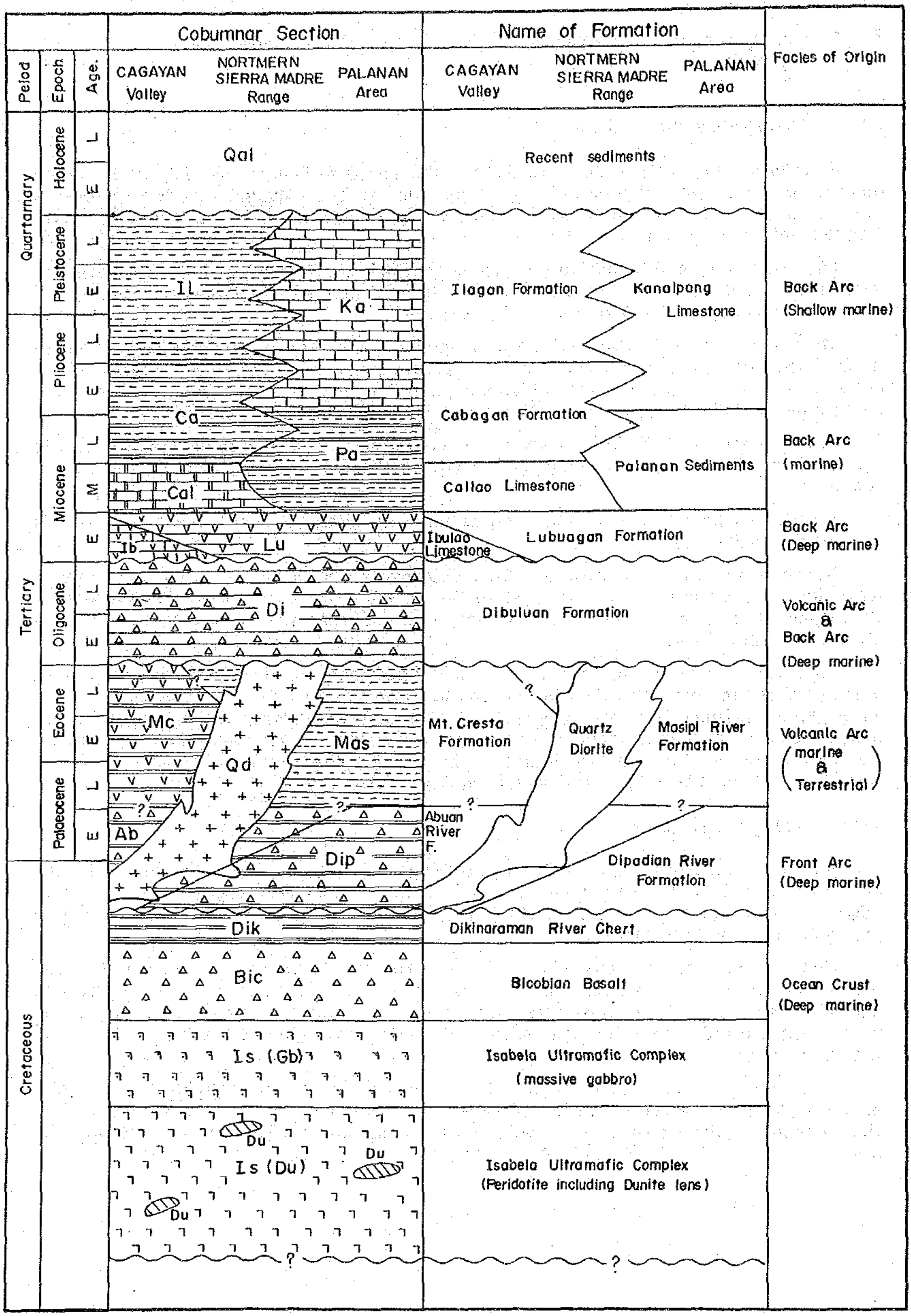


Fig. 2 Compiling Columnar Section on the Northern Sierra Madre Area

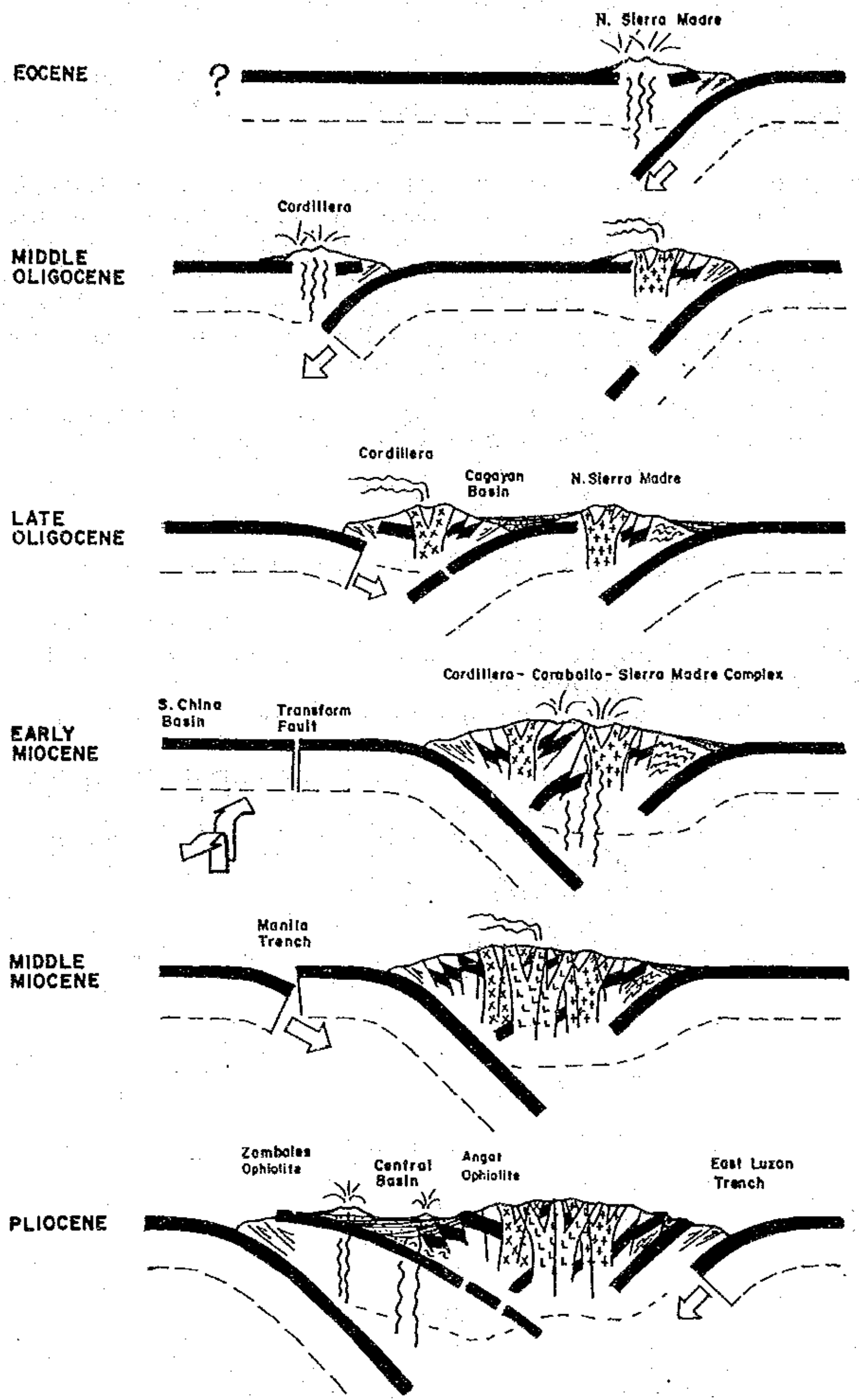


Fig-3 Schematic model of the tectonic evolution of Luzon.
(After A.S. Zanoria et al., 1984)

Many faults are observed in the Neogene and Palaeogene Formations the main strike of them show NE-SW and NW-SE also observed. This direction will conjugate to the compressional stress E-W direction.

As for folding, many N-S axis foldings are observed in the zone from Tuguegarao to Ilagan which will accompany to the E-W compression, in the east side of Bagao, many E-W axis fold are existed corresponding to the basin structure.

Sedimentary environments assumed in each formation are as follows, Isabela ultramafic rocks correspond to an ocean crust, Abuan River Formation and Dipadian River Formation corresponding Cretaceous to Palaeocene sediments are assumed to be deep marine facies of volcanic front. On the contrary Mt. Cresta Formation and Masipi River Formation correlating to the Palaeocene and Eocene sediments show sedimentary environment of marine to terrestrial sediments with volcanic arc, it suggests uplifting of Northern Sierra Madre Mountain Range occurred this time.

Formation after the Oligocene show that the sedimentary environments change from deep marine to shallow marine of the back arc of the vocanic front.

2-3 Ore Deposit

Types of mineral showings which were clarified during the survey are as follows;

(1) Orthomagmatic chromite deposit accompanied the ultramafic rocks
(2) Stratabud massive sulphide deposit accompanied boundaries of chert, basalt and tuff which overlie the ultramafic rocks.
(3) Stratabond massive sulphide and manganese deposits in the Abuan River Formation
(4) Epithermal vein and disseminated type deposits in andesite of the Abuan River Formation around diorite intrusive.
(5) Banded or nodule type iron deposits in sandstone and shale of the Cabagan Formation (Miocene-Pliocene)
(6) Lignite in the Cabagan Formation.

In these mineral showings, the attractive ones are (1), (2) and (3)

3. RESULTS OF GEOLOGICAL SURVEY AND INVESTIGATION OF ORE DEPOSITS

3. Results of the Geological Survey and Investigation of Ore Deposits

3-1 Geology and Ore Deposits of the East Side of the Northern Sierra Madre Area (Ref. Fig. 1)

3-1-1 General Summary

The main survey area corresponding to the east side of the Northern Sierra Madre Area belongs, from an administrative point of view, to Region II Isabela Province and the northern parts of area belongs Cagayan Province. There is no connecting road joining Manila -Aparri Highway along Cagayan River and the east coast. The accesibility to east coast only depends on the boat from Baler or Dilasag of Aurola Province. Airplane is available from Cauayan along Cagayan River to Dinapiqui (PATECO private air strip), Maconacon (ACME private air strip) and Palanan (pubric air strip) by charter airplane (4 persons capacity).

	6 hr.		7 hr.		8 hr.		8 hr.	
Manila	-------	Baler	-------	Dinapiqui	-------	Palanan	-------	Maconacon
	by car		by car		by boat		by boat	

In Isabela Province, east coast area is divided into 4 sub-provinces as follows; Dinapiqui, Palanan, Dibilacan and Maconacon.

The geographic situation are as follows;

Area;	2,170 km^2
Elevation;	0 ----- 1,800 m
Highest Peak;	1,805 m
Average Temperature;	26^{o}C degree (estimated)
Annual Precipitation;	3,437 mm per year

The climate belongs to a typical monsoon climatic zone of the Western Pacific, where dry season is April to June, Typhoon season is July to October and rainy season is November to March. Coral reefs are abundant on the east coast, and the inland area is covered with virgin forest. The area is infected with malaria and remain backward in development. Rice growing is only around Palanan Plain. Main industry of this area is forestry.

3-1-2 Succession of Each Formation (Ref. Fig. 4)

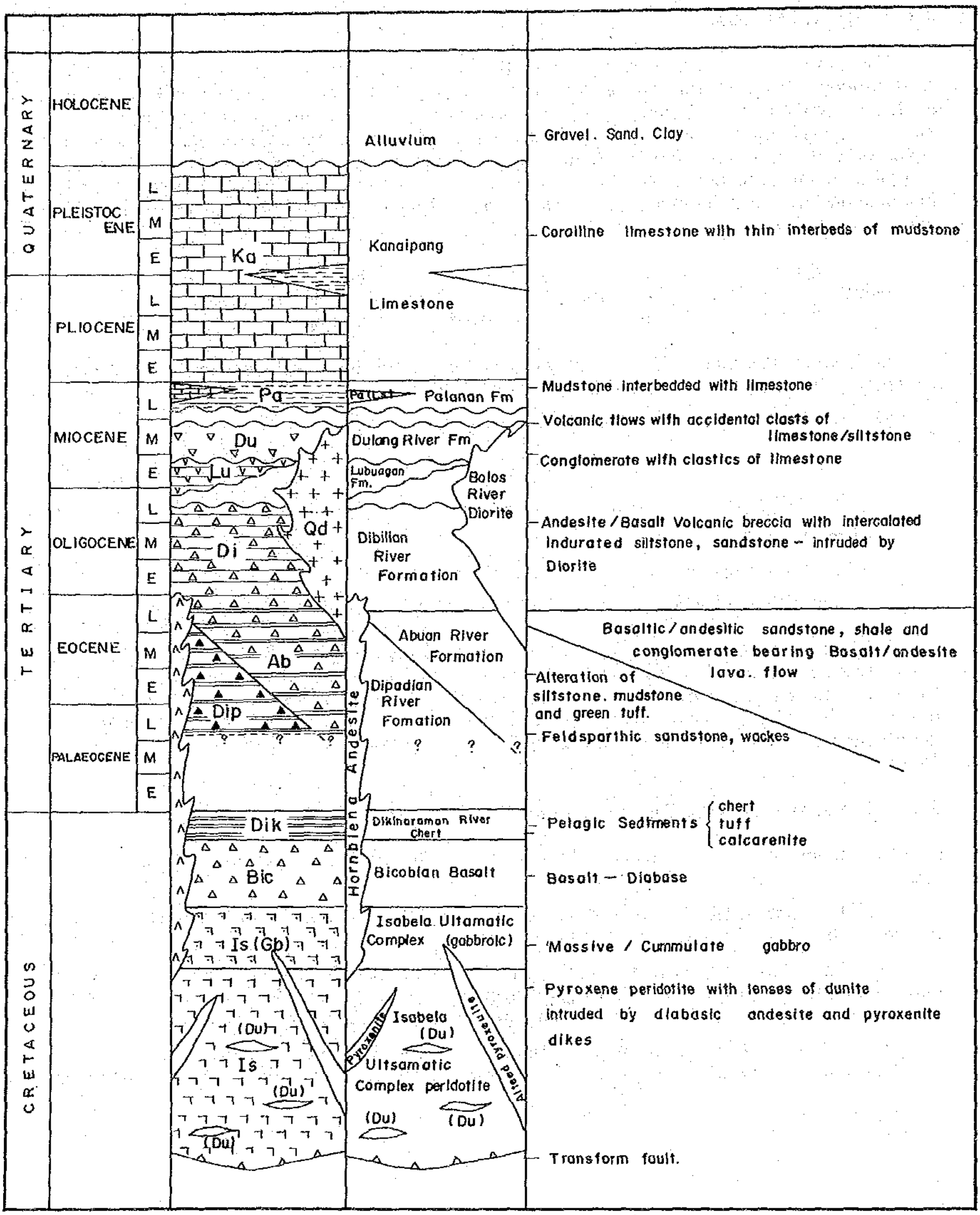
The order of the formations which underlie the area is as follows (from lower to upper);

Isabela Ultramafic Rocks consist of harzburgite, gabbro, basalt and chert which assume to be part of the Cretaceous ocean crust.

Dipadian River Formation overlie Isabela Ultramafic Rocks with unconformity and consist mainly of grayish brown to grayish green wacke interbedded with conglomerate which are assumed to compose at late Cretaceous to Palaeogene deep marine.

Abuan River Formation overlie Dipadian River Formation with conformity and consists mainly of basaltic and andesitic breccia interbedded with siltstone and sandstone.

Fig-4 Columnar Section of the East Side of the Northern Sierra Madre Area



Bolos River Diorite intruded the above mentioned formations.

Dierico Formation overlie the Cretaceous to Palaeogene Formations with unconformity and consists of alternation of limestone, mudstone and conglomerate which is thought to conform Early Miocene age.

Dulang River Formation overlying the Dierico Formation with unconformity consists of braccia of limestone, shale and siltstone which is assumed to conform in Middle Miocene.

Palanan Sediments overlain Dulang River Formation with unconformity and consist of mainly mudstone interbedded limestone, which assume to conform in late Miocene.

Kanaipang Limestone overlie the Palanan Sediments with concordant and consists mainly of coral reef limestone interbedded with thin layer of mudstone assumed to be Pliocene to Pleistocene.

Details of each formations are as follows;

(1) Isabela Ultramafic Rocks

Isabela Ultramafic Rocks is divided lower unit ultramafic rocks, and upper unit mafic rocks and chert.

1. Lower ultramafic rocks

Locality; These rocks are exposed from the Divilacan District, middle part of the Survey Area to Dinapiqui District along the east coast.

Rock Facies; This rocks mainly consists of pyroxene periodotite assumed to be harzburgite, with interbedded dunite lens in places. Small dykes of pyroxenite intruded in this rocks.

Harzburgite shows black color, bears platy pyroxene phenocrist (1 - 10 mm), sometimes color changed to dark-green or grayish-green by the influence of serpentinization.

Dunite shows black to dark-green color, strongly serpentinized parts shows gray-green color and greasy lustre, sometimes accompanied by lens shaped or disseminated chromite.

Pyroxenite dyke consists of pyroxene crystals (1 - 2 cm), mainly network penetration but sometimes dyke width reached up to 8 m. These dykes occures along platy structure of hartzburgite. Small scale amphibolite located along tectonic lines in harzburgite.

Succession of the rocks; Lower-Ultramafic Rocks is the lowest rock unit in the Survey Area.

Microscopic Observation Results; A sample (CA006) of this rock is Lherzolite (pyroxene peridotite) consist mainly of olivine, clino-pyroxene, ortho-pyroxene and hornblende accessory minerals are picotite and magnetite. Olivine occures abundant as 5 - 1 mm size idomorphic crystals, it changes to serpentine along cracks. Clino-pyroxene occurs in medium amount as 3 - 0.3 mm size semi-idiomorphic or allotriomorphic occurrence. Ortho-pyroxene appears in small amount as 3 - 0.3 mm size, some of them change to bastite. Hornblende occures very rare as later stage mineral. The sample (CL10) which was collected 5 km of Southern Divilacan Bay showed the same mineral assemblage but suffered strong serpentinization.

2. Upper-mafic rocks

Locality; This rocks distribute west side Lower- Ultramafic Rocks at the boundary with the Dipadian Formation and east coast of Palanan.

Rock facies; This rock unit consists of gabbro and diabase from the lower to the upper. Gabbro shows mainly equigranular medium- coarse grained appearance, at upstream of Dimapuna River and Pinacanaan River near Palanan, it shows layered structure. Diabase shows dark green color and distributes between gabbro and upper basalt, dykerock facies is poor and almost covered by the upper basalt, therefore extention not so much.

Succession of the rocks; At Bicobian of northern Palanan this rocks assume to thrust up on Lower-Ultramafic Rocks, because lack of lower gabbro unit in this area, such relation also assumed at the east coast of Palanan, therefore ophiolite in Bicobian is able to divide three bodies.

Microscopic observation result; The sample (CA018·CA021) which was collected 7 km north-west Palanan is holocrystalline, equigranular rock identified as gabbro, mainly consists of zoning plagioclase (3 - 0.5 mm), partially chloritized hornblende, orthopyroxene surrounded by hornblende crystals, and small amount of quartz.
Accessory minerals are magnetite, ilmenite and apatite.
Plagioclase suffered weak sericitization and pyroxene showed strong amphibolization.

Results of K-Ar dating; The result of whole rock K-Ar dating of CA-021 sample collected from this rock unit show 23.2 $\pm$ 1.2 m.y. This age is comparably younger than the estimationed age of this rocks (late-Cretaceous), it assumes to indicate alternation age to this rocks.

3. Bicobian Basalts

Locality; This basalts distribute with contact to Isabela Ultramafic Rocks, and Dipadian Formation at the south-east part of the survey area, it appears also from Digoyo to Palanan Point of the east coast.

Rock facies; This basalts show dark-green to dark grey color and well developed pillow structures, each block (pillow) show flat ellipsoid shape (30 - 80 cm dia.) around block limonite are observed in places and zeolite crystals fill cavities in sometimes, calcite veinlets also develope. Massive sulphide deposit occurs in this rock at Bicobian near Palanan.

Microscopic observation results; The sample (BIC4) of Southern Port Dimalasan North Palanan is sub-ophitic texture dolerite consisting of phenocryst (1.5 - 1 mm) albitized plagioclase and ground mass aggregated plagioclase, clino-pyroxene and ortho-pyroxene. This sample suffered strong alternation besides albitization. Chlorite, quartz and carbonate filled up in 2 -1 mm amigdaloical cavity and 1 - 0.5 mm width zeorite veinlets observed in this rock.

4. Dikinaraman River Chert;

This chert overlie Bicobian Basalts, shows dark-red to dark-brown color, accompanies stratified manganese deposit in places.

Note (1) Identification of Radiolarian is after Dr. M Okamura; Department of Geology, Faculity of Science, Kochi Univ. Japan.

Micro fossil identification results; Several radiolarian fossils were identified from the sample (Bic 5) of this chert near Bicobian, and this chert is correlated to Valanginian to Aptian Age in the Lower Cretaceous. Identified radiolarians are as follows.
Thanarla conica, Thanarla pulchra (?), Holocryptocanium geyserensis, Archacodictyomitra vulgaris, Archaeodictyomitra sp,

(2) Dipadian River Formation

Locality; This Formation distribute from west side Dinapiqui River south east part to Divilican Bay middle east coast.
Thickness of formation change to thinner from south to north.

Rock facies; Lower part consist of graysh-brown to graysh-green conglomerate layer bearing felsic wacke and alternation of hard green siltstone, palegreen to red mudstone and wacke distribute in upper part, these upper part strata change gradually to agglomerate and lapilli or fine tuff bearing tuff breccia. Sulphide bearing quartz veins occur in the southern part of this formation.

Succession of the formation; Isabela Ultra-Mafic Rocks is covered by this formation with unconformity.

Microscopic observation results; The sample (CA009) of this Formation which was collected from near south-western ridge is fresh plagioclase phenocryst bearing doleritic basalt, its groundmass consists of plagioclase, clinopyroxene and ortho-pyroxene and gas pores are filled by chlorite and calcite.

(3) Abuan River Formation;

Locality; This formation distribute south western part of Divilican River middle east Survey Area and northern and western parts of Maconacon, thickness of the formation becomming thinner from north to south.

Rock facies; This formation made up marine.sediments and consists of indurated silt stone and sandstone alternated andesitic- basaltic volcanic breccia, at Dinapiqui of southern part pillow lava which accompanies massive sulphide deposit and andesite lava occupies main part of this Formation.

Succession of the formation; This Formation overlie Dipadian Formation with concordant.

(4) Bolos River Diorite

Locality; This diorite intruded the Abuyan River Formation upstream of the Dicatayan River in north-eastern part of the Survey Area.

Rock facies; This diorite is pale colored medium to coarse grained rock which suffered strong pyritization and medium grade chloritization.
Less mafic mineral parts as monzonitic or quartz-dioritic are observed in places. At upstream of Giudo River Southern Palanan silicified zone accompanies with this diorite and at Dudenan River upstream several quartz vein parallel to the intruded direction are observed.

Microscopic observation results; The sample (CJ-5) of this diorite which was collected at upstream of Dicatayan River northern part of the survey area is holocrystalline equigranular quartz-diorite, main minerals are plagioclase, quartz, hornblende and potash feldspar accompanied by magnetite, sphene and apatite as accessory minerals and showed strong magnetism. Chlorite and epidote appear as secondary minerals. Another sample (CK654) from different intrusive body above mentioned shows about same mineral assembledge but potash feldspar amount is over half content of plagioclase, therefore this sample is named as granodiorite.

Results of K-Ar dating; The result of whole rock K-Ar dating of CJ005 collected from this diorite upstream of Dikatayan River western Maconacon showed 26.4 ± 1.4 m.y. this age will indicate intrusion time of the diorite.

Result of X-ray diffraction analysis; The X-ray sample (CJ02) of sulphide disseminated zone which collected 1.5 km upstream from the above mentioned samples (CJ05) consist mainly of chlorite, quartz and plagioclase.

(5) Dierico Formation

Locality; This formation distribute upstream part of Dimatatono River.

Rock facies; Consists of alternation of thin layer crystalline limestone, mudstone and conglomerate. The mudstone is light gray, friable with minor banding and or lamination. The conglomerate consists of red chert, limestone and serpentine.

Succession of the formation; This Formation overlies on Dipadian Formation with unconformity.

(6) Dulang River Formation

Locality; Distributed along Dulang River northern Maconacon.

Rock facies; It consists of alternation of limestone breccia and shale and siltstone breccia. Volcanic breccia containing limestone and siltstone fragments is observed sometimes.

Succession of the formation; Overlies on Dierico Formation with unconformity.

Micro-fossil identification result; Sample CK62146A collected from this formation is correlated to the CP18 - 19 Nanno Zone (Middle to Later Oligocene), this result shows good harmony to idealized columnar section (Fig. 6)

(7) Palanan Sediments

Locality; Mainly distributed along the Palanan River. Also observes at the east coast of Macomacon and along Dinapiqui River.

Rock facies; This formation which hugs the Palanan Valley consist of thickly interbedded, slightly interbedded, light brown sandstone and gray mudstone, generally calcareous and fossiliferous. Intercalation of limestone were also observed. This formation is generally dipping towards the Palanan Valley and appearently, the latter partly defines a synclinal axis.

Succession of the formation; Overlies the Isabela Ultramafic Rocks, Dipadian River Formation and Abuan River Formation with unconformity but its relation to the Dulang River Formation is unknown.

Microfossil identification result; Sample CA32R collected from this formation is correlated to the CN-9 Nanno Zone (late Miocene). This result agrees with the idealized columnar section (Fig. 6).

(8) Kanaipang Limestone

Locality; This Limestone distributes mainly along Pinacauan River middle east coast.

Rock facies; Flesh colored, highly fractured parts are recrystallized.

Microfossil identification result; Nanno Plankton identification for sample CN-9 collected from this Formation indicates that this Formation correlate to Nanno Zone CN-9 (late Miocene), this result shows good harmony to idealized columnar section (Fig. 6)

3-1-3 Geological Structure

In recent years, Plate Tectonics Theory indicate that the ophiolite derive from ocean crust, the oldest formation of the survey area is made up of ophiolitic rocks and they are thought to correspond to such ophiolites (Isabela Ultra-mafic Rocks), this ultra-mafic rocks divide two bodies namely west side N-S elongated big body which occupy 90 km in N-S and 15 km In E-W and show platy structure declined to west and east side small body which occupy around Bicobian middle of east coast, the small body assume to thrust up on east big body. Cretaceous to Palaeocene Dipadian River Formation overlain on Isabela Ultramafic Rocks, but this formation contact to the ultramafic rocks with high angle fault at Divilacan near Palanan. Dipadian River Formation elongate N-S direction and decline to west generally, formation thickness decrease to north and disappear northern part of Divilacan. Abuan River Formation overlain on Divadian River Formation, this formation increase thickness to north and occupy in broad northern area instead of Divadian River Formation.

The western part of the area uplift as volcanic arc after sedimentation of Abuan River Formation and limestone bearing shallow marine origin Dierico Formation is conformed, after that Dulang River Formation which consist of volcanic clastic sediments is conformed. At this stage middle to late Oligocene Bolos River Diorite intruded in Abuan River Formation.

Broad scale transgression carried out in Miocene and Palanan Sediments (Miocene) Kanaipang Limestone (Pliocene-Pleistocene) were conformed.

N-S folding axis predominate in the area as the result of the E-W compression stress.

3-1-4 Ore Deposits of the East Side of the Northern Sierra Madre Area

Many types of ore deposits are present in the survey area. Main types are orthomagmatic chromite deposit in ultramafic rocks, stratabound manganese and massive sulphide deposit in Cretaceous basalt, chert and tuff, epithermal disseminations and vein type deposits around dioritic intrusives.

Abstract of 15 mineral showings which were investigated in present survey are shown in Table-2 (Ref. Fig. 5). Details of that are shown in Appendix No. 11. Characteristic results of polished section studies are as follows.

No. 2 Cas Chrome Wasayan 2.
Locality; WSW 3.5 km from Dimatadmo Point of the east coast.
Polished Section: CA 60, massive chromite ore in laterite overlain by saprolite.
Ore minerals; massive chromite, shown cataclastic texture.
sulphide minerals are not visible.

No. 3 Dimakawal

Locality; Mountain ridge NW 10 km from Dinapiqui of the east coast.

Polished Section; MD-4 Strata bound massive sulphide in volcanic breccia.

Ore Minerals; Sphalerite Chalcocite / Digenite = Pyrite Covellite Polybasite / Chalcopyrite

Sphalerite. Consisting main parts of the ore, penetrated by network chalcocite and digenite, it has massive appearance and small dots of polybasite and bornite.

Pyrite. 0.3 - 0.02 mm size idiomorphic granular texture, occasionally showing colloform texture.

No. 9 Dikadiaoan.

Locality; South 6 km of Palanan in the east coast.

Polished Section; KP-16 Manganiferous Chert.

Ore Mineral; Braunite (?) as lamina along the bedding of chert.

Aggregation of small crystals elongating -0.3 mm length to lamina direction, occasionally small (-0.001 mm) particle dispersing also. Pyrolusite veinlet (0.01 - 0.03 mm width) penetrating chert in places.

No. 13 Bicobian

Locality; 3 km south of Port Dimalalasan Bay in the east coast.

Polished Section; Bic-02, Strata-bound Massive Sulphide between altered pillow basalt and chert.

Ore Minerals; Chalcocite Pyrite Sphalerite

Chalcocite. Filling up intergrain space of pyrite, partially alternating pyrite, small amount of digenite visible also.

Pyrite. 0.5 - 0.1 mm size, almost alternating to chalcocite from margin of grain, cubic crystals visible in rare case.

Sphalerite. Irregular shape, recognized as relict mineral of alternation in chalcocite.

This ore has shown high content of silver (168.5 g/t), but Ag minerals were not encountered during the microscope work.

No. 14 Lacson

Locality; 5.5 km south of Port Dimalalansan Bay in east coast

Polished Section; Lac-03, Strata-bound Massive Sulphide between altered pillow basalt and chert.

Ore Mineral; Chalcopyrite Pyrite Unknown Sulphide Sphalerite / Covellite

Chalcopyrite. occupied main parts of the ore, showing massive appearance and penetrated veinlets (-0.007 mm width) of unknown sulphide mineral, special exsolution structure is not observed.

Pyrite. 0.3 - 0.03 mm size mainly showed idiomorphic shape, aggregation of fine crystals is visible in places.

Unknown sulphide. Appearing as veinlets (-0.007 mm width) in chalcopyrite or fringe mineral of chalcopyrite.

On microscopic observation, it has creamy yellow color and pleochroism is almost not visible.

Sphalerite. Observed as -0.03 mm size granular or irregular shape in chalcopyrite with very small amount.

Covellite. Observed as foliated shape at the crack of chalcopyrite, considered as final stage product, existing in very small amount.

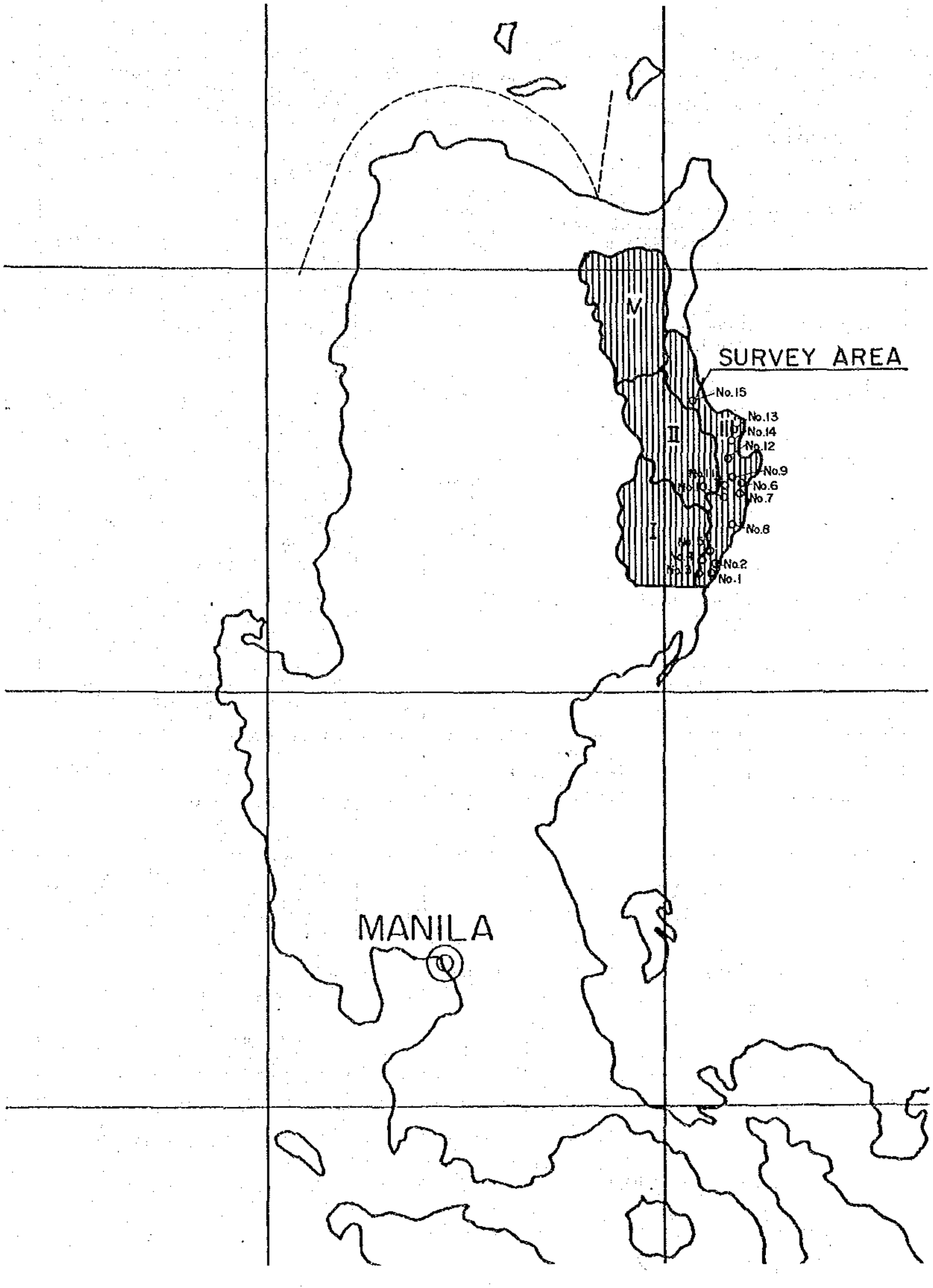


Fig-5 Location Map of the Mineral Showings, East Side of the Northern Sierra Madre Area

Table-2 Abstract of mineral showing investigation in the Eastern part of the Northern Sierra Madre Area

No.	Name of showing	Type of Ore	Ore element	Country rock	Evaluation	General description
1	CAS CHROME WASAYAN 1	Ortho-magmatic deposit (chromite lens)	Cr	Lateritized Dunite	B	Production; conc 4,000 t/M Cr_2O_3 Cr_2O_3 Al_2O_3 FeO SiO_2 MgO 49.20 16.51 14.63 1.33 14.93 (%)
2	CAS CHROME WASAYAN 2	"	"	"	C	Closed Cr_2O_3 Al_2O_3 FeO SiO_2 MgO 53.39 14.95 14.50 0.40 13.11 (%)
3	DIMAKAWAL	Stratabond manganese and massive sulphide	Mn Cu	Basaltic pillow lava	C	Mn Ore SiO_2 Mn Fe P CaO 13.97 45.47 8.49 0.05 1.72 (%) Cu Ore Au Ag Cu Zn S 2 g/t 132.3 g/t 15.88% 23.00% 18.57%
4	DINAPIQUI	Epithermal deposit	On vein	Basalt	D	On Vein (W; 0.2 m) assay Au Ag Cu S Fe 0.1 g/t 4.5 g/t 0.23% 2.87% 2.23%
5	DIMATATNO	"	"	Andesite	D	On Vein (W; 0.15 m) assay Au Ag Cu S Fe Tr Tr 0.02% 0.01% 4.27%
6	DISAWIT	Stratabond manganese deposit	Mn	Basaltic pillow lava chert	D	Ore assay SiO_2 Mn Fe P CaO 45.28% 4.86% 19.81% 0.58% 2.21%
7	KANAIPAG HILL	Residual deposit	Mn	tuff	D	Ore assay SiO_2 Mn Fe P CaO 50.06% 6.77% 18.44% 0.20% 0.62%
8	DIKAPISAN	Ortho-magmatic deposit (chromite lens)	Cr	Dunite	D	Chromite lens (W; 0.2 m) assay Cr_2O_3 Al_2O_3 FeO SiO_2 MgO 0.02 5.35 9.99 70.05 2.65 (%)
9	DIKADIAOAN	Stratabond manganese deposit	Mn	Chert	C	Manganese mad assay SiO_2 Mn Fe P CaO 47.94 4.80 20.66 0.28 0.07 (%)
10	CIWED	Epithermal deposit	Silicified zone	Hornblend andesite	D	Silicified zone assay Au Ag Cu S Fe Tr Tr 0.01 1.34 4.37 (%)
11	DIUDENAN	"	Quartz vein	"	D	On Vein (W; 0.4 m) assay Au Ag Cu S Fe Tr Tr 0.01 1.16 1.50 (%)
12	DIBENELANG	Ortho-magmatic deposit (chromite lens)	Cr	Dunite	B	Chromite pebble Cr_2O_3 Al_2O_3 FeO SiO_2 MgO 46.35 10.91 13.32 6.79 17.53 (%) Chromite lens Cr_2O_3 Al_2O_3 FeO SiO_2 MgO 43.27 9.88 11.90 9.50 19.09 (%)
13	BICOBIAN	Stratabond massive sulphide	Cu	Basaltic pillow lava	B	Sulphide boulder Au Ag Cu Zn S 5.5 g/t 168.5 g/t 54.4% 0.26% 26.14%
14	LACSON	"	"	"	b	Sulphide sample Au Ag Cu Zn S Tr g/t 1.7 g/t 0.23% 0.11% 7.95% 0.5 12.1 7.46 0.26 46.67
15	BLOS RIVER	Epithermal deposit	Calcite vein	Diorite	D	Shutter zone (W; 2 m) assay Au Ag Cu S Fe Tr Tr 0.01% 0.51% 4.08%

In these mineral showing the following 5 deposits have histories of operation.

Wasayan I (Actual Operation) Production; concentration 1,500 t	Lenticular chromite deposit
Wasayan II (Closed)	
Dimakawal (Closed)	Stratabound Copper: Manganese deposit in basalt.
Bicobian (Closed) Production; high grade Cu Ore 150,000 t	Stratabound massive sulphide deposit (Cu)
Lacson (Closed)	

3-2 Geology and Ore Deposits of the West Side of the Northern Sierra Madre Area (Ref. Plate 1)

3-2-1 General Summary

The survey area corresponding to the west side of the Northern Sierra Madre Area belong to Isabela Province and Cagayan Province of the Region II administrative district. Manila -Aparri Highway along the Cagayan River run through west side of the Area, it needs 10 hours by car from Manila to Tuguegarao (500 km distance). Flight schedule from Manila to Tuguegarao is one per day, Manila to Cauayan is twice in each week.

	6 hr.		2 hr.		2 hr.	
Manila	-------	Cauayan	-------	Ilagan	-------	Tuguegarao
	by car		by car		by car	

The geographic situation are as follows;

Area;	7,615 km^2
Elevation;	30 --- 1,800 m
Highest Peak;	1,805 m
Average Temperature;	28^oC
Annual Precipitation;	1,700 mm per year

The climate belongs to the typical monsoon climate zone of the Western Pacific region, where dry season is Nov. to May and wet season is June to Oct. during the season, many Typhoon come to the area.

This Area is divided into three parts by topographic characteristics;

(1) Lowland along the Cagayan River and its branches is used for planting rice, sugarcane, corn and bean etc.

(2) Hill area between the lowland and mountain range is used partially as meadow and farm but mainly remained as wast land.

(3) Mountain range is almost covered with virgin forest.
Main industry of this area is agriculture and forestry.

3-2-2 Succession of Each Formation (Ref. Fig. 6)

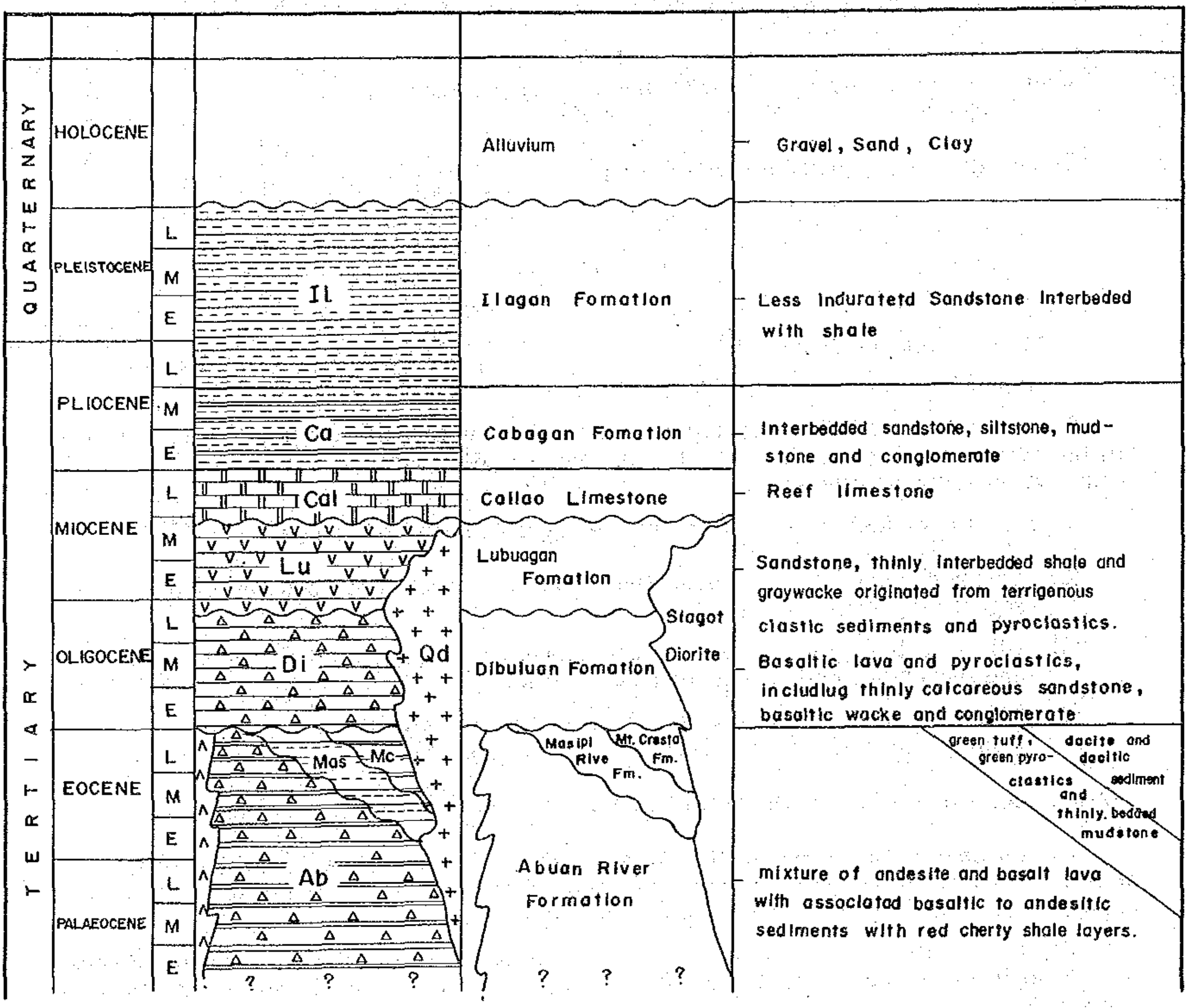
The basement formation of the Area is Abuan River Formation which consist of andesitic to basaltic volcanic breccia and wacke similar to that of the east coast area, it expose in the central part of the mountain and hill range.

Mt. Cresta Formation and Masipi Formation which conform as the result of local dacitic activity in middle east part of the Area are covered on basal formation with unconformity.

Siagot Diorite intruded into these formation. The age determination of this diorite indicate 22.3 $\pm$ 1.1 Ma. to 31.1 $\pm$ 1.5 Ma. (Corresponding to middle - late Oligocene). This age is about the same as in the east coast area.

Kburao Limestone Formation (late Oligocene) appears as west fringe of the Abuan River Formation with unconformity, Lubuagan Formation, Callao Limestone Formation, Cabagan Formation and Ilagan Formation (Neogene Formation) overlie the Ibulao Limestone. These Neogene Formation curve to the east parallel to the basin structure of Bagao.

Fig-6 Columnar Section, West Side of the Northern Sierra Madre Area



Details of each formation are as follows.

(1) Abuan River Formation

Locality; The Formation has covered broad area in the west slope of the Northern Sierra Madre Mountain Range, it has 20 km wideness at the east side of Santo Tomas but in the southern part of the area broad diorite bodies intruded the formation, so exposed area is restricted. The northern end of the Area, the northern boundary of basin structure are occupied by this Formation.

Rock facies; This formation consists of heterogenous mixture of andesite and basaltic lava with associated basaltic to andesitic sediments with occational red cherty shale layers. The clastics are made up of interbedded basaltic to andesitic sandstone, shale, conglomerate and breccia.
The conglomerate is composed of basaltic to andesitic clast and is well cemented. The breccia is characterized by the large angular fragments of amygdaloidal to vesicular basalt and andesite clast. The sandstone is poorly sorted but well indurated.

Stratigraphic position; This formation is the oldest in this area which is estimated to be Cretaceous - Paleogene by the BMG.

Results of microscopic observation; The sample (AD028R) which collected at mid-stream of Pinacawan River is basalt., it shows intergranular structure and strong magnetism consists of partially albitized plagioclase, fresh clino-pyroxene, ortho-pyroxene as phenocrysts and plagioclase, clinopyroxene, magnetite as groundmass.

Identification of micro-fossil; The sample (NQ26A) of this formation which collected upstream of Palette River north-eastern part of the Area is identified as Nanno Zone CP19 (middle Oligocene) by Nanno Plankton determination. The sample (BL069) of this Formation which collected mid-stream of Pinacauan River middle part of the Area is identified Nanno Zone CP19 as same above.

(2) Mt. Cresta Formation;

Locality; Around Mt. Cresta middle-east part of the Area.

Rock facies; This formation consist of undeferentiated dacite lava and intrusive including dacitic sediments. The dacite is white to buff in color with some plagioclase and quartz crystals which is recognizable by naked eye.
The dacitic sediments are well bedded and moderately sorted medium to coarse grained. Massive pyrite alternations are confined in this formation which are exposed along the upper Abuan River.

Stratigraphical position; This formation cover the Abuan River Formation with unconformity.

(3) Maspi River formation

Locality; This formation is distributed along the upstream of Masipi River and is folded structure at the east side of Cabagan.

Rock facies; This Formation is composed mainly of parallel bedded green tuff, green to dark green pyroclastics (lapilli, tuff breccia) and tuffacious sandstone and thinly bedded mudstone.

Stratigraphic position; This formation cover the Abuan River Formation with unconformity and has syngenetic different facies relation to Mt. Cresta Formation.

Identification of micro-fossils; The sample (BH122) of this formation which collected 10 km ENE of Ilagan is correlated Nanno Zone CP19 (Middle- late Oligocene) by Nanno Plankton identification.

(4) Siagot Diorite

Locality; Many intrusive bodies are observed from the southern part of the area to the east side of Tuguegarao (distance of it, about 135 km) intermittently in Abuan River Formation.

Rock facies; These intruded bodies are able to divide two types; quartz diorite and hornblende diorite. Hornblede diorite is shown only restricted exposure at the east of San Mariano, Isabela Province, consists of abundant hornblende and plagioclase bearing, biotite accompanying in sometimes medium and coarse grained rock. Quartz diorite expose along Siagot and Menuma Creek, abundant quartz and considerable amount of hornblende, plagioclase and biotite bearing, it has nature of head for weathering. Micro-diorite is recognized east side of San Mariano.

Results of microscopic observation; The sample AK051R which collected at 50 km ENE of Cauayan consists of mainly quartz, plagioclase, K-feldspare, hornblende and clino-pyroxene accompanied magnetite and apatite, corresponds to quartz diorite. Another sample AM054R which collected 2 km SW site of above mentioned sample shows small amount (under 40%) of quartz and K-feldspare, identifies as hornblende tonalite. The age determination of the sample (AM054R) indicates 31.1 ± 1.5 Ma.
The sample (DF024) which collected 27 km ENE Tuguegarao consists mainly of plagioclase, quartz, hornblende and K-feldspare, accompanies magnetite, sphene, apatite and small amount of epidote, and is classified as hornblende granodiorite, while 5 km SW sample (DH057) contains more quartz content is identified as quartz diorite.

Results of whole rock analysis; This analysis results show in Appendix 9, the content SiO_2 indicate +70% in quartz diorite, but in hornblende diorite it shows only 50% ±.

Results of K-Ar dating; 5 K-Ar dating samples are collected from dioritic rocks in this Area. Result of this area shown in Appendix 4 at last of this volume.
The oldest age is shown by the sample (AM054R) Which collected from hornblende-tonalite, indicated 31.1 ± 1.5 Ma. (middle Oligocene). The youngest one is the sample (DH057) which collected from granodiorite 24 km East of Tuguegarao, indicated 22.3 ± 1.1 Ma. (early Miocene).
As above mentioned, these dioritic rocks have not definit mineral assemblage and chemical composition, therefore they might be to intrude in several divided stage and the stages ranged from 31.1 Ma. to 22.3 M.

(5) Ibulao Limestone Formation

Locality; This formation distribute at 14 km east of Cabagan in 5 km length with NNW-SSE direction.

Rock facies; The limestone of this Formation is generally biohermal to biostromal. It is cream to light gray color, and contains few discernible fossils.

Stratigraphic position; This formation cover the Abuan River Formation with unconformity, correlated early Miocene by the BMG.

(6) Lubuagan Formation (Contain the so-called Dibulan Formation by BMG.)

Locality; This formation distribute as several km width zone west side of the Abuan River Formation in the middle south part of the area.

Rock facies; This formation consists of primarily a thick sequence of terrigeneous clastic sediments and some pyroclastics, composed of sandstone, thinly interbedded shale, and graywacke. The sandstone is light gray to brown in color, medium to coarse grained, moderately sorted and indurated. The shale is well bedded and is interbedded with thin beds of siltstone and occasional graywacke. Thin beds of conglomerate at its base is also noted, the clasts is composed essentially of basaltic to andesitic composition.

Stratigraphic position; This formation cover the former Formation with unconformity.

Identification of micro-fossils; The sample (DK082) of this formation which collected at upstream of Imurang River in the north-east part of the area is correlated to Nanno Zone CP19a (middle Oligocene) by Nanno Plankton identification(1).

(7) Callao Limestone Formation

Locality; This formation is distributed along the south and west side of the Abuan River Formation in northern part of the area, in the middle-west part it has contact to the west side of the Lubuagan Formation and intermittently elongate to near the Lubuluan River in the south-eastern part of the area.

Rock facies; This formation is basically a reef limestone which grades into a clastic facies in the deeper part of the Cagayan Valley. The limestone is flesh to light gray in color, some are corraine with few large foraminifera.

Stratigraphic position; This formation exhibits conformity relationship to the Lubuagan Formation.

Identification of micro fossils; The sample (BK004) of this formation which collected at 12 km NE of Ilagan is correlated to Nanno Zone CN9 (late Miocene) by Nanno Plankton identification.

(8) Cabagan Formation

Locality; This formation shows wide distribution around the Bagao Basin northern Tuguegarao and zonal distribution with 2 - 4 km width along east side of Cagayan River which elongate NNE direction.

Rock facies; This formation is composed of interbedded sandstone, siltstone, mudstone, shale and conglomerate. The sandstone is well indurated, medium grained moderately sorted well bedded and sparsely fossiliferous.
The lower portion of the formation is made up generally of flat lying, moderately sorted and well stratified sandstone and shale with intercalated mudstone and siltstone beds. Carbonaceous material are notably present in the lower portion of the formation. Cross bedding in the conglomerate horizons near the base is noted.

Note (1) Nanno Plankton Identification is Carried out by Dr. N. Okada, Geo-Sciences Faculity of Yamagata Univ. Japan.

The upper portion of the Formation is generally light colored, cross bedded, moderately sorted, stratified and sparsely fossiliferous. The whole formation is underlain by a well stratified conglomerate.

Stratigraphical position; This formation cover the Callao Limestone Formation with conformity and correlated to late Miocene - early Pliocene by BMG.

Identification of micro-fossils; The samples (BD104. DJ003) of this formation which collected at 13 km SE of Ilagan and 11 km SE of Bagao Area correlate to Nanno Zone CN9 and CN7-11 (corresponding to late Miocene - early Pliocene) by Nanno Plankton identification.

(9) Ilagan Formation

Locality; This formation is widely distribution at the northern Bagao in the northern part of the area and shows NS elongated exposure along the east side of Cagayan River from Bagao to Tumauini (60 km length).

Rock facies; This formation is composed of less indurated sandstone and interbeds of shale. The sandstone ranges from light (buff) to light gray in color and is essentially medium to coarse grained and show a moderately defined bedding. The formation contains some carbonaceous plant remains.

Stratigraphic position; This formation conformably overlies the older formation in the area, and is assumed to be shallow water sediments in Plio - Pleistocene by BMG.

(10) Alluvium Sediments

Locality; These Sediments occupy the down stream section of the Cagayan River and its branches. Between mountain ranges and hill regions some alluvial fans and taluses are recognized and they show characteristic topography. Some terrace like shaped hills are noted too.

Rock facies; These sediments consist of gravel, sand, silt and mud, accompanied by thin layer of carbonaceous materials.

(11) Dyke Rocks

Several dykes of dacite, andesite and gabbro are observed in the Abuan River Formation at the southeast part of the survey area, a part of them intrude in diorite with stock shape. These dyke rocks are shown dark green to greenish gray in color as the result of chloritization and epidotization.
Intrusion of autobrecciated basalt is noted in the Ilagan Formation at the west side of the survey area.

3-2-3 Geological Structure

N-S trending folding axis and NE-SW or NW-SE faults which might be conjugate faults to these folding controlled the geological structures in the area. For instance, the intrusion of dioritic rocks might have occurred along these folding axis. These structural lines are observed not only in the Abuan Formation but also in the Neogene Formations at the west part of the area. Aside from the above mentioned, E-W direction folding axis from Gattaran to Cappisayan and basin structure around Bagao Area were observed at the northern part of the area.

Fig-7 Location Map of the Mineral Showings, West Side of the Northern Sierra Madre Area

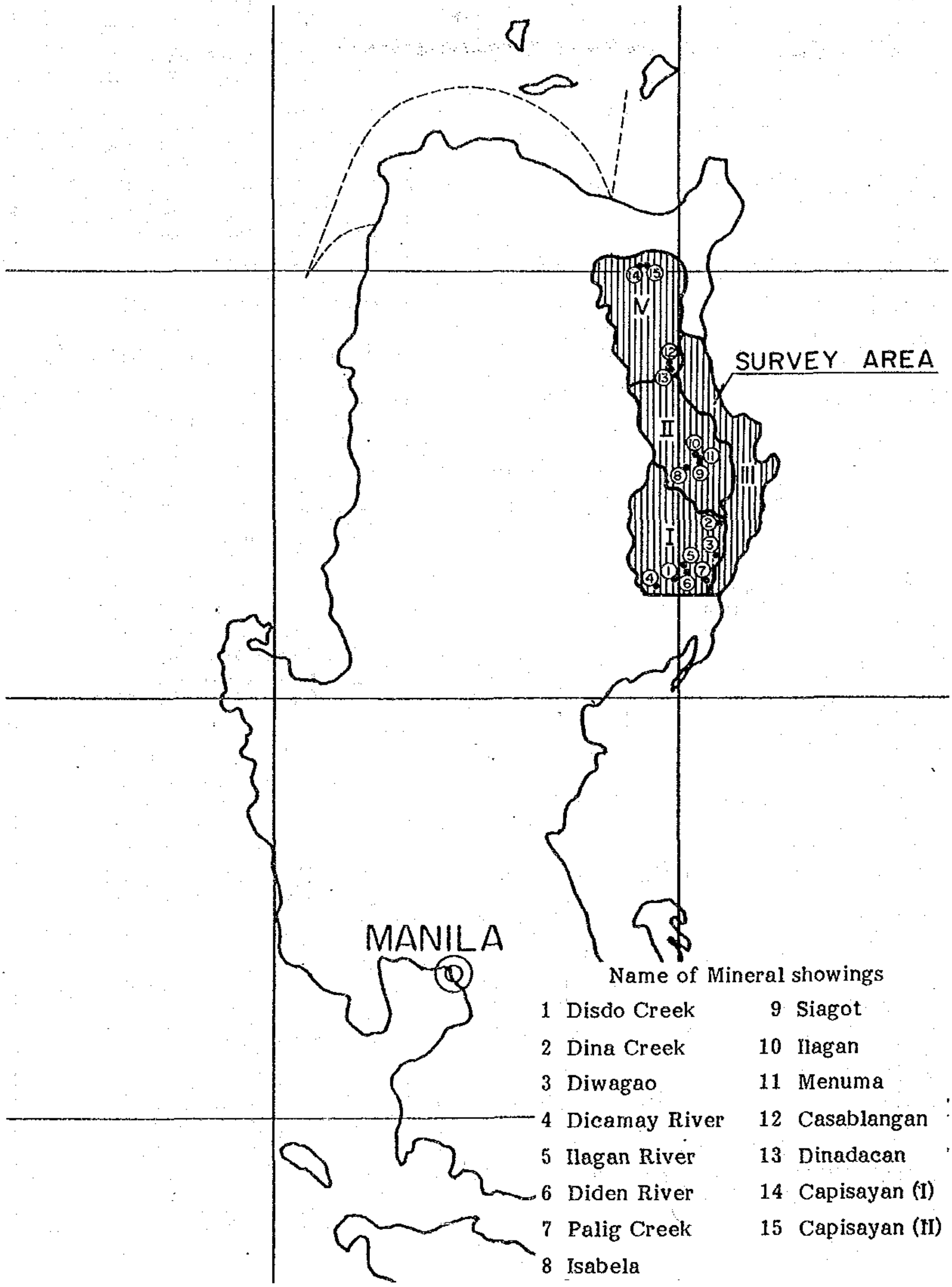


Table-3 Abstracts of mineral showing investigation West side Northern Sierra Madre Area

No.	Name	Type of ore depo	Kind of ore	Country rock	Evaluation	Remarks
1	Disudo Creek	Epithermal vein	Qu Vein	Altered andesite	D	Assay of Qu-vein Au g/t Ag g/t Cu% Pb% Zn% 0.07 1.7 0.03 -0.01 -0.01
2	Dina Creek	Network dissemination	Cu	"	B	Assay of ore Au g/t Ag g/t Cu% Pb% Zn% massive -0.07 3.3 0.06 -0.01 0.01 or not 0.14 9.0 3.07 -0.01 0.11 visible
3	Diwagao	Floating	Cu	"	B	Assay of ore Au g/t Ag g/t Cu% Pb% Zn% 2.5 -0.07 0.07 -0.01 -0.01
4	Dicamay River	Floating	Limonite	Andesite	D	Disseminated limonite in calcareous conglomerate accompanying goethite.
5	Ilaganriver	Network dissemination	Silicified zone	Altered diorite	D	Assay of ore Au g/t Ag g/t Cu% Pb% Zn% -0.07 0.3 -0.01 -0.01 0.01
6	Diden River	"	"	Altered andesite	D	Assay of ore Au g/t Ag g/t Cu% Pb% Zn% -0.07 1.7 -0.01 -0.01 0.01
7	Palig Creek	Placer Manganese Epithermal vein	Clay vein	Dacite	D	Assay of clay Au g/t Ag g/t Cu% Pb% Zn% 0.07 -0.3 -0.01 -0.01 0.01 Assay of Mn placer MnO% SiO_2% MgO% CaO% P_2O_5% 74.9 2.57 0.99 4.45 0.23
8	Isabela	Network dissemination	Silicified zone	Rhyolite	E	Assay of ore Cu% Pb% Zn% Fe% S% 0.001 0.00 0.009 4.82 0.49
9	Siagot	"	"	Silicified sandstone	E	Assay of ore Cu% Pb% Zn% Fe% S% 0.001 0.00 0.002 2.71 0.81
10	Ilagan	"	"	"	D	Ore assay Cu% Pb% Zn% Fe% S% 0.04 0.01 0.0012 7.94 0.38 0.06 0.00 0.011 5.76 1.38 0.004 0.00 0.010 5.75 0.23
11	Menuma	"	"	Grano-diorite	D	Ore assay Cu% Pb% Zn% Fe% S% 0.001 0.00 0.02 10.99 12.04 0.001 0.00 0.04 6.49 4.94 0.001 0.00 0.04 2.94 0.92
12	Casablangan	"	"	Dacite	C	Ore assay Cu% Pb% Zn% Fe% Ag g/t 0.027 0.009 0.009 6.68 21
13	Dinacdancan	"	"	"	C	Ore assay Cu% Pb% Zn% Fe% Ag g/t 0.007 0.009 0.008 1.29 8
14	Capisayan (I)	"	"	"	C	Ore assay Cu% Pb% Zn% Fe% Ag g/t 0.007 0.009 0.008 10.04 8 0.017 0.009 0.026 24.79 13 0.017 0.014 0.15 13.26 26
15	Capisayan (II)	Banded limonite	Limonite	Sandstone shale	D	Layered and nodule shape limonite length 150 m thickness 0.5 m

3-2-4 Ore Deposits of the West Side of the Northern Sierra Madre Area

Ore deposits in the survey area are copper bearing pyrite disseminated deposit within or around dioritic rocks (partially vein type), stratabound hematite deposit, stratabound manganese deposit and brown coal etc.

Location map of the ore deposits investigated at present Survey is show in Fig. 7, abstracts are shown in table-3 and details are described in Appendix 11.

Characteristic Results of polished section studies are as follows.

No. 1 Disudo Creek
Location; West side of the diorite stock at the southern part of the area
Polished Section; AF027R
Ore minerals;
Pyrite mainly shows idiomorphic shape (in 1.3 - 0.05 mm size), Existing medium amount.
Chalcopyrite. shows irregular shape (in 0.3 - 0.02 mm size), Existing small amount.

No. 2 Dina Creek
Location; Upstream of Disabungan River, east side of the diorite stock, south-east part of the Area.
Polished Section;
AK51R (Sta 45) Dissemination in andesite.
Ore minerals; Pyrite ≫ Chalcopyrite ≫ Sphalerite
Pyrite. Mainly idiomorphic shape (in 3 - 0.2 mm size)
Chalcopyrite. Mainly allotriomorphic shape, occasionally cementing inter-granular space of pyrite.
Sphalerite. Recognizing very small amount in chalcopyrite and country rock.
AK51R' (Camp I) Massive sulphide.
Ore minerals; Pyrite > Magnetite > Chalcopyrite > Sphalerite
Pyrite. Idiomorphic or irregular shape, recognizing as aggregation (of 0.1 - 0.03 mm size).
Magnetite. Mainly almond shaped, occasionally columnar or irregular shaped, recognizing (0.1 - 0.03 mm size) as idiomorphic texture.
Chalcopyrite. Mainly allotriomorphic shaped, (0.8 - 0.1 mm size) as inter-granular material of pyrite.
Sphalerite. Mainly allotriomorphic shaped (0.5 - 0.2 mm size), many chalcopyrite dots observed in itself.
Each ore minerals have habit as alternation products of some columnar shape mineral, and small particles of magnetite were recognize a at the margin of each column.

No. 4 Diwagao.
Location; 12 km south of Dina Creek, east side of the diorite stock.
Polished Section; AK95R (Sta 3) pyrrhotite and pyrite ore.
Ore Minerals; Pyrrhotite > Marcasite > Pyrite > Sphalerite > Chalcopyrite
Pyrrhotite. Aggregation of irregular shape grains, consisting of hexagonal and monoclinic crystals.
Marcasite. Framboidal texture indicating secondary origin, (0.05 - 0.02 mm size), observed at margin and crack of pyrrhotite.
Pyrite. Idiomorphic cubic habit, 0.15 - 0.05 mm in size.

No. 8 Isabela

No. 9 Siagot.

Location; 20 km SE of Ilagan, north side of Abuan River, west side of the diorite stock.

Polished Section; BA 8b Dissemination in rhyolite
BA12b Dissemination in silicified sandstone

Ore minerals; Pyrite > Magnetite (small amount of both.)

Pyrite. existing irregular shape, 0.8 - 0.1 mm size.

Magnetite. Exhibits idiomorphic or irregular shape, 0.02 - 0.05 mm in size, dispersed around pyrite, and changed partially to hematite.

No. 10 Ilagan

Location; 20 km ESE of Ilagan, west side of the diorite stock.

Plished Section; Pyrite > Magnetite > Chalcopyrite

Pyrite. Idiomorphic or irregular shaped, 1.5 - 0.1 mm in size, observed as disseminations or veinlets.

Magnetite. Idiomorphic or irregular shaped, 0.08 - 0.01 mm size, recognized as dust like disseminations around pyrite and silicate minerals and all over the country rock. Margin of crystals partially changed to hematite.

Chalcopyrite. Exhibits irregular shape, 0.3 - 0.03 mm in size as disseminated mineral. In rare case, margin of crystals changed to covellite.

No. 11 Menuma

Location; 20 km ESE of Ilagan, west side of the diorite stock.

Polished Section; BA16a, BA19b Disseminated ore in diorite.

Ore Minerals; BA16a, Pyrite > Hematite
BA19b, Pyrite > Magnetite

Pyrite. Dissemination having idiomorphic or irregular shapes, 1.0 - 0.1 mm in size.

Magnetite. dispersing around pyrite as 0.03 - 0.05 mm size irregular shape, Disseminated in all parts of the country rock and appears as aggregation of small particles.

Hematite. Observed in bserving margin of magnetite and exsists in small amount as 0.1 -0.05 mm irregular shape crystals.

No. 12 Casablangan

Location; 30 km east of Tuguegarao.

Polished Section; DF039B network disseminated ore in dacite.

Ore Minerals; Pyrite ≫ Sphalerite ≧ Enargite ≫ $\begin{matrix}\text{Galena}\\ \text{Bornite}\end{matrix}$ > Chalcopyrite

Pyrite. 0.5 - 0.05 mm size, irregular shape, occasionally including granular bornite and in rare cases Ag mineral (stephanite like mineral) associated.

Sphalerite. 0.3 - 0.03 mm in size irregular shape, mainly existing with pyrite.

Enargite. 0.2 - 0.04 mm irregular shaped crystals.

Galena, bornite and chalcopyrite exist in small amount.

No. 13 Dinacdacan

Location; 30 km east of Tuguegarao.

Polished Section; DH52R network disseminated ore in dacite.

Ore Minerals; Pyrite ≒ Fe- hydro oxide. (both is about the same amount)

Pyrite. 0.4 - 0.06 mm in size idiomorphic or irregular shape, existing as small amount of disseminated mineral. Very small amount of hematite occurring as aggregation of lattice structured columnar shaped crystals.

Fe- hydro oxide. Assumed secondary mineral of sulphide, existing as granular or irregular shaped crystals.

Polished Section; SpI A,B,D, disseminated ore in dacite (2 km north of the above sample)

Ore Minerals; Pyrite > Bornite > Hematite

Pyrite. Idiomorphic granular textured, small amount bornite bearing, small amount of dust like hematite dispersed in the country rock.

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 the 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 utilized is the univariate analysis for the whole samples.

4-1-1 Sampling Location

Sampling was carried out along active stream channels by the same method used at the Southern Sierra Madre, Polillo Area, the Bohol, Siquihol Area on 1984 in the Philippines. The density of sampling is approximately one stream sediment sample for every one to two km^2. Sampling points are pre-determined in a 1/50,000 scale map prior to the start of the survey.

4-1-2 Sampling Method

Samples collected are wet shieved in situ by using stainless sieve to 30 mesh fraction in situ by which they amount to about 500 grams. They are washed thoroughly to remove dirt and clay fractions before they are placed in properly marked water resistant kraft bags. An acompanying data sheet card (Fig. 8) is filled up to record observations like location, grid coordinates, feature of stream, pH, Eh, and topography etc. Then samples are transported to base camp 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 plastic tubes. These samples are sent to the laboratory through the base camp. Similar to stream sediment samples, a corresponding data sheet form is filled up to describe the place where the sample was taken.

Stream sediment samples are transported to each base camp, are sun-dried and are sieved to -80 mesh by stainless sieve. Then samples are put in remarked kraft paper bags and sent to PETROLAB.

4-1-3 Method of Indoor Testing

1) Adjustment method of analytical 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 for AAS analysis. Excess samples are stored for further use.

Fig. -8 Field Data Sheet of Geochemical Survey

AREA:

SAMPLE NO.	SAMPLE TYPE	EASTING	NORTHING	STREAM Ord.	Width-m	Depth cm	Flow	PH	EH	BANK Type	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 3-moderate
- 1-stagnant 4-fast
- 2-slow 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 4-bedrock
- 2-alluvial 5-colluvial and bedrock
- 3-scree

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 3-fine (silty)
- 2-medium (sandy) 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.

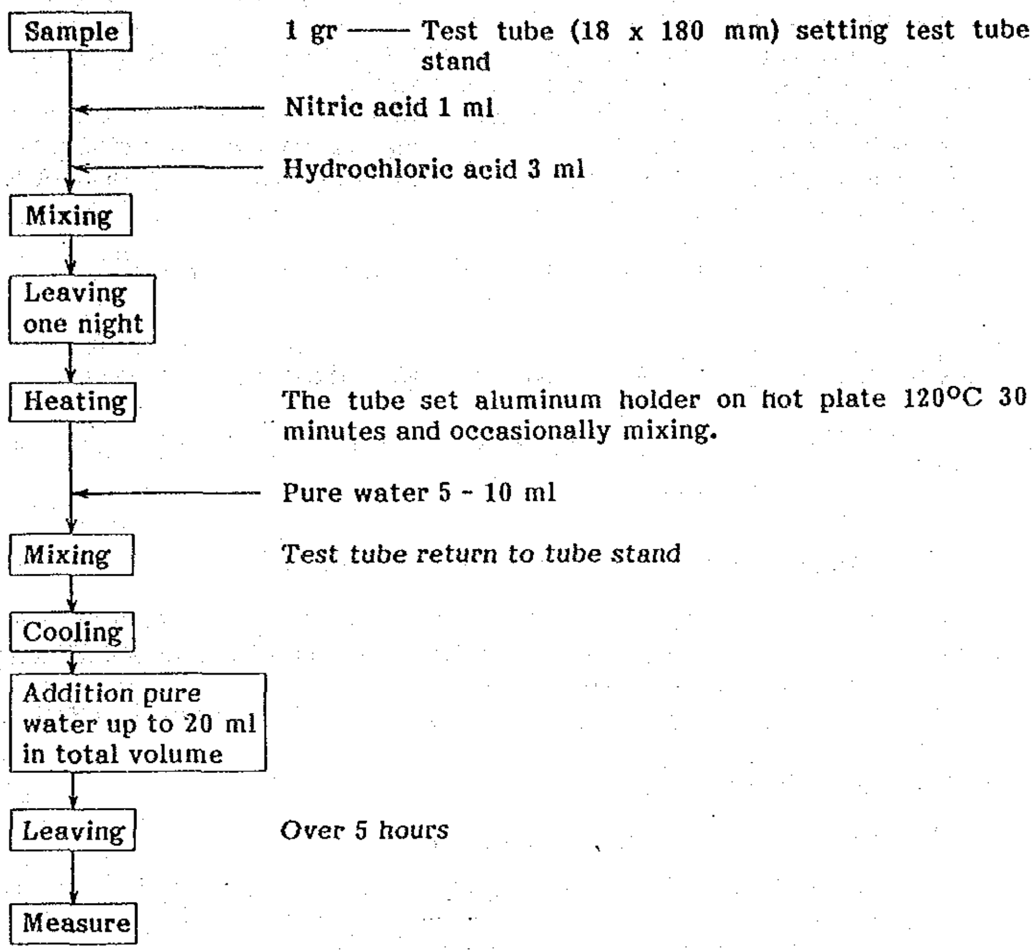
Col.34 Alteration. Note presence and type. Use code 1 if present and 0 if absent.

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 5-duplicate
- 1-stream sediment 6-several types (specify)
- 2-soil
- 3-rock
- 4-heavy mineral concentrate

Remarks. Enter any other pertinent information about the sampling locality

Fig-9 Flow Chart of Stream Sediment Preparation



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 - A.A.S.	Flameless	253.7
As	Hydration - A.A.S.	"	197.4

2) Microchemical analytical method

Weighed samples are analyzed by atomic absorption method according to the attached flow chart (Fig.-19).(Foot Note 1)
Elements analized are Ag, Cu, Pb, Zn, As, Hg, Mo, Mn, Ni (10) in Cauayan, Ilagan and Tuguegarao area, and Ag, Cu, Pb, Zn, As, Hg, Co, Cr, Mn, ni (10) in Palanan area in the east coast.
Heavy mineral samples are analyzed for Au, Ag and Ga (3) in whole Areas. The detection limit of those elements are shown in table- 4 .
In PETROLAB, 4 sets of atomic absorption spectrometer are utilized, 3 sets are made by Varian Tectron Co. (One of them is flameless type model GTA-95 while the other two AS-1475) and one set is made by Shimazu Model AA-670 which is used for heavy mineral sample analysis.

Table- 4 Detection limit of AAS at PETROLAB

(Unit; ppm)

Element	Cu	Pb	ZN	Ag	Ni	Co	Mn	As	Hg	Mo
Detection Limit	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 in each Northern Sierra Madre Area by univariate analytical method to each population group using the procedure of C. Lepeltier (1969),
Computer was used for calculation. Procedure of analysis are as follows.

Previous Procedure of Data

1) Determination of lithological population

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

(Foot Note 1) This microchemical analysis method use 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.

Univariate Analysis

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

2) Mean value, threshold value, standard deviation value, maximum value, minimum value and dispersion rate etc., these statistical values were calculated.

3) Histograms and Cumulative Frequency Curves for each population and elements were made.

4) Logarithmic data table were made for each population and elements.

5) 95% level student (t), and Senedecor (F) certification for dispersion of data were carried out between different population.

If data dispersion range among some populations are the same, these populations were consolidated.

6) List are made to pick up anomalous data.
7) Correlative coefficients between all populations and elements were calculated.

4-2 Geochemical Survey in the Northern Sierra Madre Area

4-2-1 Basic Statistical Data

1) Statistical data for each lithological code

Stream sediment samples in the Northern Sierra Madre Area are divided into following 12 populations (lithological code) according to the geochemical feature of country rocks.

Lithological Code	Contents	Sample Number
Il + Ka	Pliocene-Pleistocene sediments	817
Ca	Miocene-Pliocene sediments	699
Pa	Late Miocene sediments	185
Cal	Middle Miocene limestone	153
Lu	Early Miocene clastics	69
Di	Oligocene basaltic clastics	440
Mc	Palaeocene pyroclastics	81
Dip	Eocene sedients	318
Ab	Eocene pyroclastics	1,121
Bic	Late Cretaceous basalt	18
Is	Cretaceous ultramafics	426
Qd	Dioritic rocks	646
	Total	4,973
	Duplicate samples	95

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

Lithological code Il + Ka; Pliocene-Pleistocene sediments
Number of Samples 817

(Unit; ppm except Hg)

	Cu	Pb	Ag	Zn	As	Hg (ppb)	Ni	Co	Mn	Mo	Cr	Remarks
$\bar{x}$	33	5.01	-	80	1.4	20	20	29	1,187	-	20,469	
1 σ value	43	5.3	-	127	3.6	24	39	42	1,748	-	118,841	
1.5 σ value	50	5.4	-	161	5.7	26	54	50	2,121	-	286,352	This value estimate as threshold
2 σ value	58	5.5	-	203	9.1	28	75	60	2,574	-	689,978	
Maximum	80	15	0.5	340	33.0	71	4,800	350	9,600	1.0	155,000	
Minimum	12	5	0.5	10	0.25	20	4	9	129	1.0	800	

Number of Cr assay is 20 samples collected along east coast.

Lithological code Ca; Miocene-Pliocene sediments
Number of Samples 699

(Unit; ppm except Hg)

	Cu	Pb	Ag	Zn	As	Hg (ppb)	Ni	Co	Mn	Mo	Cr	Remarks
$\bar{x}$	33	-	-	75	3	21	21	22	1,068	1.1		
1 σ value	48	-	-	111	7	27	34	33	1,743	1.3		
1.5 σ value	57	-	-	135	10	30	43	41	2,226	1.4		This value estimate as threshold
2 σ value	68	-	-	164	15	33	54	50	2,844	1.5		
Maximum	108	5	0.5	280	22	140	166	74	6,100	4.0		
Minimum	11	5	0.5	18	0.25	20	4	6	220	1.0		

Number of Cr assay is zero because of no-samples collected along east coast.

Lithological code Pa; Late Miocene sediments
Number of Samples 185

(Unit; ppm except Hg)

	Cu	Pb	Ag	Zn	As	Hg (ppb)	Ni	Co	Mn	Mo	Cr	Remarks
$\bar{x}$	46	5.1		99	2.4	22	231	38	1,034	1.0	6,107	
1 σ value	65	6.0		138	6.3	30	656	60	1,525	-	28,926	
1.5 σ value	77	6.5		163	10.0	35	1,105	75	1,852	-	62,953	This value estimate as threshold
2 σ value	92	7.0		193	18.4	40	1,863	94	2,249	-	137,010	
Maximum	240	31.0		490	17.0	100	5,300	320	8,400	1.0	108,000	
Minimum	19	5.0		41	0.25	20	9	14	530	1.0	50	

Number of Ag assay is zero because of all samples collected along east coast.

Lithological code Cal; Middle Miocene limestone
Number of Samples 153

(Unit; ppm except Hg)

	Cu	Pb	Ag	Zn	As	Hg (ppb)	Ni	Co	Mn	Mo	Cr	Remarks
$\bar{x}$	41	5.2	0.5	81	2.7	21	32	23	998	1.1	6,940	
1 σ value	63	6.4	-	125	6.4	24	65	38	1,662	1.4	18,186	
1.5 σ value	77	7.1	-	156	9.9	26	92	48	2,144	1.6	29,439	This value estimate as threshold
2 σ value	94	7.8	-	194	15.3	28	131	61	2,767	1.8	47,655	
Maximum	125	17	0.5	300	20	64	1,100	65	7,500	7.0	23,000	
Minimum	11	5	0.5	20	0.75	20	12	3	190	1.0	1,400	

Number of Cr assay is 7 samples collected at east coast.

Lithological code Lu; Early Miocene clastics
Number of Samples 69

(Unit; ppm except Hg)

	Cu	Pb	Ag	Zn	As	Hg (ppb)	Ni	Co	Mn	Mo	Cr	Remarks
$\bar{x}$	46	5.0	0.5	85	3.1	20	38	22	836	1.0		
1 σ value	64	-	-	122	6.3	-	97	33	1,149	-		
1.5 σ value	75	-	-	145	8.8	-	154	40	1,347	-		This value estimate as threshold
2 σ value	88	-	-	173	12.4	-	245	49	1,578	-		
Maximum	75	5.0	0.5	270	18.0	20	179	47	1,930	1.0		
Minimum	13	5.0	0.5	32	0.25	20	5	7	380	1.0		

Number of Cr assay is zero because of no-samples collected along east coast.

Lithological code Di; Oligocene basaltic clastics
Number of Samples 440

(Unit; ppm except Hg)

	Cu	Pb	Ag	Zn	As	Hg (ppb)	Ni	Co	Mn	Mo	Cr	Remarks
$\bar{x}$	51	5.1	0.5	97	1.7	21	25	23	1,032	1.1	70	
1 σ value	85	5.7	-	149	4.6	23	59	35	1,495	1.3	109	
1.5 σ value	110	6.0	-	184	7.3	24	92	42	1,798	1.4	137	This value estimate as threshold
2 σ value	143	6.3	-	228	11.9	25	141	50	2,164	1.5	171	
Maximum	210	21.0	0.5	1,180	33	63	370	61	5,300	10.0	300	
Minimum	10	5.0	0.5	29	0.25	20	3	4	360	1.0	50	

Number of Cr Assay is 101 samples collected at east coast.

Lithological code Mc; Palaeocene pyroclastics
Number of Samples 81

(Unit; ppm except Hg)

	Cu	Pb	Ag	Zn	As	Hg (ppb)	Ni	Co	Mn	Mo	Cr	Remarks
x̄	50	5.3	0.5	121	4.3	22	33	21	964	1.1	1,151	
1 σ value	103	7.7	-	210	11.3	33	110	38	1,658	1.5	9,461	
1.5 σ value	147	9.2	-	276	18.2	40	199	51	2,175	1.7	27,123	This value estimate as threshold
2 σ value	212	11.1	-	363	29.5	49	361	69	2,852	1.9	77,765	
Maximum	970	110	0.5	3,400	210	450	850	73	48,000	5.0	63,000	
Minimum	7	5	0.5	50	0.7	20	3	3	290	1.0	50	

Number of Cr assay is 32 samples collected along east coast.

Lithological code Dip; Eocene sediments
Number of Samples 318

	Cu	Pb	Ag	Zn	As	Hg (ppb)	Ni	Co	Mn	Mo	Cr	Remarks
x̄	46	5.2	0.5	118	1.2	23	28	25	1,278	1.0	194	
1 σ value	75	7.0	-	203	3.2	35	103	36	2,209	-	1,002	
1.5 σ value	96	8.0	-	266	5.0	42	198	44	2,903	-	2,274	This value estimate as threshold
2 σ value	123	9.2	-	348	7.9	52	381	54	3,816	-	5,161	
Maximum	1,030	90	0.5	2,800	160	340	3,500	210	42,000	1.0	29,000	
Minimum	14	5	0.5	43	0.25	20	3	10	510	1.0	50	

Number of Cr assay is 314 samples collected along east coast.

Lithological code Ab; Eocene pyroclastics
Number of Samples 1,121

(Unit; ppm except Hg)

	Cu	Pb	Ag	Zn	As	Hg (ppb)	Ni	Co	Mn	Mo	Cr	Remarks
$\bar{x}$	48	5.1	0.5	93	1.4	20.2	17	22	996	1.1	156	
1 σ value	94	5.8	-	164	4.1	23	33	35	1,634	1.4	523	
1.5 σ value	131	6.1	-	216	6.8	25	44	45	2,092	1.7	957	This value estimate as threshold
2 σ value	183	6.5	-	285	11.4	26	61	56	2,680	1.9	1,751	
Maximum	260	26.0	0.5	550	98	460	700	81	4,000	24	9,400	
Minimum	2	5.0	0.5	13	0.25	20	3	3	100	1	50	

Number of Cr assay is 245 samples collected along east coast.

Lithological code Bic; Late Cretaceous basalt
Number of Samples 18

(Unit; ppm except Hg)

	Cu	Pb	Ag	Zn	As	Hg (ppb)	Ni	Co	Mn	Mo	Cr	Remarks
$\bar{x}$	88	5.0		127	1.5	20	235	46	1,512	1.0	4,122	
1 σ value	148	-		169	2.8	-	592	80	1,840	-	22,350	
1.5 σ value	192	-		194	3.9	-	939	105	2,030	-	45,897	This value estimate as threshold
2 σ value	249	-		223	5.4	-	1,488	137	2,240	-	102,485	
Maximum	320	5.0		280	5.7	20	2,000	210	2,440	1.0	75,000	
Minimum	52	5.0		94	0.25	20	77	24	1,090	1.0	500	

Number of Cr assay is 18 samples.

Lithological code Is; Cretaceous ultramafics
Number of Samples 426

	Cu	Pb	Ag	Zn	As	Hg (ppb)	Ni	Co	Mn	Mo	Cr	Remarks
x̄	41	5.0		77	1.03	23	1,011	89	1,309	1.0	11,766	
1 σ value	75	-		125	2.4	35	3,706	196	2,016	-	53,317	
1.5 σ value	102	-		159	3.6	42	7,094	290	2,501	-	113,495	This value estimate as threshold
2 σ value	139	-		202	5.5	51	13,580	430	3,104	-	241,597	
Maximum	1,040	5.0		420	14.0	110	6,200	530	5,800	1.0	161,000	
Minimum	8	5.0		21	0.25	20	7	8	210	1.0	50	

Number of Cr assay is 426 samples.

Lithological code Qd; Dioritic rocks
Number of Samples 646

(Unit; ppm except Hg)

	Cu	Pb	Ag	Zn	As	Hg (ppb)	Ni	Co	Mn	Mo	Cr	Remarks
x̄	32	5.2	0.51	69	1.2	20.4	13	16	749	1.03	76	
1 σ value	65	6.9	0.58	120	4.2	25	23	27	1,284	1.3	134	
1.5 σ value	92	7.9	0.61	158	7.8	27	31	34	1,682	1.4	177	This value estimate as threshold
2 σ value	131	9.1	0.65	208	14.5	30	42	43	2,202	1.6	235	
Maximum	340	98	4	1,330	170	300	91	72	50,000	7	300	
Minimum	1	5	0.50	13	0.25	20	1.5	1.5	150	1	50	

Number of Cr assay is 44 samples collected along east coast.

2) Histogram

Frequency dispersion histograms for each detected element in each lithological code are made by logarithmic scale with 1/2 standard deviation unit as shown in Appendix-6.
Each histogram features for each element are as follows.

Cu; Histogram of copper for each lithological code shows normal logarithmic dispersion except code Bic. High grade dispersion in codes Lu, Ab is not enough. In codes Ca, Pa, Mc and Mi, low grade side dispersion is not enough.

Histogram for code Bic seems to show irregular logarithmic dispersion because of little amount of samples. Maximum content of 1,040 ppm is included in code Is (Cretaceous ultramafics).

Pb; Histogram does not show normal logarithmic dispersion for samples are almostly under detection limit. Maximum content of 110 ppm is included in code Mc (Eocene pyroclastics)

Ag; Histogram does not show normal logarithmic dispersion for samples are almostly under detection limit. Maximum content of 4 ppm is included in code Qd (dioritic rocks).

Zn; Zn histogram shows normal logarithmic dispersion. In codes Lu, Mc and Dip, low grade side dispersion is not enough. Histogram for code Bic show irregular logarithmic dispersion because of the little amount of samples. Maximum content of 3,400 ppm is included in code Mc (Eocene pyroclastics).

As; As histogram for code Il + Ka, Pa, Lu, Dip and Ab shows normal logarithmic dispersion. In other codes, high grade dispersion is not enough. This cause seems to apply the value of the detection limit x 1/2 for samples under detection limit. Maximum content of 210 ppm is included in code Mc (Eocene pyroclastics).

Hg; Extreme accumulation of dispersion is observed at 20 ppb which is the assumed grade under detection limit. Hg histogram does not show normal logarithmic dispersion. Maximum content of 460 ppb is included in code Ab (Palaeocene pyroclastics)

Ni; Ni histogram shows normal logarithmic dispersion. In codes Cal, Di, Dip and Bic, low grade dispersion is not enough. High grade dispersion in code Is is not enough. Maximum content of 6,200 ppm is included in code Is (Cretaceous ultramafics)

Mn; Mn histogram shows normal logarithmic dispersion. In codes Pa, Dip and Bic, low grade dispersion is not enough. Maximum content of 24 ppm is included in code Qd (dioritic rocks).

Mo; Extreme accumulation of dispersion is observed at 1 ppm which is the assumed grade under detection limit. Mo histogram does not show normal logarithmic dispersion. Maximum content of 24 ppm is included in code Ab (Palaeocene pyroclastics).

Cr; In some codes, there are few analyzed number for all samples were collected along east coast. Therefore many histograms does not show normal logarithmic dispersion. Generally the number of low grade side samples are lack. Its cause seems come from ophiolite zone. Maximum content of 161,000 ppm is included in code Is (Cretaceous ultramafics).

3) Cumulative frequency

Cumulative frequency curves corresponding to the above mentioned histograms are shown Appendix-6. They have a transition point between mean value M + 1σ to mean value M + 2σ in each code. This justifies an estimated mean of M+1.5σ value as threshold value.

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

Cu; On codes Ca, Cal, Qd, Mc, Dip, Ab, Bic and Is, transition point is observed between M + 1σ value and M + 2σ value. They are seen to the threshold value of mineralization anomaly.

Pb,Ag; Almost all samples are under the detection limit and the histogram does not show normal logarithmic dispersion. Transition points are not clear.

Zn; On codes Pa, Cal, Dip, Ab and Qd, transition points are observed at M + 2σ value. On codes Il + Ka, Ca, Lu, Di, Mc and Bic, transition points are observed at M + 1σ value. They are seen up to the threshold value of mineralization anomaly.

As; On all codes except codes Pa and Qd, transition points are observed at M + 1σ value to M + 2σ value. They are seen up to the threshold value of mineralization anomaly.

Hg, Mo; Almost all samples are under the detection limit and the histogram does not show normal logarithmic dispersion. Transition points are not clear.

Ni; On all codes except codes Is and Lu, transition points are observed at M + 0.5σ value to M + 1.5σ value. They are seen up to the threshold value of anomaly.

Co; On all codes except codes Cal, Bic and Is, transition points are observed at M + 1σ value to M + 2σ value. They are seen up to the threshold value of anomaly.

Mn; On all codes except code Di, transition points are observed at M + 1σ value to M + 2σ value. They are seen up to the threshold value of anomaly.

Cr; On codes Pa, Cal, Dip, Ab and Bi, transition points are observed at M + 0.5σ value to M + 1.5σ value. In other codes, there are few analyzed samples and the samples are originally from the rich Cr bearing ophiolite. Therefore transition points are not clear.

4) *Correlation coefficient*

Correlation coefficient between elements for all samples is shown in Table- 5 . High correlation is observed between Cu and Zn, Zn and Mn, Co and Ni, Ni and Cr.