REPUBLIC OF THE PHILIPPINES

REPORT ON GEOLOGICAL SURVEY
OF
MINDORO ISLAND

CONSOLIDATED REPORT

AUGUST 1984

JAPAN INTERNATIONAL COOPERATION AGENCY
METAL MINING AGENCY OF JAPAN

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PREFACE

The Government of Japan, in response to the request of the Government of the Republic of the Philippines, decided to conduct the investigation in relation to the survey of the ore deposit including geological survey in order to confirm the potential of occurrence of mineral resources in Mindoro Island of the Philippines, and entrusted its execution to the Japan International Cooperation Agency (JICA). Because of its essential qualities that it belongs to a special field involved in the survey of geology and mineral resources, JICA consigned it to the Metal Mining Agency of Japan (MMAJ).

The survey was conducted for three years from fiscal 1981 to 1983 and accomplished as scheduled under close cooperation with the Government of the Republic of the Philippines and its various Agencies, especially with Bureau of Mines and Geo-Sciences (BMG) of the Ministry of Natural Resources.

This report is the compilation of the results of the whole survey during these three years.

We wish to express our heartful gratitude to the Government of the Republic of the Philippines and its appropriate agencies and organizations concerned, as well as the Ministry of Foreign Affairs, the Ministry of International Trade and Industry, the Embassy of Japan in the Philippines and the companies concerned for the operation and support extended to the Japanese survey team.

June 1984

Keisuke Arita
President
Japan International Cooperation Agency

Masayuki Nishiie
President
Metal Mining Agency of Japan

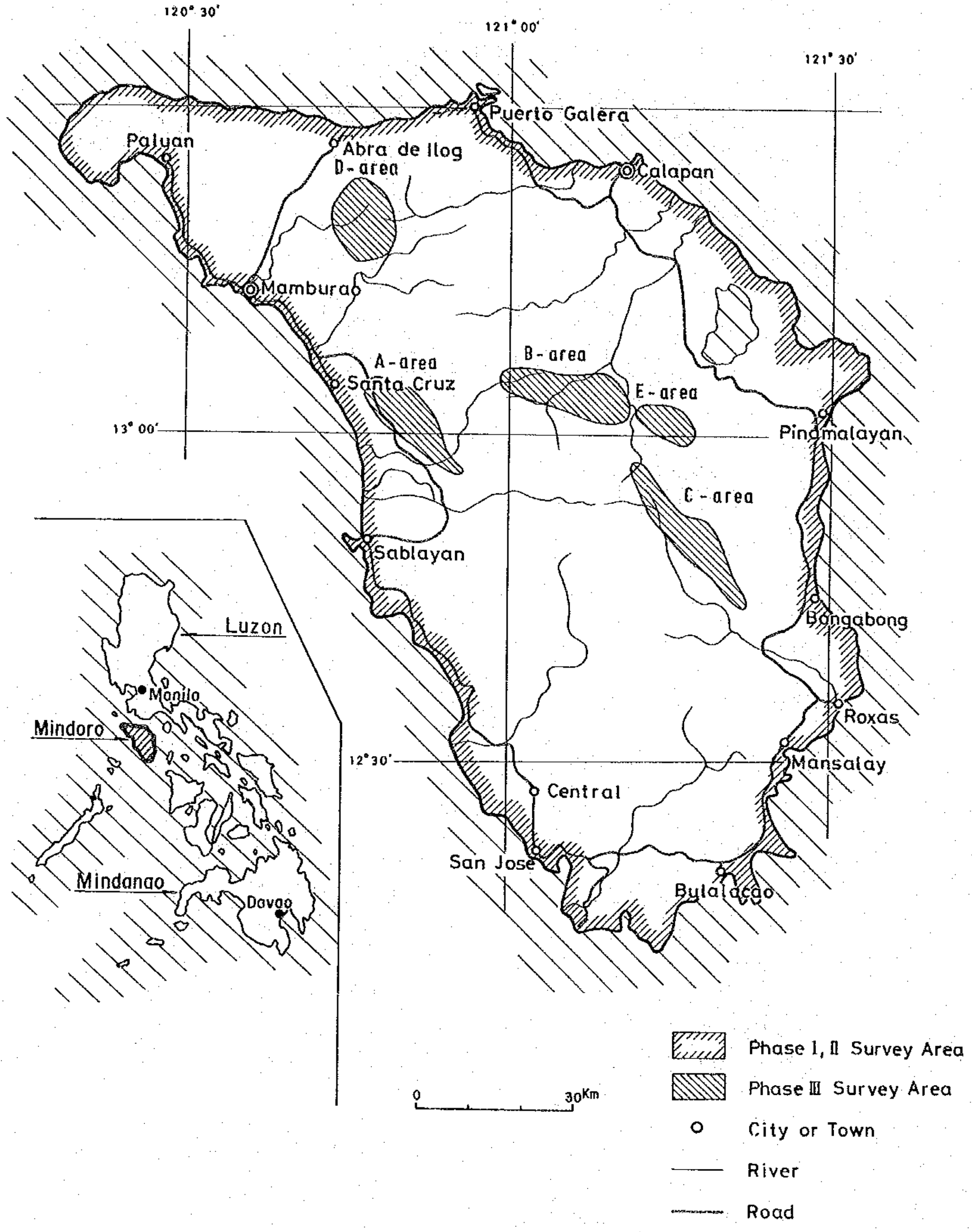

Fig. 1 Location Map of the Survey Area

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ABSTRACT

The geological survey of Mindoro Island, Philippines, aimed on the evaluation of potential for all kinds of mineral resources through clarification of the geological structure, favorable geological environment for mineralization and mineral showings.

In Phase I airborne magnetic survey, photo-interpretation, geological survey and geochemical survey were carried out for all of Mindoro Island in order to clarify the geological structure and mineralization. In Phase II, geological and geochemical surveys were conducted for areas remaining untouched and over around the area where mineral showings were found in Phase I. In Phase III, geological survey including trenching, geochemical survey for soil and stream sediment and ground magnetic survey were carried out for chrome, iron and copper areas which were considered to be promising from the results of Phase I and II surveys.

As a result, the stratigraphy and the geological structure of Mindoro Island became clear, and the occurrences of chromite, iron and others were clarified as shown in the inventory table.

Roughly speaking, the geology of Mindoro has older pre-Cretaceous formations in the central area, tending to NW–SE with the younger post-Palaeocene formations which distribute zonally on both sides of these. These older formations are composed mainly of pelitic metamorphic rocks and basic lavas, while the younger formations are neritic sedimentary rocks.

As a whole, the geological structure is an anticlinal structure with a NW–SE axis, a central uplift zone of older formations at its core and the overlying formations becoming younger towards the periphery.

The fracture systems are characterized by a NW–SE system, which is represented by the Mindoro Fault and the Wasig Fault, and a NE–SW system which is represented by the Mamburao Fault. The former system have clearly controlled the intrusion of the Ultramafic complex.

The occurrence of various ore deposits and the genetic relationship between ore deposits and igneous rocks were clarified as the followings.

1. Placer gold occurs in and around Puerto Galera in the northeast and San Jose in the southwest. Gold grains are considered to have derived from the Halcon metamorphics in the former case and from conglomerate beds of the Bongabong Group in the latter case, and have reprecipitated in a small scale.

2. Copper showings are of a vein type. They are distributed near the Mindoro Fault and the Wasig Fault and are related to Palaeogene dioritic rocks. The showings in the upper reaches of the Pula River in the east are locally rich in gold and copper. Geochemical survey for soil did not detect any apparent anomalies, that indicates the copper mineralization is quite limited.

3. Many chromite showings occur in the Ultramafic complex and can be classified into two types, viz,layered (or banded) and massive. The former type which is represented by Ogos orebody in the center in the eastern area is relatively large in scale and the latter, usually in small scale. Trenching for determination of the scale of chromite showings disclosed that Ogos orebody is 6.5 m in width with 33% of Cr_2O_3 and other showings are of small-scale lens.

4. Iron deposits concentrated in the northern part of the central range are composed of magnetite which is of a metasomatic type related to the dioritic rocks of Palaeogene. Ground magnetic surveys carried out for three promising deposits have verified that each ore reserve can be estimated to grow up to ten million ton level.

5. Barite deposits are of a vein type and are probably related to the Palaeogene dioritic rocks. The geological survey disclosed that the showing at Mansoil point in the southeast is of a middle scale in width and length.

6. Coal deposits occur in the Miocene sandstone – mudstone alternation beds. Seven bituminous coal seams of 0.75 to 2.00 m thick were confirmed. It is presumed that these seams are strongly disturbed underneath since folding structures have developed and that makes the coal exploitation difficult.

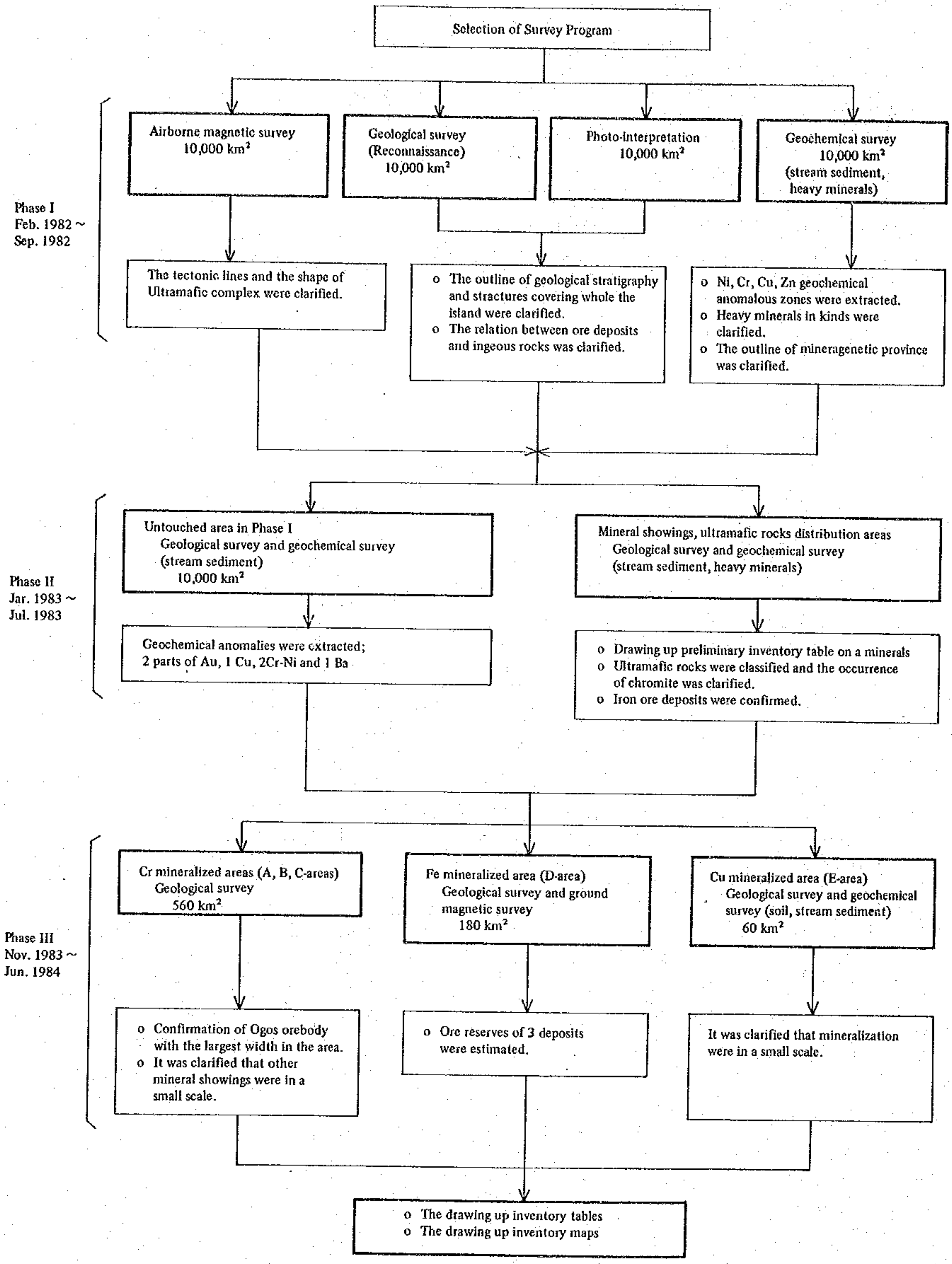


Fig. 2 Flow Sheet of the Survey

I. GENERAL REMARKS

CHAPTER 1. OUTLINE OF THE SURVEY

1–1 Purpose and Scope of the Survey

Some geological surveys were carried out on Mindoro Island and reported many deposits and showings of various ore types, including gold, copper, iron, nickel, chrome, barite, coal, silica and clay etc. These surveys were conducted in limited areas mainly for exploration and rarely referred to the internal relationship between the mineralization and geological structure or the igneous activities.

The purpose of this survey is, above all, to clarify the geological structure and the favorable geological environment for mineralization in order to evaluate the potential for all kinds of mineral resource exploitation.

1–2 Details of the Survey

This survey was carried out for all over Mindoro Island (10,000 km^2) in the period of three years from 1982 to 1984.

As the survey area was broad, the reconnaissance survey was performed for the whole area in Phase I and II, and detailed survey for the most promising area in Phase III.

The survey works and the results in every Phase are as follows.

1–2–1 Phase I Survey

In Phase I, airborne magnetic survey, photo-interpretation, geological survey and geochemical survey were carried out in order to clarify the geological structure and the favorable geological environment for mineralization.

A route mapping on a scale of 1:50,000 and a mineral showings checking were done along main routes which were perpendicular to the geological structure.

Stream sediment samples were collected from main creaks which crossed the geological routes and were analyzed for polyelement. Panned samples were also taken from almost all of the drainage systems to study the kind and distribution of heavy minerals.

Based on the field data obtained by the geological survey, photo-interpretation including field checks were conducted on aerial photographs on scales of 1:40,000 and 1:15,000.

Interpretation of the geological structure was made on the basis on analyses of airborne magnetic survey data obtained by the Bureau of Mines and Geo-sciences of the Philippines (BMG).

As a result, these surveys established a generalized stratigraphy and clarified geologic structures of Mindoro Island.

Roughly speaking, the geological structure is characterized by the uplift zone, which extends in the central area in a NW–SE direction and is accompanied with basins on both sides. Metamorphic rocks of pre-Cretaceous are at the core of the uplift zone and the overlying formations are becoming younger towards the periphery. The most distinct structure in the area has a NW–SE system, which includes a large-scale fault developed at the boundary between the above-mentioned uplift zone and the basins. Along this fault, intrusion of ultramafic rocks of Late Mesozoic and dioritic rocks of Palaeogene resulted to copper, chrome, iron and others mineralization.

The geochemical survey proved that the elements of Ni, Cr, Cu, Zn and (Ag) were effective as trace elements and extracted five geochemical anomalous zones of Ni-Cr (Ni 300 – 1,900 ppm, Cr 700 – 6,500 ppm) in the ultramafic zone, two zones of Cu-Zn (Cu 100 – 450 ppm, Zn 150 – 520 ppm) in a slate zone of the Mansalay Formation and two zone of Ag (Ag 1.2 – 3.2 ppm) in a limestone zone of the Sablayan Group.

1–2–2 Phase II Survey

In Phase II, geological and geochemical surveys were carried out for areas remaining untouched, and around the areas where mineral showings had been found in Phase I.

A route mapping on a scale of 1:20,000 was performed along the survey routes and stream sediment samples were collected from the creeks which crossed the geological routes. The detailed geological and geochemical surveys were made in the Ultramafic complex zones where chromite deposits might occur on the base of the Phase I survey. The study on chromite distribution in the complex zones was also done on the panned samples.

As a result, the geological survey confirmed that the geological stratigraphy and the structure proposed by the Phase I are mostly compatible in the Phase II survey area. The survey clarifield the occurrence of chromite in the Ultramafic complex and confirmed iron and copper mineralized zones as other promising showings.

The survey results of Phases I and II were compiled into the preliminary inventory table and the mineragenetic province map.

1–2–3 Phase III Survey

In Phase III, the detailed survey was carried out for chromite deposits in the Ultramafic complex, iron deposits in the limestone and copper deposits in order to check their continuity. All of these deposits were considered to be promising from the results of the Phases I and II

Table 2 List of the Survey Members

		Phase I	Phase II	Phase III
Japanese Member (MMAJ)	Planning and Negotiation	Nobuhisa Nakajima Ken Nakayama Kyoichi Koyama*	Takahisa Yamamoto Kazuhiko Uematsu Jiro Osako*	Toru Miura Yoshitaka Hosoi Yukihiro Minami Takahisa Yamamoto Jiro Osako*
	Geological Survey	Hiroshi Fuchimoto** Haruo Watanabe Tetsuo Sato Hiroyuki Hida	Hiroshi Fuchimoto** Hideo Suzuki Mikio Kajima Akira Takigawa Yoshiaki Shibata	Hiroshi Fuchimoto** Mikio Kajima Yoshiaki Shibata Nobuhiro Goto
	Photo-interpretation	Yoshiaki Shibata	–	–
	Airborne Magnetic Survey	Asahi Hattori Manabu Kaku Yoshinari Azuma Yaichi Tanaka Susumu Sasaki	–	–
Filipino Member (BMG)	Planning and Negotiation	Juanito C. Fernandez Francisco A. Comsti Carlos F. Teodoro Guillermo R. Balce	Juanito C. Fernandez Guillermo R. Balce Mariano G. Pacis	Juanito C. Fernandez Guillermo R. Balce Mariano G. Pacis
	Geological Survey	Mariano G. Pacis** Lope M. Cariño Jessie S. Miguel Jose R. Salvado Jesus Rotoni	Mariano G. Pacis ** Lope M. Cariño Jessie S. Miguel Jesus Rotoni Eleazar Mantaring Ronaldo Miranda	Mariano G. Pacis** Lope M. Cariño Ronaldo Miranda Eleazar Mantaring William Bondame Ariel Malicse
	Photo-interpretation	Nestor P. Punsal Jr.	–	–
	Airborne Magnetic Survey	Octavio C. Daclison Alexander M. Lacanilao Reynaldo L. Villela Romeo B. Zambarrano Enrico B. Zuño Honorio B. Cabanban Eduardo B. Alforte Anselmo Abungan	–	–

* Manila Representative
** Team Leader

surveys.

The detailed geological survey made route maps on a scale 1:10,000 for each area. It was accompanied with trenching in the chromite areas, ground magnetic survey in the iron area and geochemical survey for soil and stream sediment in the copper area.

As a result, the details of each deposit became clear and the survey results obtained in the three years were compiled into the final inventory table and the inventory map.

The outlines of each deposit checked in Phase III are as follows.

(1) Chromite showings occur in the Ultramafic complex and can be classified into two types, viz, layered and massive. The layered showings in dunite of large-scale complex, which are rich in dunite, are considered to have some extension, while massive showings in sheared zone or harzburgite are in a small scale.

(2) Iron deposits occurring in limestone are magnetite deposits of a contact metasomatic type which were formed by Palaeogene dioritic rocks. Each ore reserve of Nagsabongan, Lasala and Lapa-ao deposits can be estimated to grow up to ten million ton level from the ground magnetic survey.

(3) Copper showings in the upper reaches of the Pula River are of a vein type and they are probably related to the Palaeogene dioritic activity. The results of geological and geochemical surveys indicated the copper mineralization was locally limited.

The contents of the three years field work are shown in Table 1.

Table 1 Outline of Field Work in Phase I, II & III

	Phase I	Phase II	Phase III
Survey Period	Feb. 8 ~ May 8, 1982	Jan. 31 ~ May 5, 1983	Nov. 21, 1983~Mar. 27, 1984
Survey Area	10,000 km^2	10,000 km^2	800 km^2
Geological Survey	925 km	844 km	378.6 km
Photo-interpretation Field-Check	86 km	–	–
Geochemical Survey Number of Samples	528 pcs	1,210 pcs	618 pcs
Geophysical Survey			
Aeromagnetic	6,370 km	–	–
Magnetic	–	–	29.62 km

1–3 Survey Member

The personnel who participated in the field work as well as in interpretation is shown in Table 2.

CHAPTER 2. OUTLINE OF THE SURVEY AREA

2–1 Location and Accessibility

Mindoro Island lies about 130 km south of Manila across the Verde Island Passage which is 15 km wide. To Calapan, the capital town of Mindoro Oriental, with a population of 67,000, it takes 4.5 hours both by car and ferry via Batangas from Manila. To Mamburao, the capital town of Mindoro Occidental with a population of 14,000, and to San Jose, the largest town in the island, with a population of 80,000, 30 or 40 minutes by air from Manila.

The road system in Mindoro is such poor that the main access is only one provincial road running around the island along the coast, except a 15 km section between Puerto Galera and Abra de Ilog, and there is no transportation facilities available on the west side of the island in the rainy season due to few bridges over the big rivers.

2–2 Topography and Drainage

The topography of the island is characterized by the central mountain ranges higher than 1,500 m above the sea level, lying in a NW–SE direction. Among those mountains, Mt. Halcon (2,505 m) and Mt. Baco (2,488 m) tower. In general, the topography is rugged. In particular, the eastern side of the ranges is steep, because of large tectonic lines.

The plain in the island is less than 20% of the whole island in area. It extend narrowly along the coast except in Calapan and San Jose.

Many drainages run in the E–W direction which is a right angle to the central ranges and some in the south are in the N–S direction due to the structural lines.

2–3 Climate and Vegitation

Two seasons which are the northeast monsoon and southwest monsoon dominate in the Philippines, influenced by the Southeast Asia monsoon zone lying over. So local climates are quite different from each other.

In Mindoro Island, while the west side of the central ranges has rainy season from June to November as the southwest monsoon prevails and has dry season from December to May as the northeast monsoon little influence the area, the east side is covered by rain throughout the year. And it often causes overflowing in the lowland areas in big rivers like the Alag River, the Bukayao River, the Magasawangtubig River and the Bongabong River, after heavy rainfalls and distroy agricultural crops.

As for vegetation, while broad leaf trees called Balete or Agopanga cover much in the east side, many mountains in the west are bare due to deforestation by burning.

Ⅱ. GEOLOGY AND ORE DEPOSIT

CHAPTER 1. GEOLOGY

1–1 General Remarks

The Philippine archipelago is divided into two structural units according to Gervasio (1966); the mobile belt and the stable region. The former, extending longitudinally through Luzon, Visayas and Mindoro, is characterized by concentration of earthquake epicentres, numerous active and recently inactive volcanous, prevalence of Mesozoic to Tertiary igneous rocks, distribution of porphyry copper deposits and high-grade deformation and metamorphism of rocks. While the latter, the western side of the boundary, including southwestern parts of Mindoro Island, Palawan Island, Sulu archipelago and so on, is aseismic in nature and shows virtual absence of Tertiary igneous activity.

Mindoro Island belongs to the western one of four major physiographic provinces which are proposed by Balce et al. (1981). The province constitutes the belt of mountain ranges in the western side of the mobile belt. The ophiolite belts of both Ilocos-Mindoro and Antique are passing in the western province together with paired Magmatic belt of both Luzon Central Cordillera-

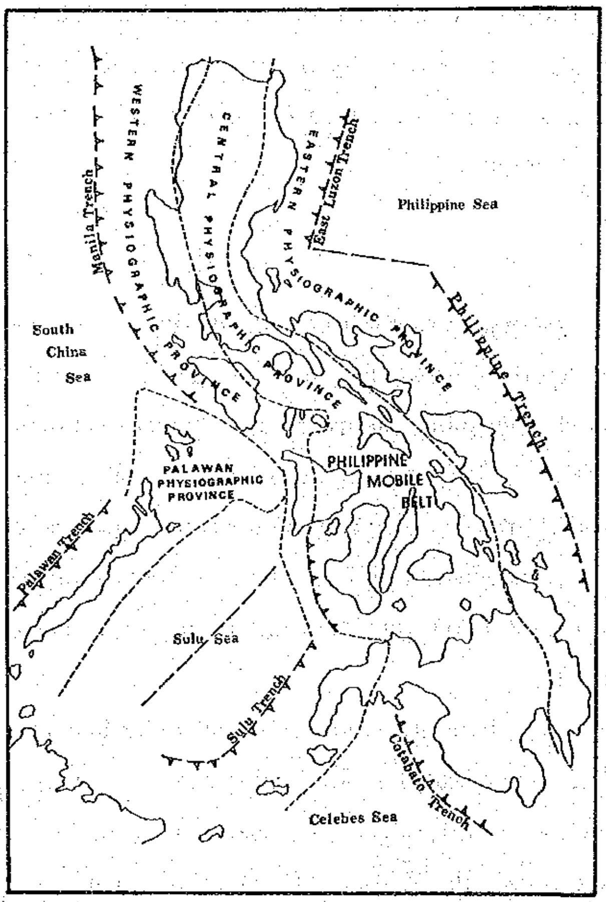


Fig. 3 Maior Physiographic Elements in the Philippines

Marinduque and Negros-Zamboanga, respectively. Balce et al. (1981) also inferred that the basement considered to be Carboniferous to Early Jurassic in Mindoro was continental crust as well as other areas surrounding the Sulu Sea. Holloway (1981) and other authors suggested that the crustal material comprising the North Palawan block which consists of Mindoro Island and the Reed Bank area had once formed a part of the mainland of Asia and had attached to southern China.

In Mindoro Island, pre-Cretaceous rocks are distributed in the central part in the direction of NW–SE, which are overlain by Cenozoic rocks dipping northeast in the eastern side and southwest in the western. It shows a large anticlinal structure.

The stratigraphy of Mindoro is divided in an ascending order into the Halcon metamorphics, the Baco Group, which comprises the Mansalay Formation and the Lumintao Formation, the Mamburao Group, the Sablayan Group, the Bongabong Group, the Socorro Group and the Alluvial deposits. And intrusive rocks consist of big Ultramafic complex, a small body of acidic to intermediate rocks such as granodiorite, quartz diorite, diorite and diorite porphyry, and small-scale basic rocks of dolerite and gabbro.

This survey was contributed to collect the basic geological data on the whole area of Mindoro Island and to establish the stratigraphy of Mindoro. Concerning the Ultramafic complex, moreover, the distribution was completely revealed, and the lithological, petrological and structural characteristics were clarified.

1–2 Previous Works

A small numbers of reports were published on geology and ore deposits of Mindoro Island; most of them had been described on the northern part, around Abra de Ilog and Calapan, and on the southern part, around Bongabong, Mansalay and Bulalacao. But many unpublished reports of the Bureau of Mines and Geo-Sciences described regional geology or mineralization were available to refer. All of these reports were utilized for compilation as references.

Over the northern part, Caagusan (1966) studied the petrography of the metamorphic rocks. And Hashimoto & Sato (1968a) confirmed Eocene formation by Paleontological work and conducted a structural analysis.

Over the southern part, there are relatively many published reports on paleontology and stratigraphy. Teves (1953) investigated around the area of Mansalay and Bongabong, and tried to establish the stratigraphy of Mesozoic and Cenozoic rocks. Andal et al. (1968) established the stratigraphy of Mesozoic rocks, the Mansalay Formation, which crops out to the west of Mansalay, and determined its age as from Middle Callovian to Oxfordian (upper Middle to lower

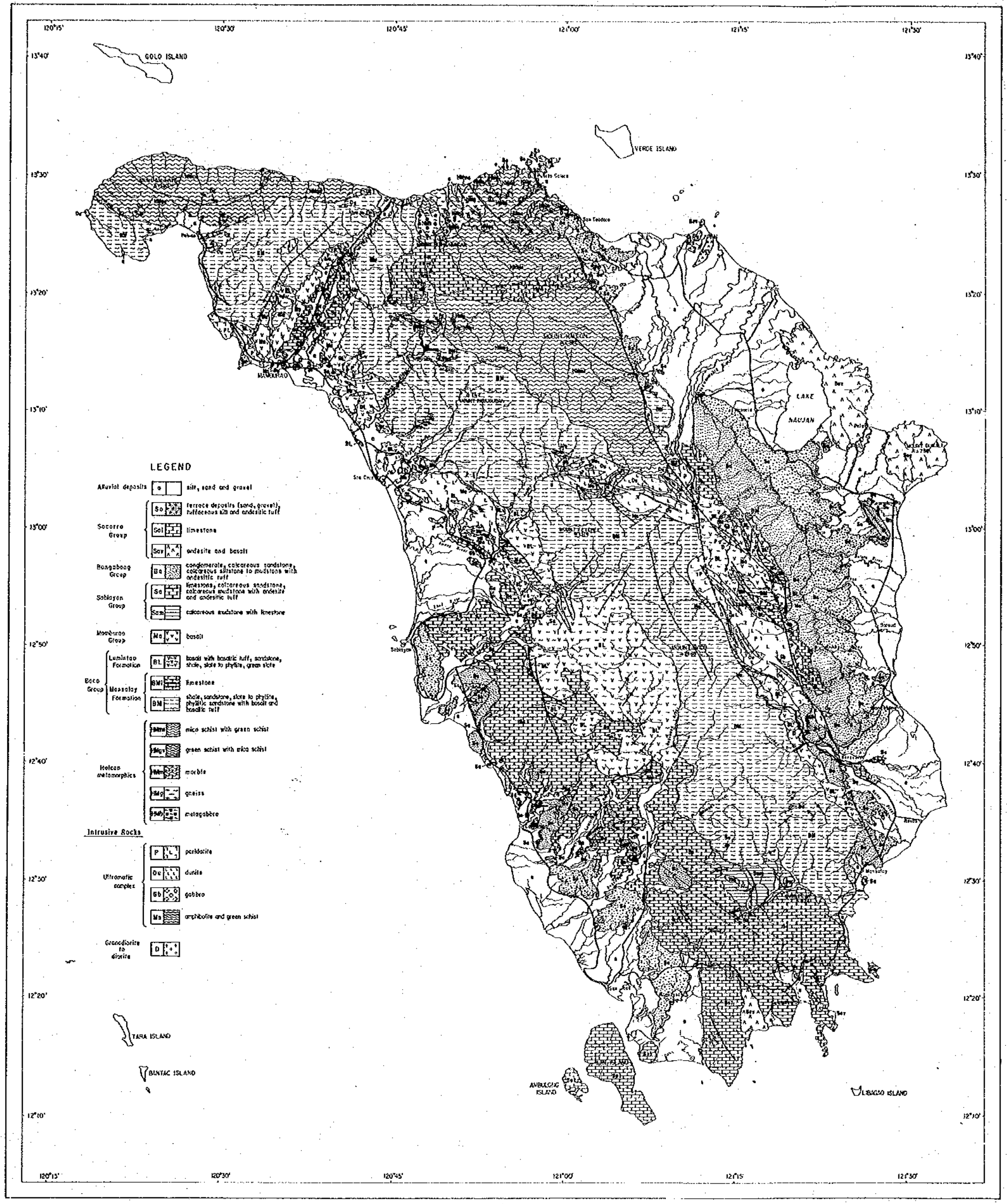


Fig. 4 Geological Map of the Survey Area

Table 3 Generalized Stratigraphic Section of the Survey Area

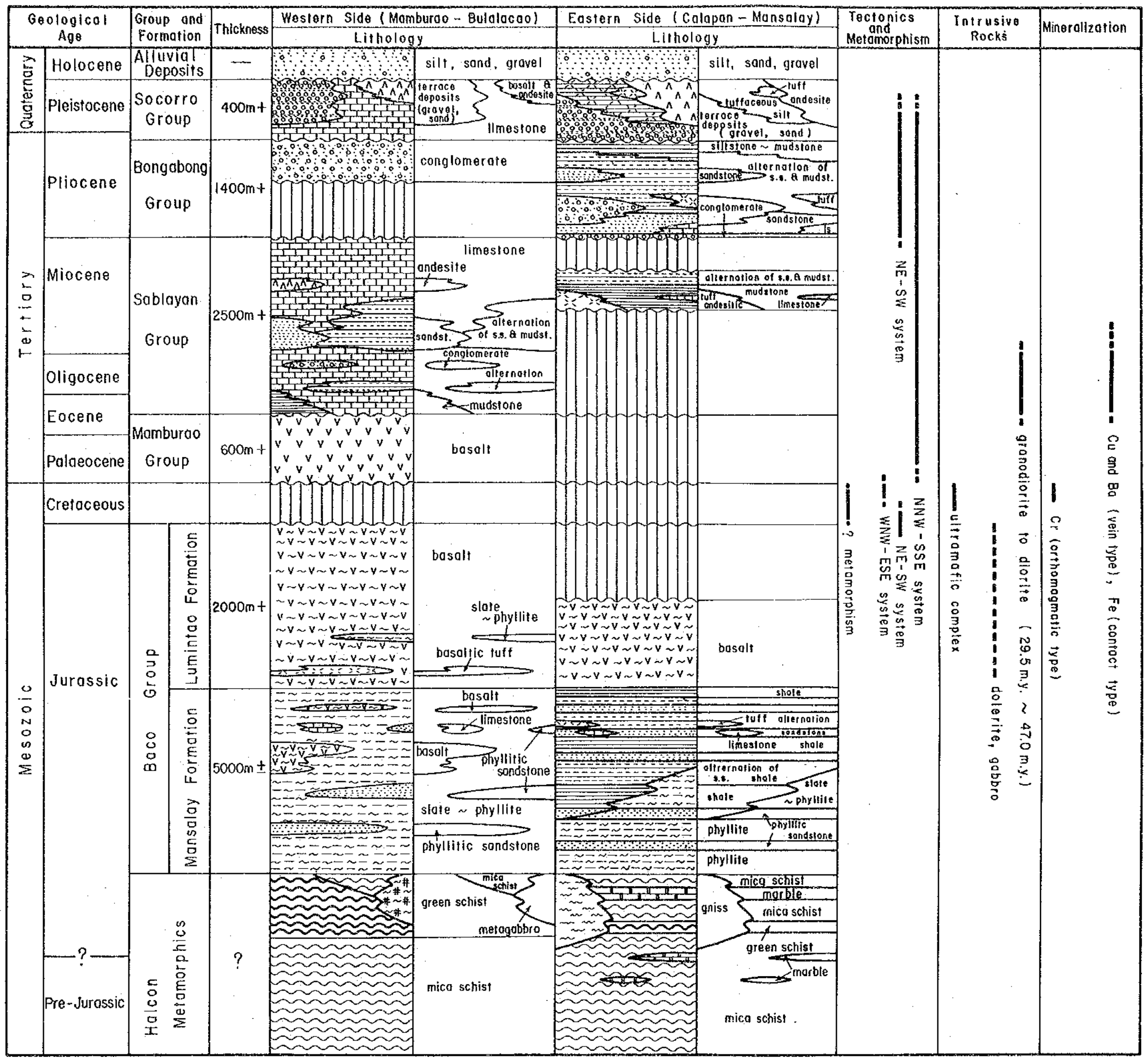


Table 4 Stratigraphic Correlation

Geologic Time: Era	Period	Epoch	Age	Teves (1953)	Weller & Vergara (1955)	Andal et. al. (1968) Hanzawa & Hashimoto (1970)	Miranda (1980)	JICA MMAJ (1982 ~1984)
Cenozoic	Quaternary	Holocene		Recent Deposits	Alluvium		Alluvium, San Jose Terrace Gravel and Eplog Volcanics	Alluvial Deposits
		Pleistocene	Late	Oreng Formation	Eplog Lava Flows and High-level Sand & Gravel	Sumagui Formation and Balanga Formation		Socorro Group
			Early					
	Tertiary	Pliocene	Late				Balanga Formation, Ambulong Limestone	
			Early	Balanga Formation		Famnoan Formation, Barubo Sandstone	Punso Conglomerate, San Teodoro Volcanics	Bongabong Group
		Miocene	Late	Famnoan Formation, Barubo Sandstone	Pocanil Formation	Pocanil Limestone	Pocanil Formation	Sablayan Group
			Middle	Pocanil Limestone	Mato-ang Limestone, Napisian Formation		Napisian Coal Measure, Napisian Limestone	
			Early	Tangon Formation	Bulalacao Limestone	Tangon Formation	Tangon Formation	
		Oligocene	Late	Camangui Sandstone		Bugtong Limestone and Camangui Sandstone	Bugtong Limestone	
			Early		Bandao Limestone			
		Eocene	Late	Mansiol Conglomerate		Eocene Formation	Agbahag Conglomerate	Mamburao Group
			Early					
		Paleocene						
Mesozoic	Cretaceous				Mesozoic Sandstone		Abra de Ilog Formation	
	Jurassic		Late	Mansalay Formation		Mansalay Formation	Mansalay Formation	Baco Group: Lumintao Formation
			Middle					Baco Group: Mansalay Formation
			Early					Halcon Metamorphics
	Triassic			Wasig Formation				
Paleozoic	Permian			Mindoro Metamorphics				
	Carboniferous						Mindoro Metamorphics	

Upper Jurassic). Hashimoto and Sato (1968b) conducted a paleontological work and a structural analysis over the region of the west and northwest of Mansalay, and proposed the distribution of Eocene formation. Hashimoto and Sato (1969) discussed the stratigraphy of Cenozoic rocks proposed by Teves (1953), conducting paleontological work. Weller and Vergara (1955) carried out a detailed regional mapping on the Bulalacao coal field.

Besides, in 1974, Bureau of Mines (presently Bureau of Mines and Geo-Sciences) published the report on geology and mineral resources of Mindoro Island which compiled the internal reports.

1–3 Stratigraphy

The general stratigraphy of Mindoro Islands and the stratigraphic correlation between this survey and previous works are shown in Table 3 and 4 respectively.

1–3–1 Pre-Jurassic and Jurassic

Pre-Jurassic and Jurassic rocks composed of the Halcon metamorphics and the Baco Group are widely distributed in the area, which form the mountain range trending northwest to south-east.

(1) Halcon metamorphics

The Halcon metamorphics consist of metamorphic rocks showing green schist facies. They are included in the Mindoro metamorphics reported by Teves (1953) and the Basement Complex of the Bureau of Mines (1974).

Distribution: The rocks crop out around the northwestern coast and the area from Puerto Galera to Mt. Halcon.

Rock facies: The Halcon metamorphics are composed of mica schist, green schist, gneiss, metagabbro and marble.

Mica schist is distributed along the northwestern coast and around the Mt. Halcon. It is light grey to black in color and shows a banded structure and a clear schistosity. It consists mainly of muscovite and quartz. Segregated quartz vein is accompanied in some places. Under the microscopic observation, the mica schist is composed of muscovite-chlorite bands and quartz-plagioclase bands, and it shows a fibroblastic texture or a nematoblastic texture. The fact that the mica schist exposed in the Dulangan River on the east foot of Mt. Halcon contains many garnet crystals which are 2–3 mm in size, suggests that this mica schist was formed by the metamorphism of higher temperature than others. Moreover, the coexistence of biotite, muscovite and chlorite supports the idea that the metamorphism is the high-pressure type such as the Sanbagawa belt in Japan.

Green schist crops out around Paluan and to the south of Puerto Galera. The rock is light green to green in color and shows a clear schistosity. Under the microscope, it shows a nematoblastic texture and the constituent minerals are generally composed of epidote, chlorite, actinolite and plagioclase. It often contains a small quantity of calcite.

Gneiss is found around the Camarong River and is composed of very coarse-grained crystals of quartz, muscovite, plagioclase and potash-feldspar. The parallel alignment of the forming minerals, especially mica, makes a gneissose texture noticeably. Considering from the fact that the boundary between the gneiss and the crystalline schist is oblique to their schistosity and gneissosity in the Matobang River and to the southwest of Puerto Galera, the source rock of the gneiss is presumed to be acidic igneous rock intruded mainly into pelitic rocks.

The gneiss in this area has been known as the Mindoro gneiss, therefore, the rock name "gneiss" is given in this report. But it is considered to be gneissose granodiorite from the metamorphic grade of surrounding area.

Metagabbro crops out in the northern slope of Mt. Buruburungan. It appears dark green in color, and shows a coarse-grained texture made of hornblende and plagioclase.

Marble is distributed to the south of Puerto Galera and the north of Mt. Halcon. To the south of Puerto Galera, it alternates with crystalline schist or shows a lenticular form in crystalline schist. On the contrary, it forms a thick bed of over 1,000 m thick to the north of Mt. Halcon. These are generally white to light pink in color, though alternating parts often appear black to dark grey in color.

Photo-characteristics: The mica schist and green schist have the same characteristics with an extremely high resistant, medium drainage density, and a parallel-subdendritic drainage pattern. The mountain ridges are extremely angular, and the valleys are shaped in an open V. A joint is characteristically developed in these rocks. The marble shows a moderate resistance, and has rounded mountain ridges as its characteristic. The drainage density is very low. Gneiss and metagabbro are also of moderate resistant, but fine drainage of dendritic pattern is developed. The mountain ridges are relatively angular, while the valleys are in an open V shaped.

Geological structure: Field observation revealed that the schistosity of Halcon metamorphics corresponded to the bedding. Considering from the general trend of schistosity and distributions of green schists and marbles, an anticlinal structure with an axis trending N–S and plunging SW is recognizable around Puerto Galera and to the north of Paluan.

Age: Concerning the age of the source rock, it is estimated to be pre-Permian because of the discovery of fusulinid-bearing limestone pebbles in a conglomerate cropping out at Agbahag

Point, Mindoro (Koike et al., 1967). The relationship between the Halcon metamorphics and the Mansalay Formation is, however, considered to be conformable as mentioned afterward. Hence, the age may be Jurassic when the Mansalay Formation was deposited.

If the source rock is of Jurassic, the age of metamorphism is reckoned to be of Late Jurassic to Cretaceous which is the same age determined by K-Ar dating on the crystalline schist of the Sanbagawa metamorphic belt in Japan.

(2) **Baco Group**

The Baco Group consists of volcanic and clastic rocks which slightly or never undergone metamorphism. It is divided into two formations; the lower which is the Mansalay Formation, comprised predominantly of clastic rocks, and the upper which is the Lumintao Formation, composed mostly of volcanic rocks.

(2)–1 **Mansalay Formation**

The name "Mansalay Formation" was given to a formation which yielded fossils of Jurassic age and is exposed in the western part of Mansalay. This Jurassic formation has previously been thought to crop out only in the western and northwestern parts of Mansalay. According to the results of this survey, however, the beds formed primarily of slate and phyllite, which were found from the north to the central area, show the quite similar rock facies of their source rocks to the Jurassic formation exposed in the southeastern part, moreover both were intergradational and continuous in structure. Consequently, it is considered that the beds composed mostly of slate and phyllite are originally equivalent to the Jurassic formation and they are included in the Mansalay Formation.

Distribution: The formation is distributed in a long belt with a northwest-southeast direction from Mamburao to Mansalay.

Thickness: At the Amnay River and the Rayusan River (namely, the Patric River on the 1:50,000 topographic map), the formation is approximately 5,000 m thick.

Rock facies: The Mansalay Formation is principally formed of pelitic and psammitic rocks, and includes basic lava and tuff locally. Because these rock facies are different from each other according to metamorphic grade, they shall be explained concerning each area.

1 Rock facies of the southeastern sections

Sandstone and shale which are accompanied by the alternating beds of sandstone and shale, conglomerate and basic tuff mainly dominate.

Sandstone is mainly consists of white to greyish-white arkose sandstone, which is coarse-grained and rich in quartz crystals. A greyish-white to grey colored greywacke can sometimes be found. These are generally massive and poorly bedded. They form a thick bed, sometimes as thick as more than 750 m in the Sinolili River of the upper reaches of the Caguray River. The sandstone is partially interbedded with shale and limestone, and the thin layer of interstratified shale with the lenticular coal less than 1 cm in thickness is encountered in the Sinolili River.

Shale is grey to black in color and generally massive but locally well bedded. It forms a thick bed and reaches more than 900 m thick in the Sinolili River. Calcareous nodule is often found in shale, which contains fossils. Pelecypoda and gastropoda fossils are obtained from the shale which crops out in the upper reaches of the Caguray River and the tributary of the Balangan River. An ammonite fossil is also discovered in the Naigan River to the northwest of Mansalay. Although the outcrop of ammonite fossil was found only in the Naigan River on this survey, floats of ammonite were observed in the upper reaches and the tributary of the Balangan River, indicating that the horizon of ammonites extends to the Balangan River.

The alternating beds of sandstone and shale are well exposed in the upper reaches and the tributary of the Balangan River, where the thickness of bed varies from 10 cm to 50 cm. The beds reaches 650 m thick in the upper reaches of the Balangan River.

Conglomerate forms thin layers which are accompanied with sandstone. The gravels consist of quartz and grey or red chert, and their size ranges from granule to pebble.

Basic tuff shows green or red in color, most of which is fine-grained and thinly layered. The tuff exposed in the Taytay River of the tributary of the Caguray River, however, is thick, light green in color and coarse-grained. The thickness is more than 300 m.

2. Rock facies of the northern to central sections

They are mainly pelitic and psammitic as in the southeastern sections and are subjected to a low grade metamorphism with a range of slate to phyllite or indurated sandstone to phyllitic sandstone. These rocks intercalate basalt lava, basaltic tuff, limestone and conglomerate.

Phyllite and slate are generally calcareous and black to dark grey in color. The schistosity or cleavage is well developed and is very fissile. Those are often accompanied with segregated quartz veins of usually a few cm to unusually 1 m thickness. They form thick beds, sometimes exceed to thicker than 1,000 m in the vicinity of the Amnay River.

Indurated sandstone and phyllitic sandstone are greyish white to grey in color, arkosic, medium to coarse-grained and predominant in quartz. The indurated sandstone is massive, but the phyllitic sandstone often shows the alignment of minerals and flattened rock fragment. Those rocks are 10 – 200 m in thickness and intercalated in slate or phyllite.

The alternating beds of pelitic rocks and psammitic rocks are also encountered in some places, and a bed is mostly below 10 cm thick and the psammitic rocks are fine-grained. But, locally, the thickness of bed ranges from 1 to 5 m and the psammitic rocks are coarse-grained.

The thickness of the alternating beds are 100 to 300 m.

Basalt lava is dark green in color, and shows a clear pillow structure. It is interbeded in slate or phyllite, and the thickness is generally 20 – 50 m.

Basaltic tuff shows light green to green or reddish brown in color and it is phyllitic in northern part. The tuff is locally distributed and less than 100 m thick.

Limestone crops out in the Pagbahan River as a thick bed of 400 m and in the upper reaches of the Abra de Ilog River as a thin bed. These are massive rocks appearing grey to light grey in color, and are recrystallized.

Thin conglomerate beds are intercalated in slate and are found in two localities. The gravels are composed of greyish white chert, crystalline schist and quartz, and their size is granule.

Photo-characteristics: The formation shows a high resistance and a high drainage density as to its characteristics. The drainage pattern is mainly parallel and subdendritic, but trellis pattern can be observed in areas where joints develop. The mountain ridges are generally angular, and the valleys are in an open V shape. In areas where slate or phyllite are found, many places show a fine texture.

Geological structure: The Mansalay Formation exhibits a slightly different structure depending on the area.

In the northern part the bed generally strikes E–W and dips south except the area from Mamburao to Abra de Ilog where the bed strikes NE–SW. The foldings with a wave length of 1 km are well developed around the Amnay River and Pagbahan River, and their axis are trending mostly E–W.

In the central part, the formation forms a NNW–SSE trending huge anticline around Mt. Baco. Besides, it forms NW–SE trending anticline and syncline along the Rayusan (Patrick) River, which plunges southeast.

In the southern part, the beds strike NW–SE around Mansalay and along the boundary with Lumintao Formation, but they tend to strike E–W toward the west. The foldings with a wave length of a few km are developed, and their axes are trending E–W, NW–SE or NE–SW.

Stratigraphic relationship: The stratigraphic relationship between the Halcon metamorphics and Mansalay Formation inferred in Phase I had been considered to be unconformable caused by the reasons that the grade of both metamorphism was different and the conglomerate of the Mansalay Formation contained gravels of metamorphic rocks. As a result of Phase II, however, it was confirmed that the structures of both formations were concordant and the metamorphic grade change gradationally in the northwestern part. These facts suggest the possibility of the initial rocks of the Halcon metamorphics and the Mansalay Formation being the sediments of the same age and the different lithofacies being caused by the metamorphism.

Age: It is reported by many researchers that the formation yields abundant Jurassic fossils in Mansalay. By a detailed study of Ammonites, Andal et al. (1968) reported the age of the formation in Mansalay area was considered as late Callovian to Oxfordian, which is a period from the late Middle Jurassic to the early Late Jurassic. The representative species of Ammonites identified are as follows;

1. Amaga River horizon
   Perisphinctes (Kranaosphinctes) cf. bullingdonensis Arkell
   Euaspidoceras cf. hypselum (Oppel)
   Taramelliceras cf. trachinotum (Oppel)
2. Parucpoc Hill horizon
   Parawedekindia arduennensis (d'Orbigny)
   Perisphinetes (Kranaosphinctes) cf. bullingdenensis Arkell
   Camphylites sp.
3. Caromata Hill Horizon
   Hecticoceras (Zieteniceras) sp.

(2)–2 Lumintao Formation

The name "Lumintao Formation" was given to the beds mainly composed of basic volcanic rocks overlying the Mansalay Formation.

Distribution: In the west side, the formation crops out the area from the Lumintao River to Mamburao, and in the east side, it is exposed in the upper reaches of the Pula River and the Balete River to the west of Pinamalayan, and in the area from the middle reaches of the Bongabong River to the places to the west of Roxas.

Thickness: It is more than 2,000 m in the Lumintao River.

Rock facies: The Lumintao Formation mostly consists of basalt lava which partially intercalates basic tuff, pelitic and psammitic rocks.

Basalt lava is classified into five units by the field survey of the Lumintao River as follows.

1 Massive lava; it is massive and does not show a pillow structure. At the margin of this unit the flow structure is sometimes observed and it grades into pillow breccia. The massive lava is greenish dark grey to dark green in color, and relatively hard in spite of much facture. It is generally fine-grained or glassy, but a coarse-grained part is sometimes recognizable. It is altered intensely and veinlets, networks and boxworks of albite, calcite, chlorite-epidote and zeolite occur. This is one of characteristics of the Lumintao Formation.

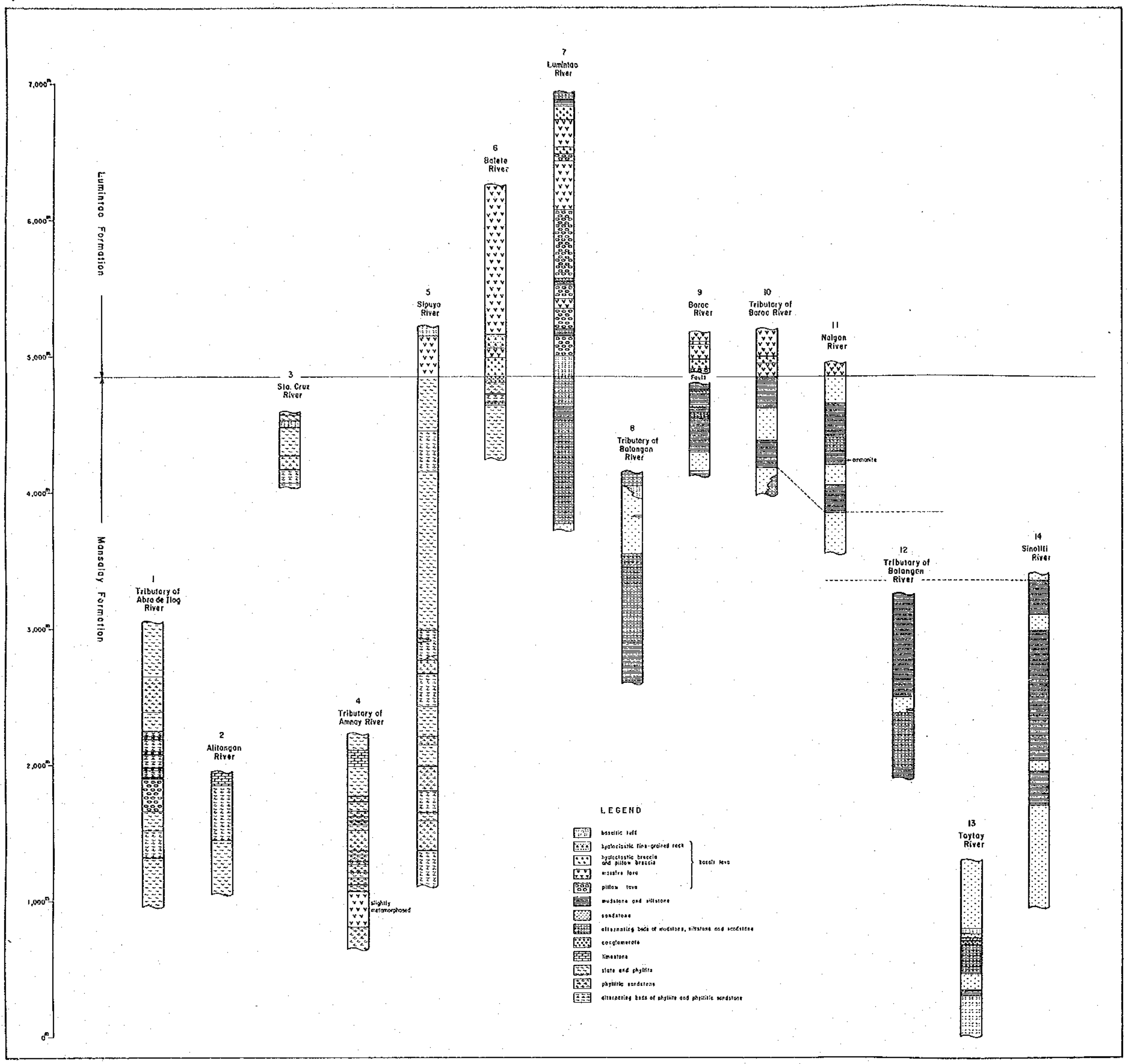


Fig. 5 Geological Columnar Section of Baco Group

2 Autobrecciated lava; it crops out in the fringe of lava flows, and is composed of breccias of basalt which are a few cm – some tens cm in size. It is a greyish green to greenish brown in color and has a small amount of homogeneous matrix. The volume of this unit is smaller than other units.

3 Pillow lava; it is alternated with the massive lava, and the volume is the next biggest to the massive lava. The size of pillow structure is relatively small (40 – 100 cm in diameter). The pillow lava generally shows dark green in color, but locally reddish brown to light greenish red at a certain horizon. Abundant calcite occurred in the matrix. The lava is predominant at the lower part of Lumintao Formation, and is intercalated with shale and the thin alternating beds of shale and sandstone near the bottom.

4 Pillow breccia and hyaloclastic breccia; these are exposed around the pillow lava and massive lava. They are generally light greenish grey to dark green in color, but reddish brown to light greenish red in the vicinity of the reddish pillow lava. The volume of this unit is smaller than other units.

5 Hyaloclastic fine-grained rock; this is the hyaloclastite whose grains are 2 mm or less in size, and the hyaloclastite whose grains more than 2 mm are included in the hyaloclastic breccia. It is light yellowish green to greyish green in color, and shows a clear lamination with intervals of 1 mm to 10 cm. It forms thin beds of 10 cm – a few meters thick, and is interbedded in the pillow lava as well as in the massive lava. In most of the cases, it has been deformed by slumping.

Besides the basalt lava mentioned above, the Lumintao Formation contains thinly interbedded layers of less than 50 m thick mostly at the lower portion, which consist of basic tuff, pelitic and psammitic rocks. The basic tuff is fine-grained and reddish brown to greyish green in color, and has often been crushed flaky. Around Sablayan and Mamburao, it is hard because of metamorphism. The pelitic and psammitic rocks are non-metamorphosed in the southern area, but slightly metamorphosed in the central and northern areas and change to slaty or phyllitic.

Photo-characteristics: The Lumintao Formation shows a high resistance and a high drainage density like the Mansalay Formation, and the drainage pattern is dendritic to subdendritic. Other characteristics also resemble those of the Mansalay Formation, therefore, it is difficult to differentiate the both.

Geological structure: The formation is distributed on the flank of anticline whose axial part is formed of the Mansalay Formation, and it generally strikes NW–SE and dips NE and SW in the east and west sides respectively. It is clarified from the structure shown in pillow lava and hyaloclastite that the formation forms the NE–SW trending anticline and syncline and the beds are exposed repeatedly in the Lumintao River. NE–SW trending faults are developed to the west of Pinamalayan.

Stratigraphic relationship: The Lumintao Formation conformably overlies the Mansalay Formation for a reason that the transitional part is observed around at the boundary, which is concordant with the structure of the Mansalay Formation.

Age: Because this formation is conformable with the Mansalay Formation, the age is supposed to be Late Jurassic.

1–3–2 Tertiary to Quaternary

The Cenozoic rocks are widely distributed in the area as if they were encompassing the Halcon metamorphics and the Baco Group. They are divided into the Mamburao Group, the Sablayan Group, the Bongabong Group, and the Alluvial deposits in the ascending order.

(1) Mamburao Group

The Mamburao Group is composed of a basic volcanic rock considered to be mostly of Paleocene.

Distribution: The group is distributed along the lowland from Mamburao to Abra de Ilog.

Thickness: It is more than 600 m in the upper reaches of the Mamburao River.

Rock facies: The group consists of basalt which shows greyish green to brown in color and have a pillow structure. The basalt is generally fine-grained or glassy, but the phenocryst of plagioclase and pyroxene are sometimes observed in parts.

Photo-characteristics: The Mamburao Group is easily distinguished from other units because of a fine dendritic drainage pattern, a low resistance and an extremely high drainage density.

Geological structure: It is difficult to clarify the structure of the group, because it is comprised of basalt lava. However, the distribution suggests that it forms a NE–SW trending syncline.

Stratigraphic relationship: In the upper reaches of the Mamburao River it was confirmed that this group unconformably overlies the Mansalay Formation.

Age: This group covers the Baco Group with angular unconformity and is overlain by the Sablayan Group with slightly angular unconformity as explained below. Accordingly, the age of this group is supposed to be Paleocene to Early Eocene.

(2) Sablayan Group

The name "Sablayan Group" is given to the beds which predominantly includes the limestone of the Late Eocene to Late Miocene age. As shown in Table 4, the beds such as Mansiol conglomerate, Camangui sandstone and Pocanil limestone reported by Teves (1953), and Bandao limestone, Bulalacao limestone, Napician Formation, Mato-ang limestone and Pocanil limestone reported by Weller and Vergara (1955) belongs to this group.

Distribution: Besides the extensive distribution of this group from Sablayan to Bulalacao, it is also exposed in the upper reaches and lower reaches of the Mamburao River, and in the upper reaches of the Magasawangtubig River, the Banus River, the Sumagui River and the Tangon River.

Thickness: It is more than 2,500 m.

Rock facies: This group is primarily composed of limestone, which is accompanied with mudstone, sandstone, alternating beds of sandstone and mudstone, conglomerate, andesite lava and andesitic to basaltic tuff.

Limestone is predominant in the area from Sablayan to Bulalacao. It shows light grey, light brown, and white in color. Some portions are massive, and others are well bedded ranging from 10 to 50 cm in thickness in each bed. It is fossiliferous, and yields larger foraminiferas, coral and so on. The limestone exposed in the upper reaches of the Mamburao River is recrystallized because of the influence of intrusive rocks such as diorite and quartz diorite.

Mudstone is calcareous and grey to black in color. It is massive, and forms thick beds. There are two types of mudstones in different ages, the one is Late Eocene beds being exposed in the upper reaches of the Caguray River and the another is Miocene beds cropping out in Siay to the northwest of Bulalacao and the upper reaches of the Banus River. The former unconformably overlies the Mansalay Formation, and intercalates limestone beds which are well bedded and yield abundant larger foraminiferas. This mudstone is restricted in distribution, and at the place where it is thining out, the Mansalay Formation is unconformably overlain by the thick limestone which contains fossils of Late Eocene age. Consequently, the mudstone changes laterally in lithofacies into the limestone. As for the latter, the mudstone exposed in the Banus River intercalates relatively many sandstone beds accompanied by the alternating beds of sandstone and mudstone, and fossiliferous limestone yielding a larger foraminifera. While, the mudstone cropping out in Siay interbeds thin layers of mudstone, limestone, sandstone, besides four coal seams of 0.2 – 1 m thick.

Sandstone is less than 100 m in thickness and is intercalated in limestone or mudstone. It is light grey or light greyish green in color, mostly medium to fine-grained, and includes abundant rock fragments with calcareous matrix. The sandstone, distributed in Aritaytayan to the northeast of San Jose, is intercalated with coal seams of more than 1.5 m thick.

The alternating beds of sandstone and mudstone crop out in Napician and the upper reaches of the Banus River in the east side, and in the Mongpong River in the west side. The thickness of each bed is 1 – 2 m, and the sandstone is predominant in general. In the Napician area, the alternating layers are more than 200 m in thickness with intercalation of coal seams. This layers and overlying sandstone beds have been designated as the Napician Formation by Weller & Vergara (1954).

Conglomerate is exposed in the Lumintao River and to the west of the river. It is dark grey to greyish brown in color, massive and relatively well consolidated. The gravels are mostly 5 – 20 cm in size, rounded to subrounded, and consist of chert, green schist, phyllite, basalt, limestone, sandstone and shale. The matrix is a calcareous, coarse sandstone.

Andesite lava crops out in the lower reaches of the Rayusan (Patrick) River, the east of Sablayan, and shows a dark green to greyish green color because of the alteration. Andesitic to basaltic tuff is exposed in the lower reaches of the Lumintao River and in the upper reaches of the Tangon River. It is light green to greyish green in color because of the alteration, mostly fine-grained, and rarely accompanied by tuff breccia.

Photo-characterisitcs: Karst topography is developed in the area where limestone crops out, and isolated peaks are scattered in hilly areas having undulated surface. At the peak, the summit is flat, and has a steep slope. The areas where notable karst topography observed are around Knob Peak in the northern part of Bulalacao, to the northeast of Mamburao, and to the east of Pasugui. The resistance of this unit is moderate to low, and the drainage density is generally low. The drainage pattern follows a joint pattern, and shows a trellis or a rectangular pattern.

Geological structure: The Sablayan Group shows a rather complicated structure with minor foldings. In particular, the beds cropping out from Sablayan to Bulalacao, exhibit irregular structures with variation of strike and dip. As a whole, nevertheless, it tends to strike NW–SE and gently dip SW. In the west of the Lumintao River, several systems of faults draw the boundary between the Lumintao Formation and the Sablayan Group, and these indicate the tectonic depression. While in the eastern portion, the group has a normal structure, striking NW–SE to N–S and dipping 40 – 60° NE to E in the upper reaches of the Magasawangtubig River, and tending to strike NW–SE and dip 40° NE in the Sumagui River and the Tangon River, though a NW–SE trending anticline is present along the Tangon River. But, in the Banus River the beds strike E–W to NW–SE and dip 30 – 55° S to SW, and contact with the Baco Group by the faults of NNW–SSE and NW–SE systems.

Stratigraphic relationship: This group shows a prominently angular unconformity with the Halcon metamorphics and the Baco group, and a gently angular unconformity with the Mamburao Group.

Age: As stated above, the limestone of the group yields abundant larger foraminiferas. Among the foraminifera identified in this survey, Halkyardia minima (Liebus) and Biplanispira mirabiris (Umbgrove) are of Eocene age and Nummulites fichteri (Michelotti) is of Oligocene age. Also, the assemblege of Miocene age was confirmed.

Based on the survey results, together with the studies of Hashimoto & Sato (1969), Hanzawa & Hashimoto (1970), the time of deposition of this group is concluded as Late Eocene to Miocene.

(3) **Bongabong Group**

The Bongabong Group consists mostly of Pliocene conglomerate, tuffaceous sandstone and mudstone – siltstone. As shown in Table 4, the Famnoan Formation and the Barubo sandstone of Teves (1953) and Hanzawa & Hashimoto (1970), and the Punso conglomerate of Miranda (1980) are included in this group.

Distribution: This group is distributed continuously from Villacerveza to Mansalay in the eastern side, and is also scattered in Pasugui and to the north of San Jose in the western side.

Thickness: It is more than 1,400 m in the Pula River located in the east side.

Rock facies: There are some differences in rock facies in this group between in the western area and in the eastern area. In the west, conglomerate are well exposed, while in the east, sandstone and alternating layers of sandstone and mudstone predominate.

In the western part, this group is composed mainly of conglomerate, which is represented by the conglomerate formation called Punso conglomerate in Pitogo to the northeast of San Jose. The conglomerate includes many kinds of gravels such as sandstone, mudstone, limestone, andesite, crystalline schist, and small amounts of quartz diorite. These range in size from pebble to cobble, unusually with a boulder size. The matrix is a reddish brown, coarse-grained sandstone. The total thickness is more than 700 m at Pasugui.

In the eastern part, this group begins with a basal conglomerate. The lower to the middle portion are made of sandstone, conglomerate, and alternating layers of sandstone and mudstone. In the upper portion, this group is formed of mudstone to siltstone and alternating beds with sandstone.

The basal and lower conglomerate are generally massive, grey to brown in color, and include many kinds of gravels as observed in the western parts. These are subrounded to subangular, and range in size from granule to pebble. The matrix is either tuffaceous or calcareous. The basal conglomerate is about 10 – 20 m thick in areas except the Pula River where the thickness reaches more than 100 m. But the lower conglomerate is relatively thick, being more than 300 m thick at the Banus River and the Balete River.

Sandstone is grey to light grey in color, fine to medium-grained, tuffaceous and calcareous, and is well bedded. It is generally 100 – 250 m thick, however it forms the bed more than 400 m thick in the Sumagui River.

Mudstone to siltstone is grey in color, calcareous and fossiliferous, and is well bedded. This is well cropping out in the Sumagui River, where the thickness is more than 400 m.

The alternating layers of sandstone and mudstone are well exposed around the Pula River, with the thickness of each bed ranging from 20 – 100 cm. The sandstone and mudstone are of a tuffsceous and a calcareous nature.

Beside above rocks, tuff and limestone are intercalated in the middle and lower portion of the group. Tuff is encountered at the tributary of the Pula River. It is light grey in color, andesitic and fine-grained. Limestone is exposed around the Hagan River (Gumao Creek), namely the area from the circumference of Bongabong bridge to the upper reaches of the Tangon River. It is massive and grey in color.

Photo-characteristics: This group can be divided into conglomerate and the other rocks from the morphological characteristics. The former, as the conglomerate in Pitogo shows, has a characteristic angular relief, high resistance and forms a fine parallel and a subdendritic drainage pattern. While, the latter has a lower resistance, rounded mountain ridges and a low drainage density.

Geological structure: In the eastern portion, this group exhibits a normal structure with a slight unduration by minor foldings, and it strikes NNW–SSE and dips 10 – 30° E. In the western portion, although the gentle syncline is formed to the southeast of Sablayan and to the north of San Jose, the beds are considered to be horizontal as a whole estimating from the distribution of outcrops.

Stratigraphic relationship: This group unconformably overlies the Sablayan Group and other lower groups. It also unconformably covers the intrusive rocks of Ultramafic complex and quartz diorite.

Age: As stated above, this group yields abundant fossils of smaller foraminifera. In this survey, planktonic foraminiferas of Pliocene age was identified. Hashimoto & Sato (1969) reported that planktonic foraminiferas of Pliocene age were obtained from the Famnoan Formation at Balahid located in the middle reaches of the Bongabong River. Data of fossils and stratigraphic relationship indicate that the Bongabong Group belongs to Pliocene age.

(4) Socorro Group

The Socorro Group is composed of volcanic rocks and sedimentary rocks of the Late Pliocene to Pleistocene ages. The group includes the Oreng Formation and the Balanga Formation of Teves (1953), as well as the formations proposed by Weller & Vergara (1955), which are the high level sand & gravel and the Eplog lava flows.

Distribution: This group is exposed extensively from Puerto Galera to Roxas through the areas of Socorro, in the eastern sections. Besides, it also covers the area round San Jose, Sablayan and Mamburao.

Thickness: Approximately 400 m.

Rock facies: This group consists of several types of beds such as terrace deposits, tuff, tuffaceous mudstone, reef limestone, andesite lava and basalt lava.

Terrace deposits crop out well in San Jose, Sablayan, Bongabong, and in the middle reaches of the Bansud River. It is primarily composed of unconsolidated gravel beds with intercalations of sand beds locally. The gravels consist of several kinds of rounded to subrounded rocks, and are poorly sorted. These beds are poorly bedded.

Tuffaceous mudstone is distributed in San Teodoro and Socorro. It is grey to dark green in color, poorly consolidated, and poorly bedded. Smaller foraminiferas are rarely contained.

Tuff is encountered in San Teodoro. It is light grey in color, porous, vitritic and andesitic, and includes volcanic glass and pumice. It sometimes shows a clear bedding.

Reef limestone is exposed on the west and south of San Jose, and also in Ilin and Ambulong Islands. It is well bedded and yields abundant larger foraminiferas.

Lava flows crops out at Calapan, the eastern shore of Lake Naujan, Mt. Dumali, Eplog hill and Mauhao. These consist of biotite-hornblende andesite at Calapan and Mt. Naujan, pyroxene andesite bearing extremely small amounts of biotite and hornblende at the eastern shore of Lake Naujan and the Mt. Dumali, hornblende andesite at Eplog Hill, and of pyroxene andesite and basalt at Mauhao.

Photo-characteristics: The beds formed of tuff, tuffaceous mudstone, and terrace deposits, are characterised by flat mountain ridges, a parallel drainage pattern, a low drainage density, and a low resistance to erosion. The reef limestone has a relatively high resistance, flat mountain ridges and clear bedding. Karst topography is well developed, and joints are often observed. The lava flows have slightly different characteristics in the area of Lake Naujan as compared with those found in the southern areas. The former remains as a non-weathered lava flows, and shows a radial drainage pattern as well as rounded mountain ridges. The latter, compared with the former, has a low resistance, with an extremely poor drainage density, and a flat topography.

Geological structure: The Socorro Group generally shows a very gentle structure except the NW–SE trending foldings formed in limestone to the east of San Jose. The group strikes NNW–SSE and dips 5 – 10° E in the eastern part, and is almost horizontal in the western part.

Stratigraphic relationship: This group covers the older beds with an angular unconformity in the northern and southern parts, and either gentle angular or parallel unconformity in the eastern parts.

Age: In this survey, the larger foraminifera of Pleistocene age was reported from the calcareous matrix of conglomerate in this group. The Sumagui Formation proposed by Hashimoto & Sato (1969) is reported as Pliocene to Pleistocene age, and it is included in the Socorro group. These facts and the stratigraphic relationship indicate that the age of this group is Late Pliocene to Pleistocene.

(5) **Alluvial deposits**

These are distributed along shores of the eastern and western sections, and are widely exposed from Calapan to Victoria. It is composed of gravels and sand in areas along the main rivers, but in other areas it is of muddy materials.

1–4 Intrusive Rocks

1–4–1 Ultramafic Complex

Mindoro Island lies within the Ilocos-Mindoro ophiolite belt, and the most complete ophiolite sequence in the Philippines is observed in Zambales which is situated in this ophiolite belt (Balce et al., 1981). It is revealed by this survey that the Ultramafic complex in Mindoro consists of ultramafic rocks and gabbro of the ophiolite sequence. The following field evidence, moreover, was collected on the Ultramafic complex by the survey; the complex shows a discordant structural relationship with the Halcon metamorphics and the Baco Group, the small bodies of the complex are distinctly intruded into those formations, no displacement is observed to suggest thrust fault along the complex and at the places on the extension as well, and the large blocks of metamorphic rocks and basalt lava accompany the complex at the peripheral part and inside of it. These evidences support the idea that the Ultramafic complex has intruded into the Halcon metamorphics and the Baco Group as the mode of solid emplacement.

The metamorphic rocks which are closely associated with the Ultramafic complex, were treated as a part of the complex from the viewpoint as follows; those metamorphic grade is different from that of the Halcon metamorphics, those are in contact with the low grade metamorphic rocks of the Baco Group in most cases, and the Ultramafic rocks are considered to be affected by metamorphism of similar grade to the metamorphic rocks.

Distribution and scale: This complex widely crops out in the area. As shown in Fig. 6, the complex in the east side consists of Ogos body, Bongabong body and Balete bodies, while in the west side of Pintin body, Liwliw body, Igsoso body, San Vicente body and Paluan bodies. As for the scale of these bodies, the Bongabong body is the biggest, 34 km in length and 8 km in width, and others are shown in Table 5.

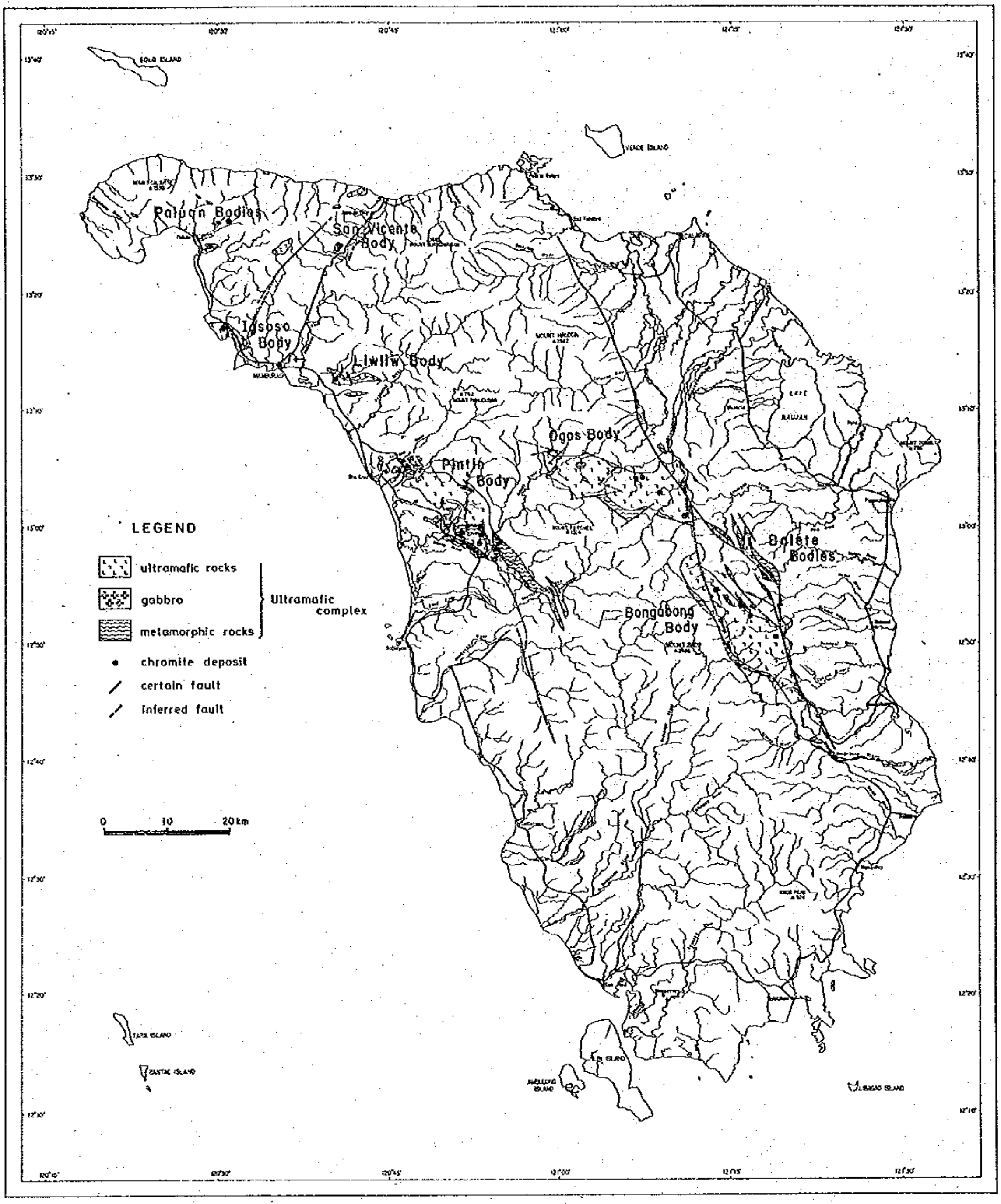


Fig. 6 Location Map of Ultramafic Complex

Rock facies: The complex mainly consists of dunite, harzburgite, lherzolite and gabbro which are accompanied with the blocks of metamorphic rocks at the peripheral part and inside of the body.

Dunite is well exposed particularly in the Ogos body. It is black to dark green in color for a fresh part, and is dark green to dark greyish green in color for an altered or a weathered part by serpentinization. As it has a smooth surface which often shows brown in color and very few quantity of pyroxene is contained in it, it is easily discriminated from the other types in the field unless it has been highly subjected to serpentinization.

Harzburgite is well cropping out in each body. It shows dark green, light greenish brown and black in color, and has been mostly undergone serpentinization. It is easy to differentiate it from dunite in the field because many pyroxene crystals can be observed on the surface at the outcrop. However, it is difficult to discriminate it from lherzolite. By the microscopic observation, a cataclastic texture is shown in most of harzburgite, nevertheless it is not shown in some which contain orthopyroxene showing exsolution texture. It is thought, therefore, that there may exist the harzburgite which belongs to a cumulate type, beside a tectonite type.

Lherzolite has less volume than the above two types of rocks in the area. It is dark grey in color for a fresh part, and dark green in color for an altered part. All samples of lherzolite collected in this survey contain orthopyroxene with exsolution lamellaes and do not show a cataclastic texture. It is presumed according to the above evidence that those are a cumulate type.

As for ultramafic rocks, wehrlite and orthopyroxinite are also observed in the complex. Under the microscope, it is observed that some of clinopyroxene contained in the above rocks have changed to tremolite. This evidence indicates that the ultramafic rocks in the complex is affected by metamorphism.

Gabbro is exposed in all bodies except the Ogos body and the Paluan bodies. The largest exposure of gabbro is distributed at the western end of the Pintin body, showing 7 km long and 0.5 km wide. Although this gabbro is in reverse fault contact with harzburgite, all the others have intruded into peridotite such as harzburgite and so on. Several kinds of gabbro can be distinguished under the microscope as follows; augite gabbro, augite-hypersthene gabbro, hornblende-hypersthene gabbro, hornblende-augite-hypersthene gabbro and hornblende gabbro.

Beside the four rock types in the above, the complex includes hornblendite, diorite porphyry and trondhjemite. These are in a small scale and a few meters to several hundred meters in width.

Table 5 Characteristics of Ultramafic Complex

Name of body or bodies	Scale (km)	Main constituent rocks	Accompanied rocks	Chemical composition*	Serpentinization	Chromite deposit
Ogos	22x10	dunite > harzburgite · lherzolite		84 ~ 86	weak	present (w: 6.5m)
Bongabong	34x8	harzburgite > dunite · lherzolite > wehrlite	orthopyroxinite, hb gabbro au gabbro au · hy gabbro	86 ~ 90	moderate to weak	present (w: 1m)
Balete	max. 7x1	harzburgite > dunite · lherzolite	au gabbro hb gabbro	86	strong	?
Pintin	40x9	harzburgite > dunite · lherzolite	orthopyroxinite, au·hy gabbro hornblendite, hb·au·hy gabbro au gabbro, trondhjemite	82 ~ 86	strong	present (w: 0.2m)
Liwliw	8x3	harzburgite · lherzolite > dunite	hornblendite au·hy gabbro hb·hy gabbro	84	strong	present (w: 0.4m+)
Igsoso	10x3	dunite > harzburgite	au·hy gabbro, au gabbro au·hb gabbro, trondhjemite	86	moderate to strong	present (w: 0.4m+)
San Vicente	1.5x1	harzburgite	au·hy gabbro trondhjemite	84	strong	present (w: 2.0m+)
Paluan	max. 2x1	dunite > harzburgite	diorite porphyry	84	strong	present (w: 0.7m)

hb: hornblende, au: augite, hy: hyperthene
* : 100 x MgO/(MgO + Total FeO) on Ultramafic rocks

As previously mentioned, the blocks of metamorphic rocks are distributed at the peripheral part and inside of the complex. These are composed of amphibolite, amphibole schist, epidote amphibolite and green schist, and are higher in metamorphic grade than the Halcon metamorphics. And these are in contact with the low grade metamorphic rocks of the Baco Group in most cases. Therefore, it seems that these rocks were brought over from the deeper part at the time of intrusion of the ultramafic rocks. Although the metamorphic rocks are found at the periphery of each body, the rocks being inside the body as xenoblock are observed only in the Pintin body and in the western part of the Ogos body. The metamorphic rocks mentioned above are recognizable in each body, however the amphibolite in the Ogos body often contains a large amount of garnet of 1 to 2 mm in size. In the small body exposed in the upper reaches of the Banus River, granulite is also observed.

The xenoblocks consist not only of the metamorphic rocks, but also of basalt lava of the Lumintao Formation in some cases, and the one in the Pintin body has a scale of 4.5 km long and 0.5 km wide.

Photo-characteristics: The ultramafic rocks have a moderate resistance that is lower than that of the Halcon metamorphics or the Baco Group, and show a poorly developed drainage, a relatively smooth texture, and rounded mountain ridges. From these characteristics, these are easily differentiated from other rocks. Also, in areas where there is little vegetation, these can be distinguished from others by the dark tone which is a characteristic of these rocks.

Geological structure: The alignment of the complex shows two trends, namely NW–SE and E–W, and it is characterized by area. In the east, both the Bongabong body and Balete bodies trend NW–SE, while in the central the Ogos body trends E–W. Moreover, in the west, the Pintin body trends NW–SE, while in the northwest, both the Liwliw body and Paluan bodies trend E–W but the Igsoso body trends NW–SE.

The structures of the Pintin body, the Ogos body and the Bongabong body are clarified in Phase III.

In the Pintin body, it is recognizable that the structure of NW–SE system at the central part to the southern part gradually changes to that of E–W system in the northern part based on the arrangement of chromite showings and the trend of elongation of xenoblocks and gabbro.

In the Ogos body, the structure of WNW–ESE system is known in the eastern half from the arrangement of dunite and the layering. In the eastern half, however, that of E–W system is shown in the western part, which shifts to NE–SW system in the eastern part. As the distribution of dunite becomes discontinuous and an extensive fracture zone was confirmed at the boundary between the eastern half and the western half, the fault of NE–SW system can be inferred.

In the Bongabong body, it is considered that it has a structure of NW–SE system, from the arrangement of dunite and chromite showings, and also the layerings.

Age: The Ultramafic complex intrudes into the Halcon metamorphics and the Baco Group, and it is unconformably overlain by the Mamburao Group. Hence the age of intrusion is assumed to be Cretaceous.

1–4–2 Basic Rocks

Dolerite and gabbro are exposed in the area. The gabbro is the one out of that are accompanied with the Ultramafic complex.

Distribution and rock facies: Dolerite and gabbro well crop out in the Lumintao River and Rayusan (Patrick) River. Most of these intrude into the Lumintao Formation, and some into the Mansalay Formation.

Dolerite is fine-grained and greyish green to dark green in color. It is mostly accompanied with marginal facies, but rarely the facies is vague. It forms dikes whose width are generally less than 10 m, and even at its largest do not exceed by 100 m. The dikes in the Lumintao River trend mainly NE–SW and the dikes in the Rayusan River trend mostly N–S.

Gabbro is coarse-grained and greyish green to dark green in color. Augite and hypersthene are observable as mafic minerals under the microscope. It intrudes into the beds near the boundary between the Lumintao Formation and the Mansalay Formation with a slightly discordant relation, and it is considered to be a small-scale phacolith. The width of outcrops is 100 – 150 m. The gabbro exposed in the Lumintao River is associated with several veins of gabbroic pegmatite with 10 – 30 cm wide.

These dolerite and gabbro are thought to be intrusive rocks related to the volcanism of the Lumintao Formation.

Age: These rocks are thought to have been intruded at the stage of the Lumintao Formation.

1–4–3 Acidic to Intermediate Rocks

These are granodiorite, quartz diorite, diorite and diorite porphyry, intruding into the Halcon metamorphics, the Baco Group and the Sablayan Group.

Distribution: These rocks are mostly dispersed in the northwestern area, and in Villacerveza, in the upper reaches of the Pula River and the Bongabong River. All of these show small exposures.

Rock facies: Granodiorite is coarse-grained and leucocratic, whose main constituent minerals are comprised of muscovite, quartz and plagioclase. Quartz diorite shows grey to dark grey in color, and the main minerals are hornblende, plagioclase and quartz. Diorite and diorite porphyry appear dark green to dark grey in color, and are fine to medium in grain size. These show a higher color index, and the constituent minerals chiefly consist of hornblende and plagioclase.

The diorite, diorite porphyry and quartz diorite exposed in the upper reaches of the Mamburao River subjected contact metamorphism to the limestone of the Sablayan Group and Mansalay Formation, and formed iron deposits. Each exposure of these rocks is of a small scale, however it is inferred from the scattering distribution and the extent undergone contact metamorphism that these have formed a considerably large body in the underground.

Age: From the results of K-Ar dating (29.5 – 47.0 m.y.) on quartz diorite in this survey, and the evidence that the Upper Eocene limestone of the Sablayan Group is affected by contact metamorphism, it is concluded that these rocks were intruded during Upper Eocene to Oligocene time.

1–5 Chemical Composition of the Rocks

Sixty four rock samples were analyzed in this survey. The results of analyses and their normative values are shown in Table A-3. For the normative calculation of the Ultramafic rocks, the method proposed by Hayashi (1968) was applied which was modified from C.I.P.W. norm calculation sequence at the following three points.

1 Equal amounts of FeO and Fe_2O_3 are added to Cr_2O_3 and NiO respectively, to make chromite and trevorite.

2 MgO is added to the equal amount of Al_2O_3 which is remnant after calculation of feldspars in order to make spinel.

3 The rest of Fe_2O_3 after the calculation of acmite and trevorite is recalculated to FeO for olivine and pyroxene.

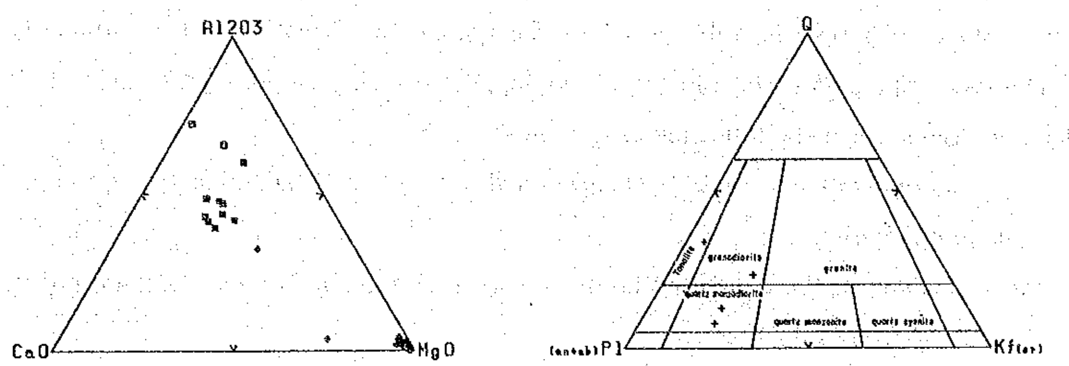
1–5–1 Chemical Characteristics of Metamorphic rocks

The analysis was conducted on the metamorphic rocks of the Halcon metamorphics and those with which accompanied the Ultramafic complex. When the data of the analysis are plotted on the ACF diagram (Fig. 7–①), the data of mica schist and gneiss of the Halcon metamorphics fall in the field of pelitic rock and greywacke, and the green schist fall in the field of basic igneous rock or of pelitic rock and greywacke. In the case of latter green schist, its composition is slightly acidic. On the other hand, amphibolite and green schist of the Ultramafic complex both fall in the field of basic igneous rock, and it is known that these rocks show a relatively homogeneous composition.

1–5–2 Chemical Characteristics of Basalt Lava of the Lumintao Formation and Associated Intrusive Rocks

Massive basalt lava, dolerite and gabbro were analyzed. The analytical data were plotted in the (Na_2O + K_2O) – SiO_2 diagram (Fig. 7–②) and Total FeO/MgO diagram (Fig. 7–③, only for basalt). In these diagrams all the analyzed samples fall in the field of tholeiitic basalt and they seem to follow the trend line of differentiation of tholeiitic rocks in the AFM diagram (Fig. 7–④) and the diagrams of solidification index (MgO x 100/(MgO + Fe_2O_3 + FeO + Na_2O + K_2O)) vs. Fe_2O_3 + FeO, TiO_2, Al_2O_3 and MgO (Fig. 7–⑥–⑨). This is supported by such aspects that the dolerite has a similar chemical composition to that of the basalt and gabbro accompanied with gabbroic pegmatite, both which were observed in the field.

The basalt samples of the Mansalay Formation and Mamburao Group were analyzed aiming at comparing them with those of the Lumintao Formation. These are spilitic according to the result of microscopic observation and have been plotted in the field of alkaline rocks in the Fig. 7–②.



⑩ Al203-CaO-MgO Diagram ⑪ Q-Pl-Kf Diagram

Fig. 7 Diagrams of Chemical Composition (3)

1–5–3 Chemical Characteristics of the Ultramafic Complex

(1) **Ultramafic rocks**

MgO x 100/(MgO + Total FeO) ratios for all of the samples, ranging from 82 to 90% with the highest value in the bongabong body (Table 5), fall in the field of the ultramafic rocks of the Alpine type. And all of the samples are plotted around MgO apex of the MgO – CaO – Al_2O_3 diagram (Fig. 7– ⑩), and they correspond to the metamorphic peridotite field of Coleman's subdivision (1977).

(2) **Basic rock (gabbro)**

The gabbro of the Ultramafic complex, having quite a wide range of SiO_2 content from 43.40% to 54.57% shows the differentiation trend of tholeiitic rock similar to that of basaltic rocks of Lumintao Formation in AMF diagram (Fig. 7–⑤) and the solidification index vs. MgO, Al_2O_3, TiO_2 and Fe_2O_3 + FeO diagram (Fig. 7–⑥–⑨). These chemical characteristics probably suggest that these gabbros represent various stages of differentiation originated from the single parental magma.

1–5–4 Chemical Characteristics of Acidic to Intermediate Intrusive Rocks

Normative values of these samples fall in the tonalite field, the granodiorite and the quartz monzonite fields in the normative Q-Pl-Kf diagram (Fig. 7– ⑪), and these show a fairly wide range of chemical composition. The distribution of these samples in the AMF diagram (Fig. 7–④), lies on the one straight line which is correspond to the differential trend of plutonic rocks of calc-alkalic series. It may suggest that these rocks are the products of differentiation of a single calc-alkaline magma.

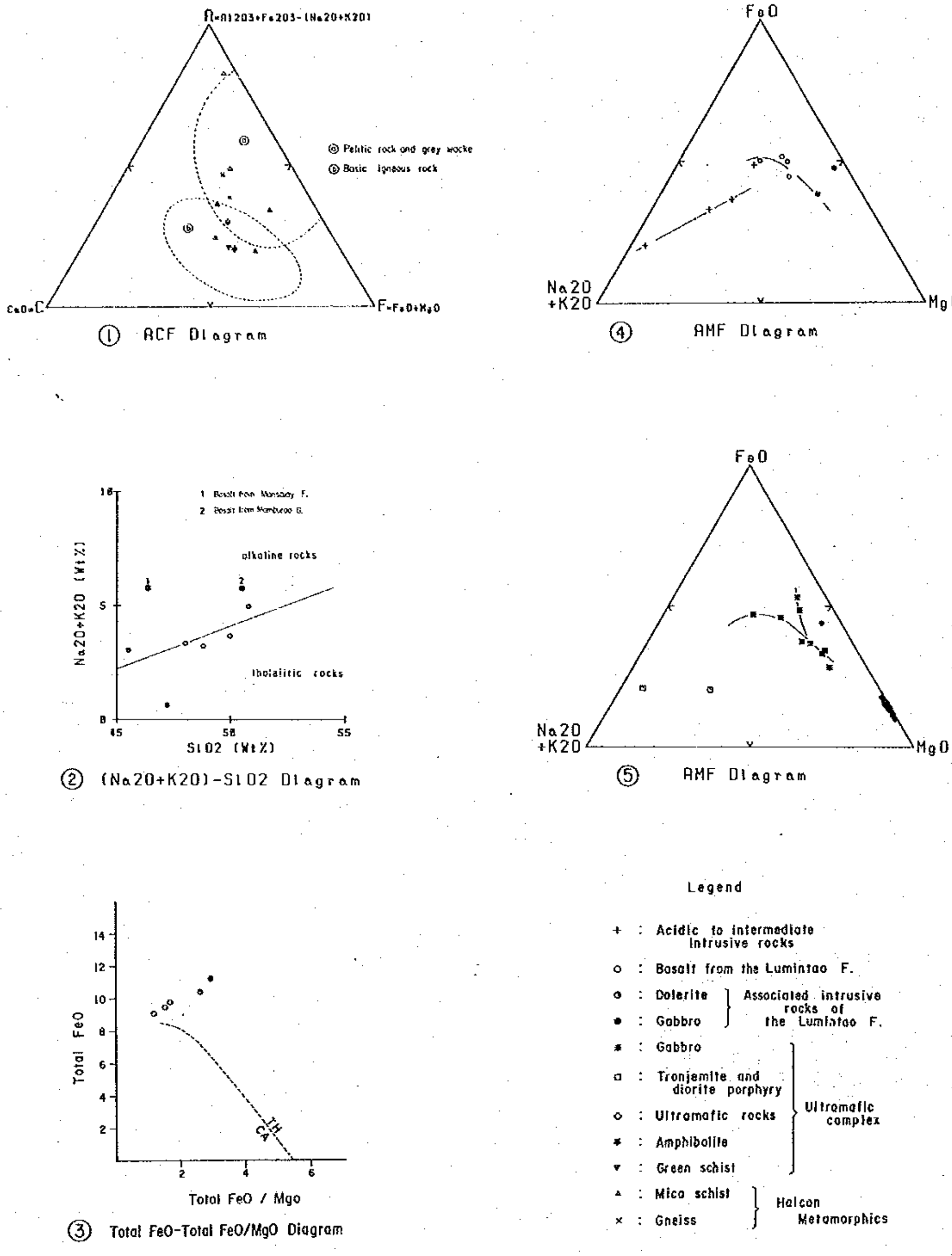
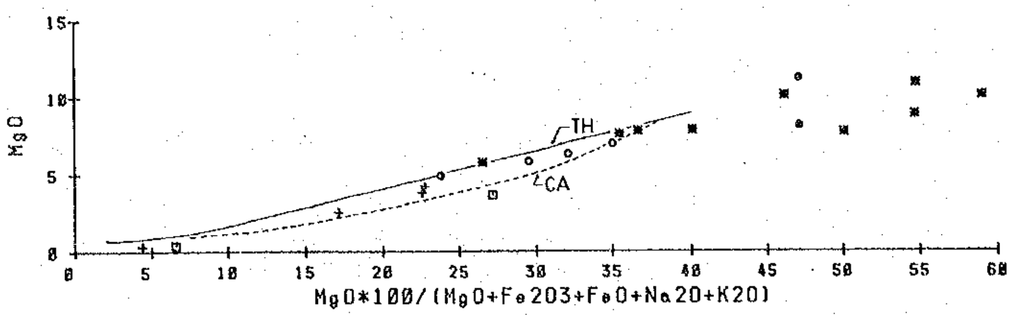
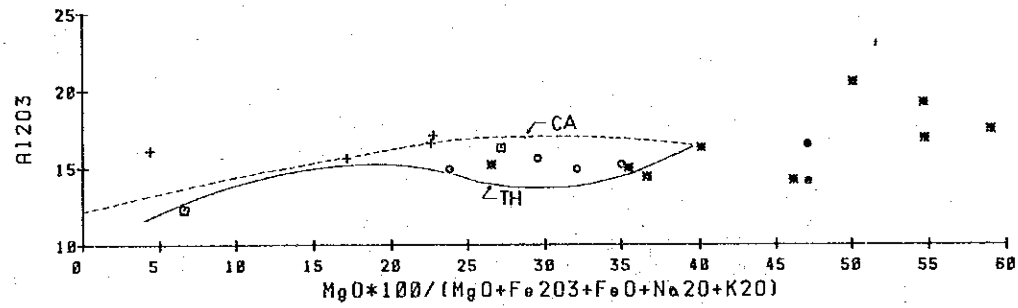


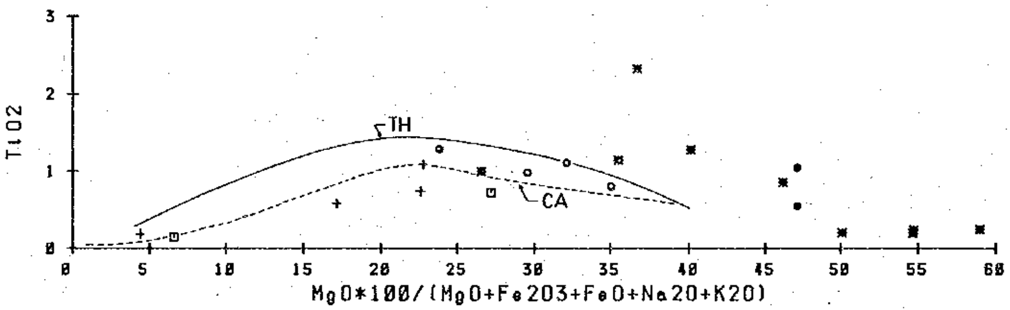
Fig. 7 Diagrams of Chemical Composition (1)



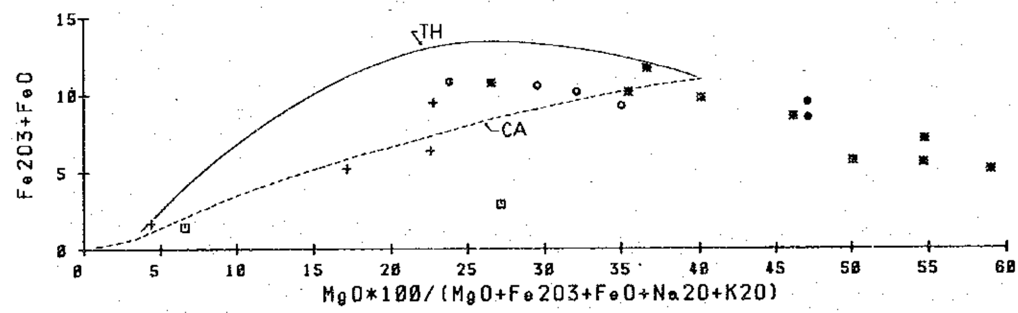
⑥ MgO-MgO*100/(MgO+Fe2O3+FeO+Na2O+K2O) Diagram



⑦ Al2O3-MgO*100/(MgO+Fe2O3+FeO+Na2O+K2O) Diagram



⑧ TiO2-MgO*100/(MgO+Fe2O3+FeO+Na2O+K2O) Diagram



⑨ Fe2O3+FeO-MgO*100/(MgO+Fe2O3+FeO+Na2O+K2O) Diagram

Fig. 7 Diagrams of Chemical Composition (2)

1–6 Metamorphism

The metamorphic rocks of Mindoro Island are classified into three groups as follows.

1 Halcon metamorphics

2 Metamorphic rocks of the Baco Group

3 Metamorphic rocks associated with the Ultramafic complex

The first group shows the green schist facies and it consists of mica schist, green schist, gneiss (gneissose granodiorite), metagabbro and marble. The general assemblage of constituent minerals is muscovite, chlorite, quartz and plagioclase as for mica schist, and of epidote, chlorite, actinolite and plagioclase as for green schist. The mica schist exposed in the Dulangan River at the east foot of Mt. Halcon contains many garnet crystals of 2 – 3 mm in size, and it shows the coexistence of biotite, muscovite and chlorite. These facts suggest that the mica schist was formed by the metamorphism at higher temperature and pressure than others.

The second group consists of the low grade metamorphic rocks, which are phyllitic in the northern part and slaty in the southern part. Pelitic rock in origin has been changed into slate or phyllite, and psammitic rock in origin has been altered to indulated sandstone or phyllitic sandstone. Besides, basic tuff in origin is changed into green slate or green phyllite.

It is obvious from the distributions of the above groups that the metamorphism tends to increase in grade northward in Mindoro.

The third group shows the highest metamorphic grade in Mindoro. It is mainly composed of the metamorphic rocks of the green schist to amphibolite facies, and granulite facies partly. Considering from the fact that this group always accompanies the Ultramafic rocks and that the Ultramafic rocks had undergone metamorphism, the metamorphic rocks of this group had been brought up from the deeper part at the time of intrusion of ultramafic rocks.

The time of metamorphism in Mindoro was previously considered to be pre-Jurassic because the non-metamorphosed conglomerate of the Mansalay Formation contained the gravels of metamorphic rocks.

As a result of this survey, however, it is considered that the Halcon metamorphics and the Baco Group are the successional formation in Jurassic age. Accordingly, it is concluded that the metamorphism in Mindoro was accompanied with the orogenic movement which took place after the deposition of the Baco Group, and that the time of metamorphism is Late Jurassic to Cretaceous.

1–7 Airborne Magnetic Survey

1–7–1 General Remarks

Mountains of higher than 1,800 m above sea level (A.S.L.) are prominent in the central part of Mindoro Island, therefore, two flight altitudes of 1,800 m (6,000 ft) A.S.L. and 2,700 m (9,000 ft) A.S.L. were adapted.

The summary of field operations are as follows;

(1) Ground station: San Jose

(2) Flight altitude: 1,800 m (6,000 ft) A.S.L. and 2,700 m (9,000 ft) A.S.L.

(3) Flight direction: N–S for the traverse lines and E–W for the tie lines

(4) Flight line spacing: 2.5 km for the traverse lines and 10 km for the tie lines

(5) Number of flight lines:

	1,800 m A.S.L.	2,700 m A.S.L.	Total
Traverse line	31	29	60
Tie line	18	14	32

(6) Length of lines:

	1,800 m A.S.L.	2,700 m A.S.L.	Total
Traverse line	1,590 km	3,601 km	5,191 km
Tie line	379 km	800 km	1,179 km
Total	1,969 km	4,401 km	6,370 km

(7) Geomagnetic dip: 14°N

(8) Geomagnetic declination: 0°C

(9) Total geomagnetic intensity: 4,000 gammas

Navigation of this survey was conducted visually, comparing prominent land marks by topographic maps on a scale of 1:50,000. Caused by this system, it was often difficult for aircraft to fly exactly over the planned survey lines, and the re-flights were requested in the case which the spacing was greater than twice of the planned.

The average speed of the aircraft is 130 mph (about 240 km/h) and the sampling interval of the airborne magnetometer is four (4) seconds.

The instrumentation systems used in the survey, which belongs to the Bureau of Mines and Geo-sciences, are as follows;

(a) Aircraft: Cessna 402, twin-engine

(b) High sensitivity airborne proton magnetometer: V-4914 made by Varian (U.S.A.)

(c) High sensitivity station proton magnetometer: G-826A made by Geometrics (U.S.A.)

(d) Crystal clock: GP-109 made by Varian (U.S.A.)

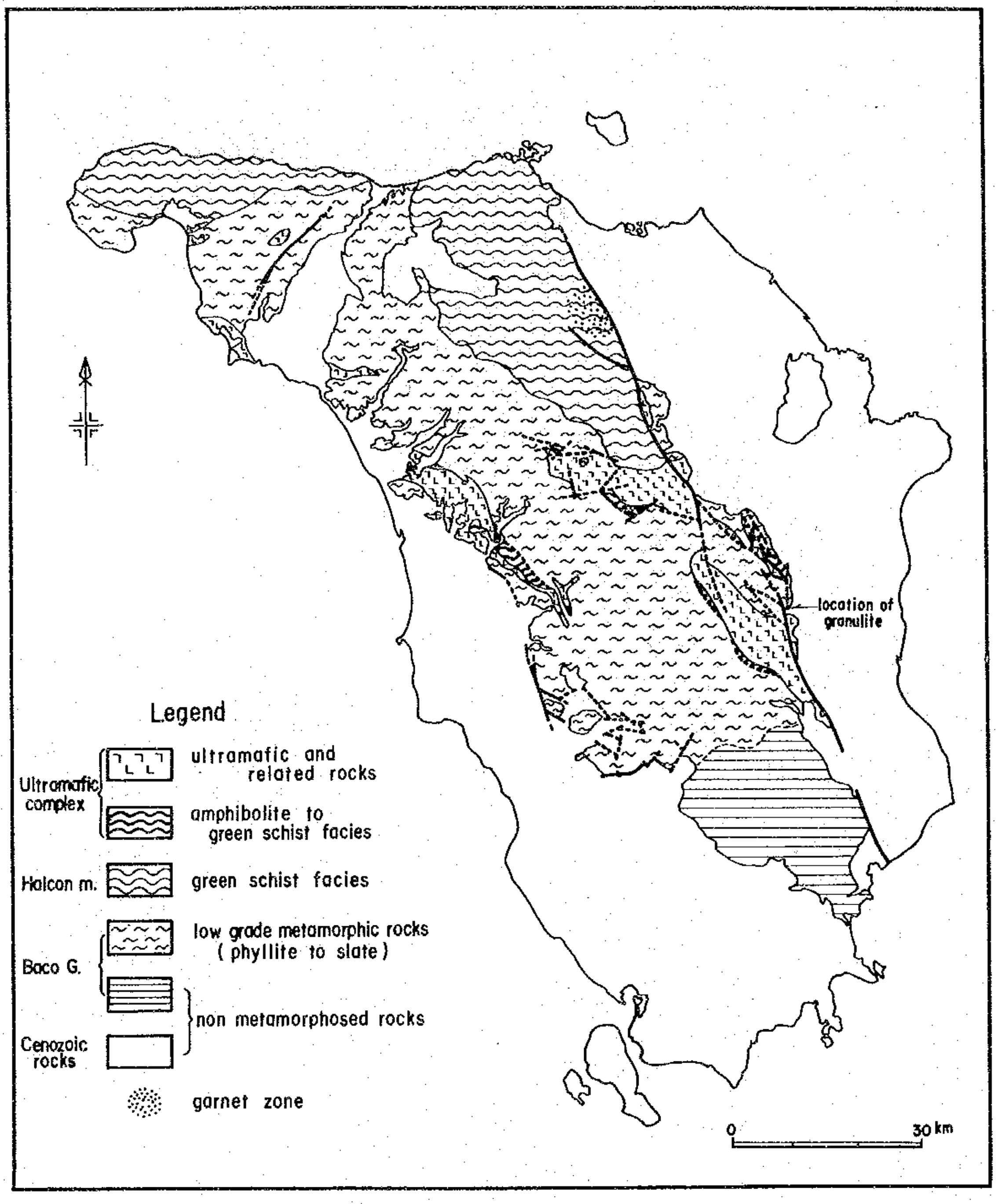


Fig. 8 Metamorphic Subdivision in the Survey Area

(e) Barometric altimeter: 5934A-A69 made by United Instrument (U.S.A.)

(f) 35 mm tracking camera: G-2 made by AUTOMAX (U.S.A.)

(g) Analog recorder: 680 made by Hewlett-Packard (U.S.A.)

(h) Digital data acquisition system: V-4991 made by Varian (U.S.A.)

1–7–2 Results of the Survey

The total-intensity map was drawn after the daily-variation corrections to all of the magnetic data. Secondly, the residual value was calculated by subtracting the standard total intensity of the International Geomagnetic Reference Field (IGRF) from the original data. The residual map covering the whole of Mindoro was made by compiling the residual map of 2,700 m A.S.L. with the upward-continuated residual map generated from that of 1,800 m A.S.L.

The interpretation of the data remained qualitatively because of the lack of basic data, however, the distribution of high magnetic body like ultramafic rocks was clarified and the geological structure was outline as well. The results of interpretation are discribed below.

From the total magnetic intensity map, the Mindoro Island is classified into three areas:

Area I (southern part): This covers the area below lat. 12°40'N. In this area, the iso-gamma lines with E–W trends are dominant and no characteristics of relief which suggests that magnetized bodies exist in the area. It is correspond to the distribution of thick sedimentary rocks which show no magnetic property such as sandstone and shale of the Mansalay Formation, and limestone and calcareous rocks of the Sablayan and Soccoro Groups.

Area II (central part): This is the area covering between the latitude of 12°40'N and the line linking from Mt. Halcon to Mamburao. In this area, Iso-gamma lines of NW–SE trend are dominant and magnetic anomalies with half wavelength of 5 to 10 km are distributed in the NW–SE direction. Judging from the continuities of magnetic anomalies, geotectonic lineaments of NW–SE and NNW–SSE trends are assumed. Large geotectonic lineaments are listed as follows:

II-a ... Geotectonic lineament running from Mt. Pamucuban to Mt. Fetchei in the area to the northeast of Sta. Cruz.

II-b ... Geotectonic lineament extrending in a NNW–SSE direction from San Teodoro to Roxas, running parallel to the upper reaches of the Bongabong River (Rosanna River) in the central part. It is correspond to the Mindoro Fault.

II-c ... Geotectonic lineament running in a WNW-ESE direction from the east of Lake Naujan to Bongabong.

Most of the magnetic anomalies distributed at the north side of above-mentioned geotectonic lineaments, coincide with the distribution of ultramafic rocks. The anomalies in the area between Mamburao and St. Cruz, also show the same feature as the above. On the contrary, the large scale magnetic anomaly situated to the southwest of Mt. Baco coincide the area where the basalt of the Lumintao Formation is exposed. Because this area is located on the extension of the Pintin ultramafic body, the existence of concealed Ultramafic complex is considerable. In the northeastern part, anomalies due to Quaternary volcanic rocks were detected and a highly magnetized body of large scale is inferred to exist at depth in the area from the north of Lake Naujan to the northern offshore area.

Area III (northern area): This is the area to the north of Mamburao and Mt. Halcon, where the iso-gamma lines with E–W trends are dominant. The geotectonic lineament trending NE–SW and the magnetic anomaly keeping parallel to the previous lineament, which were detected in the vicinity of Mamburao, are correspond to the Mindoro Fault and ultramafic bodies. The high magnetic anomaly detected in the area from the north coast towards the sea, is considered to be due to a highly magnetized body such as ultramafic rocks which exists at depth.

1–8 Geological Structure

The survey area can be divided into five geotectonic zones: (I) Central life zone, (II) Paluan lift zone, (III) Mamburao basin, (IV) Southwestern basin and (V) Eastern basin (Fig. 10).

The Central and the Paluan lift zones, which build the mountain range in Mindoro Island, are composed of Halcon metamorphics and are separated by Mamburao basin. The Mamburao, the Southwestern and the Eastern basins are filled by a series of Cenozoic sediments ranging from the Mamburao to the Socorro Groups and form the low lands. Large-scale faults and ultramafic intrusion are found near the boundary between the lift zone and the basin.

It is considered, based on the distribution of tectonic zones and the geological sections, that the whole island shows a large anticlinal structure trending NW–SE. The following three systems of the structure can be recognized in the area.

1 NW–SE system

This system is the most prominent direction as shown by the elongation of Mindoro Island, accordingly the system is recognized in the whole area on the structures such as fault, fold, general strike of the sedimentary rocks and intrusive rocks.

The faults of this system are represented by the Mindoro Fault extending over 60 km and the Wasing Fault extending over 50 km, both of which are eastside-slipped gravity faults, bordering the central lift zone from the Eastern basin. Beside these, the westside-slipped gravity fault with a steep dip is located to the east of Sablayan and the faults diverged from the Mindoro Fault and Wasing Fault are distributed in a horsetail form around the upper reaches of the Balete River.

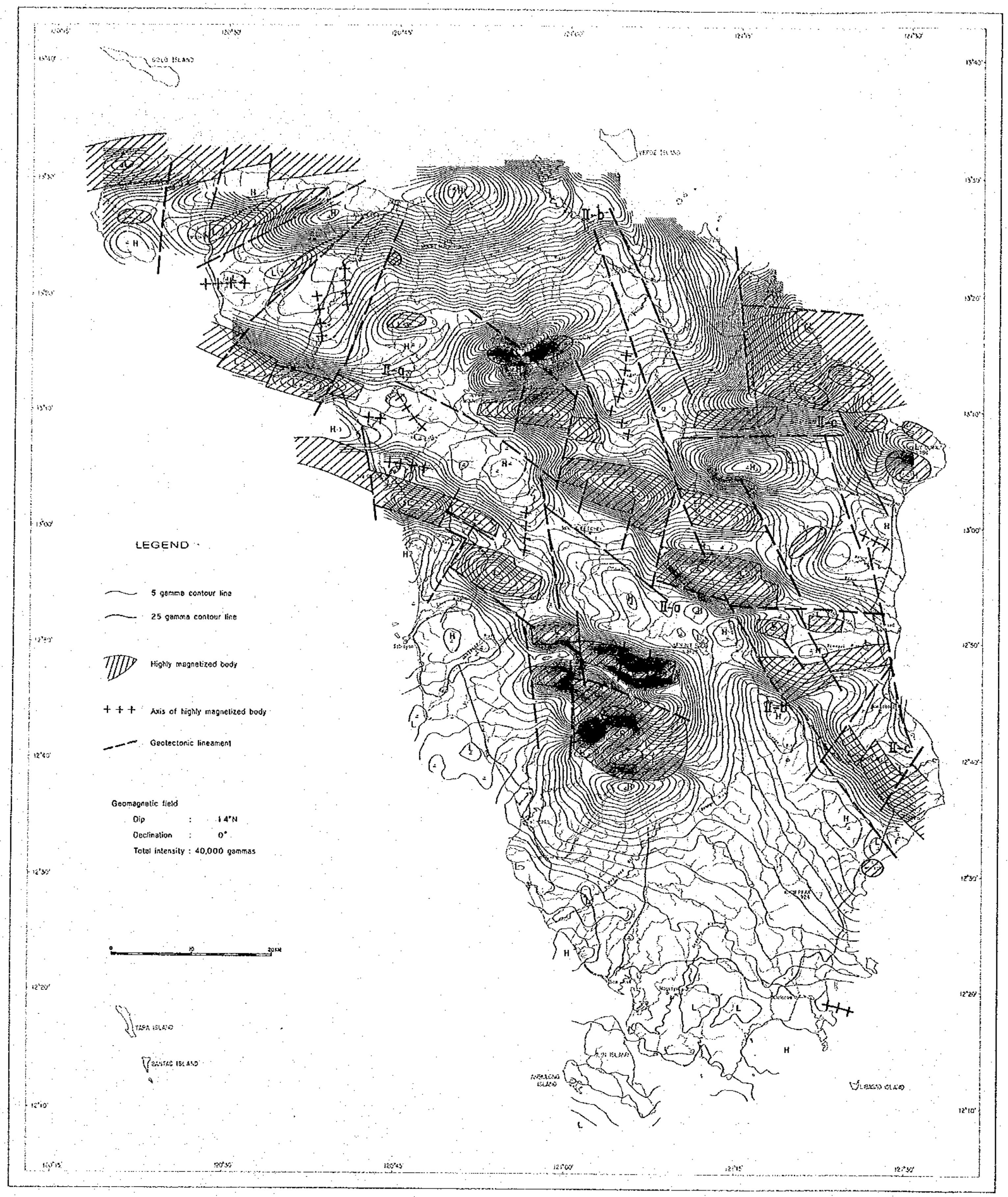


Fig. 9 Interpretation Map of Airbone Magnetic Data tv tic

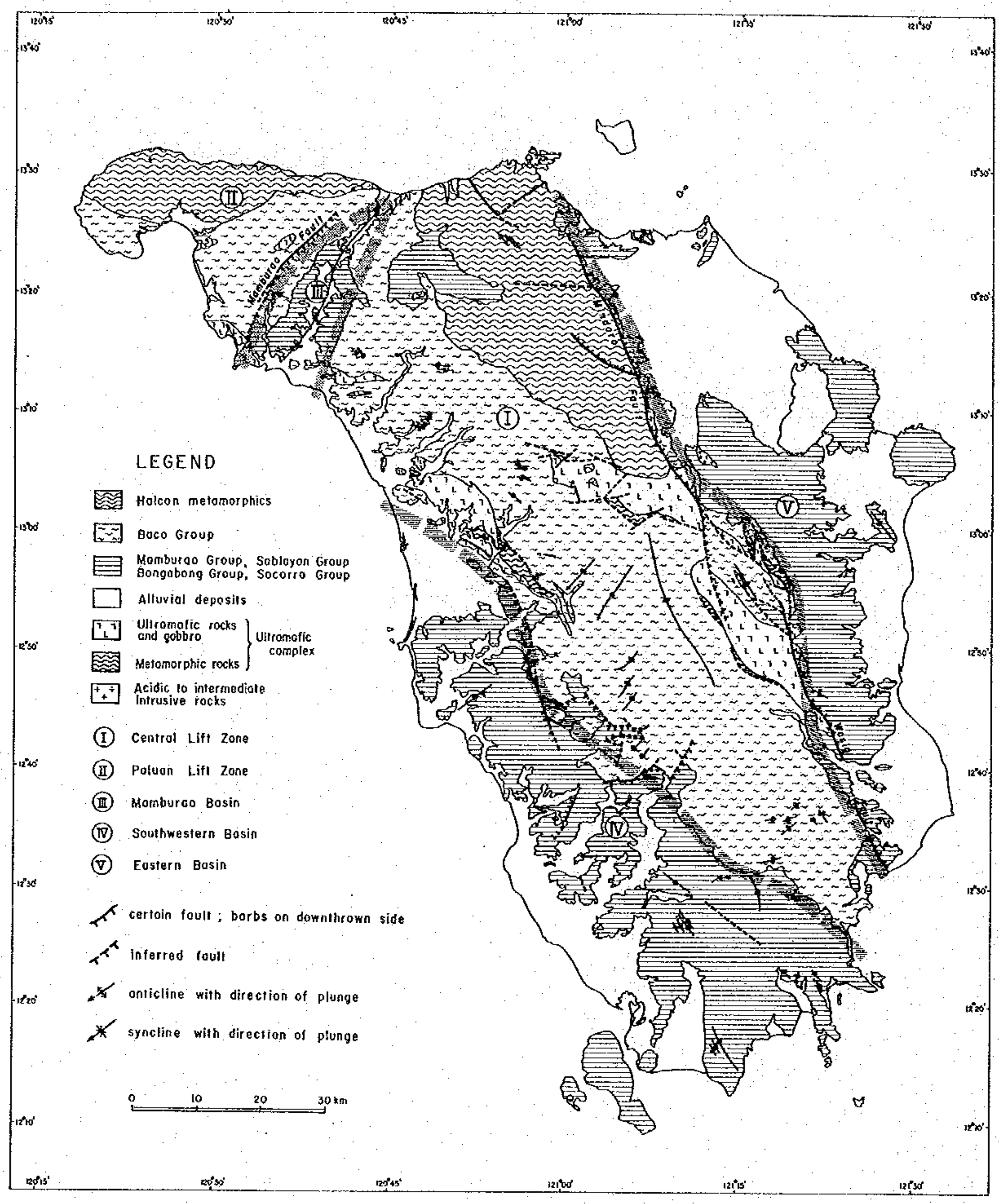


Fig. 10 Tectonic Map of the Survey Area

As for folds of this system, the broad anticline has been formed in the Mansalay Formation in the central portion and small-scale folds with an axial length of 2 – 10 km and a wave length of 1 – 2 km are formed in the Sablayan Group, Bongabong Group and Socorro Group in the southern portion. The intrusive rocks trending NNW–SSE to NW–SE are recognized as the Bongabong body, Pintin body, Igsoso body and Balete bodies of the Ultramafic complex.

The movement for forming this system is considered to have started after Cretaceous time and continued until Pleistocene time in which the movement was most active.

2 **NE–SW system**

This system can be found in the trend of fold and fault.

There are two types of fold which are old stage fold developing in the Baco Group and new one developing in the Mamburao basin. The former shows a wave length of 1 – 10 km with an axial length of 3 – 10 km, and the latter is larger scale than the former, with a wave length of more than 15 km and an axial length of more than 30 km.

Faults of this system are represented by the Mamburao Fault which is an eastside-slipped gravity fault with an extention of 25 km, bordering the Mamburao basin from the Paluan lift zone. In addition to this, the faults are observed in the middle reaches of the Lumintao River, where the tectonic depression has been formed by faults of this system together with E–W and NW–SE systems.

The activity which form these structures is presumed to have taken first place after the sedimentation of the Baco Group, from Late Jurassic to Early Cretaceous time, and secondly after the sedimentation of the Sablayan Group, from Pliocene to Pleistocene time.

3 **E–W system**

This system can be recognized as the faults distributed along the Mindoro Fault, the elongation of the Ogos body and Liwliw body, and the small-scale folds formed in the Mansalay Formation to the west of Sta. Cruz. In particular, this system is prominently recognized in the area around the Ogos body, Sta. Cruz and Mamburao.

The system may have been formed after the sedimentation of the Baco Group and before the intrusion of Ultramafic complex, namely from Late Jurassic to Creaceous time.

1–9 Geological History

Stratigraphycally, the oldest formation in Mindoro Island is the Halcon metamorphics. It has been confirmed in this survey that the Baco Group conformably overlies the Halcon metamorphics in part. Accordingly, Paleozoic rocks may not be exposed in Mindoro Island.

In Jurassic period, a large-scale subsidence took place and formed the sedimentary basin of the Baco Group. The basin is characterized by different deposition, that is, a deposition of thick sandstone and mudstone with some volcanic rocks in the earlier stage and a deposition of thick basalt lava by a vigorous igneous activity in the later stage.

From Late Jurassic age, an orogenic movement had taken place, and it is inferred that the movement was accompanied by metamorphism. By this movement the NE–SW trending folds were formed in the Baco Group, furthermore, the structure of NW–SE and E–W systems were formed between blocks with different movement, which led to the intrusion of Ultramafic complex.

During Tertiary period, marine transgression and retrogression were repeated and the netric Mamburao, Sablayan and Bongabong Groups were deposited. The differential uplifting in this period was so distinct that the sedimentary basin split into two (east and west sides) across the central portion, resulting in some differences in rock facies deposited. That is, the west side is characterized by limestone and conglomerate with few volcanic rocks, on the contrary, the east side characterized by tuff, tuffaceous mudstone to siltstone and sandstone. During Eocene to Oligocene age, the intrusion of acidic to intermediate plutonic rocks had taken place as the succession of orogenic movement, and iron ore deposits were formed.

Contrary to the Tertiary system stated above, the sedimentary environment of the Socorro Group deposited chiefly in Quaternary was almost continental except that of reef limestone.

The structure of NW–SE system formed by uplifting which started from Late Jurassic, had become more prominent during Pliocene and Pleistocene period, and appeared as the Mindoro Fault, the Wasing Fault and some foldings. At almost the same time, a synclinal structure with a NE–SW system and the Mamburao Fault were formed in Mamburao area.

CHAPTER 2. ORE DEPOSIT

2–1 Outline of Ore Deposits and their Distribution

As shown in Fig. 11 and Table 9, there are many ore deposits or mineral showings in Mindoro Island. And some mines of placer gold, barite, marble and jade are operating. These deposits are related to the igneous activities of the Ultramafic complex of Late Mesozoic and the dioritic rocks of Palaeogene.

As reflected in the name of the island (Mina de Oro = Mindoro), gold ore deposits are famous and placer gold is mining from alluvial sand in the San Teodoro area in the northeast part and in the San Jose area in the southwest part.

Copper showings, which are of the vein type, are distributed nearing to the Mindoro Fault and the Wasig Fault running in the east side of the central range. They are related to the dioritic rocks of Palaeogene and are considered small in scale, though they have locally high grades.

Nickel and Chrome showings occur in the Ultramafic complex which are distributed at places in the east and the west sides, some of which were ever explored.

Chromite orebodies can be classified into the massive type occurring in dunite and harzburgite and the layered type occurring in dunite. During this survey, many outcrops were found.

Iron deposits are magnetite deposits which are of the metasomatic type and are concentrated in the northern part of the central range. The ores are good in quality. The ore reserves of three deposits can be estimated to be ten million ton level.

As for nonmetal ore deposits, there are barite, marble, jade and coal etc.

Barite deposits which are of the vein type, occur in the Jurassic formation in the southeastern part and are either under operation in a small scale or under preparation for mining.

Marble deposits are located near Puerto Galera. In two mines, recrystalized limestone which is a member of the Halcon metamorphics, is digged a few m^3/day.

Jade, which is usually called as Mindoro Jade, is made of an aggregate of sericite, with pale green – dark green colours. At present, one mine is operating in the northwest part. Jade is accompanied by quartz vein occurring in the Jurassic limestone.

Coal intercalated by the Miocene sedimentary rocks is qualified as high-volatility C bituminous coal by the American standard (ASIM 1964). The presence of seven coal seams of 0.75 – 2.00 m thick was confirmed in two areas. The reserves is about 7,000,000 tons according to the BMG calculation (1955).