REPUBLIC OF THE PHILIPPINES

REPORT ON GEOLOGICAL SURVEY
OF
MINDORO ISLAND

PHASE I

SEPTEMBER 1982

METAL MINING AGENCY OF JAPAN
JAPAN INTERNATIONAL COOPERATION AGENCY

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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 collaborative mineral exploration in Mindoro Island of the Philippines and entrusted its execution to Japan International Cooperation Agency (JICA) and Metal Mining Agency of Japan (MMAJ).

Between 9 February, 1982 and 22 May, 1982, Metal Mining Agency of Japan dispatched a survey team headed by Mr. Hiroshi Fuchimoto to conduct the Phase I of the project.

The survey had been accomplished under close cooperation with the Government of the Republic of the Philippines and its various authorities.

This report is a compilation of the survey of the Phase I, and after completion of the project, the consolidated report will be submitted to the Government of the Republic of the Philippines.

We wish to express our appreciation to all of the organizations and members who bore the responsibility for the Project, the Government of the Republic of the Philippines, Bureau of Mines and Geo-Sciences (BMG), and other authorities and the Embassy of Japan in the Philippines.

September 1982

Keisuke Arita
President
Japan International Cooperation Agency

Masayuki Nishiie
President
Metal Mining Agency of Japan

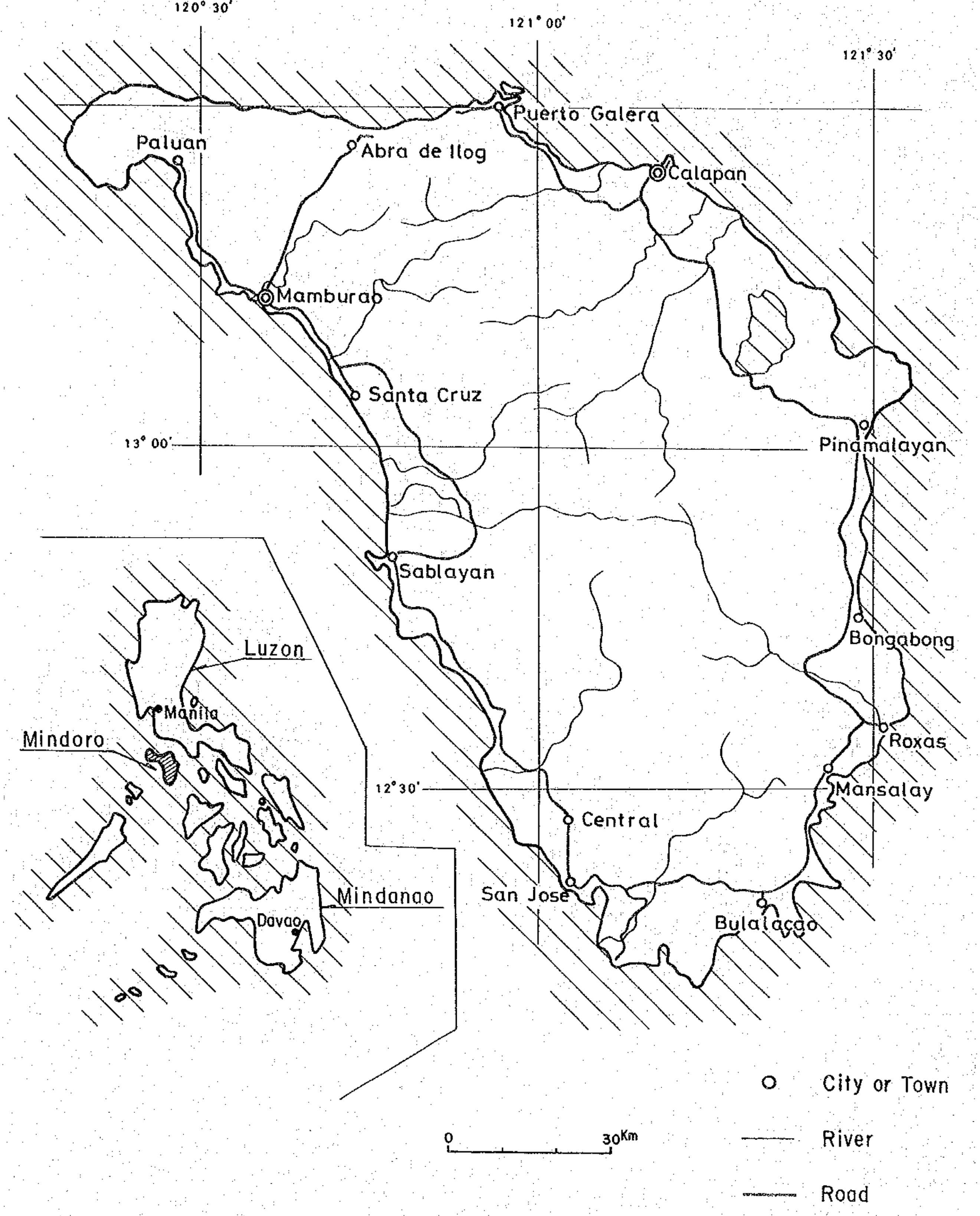

Fig. 1 Location Map of the Survey Area

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ABSTRACT

The Geological survey of Mindoro Island, Philippines, aims on the evaluation of potential for all kinds of minearl resources including non-metalic minerals. In this Phase I, geological, geochemical, photogeological and airborne magnetic surveys were carried out to disclose the geological structure and favorable geological environment for mineral resources.

Geological and photogeological surveys established a generalized stratigraphy over the whole Island, referring to existing local data and clarified the distribution of the formations in different ages.

Roughly speaking, the geological structure is characterized by the uplift zone, which extends in the central area in the direction of NW–SE and is accompanied with basins on both sides, showing an anticlinal structure where younger formations accumulate zonally from the core of Paleozoic metamorphics.

The most distinct structure in the area has a NNW–SSE system, which includes a large-scaled fault developed at the boundary between the above-mentioned uplift zone and basins. Along this fault, intrusion of ultramafic rocks of late Cretaceous and acidic intermediate igneous rocks of Eocene ~ Oligocene resulted to many kinds of mineralization.

Polyelement analyses of stream sediment samples to check adaptability of the geochemical survey disclosed that 5 elements of Ni, Cr, Cu, Zn and Ag are proven to be effective as trace element. Five anomalous zones of Ni.Cr, 2 zones of Cu.Zn and 2 zones of Ag were extracted. As Ni.Cr anomalies occur in the ultramafic zone and some are in new places, there are potential for new ore deposits. Chromite distribution by panning also suggests same potential.

The Cu.Zn anomaly found in the southern area includes a silicified zone with some gold, indicating that this mineralization is partially overlapped by barite mineralization.

Interpretation of airborne magnetic data was carried out qualitatively because of lack of basic data but distribution of high magnetic rocks like ultramafic rocks became clear as outlined by the geologic structure.

As mentioned above, the basic data on geology and ore deposits in Mindoro were obtained, so that geological and geochemical reconnaissance surveys over the uncovered area and more detailed ones over the promising area are recommended to be carried out in Phase II.

GENERAL REMARKS

Chapter 1 Introduction

1–1 Purpose and Scope of the Survey

Much geological work has been carried out on Mindoro Island and there have been reports of many ore 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 did not refer to the internal relationship between the mineralization and geological structure or the igneous activities.

The purpose of this survey is, therefore, 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

During Phase I of the survey, geological and geochemical reconnaissance surveys including the compilation of existing data, photo-geologic interpretation, and an airborne magnetic survey were carried out over all of Mindoro Island.

The geological and geochemical survey team was composed of four parties containing a total of five geologists from the Philippines and four geologists from Japan. Mapping was done on a scale of 1:50,000 along main route which are perpendicular to the geological structure. The survey parties also checked mineral showings along the route.

Sediment samples were collected from the main creeks which cross the geological routes and these were analyzed for ten elements of Cu, Ni, Cr, Pb, Zn, W, Ag, Fe, Mn and Mo, in order to get some basic data on the mineralization. Panned samples were also taken from almost all of the big rivers to study the distribution of heavy minerals.

Based on the field data obtained by the geologists, aerial photo-interpretation, including field checks, were conducted mostly by a Japanese specialist on aerial photographs with a scale of 1:40,000. An existing Landsat analysis and some aerial photographs with a scale of 1:15,000 were also used effectively to construct a geological map.

Data processing and analyses of airborne magnetic survey data obtained by the Bureau of Mines and Geo-Sciences of the Philippines were carried out in Japan. Prior to and during the field observation, two electronics engineers and two geophysicists were dispatched to the Philippines to check the instruments and the magnetic data.

The contents of the geological survey of Phase 1 is shown in Table 1.

Table 1 Outline of Field Survey in Phase I

	Duration	Area	Length of Survey Route	Remarks
Preparatory Work	Feb. 9 ~ Feb. 16, '82 7 days	–	–	–
Geological Survey	Feb. 19 ~ Apr. 16, '82 57 days	10,000 Km^2	on foot 799 Km by boat 126 Km	Geochemical Samples 423 pcs Panned Sampels 105 pcs
Aerial Photo-interpretation	Feb. 19 ~ May 21, '82 92 days	10,000 Km^2	86 Km	Aerial Photographs 1/40,000 392 sheets 1/15,000 567 sheets
Airborne Magnetic Survey	Mar. 8 ~ Apr. 23, '82 46 days	10,000 Km^2	2,700m ASL 4,401 Km 1,800m ASL 1,969 Km	Spacing survey line : 2.5 Km tie line : 10.0 Km

1–3 Organization of the Survey Team

The personnel who participated in the survey are as follows:

Japan, Planning and Negotiation

Nobuhisa Nakajima	Metal Mining Agency of Japan
Ken Nakayama	do
Kyoichi Koyama	do (Manila representative)

Phillippines, Planning and Negotiation

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Francisco A. Comsti	do
Carlos F. Teodoro	do
Guillermo R. Balce	do

Japan, Survey Team

Geological and geochemical Surveys

Hiroshi Fuchimoto (Leader)	Metal Mining Agency of Japan
Haruo Watanabe	do
Tetsuo Sato	do
Hiroyuki Hida	do

Photo-interpretation

Yoshiaki Shibata	do

Airborne magnetic survey

Asahi Hattori	do
Manabu Kaku	do
Yoshinori Azuma	do
Yaichi Tanaka	do

Philippines, Survey team

Geological and geochemical surveys	
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Jessie S. Miguel	do
Jose R. Salvado	do
Jesus Rotoni	
Photo-interpretation	
Nestor P. Punsal, Jr.	do
Airborne magnetic survey	
Octavio C. Daclison	do
Alexander M. Lacanilao	do
Reynaldo L. Villela	do
Romeo B. Zambarrano	do
Enrico B. Zuno	do
Honorio B. Cabanban	do
Elmer C. Amo	do
Paleomagnetic survey	
Eduardo B. Alforte	do
Anselmo Abungan	do

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Chapter 2 Outline of the Survey Area

2–1 Location and Accessibility

Mindoro Island lies about 130 km. south of Manila City across the Verde Island Passage which is 15 km wide. Calapan, the capital town of Mindoro Oriental, with a population of 67,000, is 4.5 hours by car and boat from Manila, via Batangas. Mamburao, the capital town of Mindoro Occidental with a population of 14,000, and San Jose, the largest town in the island, with a population of 80,000, are 30 and 40 minutes by plane from Manila, respectively.

As the road condition in Mindoro is not very good, it takes a long time to travel by automobile. The main access is a provincial road which runs around the island along the coast, except for a 15 km section between Puerto Galera and Abra de Ilog. In the rainy season, traffic on the west side of the island is held up because of the scarcity of bridges over the big rivers. It is also very difficult to go by land from Bulalacao to San Jose in rainy weather, as the clay road becomes slippery.

2–2 Topography

The topography of the island is characterized by the cental mountain ranges trending NNW–SSE. Peaks along the ridge average over 1500m in elevation, with Mt. Halcon (2505m), the fourth highest peak in the Philippines, and Mt. Baco (2488m). In general, the topography is rugged. In particular, the eastern side of the ranges is very steep.

2–3 Climate and Vegetation

The climate of Mindoro Island is very different on the east side of the central mountain range than in the west side. The west side has a very pronounced and clear dry season from November to April, and the rainy season is from May to October. However, the east side is covered by rain throughout the whole year. As for vegetation, broad leaf trees called Balete or Agopanga cover much of the east side, while many of the mountains on the west side are bare due to deforestation by burning. Because of the steep topography and the sparse vegetation, the rivers flood very easily when it rains.

Chapter 3 General Discussion

Many basic data on stratigraphy, igneous activities, geological structure and mineralization etc. were collected in this Phase. Each items will be discussed in the following chapters and some important problems related to the future survey will be discussed in this chapter.

3–1 Geology

None of the previous geological surveys have been conducted in Mindoro Island from the unific point of view. This time a new attempt was made to establish a generalized stratigraphy and disclose geological structure. The Cenozoic system in the southwest area was subdivided on the basis of the study of lithology and fossil. But there are very few data in the rest and the Phase I survey was carried out only along the main routes, so that, the island was divided into groups which boundaries were traced by photo-interpretation.

The stratigraphy of the island thus interpreted is as follows in the ascending order.

Paleozoic		Halcon metamorphics
Jurassic	Baco group	Mansalay formation
		Lumintao formation
Paleocene-Lower Eocene		Mamburao group
Upper Eocene-Miocene		Sablayan group
Pliocene		Bongabong group
Upper Pliocene-Pleistocene		Socorro group
Holocene		Alluvial deposits

The groups of Paleozoic and Jurassic differ from those of the existing reports and their distribution are also different. The rocks which have been called as Mindoro Metamorphics or Basement Complex were divided into two groups, viz, lower group (Halcon metamorphics) consisting of green schist facies and epidote-amphibolite facies and upper group consisting of slate and phyllite. The stratigraphic relationship between the two groups is considered to be uncomformable from the field evidences stated below.

1. The conglomerate in the upper group contains pebbles of the lower group
2. A structural uncomformity contact is recognized at the boundary between the two groups
3. There are sharp changes in the metamorphic grade between them

The rock facies of the upper group have a strong resemblance to those of the Jurassic formation (Mansalay formation) which is distributed in the southeastern part and was already dated by fossil. From the geologic structure and the photointerpretation results, the upper group seems to extend toward southeast, so the writers have correlated it with the Mansalay formation. It was proven that the basalt lava flows covering the central part of the island have a conformable contact with the Mansalay formation and extend continuously to Mamburao. Therefore, the flows are considered to be Jurassic and tentatively called the Lumintao formation.

These problems stated above are brought up this time and could be solved by clarifying stratigraphy and structures, both of which are possible by further geological survey.

The distribution of the ultramafic rocks defined by geological survey and photointerpretation mostly agree with that of magnetic bodies detected by airborne magnetic survey. But in the southern part of the Mt. Baco, the ultramafic rocks was not reported though a magnetic body can be expected. This area is to be covered in Phase II, because the geological survey was not carried out in this phase.

K–Ar dating on the Halcon metamorphics and acidic intrusives shows the same Eocene-Oligocene ages, though the former considered to be Paleozoic are intruded by the latter. This fact may be due to the reason that some amount of Ar contained in the metamorphic rocks has been lost by the regional thermal effect caused by the igneous rocks intrusion, resulting in younger age than the original. The acidic intrusive rocks with small exposures are considered to extend downwards as shown from the distribution of iron deposits of a contact metasomatic type. Rb–Sr dating is recommended to know the metamorphic age of the Halcon metamorphics.

3–2 Ore Deposit

Based on existing data and compilation of the geological and geochemical results of Phase I, the main ore deposits in Mindoro Island are limited to placer gold, copper, zinc, nickel, chrome, iron, barite, coal and silica sand.

Placer gold is being collected from the alluvial deposits in San Teodoro and San Jose areas but gold could not be recognized in the heavy mineral samples. It was experimentally known that the placer gold in the island occurs in coarse grained sands filling interstices between big boulders.

Judging from lack of igneous rocks in the upstream and existence of no other veins than barren quartz, the placer gold may be derived from Halcon metamorphics.

Copper and zinc deposits seems to be related to the small scaled dioritic rocks intruding along the Mindoro Fault. As the sampling density was too low, geochemical anomalies were not obtained even in the known mineralized area. On the other hand, Cu and Zn anomalous zone extending in a N–S direction came out in the Siange River, a branch of the Bongabong River. It is located on the extension of the Mindoro Fault, so further detailed survey is recommended.

All showings of nickel and chrome are reported to occur in the ultramafic rocks and geochemical anomalies detected by this survey are likely caused by these rocks. Being not discussed here because no outcrops were observed, nickel and chrome deposits are considered from a geological point of view to be an Alpine type like Zambales deposits. As the geological anomalies spread over the wide area, the detailed survey is needed in the ultramafic zone in order to clarify the nature of deposits.

Many iron deposits are concentrated in the limestone which overlie the northern part of the central mountain ranges. They are contact metasomatic deposits caused by acidic intrusive rocks and are composed of magnetite and hematite. Judging from the report (BM 1974) and floats (though outcrops were not checked because of very poor accessibility), iron ore has a high-grade and ore reserves may be in a class of 1,000,000 tons. In spite of existence of numerous iron floats with a fist – human head size in the riverbed, no geochemical iron anomalies were obtained by stream sediment or panning survey. There is a reason to consider that the ore grains might have been taken off when sieving with an 80-mesh screen or panning because the distance between ore sources and sampling site was too short for floats to become fine granules.

In this area no distinct magnetic anomalies were obtained by airborne magnetic survey because the flight altitude of 9,000 feet (altitude to ground : 6,000 feet) seemed to be too high to detect iron deposits with this scale.

As iron deposits in the island may be considered most important next to nickel and chrome, a detailed geological survey will be needed to recognize the nature of mineralization.

Barite deposits occurring in the clastic rocks distributed in some parts of Mansalay area are of a vein type and are accompanied by few minerals. In the Taoga deposits now in operation, a few gold occur in the alteration zone near veins. The same is true in Siange mineralized zone, 5km north of the Taoga, suggesting some overlap of two kinds (gold and barite) of mineralization. As the igneous rock related with mineralization was not found, further geological survey is needed.

The coals occurring in Bulalacao and Alitaytayan areas have a calorific value of 12,000 b.t.u./lb, corresponding to the high-volatile C bituminous coal in the American coal class.

Chapter 4 Conclusion and Recommendations

4–1 Conclusion

Based on data collection from the previous reports and present works on photogeological, geological, geochemical and airborne magnetic surveys, the following conclusions are summarized :

1. The Survey area consists of the Halcon metamorphics of Paleozoic, the Baco group (the Mansalay formation and the Lumintao formation) of Mesozoic and the Mamburao group, the Sablayan group, the Bongabong group, the Socorro group and the Alluvium of Cenozoic in the ascending order.

2. A large-scaled ultramafic and small-scaled acidic ~ intermediate rocks (granodiorite, quartz diorite and diorite) and basic rocks (dolerite and gabbro) are recognized. Among them acidic ~ intermediate rocks crop out in a very small scale.

3. The geologic structure of the Island is characterized by the uplift zone, which extends in the central area in the direction of NW–SE and is accompanied with basins on both sides, showing as a whole an anticlinal structure with a NW–SE system. Large-scaled faults are developed at the boundary between the uplift zone and basins (including a small-scaled Mamburao basin), which seems to had accelerated the ultramafics intrusion.

4. The main deposits in the Island can be classified into 6 kinds, viz. placer gold, nickel – chrome, iron, barite, coal and silica sand. Nickel and chrome deposits are accompanied by the ultramafic rocks. In the ultramafic zone, 5 geochemical anomalous zone were found by stream sediment survey and high concentration of chromite and magnetite was recognized by heavy mineral survey.

5. Iron deposits occurring in limestone is a contact metasomatic type and is likely related with acidic intrusive rocks of Eocene ~ Oligocene. Geochemical anomalies were not obtained probably because of particles of a big size.

6. Taoga barite deposit in the southern area is included in the Siange Anomaly (Cu-Zn), suggesting an overlap of mineralization.

7. Results of analysis of airborne magnetic data indicate that most of the magnetic anomalies detected on the magnetic map agree with the distribution of ultramafic rocks and that magnetic discontinuity lines correspond well to the structural lines estimated by the geological team.

8. A large-scaled magnetic anomaly detected in the southern part of Mt. Baco appears

to be an ultramafic rock body, therefore, a ground check is needed.

9. The mineragenetic province in Mindoro Island can be illustrated in Fig. 2 on the basis of the whole survey results in this phase.

4–2 Recommendation

As the continuous geological sequence from Paleozoic to Cenozoic can be seen in Mindoro Island, establishment of stratigraphy will contribute to the Philippine geology. In addition, the ultramafic rocks traversing the island longitudinally are on the southern extension of those in Zambales which are accompanied with large-scaled chromite deposits. Therefore, the island seems to be also interesting from a viewpoint of ore deposits.

As stated above, a generalized stratigraphy effective for the whole island was tentatively proposed on the basis of the survey results. But it has unsolved important problems on geological age and geological structure, because geological survey was carried out along the main routes and distribution of formations was interpreted from photographs.

Although geochemical survey was proven to be adaptable, geochemical anomalies should be restudied because the sampling pattern is not uniform. In Phase II, therefore, geological and geochemical reconnaissance surveys and detailed ones are needed over the uncovered area and over the promising area, respectively.

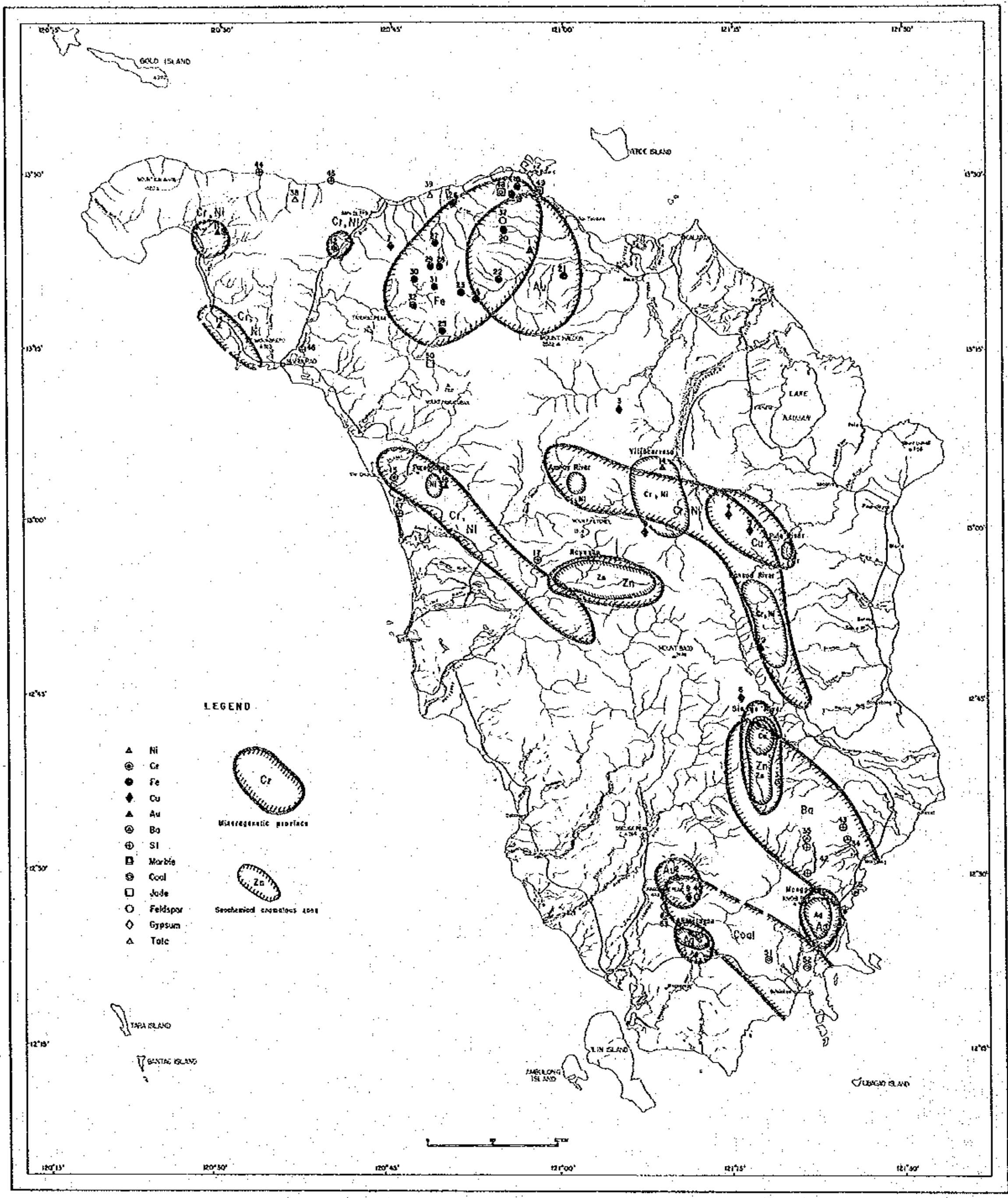

Fig. 2 Mineragenetic Province of the Survey Area

PART I GEOLOGICAL SURVEY

Chapter 1 Geology

1–1 General geology

The Philippine archipelago is divisable into two structural units by Gervasio (1966) ; the mobile belt and stable region. The former, extending longitudinally through Luzon, Visayas and Mindanao, is characterized by a concentration of earthquake epicentres, numerous active and recently inactive volcanoes, prevalence of Mesozoic to Tertiary igneous rocks, distribution of porphyry copper deposits and greater degree of deformation and metamorphism of the rocks. While the latter, being the western side of the boundary passing through southwestern Mindoro Island, southwestern edge of Panay Island, western part of Zamboanga Peninsula in Mindanao Island and western part of Basilan Island, is aseismic in nature and shows virtual absence of Tertiary igneous activity.

Mindoro Island belongs to the western physiographic province of four major physiographic provinces which are proposed by Balce, et al (1981), and the province constitutes the belt of mountain ranges in the western side of the mobile belt. Moreover, it is considered that the ophiolite belts, Ilocos-Mindoro ophiolite belt and Antique ophiolite belt, are passing in the province with pared Magmatic belt, Luzon Central Cordillera-Marinduque magmatic belt and Negros-Zamboanga magmatic belt. Balce, et al (1981) inferred also that the basement considered to be Carboniferous to Early Jurassic in Mindoro as well as other areas surrounding the Sulu Sea is continental crust. Holloway (1981) and many authors suggested that the crustal material comprising the North Palawan block which consists of Mindoro Island, and the Read Bank area, once formed part of the mainland of Asia, attached to southern China.

In Mindoro, Paleozoic and Mesozoic rocks are distributed in the central trending northwest, which are overlain by Cenozoic rocks dipping northeast and southwest. It means that they form the huge anticlinal structure.

From the survey of this year, the stratigraphy of Mindoro is divided from the oldest into the Halcon Metamorphics; the Baco group, which comprises the Mansalay formation and the Lumintao formation; the Mamburao group; the Sublayan group; the Bongabong group; the Socorro group and the Alluvial deposits as shown in Table I–1. It was also confirmed that intrusive rocks consists of big ultramafic body, small body of acidic to intermediate rocks such as granodiorite, quartz diorite and diorite, and small scale of basic rocks of dolerite and gabbro. The stratigraphic correlation between the present survey and previous works is shown in Table I–2.

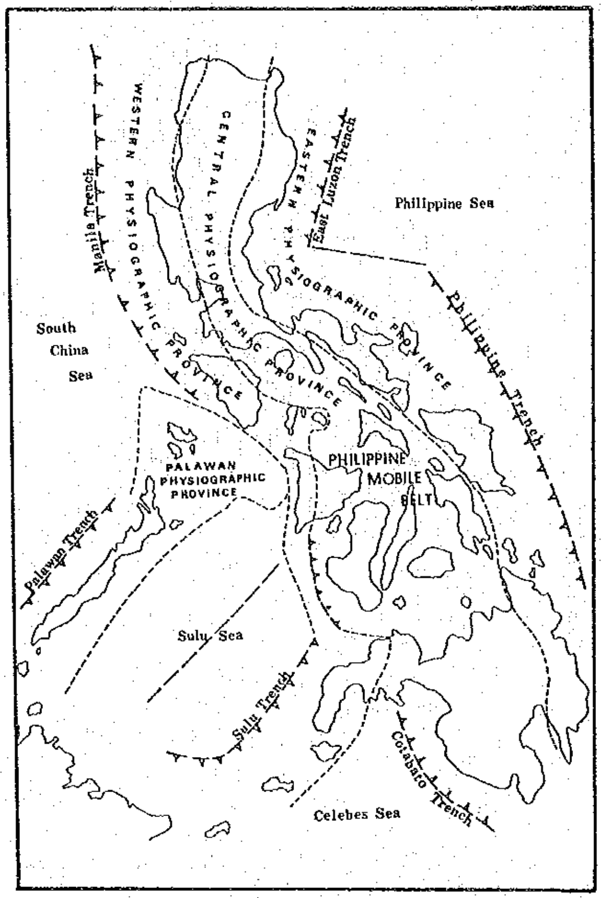

Fig. Ⅰ-1 Major Physiographic Elements in the Philippines
(after Balce et al., 1981)

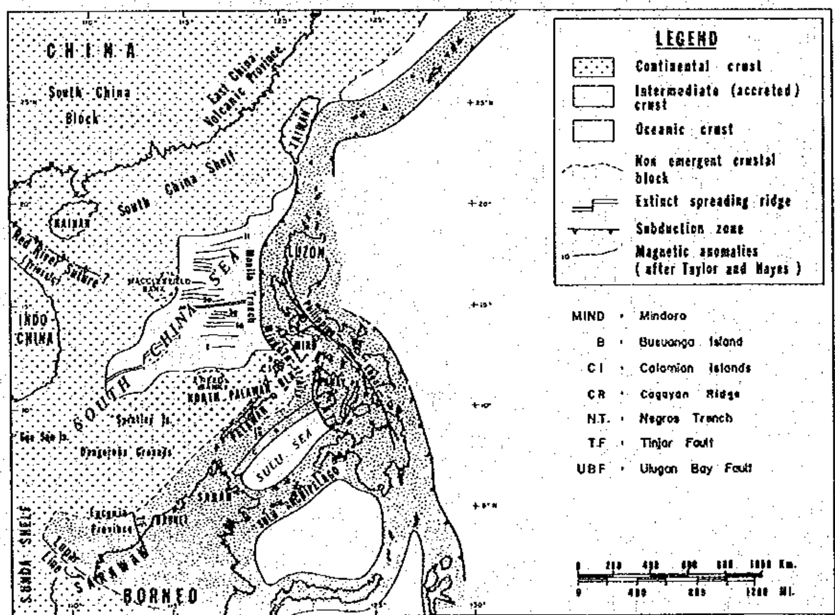

Fig. Ⅰ-2 South China Sea Area Geography and Tectonic Elements
(after Holloway, 1981)

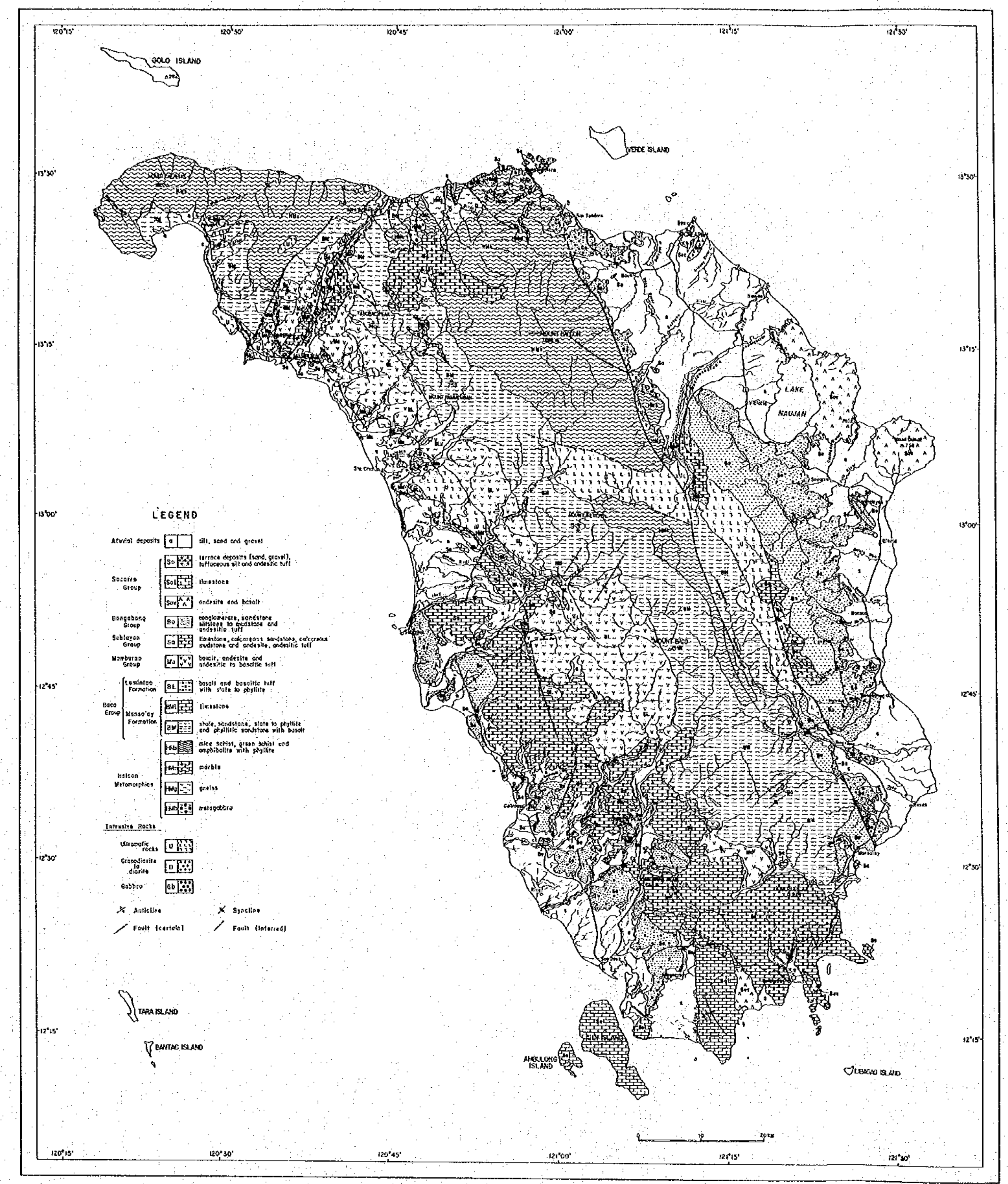

Fig. Ⅰ-3 Geslogical Map of the Survey Area

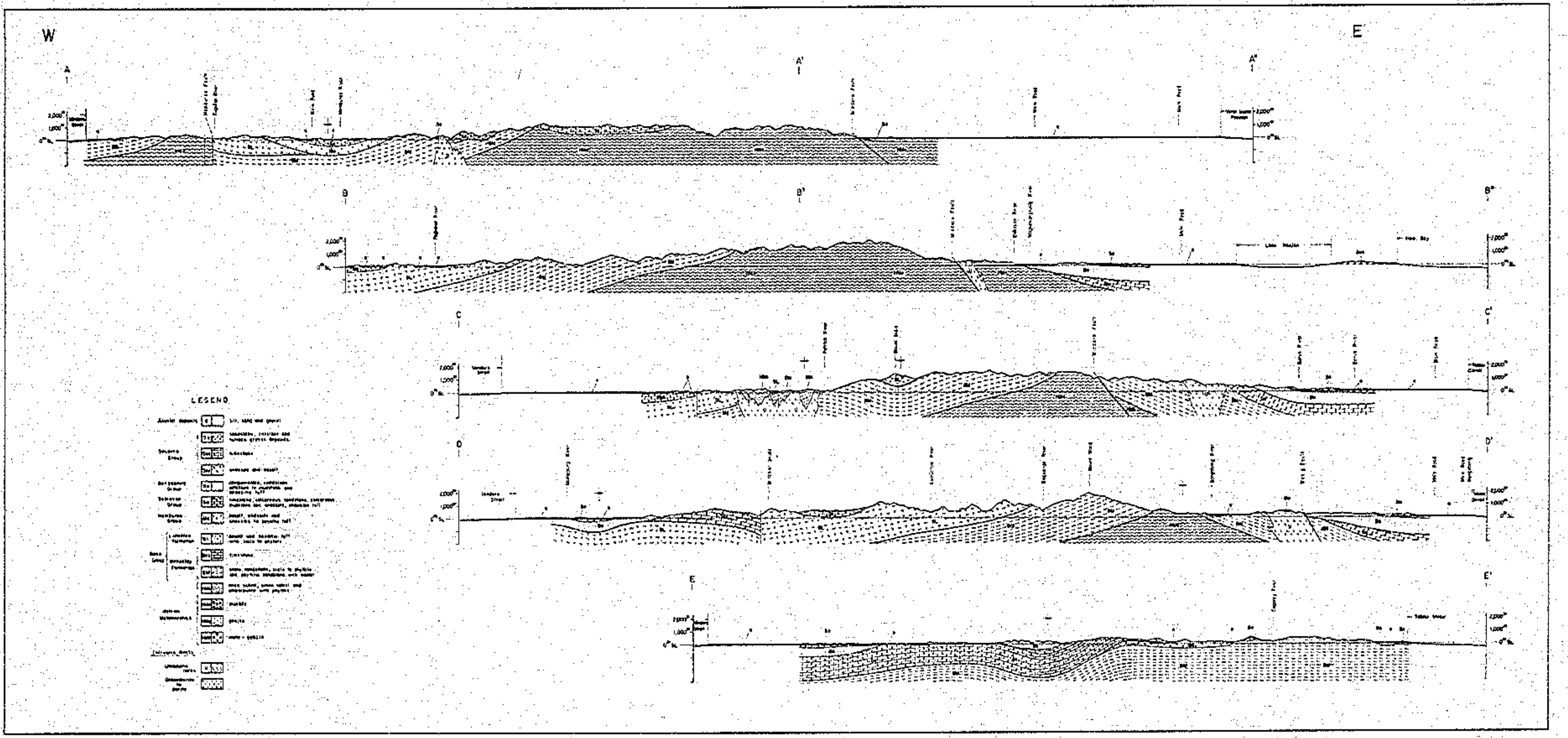

Fig. I-4 Geological Profile of the Survey Area

Table I-1 Generalized Stratigraphic Section of the Survey Area

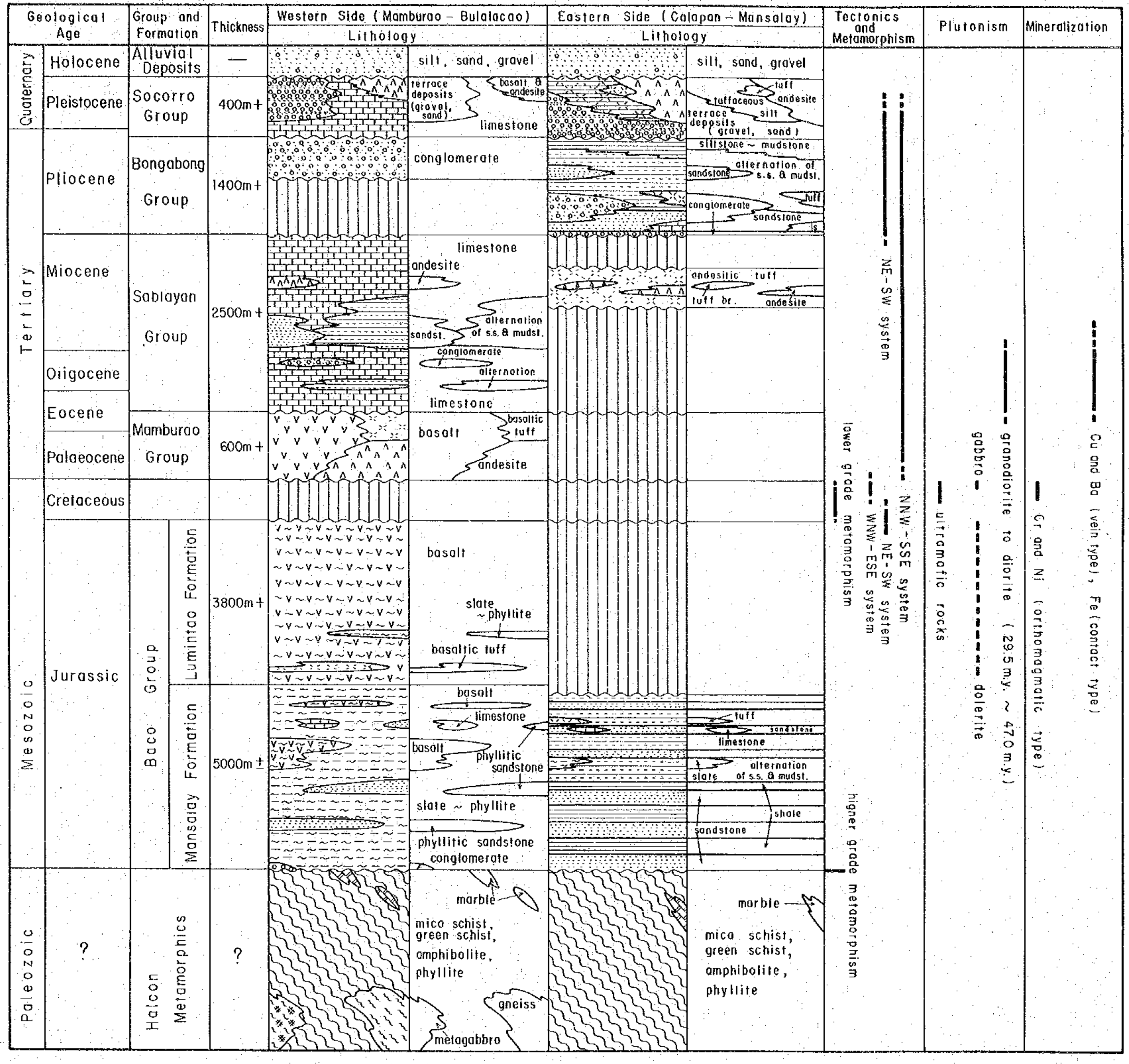

Table I-2 Stratigraphic Correlation

Era	Period	Epoch	Age	Teves (1953)	Weller & Vergara (1955)	Andal et. al. (1968) Hanzawa & Hashimoto (1970)	Miranda (1980)	JICA (1982)
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	Malo-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	Agbanag Conglomerate	
			Early					Mamburao Group
		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					
	Triassic			Wasig Formation				
Paleozoic	Permian			Mindoro Metamorphics			Mindoro Metamorphics	Halcon Metamorphics
	Carboniferous							

1–2 Previous works

A small number of reports was published about geology and ore deposits of Mindoro Island, moreover most of them were described mostly 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 about regional geology or mineralization are existent. All of these reports were used for compilation as references.

On 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.

On the southern part, relatively many reports on paleontology and stratigraphy were published. Teves (1953) had investigated around the area of Mansalay and Bongabong, and tried to establish the stratigraphy of Mesozoic rocks 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 from Middle Callovian to Oxfordian (upper Middle to lower Upper Jurassic). Hashimoto and Sato (1968a) had conducted a paleontological work and a structural analysis on the region to 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) had carried out a detailed regional mapping about 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 Photo-interpretation

As the surveyed area was very wide, aerial photo-interpretation was conducted in order to acquire the general information on lithology and structure, and to compile finally the geological map after checking the data collected during a ground survey. The interpretation on Landsat image of the area was carried out by Bureau of Mines and Geo-sciences (Fernandez, et al, 1978, MS), and its data was also refered.

For carrying out the classification of the geological units, identification of rock type and interpretation of geological structure after extracting a lineament, the stereoscopic observation was conducted using 392 sheets of black/white aerial photographs with scale of 1:40,000 and

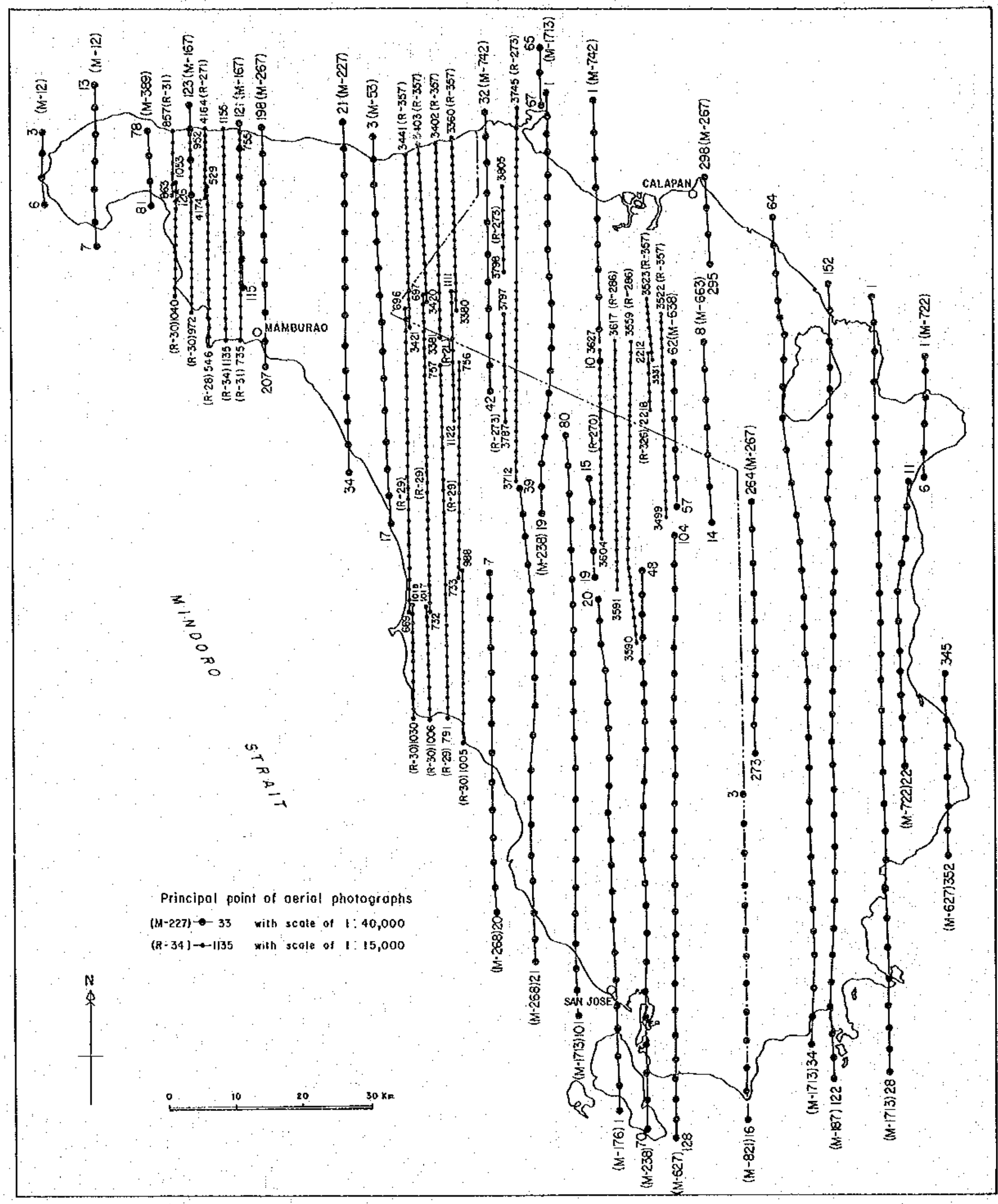

Fig. I-5 Index Map of Aerial Photographs

Table I-3 Characteristics Chart of Photogeological Units

Characteristics / Units	Texture	Drainage			Rock properties		Remarks	Lithology (dominant rocks)	Formation and Group
		Pattern	Density	Cross section of valley or gully	Resistance	Jointing			
A_1	uneven	parallel subdendritic	medium	gentle V-form	very high	high density	with very sharp ridge	mica schist, phyllite, green schist	Halcon Metamorphics
A_2	uneven	–	very low	U-form	moderate	low density	with rounded ridge	marble	Halcon Metamorphics
A_3	uneven	dendritic	high	gentle V-form	moderate	low density		gneiss, metagabbro	Halcon Metamorphics
B	uneven partly fine	parallel, subdendritic, partly trellis	high	gentle V-form	high	medium density		shale, sandstone, slate to phyllite, phyllitic sandstone	Baco Group: Mansalay Formation
C	uneven	dendritic, subdendritic	high	gentle V-form	high	medium density		basalt, basaltic tuff	Baco Group: Lumintao Formation
D	uneven	fine dendritic	very high	U-form	low	none	with rounded ridge	basalt, andesite	Mamburao Group
E	uneven	trellis, rectangular	low	U-form	moderate to low	high density	showing karst topography	limestone, calcareous sandstone, andesitic tuff	Sablayan Group
F_1	uneven	parallel, subdendritic	high	sharp V-form	high	none	with very sharp ridge	conglomerate	Bongabong Group
F_2	relatively even	dendritic	low	gentle V-form	moderate to low	none	with rounded ridge	sandstone, siltstone to mudstone	Bongabong Group
G_1	relatively even	parallel	low	V-form	low	none	with flat ridge	terrace deposits, tuffaceous mudstone	Socorro Group
G_2	relatively even	–	very low	V-form	relatively high	high density	showing clear bedding, karst topography	reef limestone	Socorro Group
G_3	relatively smooth	radial	medium to low	U-form	moderate	low density		andesite	Socorro Group
G_4	even, smooth	–	very low	U-form	low	none		basalt, andesite	Socorro Group
H	relatively smooth	subdendritic	low	U-form	moderate	none	showing dark tone in the poor vegetation	ultramafic rocks	Intrusive Rocks

567 sheets of black/white aerial photographs with scale of 1:15,000. On account of confirmation of these items, detailed and comprehensive investigation have been carried out about the characteristics of units such as texture, pattern and density of drainage system, and resistance.

The numbers and the position of principal points of the aerial photographs used for these works are shown in Fig. I–3.

The details and results of photo-interpretation are described in the paragraph of stratigraphy and the characteristics of geological units are summarized in Table I–3.

1–4 Stratigraphy

1–4–1 Paleozoic (Halcon Metamorphics)

The Halcon metamorphics is the tentative name given to the old metamorphic rocks which form the basement of the surveyed area. The name was taken from the Mt. Halcon, which is situated in the central area where the rocks are exposed. It is included in the Mindoro metamorphics reported by Teves (1953) and the Basement Complex of the Bureau of Mines (1974).

Distribution: The rocks widely crop out in the northwestern part of the present area and from the north to the east of Mt. Baco. Also, small exposures can be observed in the area where ultramafic rocks are found in the northwestern and northern parts of Sablayan.

Rock facies: The predominant rocks are mica schist, green schist, amphibolite, phyllite, gneiss, and metagabbro. Marble and psammitic phyllite are observed to be intercalated. These are formed by the metamorphic rocks which show green schist facies and epidote-amphibolite facies.

Mica schist and green schist are found prominently in the northern and northwestern areas. The mica schist is mainly grey-dark grey in color. Schistosity is developing, and there is fissility along this. The green schist is light green-green. Schistosity is developing, but fissility is poorly developed. Both show a striped structure of light and dark bands, and there are also some places where segregated quartz vein was observed. From microscopic observation, the mica schist is composed of muscovite-sericite bands and quartz-plagioclase bands, and chlorite is often observed to be closely associated with the muscovite-serivite bands. The green schist mainly shows the nematoblastic texture and consists of two types; the chlorite and quartz with small amount of sericite and plagioclase; while the other of epidote, actinolite and plagioclase with chlorite.

Phyllite is prominent in the central and southern sections, these are compact rocks with a

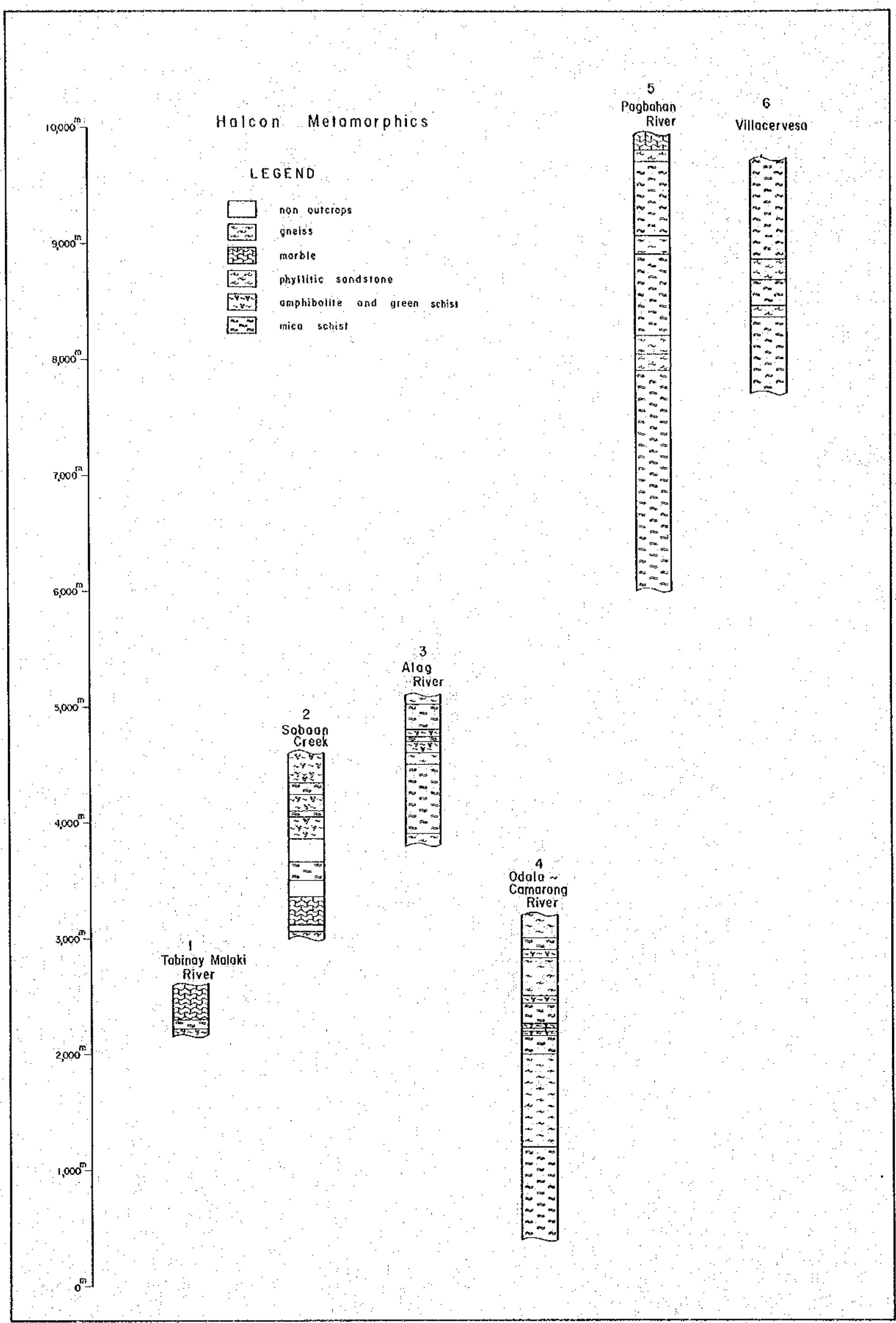

Fig. I-6 Geological Columnar Section of Halcon Metamorphics fine grained, grey-dark grey color, and schistosity is developing.

Amphibolite is abundant in areas such as the tributary of Abra de Ilog River and the Odala River. These are interlayered strata of about 10m in width in the mica schist. Under microscopic examination, it shows the lepidoblastic or granoblastic texture and is composed of coarse grained crystals of hornblende and plagioclase with epidote, chlorite, sphene, quartz and garnet. Plagioclase is often altered to sericite in a vermicular form.

Gneiss is found in areas such as the Camarong River in the northern section, and is formed of very coarse-grained crystals of quartz, muscovite, plagioclase, and potash-feldspar. Because of the nature of the forming minerals, and especially the parallel arrangement of mica, a gneissose texture develops noticeably. As this rock can be seen cutting the structure of the crystalline schist at the Matobang River, this source rock is thought of as acidic igneous rock. From the microscopic observation, gneiss shows porphyroblastic texture and consists of phenocryst of quartz 1–2mm in size, plagioclase and potash-feldspar 0.6–3mm in size and muscovite surrounded and cut by small grained crystals of quartz. Besides, network of sericite is found. Plagioclase is altered to sericite and epidote in vermicular form.

Metagabbro is found in the northern slope of Buruburungan. It appears a dark green color, and shows a coarse-grained structure of hornblende and plagioclase. Under microscopic examination, hornblende forms subhedral and often shows a mosaic texture, and some exhibits bended cleavage. Plagioclase is strongly altered to sericite with epidote.

Marble is found in the southern part of Puerto Galera, and there are areas alternating with crystalline schists. Some marble can also be seen in the crystalline schists as lens-shaped or massive. These are generally white-light pink in color, and the alternating parts often appear as a black-dark grey color.

Photo-characteristics: The mica schist, green schist, amphibolite, and phyllite have the same characteristics, (unit A1), 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. The well developed jointing is also a characteristic. The marble (Unit A2) shows a moderate resistance, and rounded mountain ridges are a characteristic. The drainage density is very low. Gneiss and metagabbro (Unit A3) are also of moderate resistant, but small drainage patterns are developing, these appear dendritic. The mountain ridges are relatively angular, while the valleys are in an open V shape.

Geological structure: The schistosity as observed along the route maintains its trend and corresponds closely to the bedding. Although the strike of schistosity measured is undulated by minor folding, the general trend strikes northeast within San Teodoro area, east-west in the upper stream of Alog River. The general trend of genissose structure strikes east-west in the Camarong River, northwest in the Odala River. The above data suggests that Halcon metamorphics in the northern area form folding with an axis trending northeast.

Age: Pebbles of metamorphic rocks are included in the conglomerate of the Mansalay formation found in the eastern part of Abra de Ilog. The pebbles can also be seen in the conglomerate of the Mansalay formation in the Kipalaye River, which is a tributary of the Caguray River to the west of Mansalay (P.P. Andal, 1967). Some K-Ar dating of the metamorphics was carried out, and the results show an age of 23.7 m.y.–38.9 m.y. This is almost the same age as the results which were obtained from the granodiorite and quartz diorite intruding into the metamorphics. However, when granitic rocks are found in the areas where metamorphic rocks are exposed, they show about the same age. This is thought to be because the Ar is forced out by the heat of the intruding granitic rocks (Shibata, 1968). Consequently, despite the present age dating results, the age of the Halcon metamorphics is thought to be pre-Jurassic.

Concerning the age of the source rock, from the production of fusulina such as Pseudofusulina fusiforms (Schellwien), Schwagerina hawkinsiformis Igo, etc. from the conglomerate in Mindoro (Koike et al., 1967), and from the discovery of fusulina which is Neoschwagerina, Parafusulina, etc. from the limestone of the basement rock in Carabao Island, an age of pre-Permian is assumed.

1–4–2 Mesozoic (Baco group)

The Baco group is the tentative name given to the volcanic rocks, slight and non-metamorphosed clastic rocks, which are thought to uncomformably cover the Halcon metamorphics. The name was taken from the Mt. Baco, which is located in the central areas where these rocks are exposed. These rocks are divided into two formations; the lower is the Mansalay formation, comprised primarily of clastic rocks, and the upper is the Lumintao formation composed mostly of volcanic rocks.

(1) Mansalay formation

The Mansalay formation is named to the formation which produces fossil of Jurassic age, and is found in the western part of Mansalay. A detailed survey to establish the stratigraphy, was conducted by Andal et al. (1968). Until now this Jurassic formation was thought to have been found only in the western and northwestern parts of Mansalay. However, according to the results of this survey, the beds formed primarily of slate, which is found from the north to the central area, is intruded by ultramafic rocks which are thought to be intrusive rocks of Cretaceous age. When the regional differences are considered in the metamorphism, it was realized that they are quite similar to the rock facies of the Jurassic formation of the southeastern section. Consequently, it was inferred that this beds composed mostly of slate is equivalent to the Mansalay formation.

Distribution: The formation is distributed in a long belt in a northwest-southeast part, from Manburao to Mansalay. There are also small exposure in the Paluan area.

Thickness: At the Amnay and Rayusan Rivers in the central section of the area, the formation is approximately 5,000m thick.

Rock facies: This stratigraphy is formed principally of pelitic and psammitic rocks, and includes basic lava and tuff locally. Because these rock facies are varying on account of the differences in metamorphic grade, they will be discussed according to area.

① Rock facies of the southeastern sections

In the lower part, thick layers of sandstone and shale are developing, while in the upper sandstone and alternating beds of sandstone and shale are prominent.

The sandstone is mainly a white to greyish-white arkose sandstone, which is abundant in quartz crystals, and greyish-white to grey colored greywacke can sometimes be seen. These are generally massive, with a poor bedding, having both well-consolidated and poorly-consolidated areas.

Shale is grey, dark grey and black in color, and in areas with thick layers the bedding is poor, in areas where it alternates with sandstone the bedding is well developed. Slatinized areas are found in the upper stream of the Bugsanga River.

The alternating layers of sandstone and shale are found in some areas, where the thickness of bed varies from 10cm to several meters, grading can sometimes be seen.

Besides, the pebble to granule conglomerate which contains the gravels of chert, slate and sandstone, and limestone which is abundant in fossils with a thickness of 10m, are exposed in the Bugsanga River. Several layers of andesitic tuff, with a thickness of 10–20m, is exposed in the Siange River.

Andal et al. (1968) carried out a geological survey in the southeastern area, along the Mansalay River, the Amaga River, and the Cagancan River, and from the upper member made the following divisions.

10. Black sandy shale, very finely laminated, revealing the socalled flysch facies, yielding abundant animal trails on the surface of the stratification. About 150m thick.

9. Granule conglomerate and coarse grained sandstone. Thickness unknown.

----- Relation unknown, fault contact -----

8. Lithic sandstone: bluish grey in color, medium to coarse grained, intercalated by several black shale layers 30–50cm thick. Total thickness unknown.

7. Black shale, typical pure lutite. About 250–300m thick. No fossils.

6. Alternation of black shale, white vitritic tuff and devitrified cream fine tuff. About 20–30m thick.

5. Amaga River horizon: black sandy shale or dark grey argillaceous siltstone with frequent intercalations of bluish gray clayey shale; ammonites very common. Thickness about 350m.

4. Bluish grey, medium grained, very compact sandstone; frequently interbedded with black sandy shale layers; yielding fossils. Thickness 1,200m.

3. Parucpoc Hill horizon: black sandy shale with calcareous concretions; rich in ammonites. Thickness about 200m.

2. Grey, fine to medium grained sandstone, very quartzose, and frequently intercalated by black, arenaceous, somewhat bituminous shale, yielding fossils. Thickness roughly 700 to 1,000m.

1. Caromata Hill horizon: black shale, frequently alternating with carbonaceous, medium grained, grey sandstone: many animal tracks can be observed on the surface of the stratification; relatively rich in ammonites.

Because this phase was a reconnaissance survey, not enough data was used to examine these stratigraphical divisions.

② Rock facies of the northern to central sections

As in the southeastern sections, these are mainly pelitic and psammitic rocks, but both have a low grade metamorphism and are changing to slate to phyllite or indurated sandstone to phyllitic sandstone. Rocks such as basalt lava, basaltic tuff breccia, limestone and conglomerate are intercalated with these rocks.

Phyllite to slate is generally calcareous, black to dark grey in color. The schistosity or cleavage is well developed, and it is often accompanied by segregated quartz veins.

The indurated sandstone and phyllitic sandstone are greyish white-grey in color. The indurated

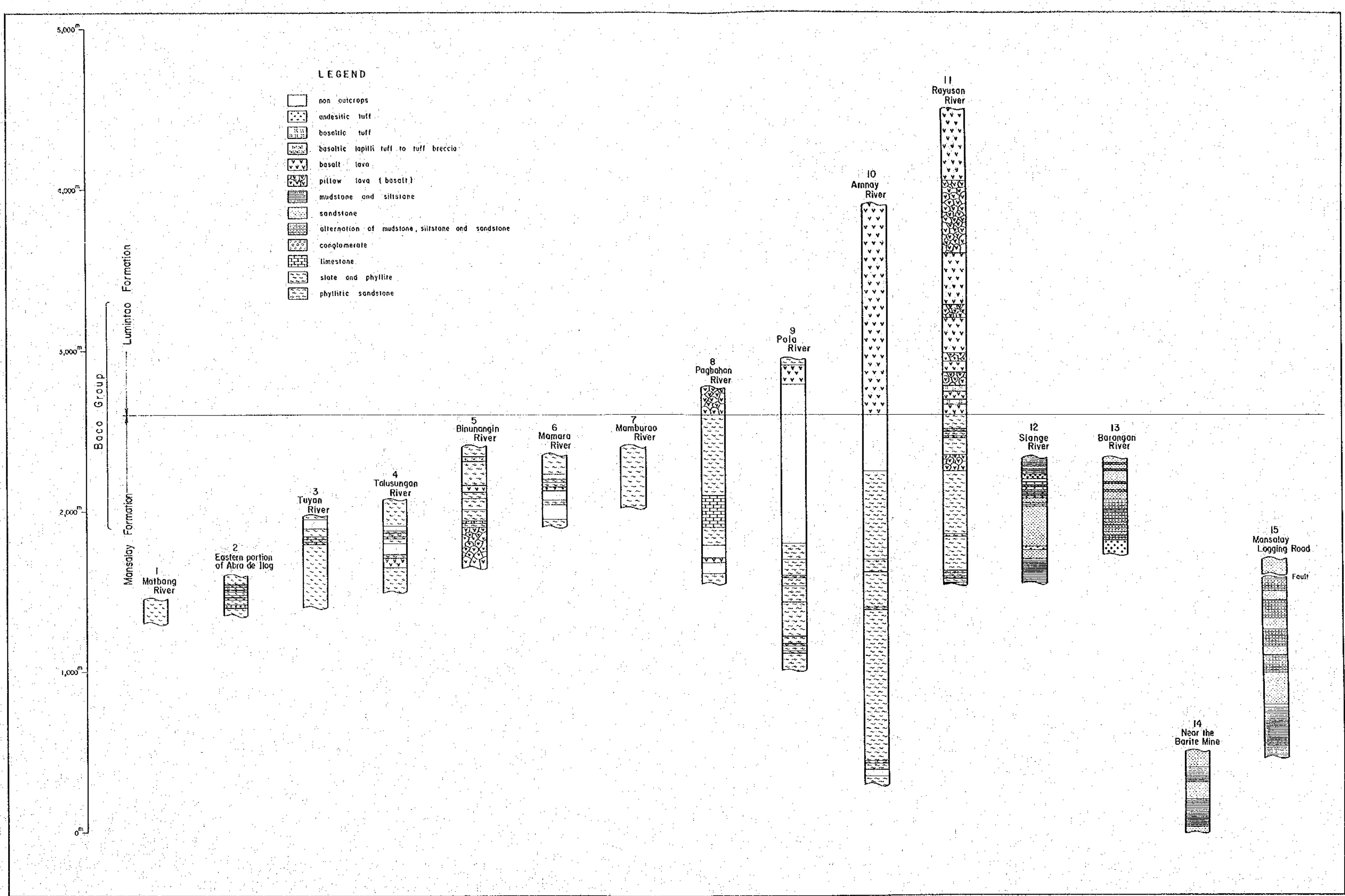

Fig. I-7 Geological Columnar Section of Baco Group sandstone is massive, but the phyllitic sandstone often shows the schistosity by arrangements of minerals and flattened rock fragments. These sandstone are the greywacke and calcareous, which contains many shale fragments with middle to coarse grain size. Generally these are interbedded as thin layers of less than 10m thick in the slate-phyllite, and in some areas, fine alternating layers can be seen. However, in the Pola River, a well bedded indurated sandstone over 400m thick are found. Worm tracks and ripple marks can rarely be seen on the bedding plane of these rocks.

The basalt lava is dark green in color, and a pillow structure is generally well-developed. In the Binunangin River these become over 500m thick, but are generally 50–200m thick in other areas. It exists in slate-phyllite and phyllitic sandstone. Basaltic tuff breccia found in the slate of the Binunangin River is green and thin layer of 2–3m thick.

Limestone crops out in the Pagbahan River, and is a massive rock appearing grey to light grey in color, and is relatively recrystallized, it has a thickness of about 400m.

Conglomerate is found locally in thin layers. Those which are exposed in the tributary to the east of Abra de Ilog form the basis of the stratigraphy, and the gravels are formed of sub-angular phyllite, sandstone, crystalline schist, and quartzite. These are well sorted, and range in size from 5 to 10cm. However, the conglomerate exposed in the Mamara River forms the upper section of this stratigraphy and show the same kinds of gravels, and are well-rounded and fine, being less than 1cm across.

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

Geological structure: The Mansalay formation shows a normal structure in the central area, but a relatively complicated structure in the northern and southern area. In the central area from the east of Mamburao to Mt. Baco, the bed mostly strikes N30–60°W and dips NW, though it strikes E–W to the east of Sablayan because of NE trending foldings. While, in the northern section, around Abra de Ilog it forms a NE trending syncline as a whole, but the strikes and dips of each bed are irregular. In the southern section, to the northwest of Mansalay the strikes and dips varies and NE trending minor foldings are prominent.

Stratigraphic relationship: The relationship between this formation and the underlying Halcon metamorphics could not be observed directly. However, it was observed that the gravels of crystalline schist and quartzite are included in the conglomerate, there are areas where the obvious differences exist in the structures between both, (as to the east of Abra de Ilog), and that the degree of metamorphism changes suddenly from slightly-metamorphosed rock facies to green schist facies or epidoto-amphibolite facies. From these facts, the relationship can be thought of as unconformable.

Age: The fact that Jurassic fossils are produced in abundance in Mansalay is reported by many researcheers, such as; Hayasaka, 1943; De Villa, 1944; Kobayashi and Mori, 1955; Kobayashi, 1957; Teves, 1953; Sato, 1961; Andal et al., 1968. Numerous Ammonite, Belemite and bivalves such as Trigonia are observed frequently in the area.

A detailed study of these Ammonites was made by Andal et al. in 1968, and they reported the age of this layer of the Mansalay area as being from upper Callovian to Oxfordian, which is a period from the upper Middle Jurassic to the lower Upper 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) The Lumintao formation

This formation has been tentatively named, as it is widely found in the area surrounding the Lumintao River. Its stratigraphic relationship and distribution has been clarified in this survey.

Distribution: It is exposed from the Lumintao River to the Pagbahan River in the eastern part of Mamburao.

Thickness: more than 3800m

Rock facies: This formation is generally composed of basalt lava, including thin layers of slate and tuff locally.

The basalt lava is green to dark green in color. Pillow structure was observed in many places. An amygdaloidal texture is also seen frequently. This rock often accompanies veins of epidote and calcite, and the spaces among the cores of pillow structure are filled with chlorite and epidote which were altered from volcanic glass.

Tuff is exposed in two layers about 50m thick in the Rayusan River around the boundary with the Mansalay formation. It is basaltic, a green or reddish brown in color, fine-grained, and slatinized.

Slate is exposed in the Pola River, and is a dark grey in color.

In the boundary between this formation and the Mansalay formation, lenticular slate can be seen in this basalt lava, and lenticular basalt is evident in the slate of the Mansalay formation. Accordingly, both are understood to be gradually changing. This relationship can easily be seen in the Rayusan River.

The results of the microscopic examination are as follows.

Basalt (YR–26)

Texture: Intergranular texture, partly showing subophitic texture.

Constituent minerals: Phenocrysts consist mainly of euhedral to subhedral plagioclase 0.2 – 1mm in size and subhedral augite 0.2 – 0.4mm in size. Groundmass is composed of microcrystals. Alteration is prominent, epidote transformed from mafic minerals is predominantly observed and chlorite is also seen. Quartz and calcite veinlets are impregnated along fractures.

Dolerite (YR–10)

Texture: Doleritic texture.

Consituent minerals: Euhedral plagioclase 0.6 – 0.8mm in size and euhedral augite 0.2 – 0.4mm in size with opaque minerals. Chlorite and epidote altered from mafic minerals were also observed. Plagioclase has partly affected albitization and most of them have albite rim.

Photo-characteristics: The Lumintao formation (Unit C) shows a high resistance and high drainage density like the Mansalay formation, and the drainage pattern is dendritic to sub-dendritic. Other characteristics also resemble those of the Mansalay formation, therefore it is difficult to differentiate between the two.

Geological structure: No bedding was noted on this formation because it is made up mostly of lava. The structure is assumed to strike NW and dip SW from the Mansalay formation.

Stratigraphic relationship: As stated above, it conformably overlies the Masalay formation.

Age: Because this formation is in a concordant relationship with the Mansalay formation, the age of formation was thought to be Jurassic.

1–4–3 Cenozoic

The Cenozoic is widely distributed in this area so as to encompass Paleozoic rocks and Mesozoic rocks, and is divided, from the older age, into the Mamburao group, the Sablayan group, the Bongabang group, the Socorro group, and the Alluvial deposits.

(1) Mamburao group

This group was tentatively named after the town of Mamburao, which is located in the area where basic pyroclastic rocks and volcanic rocks thought to be Paleocene are widely found.

Distribution: Other than being found along the road from Abra de Ilog to Mamburao, there are also small exposure in Sta. Cruz and in the upper stream of the Caguray River.

Thickness: In the upper stream of the Mamburao River, it is more than 600m.

Rock facies: This formation is composed of basalt and andesite lavas, and basic-andesitic tuff.

The rock facies differ according to the area. In Mamburao this group is formed of basalt which shows green to brown in color and a pillow structure. In Sta. Cruz it consists of basalt accompanied with basaltic andesite in which many plagioclase crystals can be seen on the surface. However, in the upper reaches of the Caguray River, this group shows rock facies comprising of green or red basaltic-andesitic tuff, basalt and andesite. The results of the microscopic observation are as follows.

Basalt (FR–17)

Texture: Intersertal texture.

Constituent mineals: Phenocrysts are made up of euhedral plagioclase 0.3 – 5mm in size being rectanglar or lathlike shape and euhedral augite 0.2 – 0.3mm in size, and groundmass of needle-like plagioclase, microcrystals of clino-pyroxine, opaque minerals and glass. As for secondary minerals, chlorite altered from mafic minerals, probably augite, vermicular sericite from plagioclase, and calcite can be observed.

Photo-characteristics: The group (Unit D) is easily distinguished from other units because of the fine dendritic drainage pattern, the low resistance and the extremely high drainage density. In general, mountain ridges are rounded, but in the area of the Caguray River show angular ridges.

Geological structure: It is difficult to clarify the structure of this formation, because the formation consists mainly of lava and the field data is limited. However, the distribution and the result of photo-interpretation suggest that it forms the NE trending syncline around Mamburao and the E–W trending syncline to the west of Mansalay.

Stratigraphic relationship: In the upstram of the Mamburao River it is comfirmed that this group unconformably overlies the Mansalay formation.

Age: This group unconformably covers the Baco group, moreover it is observable on aerial photographs that the group unconformably overlies the ultramafic rocks. As expalined below, because it is unconformably overlain by the Sablayan group, the age of this group is thought to be Paleocene to Eocene.

(2) Sablayan group

This group was given a tentative name for the beds which predominantly includes the limestone of Upper Eocene- Upper Miocene. As shown in Table I–2 the beds such as the Mansiol conglomerate, Camangui sandstone and Pocanil limestone by Teves (1953), and Bandao limestone, Bulalacao limestone, Napisian formation, Mato-ang limestone and Pocanil limestone by Weller and Vergara (1955) are included in this group.

Distribution: Other than being widely found from Sablayan to Bulalacao, there are also exposures in the downstream of the Mamburao River, to the northeast of Mamburao, to the northwest of Bongabong, and in the upstream of the Magasawangtubig River.

Thickness: More than 2,500m.

Rock facies: This group is primarily composed of limestone, and found in some places to interbed with sandstone, mudstone, andesite lava and andesite tuff. Conglomerate can also be observed locally. Sedimentary rocks other than the limestone is also calcareous in nature.

The limestone is predominant 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 50cm in thickness of each bed. Abundant fossils of larger foraminifera and corals are observed. The limestone exposed on the northeast of Mamburao is recrystallized.

The sandstone is light grey to grey in color, mostly medium to fine grained, and includes abundant quartz and rock fragments with calcareous matrix. In the sandstone which is found to the northeast of San Jose, coal seams of over 1.5m thick are intercalated.

The mudstone is grey-dark grey in color, and is generally calcareous. Marl is also observed.

These sandstone and mudstone form alternating layers in the northern part of Bulalacao, and include coal layers in between. This of alternating layers is over 200m thick, and has been designated as the Napisian formation by Weller & Vergara (1954).

The andesite lava is found downstream of the Rayusan River in the eastern section, and in the Balete River in the east. Altered rock shows dark green-grayish green in color. The brecciation caused by water fragmentation are well observed.

Andesitic tuff is well exposed in the eastern area, and is formed primarily of fine-grained tuff appearing light green to greyish-green, with intercalation of tuff breccia and volcanic conglomerate.

Conglomerate crops out locally and interbed with other rocks in the northeastern portion of San Jose and the eastern section of Sablayan. The gravels consist of chert, crystalline schist and andesite, and are sub-rounded to sub-angular. Their size ranges from granule to cobble, and they are generally poorly sorted.

Photo-characterisitcs: Karst topography is developed in the area where this group (Unit E) is distributed. 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 is 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 the joint pattern, and shows a trellis or rectangular pattern.

Geological structure: The group shows a rather complicated structure with minor foldings. In particular, the beds cropping out from Sablayan to Bulalacao, exhibit the irregular structure and the different directions of strike and dip. As a whole, nevertheless, it tends to strike NW and gently dip SW. The group in the eastern portion has a normal structure, it strikes N30 – 50°E and dips 30°SW in the Balete River, and strikes N25 – 60°W and dips 40°NE in the Tangon River.

Stratigraphic relationship: This group exhibits an angular uncomformity with the Halcon

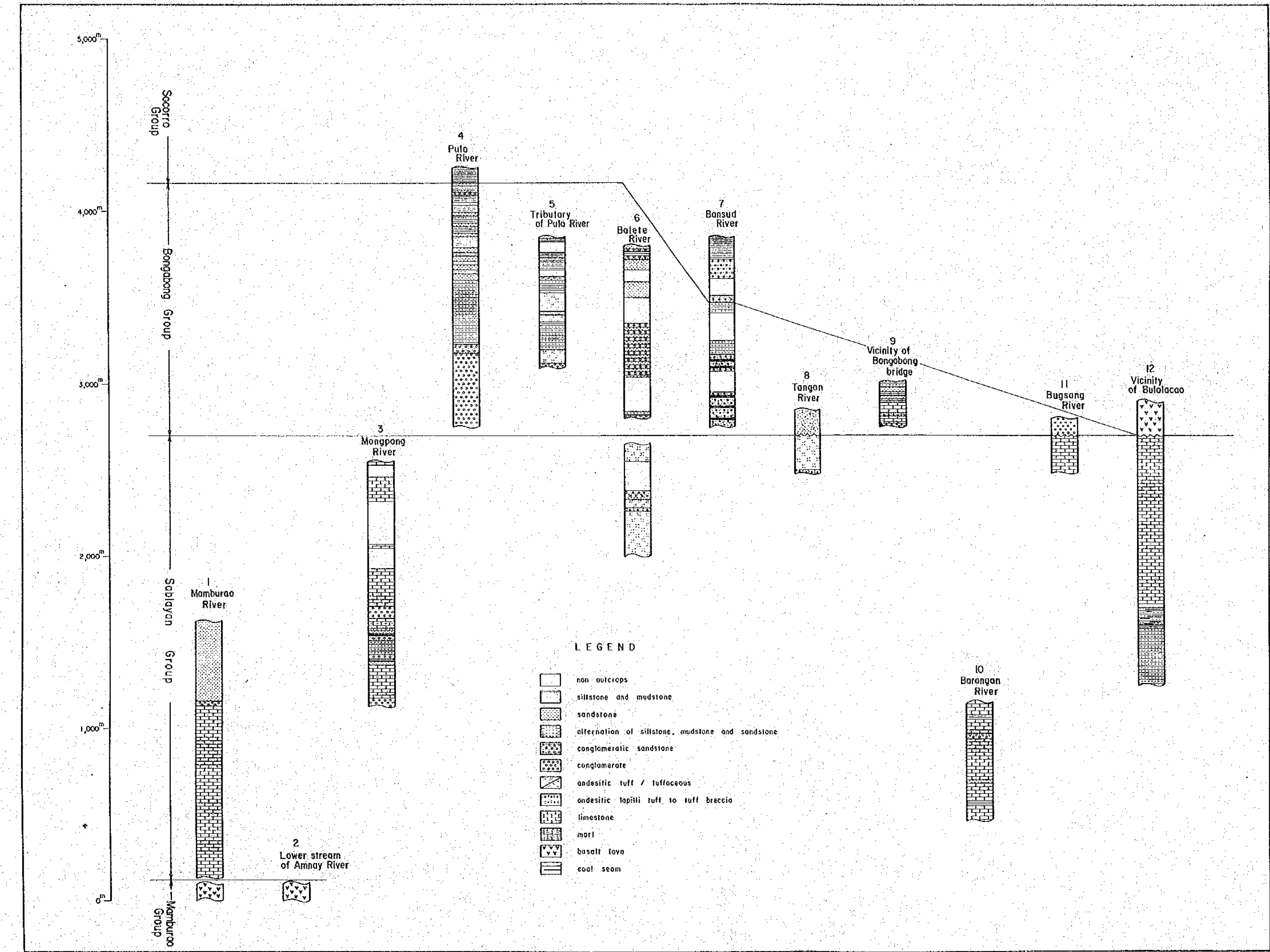

Fig. I-8 Geological Columnar Section of Cenozoic Rocks metamorphics, the Baco group, and the Mamburao group.

Age: As stated above, larger foraminifera are found in the limestone of this group, and the types as shown in Table A–1–1 were identified at this time. Of these, Halkyardia minima (Liebus) and Biplanispira mirabiris (Umbgrove) are of Eocene age and Nummulites fichteri (Michelotti) is Oligocene age. Also, the assemblege of Miocene age was comfirmed.

From the results of this findings, and the works of Hashimoto & Sato (1969), Hanzawa & Hashimoto (1970), the sedimentary age of this group is determined as Eocene to Miocene.

(3) The Bongabong group

The Bongabong group is the tentative name given to those beds composed mostly of Pleistocene conglomerate, tuffaceous sandstone, and mudstone to siltstone. As shown in Table I–2, the Famnoan formation and the Barubo sandstone of Teves (1953) and Hanzawa & Hashimoto (1970), as well as the Punso conglomerate of Miranda (1980), are included in this group.

Distribution: Being found continuously from Villacervesa to Mansalay in the eastern section, this group is also in scattered locations in Pasugui and to the north of San Jose.

Thickness: At the Pula River in the eastern section, the thickness is more than 1400m.

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

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. Generally, the conglomerate include many types of gravels such as sandstone, mudstone, limestone, andesite, crystalline schist, and small amounts of quartz diorite. These range in size from pebble to cobble, rarely with boulder size. The matrix is reddish brown coarse-grained sandstone. The layer thickness is over 700m at Pasugui.

In the eastern part, this group begins with a basal conglomerate. The lower to the middle part are made up of sandstone, conglomerate, and alternating layers of sandstone and mudstone-siltstone with intercalations of tuff and limestone. In the upper part, this group is formed of mudstone-siltstone and alternating beds with sandstone. Large amounts of smaller Foraminifera are found in the mudstone-siltstone.

The basal and lower conglomerate are generally massive, grey to brown in color, and include many kinds of gravels as found in the western parts. These are subrounded to sub-angular, and range in size from granuale to pebble. The matrix is either tuffaceous or calcareous. The basal conglomerate is about 10–20m thick, but the lower conglomerate is over 300m thick at the Pula River and the Balete River. Moreover, thin layers of sandstone and siltstone are abundant in the latter conglomerate.

Sandstone is exposed at the Pula River, the Balete River, and the Tangon River, with a thickness of 150 to 250m. These are grey to light grey in color, fine to medium-grained tuffaceous sandstone, and calcareous. Bedding is well developed, and it is interbedded with thin layers of conglomerate and mudstone-siltstone.

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

The mudstone-siltstone is grey, calcareous and fossiliferous, and the bedding is well developed. There are many outcrops of these rocks at the Pula River, where they become over 300m thick.

Tuff crops out at the tributaries of the Pula River. It is light grey, fine-grained and andesitic, and crystals of plagioclase, hornblende and pyroxene are visible on the surface.

The limestone lying above the basal conglomerate in the midstream of the Bongabong River is a light brown in color, and gradually changes to calcareous conglomerate or sandstone towards the upper sections.

Photo-characteristics: This group can be divided into conglomerate (unit F1) and the other (Unit F2) from the morphological characteristics. Unit F1, as the conglomerate of Pitogo shows, has a characteristic angular relief, high resistance and a fine parallel and subdendritic drainage pattern. However, unit F2 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 undulation by minor foldings, and it strikes NNW 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 is considered to be a horizontal as a whole from the distribution of outcrops.

Stratigraphic relationship: This group uncomformably covers the Sablayan group and other layers older than it. It also uncomformably overlies quartz diorite and ultramafic rocks.

Age: As stated above, this group is rich in smaller foraminifera, and as shown in TableA–1–2, various types were identified. Hashimoto & Sato (1969) detected planktonic foraminifera from the Famnoan formation exposed in Balahid, in the middle reaches of the Bongabong River. They reported that these are of Pliocene age. The sample WR–15 lies just about on the same horizon as their sample, and the assemblage of planktonic foraminifera resembles each other. As other samples also contained the same types of foraminifera, the sedimentary age of this group is thought to be Pliocene.

(4) The Socorro group

The name of this group was taken from the name of the town of Socorro which is situated to the south of Lake Naujan in the eastern part of this area. The name was given to the layers composed of volcanic rocks and sedimentary rocks of the Pliocene to Pleistocene period. This group includes the Oreng formation and the Balanga formation of Teves (1953), as well as formations described by Weller & Vergara (1955), which are the high-level sand & gravel and the Eplog lava flows.

Distribution: The group is exposed extensively from Puerto Galera in the northern part through the area of Socorro in the east, and to Roxas in the southeast. It also covers the area around San Jose, Sablayan and Mamburao.

Thickness: Approximately 400m.

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

The terrace deposits well crops out in San Jose, Sablayan, Bongabong, and in the mid-stream of the Bunsud River. It is primarily composed of unconsolidated gravel beds with sand beds locally. The gravels are formed of several kinds of rounded to subrounded rocks, and are poorly sorted. In some areas, poor bedding was observed in these beds.

Tuffaceous mudstone is widely distributed in San Teodoro and Socorro areas. It is grey to dark-grey, poorly consolidated, and the bedding is weakly developed. Smaller foraminifera was rarely contained in it, as shown in Table. A–1–2.

Tuff is found in San Teodoro. It is light grey, porous vitritic tuff, and includes volcanic glass and pumice. There are areas where the bedding is well developed.

Reef limestone is exposed on the west and south of San Jose, and in Ilin and Ambulong islands. It is well bedded and rich in larger foraminifera (Table A–1–1).

Lava flows is distributed in Calapan, the eastern shore of Lake Naujan, Mt. Dumali, Eplog hill and Mauhao. These consist of biotite-hornblende andesite in Calapan and Mt. Naujan, pyroxene andesite (containing extremely small amounts of biotite and hornblende) in the eastern shore of Lake Naujan and the Mt. Dumali, hornblende andesite in Eplog hill, and of pyroxene andesite and basalt in Mauhao. The results of the microscopic observation are as follows.

Biotite-hornblende andesite (SR–93)

Texture: Hyalopilitic texture.

Constituent minerals: Phenocrysts are made up of euhedral plagioclase 0.2 – 1.8mm in size being rectangular, euhedral hornblende 0.1 – 2.5mm, opaque minerals 0.1 – 0.2mm with subhedral biotite 0.1 – 0.2mm. Most of plagioclase show a zonal structure. Groundmass consists of microcrystals of plagioclase and glass, containing a large amount of opaque mineals. No alteration is observed.

Pyroxene andesite (SR–71)

Texture: Microcrystalline texture.

Constituent minerals: Phenocrysts are composed of euhedral plagioclase 0.1 – 0.2mm in size being rectangular and lathlike shape, and euhedral augite with a small amount of hornblende, biotite and hypersthene. Groundmass consists of microcrystals of plagioclase, pyroxene and so on. No alteration.

Basalt (WR–32)

Texture: Intergranular texture, partly showing subophitic texture.

Constituent minerals: Phenocrysts are made up of euhedral plagioclase 0.1 – 0.6mm in size being lathlike shape, euhedral augite and olivine 0.1 – 0.6mm in size. Groundmass consists of glass showing yellowish part and brownish part; the latter contains a large amount of opaque minerals. No alteration.

Photo-characteristics: Unit G1, which are 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 (Unit G2) 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 (Unit G3) as compared to those found in the southern areas (Unit G4). Unit G3 remains as a non-weathered lava flows, and shows a radial drainage pattern as well as rounded mountain ridges. Unit G4, compared to Unit G3, has a low resistance, with an extremely poor drainage system, and flat topography.

Geological structure: The Socorro group generally shows a very gentle structure except the NW trending foldings formed on the east of San Jose. It strikes NNW and dips 5–10E in the eastern portion, and is almost horizontal in the western portion.

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

Age: Calcarina Delicata Todd and Post of Pleistocene age is found in the limestone exposed to the east of San Jose, and in the conglomerate in Mamburao which have a calcareous matrix. This group also includes unconsolidated beds and undissected lava flows. From this, the age of the group is thought to be Pliocene to Pleistocene.

(5) Alluvial deposits

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

1–5 Intrusive rocks

1–5–1 Ultramafic rocks

The rocks widely crop out in Mindoro Island and is distributed in the areas where the Halcon metamorphics and the Baco group are exposed.

Mindoro Island lies within the Ilocos-Mindoro ophiolite belt. It is reported that the most complete ophiolite sequence in the Philippines is observed in Zambales within this ophiolite belt (Balce et al., 1981). Furthermore, it is stated in Bureau of mines (1974) that the ultramafic rocks in Mindoro are generally thrusted or upfaulted.

In this survey, the following fact was obtained on the ultramafic rocks; these exhibite a discordant structural relationship with the Halcon meramorphics and the Baco group, no evidence was observed to suggest the thrust fault along these bodies and on the places of these extension, and the irregular relationship was comfirmed between them and other beds on the outcrop as describe later. From these facts it is inferred that the rocks are intrusive bodies, however, a future survey and examination are still required to clarify the genesis of the rocks.

Distribution: As large rock bodies, the western body trending NW is exposed from Sta. Cruz to the west of Mt. Baco, the central body trending E–W from the upstream of the

Amany River to Villacervesa, and the eastern body trending NNW from Villacervesa to the Bongabong River. Smaller bodies are distributed in the areas of Mamburao, Paluan, and to the east and west of Abra de Ilog.

Rock facies: These rocks show dark green to black and most of them are serpentinized. The strongly serpentinized rocks exhibit a lustered surface and a yellowish green to greyish green color.

At the contact between the ultramafic rocks and host rocks, the former intrude irregularly into the latter and small blocks of Baco group and Halcon metamorphics are included in the ultramafic rocks. As can be seen in Sta. Cruz and the eastern section of Sablayan, large blocks of metamorphic rocks which are thought to have risen from the lower part on intrusion, are also evident.

From the results of microscopic examination, the rock samples collected in this survey are all peridotite, and these are divided into harzbergite and lherzolite. However, many of the rocks are undergoing complete serpentinization. The results of the microscopic observation of representative samples are as follows:

Harzbergite (SR–65)

Texture: Equigranular.

Constitutent minerals: Primary minerals are olivine with enstatite. Olivine remarkably altered to serpentinite along fracture. Enstatite is 0.4 – 2mm in size and slightly altered to serpentinite. Spinel and opaque minerals are also observable.

Lherzolite (WR–161)

Texture: Equigranular.

Constituent minerals: The order of distribution of main primary minerals is the following; olivine $\gg$ augite $>$ enstatite. The alteration is remarkable, olivine changed to serpentinite along fracture and augite altered to serpentinite, chlorite, talc and calcite. Spinel and opaque minerals associated with serpentinite are also observed.

Photo-characteristics:

The ultramafic rocks (Unit H) have a moderate resistance that is lower than that of the Halcon metamorphics or the Baco group, and shows a poorly developed drainage, a relatively smooth texture, and rounded mountain ridges. From these characteristics, it is easily differentiated from other units. Also, in areas where there is little vegetation, it can be distinguished from other units by the dark tone which are a characteristic of this unit.

Age: These rocks intrude into the Baco group, and these are unconformably overlain by the Mamburao group, consequently the age of intrusion is thought to be Cretaceous.

1–5–2 Acidic to intermediate rocks

These are granodiorite, quartz diorite and diorite, intruding into the Halcon metamorphics, the Baco group, the ultramafic rocks and the Sablayan group. These trends NW–SE to NNW–SSE. The average width is about 1km, and the length along the strike is 5km.

Distribution: These dikes are found in scattered areas from the northern parts to the central parts. Exposure of granodiorite can be seen in the Camarong River. Quartz diorite crops out in the upper reaches of the Bongabong River and Villacervesa in the east, and the upper reaches of the Mamburao River in the north. Diorite is exposed on the southeast of Villacervesa.

Rock facies: Granodiorite is coarse-grained and leucocratic, the main constituent minerals being muscovite, quartz, and plagioclase. Quartz diorite shows a grey to dark grey color, and the main minerals are hornblende, plagioclase, and quartz. Diorite appears dark green to greyish black in color, and is fine to medium in grain size. It shows a higher color index and the main minerals consist of hornblende and plagioclase. Partial pyrite impregnation can be observed in all of the above. The results of the microscopic examination of representative samples are as follows;

Granodiorite (FR–41)

Texture: Equigranular.

Constituent minerals: The order of distribution of main minerals is the following: quartz, plagioclase $\gg$ muscovite, biorite, potash-feldspar. Quartz is anhedral and 0.4 – 3mm in size. Plagioclase is euhedral or subhedral and 0.4 – 3.5mm in size, it contains a 10 – 30% of An component, and partly altered to epidote and sericite. Biotite chloritized partly and muscovite are subhedral, 0.2 – 2mm in length. Potash-feldspar is anhedral and 0.2 – 0.3mm in size. Zircon and apatite are also observable.