REPORT
ON
THE MINERAL EXPLORATION
IN
THE BICOL AREA,
THE REPUBLIC OF THE PHILIPPINES

(PHASE I)

MARCH 1998

JAPAN INTERNATIONAL COOPERATION AGENCY

METAL MINING AGENCY OF JAPAN

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PREFACE

In response to the request of the Government of the Republic of the Philippines, the Government of Japan decided to conduct a regional survey for mineral resources in the Bicol area, the Republic of the Philippines, and entrusted the survey work to the Japan International Cooperation Agency (JICA). JICA, considering the importance of the technical nature of the survey work, in turn, sought the cooperation of the Metal Mining Agency of Japan (MMAJ) to accomplish the work.

JICA and MMAJ concluded the Implementing Arrangement (I/A) with the Mines & Geosciences Bureau (MGB), Department of Environment and Natural Resources (DENR), the Republic of the Philippines after discussing the survey, on May 30, 1997. The survey work will be carried out within a period of two years commencing from 1997.

This year is Phase-I of the survey. MMAJ dispatched a survey team consisting of four members to the Philippines from July 14 to August 29, 1997. The survey work in the Philippines was carried out successfully with cooperation of the Philippine government authorities.

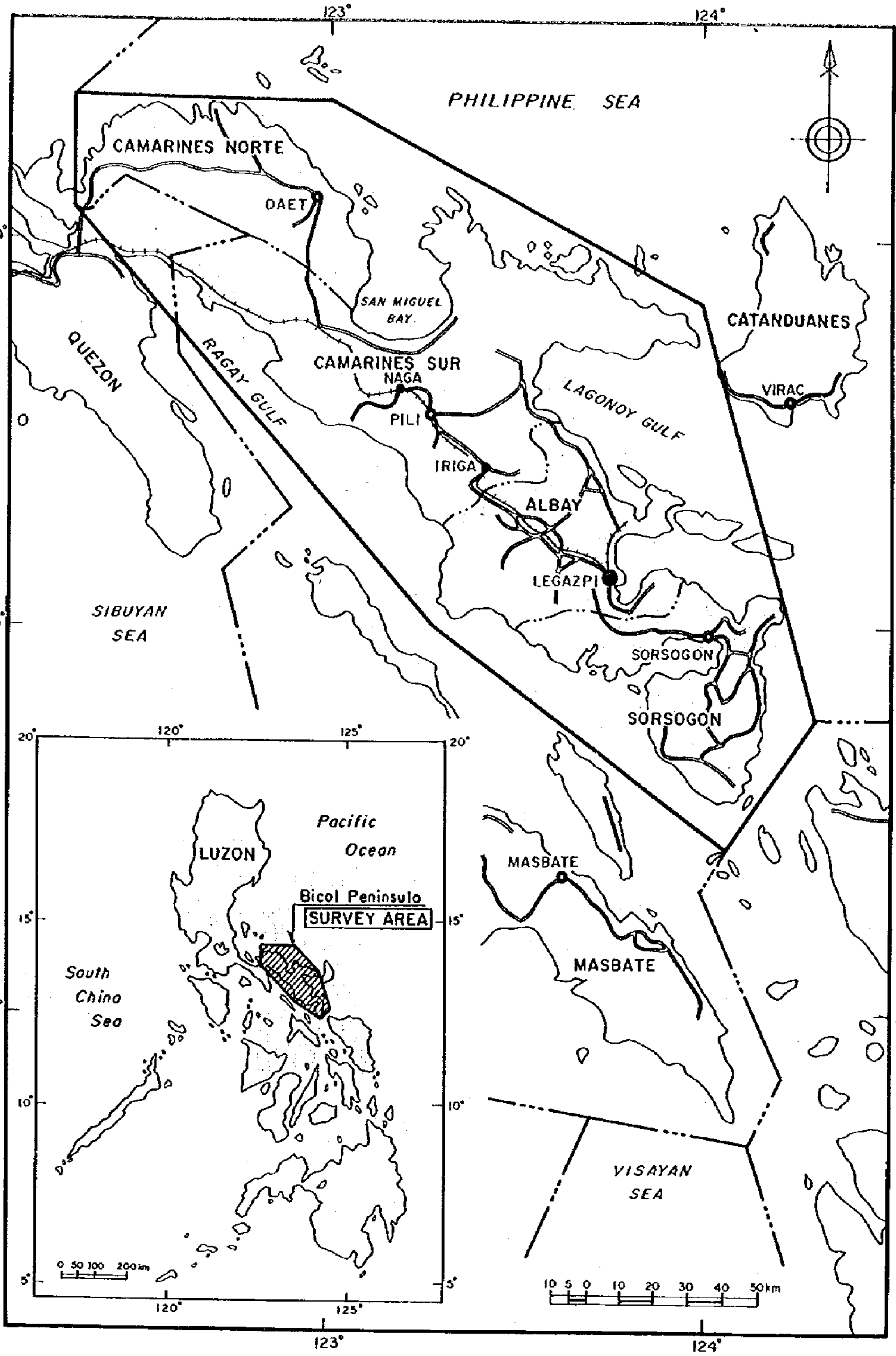
This report summarizes the result of the survey work carried out in 1997 and also forms a part of the final consolidated report which will be submitted to the Government of the Republic of the Philippines after completion of the survey work.

We wish to express our deep appreciation to the officials concerned of the Government of the Republic of the Philippines for their close cooperation extended to the survey team.

March, 1998

Kimio FUJITA
President
Japan International Cooperation Agency

Hiroaki HIYAMA
President
Metal Mining Agency of Japan



Location map of the Survey Area

Summary

The present study, which is based on the work implementation agreement (I/A) concluded between the Government of the Philippines and the Japanese Government on May 30, 1997, and which to be implemented over a period of two years, is for the purpose of selection of promising areas in terms of metal mineral resources in the Bicol Area in the southeast part of Luzon in the Philippines, which consists of the Bicol Peninsula, extending in the northwest-southeast direction, with a view to further surveying in the future on an intergovernmental basis and also taking into account the possibility of participation of private companies.

In this fiscal year (extending from April 1, 1997, to March 31, 1998), the first year of the survey, analysis of existing data, satellite image analysis, ground truth surveying and airborne physical exploration have been carried out. On the basis of analysis of existing data an understanding of the geology of the region was achieved, the distribution and characteristics of the deposits, mineral showings and alteration zones in the region were identified, and basic data was prepared for the task of selection of promising areas.

The Bicol Area can be divided into three zones in terms parallel to the direction in which it extends: the northeast zone, the central zone and the southwest zone. The northeast zone and the southwest zone is underlain by Cretaceous basement rock, with intrusion into it of Tertiary diorite rock bodies. Moreover, those basement rocks in the southwest zone is overlain by late Tertiary sedimentary rock. The central zone is underlain by recent young volcanic rocks. Each zones include the following mineral showings and alteration zones as a reflection of the geology respectively. In the northeast zone there is distribution of porphyry, skarn and mesothermal volcanic massive sulfide deposits and mineral showing, in the southwest zone there is distribution of skarn mineral showings, and in the central zone epithermal gold deposits and mineral showings are to be noted.

In the satellite image analysis areas with high lineament density and intersection of lineaments were extracted from the geological element divisions and lineament analysis as areas with high potential in terms of deposit endowment.

On the basis of the above-mentioned data and also taking into account the situation regarding establishment of mining areas, access and the security conditions twenty-four areas were selected for the ground truth survey. As a result of the ground truth survey twelve of those areas

have been selected as promising areas. The following eight areas were selected as the areas to be covered in the second year of the present survey after analysis of laboratory data as well: the Larap-Exiban area, the Mt. Bagacay area and the eastern part of the Caramoan Peninsula in the northeast zone, the Tuba area in the southwest zone and the Tiwi-Mt. Malinao northwest part area, the Bacon-Manito west part area, the Gate Mountains area and the Kilbay area in the central zone.

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** Figure are attached only in back front of the report

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PART I GENERAL

Chapter1: Introduction

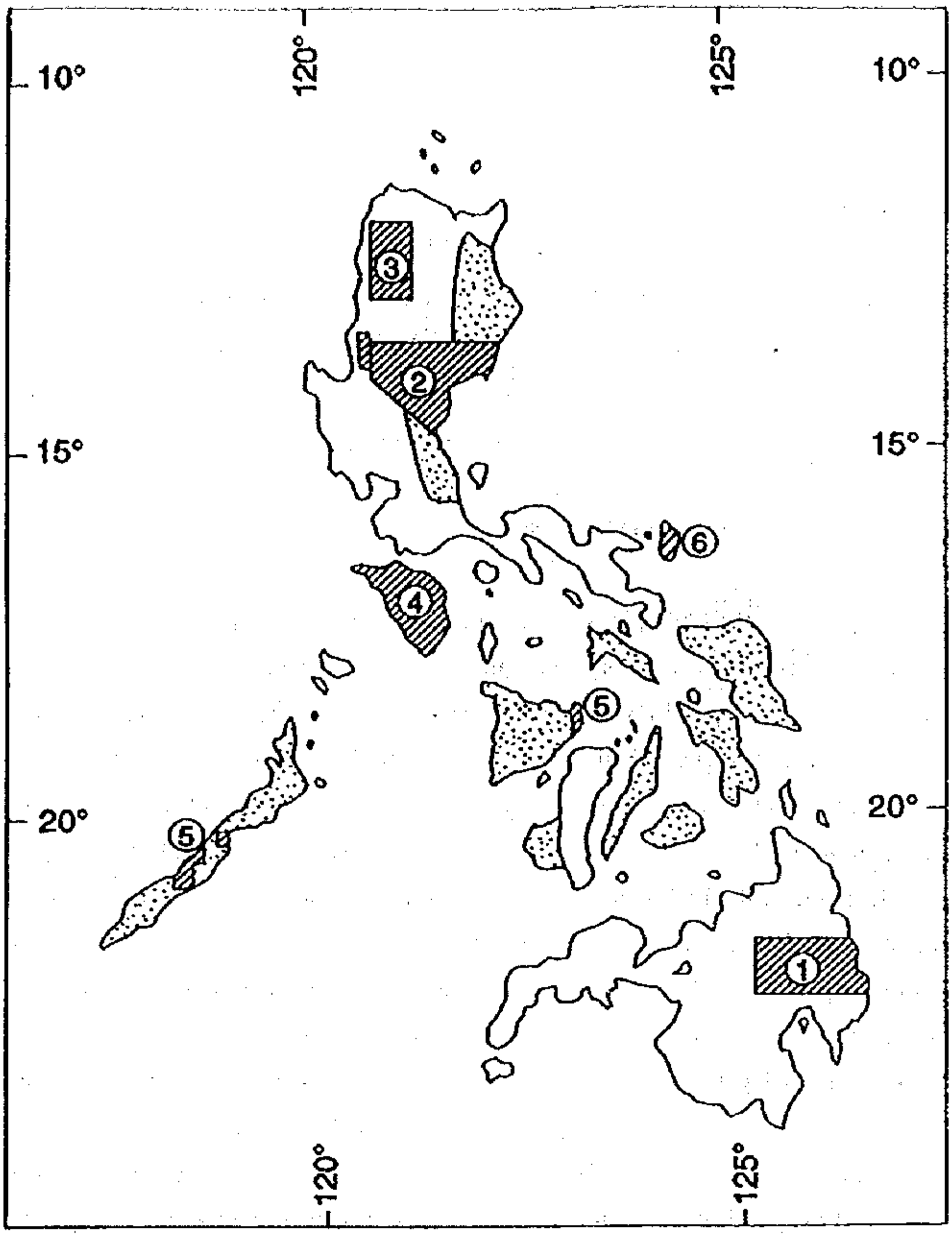
1.1 The Objective of the Survey

The objective of the survey is to select promissing areas of mineral resources from the Bicol area in the Republic of the Philippines, through analyzing synthetically the results obtained from collection, compilation, analysis, and evaluation of the existing data, interpretation of the satellite image, airborne geophysical survey, and ground truth survey accompanied by geological survey.

1.2 Description of Implementation of the Survey

The Republic of the Philippines is a country with considerable mineral resources, producing gold, silver, copper, nickel, chromite, etc., and has a high potential as regards mineral resource endowment in terms of porphyry copper ore deposits accompanying island-arc igneous activity, epithermal vein deposits, etc. Furthermore, long ago 100% of the Philippines' copper concentrate was exported to Japan, and even now 86% of it still is, as well as 100% of its nickel ore exports as an indication of the close relationship between the two countries in the field of mining. Up until 1989 the Republic of the Philippines ranked among the top ten countries in the world in terms of volume of production of gold, copper and nickel, but recently production has slumped for reasons such as rising production cost, higher environmental costs and depletion of ore bodies, and it has become necessary to introduce foreign capital in an effort to promote development of mineral resources. That being the case, the government of the Philippines lowered taxes on mining production in 1994, revised the Mining Industry Law (including FTAA allowing 100% foreign capital) in 1995 and started to make changes in registration of mining right in 1997. With stabilization of the political situation in the country and inauguration of an system open to foreign capital, many foreign companies will be participating in prospecting, and that can be expected to vitalize prospecting and development in the coming years.

Basic surveys by the Japan International Cooperation Agency (JICA) and the Metal Mining Agency of Japan (MMAJ) for cooperation in development of mineral resources in the Republic of the Philippines got started in 1971 and up to 1995 were carried out in the 7 areas indicated below (the figures for the years of implementation indicate the Japanese fiscal years [running from April 1 through March 31] in question) (see Fig.I-1-1):



MINERAL EXPLORATION PROJECTS

① Eastern Mindanao(1971-1973)
② Northeastern Luzon(1974-1976)
③ Northwestern Luzon(1978-1980)
④ Mindoro Is. (1981-1983)
⑤ Palawan·Panay(1990-1992)
⑥ Catanduanes(1993-1995)

Supra-Regional Survey(1984-1989)

Luzon, Visayas, Palawan

Figure I-1-1 Location map of the past projects

- East Mindanao (resource development survey)	1971-1973
- Northeast Luzon (resource development survey)	1974-1976
- Northwest Luzon (resource development survey)	1978-1980
- Mindoro area (resource development survey)	1981-1983
- Bisayas area (mineral resources basic mapping survey)	1984-1989
- Palawan-Panay area (resource development survey)	1990-1992
- Catanduanes area (resource development survey)	1993-1995

As a result of those surveys progress was made in such terms as identification of mineralization zones and calculation of ore reserves in the different areas. In the mineral resource basic mapping survey 6 areas were selected as first-rank promising areas, and in 2 of them a subsequent transition to resource development surveys has taken place. Thus, the surveys by JICA/MMAJ are playing a certain role in promotion of development of the country's mining industry.

The Regional survey of the Bicol area implementation of which will start this year is in response to a request by the government of the Philippines made in December 1996. Initially a request for a survey of the Bicol area was made unofficially immediately after completion of the survey in the Catanduanes, and a project selection mission was sent in February of 1996, but implementation of the survey was not decided then because of the fact that mining right participated in by foreign capital had been set up in many areas and also because of the fact that the official written request had not yet been made. In March 1997 a project selection mission was sent again, one of the purposes being redetermination of the mining right situation, which was quite fluid, after receiving the official written request. After confirmation of the mining right issue and the content of the survey, the survey was adopted as a Regional survey for mineral resources for 1997. On May 30, 1997, the "Implementing Arrangement" (I/A) was signed by Mr. Shigeo TAKENAKA, Executive Director of the Metal Mining Agency of Japan, and Mr. Horacio C. RAMOS, Director of the Mines and Geosciences Bureau of the Department of Environment and Natural Resources of the Republic of the Philippines.

The aim of the Regional survey for mineral resources resumed this year is extraction, for prospecting, of promising areas in terms of mineral deposit endowment from within the extensive area covered by the survey by analyzing data from past surveys, satellite images and other information from many different viewpoints, formulating ore deposit models and implementing ground traces. The scheduled duration of the survey is two years. This year, the first year of the survey, has seen collection of detailed geological and mineral deposit information, analysis of satellite images and implementation of ground traces and airborne geophysical survey in promising areas extracted from the information and data obtained in those ways.

1.3 Survey Area

The survey area covers an area 10,000 km2 in the provinces of Camarines Norte, Camarines Sur, Albay and Sorsogon on the Bicol Peninsula of southeastern Luzon (see Fig.I-1-2). In the area there is a fault running NW-SE, along with many volcanoes are to be found. One of them is the famous Mayon Volcano, which soars nearby the city of Legazpi, the largest in the area. Much is expected of this survey in view of the fact that many places in it could not be entered in the past because of guerilla activity and hence not much progress has been made before now in surveying it.

1.4 Survey Methods

(1) Analysis of Existing Data

Collection and sorting out of existing data from geological surveys, geochemical exploration, geophysical exploration, boring surveys, etc. kept by the entities concerned and related entities in the Philippines and use of such data for extraction of promising zones in terms of ore deposit endowment.

(2) Analysis of Satellite Images

Implementation of lineament analysis, geological structure analysis, extraction of alteration zones, etc. regarding the Bicol Peninsula as a whole using SAR images of Japan's JERS-1 satellite and LANDSAT TM images as a basis for extraction of promising areas in terms of ore deposit endowment.

(3) Ground Truth Survey

Selection of ground truth survey areas on the basis of the results of analysis of existing data and analysis of satellite images and implementation of a geological survey for the purpose of determining local geological conditions, alternation zones, mineral occurrences, etc.

(4) Airborne Geophysical Survey

Selection of areas on the basis of the results of analysis of existing data, analysis of satellite images and the ground traces and implementation of airborne geophysical survey for the purpose of determining geological structure under the surface of the ground. Aeromagnetic and aeroradiometric measurement with flight line intervals of 200m using helicopters (only acquisition

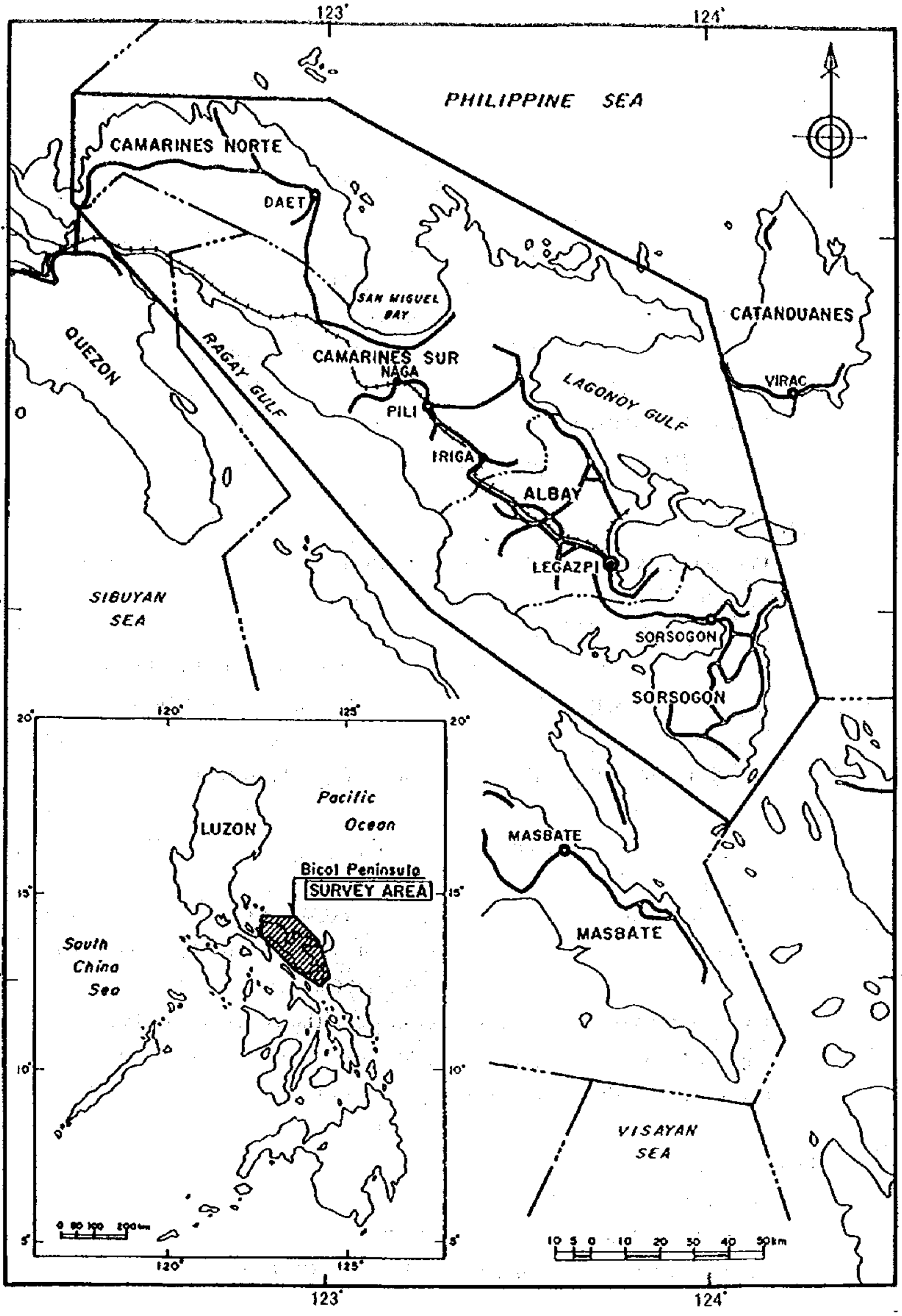


Figure I-1-2 Location map of the survey area of data in the first year).

1.5 Members Participating for the Survey

(1) Members participating in planning and negotiation

a) Japanese side

Shigeo TAKENAKA	(Leader of the team, Executive Director, Metal Mining Agency of Japan=MMAJ)
Toru NAWATA	(Energy & Mining Development Study Division, Japan International Cooperation Agency; JICA)
Yoshiaki IGARASHI	(Overseas Activities Department, MMAJ)
Kunihito YAMAMOTO	(Overseas Activities Department, MMAJ)
Naoki SATO	(Representative of Manila Office, MMAJ)

b) Philippine side

Horacio C. RAMOS	(Director, Mines & Geosciences Bureau; MGB, Department of Environment and Natural Resources; DENR, Republic of the Philippines)
Romeo L. ALMEDA	(Chief, Lands Geology Division; LGD, MGB, DENR)
Rogel A. SANTOS, Dr.	(Geologist, Lands Geology Division, MGB, DENR)
Corinthia NAZ	(OIC, Chief, Planning and Management Staff, MGB, DENR)
Salvador G. MARTIN	(Regional Director for Region V, MGB, DENR)

(2) Members participating in the survey in the Philippines

a) Japanese side

Yoshitaka HOSOI	(Leader, Analysis of existing data, Ground truth survey, Airborne geophysical survey), Japan Mining Engineering Center for International Cooperation; JMEC
Toshihiko HAYASHI	(Analysis of existing data, Ground truth survey) JMEC
Seiya MORITA	(Analysis of existing data, Ground truth survey) JMEC
Kunihito YAMAMOTO	(Analysis of existing data, Ground truth survey) JMEC

b) Philippine side

Discussing the survey(at Manila and Legazpi)

Horacio C. RAMOS	Director, MGB, DENR
Edwin G. DOMINGO	OIC, Assistant Director, MGB, DENR

Lomeo L. ALMEDA	Chief, LGD, MGB, DENR
Salvador G. MARTIN	Regional Director for Region V, MGB, DENR

Analysis of existing data and Ground truth survey

Rogel A. SANTOS, Dr.	Lands Geology Division, MGB, DENR
Jerry H.G.SALVADOR	Lands Geology Division, MGB, DENR
Federico C. JACOBA, Jr.	Lands Geology Division, MGB, DENR
Valentin P. NARIDO	MGB, Region V
Arnel F. JUSI	MGB, Region V

(3) Analysis of Satellite Images

Takehiro SAKIMOTO	(Report) JMEC
Hiroyuki TAKAHATA	(Photogeological interpretation, Report) JMEC
Hirofumi YOSHIZAWA	(Image processing, Photogeological interpretation, Report) JMEC
Masanori FURUNO	(Photogeological interpretation, Report) JMEC
Takayuki TANAKA	(Image processing) JMEC

(4) Airborne Geophysical Survey

Supervising the survey in the field

Yoshitaka HOSOI	JMEC
Arnel F. JUSI	MGB, Region V

Data acquisition

Bill Churchward	(Crew Leader) World Geoscience Corporation Limited (WGC)
Glen Morrow	(Operator/Technician) WGC
Cameron MacNaughton	(Installation Engineer) WGC
G. Hongell	(Engineer) WGC

Helicopter Flight

M. Ongchango Jr.	(Pilot) Airspan Co. Ltd.
E. Malinis	(Aircraft Engineer) Airspan Co. Ltd.

(5) Comprehensive Analysis (in Japan)

Yoshitaka HOSOI	JMEC
Toshihiko HAYASHI	JMEC
Seiya MORITA	JMEC
Kunihito YAMAMOTO	JMEC

1.6 Period and Performance of the Survey

(1) Planning and negotiation

1997.5.25.(Sun)~1997.5.31.(Sat)

(2) The survey in the Philippines

1997.7.14.(Mon)~1997.8.29.(Fri)

Analysis of existing data and Ground truth survey

Table I-1-1 Record of the survey

Item	Performance
Collecting & Analysis existing data	No. of survey reports···224 reports
Ground truth survey	35 areas
Collecting samples	Rocks・Ores···315 pieces

(3) Analysis of Satellite Images

1997.7.1.(Tue)~1998.1.30.(Fri)

- Data processing, Image printing and Photogeological interpretation for 13 scenes of JERS-1 SAR images data
- Data processing, Image printing and Photogeological interpretation for 4 scenes of LANDSAT TM

(4) Airborne Geophysical Survey

1998.1.21.(Wed)~1998.3.14.(Sat) (expected schedule)

Irosin Area : Flight lines 3,000km

Legaspi Area : Flight lines 1,250km

Tiwi Area : Flight lines 1,350km

(5) Laboratory Test, Comprehensive Analysis and Report Making

1997.9.1.(Mon)~1998.3.25.(Wed)

Table I-1-2 Laboratory Test

Item	Number of performance
Thin sections of rocks for microscopic observation	67 pieces
Polished sections of ore samples for microscopic observation	20 pieces
X-ray diffraction examination	110 samples
Chemical analysis Ore samples(Au & other 22 elements) Rocks/soils(Au & other 32 elements) XRF whole rock anaysis for main & rare elements	 21 samples 133 samples 26 samples
Measurement of the homogenization temperature and salinity of the fluid inclusion	22 samples
Age determination by K-Ar method	15 samples
Measurement of the ratio of isotope $\delta^{34}S$ δD $\delta^{18}O$	 2 samples 1 sample 1 sample

Chapter 2: Geography of the Survey Area

2.1 Location and Accessibility

The survey area, bicol peninsula, is located in the southern part of Luzon island which is the biggest one among the three major islands of the country. It is bounded in the north by Quezon province and on the south by San Bernadino Strait, on the east by the Pacific ocean, and, on the west by Ragay and Burias Pass. Specifically, it is bounded by 12 degrees 30 minutes to 14 degrees 30 minutes north latitude and 122 degrees 15 minutes to 124 degrees 15 minutes east longitude (Fig. I-2-1). It is included in the fifth administrative region under the Integrated Reorganization Plan implemented under Presidential Decree Number 1 in 1972. The region is composed of six provinces and three cities. The survey area includes four provinces of Camarines Norte, Camarines Sur, Albay and Sorsogon.

Legaspi City is the seat of the regional center. Two airplane companies regularly fly to Legaspi city from Manila city or from Cebu city. The other points serviced by planes are Pili in Camarines Sur province, Daet in Camarines Norte province. All the provincial capitals are serviced by public utility busses from metro Manila. Other municipalities in the region are accessible by bus and jeepney from respective provincial centers. Most of the barangays can be reached by public utility jeep and some maybe reach by 4-wheel drive vehicle. Some barangay may be reach only by motorized boat or banca. Railway system reaches Naga city from Manila city and may soon reach Legaspi city upon its rehabilitation completion.

2.2 Topography

Region V land area is 17,632 square kilometers and the survey area covers about 68.5 % of it. The survey area is characterized by hills or mountains in the eastern and western portion of the bicol peninsula while the central portion is moderately sloping.

About 55% of the regions land area is moderately sloping, i.e., 0-18 degrees slope mostly alluvial plains, mountain footslopes, floodplains and valleys. The alluvial plane extends from metro Naga in Camarines Sur province to Ligao, Albay forming the bicol river basin between two parallel mountain ranges. The remaining 45% are mostly hilly mountains with slopes above 18 degrees. The provinces of Camarines Norte and Camarines Sur have more sloping lands than level lands.

Two active and several extinct volcanoes form a volcanic chain from Camarines Norte in the

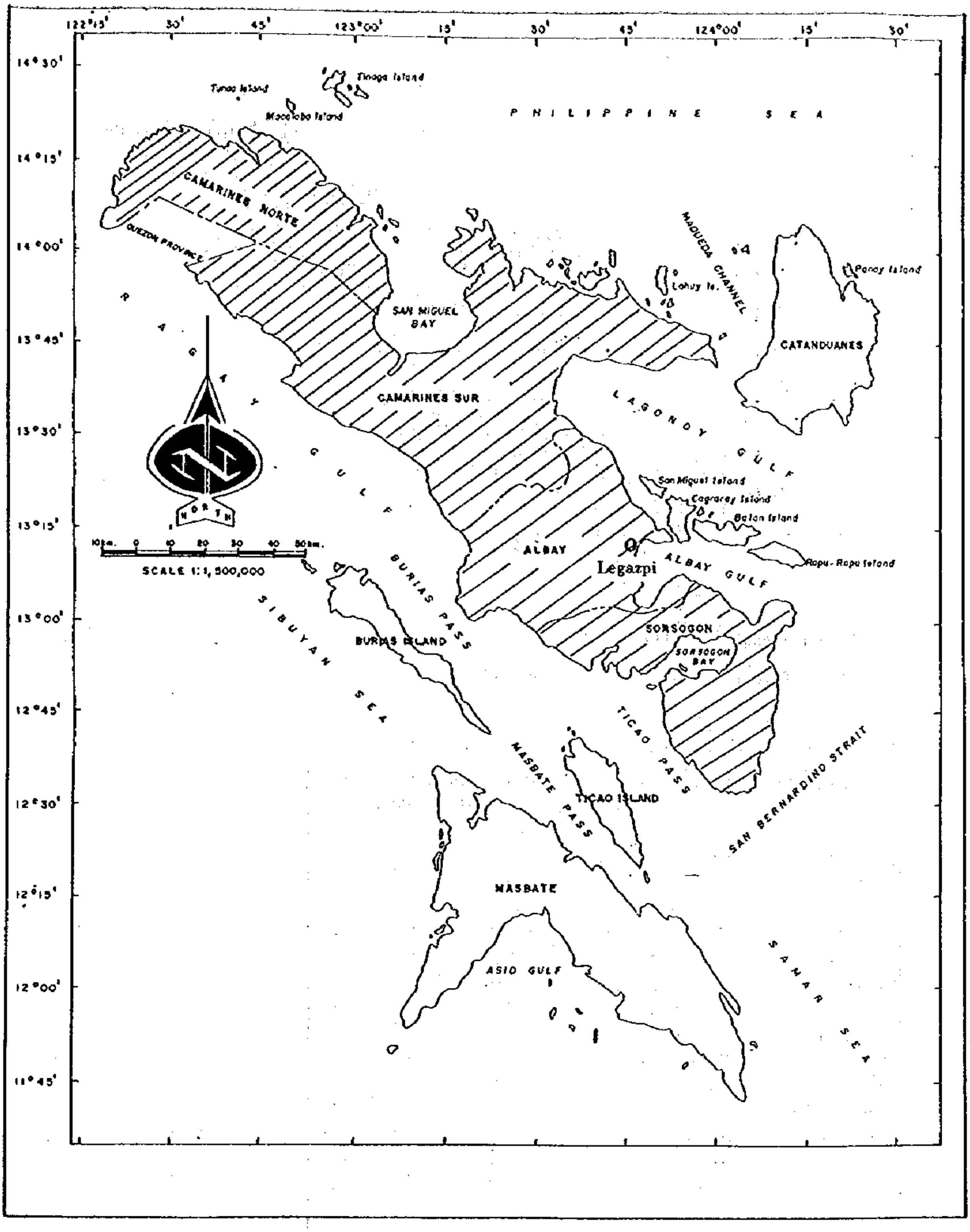


Figure I-2-1 Administrative Map of Region-V

▨ Survey area

north to Sorsogon in the south.

The active volcanoes from the north to the south are Mayon volcano in Albay and Bulusan volcano in Sorsogon, and the dormant volcano is Mt. Iriga in Camarines Sur. The other inactive volcanoes are shown below:

Name of Volcano	Location
Mt. Labo	Camarines Norte
Mt. Bagacay	Camarines Norte
Mt. Isarog	Camarines Sur
Mt. Malinao	Albay
Mt. Masaraga	Albay
Mt. Manito	Albay
Mt. Gate	Sorsogon

2.3 Drainage

Bicol peninsula is well drained by numerous rivers and creeks. The survey area is divided into several river basins with the larger one shown below:

Table 1-2-1 Major river basins

River Basin (RB)	Province	Drainage Area (sq. Km)	Estimated Annual Runoff (MCM)
Daet-Basud	Camarines Norte	270	365
Labo	Camarines Norte	913	1235
Bicol	Camarines Sur	3771	5102
Kilbay	Camarines Sur	285	386
Lagonoy	Camarines Sur	228	308
Ragay	Camarines Sur	188	254
Sipocot	Camarines Sur	447	605
Tambang	Camaines Sur	164	222
Tinalmod	Camarines Sur	119	161
Quinale	Albay	103	139
Banuang Duan	Sorsogon	46	62
Cadacan	Sorsogon	197	266
Donsol	Sorsogon	396	536
Fabrica	Sorsogon	56	76
Matnog	Sorsogon	63	85
Ogod	Sorsogon	122	165
Putiao	Sorsogon	188	254
		7556	10221

Source : National Water Resource Council, 1988

MCM : million cubic meters

The five largest river basins with drainage area in decreasing order are, ① Bicol river basin with an estimated annual runoff of 5,102MCM, ② Labo river basin with 1,235 MCM estimated annual runoff, ③ Sipocot river basin with 605 MCM draining the southern portion of Mt. Labo and joining Bicol river near Naga city, ④ Donsol river basin with 536 MCM draining westward to Ticao pass, and, ⑤ Kilbay river basin with 386 MCM draining westward to Ragay gulf. Quinale river drains the western portion of Mayon volcano and empties into lake Bato which in turn drains into the Bicol river and finally into San Miguel bay.

2.4 Climate

Based on the Corona Climate Classification System , three climate types occur over Region-V, namely: Type II, Type III and Type IV. (Fig. I-2-2, Fig. I-2-3)

Type II climate is characterized by the absence of dry season with a very pronounced maximum rain period generally in the months of December and January. It is experienced in the southern coasts of the region directly facing the Pacific ocean including Catanduanes province and Camarines Norte.

Type III climate is characterized by a very pronounced dry period and a short rainy period. This includes Masbate province and the western coastline of Burias and Ticao islands.

Type IV climate is characterized by rainfall which is more or less evenly distributed throughout the year except for the occurrences of tropical cyclones in the vicinity which causes rainfall abnormalities. It is experienced in the rest of the region from western Camarines Sur to western part of Sorsogon.

Data from Philippine Atmospheric, Geophysical and Astronomical Sciences Administration (PAGASA) showed that the majority of the country's rainfall is due to the occurrence of tropical cyclones. Other causes includes southwest and northwest monsoons, the effect of inter-tropical convergent zone, shearlines, easterly waves and other rainfall causing weather patterns. PAGASA annual climatic rainfall amount (in mm) is 3,316.9 for Albay (1972-1976), 3,845.1 for Camarines Norte (1974-1976), 2,276 for Camarines Sur (1977-1994), 3,094 for Catanduanes (1968-1996), 1,615.8 for Masbate (1983-1988), and 2,451 for Sorsogon (1972-1988). Furthermore, PAGASA

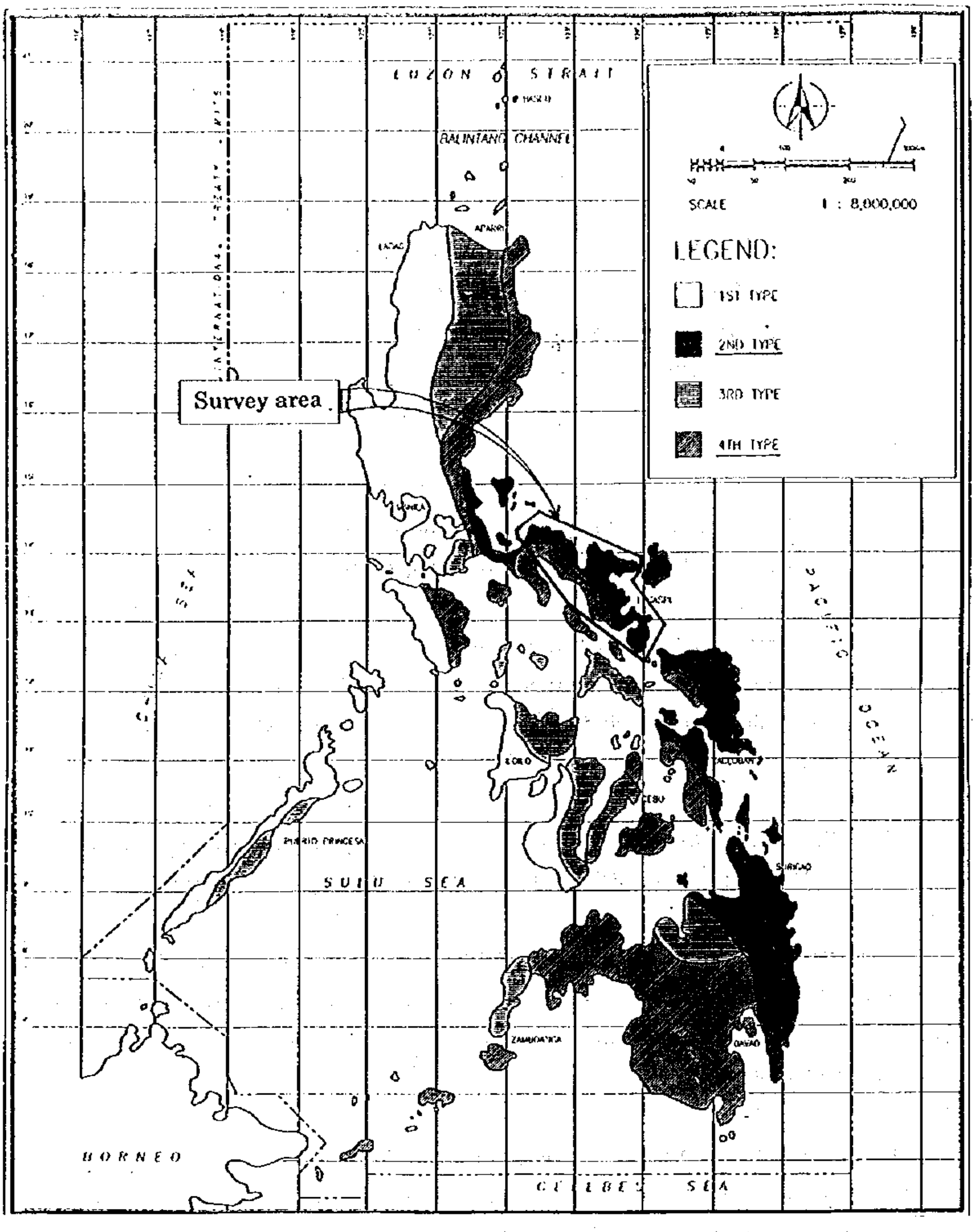


Figure I-2-2 Climate of the Philippines classified according to Coronas (1920)

reported that the high values on rainfall occurrence falls in the months of June to January attributed to the tropical cyclones that hit the country during this months.

The prevailing surface airflow over the region is northeasterly, especially when the northeast monsoon is dominant during the months of October to April. PAGASA data also shows that the hottest months are May and June with temperatures ranging from 28.1 to 29.4 degrees centigrade and the coldest months are January and February with temperature from 20.8 to 25.3 degrees centigrade based on1951 to 1985 records. The average humidity in the region is 82% and is similar to the country's relative humidity. The high relative humidity is due to the warm moist air streams flowing over the country, the surrounding seas, its rich vegetation and the abundant rainfall the region is receiving.

The occurrence of tropical cyclones in the Region-V from 1990 to 1996 totals 61 mostly during the 4th quarter. The annual average number of typhoons that passes the Philippine area of responsibility is 9 and 2 of these are expected to cross the Bicol region.

2.5 Vegetation

In general, the survey area is covered by secondary trees growth, bushes, shrubs, and agricultural plants such as coconut, abaca, rice, corn and various types of grasses. Primary forestation is limited and sporadically distributed at higher elevations and ridges. The 30 % of the survey area is forest.

Forest lands, national parks and other protected areas are the subject of reforestation programs and are mostly covered by secondary trees growth. Primary forestation of the closed canopy type is very limited. A considerable portion of the forest land is being utilized and claimed by some local inhabitants for agricultural, i.e. coconut, abaca, rice, corn plantations, and for other root crops. Slash and burn agricultural method is still practiced in several areas. Minor forest products such as rattan are collected from the ridge area for local and export use.

Roads and trails are interconnected in the forest land, making mineral exploration easier.

The alienable and disposable land which comprises the majority are titled lands and are utilized for agricultural purposes (i.e. coconut, rice, corn, fruit trees and root crops), residential, commercial and industrial use. This land consist of flat or moderately slopping terrain.

A considerable part of the survey area is unutilized or unproductive. It is covered with cogon and other grasses. Barren areas are limited owing to the high rainfall the region is receiving. Outcrops are mostly confined along the river banks or at very steep slopes.

In viewing of Landsat images, almost all of the survey area is covered by vegetation and with scattering clouds over images, because of tropical weather. This means difficulty of spectral analysis of satellite images.

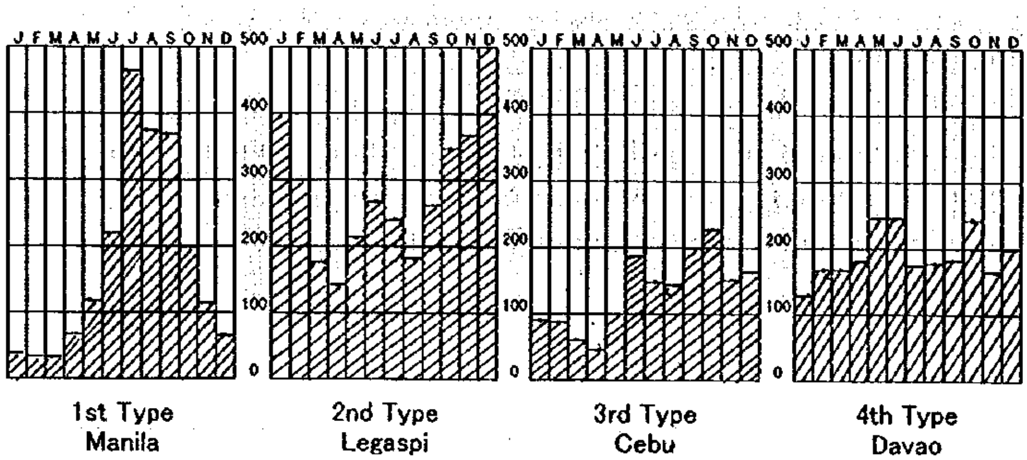


Figure I-2-3 Types of monthly distribution of rainfall

Chapter 3 : The Geology, Ore Deposits and Mining Industry Circumstances of the Survey Area

3.1 Summary of the Geology of the Bicol Area

Fig. I-3-1 is a geological map of the Bicol Region. It has been compiled by referring to the following published maps:

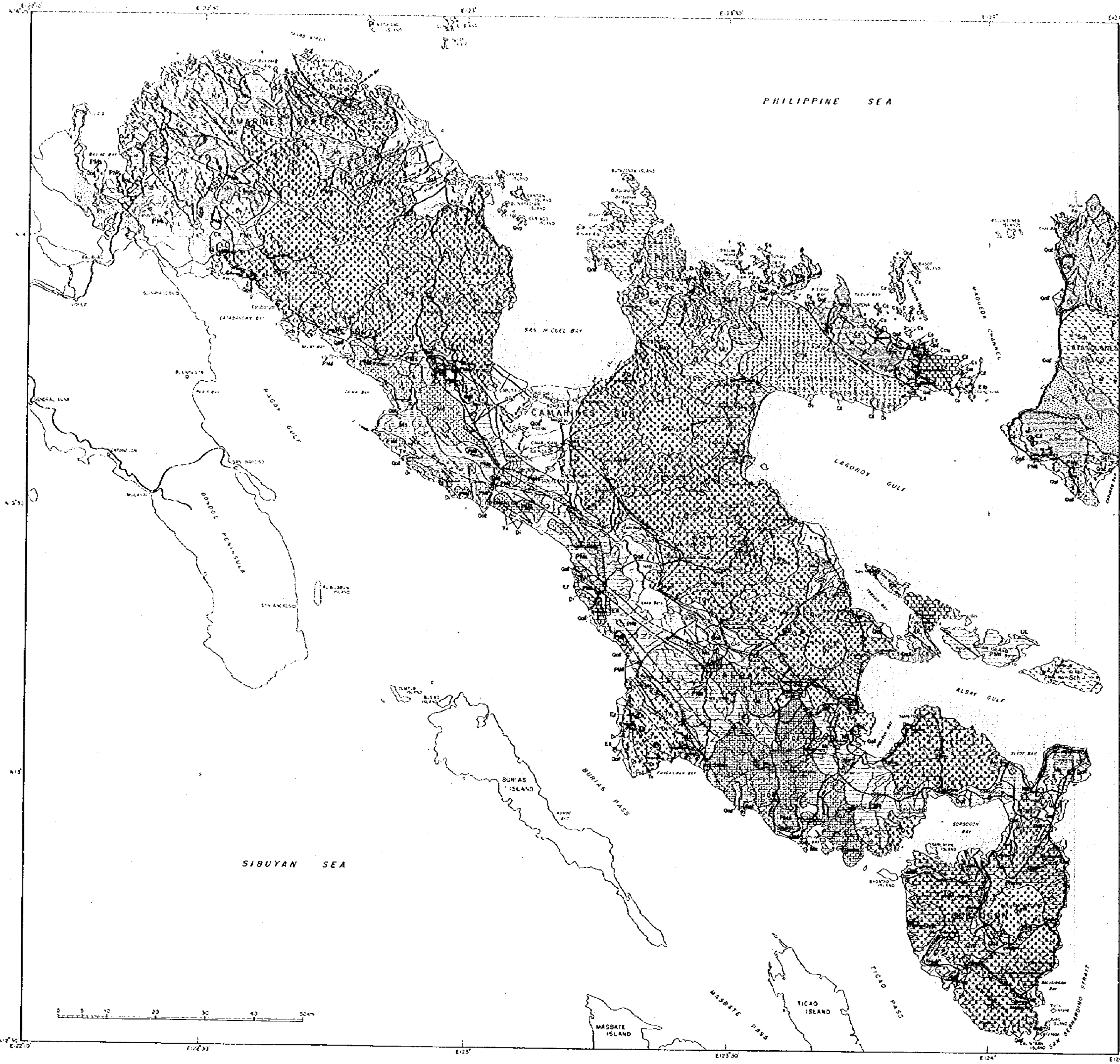
- Geological Map of Bicol Region (1:250,000) by BMG Regional Office V
- Geological Map Quadrangles (1:50,000) of Sheet No. 3462-I, II; 3560-I; 3561-I, II, III, IV;3562-I,II,III,IV; 3563-II, III; 3659-I, II; 3661-I, II, III, IV; 3662-II, III; 3761-I, II, III, IV
- Geological and Geochemical Interpretation Map of Catanduanes Island (1:250,000), The Cooperative Mineral Exploration by JICA/MMAJ-MGB, 1993-1995
- David S. D. Jr., et al., 1996, Geology, Geochemistry, Geochronology and Structures of the Ophiolites in Southeastern Luzon, Philippines. Jour. Soc. Geol. Phil. v.LI, pp. 115-129

A book published by the Bureau of Mines and Geosciences (1982) comprehensively treats the succession of geologic system of the Bicol Area. Presently editing work is in progress for its 1996 revised version (LGD GOP Editorial Team, 1996: Geological and Mineral Resources of the Philippines, Volume I (First Draft); the quotes from it in the following text are based on the 1996 draft). Although the publication is still in the draft stage, it is based on the latest data. The following description therefore represents a simplification of the contents of the Bureau of Mines and Geosciences publication of 1982 and that draft of 1996. Furthermore, Mitchell and Leach (1991) and David et al. (1994, 1996) have, respectively, been referred to concerning Camarines Norte, on the one hand, and the Caramoan Peninsula and Cagraray/Rapu-Rapu, on the other.

3.1.1 The Sedimentary Rock and Volcanic Rocks of the Bicol Region

The Bicol Region can be divided into four blocks as regards its characteristics concerning succession of geology:

(1) Quezon-Camarines Norte (hereinafter referred to as Bicol North)
(2) the Caramoan Peninsula (hereinafter referred to as Caramoan)
(3) Cagraray Island - Rapu-Rapu Island (hereinafter referred to as Cagraray)
(4) the southern part of the Bicol Peninsula (hereinafter referred to as Bicol South)



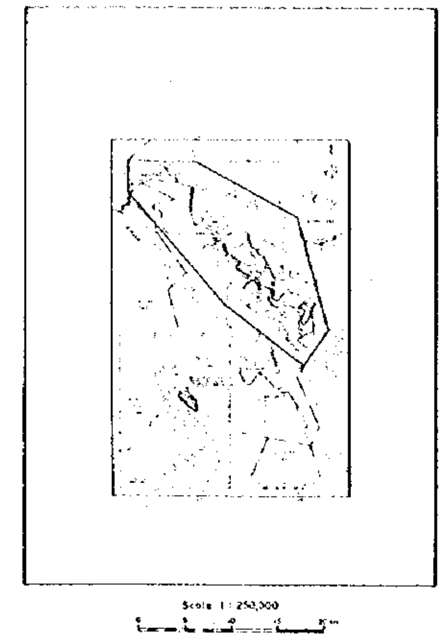


Fig.I-3-1 Geological Map of the Bicol Area

LEGEND

- Chartered city
- City capital of province
- Capital of province
- Municipality or municipal district
- Barangay
- Railroad
- Provincial boundary
- First and second class road
- Route markers : National
- Route markers : Provincial

EXPLAWTION

STRATIFIED ROCK

INTRUSIVE AND PSEUDO - STRATIFIED ROCKS

GEOLOGIC STRUCTURE

- Formational boundary
- Major fault
- Thrust fault
- Plunging anticline
- Plunging syncline
- Strike and dip of bedding plane

Compiled from :

- Geologic Map of Bicol Region (1 : 250,000) by BMG Regional Office V
- Geological Map Quadrangles (1 : 50,000) of Sheet No. 3462-I, II, 3560-I, 3561-I, II, III, IV 3562-I, II, III, IV, 3563-II, III, 3659 I, II 3661-I, II, III, IV, 3662-II, III, 3761-I II III IV
- Geologic and Geochemical Interpretation Map of Catanduanes Island (1 : 25,000) / The Cooperative Mineral Exploration by JICA/MMAJ - MGB, 1993-1995
- David S.D. Jr., et al (1996). Geology, Geochemistry, Geochronology and Structures of the Ophiolites in Southeastern Luzon, Philippines Jour Soc Geol Phil. 1996.

The succession of geology of the different blocks is indicated in Fig. I-3-2, and comparison with the geologic system of previous surveys is indicated separately for each block in Fig. I-3-3 – Fig. I-3-6.

The following description is broken down by geological period and block.

(1) Jurassic - Lower Cretaceous

Ophiolites (Jurassic - Lower Cretaceous)

The above-mentioned blocks is underlain by ophiolites at the basemant. In Bicol North serpentinized ultrabasic rock and gabbro are distributed in the region of Mt. Cadig and Paracale-Jose Panganiban, Guintinua Island to the northeast and elsewhere.

The Lagonoy Ophiolite of Caramoan is characterized as a perfect ophiolite sequence. Ultrabasic rock (dunite accompanied by chromite layers, pyroxenite, peridotite), gabbro (massive and cumulate), pillow basalt and sedimentary rock covering them are to be observed. Ophiolites are widely observed at Mt. Putianay, Lagonoy, Tambang and elsewhere in the northwest part of the Caramoan Peninsula. At Mapid on the east side of the Tambang River there is distribution of intrusion of massive to layered gabbro in the basaltic dike, with covering by partly brecciated basaltic pillow lava. At Denrika that gabbro is covered by alternation of slightly metamorphized pyroclastic rocks and tuff (with some basalt reworked block in between). Furthermore, there is transition to turbidite sediments. The metamorphic leucocratic diabase and gabbro outcropping to the east of Alto Point have radiometric age values of 151-156 Ma ($^{39}Ar/^{40}Ar$) and are correlated with the Jurassic period (Geary, 1986; Geary et al., 1988). The gabbro of Mayon Mine shows a radiometric age measurement value of 117 Ma, which correlates it with the early Cretaceous period.

In Cagraray serpentinized peridotite is distributed in the southern part of Cagraray Island, at the northeast end of Batan Island and on Rapu-Rapu Island.

In Bicol South there is distribution of the Panganiran ultrabasic rock consisting of serpentinized pyroxene peridotite and pyroxenite (De Guzman, 1963).

Of the rock units constituting the ophiolites, the upper-level volcanic rock and sedimentary rock, which have undergone a low degree of metamorphism, consist of greenschist, albite-epidote-

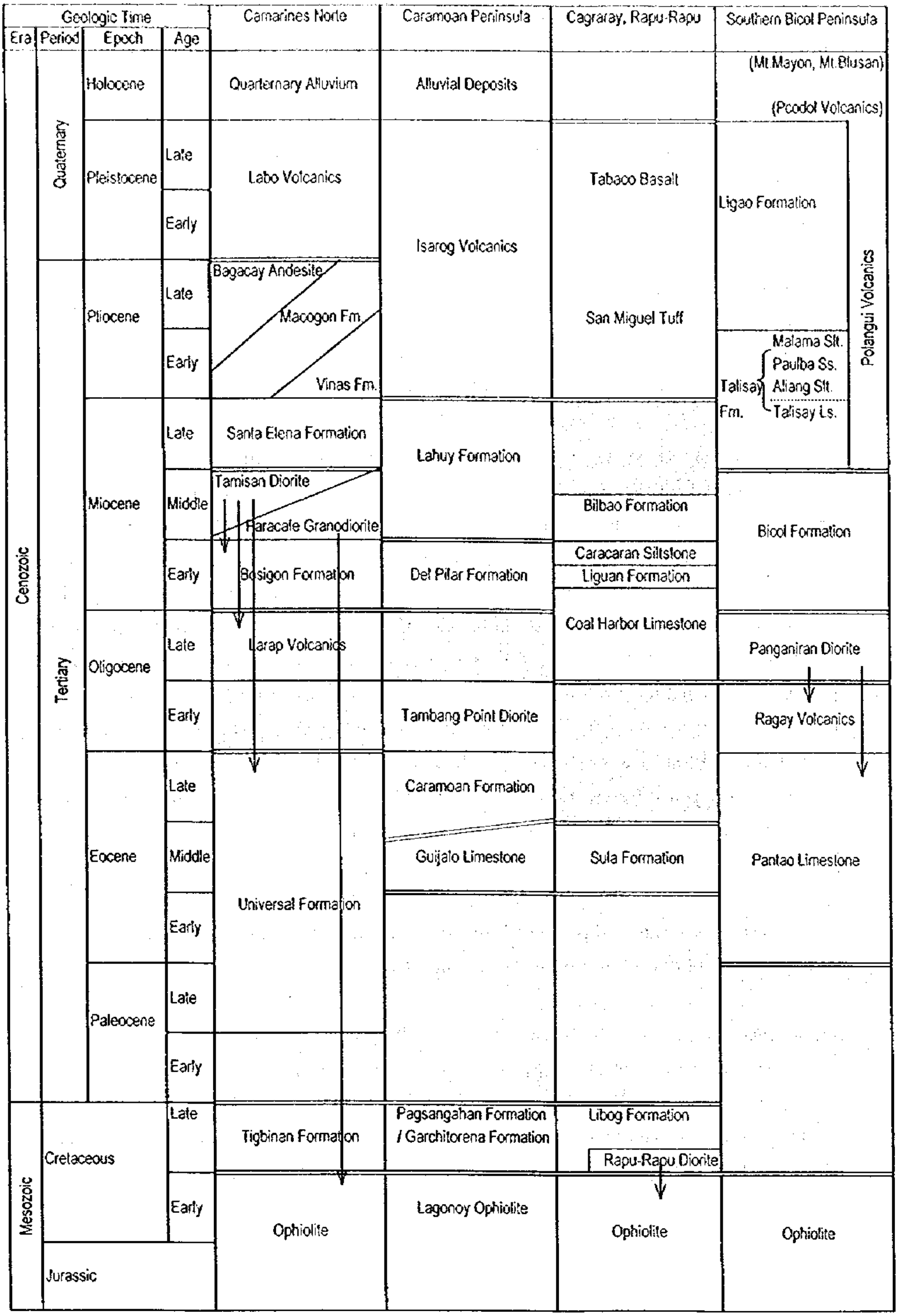


Fig.I-3-2 Generalized Stratigraphy of Bicol Area

Era	Period	Epoch	Age	Miranda and Caleon (1979)	BMG (1982)	This Report
Cenozoic	Quaternary	Holocene		Alluvial Deposit	Quarternary Alluvium	Quarternary Alluvium
		Pleistocene	Late	Terrace Gravel Dep. Labo Volcanics	Terrace Gravel Labo Volcanics	Labo Volcanics
			Early			
	Tertiary	Pliocene	Late	Bagacay Andesite Macogon Fm. Vinas Fm.	Bagacay Andesite Macogon Fm. Vinas Fm.	Bagacay Andesite Macogon Fm. Vinas Fm.
			Early			
		Miocene	Late	Conglomerate, Sandsone Siltstone, Shale and Limestone	Santa Elena Formation	Santa Elena Formation
			Middle	Diorite and related rocks	Tamisan Diorite	Tamisan Diorite Paracale Granodiorite
			Early	Cgl., Sh., Arkose, Ls., Basaltic flows, Volc. Wackes, shale and chert	Bosigon Formation	Bosigon Formation
		Oligocene	Late	Larap Volcanics	Larap Volcanics	Larap Volcanics
			Early	Paracale Granodiorite	Paracale Granodiorite	
		Eocene	Late	Universal Formation	Universal Formation	Universal Formation
			Middle			
			Early			
		Paleocene	Late			
			Early			
Mesozoic	Cretaceous		Late	Ultramafic Complex Greywacke, Spilite, and Chert, Ls, Sh, Ss	Ultramafic and Mafic Plutons Tigbinan Formation	Tigbinan Formation
			Early	Schistose Sed. and Volcanic rocks	Schists and Quartz Diorite	Ophiolite
	Jurassic					

Fig.I-3-3 Generalized Stratigraphy of Camarines Norte Province

Geologic Time				Miranda (1976)	BMG (1982)	David et al (1994)		This Report
Era	Period	Epoch	Age			Western Caramoan Structural Unit	Eastern Caramoan Structural Unit	
Cenozoic	Quaternary	Holocene		Alluvial Deposits	Alluvial Deposits			Alluvial Deposits
		Pleistocene	Late	Terrace Gravel	Terrace Gravel	Isarog Volcanics		Isarog Volcanics
			Early	Andesitic flows and pyroclastics	Isarog Volcanics			
	Tertiary	Pliocene	Late					
			Early					
		Miocene	Late	Taffaceous sandstone basalt and dacite flows	Lahuy Formation			Lahuy Formation
			Middle					
			Early	Conglomerate,volcanic wackes and limestone	Del Pilar Formation			Del Pilar Formation
		Oligocene	Late	Diorites and related stocks				
			Early		Tambang Point Diorite			Tambang Point Diorite
		Eocene	Late	conglomerate, arkostic sandstone, coal, shale, and limestone			Caramoan Formation (Ragas Point Olistostrome (Tabgon Flysch)	Caramoan Formation
			Middle			Guijalo Limestone		Guijalo Limestone
			Early		Guijalo Formation			
		Paleocene	Late	Volcanic wackes, chert, shale, limestone, and basaltic flows	Garchitorena Formation			
			Early					
Mesozoic	Cretaceous		Late	Ultramafic Complex	Ultramafics	Pagsangahan Fm.	Garchitorena Fm.	Pagsangahan Formation / Garchitorena Formation
			Early	Grwc.,Chert, Sh.,spilitic basalt flows, limestone	Pagsangahan Formation	Lagonoy Ophiolite		Lagonoy Ophiolite
	Jurassic			Schistose sedimentary and volcanic rock	Lagonoy Schist			

Fig.I-3-4 Generalized stratigraphy of Caramoan Peninsula

Era	Period	Epoch	Age	Corby et al. (1951) (Batan-San Miguel)	Corby et al. (1951) (Cagraray)	BMG (1982)	This Report
Cenozoic	Quaternary	Holocene					
		Pleistocene	Late			Tabaco basalt	Tabaco Basalt
			Early	Tabaco Basalt			
	Tertiary	Pliocene	Late			San Miguel Tuff	San Miguel Tuff
			Early	San Miguel Tuff			
		Miocene	Late	Casolgan Limestone		Casolgan Limestone	
			Middle	Camisog Sandstone Bilbao Formation	Calicia ss. / Cagraray slt	Camisog Formation Bilbao Formation	Bilbao Formation
			Early	Caracaran Silt	Coal Habor Limestone	Caracaran Siltstone Liguan Formation	Caracaran Siltstone Liguan Formation Coal Harbor Limestone
		Oligocene	Late	Liguan Formation		Coal Habor Limestone	
			Early				
		Eocene	Late			Rapu-Rapu Schist	
			Middle		Sula Formation	Sula Formation	Sula Formation
			Early				
		Paleocene	Late				
			Early				
Mesozoic	Cretaceous		Late	Serpentine Basement Complex	Libog Volcanics	Libog Volcanics Serpentinized Peridotite	Libog Formation Rapu-Rapu Diorite
			Early				↓ Ophiolite
	Jurassic						

Fig.I-3-5 Generalized Stratigraphy of Cagraray, Rapu-Rapu Area

Geologic Time Era	Period	Epoch	Age	Corby et al (1951) (Camarines Sur)	Corby et al. (1951) (Albay Mainland)	De Guzman (1963)		BMG (1982)		This Report	
Cenozoic	Quaternary	Holocene				Alluvium		Quardernary alluvium		(Mt.Mayon, Mt.Bulusan) (Pcodol Volcanics)	
Cenozoic	Quaternary	Pleistocene	Late		San Roque Tuff	Polangui Formation		Ligao Formation	Polangui Volcanics	Ligao Formation	Polangui Volcanics
Cenozoic	Quaternary	Pleistocene	Early	Caramoan Tuff	San Roque Tuff	Polangui Formation		Ligao Formation	Polangui Volcanics	Ligao Formation	Polangui Volcanics
Cenozoic	Tertiary	Pliocene	Late	Caramoan Tuff	Sorsogon Marl	Polangui Formation	Sorsogon F. / Ligao F.	Ligao Formation	Polangui Volcanics	Ligao Formation	Polangui Volcanics
Cenozoic	Tertiary	Pliocene	Early	Nabua Formation	Sorsogon Marl	Polangui Formation	Talisay Basin Fm.	Albay Group: Malama Slt., Paulba Ss., Aliang Slt., Talisay Ls.	Polangui Volcanics	Talisay Fm.: Malama Slt., Paulba Ss., Aliang Slt., Talisay Ls.	Polangui Volcanics
Cenozoic	Tertiary	Miocene	Late	Nabua Formation	Malama Silt	Polangui Formation; Tafisay Limestone	Talisay Basin Fm.; Tafisay Limestone	Albay Group	Polangui Volcanics	Talisay Fm.	Polangui Volcanics
Cenozoic	Tertiary	Miocene	Middle	Sto. Domingo Shale	Paulba Sandstone; Aliang Silt / Talisay Ls; Ligao Ls./ Jovellan Slt	Bicol Clastic Formation		Bicol Formation		Bicol Formation	
Cenozoic	Tertiary	Miocene	Early	Bicol Coal Measures		Bicol Clastic Formation		Bicol Formation		Bicol Formation	
Cenozoic	Tertiary	Oligocene	Late	Ragay Volcanics	Daraga Formation	Panganiran Diorite		Panganiran Diorite		Panganiran Diorite	
Cenozoic	Tertiary	Oligocene	Early	Siramag Marble	Daraga Formation	Ragay Volcanics		Ragay Volcanics		Ragay Volcanics	
Cenozoic	Tertiary	Eocene	Late	Basement Complex	Basement Complex	Apud Limestone		Pantao Limestone		Pantao Limestone	
Cenozoic	Tertiary	Eocene	Middle	Basement Complex	Basement Complex	Apud Limestone		Pantao Limestone		Pantao Limestone	
Cenozoic	Tertiary	Eocene	Early	Basement Complex	Basement Complex	Apud Limestone		Pantao Limestone		Pantao Limestone	
Cenozoic	Tertiary	Paleocene	Late	Basement Complex	Basement Complex						
Cenozoic	Tertiary	Paleocene	Early	Basement Complex	Basement Complex						
Mesozoic	Cretaceous		Late	Basement Complex	Basement Complex	Panganiran Ultramafics		Basement			
Mesozoic	Cretaceous		Early	Basement Complex	Basement Complex	Panganiran Ultramafics		Basement		Ophiolite	
Mesozoic	Jurassic			Basement Complex	Basement Complex	Panganiran Ultramafics		Basement		Ophiolite	

Fig.I-3-6 Generalized Stratigraphy of Southern Bicol Peninsula amphibolite, quartz-feldspar mica schist and garnet-mica schist. In Bicol North, Caramoan and Cagraray (Rapu-Rapu Island) they have up to now been considered to be schist and have been treated as geological bodies different from ultrabasic rock. For instance, on the Caramoan Peninsula the Lagonoy ophiolite metamorphic rock units have been treated as Lagonoy schist by Miranda (1976) and BMG (1981). But with recent surveys it is becoming clear that they represent the result of metamorphism of the volcanic rock and sedimentary rock constituting the upper level of the ophiolite sequence.

That being the case, they will be treated here as a part of the ophiolite sequence. Of them, however, more will be said concerning the ultrabasic rock in another section.

(2) Upper Cretaceous

1) Bicol North

Tigbinan Formation (Upper Cretaceous)

The Tigbinan formation consists of graywackized spilite, andesite, chert, chertic limestone, black shale and arkosic sandstone. At Tigbinan, Labo and elsewhere in the Bulala-Paraiso region it occurs as thrust sheet.

The main rock facies is graywackized spilite and chert.

The chert is dark red to chocolate in color and is accompanied by manganese. The limestone is bright gray and consists of coral reef limestone and microfossils. Several species of "Globotruncana" in the limestone show that such limestones were formed in the late Cretaceous period.

Considered to be correlated to the Tigbinan formation are the Pagsangahan formation of the Caramoan Peninsula and the Yop formation of Catanduanes Island, which are discussed next.

2) Caramoan

The upper Cretaceous distributed on the Caramoan Peninsula is comprised by the Pagsangahan and Garchitorena formation. They are contiguous at the Minas fault, with the Pagsangahan formation on the west side and the Garchitorena formation on the east side (David et al., 1994).

The Pagsangahan formation is distributed in the eastern half of the Caramoan Peninsula from Guijalo to north of Lagonoy. It consists of a combination of wacke, chert, shale, spilitic basalt to andesite lava and siliceous to oolitic limestone. Andesite lava, agglomerate and vesicular basalt breccia and coarse graywacke occur on top of the metamorphic sequence of the Lagonoy Ophiolite. At the southern end of the Caramoan Peninsula this formation ischaracterized by slightly metamorphic (greenschist facies) graywacke, tuff and conglomerate containing volcanic rockgravel. This formation extends continuously to Maagnas on Lagonoy Gulf, where it becomes a lava sequence accompanied by alternation of layers of conglomerate and fine to coarse graywacke. At Parabcan and Bitaogan lava with a pillow structure is predominant in that sequence. The degree of metamorphism of the unit gets weaker going eastward. In the southern part of the peninsula there is alternation between the limestone and volcanic fragmental rock. The limestone shows considerable facies variation from white to gray massive limestone to red pelagic limestone with developed stratification and intromission of chert. Usually the limestone is marbleized. Fossil "Globotruncana" indicative of the late Cretaceous period have been detected in several samples.

Garchitorena Formation (Upper Cretaceous)

The Garchitorena formation was named by Miranda (1976). The sequence volcanic wacke, chert, shale, limestone and shale is distributed in the northeast part of the Caramoan Peninsula over a wide range from Garchitorena to south of Tabgon. The chert has development of thin stratification and is bright brown to chocolate in color. The shale has developed stratification and is bright gray in color, hard and slightly calcareous. The limestone is generally massive with developed stratification and turbid white to bright brown in color. In the vicinity of Tinajuagan Point and Tabgon, this formation is characterized by a turbidite sequence with intromission of agglomerate that includes red to gray tuff and andesite gravel. Coral reef gravel is to be found in course sandstone layers.

The thickness of this formation is estimated to be 1,500 m.

Before it was thought to belong to the Paleocene epoch (BMG, 1982), but recent research has confirmed that it dates back to late Cretaceous period in view of the fact that the nannofossils in the interposed shale belong to the Cretaceous period (David, 1994). Radiometric age values of 91.1 +/- 0.5 Ma have been obtained from the andesite gravel in the agglomerate by the $^{40}Ar/^{29}Ar$ method.

3) Cagraray

Libog Formation (Upper Cretaceous)

There is distribution of tuff called Libog volcanic rock and some lava and agglomerate (Corby et al., 1956; BMG, 1982). Although it has marked metamorphism, it also has very good stratification. Since alternation of coarse graywacke, siltstone and conglomerate is observed in the eastern part of Cagraray Island, the draft of 1996 changed the name from Libog volcanic rock to the Libog formation. Furthermore, David et al. (1996) have asserted that this formation is of the same age as the Pagsangahan formation or Garchitorena formation distributed on the Caramoan Peninsula.

(3) Paleocene Series to Eocene Series

1) Bicol North

Universal Formation (Upper Paleocene series to Eocene series)

The Universal formation partly covers the pre-Tertiary system with unconformity and partly thrusts into it. Furthermore, in the southern and eastern parts it iscovered with conformity by Larap volcanic rock, which isan upper-level formation. The Universal formation is distributed in Palacale - Jose Panganiban and also outcrops in the northern part of Calambayungan Island and on the Larap Peninsula. This formation consists of the following two members.

The lower member consists of conglomerate, arkosic sandstone and shale and has interposed graywacke. The conglomerate occurs in lenticular fashion and consists of rounded to subrounded pebbles of schist, chert, graywacke, peridotite, spilite and sandstone and sandy feldspathic matrix. Furthermore, at places it also contains quartz vein, andesite, basalt and gabbro pebbles (United Nations, 1987). The arkosic sandstone has alternation of shale and is green to gray in color and coarse to medium-coarse. The shale is silty, tuffaceous and calcareous.

The upper member consists of limestone, marlstone and shale. The limestone has developed stratification and is white in color, finely crystalline and marbleized. The shale is thin and green to black in color.

This formation is thought to be from the Paleocene epoch to the Eocene epoch (Miranda and Caleon, 1979; BMG, 1982). It has also undergone widespread alteration and constitutes the wall rock of the gold deposits, iron deposits and porphyry copper deposits in the vicinity of Palacare.

The K-Ar age of the orthoclase of the trachytic tuff and the secondary biotite shows values of 15.2 +/- 0.8 Ma and 13.4 +/- 0.7 Ma, respectively, and those ages are considered to reflect the hydrothermal alteration activity of the mid-Miocene (Mitchell and Leach, 1991).

This formation thought to be correlated to the Caramoan formation of the late Eocene distributed on the Caramoan Peninsula and the Payo formation of Catanduanes Island.

2) Caramoan

Guijalo Limestone (mid-Eocene series)

This limestone is distributed in the eastern part of the Caramoan Peninsula from north of Guijalo to east of Caramoan. It has in the past been called the Guijalo formation by Miranda (1976) and BMG (1982). However, in view of the fact that the clastic rock and the limestone constituting a part of the Guijalo formation are of different age, David et al. (1994) called the clastic rock the Caramoan formation (see the next section) and the limestone Guijalo limestone. Here the terminology follows David et al. (1994).

This rock covers with unconformity the volcanic rock and pyroclastic rock of the Pagsangahan formation west of Minas Point. The limestone is cream to gray in color, generally massive and rich in variation from limestone with lots of algae to bioclastic limestone. East of Guijalo there is development of karst topography. The age determination of the large foraminifera in the limestone is Upper Lutetian - Lower Bartonian, corresponding to the mid-Eocene. The thickness of this limestone is about 100 m at Minas Point and 200 m east of Guijalo.

Caramoan Formation (middle Eocene series to upper Eocene series)

The name of this formation was given by David et al. (1994) to the turbidite sequence and the olistostrome unit outcropping to the north from Tabgon to Ragas Point in the northern part of the peninsula and to the south from Minas to Rungus Point. The Caramoan formation consists of the following two members: the Tabgon flysch and the Ragas Point olistostrome.

Tabgon flysch: Northwest of Tabgon it consists of rhythmic alternation of fine to coarse graywacke, siltstone, shale and conglomerate and has a typical flysch sedimentary facies. The foraminifera in the limestone and conglomerate have an age of early Lutetian to late Bartonian. Furthermore, the nannofossils extracted from the shale layer interposed in the flysch sequence indicate an age from the end of the mid-Eocene to the beginning of the late Eocene.

Ragas Point olistostrome: It is distributed over most of the eastern end of the Caramoan Peninsula, to the south from Guijalo to Rungus Point and to the north from Bikal to Ragas Point. In this olistostrome are to be observed the following various kinds and various sizes from block to pebble in the shaly matrix. Nummulitic conglomerate, limestone containing foraminifera, limestone with interposed layers of chert, andesite, volcanic fragmental rock and siltstone are to be observed from blocks to pebbles. The olistolith sometimes has a diameter in excess of 100 m. In the limestone olistolith there are foraminifera fossils indicative of the Cretaceous period and others indicative of the mid-Eocene as in the case of the above-mentioned Caijalo limestone.

The nannofossils of the matrix of the olistostrome indicate an age from the end of the mid-Miocene to the beginning of the late Eocene.

3) Cagraray

Sula Formation (mid-Eocene)

This formation was named by Corby et al. (1956) as a formation covering the Libog formation with conformity. It is distributed mainly in the southwest part of Cagraray Island but also in the eastern part of the island and on the west coast of Batan Island. It consists mainly of massive limestone containing fossils. Judging from the foraminifera fossils, the age of the Sula formation was considered by Corby et al. (1956) to be the Eocene epoch. Considering the association of fossil, the mid-Eocene would seem to be an appropriate estimate (draft of 1996).

4) Bicol South

Pantao Limestone (Eocene series)

This limestone is distributed sporadically with a northwest-southeast trend from Caorasan to Panganiran along the coastline of the southwest side of Albay province. On the Panganiran Peninsula this limestone covers the pre-Tertiary bedrock with unconformity, and it occurs in the central part of the region of distribution of the Ragay volcanic rock (discussed below). This limestone has thin stratification and recrystallization, with dense development of cracks. The cracks are filled with calcite. The association of fossils indicated the age to be the Eocene (BMG, 1982). This limestone is correlated with the Apud limestone of De Guzman (1963).

(4) Oligocene Series

1) Bicol North

Larap Volcanic Rock (Oligocene series)

The Larap volcanic rock covers the Universal formation with unconformity and is covered by the upper-level Bosigon formation with angular unconformity. The rocks consist of brecciated andesite, tuffaceous breccia, andesitic and trachytic crystalline tuff, lapilli tuff and welded tuff. The welded tuff has interbedding with altered andesite at the Bosigon River. Miranda and Caleon (1979) asserted that eruption of Larap volcanic rock was partially simultaneous with intrusion of the Paracale granodiorite.

According to the United Nations (1987) interpretation the Larap volcanic rock is a member of the Universal formation.

3) Cagraray

Coal Harbor Limestone (upper Oligocene series to lower Miocene series)

This limestone was named by Corby et al. (1956). It is distributed from the central part of Cagraray Island to thesoutheast part of Cagraray Point. It is massive and pink to yellowish brown in color. Hasimoto et al. (1981) placed the age of this rock at late Oligocene to early Miocene on the basis of the foraminifera fossils in the limestone.

4) Bicol South

Ragay Volcanic Rock (Lower Oligocene series)

This rock was named by Corby (1951). It is distributed sporadically from Tinalmud to Panganiran (Pio Duran) on the coastline of the southwest side of the Bicol Peninsula. This volcanic rock consists of andesitic lava and agglomerate. It covers the Pantao limestone with conformity and has undergone intrusion by the late Oligocene Panganiran diorite. Furthermore, this volcanic rock sometimes has intrusion in thin sheet form into the stratification of the Pantao limestone in its direction. It is porphyritic with fine to medium coarseness and light green to bright greenish gray in color. Most of the andesite is subject to hydrothermal alteration. The primary plenocryst is plagioclase, clinoaugite and hornblende, but they are subject to considerable chloritization and epidotization. A fault with a north-northeast-northeast trend is to be observed. In the fault zone this rock is subject to strong shear, resulting in brecciation. At such places this rock undergoes chloritizaton, and pyrite dissemination is to be observed.

(5) Miocene Series

1) Bicol North

Bosigon Formation (Lower Miocene series)

Miranda and Caloen (1979) reported outcropping of the sequence conglomerate, shale, arkosic sandstone, limestone, basaltic lava, wacke, tuffaceous shale and chert at Labo along the Bosigon River in Camarines Norte Province and named it the Bosigon formation.

That formation covers the Larap volcanic rock with unconformity and is covered by the Santa Elena formation with unconformity. An upper and a lower member of the formation are recognizable.

The lower member consists of alternation of conglomerate, sandstone, shale and limestone. The conglomerate consists of pebble-size andesite, welded tuff, quartz schist, and skarn rubble to subrounded pebbles and is cemented by a calcareous matrix. The sandstone is arkosic, gray in color and fine to medium coarse. The shale is gray to black and tuffaceous to calcareous. The limestone is coral reef sandstone turbid gray to black in color and fine-grained and compact. The United Nations (1987), however distinguished the lower member from the Bosigon formation, calling it the Tamisan mudstone.

The upper member consists of interbedding of basalt lava, volcanic wacke, tuffaceous conglomerate, chert and limestone. There is little chert or limestone in the sequence, both consisting of only thin layers. But the chert is thicker than the fine-grained limestone.

This formation has a thickness of about 1,500 m and is considered to belong to the early Miocene epoch (BMG, 1982). But the United Nations (1987) considers the horizon of this formation to be below the Universal formation, and Mitchell and Leach (1991) also mentioned that possibility.

Sta. Elena Formation (Upper Miocene series)

This formation was reported by Miranda and Caleon (1979) as consisting of the rock outcropping along the Macogon-Kanapawan Road and the Sto. Tomas-Sta. Elena Road in Camarines Norte Province and the rock group distributed on the upper reaches of Kilbay Creek in

Quezon Province. The Sta. Elena formation covers the Bosigon formation with unconformity and is covered by the Vinas formation with conformity.

It consists of conglomerate, sandstone, siltstone, shale and small quantities of limestone. The conglomerate consists of pebble-size basalt, diorite, volcanic sandstone, limestone and chert rounded to subrounded pebbles. The sandstome is massive, dark gray and medium-grained to coarse. The limestone is medium-grained to fine and includes fossils. This formation is considered to date back to the late Miocene (BMG, 1982).

2) Caramoan

Del Pilar Formation (Lower Miocene series)

This formation is distributed on a small scale in the Del Pilar area northwest of Grachitorena. It covers the Garchitorena formation with unconformity and consists of conglomerate, volcanic wacke and limestone. The conglomerate is generally massive and consists of pebble- to cobble-sized volcanic rock, graywacke, limestone and quartz and schist subrubble to subrounded pebbles. Such pebbles, cobbles and rubble are cemented by a calcareous matrix. The wacke has developed stratification and is coarse and reddish brown in color. The limestone has thin stratification and is turbid white to gray or yellowish brown in color and fine-grained. BMG (1981) assigned the formation to the early Miocene epoch.

Lahuy Formation (middle to upper Miocene series)

According to Miranda (1976) this formation consists of alternating beds of sandstone, basalt and dacite lava. It is distributed on Lahuy Island and neighboring islands (BMG, 1982). The sandstone has developed stratification and is bright gray in color and quite hard. It is tuffaceous and rich in magnetite sand. This formation was assigned by BMG (1982) to the middle Miocene to late Miocene. David et al. (1994) included this formation in the Garachitorena formation because of the fact that its facies is similar to that of that formation.

3) Cagraray

Liguan Formation (Lower Miocene series)

This formation is distributed along the southern part of Batan Island and consists of the following three members given in the order from lowest upward: the Coast limestone, the Coal layer and the Hill limestone.

Caracaran Siltstone (Lower Miocene series)

This is the name given by Corby et al. 91956) to the siltstone distributed along the Caracaran River on Batan Island. It has interposition of limestone and coal layers.

Bilbao Formation (middle Miocene series)

The Bilbao formation, which is distributed on Batan Island, consists of a lower limestone, Galicia sandstone, a coal formation and an upper limestone. The lower limestone consists of calcareous and coral limestone and has lenticular interposition of siltstone and sandstone. The Galicia sandstone is coarse and conglomeratic at places. The coal formation mounts the lower limestone and consists of thin layers of coal interposed in brownish sandstone and calcareous shale. The upper limestone outcrops between Gaba and Kalanaga Bay and has a facies similar to the lower limestone.

4) Bicol South

Bicol Formation (Lower to upper Miocene series)

This formation is distributed along the southwestern coast of the Bicol Peninsula from Caima Bay in Camarines Sur Province in the north to the area southeast of Pantao in Albay Province in the south. It also outcrops slightly inland south of Libon. It also stretches in the vicinity of Legazpi to the southeast. It covers the pre-Tertiary bedrock with unconformity and is covered by the Talisay formation with unconformity.

This formation can be divided into the following four facies. The lowest unit consists of alternating layers of conglomerate and sandstone with developed thin stratification and has interposition of lenticular coal layers between the layers of conglomerate. The next unit, which consists of limestone, outcrops in the vicinity of Panganiran (Pio Duran). Calcareous sandstone comprises the third unit, which is distributed northeast of Pantao, is yellowish brown to gray in color and has comparatively developed stratification and lenticular interposition of mudstone and layers of coal. The youngest unit consists of slate and meta-sandstone, with some interposition of lenticular granite. The slate is somewhat altered and has developed thin lamination. It peels off easily and is black to gray in color. The meta-sandstone is coarse and brown in color and has developed jointing.

The fossils are indicative of the early Miocene to the late Miocene. The thickness of the formation is 1,200 m, and it is thought to derive from shallow sea sedimentation.

(6) Pliocene Series

1) Bicol North

Vinas Formation (Pliocene series)

This formation is distributed in the vicinity of San Lorenzo north of Calauag in Quezon Province and west of Daet in Camarines Norte Province. It consists of alternating layers of sandy limestone without developed stratification, calcareous sandstone and slate and a limestone and conglomerate base formation (Espiritu and others, 1968). It has a thickness of 475 m. Judging from the fossils, the age of sedimentation of this formation is thought to be the Pliocene epoch.

Macogon Formation (Pliocene series)

This is the name given by Miranda and Caleon (1979) to the rock outcropping along the Kanapawan-Macogon Road. The formation is distributed along the Bosigon River and Palall River in south Daguit. It covers the Sta. Elena formation with conformity and the Bosigon formation without conformity and consists of volcanic fragmental rock, black tuffaceous slate and basalt lava. The volcanic fragmental rock, which is dacite, is to be found in the upper part of the formation. It is covered by pillow basalt and basaltic pyroclastic rock. This formation is the wall rock of the Nalesbitan ore deposit (Angeles et al., 1987; Sillitoe et al., 1990). It is considered to date back to the Pliocene epoch (BMG, 1982).

Bagacay Andesite (Pliocene series)

This is the name given by Meek et al. (1941) to the massive or pyroclastic andesite widely distributed at Mt. Bagacay southeast of Paracale. The rock is andesite with hornblende plenocryst in the gray to dark gray matrix. It is also the wall rock of gold deposits of the metalliferous-vein type.

Pyritization and chloritization are to be observed along faults. This rock is considered to date back to the Pliocene epoch.

3) Cagraray

San Miguel Tuff (Pliocene series to Pleistocene series)

The San Miguel tuff a thin formation of marine sediment distributed at the southern coast of San Miguel Island. The lower part consists mainly of tuffaceous shale accompanies by layers of sandstone, and the upper part consists mainly of sandstone. Going upward there is gradual transition from them to the Tabaco basalt consisting of basaltic lava and agglomerate.

4) Bicol South

Talisay Formation (Upper Miocene series to Pliocene series)

This formation used to be called the Albay Group (Corby et al., 1951), that name also having being adopted by the Bureau of Mines Petroleum Division (1966, 1975) and BMG (1982). However, de Guzman (1963) lowered the rank from group to formation, and called it the Talisay Basin formation.

This formation is distributed over a wide range along the coast on the southwest side of the Bicol Peninsula. The strike is in the northwest-southeast direction almost parallel to the direction of the coastline. The formation has a gentle synclinal structure called the Albay syncline. It covers the inclined Bicol formation with unconformity. It consists of the Talisay limestone, the Aliang siltstone, the Paulba sandstone and the Malama siltstone in the order from the bottom upward. The lowest layer, the Talisay limestone, is classified in the upper Miocene series, and the layers above it are classified in the Pliocene series.

The Talisay limestone is distributed on both wings of the Albay syncline and mounts the Bicol formation with unconformity. It has developed thin stratification, and the facies changes from sandy to crystalline to coral reef limestone from the bottom upward. The thickness of the formation is about 290 m. The Aliang siltstone is covered by the Ligao formation (described below) with unconformity. The Malama siltstone is calcareous with developed thin stratification and has thin interpostion of coarse arkosic sandstone. This unit is 250-350 m thick and is assigned to the Pliocene epoch. The Paulba sandstone is distributed between Paulba and San Jose. This unit consists of thin stratification and contains a great deal of volcanic fragmental material. Furthermore, the tuffaceous matrix has interposition of conglomerate layers that include pumice, volcanic fragmental rock and coral reef cobbles, pebbles and gravel. The thickness is 100-200 m. The Malama siltstone forms gently sloping terrain between the Pantao Mountain Range and Ligao-Oas. That siltstone consists of thick stratification and is gray to brown in color. It containsfossils and has interposition of layers of calcareous shale. The thickness of this formation is approximatel 1,800 m. It is mounted on the Bicol stratus with unconformity and on the Paulba sandstone with conformity.

(7) Pleistocene Series

1) Bicol North

Labo Volcanic Rock (Pleistocene series)

This volcanic rock was named by Miranda and Caleon (1979). It has wide distribution on and surrounding Mt. Labo. It covers the Pliocene with conformity.

This volcanic rock consists of interbedding of andesite lava and dacite lava and has interposition of layers of tuff and other volcanic fragmental rock. The andesite contains small amounts of hornblende plenocryst and plagioclase plenocryst and has a vesicular tuffaceous to vitreous matrix. The dacite has coarse plagioclase plenocryst, biotite plenocryst and a small quantity of quartz plenocryst. The andesite and dacite have silicification and bleaching along faults. The volcanic fragmentary rock is distributed around Mt. Labo and is bright greenish gray to gray where it is fresh and reddish brown where it has undergone weathering. The layers of tuff sometimes have hornblende, biotite and plagioclase plenocryst fragments, and some of the vocanic fragmentary rock has well developed stratification and frequently cross stratification.

To the east of Mt. Labo lies Mt. Culasi facing on San Miguel Bay. To the east can be observed an open oval-shaped depression which is surmised to be a dissected ruptured crater. There, as on Mt. Labo, is to be seen wide distribution of massive hornblende andesite, dacite lava and tuff and tuff breccia. Culasi Peak, Tacubtacuban Hill and other small hills along the coast and the 798 m beak of Mt. Culasi are biotite dacite plugs, and the other parts consist of hornblende andesite and pycroclastic rocks.

2) Caramoan

Isarog Volcanic Rock (Pliocene series to Pleistocene series)

The youngest formation on the Caramoan Peninsula are the Isarog volcanic rock. They consist of interbedding of massive andesite lava and volcanic fragmental rock. Those rocks are distributed on Mt. Isarog and at Tinambac nearby. They cover the Lagonoy ophiolite and the Tambang hornblende with unconformity. The andesite has developed stratification, and silification and kaolinization are to be noted over a wide range. At some outcrops it has been alterated to clay rich in silica and to opaline rock. The interposed volcanic fragmental rock contains andesite rubble to subrounded pebbles. This rock is considered to date back to the Pliocene epoch to Pleistocene epoch and is thought to have been formed in connection with the sinking of Phillipine Trench.

3) Cagraray

The San Miguel tuff and *the Tabaco basalt* are assigned to the Pliocene series to Pleistocene series.

4) Bicol South

Ligao Formation (Pliocene series to Pleistocene series)

The name Ligao was first used by Corby et al. (1951) for the limestone distributed along the Talisay River in Ligao. This formation was called the Ligao formation by de Guzman (1963). He used that name to cover both the limestone and the pyroclastic rock to be found in the Ligao Range. This formation is distributed over a wide range from Javellar to Dapdap. This limestone is massive and consists of thick stratification. It is coral reef limestone, white to pink in color and forming cliffs along the coast. The pyroclastic rock is situated under the limestone or occursinterposed in it. The calcareous sandstone of the Nabua formation (Corby et al., 1951) distributed in the northwest part of Albay and in Camarines Sur and the Sorsogon calcareous clastic rock (Corby et al., 1951) are considered to be the same facies as the Ligao formation. This formation has a thickness of approximately 500 m and is considered to belong to the Pliocene epoch to Pleistocene epoch.

Polangui Volcanic Rock (Pliocene series to Pleistocene series)

This name was given by de Guzman (1963) to the volcanic rock distributed in the vicinity of Oas, Polangui, Ligao and Tabaco. This volcanic rock consists of volcanic fragmental rock and lava and forms the topography of the volcanic region of Albay and Sorsogon. As the situation presently stands, the volcanic rock distributed in Albay and Sorsogon has not yet been sufficiently surveyed, and the succession of strata has not been made clear. Mt. Masaraga and Mt. Malinao are representative of the relatively old volcanos. Mt. Mayon and Mt. Bulusan are active volcanos. Mt. Mayon last erupted in 1993, the fourth time since 1968. That is known because of the fact that recently there has been closer observation than in the past. The volcanic rock distributed in the Bacon-Manito area is known as Pocdol volcanic rock (e.g. Espiritu, 1979). In the southern part of Sorsogon is to be found the Irosin caldera, and in connection with formation of the Irosin caldera the volcanic rocks distributed in southern Sorsogon are classified into pre-caldera volcanic rock, caldera pumice flow deposits and post-caldera volcanic rock (e.g. Delfin et al., 1988). The Irosin caldera has a diameter of approximately 11 km and was formed about 40,000 years ago by a large-scale rhyolitic pyroclastic eruption (Ui, 1993). Early caldera (pre-caldera?) volcanic rock is distributed in the Gate Mountains south of the caldera. On the side slightly northeast of the center of the caldera are situated the post-caldera volcanos Mt. Bulusan, Mt. Jormajan, etc. Mt. Bulusan has repeatedly shown vulcanian activity since 1852.

(8) Holocene Series

The alluvial deposit constituting the flood plains and large rivers of the northwest to eastern parts of Bicol North and Caramoan has poor sorting and consists of unconsolidated soil, clay, silt, sand and gravel. The alluvial deposit constituting the coast and rivers of Bicol South consists of clastic rock, limestone, volcanic rock and diorite detritus.

3.1.2 Intrusive Rock of the Bicol Area

(1) Granites

1) Bicol North

Paracale Granodiorite (Middle Miocene?)

The Paracale granodiorite distributed in Jose Panganiban-Paracale (Meek et al., 1941; Frost, 1959) has a length of approximately 17 km and a width of 4 km. That rock intrudes in the serpentinized ultrabasic rock. The contact between the two slopes towards the outside of the rock body, the slope of the southwest side of the rock body being greater than that of the northeast side. Mitchell et al. (1986), Mitchell (1988) and the United Nations (1987) thought that the ultrabasic rock thrusted into this rock body rather than this rock body intruding into the ultrabasic rock.

In the past there have been several different assertions concerning the time of penetration by the granodiorite, ranging from the Paleozoic era (Alvir, 1950) to the Pleistocene epoch (Meek et al., 1941). Frost (1959) suggested that intrusion of that stock occurred after sedimentation of the Universal formation and continued to after eruption of the Larap volcanic rock covering the Universal formation. Miranda and Caleon (1979) asserted that the time of the intrusion of this stock was the early Pliocene epoch and that that was the same time as that of intrusion of the Caramoan quartz diorite and the Batalay intrusive rock. In the way of radiometric age values for this rock, Wolfe (1981) gave 14.9 Ma in terms of K-Ar for the biotite of the stock and reported that that was indicative of the middle Miocene epoch. The United Nations (1987) gave a K-Ar age of the biotite of 17.1 +/- 0.9 Ma, and Geary et al. (1988) obtained 18.7 +/- 0.4 Ma for the 40 Ar/39 Ar age. However, Mitchell and Garcia (1981) and the United Nations (1987) consider that the time of intrusion was the pre-Tertiary period or the Mesozoic era since those radiometric age values are indicative of the time of thermal events after the intrusion of this rock.

This granodiorite is medium coarse to coarse and bright gray in color. Its main constituent minerals are Albay to oligoclase, orthoclase, biotite and quartz. Gneissic structure, marked lamination and lineation are to be seen along the margin of the rock body. The direction of the lamination is approximately parallel to the outer fringe of the rock body. Such lamination and lineation are not to be seen in the central core of the rock body. The rock has experienced pronounced fracturing and has many faults. In many cases there is bleaching and occurrence of pyrite along the faults.

According to the underground mapping of the Paracale Gumaus gold mine at the 350-foot level, the granodiorite is cut by considerable pegmatite, aplite and lamprophyre. The pegmatite is sparse, occurring as thin discontinuous dikes. It intrudes into the granodiorite and aplite. It contains large orthoclase and quartz crystals attaining 2 cm in some cases. The aplite dikes contain biotite, mafic minerals and other forms of garnet. The granodiorite is bleached at places where there is multiple intrusion by such dikes, but mineralization is not to be observed. The aplite expands and contracts in a range of 2 m to 10 m and cuts the lamination of the granodiorite in the northwest direction. The lamprophyre has a width of 0.3-1.5 m, is fine and dark green in color and cuts the lamination of the granodiorite and some aplite veins.

This granodiorite is thought to be, in part, of the same period as the penetration of the Tamisan diorite, which is discussed below.

Tamisan Diorite (Middle Miocene)

The Tamisan diorite is the name given to the quartz diorite that outcrops at Bosigon, Bayabas and the tributaries of the Labo River in the Tamisan area of Camarines Norte. This intrusive rock has a wide range of composition from hornblende diorite to quartz diorite. As related igneous rocks there are andesite, syenite and dacite porphyry, which occur in stock form, dike form and sill form. They intrude into the Universal formation, the Larap volcanics and the Bosigon formation, such penetration being thought to have occurred in the middle Miocene epoch, and they form contact metasomatic iron deposits and hydrothermal deposits.

The quartz diorite is medium-coarse, leucocratic andporphyritic and has quartz, plagioclase and ordinary hornblende as its chief mineral constituents, but some of the hornblende is chloritized. The hornblende diorite of the Tabas-Pinagbirayan region is fine to medium-course, porphyritic and light gray to green in color, and the hornblende shows lineation. The quartz andesitic porphyry occurs in stock form in the southeast part of the Larap peninsula and as dikes or sills at Calambayunga Inlet. It is light green in color and fine to coarse and has quartz, orthoclase and biotite as its main mineral constituents. Magnetite is generally to be seen as an accessory mineral.

Dacite porphyry occurs as extremely small stocks in the Universal formation and the Larap volcanic rock and has quartz, feldspar and biotite phenocrysts. However, concerning this rock, the United Nations (1987) discovered 22 small stocks and considers that it represents activity of a younger period than the Tamisan diorite considering this rock's K-Ar age (2.4 +/- 0.3 Ma).

Syenite occurs as syenitic porphyry dikes to sills on the Larap Peninsula. It is thought to be the same thing as the syenite outcropping at the Bessemer pit of the Larap mine (United Nations, 1987).

Andesite is sparse, but it does occur as dikes or sills in the southeastern part of the Larap Peninsula. It is melanocratic, fine to medium-coarse and porphyritic and accompanied by plagioclase and ordinary hornblende.

2) Caramoan

Tambang Point Diorite (Oligocene)

The dioritic rock of Caramoan is called Tambang Point diorite and occurs as schist and small rock bodies intruding into the rock of the Cretaceous period to the Eocene epoch. It also occurs as dikes and sills with a maximum width of about 10 m. This rock is distributed mainly on the western side of the Caramoan Peninsula on Tambang Point, the eastern bank of the Tambang River and at Magtan and elsewhere. The largest rock bodies are distributed on the eastern bank of the Tambang River. The composition varies considerable from place to place, but generally the rock is classified into quartz diorite and hornblende diorite. Generally the quartz diorite is medium-coarse, leucocratic and porphyritic and has the primary minerals quartz, albitic plagioclase and hornblende. Ordinarily the plagioclase is altered to fine sericite, and the hornblende to chlorite. The typical hornblende diorite is medium- to fine-grained, melanocratic and porphyritic and always has dark green hornblende spots. The age of intrusion is considered to be the early Oligocene epoch.

3) Cagraray

Rapu-Rapu Diorite (Upper Cretaceous)

Diorite intruding into the ultrabasic rock is to be observed on the southwest coast of Rapu-Rapu Island. Theserock bodies are massive and have developed fissuring. They are medium-coarse to coarse and have undergone slight silicification. Their radiometric age is 79 Ma as an older value than the 42 Ma obtained by Wolfe (1981) on that island.

4) Bicol South

Panganiran Diorite (Upper Oligocene)

The Panganiran diorite is distributed on the Panganiran Peninsula of southern Bicol. The rock bodies occur as three rows of rock bodies extending in the northwest-southeast direction. Of them, the rock bodies on the northwest side have the widest area of distribution, continuing from Pantao Point to Malacbalac. The Panganiran diorite is dividedroughly into hornblende diorite and hornblende quartz diorite. The hornblende diorite is further divided into that which is fine-grained to porphyritic and hypautomorphic granular and that which is coarse and hypautomorphic granular to pegmatitic. The hornblende diorite has andesine and ordinary hornblende as its main constituent minerals, with accompaniment of epidote, calcite, sphene and clay minerals as accessory minerals. The crush part of the plagioclase is altered to an aggregate of clay minerals, sericite, calcite and microminerals, and the ordinary hornblende is altered to chlorite and sphene. The porphyritic hornblende quartz diorite that constitutes most of the diorite is distributed in the vicinity of Panganiran Bay. The pegmatitic quartz hornblende diorite occurs on the Maragondong-Pasacao coastline as dikes along the joints. Such Panganiran diorite intrudes into the Ragay volcanic rock, and hornfelsization is to be observed in the volcanic rock at the places of intrusion contact. It is supposed that the intrusion occurred along faults in the Ragay volcanic rock.

(2) Basic to Ultrabasic Rock

1) Bicol North

The basic to ultrabasic rock of Bicol North is distributed at Mt. Cadig in the Paracale-Jose Panganiban region and on the islands in the northeast offing. It occurs as rock bodies that have thrusted into the folded schist and Cretaceous system, and in the Paracale-Jose Panganiban region it is intruded by the Paracale granodiorite.

The serpentinized ultrabasic rock is light yellowish green to dark green in color. In general, it is sheared and brecciated, with fibrous talc, chlorite and carbonate minerals filling the fissures. Yellow to reddish brown lateritic soil has been formed from the completely weathered ultrabasic rock. The peridotite consists of xenomorphic granular pyroxene and olivine. The cleavages of the pyroxene are filled with serpentine and acicular magnetite. At places where there is extreme serpentinization there is mostly antigorite, with accompaniment of poikilitic talc and chlorite. On Ingalan Island the pyroxene occurs in strips with a thickness of 6-10 cm, with accompaniment of olivine and dunite. The pyroxene consists of massive coarse rock with a pyroxene content in excess of 90%. The dunite is massive, medium-coarse and yellowish green in color and consists mainly of olivine, with accompaniment of small quantities of orthopyroxene and chromite.

2) Caramoan

The Caramoan ultrabasic rock is considered to be a unit

of the Lagonoy ophiolite sequence and occurs as strongly sheared rock bodies thrusting into the folded schist and Cretaceous period Pagsangahan formation. It is distributed at Mt. Putianay and the southeast part of Tambang. North of Lagonoy small rock bodies are sprinkled along lateral faults in the E-W direction. The color is mostly light yellowish green to dark green, with some dark turquoise, dark greenish gray or light brown. The main rocks are olivine, harzburgite and pyroxene, with interposition of layers of gabbro, dunite and chromite. Those rocks are usually completely serpentinized, sheared and brecciated. Many different facies are mixed together in complex fashion. The gabbro is granular and melanocratic and contains sericitized plagioclase. Once in a while it has a thin bedded structure. The ultrabasic rock distributed on the Caramoan Peninsula has undergone hydrothermal alteration and is thickly covered with laterite with nickel content and including iron and cobalt.

3) Cagraray

The Cagraray ultrabasic rock is serpentinized olivine intruding into metamorphic rock. It outcrops at three places on Batan Island, on the southern coast of Cagraray Island and in the western part of Rapu-Rapu Island. Around the rock bodies there is brecciation and shearing. The peridotite is dark in color and xenomorphic granular to porphyritic. In the porphyritic peridotite, orthopyroxene phenocryst is to be seen in the fine matrix consisting of orthopyroxene, olivine and clinoaugite. The pyroxene is mostly enstatite, which constitutes approximately 60%

of the rock. The other minerals are opaque iron oxide minerals, antigorite and iddingsite.

4) Bicol South

The Panganiran ultrabasic rock of Bicol South is lenticular or of discordant form, consists of serpentinized pyroxene peroditite and pyroxene and occurs as thrusting rock bodies. It is distributed along the Panganiran River extending in the northwest direction from Maragondong. The rock is dark green to pitch black and xenomorphic granular and consists mainly of clinoaugite and olivine, with accompaniment of serpentine, magnetite and uralite.

3.2 Ore Deposits and Mineral Showings in the Bicol Area

A map of distribution of ore deposits and mineral showings is given in Fig. I-3-7. Furthermore, a list of those ore deposits and mineral showings is given as Appendix at the end.

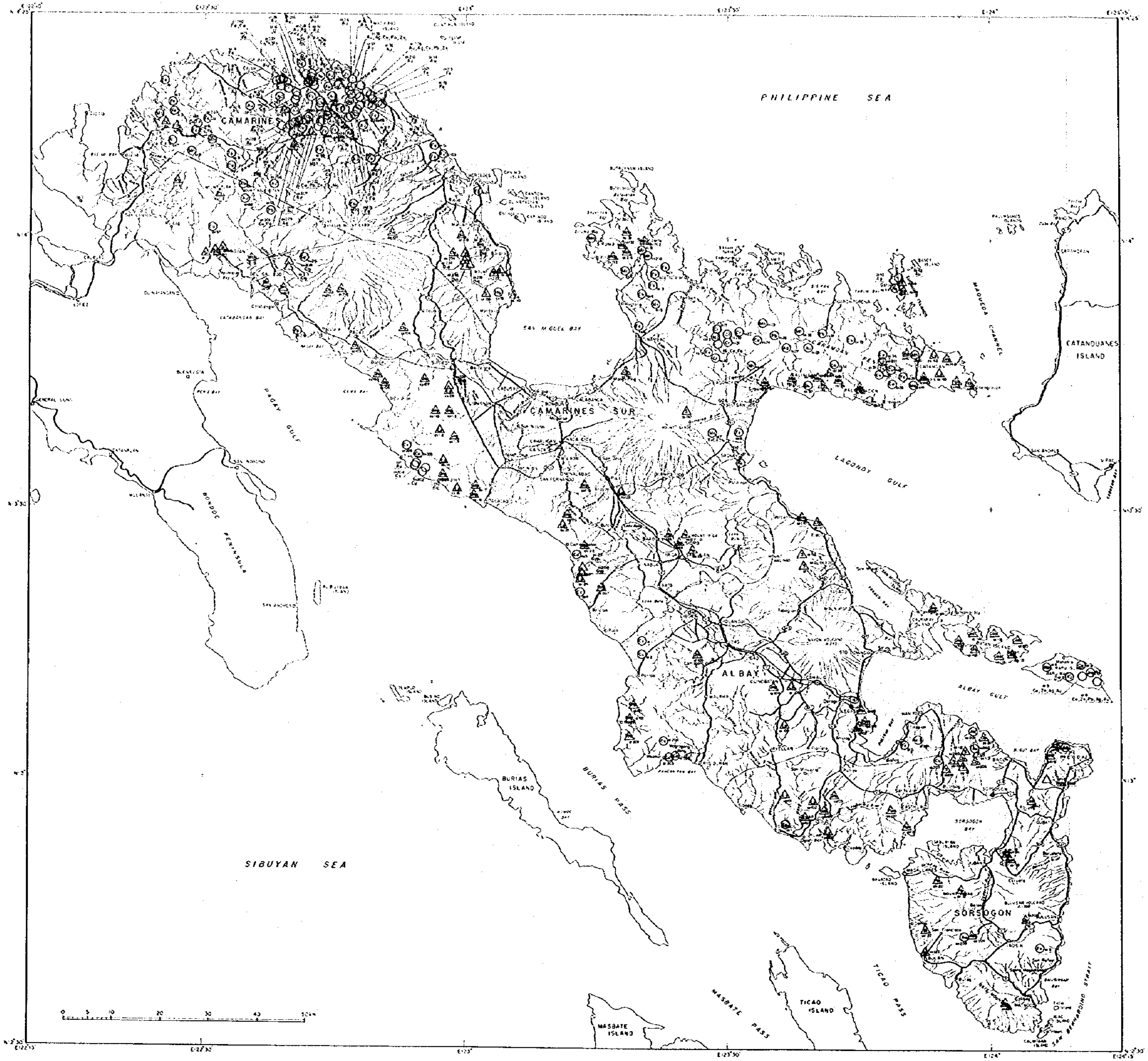
Fig. I-3-7 has been prepared from mainly the existing data indicated below. Those of the indicated ore deposits and mineral showings that were not given in the sources mentioned below were taken from other literature and added to the table and plotted on the map of Fig. I-3-7.

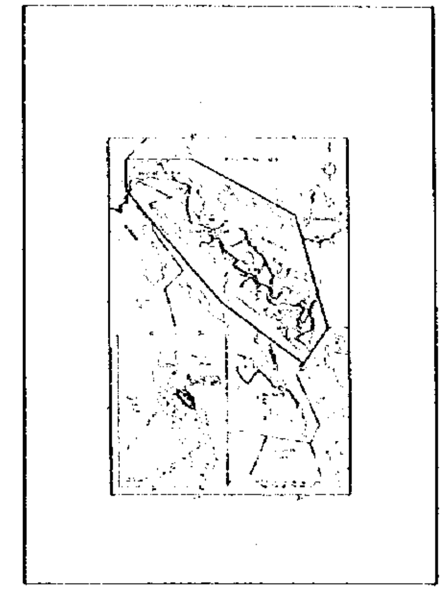
In preparation of Fig. I-3-7 and Appendix not only metal ore deposits but also nonmetal ores, including clay, manganese, phosphate ore and heavy minerals, etc. were considered. That is because there are cases in which kaolin clay, etc. are related to epithermal gold deposits. As for metal ore deposits and mineral showings, they were plotted on Fig. I-3-7 even if what is concerned is only recognition in the literature of geochemical anomalies at the points in question.

- "MINERAL POTENTIAL OF THE BICOL REGION", scale of 1:250,000, published by Bureau of Mines and Geosciences, Region V.
- Bureau of Mines and Geosciences (1986)
- Metal Mining Agency of Japan Resource Information Center (1997)
- JICA/MMAJ (1985) (PH16)

Regarding the Bicol Region, there is comprehensive treatment of Camarines Norte, which has a dense concentration of occurrence of gold deposits, in Mitchell and Leach (1991), the United Nations (1987;CN-52), Frost (1959, 1965) and elsewhere. There is not any comprehensive treatment of ore deposits and mineral showings in other areas of the Bicol Region, except for the Caramoan Peninsula (Miranda, 1976;CS-32). Of those sources, Frost (1959) divides the base metal deposits and mineral showings situated in the southwestern part of the Paracale gold deposits zone into an "iron belt" and a "base metal belt" and discusses the characteristics of both. The United Nations (1987) gives the findings of the cooperative survey carried out with BMG in Camarines Norte in 198?-1987. Mitchell and Leach (1991) give comprehensive treatment of the Philippines' epithermal gold deposits, including discussion in detail of the gold deposits of the Camarines Norte area on the basis of the United Nations (1987).

In the following ore deposits and mineral showings are discussed separately for each kind of ore. Since there is a comparatively large number of deposits and mineral showings for gold and copper, the provinces in which they are situated are treated one by one.





Scale 1 : 250,000

Fig.I-3-7 Location map of ore deposits, mineral showings, and geochemical anomaly in the Bicol Area

LEGEND

- Chartered city
- City capital of province
- Capital of province
- Municipality or municipal district
- Barangay
- Railroad
- Provincial boundary
- First and second class road
- Route markers : National
- Route markers : Provincial

Keys

prospects

- ○ Metallic Mineral Resources
- △ Non-Metallic Mineral Resources

metallic resources

Ag	Silver
Al	Aluminum
Au	Gold
Co	Cobalt
Cr	Chromium
Cu	Copper
Fe	Iron
Hg	Mercury
Mn	Manganese
Mo	Molybdenum
Ni	Nickel
Pb	Lead
U	Uranium
Zn	Zinc

non-metallic resources

Bnt	Bentonite
Ccly	China Clay
Cly	Clay
Coal	Coal
D-e	Diatomaceous Earth
Fcly	Fire Clay
Fd	Feldspar
Grp	Guano-Phosphate
Gyp	Gypsum
Kao	Kaoline
Ls	Limestone
Mbl	Marble
Per	Perlite
Pum	Pumice
Py	Pyrite
S	Sulfur
Si	Silica
Wcly	White Clay

3.2.1 Gold

The Bicol region has the Paracale gold deposit zone, known as one of the most important such zones in the Philippines. As can be seen from Fig. I-3-7, most of the gold deposits and mineral showings indicated by the existing data are distributed in the Paracale district of Camarines Norte. The other gold mineral showings indicated in that figure are, in Camarines Sur, in the middle part of the Caramoan Peninsula, on Lahuy Island and in the northwest part of Dalupaon; in Albay, on Rapu-Rapu Island and in the Bacon-Manito area; and, in Sorsogon, in the eastern part of San Francisco. The following is a simple discussion of the gold deposits and mineral showings in each area, the gold deposits and mineral showings of Camarines Norte being discussed in somewhat greater detail than the others on the basis of Mitchell and Leach (1991).

(1) Camarines Norte

The gold deposits and mineral showings of Camarines Norte can be classified into the following three areas in terms of distribution:

1. The Jose Panganiban-Paracale area
2. The Sta. Elena-Tabas area
3. The Nalesbitan-Tuba area

Of those areas, 1. and 2. represent the second most important gold production area in the history of the Philippines, having produced more than 160 t of gold in the past (Mitchell and Leach, 1991).

The Jose Panganiban-Paracale Area

That area is located approximately on the north side of the east-west line connecting Paracale and Jose Panganiban. It is an area with distribution of the ultrabasic rock considered to be the Cretaceous period ophiolite sequence and the Paracale granodiorite distributed through it (Fig. I-3-1).

Most of the gold deposits distributed in the area were developed before World War II, and many of the mines were closed by the end of the fifties. Many of them underwent further prospecting in the eighties in a redevelopment effort, but only one of the mines is still operational: the Longos Mine of the company United Paragon (actual production figure for 1994: 2.37 t of gold;

MMAJ Resource Information Center, 1977 [sic; 1997?]).

Among the main mines located in this area are the Longos Mine (cn37), the La Suerte Mine (cn225), the San Mauricio (Olecram) Mine (cn230), the Magna Mine and the Paracale Gumaos Mine (cn30). All of them are of the metalliferous vein type, with the characteristics indicated below. Mitchell and Leach (1991) consider all of them to be epithermal gold mines, whereas Sillitoe et al.(1990) consider them to be the metalliferous vein type of gold base metal mineralization often observed in the vicinity of porphyry type copper and gold systems.

- Wall rock: Paracale granodiorite (Mitchell and Leach (1991) call it the Paracale trondjhemite)
- Direction: N 10o E strike, with steep slope
- Distribution: Most of it is distributed at the north side contact (with the ultrabasic rock) of the Paracale granodiorite body. There is hardly any distribution of it at the south side contact.
- Morphological characteristics: The veins are thicker at the fringe of the granodiorite bodies, and the mineralization there is also more pronounced.

It disappears within several meters to several tens of meters after entering the ultrabasic rock.

The vein width gets narrower going toward the inside of the granodiorite rock body, and the grade also declines until a "barren core" is reached.

- High grade part: At intersections of veins and where branch veins leave main veins.Characteristics of the veins: There are two kinds of veins:
    1. Green quartz veins: Distributed near contact with the ultrabasic rock.
    2. White quartz veins: This kind is more frequent. Quartz and quartz-calcite veins. Microcrystal quartz stringers, vugs, coarse sphalerite and galena bands, etc. are observed. Also characterized by high base metal content.
- Ore minerals: pyrite, pyrrhotite, arsenopyrite, chalcopyrite, bornite, covelline, sphalerite, galena, tetrahedrite. Characterized by many base metal sulfide minerals, Pb, Ag, Zn and Cu having been recovered at many mines. Mo and W also present in traces. The combined Pb and Zn content is 0.5-1.0%.
- Fluid inclusion homogenization temperature: According to the data available on the veins of the San Mauricio (Olecram) Mine (cn230) for the most part it lies within the range 220-300° C.

- Other characteristics: The veins undergo the following change from the deep part to the shallow part:
- Deep part: Quartz vein with clear profile and without development of alteration zone of the wall rock.
- Shallow part: Change to stringers, with silicification and developed sericitization alteration of the wall rock and with decline in gold content.

Extraction took place at a depth of approximately 300 m (because there is inflow of water at the deep part).

Sta. Elena-Tabas Area

This area extending from the Larap Peninsula through the vicinity of Batobalani and to the north of Mt. Bagacay, is situated south of the above-mentioned Paracale area. It roughly coincides with the "base metal belt" and "iron belt" defined by Frost (1959). It is an area of distribution of the Universal formation, considered to date back to the late Paleocene epoch to the Eocene epoch, which is intruded by many stocks of what is called the Tamisan diorite (middle Miocene epoch). That Universal formation is also intruded by about twenty small rock bodies of dacitic porphyry assigned to the Pliocene epoch (United Nations, 1987).

The gold deposits and mineral showings of this area are divided by Mitchell and Leach (1991) into the following two types:

1) Base metal and gold showings accompanying iron deposits
2) Epithermal metalliferous vein deposits

The following deposits and mineral showings are cited by that source as belonging to type 1):

- Matanlang porphyry copper and molybdenum deposit

  Sillitoe and Gappe (1984) say that this deposit has a gold grade of 0.4 g/t Au. This will be discussed further in a later section (concerning copper).
- Submakin base metal mineral showing (cn222)

  The sulfide ore has a gold grade of 0.26 g/t Au.
- Penarco magnetite and base metal deposit

  Gold anomalies are noted in soil thought to originate in calcite veins cutting the skarn.
- Pinagbirayan Munti magnetite deposit (cn239)

In geochemical exploration of the soil the abnormal values of 3.9 ppm Au and 3 ppm Ag were obtained. In rock samples the values were 0.3 ppm Au and 0.2 ppm Ag. The value for copper was 350 ppm.

- Tabas mineral showing (cn219)

Gold particles have been detected in the soil and in heavy minerals. The soils originate in the hornfelsized mudstone and andesite-diorite breccia that is the wall rock of the magnetite deposits. The gold accompanying such porphyry copper and base metal-iron skarn deposits occurs widely in this area, but its economic value is considered to be low.

The following deposits and mineral showings are cited by that source as belonging to type 2): Paracale National, Paracale d'Oro Mine, Nico Mine, Exciban Mine (cn203, cn228) and Santa Rosa Sur (Tidi) (cn207), etc.

The common characteristics are the fact that they are all the metalliferous vein type of deposit and the fact that they are all amply accompanied by not only pyrite but also chalcopyrite, sphalerite, bornite, covelline and other base metal sulfide minerals. Furthermore, in many cases the fluid inclusion homogenization geotemperature has the comparatively high value of 250-270° C. Geologically they are distributed in the Universal formation of the Eocene epoch, and around them there is distribution of small rock bodies of diorite from the middle Miocene or dacite porphyry from the Pliocene. The main deposits are briefly discussed in the following.

The Paracale National deposit has two veins with a north-northeast strike as its main ore bodies, and its gold grade is 6-9 g/t Au. Its ore minerals are pyrite, chalcopyrite and sphalerite >>(?) bornite, chalcocite and covelline. The fluid inclusion homogenization geotemperature of the quartz vein is 255-270° C. Between the two veins there is a developed zone of illite-quartz-pyrite alteration which going eastward becomes a zone of epidote-chlorite alteration. There is accompaniment by skarn mineralization.

The Exciban deposit (cn203, cn228) is situated at the southwest end of the Sta. Elena-Tabas area. The wall rock is andesite, siltstone and tuff of the Bosigon formation dating back to the early Miocene which are intruded by diorite and dacite dikes. Recently boring data, too, as been given by James and Fuchs (1990). Mineralization is to be noted in veins with a north-northeast direction and in shear zones. The veins are massive to cockscomb quartz veins accompanied by calcite and dolomite. The gold is accompanied by pyrite. There is also up to 3% accompaniment by chalcopyrite and bismuth tellurides. In the deep part molybdenite is also to be observed. The cobalt content of the sulfides is 1000 ppm. James and Fuchs (1990) are of the opinion that the magmatic constituent contributed the most to such mineralization considering the combination of minerals and the fluid inclusion homogenization geotemperature, and they surmise that there is basic rock in the deep part from the fact that cobalt is included.

The Santa Rosa Sur (Tidi) deposit (cn207) is located 1 km east of the Paracale National Mine. In the eighties it was exploited by small operators. After a high-grade part was discovered, the company Benget started strip mining in 1988. Mineralization is to be seen in shear zones and at quartz stringers. From the direction of the old pit it can be seen that the vein direction has a strike in the direction of the east. There is a zone of developed silicification with a width of 2 m in the quartz-illite-pyrite alteration zone with a width of approximately 7 m. Pyrite veins are also to be observed. The fluid inclusion homogenization geotemperature of the pyrite has values of 210-260 degree C.

The Nalesbitan-Tuba Area

This area is situated near the provincial border between Camarines Norte and Quezon. In it are distributed the Macogon formation dating back to the Pliocene and, to the southwest of it, the Tigbinan formation, which is assigned to the late Cretaceous period. The United Nations (1987) says that before World War II there was extraction of gold and silver at the Tuba Mine located near Mt. Tuba in the Tigbinan formation, but there are no details concerning that in view of the fact that the existing literature does not mention it.

The Nalesbitan Mine (cn204) is discussed in detail by Sillitoe et al. (1990: CN-5). Furthermore, a summary description of recently implemented exploration is given in "Mining Philippines '97" (PH-17). The following is an outline description of the characteristics of the mine.

- Location: The mine is located on a ridge with an elevation of 100-300 m and running in the northwest direction at the upper reaches of the Palali, a tributary of the Bosigon River.
- History: After being discovered earlier than 1930, the mine was developed intermittently up to the World War II. In the early eighties it was worked by some 20,000 "small-scale workers" for an estimate production of 5-10 tons of gold. In 1975 Gold Fields Asia Ltd. (a subsidiary of Renison Goldfields Consolidated Limited of Australia) reassessed this deposit as a bulk mineable deposit, and boring was undertaken in 1977-1979, but at that time no economically feasible deposits were found. But along with rise in the price of gold and development of technology for

recovery of gold from low-grade ore by heap leaching it was decided to reassess this deposit once again. Gold Fields Asia Ltd. again undertook prospecting activities and obtained the results of an estimated 1.44 million tons of ore reserves and a grade of 2.53 g/t Au (the cut-off grade being 1.25 g/t Au). Mine construction was started in 1989, and in 1990 2,337 ounces (= approx. 70 kg) of gold was produced by strip mining and heap leaching (from 171,030 tons of treated ore). In 1996 Triarx bought out GFPC and has now embarked on a prospecting program as El Dore Mining Corporation.

- Wall rock: The deposit lies in hornblende andesite and homogeneous lapilli tuff considered to belong to the Macogon formation dating back to the Pliocene epoch.
- Mineralization: The mineralization is restricted by a fault in the northwest direction (a left lateral fault). It is distributed over an elevation interval of approximately 150 m from 300 m to 150 m on a ridge top outcropping to the surface. The mineralization zone continues for 1.3 km in the direction of the strike, the width varying between 145 m and 12 m. Mineralization exists in two en echelon strips of hydrothermal rubble running in the northwest-southeast direction that are subject to chalcedonic silicification. Those silicified rubble strips broaden as the depth gets shallower, and it appears that they each converge artericaily going down to deeper depths. Furthermore, a large number of chalcedonic quartz stringers are to be observed in the silicificated rubble strips as well as evidence of repeated occurrence of brecciation and vein activity. The mineralization strips have been subjected to oxidation by supergene to a depth of 130 m. At places where sulfide minerals remain gold occurs accompanied by sulfides that include copper of the rubble strip matrix and veins. However, it appears that there has been no copper or gold mineralization in the initial-stage chalcedonic quartz-pyrite strips. The most frequent combination of sulfide minerals is pyrite-chalcocite, and next come the combinations pyrite-bornite and pyrite-covelline. At some places there is occurrence of enargite with accompaniment of chalcocite and bornite. Gold and silver tellurides are to be observed as exsolution lamella of enargite. No galena or sphalerite are to be found.
- Homogenization geotemperature: According to the United Nations (1987:CN-52), the homogenization geotemperature of the quartz is 210-240° C. Sillitoe et al. (1990: CN-5) reported 223-225° C and estimated the depth of trapping of the fluid at 300-500 m below the old groundwater level.
- Alteration: Silicification strips occur lenticularly with a northwest trend. That is roughly in the middle of the hydrothermal brecciation zone. They consist of chalcedonic silica and contain considerable quantities of pyrite dissemination. The

silicification strips are surrounded by an advanced argillic zone. The combination quartz-kaolinite-alunite is predominant, with accompaniment of trace quantities of sericite and diaspore. An illite zone is distributed around the silicification zone and advanced argillic alteration zone. There are illite and smectite mixed-layer clays, further outward becoming the combination chlorite-calcite.

Sillitoe et al. (1990) asserted that this mineralization was formed in a "dilational jog" that occurred in the lateral fault system and surmised that the mechanism for precipitation of the gold was boiling. Furthermore, they suggested the possibility of existence of a porphyry type copper and gold deposit deep down in this area in view of the fact that there are more copper sulfides and a higher Mo content than in the case of other gold deposits of the acid-sulfate type.

The findings of Phase I of the prospecting program recently implemented by El Dore Mining Corporation can be summarized as follows:

- A deposit with the high grade of 81 g/t Au was found at a point 300 m northeast of the strip mining (Mill site/Singko Zone). That mineralization strip can be pursued 250 m in the strike direction and has a maximum width of 25 m. It has roughly the same direction as the first open-pit deposit.
- High-grade ore was also found at Bagong Trese, Tres and Bagong Dose.
- An IP anomaly (700 m x 400 m) was found deep at Bagong Dose (about 800 m south of the open pit). Dissemination-type sulfide ore is surmised, and there are hopes regarding the possibility of a porphyry type deposit. The small quartz vein at the surface of Bagong Dose has a grade of 30 g/t Au.

(2) Camarines Sur

Since there is no mention of the gold mineral showing in the central part of the Caramoan Peninsula (cs29), it is not clear what kind of mineralization it is. From the position it would appear that the wall rock is the Lagonoy ophiolite or the Pagsanghan formation dating back to the late Cretaceous period.

There is mention of two gold mineral showings on Lahuy Island (cs42 and cs44). Of those, cs44 was worked before World War II as the Treasure Island Mine (by the Rajah Lahuy Mining Company). In the analysis of Torron (CS31) many ore samples showed 0.7-4.0 g/t Au, and the highest grade was 96.68 g/t Au. According to Cabantog (1977; CS28), the veins have a maximum width of about 1 m, strikes of N40°W, N80°W and N10°E and steep slopes. There are pyrite, galena and chalcopyrite as ore minerals, and quartz and amethyst as gangue minerals. The veins have development of crustiform banding. The wall rock is sedimentary rock, basalt and andesite, and in the way of alteration there is silicification

and argillization, with surrounding prophyritic alteration. Considering the vein texture, the combination of minerals and the alteration, there is the possibility that it is epithermal gold mineralization.

We were not able to find any mention of the gold mineral showing in the northwest part of Dalupaon (cs1) in the existing literature. But considering the fact that there is distribution of copper mineral showings very nearby (cs203, cs204 and cs205), one can suppose that the cs1 gold mineral showing is an accompaniment of copper mineralization. According to Marcelo (1970; CS-9) and Castaneda (1972; CS-43), at those copper mineral showings there is mineralization in the shear zones or along the faults of the andesite, and quartz stringer stockwork is to be observed on an outcrop scale. Furthermore, in view of distribution of diorite in proximity to those copper and gold mineral showings, there is the possibility of mineralization in a porphyry environment.

(3) Albay

There is distribution of several gold mineral showings on Rapu-Rapu Island (al7, al8 and al9). They represent gold accompanied by volcanic massive sulfide deposits. Those deposits will be discussed in the section on copper. The mineral showing al8 is called the BCI deposit, and al9 the Hixbar deposit. A gold grade of the massive sulfide deposit of 2-3 g/t Au is reported (Domingo (AL14)) for the BCI deposit, and for the Hixbar deposit gold grades of 3 g/t Au for the primary deposit and 45 g/t Au for the gossan body of the massive sulfide ore outcropping on the surface are reported (Kinkel and Samaniego, 1956; Al21).

(4) Sorsogon

There is distribution of several gold mineral showings in the Bacon-Manito area (al201, so201 and so202). They are gold anomalies detected in implementation of geochemical prospecting in a region of geothermal development. The highest values of gold were 0.23 ppm Au at al201 and 0.77 ppm Au at so201. All those mineral showings are located in zones of silica-clay-pyrite alteration (PNOC-EDC, 1990; AL/SR-01).

At the gold mineral showing west of Irosin (so209) there is a silicification alteration zone, and considering the mode of occurrence epithermal gold mineralization can be surmised (Rint, 1991; SR-02; Carranza, 1992; SR-01).

In addition, although not plotted on Fig. I-3-7, a large number of gold drift sand deposits are distributed in the Paracale area and on the Caramoan Peninsula (the Tambam-Olas region). There the gold is being recovered by small extraction operators.

3.2.2 Copper (and molybdenum)

Many copper deposits and mineral showings are distributed in Frost's (1959) above-mentioned "base metal belt" and the Paracale area in Camarines Norte. Furthermore, several copper mineral showings are to be found bunched together in eastern Sta. Elena in the west part of that province. In Camarines Sur several copper mineral showings are distributed relatively close to one another in the eastern part of the Caramoan Peninsula, and others are to be found comparatively near one another in the northwestern part of Dalupaon and the northern part of Balatan. In Albay they are distributed in northern Pantao, in the southern part of the Panganiran Peninsula and on Rapu-Rapu Island. In Sorsogon there is a copper mineral showing at one place in the Bacon-Manito area.

There are no separate molybdenum mineral showings, that metal always occurring as an accompaniment of copper.

(1) Camarines Norte

A famous copper deposit is the Larap deposit (cn14) in Camarines Norte. That deposit is one that used to be worked as the Larap iron mine, as will be discussed later in the section on iron. It occurs in the skarn formed by substitution of limestone in the Universal formation of the Paleocene epoch to Eocene epoch along with intrusion of the diorite to syenite porphyric porphyry of the middle Miocene epoch. In the deposit there are magnetite-pyrite strips, chalcopyrite-molybdenite strips and gold-quartz-calcite veins overlapping those strips. The ore reserves are reported (BMG, 1986) to consist of about 17 million t (Cu: 0.42%, Mo: 0.09%, Au: 3 g/t, Fe: 22%).

In addition, in the way of copper and molybdenum mineral showings considered to be porphyry type mineralization there are the Matanlanga, Meycauayan and Igang mineral showings. The Matanlanga mineral showing is situated about 1.5 km southeast of the Larap deposit. Middle Miocene quartz diorite has intruded into the Larap volcanic rock. There is also intrusion by dacitic porphyry dikes. Sillitoe and Gappe (1984) consider that there is porphyry type copper and molybdenum mineralization rich in gold. 65 million tons of ore reserves with a grade of 0.35% Cu, 0.05% Mo and 0.4 g/t Au are reported. The white quartz veins are accompanied by molybdenum, and the homogenization geotemperature is 300-360℃ (United Nations, 1987). The Meycauayan mineral showing is located about 4.5 km west-southwest of Batobalani. According to the United Nations (1987) surface survey, mineralized diorite intrudes into the andesite, and soil geochemical anomalies showed the following values: Cu 250 ppm, As 28 ppm, Te 0.5 ppm, Mo 63-208 ppm. Quartz stringer stockwork is developed in the quartz-sericite alteration zone. The mineralization is considered to be a porphyry type copper and molybdenum system with low gold grade. There is also distribution of acid alteration zones consisting of pyrophyllite, diaspore, quartz and alunite. The Igang mineral showing is situated about 7.5 km west of Batobalani. The Philippine Iron Mine carried out boring in 1974, confirming the following mineralization in the marbleized limestone and skarn zones: Cu 1.2% and Mo 0.05% (United Nations, 1987).

As mentioned above, on the south side of the Paracale area in Camarines Norte are to be found a large number of iron deposits and mineral showings, and in the case of many of them copper occurs in accompaniment with such iron mineralization. Those iron deposits are thought to be skarn type deposits, and therefore they are expected to be accompanied by copper. Of those, the main one is the Larap deposit, as mentioned above. Others include the Dawahan-Penarco mineral showing (cn237), the Capacuan deposit (cn17, cn238), the Batobalani mineral showing, the Submakin mineral showing (cn222), the Dagang mineral showing, the Agusan deposit (cn42), the Pinagbirayan deposit (cn220) and the Tagas mineral showing (cn45, cn219). They will be discussed in the next section ("Iron").

(2) Camarines Sur

According to Miranda (1976), the copper deposits and mineral showings of the Caramoan Peninsula are accompanied by Cretaceous chlorite schist and quartz-sericite schist, lenticular to sheath-shaped and parallel to the schistosity. The ore minerals consist mainly of pyrite, with accompaniment of a small quantity of chalcopyrite. The lenticular and pod-shaped ore bodies often have pyrite dissemination halo. Among those with that kind of mode of occurrence are the Malaiba mineral showing (cs38), the Patag-Belen mineral showing (cs36), the Pili-Pagsangahan mineral showing (cs37) and the San Vicente-Maslog mineral showing (cs14). Those modes of occurrence are the same as those of the Hixbar deposit and BCI deposit on Rapu-Rapu Island (discussed later), which are thought to be volcanic massive sulfide deposits. It might be added that although the Magna Rosa mineral showing (cs31) has accompaniment of small quantities of

Cu and Ag, it is mainly a Pb and Zn mineral showing. It is surmised to be a deposit of a different type than those mentioned above, including the fact that the ore occurs along faults and shear zones of the calcareous tuff and Cretaceous graywacke and spilite of the limestone formation.

Elsewhere in Camarines Sur there is comparatively dense distribution of copper deposits and mineral showing in the northwest part of Dalupaon (cs2, cs203, cs204, cs205 and cs206) and in the northern part of Balatan (cs3 and cs4), and there is also a copper mineral showing at one place on the southwest foot of Mt. Labo (cs216).

The mineral showings in the northwest part of Dalupaon have already been discussed in the section on gold. According to Reyes and Balce (1970; CS-30), at the mineral showings in northern Balatan the quartz veins in the diorite and andesite are accompanied by chalcopyrite and bornite. The quartz veins are lenticular and irregular. There is also occurrence of malachite and other oxidized copper. The findings of river sand geochemical prospecting show that the region of the upper reaches of the Caorasan River is promising.

(3) Albay

The Hixbar deposit (al9) on Rapu-Rapu Island was operated before and during World War II. It is the only example of operation of a volcanic massive sulfide deposit (Besshi type of deposit) in the Bicol region. As the same type of deposit on that island there is also the BCI deposit (al8). Domingo (AL14) and Kinkel and Samaniego (1956;Al21) discuss them. According to those sources, both of them are volcanic massive sulfide deposits that developed between chlorite-epidote-actinolite schist (under level) and quartz-feldspar-muscovite schist (upper level). The most abundant of the ore minerals is pyrite, but there is also chalcopyrite, covellite, tetrahedrite, sphalerite and bornite. The BCI deposit has an estimated 3.2 million tons of ore reserves of the following grades: 1.8% Cu, 2.5% Zn, 0.8% Pb, 40 g/t Ag and 2 g/t Au (Domingo (AL14)). Unlike the BCI deposit, which is deep in the ground, the ore body of the Hixbar deposit outcrops on the surface, and therefore secondary enrichment is to be noted there. The grade of the primary ore body is 1-2% Cu, with traces of Au, Ag and Zn. The thickness of the secondary enrichment zone is about 30 m. There the Cu grade rises to 9% (maximum of 20%). As of 1955 the remaining ore reserves were 229,400 tons, with an average grade of 2.4% Cu (Kinkel and Samaniego, 1956; Al21).

Since there is no mention of the mineral showings in the northern part of Pantao (al1 and al2) in the existing literature, it is not clear what kind of mineralization they accompany. According to

Tupas (1951), at the mineral showings of the southern part of the Panganiran Peninsula (al202, al203 and al204) the mineralization consists of lenticular to irregular quartz veins with accompaniment of chalcopyrite, bornite and pyrite. Malachite, azurite and other oxidized copper is also to be noted. Furthermore, copper mineralization is to be observed in silicificated veins as well. But that source considers the potential to be low considering the fact that there is almost no surrounding alteration and the fact that the mineralization is weak.

(4) Sorsogon

As mentioned in the section on gold, the copper mineral showing in the Bacon-Manito area (so203) represents an anomaly in geochemical prospecting. The highest value obtained in such prospecting was 800 ppm Cu. The distribution is in hydrothermal alteration zones (PNOC-EDC, 1990: AL/SR-01).

3.2.3 Iron

There is concentrated distribution of iron deposits and mineral showings in Camarines Norte, particularly in the area extending from Larap to Batobalani and on to the north of Mt. Bagacay. There is also dense distribution in the northeastern part of Sta. Elena in the western part of the province. Those distributions are about the same as the distribution of copper mineral showings previously discussed. Camarines Norte will be discussed further below.

In Camarines Sur there is distribution over the entire Caramoan Peninsula, but it is densest in the western part. According to Miranda (1976: CS-32; 1977: CS-45), there are two kinds of iron mineral showings on the Caramoan Peninsula: the type consisting of hematite and magnetite ore bodies occurring lenticularly and tabularly along the graywacke, spilite and chert stratification and the type occurring as ultrabasic rock weathered residual deposits (laterite), as in the case of nickel. The mineral showings cs11, 12 and 13 in the western part of the peninsula are of the first type, and cs19 in the central part of the peninsula is of the second type. Although there is no information on them in the existing literature, the iron mineral showings near the coast at Sagnay at the top of the Caramoan Peninsula (cs5, 6) are surmised to be iron sand deposits.

In Albay there is one mineral showing in the western part of the Bacon-Manito area (al3). In Sorsogon there is a mineral showing on the coast at Donsol (so1) and another one east of Irosin (so3). The mineral showing so1 is an iron sand deposit, and so3, although the existing literature does not say anything about it, can be surmised to be a iron-sulfide or limonite deposit, limonite being an oxidized form of iron-sulfide.

(1) Camarines Norte

Frost (1959, 1965) defined an "iron belt." That belt extends roughly in the direction of the strike of the Universal formation. It has eighteen iron deposits and mineral showings. Four of them have been developed as mines, the largest of them being the Larap Mine.

The Larap Mine started production in 1936. When it was closed down in 1975, it was the largest iron mine in Asia, with annual production of 1 million tons of magnetite ore and a small quantity of hematite ore.

The magnetite and magnetite-pyrite ore occurs as lenticular ore bodies with a gentle slope surrounded by skarn zones. The skarn consists of diopside, garnet, scapolite, biotite, apatite and late-state tremolite, chlorite, epidote and calcite. Minerals existing in small quantities in the ore bodies include pyrrhotite, scheelite and base metal sulfides as well as molybdenite and copper ore. Gold is reported to exist in the magnetite deposits.

Among other iron deposits and mineral showings considered to represent mineralization of the porphyry or skarn type are the Dawahan-Penarco mineral showing (cn237), the Capacuan deposit (cn17, cn238), the Batobalani mineral showing, the Submakin mineral showing (cn222), the Dagang mineral showing, the Agusan deposit (cn42, cn221), the Pinagbirayan deposit (cn220) and the Tagas mineral showing (cn45, cn219). Of them, the Capacuan, Pinagbirayan and Agusan deposits were in production intermittently from the fifties up to 1975. All of those deposits occur as ore bodies interposed in alterated fine sedimentary rock, with occurrence of hematite in magnetite oxidation zones. Crispin and Pilac (1961; CN-30) describe the Agusan deposit as having a magnetite ore body with a thickness of 10 m, a N40o E strike roughly parallel to the stratification of the alterated sedimentary rock wall rock and a slope of 30o to the southeast.

The Dawahan-Penarco mineral showing is situated about 1.3 km southeast of the Larap deposit. It is considered to represent mineralization of the skarn type. The ore minerals noted there are magnetite, pyrite, chalcopyrite, barite and molybdenite. The Submakin mineral showing is located about 2.5 km southwest of Batobalani. Garnet skarn is observed there, and there is distribution of sericite alteration zones in the eastern part. There is also hydrothermal biotite. Cu-Pb-Zn-Mo sulfides and magnetite are to be observed in the gossan pebbles, and the boring cores have included Zn-Pb-Cu sulfides and small quantities of gold and silver.

Massive sulfide ore bodies are to be observed (United Nations, 1987). In the United Nations geochemical prospecting (1987) copper and molybdenum anomaly zones were recognized at the Tagas mineral showing. There is wide distribution of quartz-sericite alteration zones, with detection of biotite, wollastonite, andalusite and pyrophyllite.

3.2.4 Lead and Zinc

Several such mineral showings are distributed in Camarines Norte (cn32, cn35, cn222), on the Caramoan Peninsula (cs26, cs35) and on Rapu-Rapu Island (al8, al9) and elsewhere. They are accompanied by the gold, copper and iron mineralization already discussed. Juan and Narido (1978; CN-9) discuss cn35. According to that source, that mineral showing, too, is basically the same as the metalliferous vein type of gold deposits in the Paracale area. The veins with a NE direction are predominant, and a characteristic is considerable galena, sphalerite and other base metal sulfide minerals. The Submakin mineral showing (cn222) has already been discussed in the section on iron. From the existing literature it is not possible to determine of what kind the mineral showings accompanying mineralization cs26 and cs35 per se are, but considering the description of the geology and mineralization covering their areas of distribution as well (Caloen, 1971: CS-7), it can be surmised that both are sulfide deposits occurring in schist and that they accompany mineralization of the volcanic massive sulfide deposit type, just as the copper mineral showings already discussed. All of the lead and zinc mineral showings on the Caramoan Peninsula and Rapu-Rapu Island represent mineralization of the volcanic massive sulfide deposit type as already discussed in the section on copper.

3.2.5 Chrome and Nickel

In Camarines Norte there is distribution of such mineral showings at Mt. Cadig (cn7) and in the Paracale area (cn27). In Camarines Sur they are distributed in large number in the central part of the Caramoan Peninsula (cs17, 18, 20, 21, 22 and 210). They originate in the ultrabasic rock of the ophiolite sequence.

According to Miranda (1976: CS-32; 1977: CS-45), the ultrabasic rock distributed in the central part of the Caramoan Peninsula consists of peridotite, pyroxene, gabbro and dunite, with layers of chromite to be observed in the dunite. The peridotite is serpentinized. They are covered by lateritized soil, the laterite containing nickel, cobalt and iron. The chromitite mineral showings have had chromitite layers extracted from the dunite. The main mineral showings are the Mayon Mine mineral showing (cs20) and the Habikihon mineral showing. Lenticular chromite with a thickness of 5 m and a length of 26 m is to be observed at the Habikihon mineral showing. The nickel is accompanied by laterite.

3.2.6 Manganese

Manganese is distributed mainly on the Caramoan Peninsula, occurring sporatically over almost the entire peninsula. According to Miranda (1976: CS-32; 1977: CS-45), the main mineral showings include the Cagiskan mineral showing (cs25), the Bani deposit (cs9, cs200), the Paniman deposit (cs40), the Salvacion mineral showing (cs41), the Del Pilar mineral showing (cs28) and the Malatigao mineral showing (cs7). All of them occur parallel to the stratification in the schist or sedimentary rock. The main ore minerals are psilomelane and pyrolusite.

The Cagiskan mineral showing (cs25) is a mineral showing accompanying schist that is located 5 km north east of Lagonoy. Other manganese mineral showings accompanying schist are the Daldagan, Tandoc, Babuan and Siruma (cs8) mineral showing in the northern part of the peninsula.

The Bani deposit (cs9, cs200) is a manganese mineral showing accompanying sedimentary rock. It occurs in Cretaceous sedimentary rock (graywacke, chert, spilite) and has tabular ore bodies with an average thickness of 2 m. Similar to it are the Paniman deposit (cs40) and the Del Pilar mineral showing (cs28).

The manganese mineral showings distributed in the western part of Camarines Norte are probably of the same type as them.

3.2.7 Other Minerals

The following is a outline description of other deposits and mineral showings in the Bicol region.

Gypsum deposits are distributed in the northern part of Balatan in Albay Province (cs122, cs207 and cs208) and on the Panganiran Peninsula (cs205). According to Cruz and Domingo (n/a; CS-12) and Reyes and Balce (1970; CS-30), at gypsum deposits in northern Balatan pyrite and gypsum mineralization is to be noted in silicificated and kaolinized zones along fault and shear zones in the andesite and sedimentary rock. Analysis of pyrite-gypsum samples shows a 0.07%

copper content. At the Siramag deposit (cs207) gypsum occurs in veins with a width of about 5-60 cm, filling the faults and joint walls. At the Caorasan deposit (cs208) gypsum fills the shear zones in the andesite. There is more pyrite there than at the Siraman deposit. According to Cruz and Domingo (n/a; CS-12), the Tapil gypsum deposit (al 205) on the Panganiran Peninsula was worked up to World War II.

In the way of clay deposits, there is white clay, pottery and china clay, hard kaolinite and other flint clays as well as bentonite, etc. White clay deposits are to be found in the Paracale area and the eastern part of Tagkawayon in Camarines Norte, on the Siruma Peninsula in Camarines Sur, in the northwest par of Tiwi in Albay, in the eastern part of Sorsogon and elsewhere. Pottery and china clay deposits are located in the northwest part of Lupi in Camarines Sur, in the northern part of Tiwi in Albay and elsewhere. Flint clay deposits are situated in the northeast part of Sta. Elena in Camarines Norte, in the eastern part of the Caramoan Peninsula in Camarines Sur, in the northern part of Sorsogon and elsewhere.

3.3 Outline of the Recent Situation of the Mining Industry in the Philippines

The Metal Mining Agency of Japan (MMAJ) has recently compiled information on the situation of the mining industry in the Philippines (MMAJ Resource Information Center, 1997), and Alen Clark (1997) has compiled a report on projections for the mining industry in that country. The summary treatment in this section is based on both those sources.

3.3.1 Mining Industry

The Philippines has abundant mineral resources and used to be known as the foremost mineral product producing country in Southeast Asia. As recently as 1989 it still ranked among the top ten mineral product producing countries in the world for several mineral products (10th place for copper, 8th place for gold and 6th place for chrome), but now it now longer ranks that high for any mineral product. As for the picture for Southeast Asia alone, in 1992 it was overtaken for the first time by Indonesia in terms of gold production, and now that country leads it in production of copper, gold (silver) and nickel.

The Philippines' main metallic mineral resources are copper, gold, silver, nickel, chrome, manganese, lead, zinc, molybdenum, mercury, platinum and iron, and its nonmetallic mineral resources include limestone, silica sand, gravel, gypsum, marble, clay and barite. In addition, it has coal, petroleum, natural gas and geothermal energy as energy resources.

The Philippines does not presently produce lead, zinc, molybdenum, mercury or platinum (molybdenum and platinum were recovered as by-products, respectively, from copper ore and from chrome ore).

The Philippines' Main Mineral Product Reserves (1993)

	Reserves	Grade	Quantity of metal
Copper ore	3,700 million t	0.44% Cu	16 million t
Gold ore	137 million t	2.79 g/t Au	382 t

The country's metallic mineral resource production figures are trending downward across the board:

- Gold production in 1994 was 27 t, 23% down from 1986.
- Copper production in 1994 was 110,000 t, or half of what it was in 1986.

- Nickel ore production in 1994 was 430,000 t, 22% down from 1986.
- The breakdown of the value of metallic mineral resources production in 1994 was gold 59%, copper 37%, nickel 2%.

Under the government's energy self-sufficiency policy prospecting and development of the country's energy resources were carried forward. In the seventies more than 90% of its energy needs had to be met by imports, but by 1988 the country was able to meet 38% of its total energy needs with its own resources. Progress has been made in geothermal energy resources prospecting and development efforts centering on the PNOC (Philippine National Oil Company), and the Philippines now ranks second in the world behind the United States in geothermal power production (with an installed capacity of 1,054 MW).

The Philippines in second place in the world in term of geothermal power production (1993):

1st place:	the U.S.	2,594 MW
2nd place:	the Philippines	1,054.7 MW
3rd place:	Mexico	752 MW
4th place:	Italy	637.3 MW
5th place:	New Zealand	285.2 MW
6th place:	Japan	270.1 MW
7th place:	Indonesia	144.5 MW

Steam is produced by the government-run PNOC (Philippine National Oil Company) and the private PGI (Philippine Geothermal Inc., a subsidiary of the U.S. company Energy) and sold to the electric power company National Power Corporation (NPC).

The following are the production plans of the different geothermal fields:

1.	Tiwi field in Albay Province	330MW (PGI/NPC)
2.	Makiling-Banahaw (Mak-Ban) field in Laguna Province	330MW (PGI/NPC)
3.	Makiling-Banahaw Binary field in Laguna province	15.73MW (PNOC/ORMAT)
4.	Tongonan field on Leyte Island	112.5 MW (PNOC/NPC)
5.	Palinpinon I field in southern part of Negros Island	115.5 MW (PNOC/NPC)
6.	Palinpinon II field""	80 MW (PNOC/NPC)
7.	Bacon-Manito I field in Sorsogon/Albay Provinces	110 MW (PNOC/NPC)
8.	Bacon-Manito II field in ""	20 MW (PNOC/NPC)

From early times in the past the mining industry played any important role in the economy of the Philippines, making a great contribution to the national economy, particularly in terms of acquisition of foreign exchange, employment and tax revenues. Along with the downward trend of mining industry production in recent years, however, the relative weight of the mining industry in the economy of the Philippines has been declining. As the situation now stands, its is still contributing to acquisition of foreign exchange through exports, but it is not a major industry.

At its peak in 1985 and 1986 the mining industry accounted for 2.08% of GDP, but that figure declined to 1.54% in 1993 and 1.40% in 1994.

That industry's share of total exports was over 20% in the first half of the seventies (24.56% in 1973). It was still 21.33% in 1980, but after that it trended down. By 1993 it was down to 6.0% and by 1994 only 5.8%, but the mining industry is still contributing somewhat to the economy of the Philippines in terms of acquisition of foreign exchange, although much less so than in the past.

Looking at trade relations with Japan, one sees that Japan represents a major market for the exports of the Philippines' mining industry, accounting for 32% of its copper bullion exports, 90% of its copper concentrate exports and 100% of its nickel ore exports (1994). As for the position of the Philippines in Japan's mineral product imports, that country accounts for 13% of Japan's copper bullion imports, 8% of its copper concentrate imports (in 5th place behind Chile, Canada, Indonesia and Papua New Guinea) and 22% of its nickel imports (in 3rd place behind New Caledonia and Indonesia).

3.3.2 The History of the Philippines' Mining Industry

The mining industry in the Philippines got started long ago, even quite some time before Spanish rule.

In the days of Spanish rule copper and gold were extracted in the northern Luzon region, but mining activities had not yet become an organized industry.

U.S. President Roosevelt's major hiking of the price of gold in his New Deal policy of the thirties triggered development of the Philippines' gold mining industry.

The company Benguet, which opened the Philippines's first modern mine before World War II, became the largest domestic gold mining company, operating the Balatoc and Antamok mines.

In 1953 the company Atlas was founded. With discovery of porphyry copper deposits, it introduced the open-pit method of large-scale exploitation of low-grade copper ore as the start of a new type of mine operations.

The Philippines's experienced a new mining boom in the sixties as a result of increase in demand for copper ore by the Japanese smelting industry.

But after the "first oil shock" of 1973 the situation of the Philippines' mining industry deteriorated because of the double punch of higher production costs and slumping metal prices, copper being representative in that respect. Furthermore, even the porphyry copper deposits that had been developed in the seventies and eighties experienced a deteriorating profit situation because the grade declined has exploitation depth increased.

Domestic mining companies in the Philippines find them in a serious situation, burdened with large debts and unable to come up with sufficient funds for prospecting. However, interest on the part of foreign capital in the Philippines' mining industry has increased with such developments as lowering of taxes on mineral products and recognition of foreign capital mining operations by the country's new Mining Industry Law, and therefore in the coming years one can expect more introduction of foreign capital and more prospecting and development mainly by foreign capital as a way of supplementing very insufficient domestic capital.

3.3.3 Trends Regarding Prospecting and Development

Since about 1994 prospecting and development activities by foreign capital from Australia, Canada, the U.S. and other countries have become more active as a result of lower excise taxes on mineral products and enactment of the new Mining Industry Law, which gives freer rein to foreign capital. By October 1995 sixty-seven applications had been filed (and two already approved) to benefit from the provisions of the Financial or Technical Assistance Agreement (FTAA), under which foreign capital could acquire majority and even 100% participation in mining operations in the Philippines. The two approved applications were that for ARIMCO's (Australia) Didipio project (June 1994) and that for Western Mining's (Australia) Tampakan project (March 1995).

The following are the only two prospecting and development projects based solely on Philippine capital:

- the Bulawan gold project (Philex)
- the Sibutad gold project (Philex)

Recently Philex also announced plans for prospecting at the Larap deposit (copper) in Camarines Norte.

The following are the regions where active efforts are being made in the way of reviewing the Philippines' potential concerning gold and copper:

1) Regions where in the past development has lagged because of inadequate infrastructure and a poor security situation and concerning which there has therefore been little existing geological information and organized prospecting (northern Luzon Island and Mindanao Island).

2) Review of the potential of existing mineral showings and mines on the basis of new prospecting theory (King King, Tayasan, Nocomin, Rapu-Rapu, Cantatuan, Larap and elsewhere).

3) Prospecting of concealed deposits suspected on the basis of the distribution of surface acid alteration zones and alkali rock (Didipio, Tampakan, Marian, etc.).

Recently a conference was held for the purpose of promoting investment in the Philippines's mining industry. In one of the speeches at the conference included in the collection thereof entitled "Mining Philippines '97," A. L. Clark (1997) made the following analysis, drawing a comparatively bright future for the Philippines' mining industry. According to him, there are presently twenty-five operational mines in the Philippines not including small-scale mining. Most of them are run by the following seven Philippine companies:

1) Atlas Consolidated and Mining Development Corporation (Atlas)
2) Benget Corporation
3) Lepanto Consolidated Mining Company (Lepanto)
4) Manila Mining Corporation
5) Marcopper Mining Corporation
6) Maricalum Mining Corporation
7) Philex Mining Corporation

He asserts that the Philippines' mining industry has a bright future because of the following five factors:

1) the high mineral potential (prospectivity) and diversity of the nation
2) the large number of know mineral occurrences (showings)
3) a modern mining code
4) a long mining tradition
5) increased foreign investment in the mineral sector

He also gives the following figures on the projected number of mines that will be developed in the Philippines:

- 11 mines to be developed between 1995 and 2015
- 25 mines if one lowers the projection reliability to 50%
- an average of 1 mine developed every year

Most of the 11 mines to be developed according to the first projection are epithermal gold deposits, and five of the 25 mines to be developed according to the projection with 50% reliability are porphyry type copper and gold deposits.

3.3.4 The Mining Industry Law and Mining Rights

There are two basic modes of mining operations in the Philippines: operation under the Mineral Production Sharing Agreement (MPSA), which is for Philippine natural or juristic persons with up to 40% foreign capital participation, and operation under the Financial or Technical Assistance Agreement (FTAA), which is for Philippine or foreign juristic persons and which allows up to 100% participation by foreign capital. For the stage before operation under the MPSA or the FTAA there is a system whereby a two-year (extendible up to a total of six years) exploration permit is granted. The "mining lease" under the old Mining Industry Law is to be changed to the MPSA.

There have been many applications for operation under the FTAA that concern mining operations in the so-called northeastern belt mentioned herein consisting of Marines Norte Province, the Caramoan Peninsula and Catanduanes Island, in the region covering the southern part of Legazpi, including the southwest coast of the Bicol Peninsula (the limestone belt), and on

Marinduque Island and elsewhere.

Persons or companies intending to engage in prospecting and development apply for acquisition of status under the MPSA or the FTAA. Since, naturally, foreign-capital majors apply for status under the FTAA, places to be operated under the FTAA do not lend themselves to cooperative surveys on a country basis and also cannot be participated in by other private entities unless they are invited to participate in joint ventures. Most applications for status under the MPSA will be by local companies and individuals, and since they are short of technology and funds, they welcome surveys on a country basis and cooperation in the form of studies by other private entities, which means that there are good possibilities as regards joint surveys.

That is why the order of priority of areas covered by the FTAA has been made lower that it would otherwise be.

On September 15, 1997, by which time the field survey for the present fiscal year (April 1997 - March 1998) had already been completed, all of the mining leases under the old Mining Industry Law expired, and it was necessary to reapply for MPSA status. At the same time it was necessary to review whether or not the stipulated obligations were being met by those who had already acquired MPSA status. Since mining areas have not been follow-up after that it will be necessary to check again in the second year of the study.

Matters of interest to investors are considered in the following.

1)Exploration Permits (exploratory boring rights)

If the company limits its exploration to one province, the maximum surface area is 16,200 ha and the exploration period is 2 years, extendible twice (for a maximum total duration of 6 years). The annual occupancy fee is 5 pesos/ha. The prospecting program is submitted to the MGB, which grants the permit. If promising results are obtained during that period, MPSA or FTAA status can be applied for. The prospecting surface area has to be reduced by 20% after the first year, another 20% after the second year and 10% after each year thereafter.

2) Mining Rights (exploitation rights)

There are three modes of running the mining operations: those stipulated by each of the three mineral agreements: the MPSA, the Co-Production Agreement and the Joint Venture Agreement.

Such mining rights have to be approved by the Secretary of the Department of the Environment and Natural Resources, and the conditions for granting them are good expectancy regarding production of mineral products, approval of the work program, adequate funding, issue of an Environmental Compliance Certificate and a recommendation by the local branch of the MGB.

3) FTAA

In projects recognized by the government as large-scale mining (projects involving expenditures of at least US$4 million for prospecting and US$25 million for development) it is possible for foreign capital to acquire a 100% share. Presidential approval is required.

4) Areas in Which Mining Activities Are Possible

Mining activities are possible even in military bases, government reservations and areas worked by small-scale exploitation operators, provided that agreement is reached with the parties concerned.

5) The exploitation rights include lumber rights, water rights, rights to use explosives and easements.

6) For treatment of minerals a permit for that purpose must be obtained from the government (based on the assumption of recovery of gold from tailings).

7) The party engaged in exploitation must obtain an Environmental Compliance Certificate (ECC).

8) Incentives

On the basis of the Omnibus Law of 1987 (EO226) the following privileges are automatically granted upon acquisition of exploitation rights:

- Tax exemption for mining pollution prevention facilities (real estate tax and other taxes)
- Carrying forward of losses for income tax purposes
- Accelerated depreciation
- Also guaranteed in the way of making investments safe are repatriation of both investments and profits and exemption from confiscation of property.

9) The Government's Share of the Take

The government's share of the take under the MPSA is limited to the excise tax on the value of mineral product production. Under the Co-Production Agreement and joint-venture agreements (including the FTAA) individual negotiations with the government are necessary.

10) Fees

- Occupancy fee for Exploration Permit5 pesos/ha/year
- Occupancy fee under the MPSA or FTAA 50 pesos/ha/year
- Mining muck and ore dressing wastes0.1 peso/t

The Exploration Permit (EP), the Mineral Production Sharing Agreement (MPSA) and the Financial or Technical Assistance Agreement (FTAA) are outlined below (when using this information for reference purposes, please check with the authorities on whether or not there have been any changes).

Exploration Permit (EP):

1. Those eligible: Anyone, whether Philippine natural person, Philippine juristic person, foreigner or foreign company.
2. Period: 2 years. With the approval of the Secretary of the Department of the Environment and Natural Resources two extensions by the same amount of time are possible, i.e. up to a maximum total period of 6 years.
3. Content: An exploration permit is issued.
4. Scope:

    1) Within a single province
    - Natural person: 1,620 ha
    - Juristic person: 16,200 ha

    2) The whole country (in more than one province)
    - Natural person: 3,240 ha
    - Juristic person: 32,400 ha

5. Options:

    1) Priority in applying for status under MPSA or FTAA
    2) Transfer of exploration permit to a third party

Mineral Production Sharing Agreement (MPSA):

One of the three mineral agreements.

1. Eligibility: Philippine natural person or juristic person (at least 60% of the capital of which is owned by Filipinos)
2. Period: 25 years (including the exploration period of up to 6 years), extendible by a maximum of 25 more years.

3. Content: The party to the contract is granted by the government the right to exploits other mineral resources discovered in the area in question on the condition that a part of the production be paid to the government (its share). The government's share consists only of the excise tax (2% tax on mineral product production).

4. Scope:

1) Within a single province
- Natural person: 810 ha
- Juristic person: 8,100 ha

2) The whole country (in more than one province)
- Natural person: 1,620 ha
- Juristic person: 16,200 ha

5. Options:

1) Use of temporary exploration permit (useable once the application has been cleared by the Director of the MGB)

2) Possibility of transferring all or a part of the status under the MPSA with the permission of the Secretary of the Department of the Environment and Natural Resources

3) Conversion to another mineral agreement or FTAA status

Financial or Technical Assistance Agreement (FTAA):

1. Eligibility: Foreign or Philippine juristic person
2. Period: 25 years (including exploration period of 2 years (maximum of 4 years and 2 years for feasibility study), extendible by a maximum of 25 more years
3. Content: If recognized by the Philippine government as large-scale mining, foreign capital can acquire a 100% interest. Mining rights for foreign firms that want to acquire more than a 40% interest. In that case the government's take includes not only excise tax and other taxes but also its share, which is decided by negotiations with it. It appears that the government receives about 50%of net profits (all taxes included), but we are presently seeking more reliable information on that.
4. Scope: Maximum of 81,000 ha.
5. Options:

1) A temporary exploration permit can be obtained from the Secretary of the Department of the Environment and National Resources before FTAA screening by the President.

2) Conversion to MPSA or other mineral agreement status.

3) Partial or entire transfer to third party with the permission of the President.

Chapter 4: Summary of the Results of the Survey

4.1 Analysis of Existing Data

Published topographical maps, published geological maps and approximately 200 items of literature were collected. Regarding the items of literature, for each the contents were plotted on a map on a scale of 1:250,000 for the area covered and a list was compiled in terms of key words assigned. Information concerning mineral showings and alteration zones was sorted out from those items of literature, and that information was used to surmise the possible types of deposits and to served as a basis for selection of promising areas. Also used for selection of promising areas was various data concerning geological surveys, geothermal energy development and mining acquired in visits to organizations and private companies concerning with such activities.

4.2 Satellite Image Analysis

In this survey division into geological elements, tracing of strata, interpretation of fold structures, faults and ring structures and extraction of lineaments were accomplished on the basis of photogeological interpretation of LANDSAT-TM false-color images and JERS-1/SAR black-and-white images. Furthermore, alteration zone candidate areas were extracted from LANDSAT-TM relational operation images. Such satellite image analysis has made it clear that in the Bicol Region there is development of NW-SE lineaments parallel to the Philippine Fault and distribution of many NE-SW lineaments at right angles to it. Also noted were N-S and E-W lineaments. Furthermore, it was possible to get a good idea of the wide-area geological distribution. However, in regions with vegetation such as this region it is a difficult matter to extract alteration zones from relational operation images. By making a comparative study of the results of such analysis and available information on geology and deposits, criteria for selection of promising areas in terms of metallic ore deposit endowment were set, and eleven promising areas were extracted. Six of those areas include known metallic ore deposits and mineral showings, and the other five have no known metallic ore deposits or mineral showings.

4.3 Ground Truth Survey

Ground truth survey candidate areas were selected on the basis of the results of analysis of existing data and satellite images and taking into account the situation regarding establishment of mining areas, access and security conditions. Twenty-four areas were selected for the 23-day survey. The results of the survey are presented according to the items "Location", "Accessibility", "Geology", "Alteration", "Mineral showings", "Mining Claims", and evaluation of how promising each area (in terms of possibility of existence of deposits, whether or not there is room for further prospecting, etc.) is given.

4.4 Geological Structure, Mineralization Characteristics and Restriction (Control) of Mineralization

The Bicol region can be divided into the following three zones according to geological characteristics:

1. Northeast Zone: The zone from the northern part of Camarines Norte to the Caramoan Peninsula to Catanduanes Island to Rapu Rapu Island on the northeast side along the direction of extension of the Bicol Peninsula.

2. Southwest Zone: The zone extends along the coast on the southwest side of the Bicol Peninsula from Mt. Cadig in Camarines Norte to Pasacao and Balatan and on to the Panganiran Peninsula. Further extension on the southeast side is not clear, but it might possibly extend to the southern end of Sorsogon since there is distribution of high gravity areas in that area, which is indicative of comparatively shallow distribution of the basement rock.

3. Central Zone: The zone between the zone on the northeast side and the zone on the southwest side: This zone corresponds to the area of distribution of Pliocene to Quaternary volcanic rock. It is a zone of distribution of volcanos connecting Mt. Labo, Mt. Culasi, Mt. Isarog, Mt. Iriga, Mt. Malinao, Mt. Pulog (Bacon-Manito) and Mt. Bulusan. Around those volcanos is distributed somewhat older Pliocene to Pleistocene volcanic rock with developed topographical dissection.

Looking at connection between the geology of each zone and metallic ore deposits and mineral showings, one sees that each zone has the characteristics described below as a reflection of the geological distribution in it and that the mineralization also described below can be expected in it.

Northeast Zone:

In this zone the deposit-bearing level outcrops. Considerable prospecting has been done in it in the past, and many deposits and mineral showings have been discovered. As a reflection of its geology, the mineralization of this zone can be roughly classified into that originating in the ultrabasic rock, that originating in greenschist, mica schist and other rock constituting the upper stratum of the oceanic crust and that resulting from Miocene magma activity. The mineral showings originating in ultrabasic rock are chromium and nickel. The chromatite is of the podiform type and accompanies dunite. The nickel accompanies laterite. The mining showings distributed in the schist area are Cu, Mn, Au, Zn and Pb. Mineralization of the volcanic massive sulfide type and mineralization of the mesothermal vein type occurring in shear zones are to be noted. Those resulting from Miocene magma activity are Au, Cu, Fe and Mo. They often are mineralization of the porphyry type or mineralization of the skarn type or originate in pluton-related metalliferous veins. Almost the entire zone is covered by established mining areas.

Southwest Zone:

There are several known copper mineral showings in this zone, with distribution as well of gold mineral showings accompanying the copper. They are either chalcopyrite and bornite accompanying quartz veins in diorite and andesite or mineralization noted in shear zones or along faults in theandesite. It is difficult to specify the type of mineralization because of the small scale of the mineral showings, insufficient surveying and scant data. However, in view of distribution of diorite in the vicinity of such copper and gold mineral showings it is thought to be possible that there is endowment of deposits of the porphyry type or of the mesothermal metalliferous vein type relating to plutonic rock. Furthermore, in view of distribution of limestone older than the time of intrusion of the diorite rock bodies there are expectations of Carlin type gold deposits as well as existence of skarn type deposits. However, the deposit endowment potential is considered to be low in view of the small areas of distribution of the limestone.

Almost all of this zone is covered by applications for FTAA status. Not all the mining areas applied for concern metallic ore deposits: some are for limestone.

Central Zone:

Other than the Nalesbitan deposit, there is no distribution of metallic ore deposits in this zone. There were only gold and copper mineral showings and indications on the geochemical anomaly level. Around the Quaternary volcanos with remaining volcanic body topography is to be found volcanic rock with greater dissection, and it is clear that there is development of alteration zones of the steam-heated type in that zone. In view of distribution of new geological bodies has not yet progressed to the level of occurrence of deposits, but epithermal system shallow phenomena are to be observed. It is surmised that at some places fluid from deep down has come up to near the ground surface, and there are zones with considerable possibility of existence of epithermal gold deposits deep underground. Recent geothermal areas are also included in this zone. Most of the present geothermal systems have NW faults as reservoir strata. Other than in the Nalesbitan area and Bacon-Manito area prospecting for metallic ore deposits has not been carried out in this zone, which means that there are still areas in it that have not been established as mining areas.

4.5 Selection of Promising Areas

The following priorities were set regarding ground truth survey areas. High priority was given to areas not covered by any mining-related applications and areas for which application has been made for MPSA status because of the importance attached to the situation regarding establishment of mining areas from the viewpoints of suitability for future surveying on an intergovernmental basis and the possibility new participation by private companies in the surveying. Regarding type of mineral, highest priority was given to gold and copper, and regarding type of mineralization, highest priority was given to deposits of the porphyry type and epithermal type.

Regarding areas in the Northeastern Belt and the Southwestern Belt with outcropping of the deposit-bearing level, highest priority was given to places where the situation regarding establishment of mining areas is such as to make surveys on an intergovernmental basis possible (Larap-Exiban and Mt. Bagacay). In the Central Belt first priority was given to areas of distribution of comparatively large alteration zones suggestive of epithermal deposits that are do not correspond to any established mining areas or that are PNOC geothermal development mining areas (Tiwi-Mt. Malinao, Bacon-Manito, Gate Mountain and Kilbay). Areas in which ground truth surveying had not yet taken place were reviewed on the basis of the most recent available information. On the basis of the above the following areas have been considered as being promising and have therefore been selected as candidate areas for the second year of the present survey:

Northeastern Belt: The Mt. Bagacay area, the Larap-Exiban area and the eastern part of the Caramoan Peninsula.

Southwestern Belt: The Tuba area.

Central Belt: The northwestern part of the Tiwi-Mt. Malinao area, the western part of the Bacon-Manito area, the Gate Mountains area and the Kilbay area.