NO. 23

REPORT
ON
REGIONAL SURVEY
FOR
MINERAL RESOURCES
IN
THE BICOL AREA
THE REPUBLIC OF THE PHILIPPINES

Final Report

MARCH 1999

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-II of the survey. MMAJ dispatched a survey team consisting of four members to the Philippines from May 25 to July 24, 1998. The survey work in the Philippines was carried out successfully with cooperation of the Philippine government authorities.

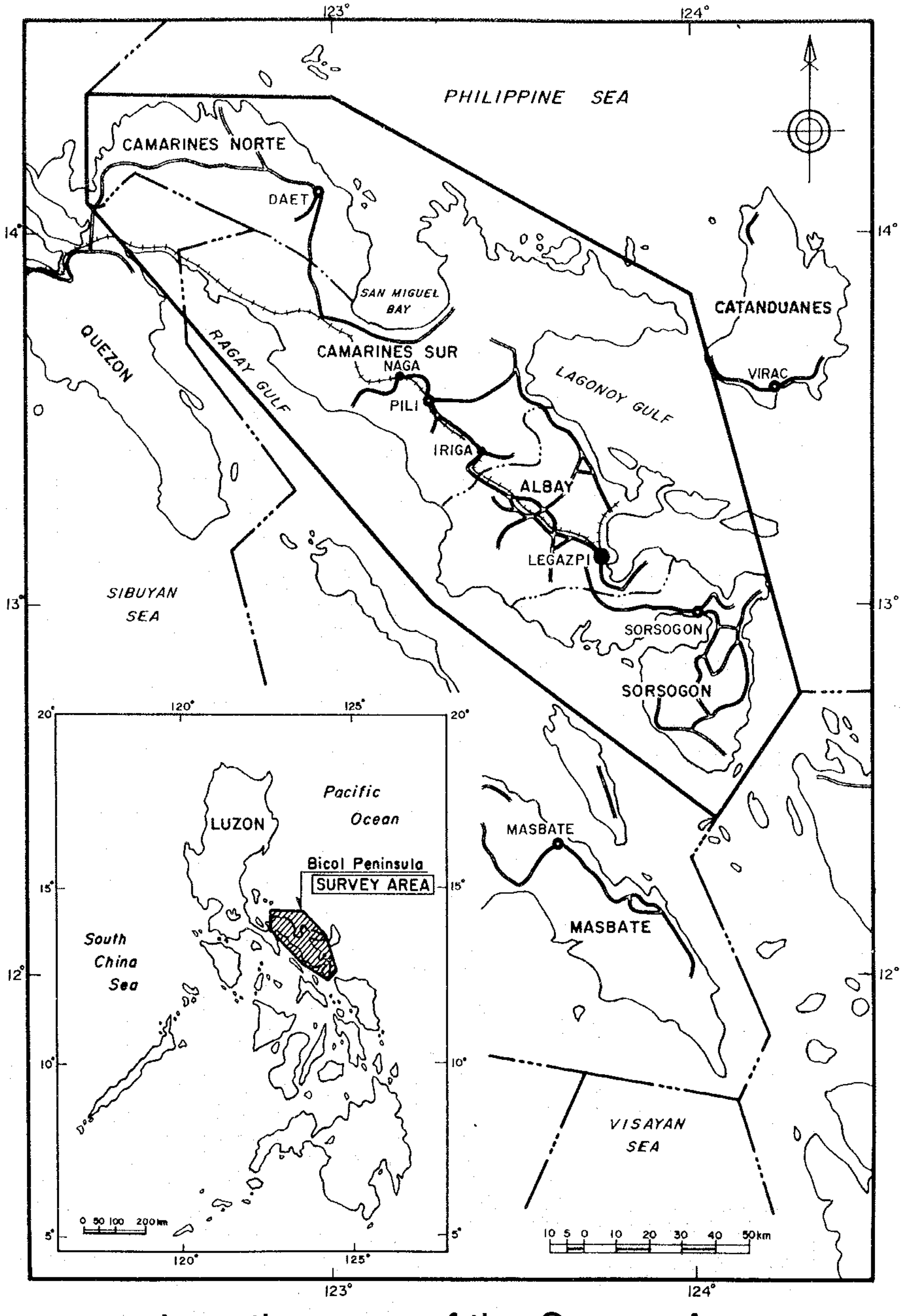
This report summarizes the result of the survey work carried out in 1998 and also summarizes the result of the works carried out in 1997 & 1998, as the final consolidated report which will be submitted to the Government of the Republic of the Philippines after completion of the survey work.

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.

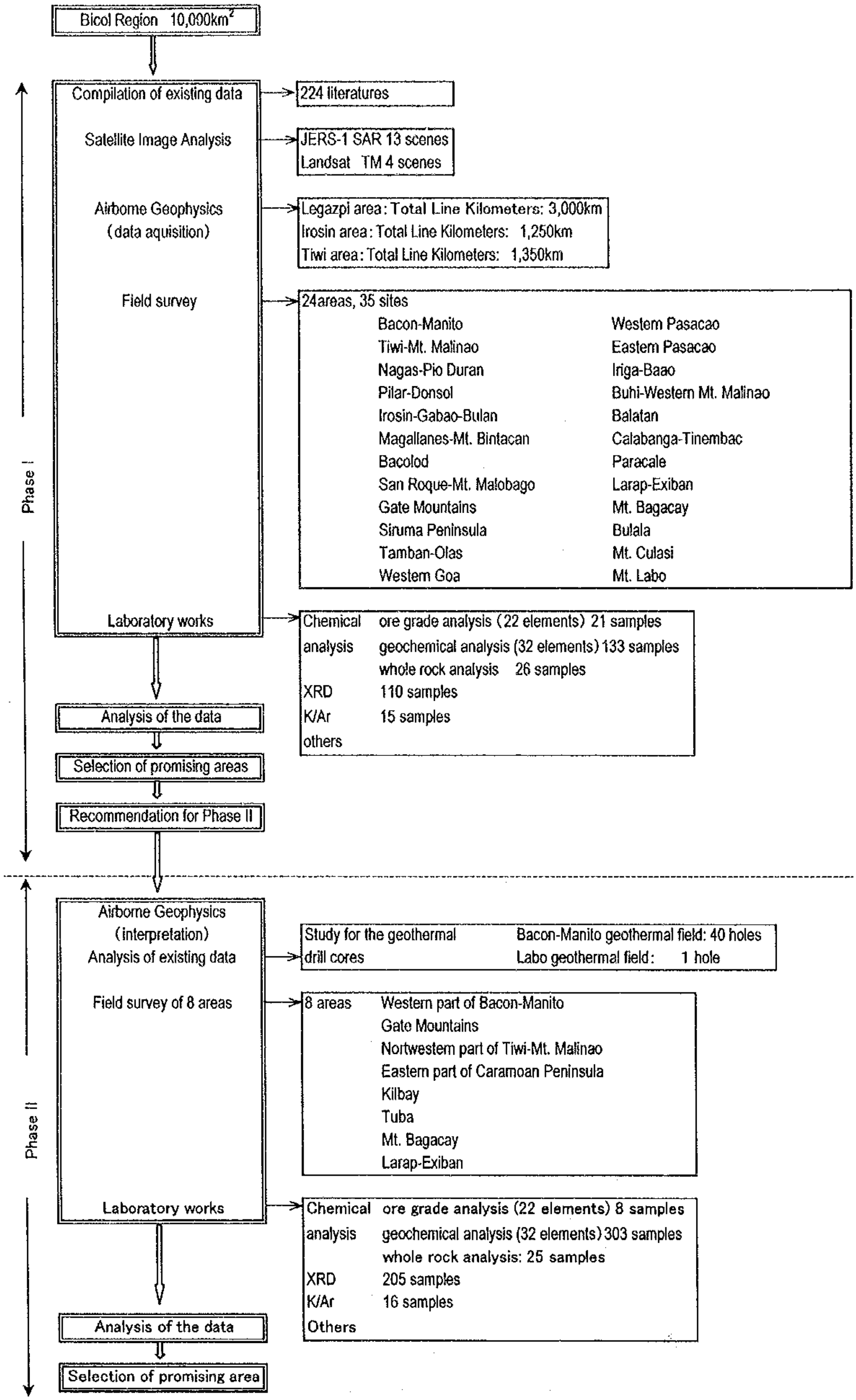
March, 1999

Kimio Fujita
President
Japan International Cooperation Agency

Hiroaki Hiyama
President
Metal Mining Agency of Japan



Location map of the Survey Area



Survey flow in the Bicol Region

Bicol Region 10,000km2

↓

method compilation of existing data, satellite image analysis

selection filter **exsitence of mineral showings, geochemical anomaly, alteration, intersection of lineaments condition of access, peace and order, mining rights**

↓

Bacon-Manito	Western Pasacao
Tiwi-Mt. Malinao	Eastern Pasacao
Nagas-Pio Duran	Iriga-Baao
Pilar-Donsol	Buhi-Western Mt. Malinao
Irosin-Gabao-Bulan	Balatan
Magallanes-Mt. Bintacan	* Simod
Bacolod	Calabanga-Tinembac
San Roque-Mt. Malobago	Paracale
Gate Mountains	Larap-Exiban
* Malobago	Mt. Bagacay
Siruma Peninsula	Bulala
Tamban-Olas	* Nalesbitan-Tuba-Kilbay
Western Goa	Mt. Culasi
* Oas	Mt. Labo

* The field survey was not conducted in Phase I.

↓

method Field survey, Laboratory works

selection filter **mineral potential, mining rights, accessibilty**

↓

8 areas
- Western part of Bacon-Manito
- Gate Mountains
- Nortwestern part of Tiwi-Mt. Malinao
- Eastern part of Caramoan Peninsula
- Kilbay
- Tuba
- Mt. Bagacay
- Larap-Exiban

↓

method Field survey, Core logging of the exsinting drills, Airborne Geophysics

selection filter **mineral potential, mining rights, accessibilty, peace and order**

↓

Kilbay area including Nalesbitan and Tuba area

Flow chart of the selection of promising area in the Bicol Region

SUMMARY

Based on the Implementation Agreement (I/A) concluded on May 30, 1997 between the governments of the Philippines and Japan, this Survey is to be implemented for a period of 2 years in the Bicol area located in the southeastern part of Luzon, the Philippines' main island. The objective of the survey is to extract promising areas in search of metallic mineral resources with an eye toward a potential for future intergovernmental surveys or entries by private companies with the intention of conducting new exploratory surveys.

In the current year or the last year of the project, surveys were conducted in the following eight areas that have been identified as promising as a result of the surveys conducted during the first year:

Western part of Bacon-Manito
Gate Mountains
Northwestern part of Tiwi - Mt. Malinao
Eastern part of Caramoan Peninsula
Kilbay
Tuba
Mt. Bagacay
Larap - Exiban

Survey methods that have been employed include the analysis of already-existing data, the analysis of airborne geophysical survey data and field surveys. As to the analysis of existing data, we made attempts at estimating what it would be like at great depths beneath target field areas that are located adjacent to geothermal fields particularly by analyzing drilling data which was obtained by drilling in those geothermal fields. As for the following three areas, airborne geophysical surveys were conducted to analyze geothermal structures and extract alteration zones:

Western part of Bacon-Manito, Gate Mountains, and Northwestern part of Tiwi - Mt. Malinao

Field surveys were performed for the purpose of determining the distribution/features of ore deposits/prospects and alteration zones in individual areas.

Coupled with the results of the first year's surveys, comprehensive analyses were carried out. As s result, the Kilbay area, the Mt. Bagacay area and the Larap - Exiban area were extracted as highly potential ore-deposit-existing areas. As a new exploration-project area, it is, however, desired that a larger region having the Kilbay area at its center and including the Nalesbitan area and the Tuba area be designated as such.

CONTENTS

Part II

List of Figures, Tables, and Appendix

* Large figure is attached in back front of the report as a plate.

PART I

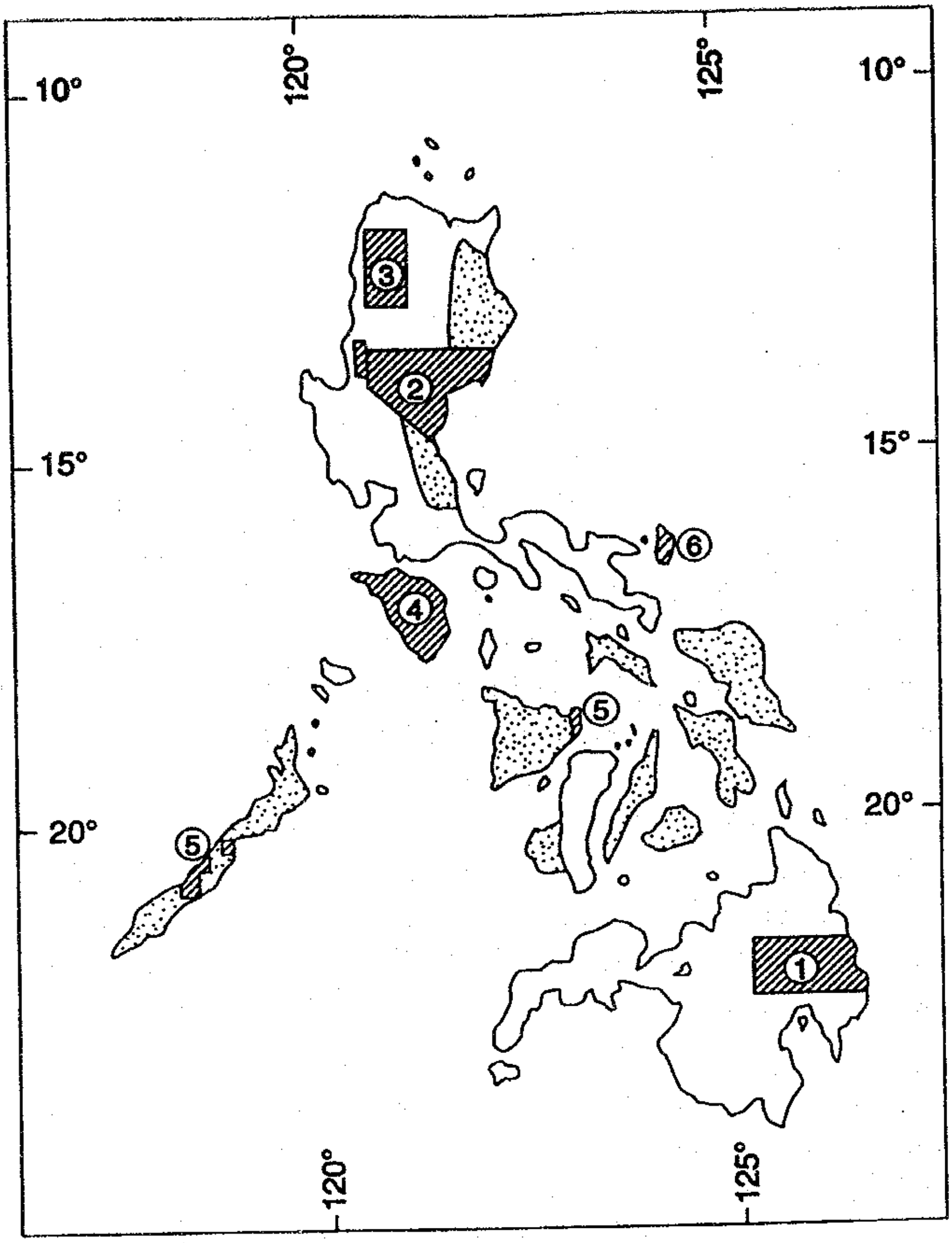
Chapter 1 Introduction

1-1 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):

- 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



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

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.

1-2 Conclusion ans Proposals of Phase I

1-2-1 Conclusion

The survey activities carried out this fiscal year have made the following clear:

In terms of geological structure the Bicol Region can be roughly divided into three zones: the Northeast Zone, the Central Zone and the Southwest Zone. They lie roughly parallel to the direction in which the Bicol Peninsula extends.

The Northeast Zone and the Southwest Zone are characterized by distribution of Cretaceous basement rock and Tertiary intrusive rock, and the Central Zone is characterized by Pliocene to recent volcanic rock. The Northeast Zone and the Southwest Zone have outcropping of the deposit-bearing level and distribution of existing deposits and mineral showings. The types of deposits concerning which there are expectations are porphyry type copper and gold deposits, skarn type deposits and volcanic massive sulfide deposits. Because of distribution of young geological bodies in the Central Zone the denudation level there has not reached the deposit-bearing level except for the northwest end, but there is possibility of epithermal gold deposit endowment deep underground.

On the basis of the results of study of existing literature, satellite image analysis and the ground truth survey and taking into account the situation regarding establishment of mining areas, the following areas are considered to be promising:

- Northeast Zone: The Mt. Bagacay area in Camarines Norte, the Larap-Exiban area and the eastern part of the Caramoan Peninsula
- Central Zone: The Kilbay area in Camarines Sur, the northwest part of the the Tiwi-Mt. Malinao area in the vicinity of the border between Camarines Sur and Albay, the western part of the Bacon-Manito area near the border between Albay and Sorsogon and the Gate Mountains area in the southern part of Sorsogon
- Southwest Zone: The Tuba area

1-2-2 Proposals for the Second Year(Phase II) of the Survey

It is desirable that the following kinds of surveys be implemented in the second year in the promising areas identified in the preceding section, "Conclusion."

Regarding the promising areas in the Central Zone, it is possible that there are epithermal gold deposits in them deep underground. It is therefore necessary to carry out surveys that make it possible to surmise the places and depths of possible existence of deposits. For instance, it might be possible to determine places of rise of deep hydrothermal fluid by analysis of the chlorine content of the altered rock, which is an index of the shallow part of epithermal systems. At the same time, there should be detailed study of areas of distribution of fracture systems with the same direction as that of fracture systems constituting reservoir strata of nearby active geothermal systems. It is also a good idea to considering boring for the purpose determining change in direction of alteration zones at different depths, their temperature structure and whether or not there is possibility of mineralization.

It is also necessary to survey in detail the areas in the vicinity of existing mineral showings in promising areas lying in the Northeast Zone and the Southwest Zone.

Attention should be given to the following points in surveying the different areas:

The Mt. Bagacay area:

There is distribution of several iron skarn deposits and mineral showings, and on the south side there are gold and base metal mineral showings of the metalliferous vein type. They suggest the possibility of existence of porphyry type deposits. There will be systematic study of existing skarn mineral deposits and mineral showings, the combinations of metallic ore minerals and fluid inclusion homogenization geotemperatures for the purpose of depicting the temperature structure within the area. Intrusive rock stocks will also be looked for detailed surveying in their vicinity. In the United Nations (1987) survey of the Tabas area biotite, wollastonite and andalusite were noted as altered minerals, and two of the samples contained pyrophyllite. They represent acidic alteration in which a porphyry system is developed nearby. It is therefore desirable that the Tabas area also be included in the survey.

The Larap-Exiban area:

Since this area is comparatively extensive and has distribution of many deposits and mineral showings in it, it will be difficult to narrow down the areas to be surveyed. Since Philex, Altas and other companies have done prospecting in it, that data should be obtained as far as possible so that it can be analyzed as a means of narrowing down the area of the survey. Furthermore, since there is distribution of many intrusive rock stocks in this area and since it is considered that most of the deposits and mineral showings in it were formed in connection with such intrusive rock, it is desirable to get a precise idea of its distribution and to undertake detailed surveying in the vicinity of it.

Eastern part of the Caramoan Peninsula:

This area was not included in the ground truth survey this year because of its situation regarding establishment of mining areas and because of poor access, but the latest information received from BMG Region V indicates that those problems have been cleared up. In this area there is distribution of mineral showings of the volcanic massive sulfide deposit type in the greenschist and mica schist, and they are characterized by occurrence roughly parallel to the schistosity of such schist. It is therefore thought to be necessary to determine its structure, horizons and facies at existing mineral showings so as to be able to estimate extension thereof.

In the Tuba area it is necessary to survey veins and alteration zones at known mineral showings to determine whether it is a matter of the metalliferous vein type of deposits as in the Paracale area or epithermal deposits. If they are determined to be of the metalliferous vein type, the vicinity of the intrusive rock thought to belong to the Tertiary period and the fracture systems in the vicinity of existing mineral showings and with the same direction will be surveyed. If they are determined to be of the epithermal type, in view of the connection with the Nalesbitan deposit in terms of position fracture systems that both have in common will be surveyed.

The Kilbay area:

This area was not included in the ground truth survey this year because of insufficient information and the schedule. However, it is considered to be a promising area in terms of possibility of developed hydrothermal systems since the volcanic rock distributed in it is hornblende andesite and it is surmised that the magma involved in deposit formation contained more water than other volcanic rock zones. Therefore it is desirable that it be surveyed in the second year of the present study.

The northwestern part of the Tiwi-Mt. Malinao area:

The existence of alteration zones was confirmed on the basis of floats in this year's survey. From the state of distribution it is surmised that the alternation zones lie at the upper reaches of the Santa Cruz River and the Cayohoson Creek. The NE-SW system of faults (Kagumihan fault, Tiwi fault and Naglagbong fault) forming the main reservoir strata of the Tiwi geothermal development area and the NW-SE Tutsan-Bolo fault are the main ones. In this area there is also development of NW-SE and NE-SW lineaments. The area of distribution of such fracture systems is considered to be important because of the fact that the intersection of those two lineaments just about coincides with the upper reaches of the Santa Cruz River and the Cayohoson Creek.

The western part of the Bacon-Manito area:

The low resistivity area from the Cawayan River to Calpi is surmised to have a comparatively high gold potential. The upper reaches of the Cawayan River are situated in the Bac-Man fault zone, which has an E-W direction. Furthermore, since the slope of the upper plane of the Calpi steam-heated alteration zone is roughly parallel to the river's present hydraulic gradient, it is surmised that the upflow region is situated on the further upstream side of Calpi creek. That

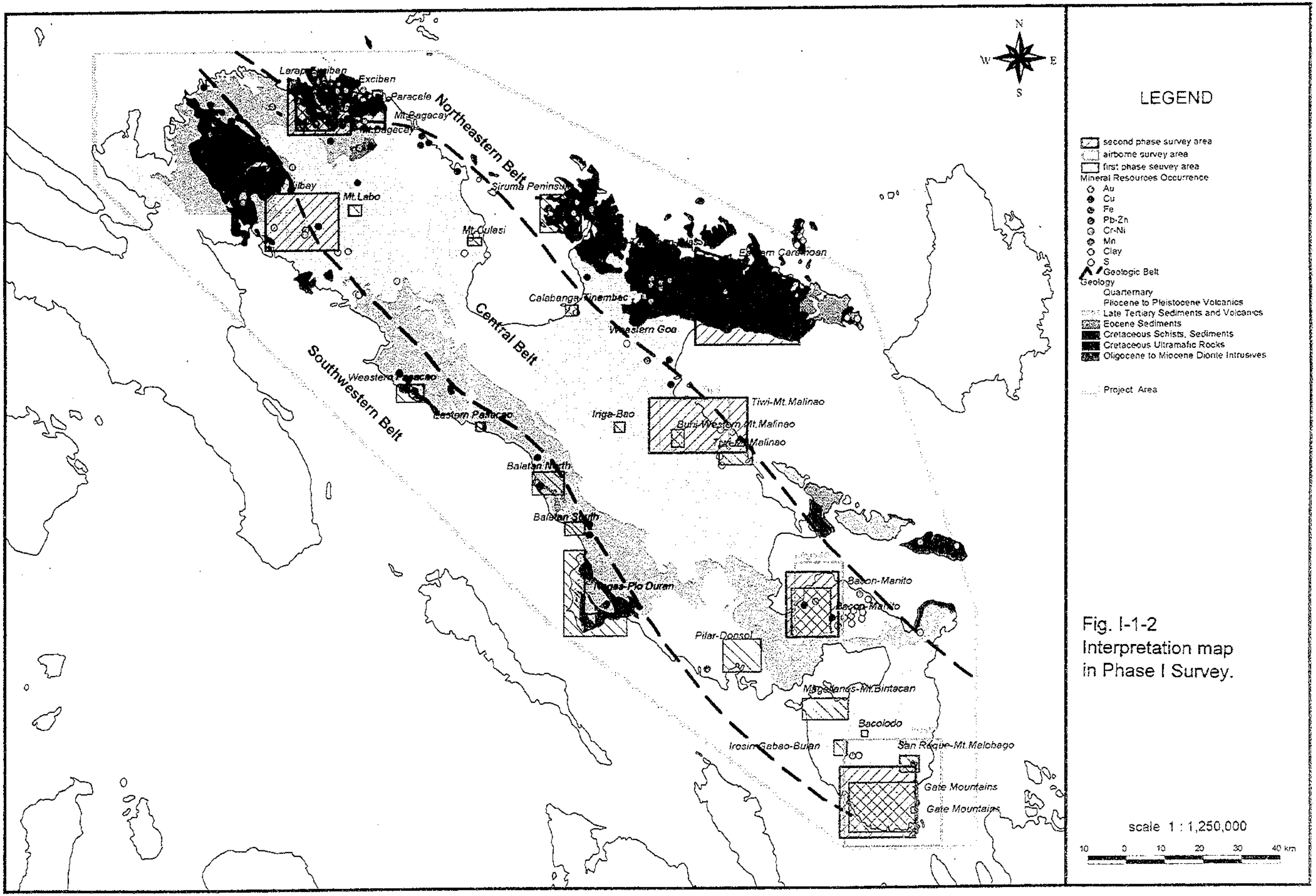


Fig. I-1-2
Interpretation map
in Phase I Survey.

upstream side corresponds to the Bac-Man fault zone, and it is therefore necessary that the survey be centered on that fault zone.

Gate Mountains area:

Since the results of the ground truth survey this year point to the possibility that the hydrothermal activity in the area extending from the vicinity of Tugas north of Mt. Sujac to Culasi on the southeast side was controlled by fractures in the NW-SE direction, surveying along those fractures is considered necessary. Furthermore, many floats of silicified rock and altered rock were noted along the coast in the southwest part of the Gate Mountains area. Although it is not yet clear which fracture controlled the hydrothermal system that caused such alteration, it is considered necessary to survey the upstream side of the creek considered to be the source of supply of those floats.

In the above three areas what are thought to be alteration zones on the basis of the results of the airborne magnetic survey will be surveyed, as will the fracture lines passing through them. Moreover, it is also considered to be important to determine the age of the volcanic rock and the alteration and mineralization, which it was not possible to do adequately in this year's survey.

1-3 Overview of the Phase II survey

1-3-1 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 airborne geophysical survey data, and geological survey.

1-3-2 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-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.

1-3-3 Survey Methods

(1) Interpretation of Airborne Geophysical Survey data

Interpretation of airborne geophysical survey data (Aeromagnetic and aeroradiometric data) which was acquired in the phase-I, has been conducted for the purpose of determining geological structure under the surface of the ground.

(2) Analysis of Existing Data

Collection and sorting out of existing data (especially drilling core in geothermal area) kept by the authorities concerned and companies in the Philippines and use of such data, has been conducted for the purpose of understanding mineralization in the selected areas.

(3) Geological Survey

Geological survey has been conducted in the eight areas which were selected by the study of Phase-I (Analysis of existing data, analysis of satellite images and implementation of geological survey), for the purpose of determining local geological setting, alteration zones, mineral occurrences, etc.

1-4 Members participating for the survey

(1) Members participating in the survey in the Philippines

a) Japanese side

Yoshitaka HOSOI (Leader, Analysis of existing data, Geological survey)
Japan Mining Engineering Center for International Cooperation : JMEC

Toshihiko HAYASHI (Analysis of existing data, Geological survey) JMEC

Shuichi MIYATAKE (Analysis of existing data, Geological survey) JMEC

Kunihito YAMAMOTO (Analysis of existing data, Geological survey) JMEC

b)Philippine side

Discussing the survey(at Manila and Legazpi)

Horacio C. RAMOS	Director, Mines & Geosciences Bureau=MGB, Department of Environment and Natural Resurces=DENR, Republic of the Philippines
Edwin G. DOMINGO	OIC, Assistant Director, MGB, DENR
Romeo L. ALMEDA	Chief, Lands Geology Division=LGD, MGB, DENR
Salvador G. MARTIN	Regional Director for Region V, MGB, DENR

Analysis of existing data and Geological survey

Sevillo D. DAVID, Jr., Dr.	Lands Geology Division, MGB, DENR
Gilbert Emerson C. BASCOS	Lands Geology Division, MGB, DENR
Arnel F. JUSI	MGB, Region V, DENR

Jose Marcel S. LAUD MGB, Region V, DENR

(2) Interpretation of Airborne Geophysical Survey data

Batty World Geoscience Corporation Limited(WGC)

(3) Synthetic Analysis (in Japan)

Yoshitaka HOSOI, JMEC

Toshihiko HAYASHI, JMEC

Shuichi MIYATAKE, JMEC

Kunihito YAMAMOTO, JMEC

1-5 Period and Performance of the Survey

(1) The survey in the Philippines

1998.5.25.(Mon)~1998.7.24.(Fri)

Analysis of existing data and Geological survey

Table I-1-1 Record of the survey

Item	Performance
Collecting & Analysis of existing data	No. of drillings: 41
Geological survey	8 areas
Collecting samples	Rocks・Ores: 466 pieces

(2) Interpretation of Airborne Geophysical Survey data

1998.5.8.(Fri.)~1998.8.21.(Fri.)

Irosin Area : Survey lines 3,000km

Legaspi Area : Survey lines 1,250km

Tiwi Area : Survey lines 1,350km

(3) Laboratory Test, Synthetic Analysis and Report Making

1998.7.27.(Mon.)~1999.3.24.(Wed.)

1999. 3.8. (Mon.)~1999.3.11 (Thu.) (Presentation of the results; Philippines)

Table I-1-2 Laboratory Test

Item	Number of performance
Microscopic observation Thin sections Polished thin sections	 78 pieces 14 pieces
X-ray diffraction examination	205 samples
Geochemical analysis Ore grade assay (FA+AA+ICP, 22 elements) Trace level geochemistry (FA+ICP, 32 elements) Bulk chemical analysis (XRF)	 8 samples 303 samples 25 samples
Fluid inclusion (Th & salinity)	22 samples
K-Ar Dating	20 samples

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.

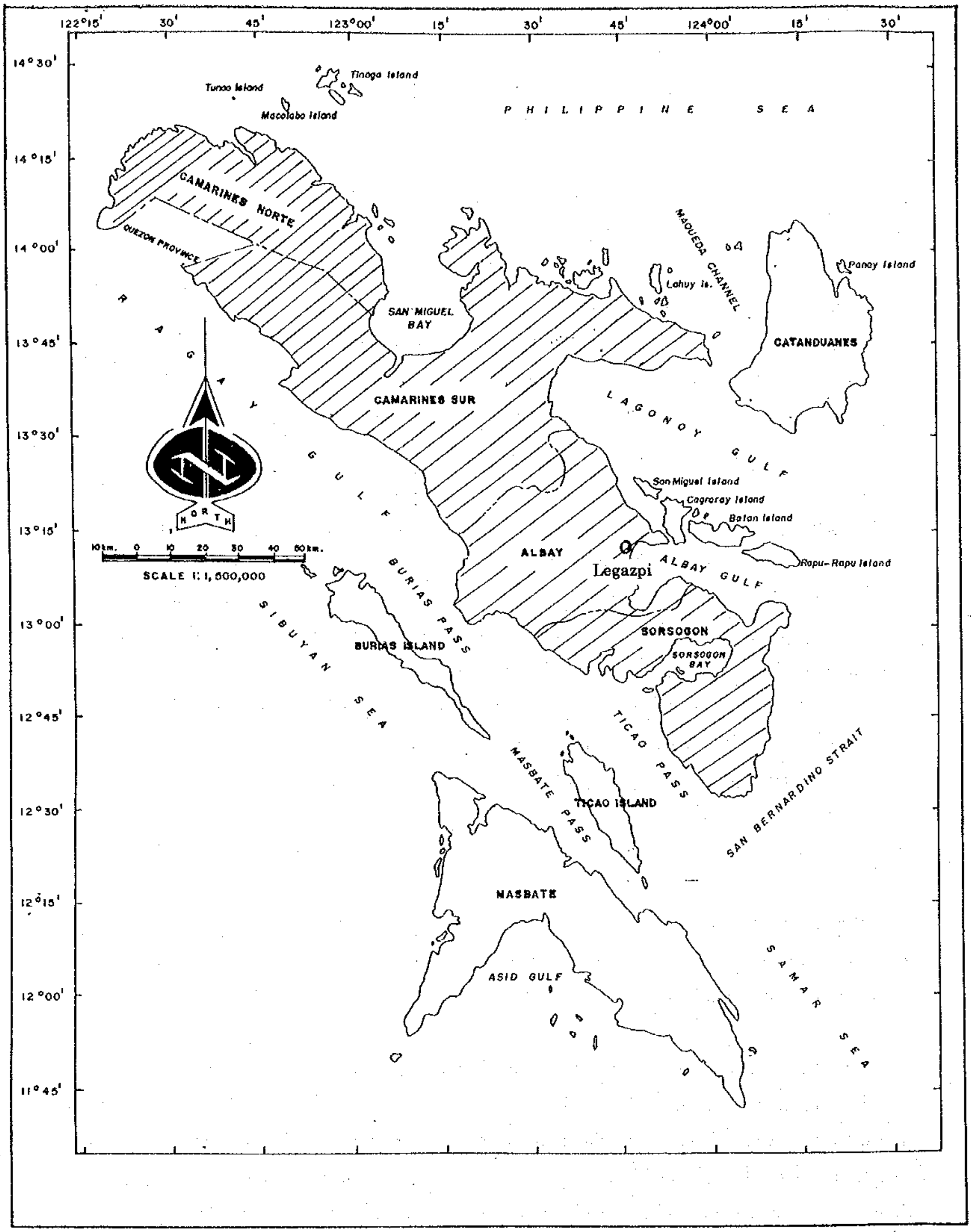


Figure I-2-1 Administrative Map of Region-V

Survey area

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

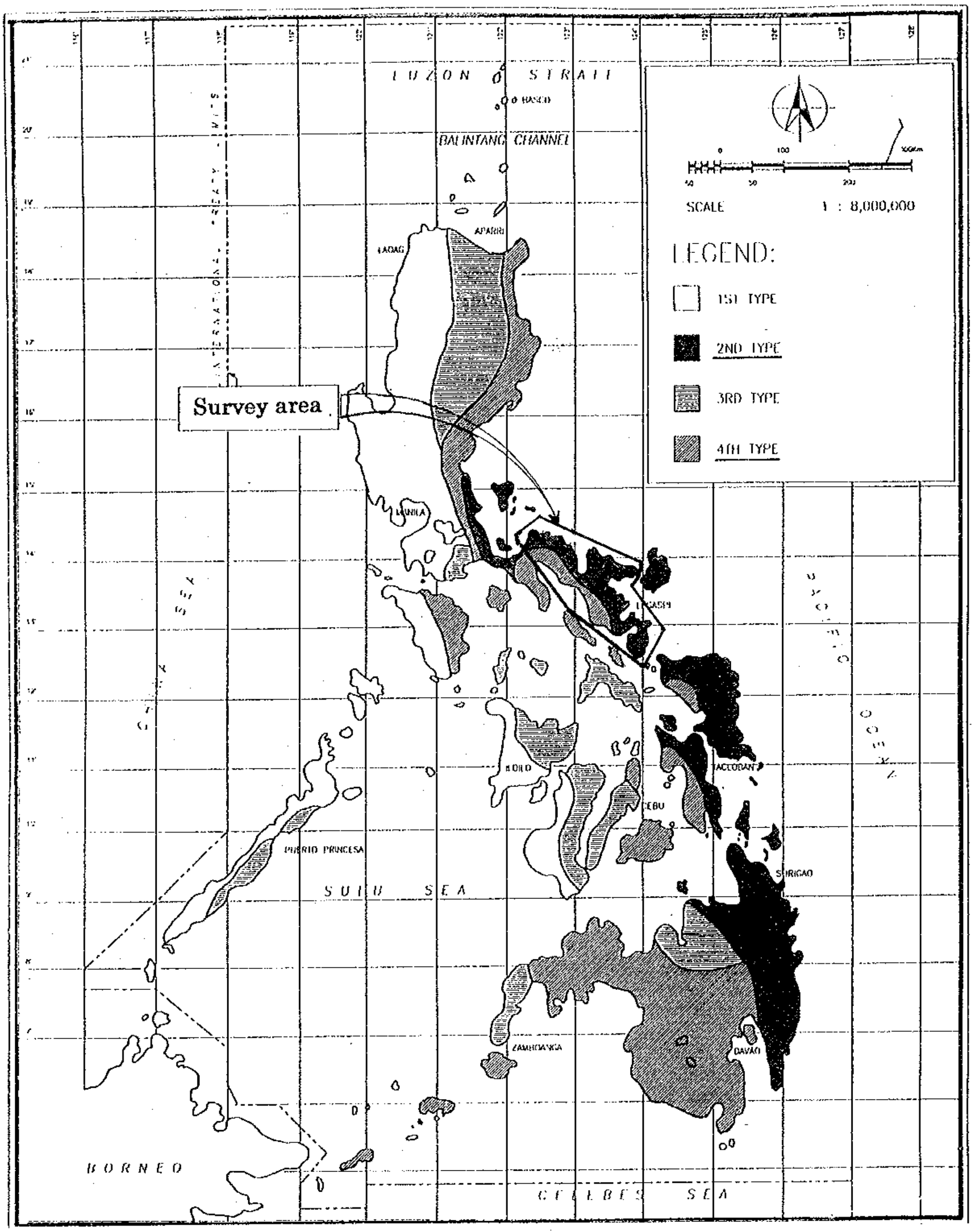


Figure I-2-2 Climate of the Philippines classified according to Coronas (1920)

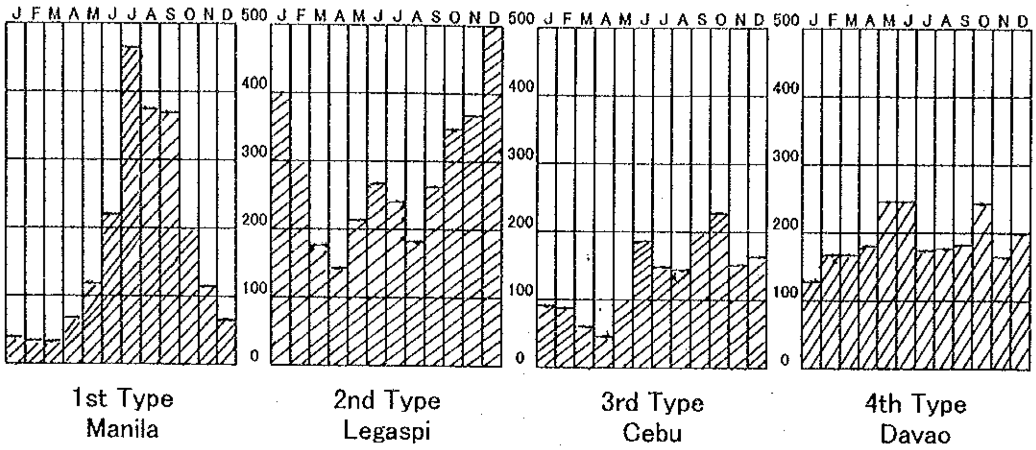


Figure I-2-3 Types of monthly distribution of rainfall

Chapter 3 General Geology and Ore Deposits of the Bicol Region

3-1 General Geology

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 Region. 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. For further details, please refer the Phase I report.

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 geologic system:

(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)

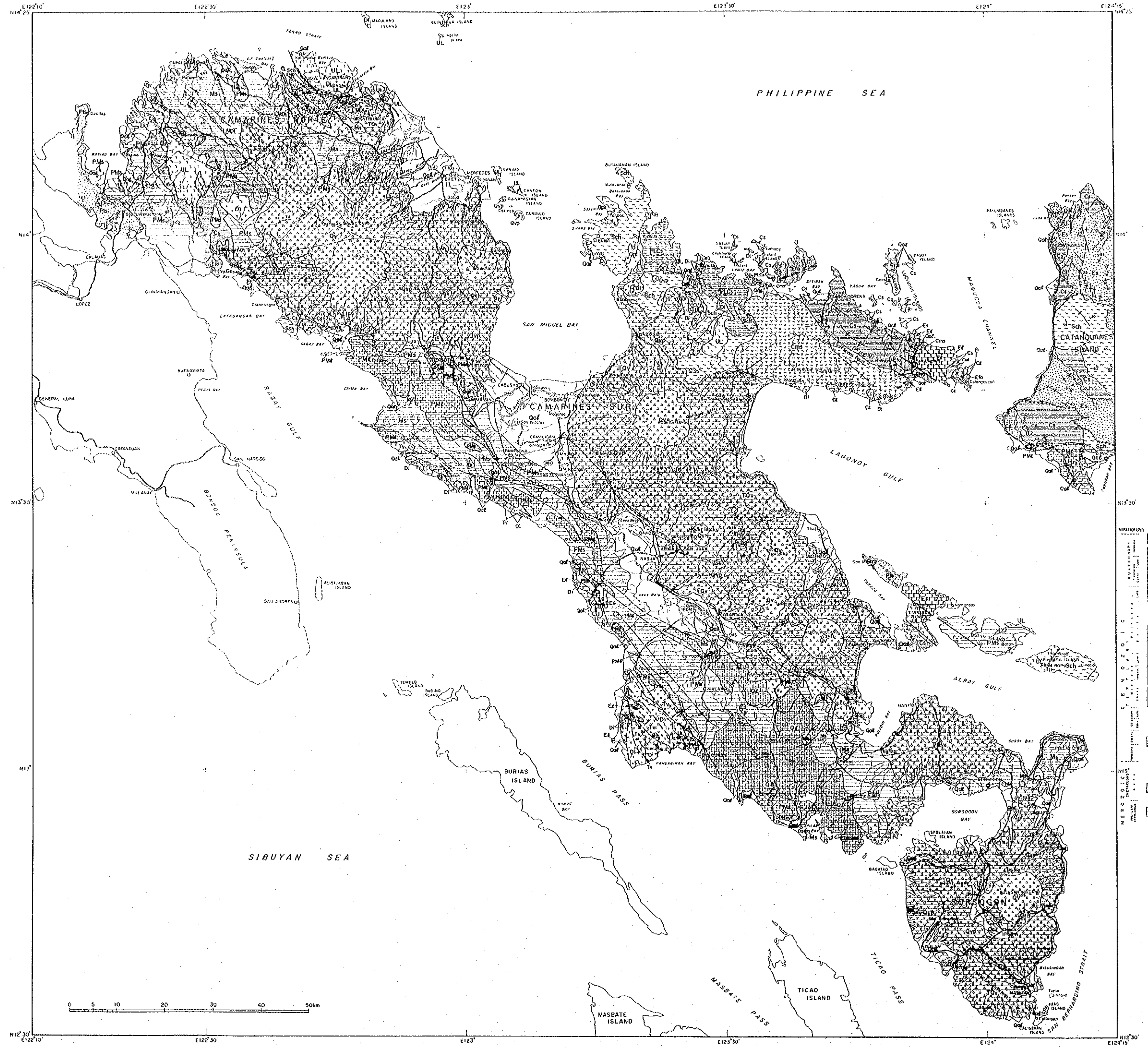
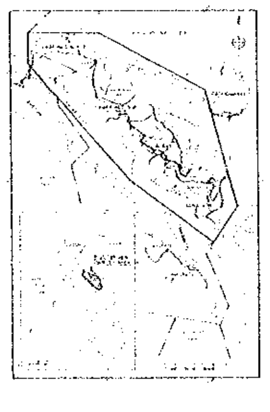


Fig. I-3-1* Geological Map of the Bicol Area



Scale 1 : 250,000

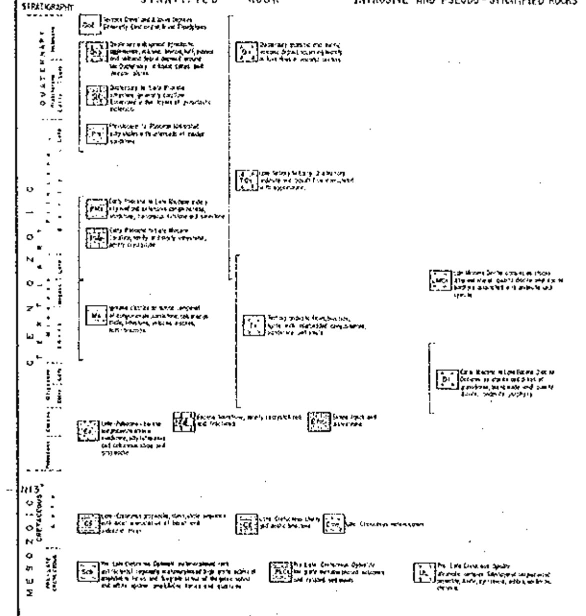
Fig.I-3-1 Geological Map of the Bicol Area

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 : 125,000) / The Cooperative Mineral Exploration by JICA/MMAJ – MGB, 1993-1995
- David S.D. Jr., et al (1996) : Geology, Geohemistry, Geochronology and Structures of the Ophiolites in Southeastern Luzon, Philippines Jour. Soc. Geol. Phil. 1996.

Era	Period	Epoch	Age	Camarines Norte	Caramoan Peninsula	Cagraray, Rapu-Rapu	Southern Bicol Peninsula
Cenozoic	Quaternary	Holocene		Quarternary Alluvium	Alluvial Deposits		(Mt.Mayon, Mt.Blusan) (Pcodol Volcanics)
		Pleistocene	Late	Labo Volcanics		Tabaco Basalt	Ligao Formation; Polangui Volcanics
			Early		Isarog Volcanics		
	Tertiary	Pliocene	Late	Bagacay Andesite / Macogon Fm.		San Miguel Tuff	
			Early	Vinas Fm.			Talisay Fm. (Malama Slt., Paulba Ss., Aliang Slt., Talisay Ls.)
		Miocene	Late	Santa Elena Formation	Lahuy Formation		
			Middle	Tamisan Diorite / Paracale Granodiorite		Bilbao Formation	Bicol Formation
			Early	Bosigon Formation	Del Pilar Formation	Caracaran Siltstone; Liguan Formation	
		Oligocene	Late	Larap Volcanics		Coal Harbor Limestone	Panganiran Diorite
			Early		Tambang Point Diorite		Ragay Volcanics
		Eocene	Late		Caramoan Formation		
			Middle	Universal Formation	Guijalo Limestone	Sula Formation	Pantao Limestone
			Early				
		Paleocene	Late				
			Early				
Mesozoic	Cretaceous		Late	Tigbinan Formation	Pagsangahan Formation / Garchitorena Formation	Libog Formation; Rapu-Rapu Diorite	
			Early	Ophiolite	Lagonoy Ophiolite	Ophiolite	Ophiolite
	Jurassic						

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

Geologic Time: 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.		Bagacay Andesite Macogon Fm.		Bagacay Andesite Macogon Fm.
			Early	Vinas Fm.		Vinas Fm.		Vinas Fm.
		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

Era	Period	Epoch	Age	Miranda (1976)	BMG (1982)	David et al.(1994) Western Caramoan Structural Unit	David et al.(1994) Eastern Caramoan Structural Unit	This Report
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

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	Quarternary alluvium	(Mt.Mayon, Mt.Blusan) (Pcodol Volcanics)
		Pleistocene	Late		San Roque Tuff		Ligao Formation; Polangui Volcanics	Ligao Formation; Polangui Volcanics
			Early	Caramoan Tuff				
	Tertiary	Pliocene	Late		Sorsogon Marl	Polangui Formation; Sorsogon F. / Ligao F.		
			Early	Nabua Formation		Talisay Basin Fm.	Albay Group { Malama Slt., Paulba Ss., Aliang Slt., Talisay Ls.	Talisay Fm. { Malama Slt., Paulba Ss., Aliang Slt., Talisay Ls.
		Miocene	Late		Malama Silt	Talisay Limestone		
			Middle	Sto. Domingo Shale	Paulba Sandstone; Aliang Silt / Talisay Ls; Ligao Ls./ Jovellan Slt.	Bicol Clastic Formation	Bicol Formation	Bicol Formation
			Early	Bicol Coal Measures				
		Oligocene	Late	Ragay Volcanics	Daraga Formation	Panganiran Diorite	Panganiran Diorite	Panganiran Diorite
			Early	Siramag Marble		Ragay Volcanics	Ragay Volcanics	Ragay Volcanics
		Eocene	Late	Basement Complex	Basement Complex			
			Middle			Apud Limestone	Pantao Limestone	Pantao Limestone
			Early					
		Paleocene	Late					
			Early					
Mesozoic	Cretaceous		Late			Panganiran Ultramafics	Basement	
			Early					Ophiolite
	Jurassic							

Fig.I-3-6 Generalized Stratigraphy of Southern Bicol Peninsula

(4) The southern part of the Bicol Peninsula (hereinafter referred to as Bicol South)

The succession of geologic system 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 basement of the above-mentioned blocks is ophiolite. 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, and Tambang and elsewhere in the northwest part of the Caramoan Peninsula.

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).

(2) Upper Cretaceous

1) Bicol North

Tigbinan Formation (Upper Cretaceous)

The Tigbinan formation consists of graywackized spilite, andesite, chert, cherty 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.

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. 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 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 is covered with conformity by Larap volcanic rock, which is an 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 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 Palacale. 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).

The geologic system correlated to this formation are 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. 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 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. 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.

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 the southeast 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. 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 Caleon (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 United Nations (1987), however distinguished the lower member from the Bosigon formation, calling it the Tamisan mudstone.

This formation has a thickness of about 1,500 m and is considered to belong to the early

Miocene epoch (BMG, 1982).

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. 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. 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). 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 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 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 phenocryst 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.

(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 phenocryst and plagioclase phenocryst and has a vesicular tuffaceous to vitreous matrix. The dacite has coarse plagioclase phenocryst, biotite phenocryst and a small quantity of quartz phenocryst. 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 phenocryst fragments, and some of the volcanic fragmentary rock has well developed stratification and frequently cross stratification.

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 silicification 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 Philippine 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 occur sinterposed 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 volcanoes. Mt. Mayon and Mt. Bulusan are active volcanoes. 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 volcanoes Mt. Bulusan, Mt. Jormajan, etc. Mt. Bulusan has repeatedly shown volcanism 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 Region

(1) Granites

1) Bicol North

Paracale Granodiorite (Middle Miocene series?)

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. 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.

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.

Tamisan Diorite (Middle Miocene series)

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 and porphyritic 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).

2) Caramoan

Tambang Point Diorite (Oligocene series)

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 system)

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 series)

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 divided roughly 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. 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.

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 augite and olivine, with accompaniment of serpentine, magnetite and uralite.

3-2 Ore Deposits and Mineral Showings in the Bicol Region

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 plate 2 at the back front.

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 Plate 2 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), 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). 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 gold and copper in Camarines Norte. For other metals please refer to the Phase I report.