REPORT ON THE MINERAL EXPLORATION IN THE REPUBLIC OF THE PHILIPPINES

PHASE I

JUNE 1985

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

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JAPAN INTERNATIONAL COOPERATION AGENCY
METAL MINING AGENCY OF JAPAN

No. 36

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Preface

The Government of Japan, in response to the request by the Government of the Republic of the Philippines, decided to investigate the potential of mineral resources in the Eastern Luzon, Visayas and Palawan and entrusted the survey work to the Japan International Cooperation Agency. The Agency, considering the importance of technical nature of the survey work, in turn sought the cooperation of the Metal Mining Agency of Japan to accompolish the work.

The survey work, in its first fiscal year was carried out from December, 1984 to June, 1985 to collect and compile existing survey data and to analyze the Landsat Imagery. The work in the Philippines was carried out in two periods: December 10 to December 19, 1984 and January 10 to February 28, 1985, with great cooperation of the Philippine authorities concerned, especially the Bureau of Minies and Geo-Sciences, Ministry of Natural Resources.

We wish to take this opportunity to express our heartfelt gratitude to the officials of the Government of the Philippines and the Ministries of Foreign Affairs and International Trade and Industry of Japan and the officials of the Embassy of Japan in the Philippines.

June 1985

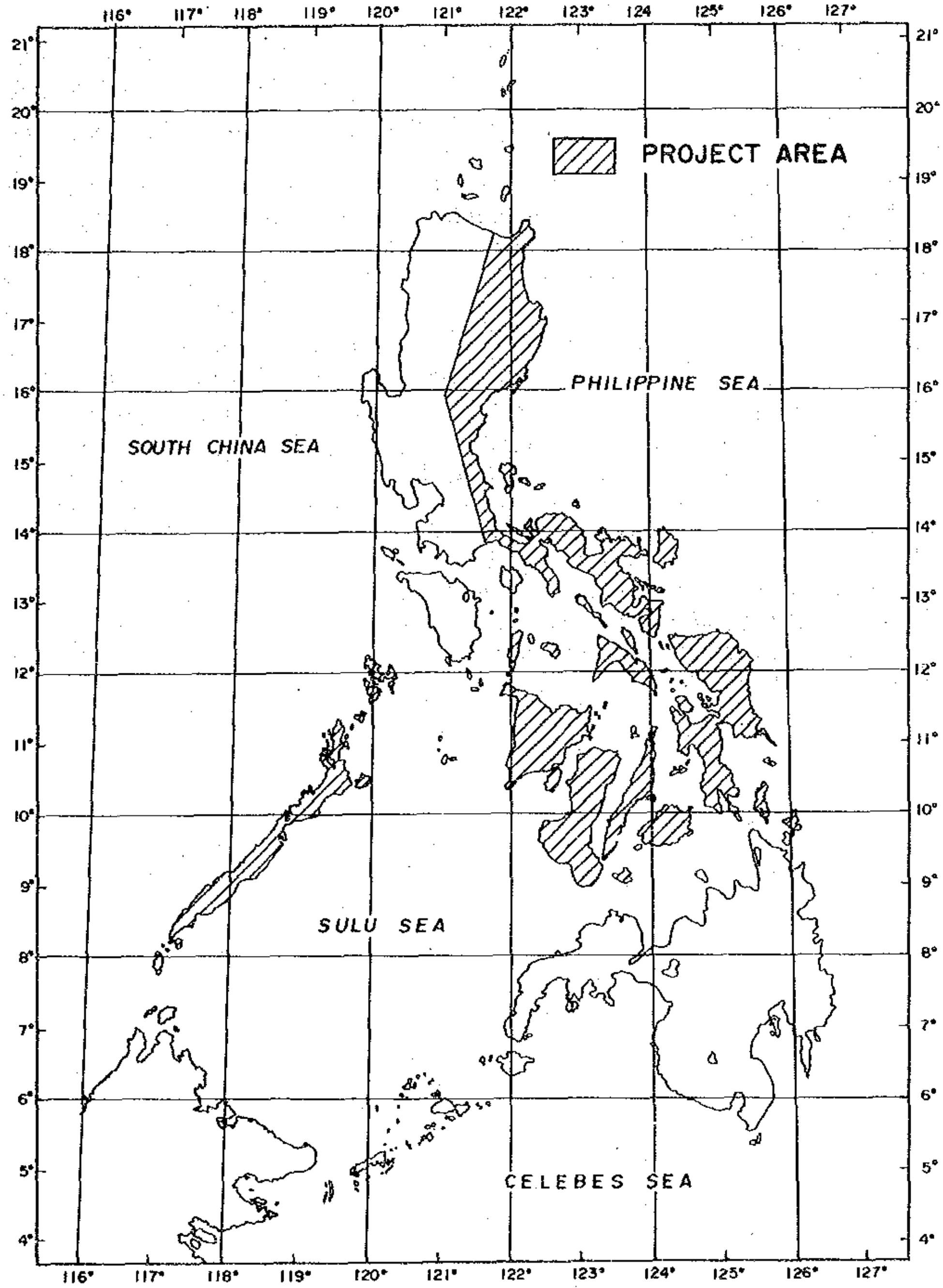
Keisuke Arita

President
Japan International Cooperation Agency

Masayuki Nishiie

President
Metal Mining Agency of Japan

Fig-1 LOCATION MAP OF THE PROJECT AREA



Summary

The Japanese government decided to carry out the cooperative mineral exploration project between the Republic of Philippines and Japan in eastern Luzon, Visayas and Palawan, in response to the request by the Philippine Government. Work for the first fiscal year includes collection, compilation and analysis of existing survey data in the Philippines. This work was carried out by a Japanese mission consisting of two experts for sixty days, from 10 December, 1984 to 19 December, 1984 and from 10 January, 1985 to 28 February, 1985.

Subsequently, synthesis was made combining the results of compilation and the results of the lineament analyses using Landsat data.

The principal objective was to determine the data gaps that need to be filled in the subsequent phases of the project. This was achieved successfully through the strong cooperation extended by the Bureau of Mines and Geo-Sciences, Ministry of Natuaral Resources. Geological maps and mineral inventory maps were collected and compiled covering more than ninety percent of the project area (=about 130 thousand km^2). Topographic maps and regional geophysical maps were also compiled as well as mining activity and mining statistics data.

Synthesis of compiled data and Landsat analyses data indicated that — (1) copper, gold, silver, chrome, nickel and cobalt are the mineral resources of high potentials in the Philippines; (2) these mineral resources were generated closely with crustal tectonics; (3) some of the regional geophysical anomalies indicate the existence of mineralized zones and mineralized igneous rocks; (4) areas of high lineament densities usually coincide with acidic ingeous rocks and promising zone of copper-gold deposits; (5) mineralized areas in the Philippines have local characteristics related to geology and tectonics; (6) high potentials of Cr-Ni-Co are considered in areas where ophiolite is distributed predominantly (Zone - **VII**, Zone - I and Zone - IV in Fig-42); (7) high potentials of Cu are considered in magmatic belts with ophiolite (Zone -I, Zone - **II** and Zone - **IV** in Fig-42); and (8) high potentials of Au-Ag are considered in areas due to association with porphyry copper etc. and related to the Philippine Fault (Zone -**II**, Zone - **III**, Zone - **V** and Zone - **IV** in Fig-42).

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CHAPTER 1. INTRODUCTION

Chapter 1 Introduction

1-1 Background and Purpose of Survey

1-1-1 Background

Cooperative mineral exploration projects in the Republic of the Philippines had been carried out in eastern Mindanao Island (1971-1973), northeastern Luzon (1974-1977), northwestern Luzon Island (1978-1980) and Mindoro Island (1981-1983). The results were appreciated by the Philippine Government. Recently, Philippine Government requested the Japanese Government for a mineral potential evaluation survey in all of eastern Luzon, Visayas and Palawan.

The official request was communicated to the Japanese Government by the offical letter No. 1673 dated December 16, 1983. The Japanese Government sent several missions to the Philippines and the Implementing Arrangement was agreed upon between the Bureau of Mines and Geo-Sciences (BMG), Ministry of Natural Resources and the Japan International Cooperation Agency (JICA) and the Metal Mining Agency of Japan (MMAJ) on September 26, 1984. Thereby the survey started on December 10, 1984 with a preliminary survey phase in its first fiscal year.

1-1-2 Purpose

The main purpose of this preliminary survey phase is to collect and compile existing data and to synthesize these data with the results of Landsat lineament analyses for the purpose of providing an effective data base for the succeeding phases of the project.

1-2 Contents of Surveys

1-2-1 Preliminary Survey in the Philippines

A preliminary survey mission discussed with BMG the working problems of the coming main survey for 10 days from December 10, 1984 to December 19, 1984. The existing data were compiled, collated and reproduced when necessary.

1-2-2 Main Survey in the Philippines-Data Collection and Compilation

The main survey was carried out for 50 days from January 10, 1985 to February 28, 1985 in the Philippines by two Japanese experts and several Philippine counterparts. Various survey data—geological, geochemical and geophysical—existing in the Philippine governmental organizations were compiled and arranged according to survey method in data sheets.

1-2-3 Survey in Japan

Philippine data kept in Japan were collected mainly from the Geological Survey of Japan. Those supplemented the data compiled previously in the Philippines.

1-2-4 Landsat Imagery Analysis

Lineament analysis of the false color and black and white GEOPIC imagery was carried out in Japan. The reason to select the lineament analysis was that the lineament analysis was more effective than spectroscopic analysis to interpret regional tectonics and ore setting in the thick vegetation terrain such as the Philippines.

- Extraction of lineament
  -- analysis of structual element of geographical features, river flow pattern etc.,--
- Rose diagram and lineament density map

1-2-5 Synthesis

Synthesis of the compiled data and results of lineament analysis from Landsat imagery was carried out and then the regional mineral potential was tried to evaluate.

- Relationship between regional geological structure and mineral distribution
- Relationship between regional geological structure and areal geophysical survey data
- Relationship between the results of Landsat lineament analysis and mineral distribution
- Evaluation of the mineral potential in the whole "RP-Japan Mineral Exploration Project Area"

1-3 Member and Itinerary of Survey Mission

1-3-1 Constitution of Survey Team

Participants in planning and negotiation, and survey members for the first fiscal year are listed as follows:

A. Planning and Negotiation

Japanese panel	Masao Tsuge	Metal Mining Agency of Japan (MMAJ)
	Ken Nakayama	Metal Mining Agency of Japan (MMAJ)
	Yoshikazu Ōkubo	Metal Mining Agency of Japan (MMAJ)
	Yasuo Endo	Metal Mining Agency of Japan (MMAJ)
	Jiro Osako	Metal Mining Agency of Japan (MMAJ)
	Hideyuki Ueda	Japan International Cooperation Agency (JICA)
Philippine panel	Juanito C. Fernandez	Bureau of Mines and Geo-sciences (BMG)
	Constante B. Belandres	Bureau of Mines and Geo-sciences (BMG)

		Benjamin A. Gonzales	Bureau of Mines and Geopsciences (BMG)
		Guillermo R. Balce	Bureau of Mines and Geo-sciences (BMG)
		Juan E. Pilac	Bureau of Mines and Geo-sciences (BMG)
		Romeo L. Almeda	Bureau of Mines and Geo-sciences (BMG)
		Noel V. Ferrer	Bureau of Mines and Geo-sciences (BMG)
B.	Survey		
	Japanese member	Naoto Aizawa	Overseas Mineral Resoures Development Co., Ltd. (O.M.R.D)
		Naoaki Tomizawa	Overseas Mineral Resources Development Co., Ltd. (O.M.R.D)
	Philippine member	Romeo L. Almeda	Bureau of Mines and Geo-Sciences (BMG)
		Noel V. Ferrer	Bureau of Mines and Geo-Sciences (BMG)
		Panfilo Montero	Bureau of Mines and Geo-Sciences (BMG)
		Edwin G. Domingo	Petrolab, BMG
		Arnulfo V. Cabantog	Petrolab, BMG
		Manuel Corpuz Jr.	Petrolab, BMG
		Raymundo Villones Jr.	Petrolab, BMG
		Lilian Rollan	Petrolab, BMG
		Olivia Bernardo	Petrolab, BMG
		Benjamin Q. Obra	BMG Regional Office No. I, Baguio
		Federico E. Miranda	BMG Regional Office No. I, Baguio
		D. Custodio	BMG Regional Office No. I, Baguio
		Eligio Z. Ariate	BMG Regional Office No. VII, Cebu
		Alvin Matos	BMG Regional Office No. VII, Cebu
		W. Diegor	BMG Regional Office No. VII, Cebu
		Pedro C. Caleon	BMG Regional Office No. V, Daet
		R. Juan	BMG Regional Office No. V, Daet

Besides more than 20 geologists of BMG engaged in this survey work.

1-3-2 Brief Itinerary of Survey Mission

Table-1 Itinerary of Survey Work in the Philippines

	1984	1985	
	December	January	February
1. Preliminary Survey	10 – 19		
2. Data Collection and Compilation			
in Quezon		10 –	– 28
in Regional office and Major Mines		23 – 27: · Regional office No.I · Dizon · Coto · Barlo · Sto. Tomas · Acupan; 30 –	– 3: · Regional office No.VII · Toledo · Alcoy; 7 – 10: · Regional office No.V · Panganiban

CHAPTER 2. STATUS OF MINING ACTIVITY IN THE PHILIPPINES

Chapter 2. Status of Mining Activity in the Philippines

2.1 Mineral Ore Reserves

The estimated mineral ore reserves of the Philippines, on yearly updated basis for 1973-1982 is shown in the Table-2.

In recent years, chromite (metallurgical), copper and gold are incressing but nickel and iron are decreasing in reserves. Clay, quartz and silica sand are greatly increasing and raw material of cement and coal are decreasing.

Table—2 Mineral Ore Reserves: 1973 to 1982 (in thousand tonnes)

Kind of ore	Estimated reserves as of December 31										Grade or Analysis 1981
	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982p	
Total	35,642,422	39,097,307	331,118,486	35,113,441	30,470,170	32,734,345	33,819,009	33,601,130	34,650,919	34,744,188	
Metallic	10,804,563	11,861,429	11,195,509	11,512,853	11,888,743	10,183,296	11,345,190	9,592,459	10,248,615	10,306,584	
Cadmium	47	47	47	47	47	47	47	47	47	47	0.10% Cd
Chromite											
(metallurigical)	2,194	2,031	2,298	4,009	6,359	10,249	65,389	86,627	87,599	83,470	10.00 - 54.20% Cr_2O_3
(refractory)	16,491	16,263	8,398	7,845	7,815	7,006	7,457	8,226	9,117	8,106	20.00 - 38.43% Cr_2O_3
Copper	2,294,141	2,775,908	3,206,225	3,518,324	3,628,113	3,657,290	3,939,934	4,313,253	4,333,613	4,310,620	0.16 - 32.625% Cu
Gold	1,361,978	1,692,538	520,876	517,772	902,100	1,003,876	1,684,487	2,014,467	1,933,140	2,108,260	0.194 - 22.39 g/t Au (Primary) 0.11 - 20.57 g/t Au (Secondary)
Iron											
(aluminous laterite)	292,010	292,010	292,010	292,010	292,010	292,010	292,010	292,010	292,010	292,010	41.64 - 50.65% Fe
(laterite)	2,937,176	2,957,019	3,048,102	3,048,102	3,048,102	3,513,323	3,513,054	727,393	783,878	793,675	12.80 - 58.00% Fe
(lump ore)	102,353	75,747	74,853	74,853	60,132	71,103	95,953	98,378	123,278	120,179	10.00 - 68.44% Fe
(magnetite sand)	81,882	117,338	121,670	129,457	128,551	155,823	169,112	120,224	120,224	120,224	17.29 - 66.32% Fe
Lead	4,028	4,208	10,332	7,101	6,750	6,489	9,328	9,360	9,237	9,318	0.24 - 2.50% Pb
Manganese	2,788	59,378	1,034	1,244	1,451	1,054	7,546	7,535	7,535	7,537	0.65 - 51.00% Mn
Mercury	3,774	5,979	5,582	5,435	5,435	15,897	15,897	15,897	15,887	15,897	0.15 - 10.461 lb/T Hg
Molybdenum	93,868	192,468	74,986	74,986	70,999	70,999	70,999	184,130	765,515	670,980	0.08 - 49.00 PPM Mo
Nickel	3,602,410	3,622,220	3,814,939	3,822,386	3,819,285	1,368,122	1,479,463	1,708,854	1,751,007	1,752,120	0.23 - 2.39% Ni
Platinum	942	942	942	942	942	942	942	942	942	942	0.08 OZ/T Pt
Uranium	500	500	90	90	90	90	90	90	90	90	0.04% U_3O_8
Zinc	8,091	7,015	13,125	8,250	10,782	10,526	13,374	14,353	15,285	16,210	0.36 - 7.28% Zn
Non-metallic	24,837,859	27,235,878	21,920,977	23,600,588	18,581,436	22,551,049	22,473,819	24,008,671	24,402,304	24,437,604	
Asbestos	4,346	4,346	4,201	4,615	2,421	2,093	2,903	24,498	24,498	24,498	7.20 - 16.79%
Barite	200	120	...	118	139	105	192	149	174	180	86.40% $BaSO_4$
Cement raw materials	11,789,695	12,452,004	9,953,552	10,320,107	6,454,097	5,571,133	5,306,066	5,849,888	6,350,588	6,249,970	48.50 - 96.70% $CaCo_3$
Clay	272,882	292,695	293,736	895,216	891,675	876,819	782,109	1,061,502	1,089,073	1,076,390	
Coal	104,294	104,255	...	...	...	...	...	...	...	...	
Construction materials	763,333	751,376	728,480	832,944	542,070	593,109	659,551	837,802	655,607	656,710	
Diatomaceous earth	3,697	3,697			3,543	3,903	2,903	2,903	3,903	3,903	
Dolomitic limestone	493,798	492,798	488,798	475,798	239,798	240,765	290,758	290,745	264,578	271,672	9.21 - 20.00% MgO
Feldspar	538,322	538,322	350,371	355,511	354,249	27,124	25,192	25,114	30,038	32,298	
Gypsum	7,100	1,898	1,955	1,955	1,908	1,882	1,882	1,882	1,884	1,884	19.19 - 89.89% $CaSo_4 \cdot 2H_2O$
Limestone	8,005,041	8,538,716	6,390,706	7,152,923	5,973,433	9,133,316	8,979,480	8,793,041	9,633,627	9,770,269	50.00 - 99.05% $CaCo_3$
Magnesite	1,233	1,491	1,491	1,491	691	1,491	580	26,538	26,535	26,536	36.43 - 57.00% MgO
Marble	2,600,760	3,801,203	3,309,435	3,150,391	3,196,051	3,739,454	3,773,313	3,942,751	3,955,039	3,970,772	
Peat			2,106	2,016	2,016	2,016	2,016	2,016	2,016	2,016	2,500 - 5,000 BTU
Perlite	27,500	26,499	18,797	18,533	18,532	18,531	18,528	18,526	18,518	18,526	
Pumice and pumicite	31,678	31,678	31,678	31,678	31,678	21,878	21,878	21,878	21,878	21,878	
Pyrite	19,052	19,052	19,042	18,855	18,760	987,502	987,419	987,324	987,257	987,470	26.00 - 53.41% FeS_2
Quartz	9,638	9,638	19,262	19,310	161,296	511,606	511,925	512,476	511,287	510,390	82.50 - 99.70% SiO_2
Rock asphalt	550	550	550	550	...	...	...	...	...	...	
Sproilte	...	...	172,981	172,981	...	...	...	...	...	...	
Silica rock	23,349	23,349	15,589	15,589	15,544	15,544	13,876	13,876	13,876	13,876	79.68 - 98.00% SiO_2
Silica Sand	117,791	117,791	75,117	88,639	637,029	772,869	1,061,328	765,810	782,992	797,410	58.50 - 99.20% SiO_2
Sulphur	24,132	24,132	39,408	39,541	35,542	29,454	29,454	29,453	29,453	29,453	3.00 - 83.0% S
Talc	268	268	268	374	374	455	469	503	503	502	

Source: Bureau of Mines and Geo-Sciences

2-2 Mining Production

The Philippine mineral production (1955-1984) and value (1955-1983) are shown in Table-3 and Table-4 respectively.

It is noticeable that gold is increasing and iron is decreasing sharply. Quartz and sand/gravel among nonmetallics are decreasing gradually. Major mining production in the Philippines are copper, chromite, gold and nickel, which are important supply in the free world. Gold and silver are increasing suddenly in value of mining production reflecting a jump in metal prices.

Table—3 Mining Production: 1955 to 1984 (in thousand units)

Year	Precious metals: Gold metal (kg)	Silver metal (kg)	Platinum and palladium metals (kg)	Base metals[1]: Chromite ore (Dmt)	Copper metal (tonnes)	Iron ore (Dmt)	Lead metal (tonnes)	Manganese ore (Dmt)	Molybdenum metal (tonnes)	Nickel metal (tonnes)	Pyrite cinders (Dmt)	Quick silver (Flask)[2]	Zinc metal (tonnes)	Non-metallics[3]: Gypsum (tonnes)	Coal (tonnes)	Sand and gravel (tonnes)	Salt (tonnes)	Silica sand (tonnes)
1955	11.9	14.2	...	595.0	17.5	1,432.7	2.3	11.9	...	...	...	0.6	...	...	130.2	1,231.1	1,599.9	30.8
1960	11.6	33.1	...	234.4	44.0	1,136.8	0.1	17.4	*	...	...	3.0	5.0	9.1	147.9	2,555.1	94.7	88.4
1965	12.4	26.5	...	554.6	62.7	1,437.8	0.1	51.7	0.1	...	19.4	2.4	2.1	27.5	94.5	3,325.9	225.3	279.8
1970	17.1	48.2	34.9	565.4	160.3	1,889.9	*	5.1	*	0.1	101.7	4.6	3.2	17.5	42.4	4,019.1	310.3	664.6
1971	18.1	55.4	69.7	429.6	197.6	2,250.1	...	5.1	*	0.2	129.4	5.0	8.9	41.8	40.0	4,627.5	335.0	491.5
1972	17.2	52.4	213.2	349.6	213.1	2,204.9	...	2.5	...	0.4	105.0	3.3	4.6	64.9	38.9	5,598.6	219.5	411.6
1973	16.2	53.6	6.7	580.3	221.2	2,254.6	...	4.0	...	0.4	125.7	2.2	5.4	2.6	39.0	5,690.7	210.0	504.9
1974	16.7	53.9	0.1	529.5	225.5	1,608.1	1.3	0.9	...	0.3	...	*	7.6	1.6	50.7	2,160.6	213.6	689.2
1975	15.6	50.4	*	433.0	225.8	1,351.4	3.4	...	*	9.5	99.4	*	10.4	6.9	105.1	5,264.9	202.1	427.2
1976	15.6	46.0	...	346.3	237.6	671.0	4.5	10.6	...	15.3	100.4	...	11.6	2.84	120.8	6,113.1	203.4	391.4
1977	17.4	50.4	...	443.1	272.8	...	3.7	20.6	...	36.8	89.2	...	12.4	1.7	284.5	7,347.1	200.0	310.9
1978	18.2	51.0	...	438.0	263.6	1.7	1.4	3.9	*	39.5	80.5	...	9.5	...	253.0	9,775.6	235.6	418.9
1979	16.6	57.2	...	420.1	298.3	6.3	1.9	3.8	0.1	33.3	86.3	...	9.7	...	263.1	11,042.6	322.1	466.8
1980	20.0	60.7	...	358.6	304.5	...	1.8	2.6	0.1	25.4	75.5	...	6.8	...	325.0	13,251.2	346.4	476.6
1981	23.5	62.9	...	306.1	303.3	5.7	1.3	10.7	0.1	23.9	...	...	5.8	...	373.0	16,227.4	355.3	484.3
1982	25.9	61.7	...	355.5	271.4	5.6	...	1.6	0.1	13.9	...	...	3.0	...	556.7	18,827.3	364.4	527.3
1983	25.4	56.7	...	...	271.4	2.6	...	2.2	40.3	13.9	...	...	2.3	0.5	1,019.8	15,093.3	381.9	243.7
1984 1st Quarter	3.6	8.4	...	54.8	51.1	...	...	...	...	4.6	...	...	...	...	...	...	...	...

[1]Excludes cadmium metal production in 1965 (9.6 m.t.) and 1975 (15.0)
[2]A flask contains 76 lb of mercury.
[3]Excludes rock asphalt production in 1955 (3.2 m.t.) and 1980 (18.4 m.t.)
Source: Bureau of Mines and Geo-Sciences.

Table—4 Value of Mining Production: 1955 to 1983 (In thousand Pesos)

Year	Total all minerals	Precious metals: Sub-total	Gold metal	Silver metal	Palladium & platinum metal	Base Metals: Sub-total	Chromite ore	Copper metal	Iron ore	Lead metal	Manganese ore
1955	167,872.0	44,713.8	43,850.1	853.7	-	75,599.0	19,420.1	29,795.4	24,033.9	1,426.4	559.7
1960	224,245.8	60,030.9	57,987.5	2,043.4	-	119,221.0	33,937.1	59,067.2	20,706.3	65.5	1,147.8
1965	58,014.4	86,837.6	82,592.9	4,254.7	-	289,414.3	37,441.1	184,884.9	52,766.9	128.7	5,204.7
1970	1,719,367.4	146,297.3	130,349.5	15,500.4	447.4	1,279,239.6	63,570.5	1,113,334.3	83,123.4	14.6	733.7
1971	2,008,011.3	169,909.1	151,603.1	17,799.0	507.0	1,409,793.2	53,095.5	1,233,494.2	102,141.1	-	910.1
1972	2,245,093.4	246,545.1	225,172.7	18,050.0	3,292.4	1,531,686.9	48,084.2	1,360,427.8	105,339.6	-	407.3
1973	3,533,765.4	391,489.3	359,951.6	28,385.5	3,142.2	2,503,456.3	75,321.2	2,296,138.7	111,197.2		633.6
1974	4,501,100.2	608,882.7	554,014.6	52,128.1	2,740.0	2,978,718.9	79,432.6	2,793,932.5	81,807.2	1,335.4	241.6
1975	3,950,612.5	626,267.5	575,132.3	49,989.6	1,135.6	2,132,117.6	86,492.4	1,640,032.6	90,676.9	6,544.7	-
1976	4,387,203.6	459,894.1	445,908.5	43,935.6	-	2,549,762.8	119,345.0	1,841,542.3	38,502.3	11,338.2	1,676.2
1977	5,262,761.4	616,352.3	586,913.5	49,435.8	-	3,109,817.7	196,000.4	1,927,152.8	-	6,969.8	7,644.3
1978	5,804,233.1	857,161.9	798,859.9	58,302.0	-	3,036,813.1	201,202.9	2,163,552.2	270.4	4,828.0	1,323.4
1979	8,478,488.1	1,313,665.0	1,180,406.0	133,280.0	-	4,319,500.8	229,362.4	3,689,670.3	1,068.8	13,936.0	1,227.8
1980	12,820,538.0	3,053,119.7	2,784,856.7	268,252.0	-	6,104,562.7	205,778.0	4,409,279.1	-	12,503.3	833.8
1981	11,877,429.6	2,794,754.3	2,642,455.5	152,298.8	-	5,034,555.3	187,106.6	3,781,851.6	969.4	5,347.5	1,054.4
1982	11,301,745.8	2,773,131.3	2,651,336.5	121,797.8	-	4,368,496.0	173,052.0	3,446,323.4	908.4	-	552.9
1983	13,630,382.0	4,039,018.0	3,821,873.0	217,145.0	-	4,735,939.0	165,043.3	4,046,609.0	518.0	-	628.0

Year	Base Metals: Molybdenum metal	Nickel metal	Pyrite cinders ore	Quick silver metal	Zinc metal	Non-metallics: Sub-Total	Gypsum	Coal	Sand and gravel	Salt	Silica sand	Other minerals[1]
1955	-	-	-	357.9	-	11,270.4	-	3,104.1	3,744.8	3,913.5	509.0	36,288.8
1960	150.0	-	-	1,299.9	2,847.2	22,449.7	549.2	3,438.1	8,785.4	7,553.5	2,143.5	72,544.2
1965	1,125.1	-	410.2	5,075.8	2,363.1	26,335.4	921.6	2,375.0	5,653.9	14,246.3	3,035.8	177,557.1
1970	456.8	1,699.6	2,116.1	10,688.0	4,204.4	61,572.2	835.1	1,131.5	24,484.1	26,518.2	8,601.2	23,758.5
1971	71.0	3,298.0	2,578.8	3,653.5	5,541.1	71,733.9	2,654.5	1,588.3	29,228.7	32,709.0	5,353.4	356,585.0
1972	-	4,476.6	2,731.7	4,196.5	6,024.2	8,453.4	6,397.6	1,635.5	37,510.8	30,103.3	6,706.2	384,408.0
1973	-	4,842.0	3,178.5	3,833.8	8,760.8	79,150.0	350.0	1,755.8	39,834.9	30,380.0	8,799.3	552,659.8
1974	-	7,143.0	-	1,708.4	21,557.0	107,941.3	2,816.2	7,608.5	45,211.6	43,568.4	10,758.6	795,557.3
1975	474.2	262,632.0	2,284.3	703.1	32,271.4	279,430.7	25,971.3	13,157.6	103,462.2	67,894.5	9,945.1	971,798.7
1976	-	483,593.0	11,327.2	-	42,218.6	277,987.3	248.0[2]	10,329.6	157,158.6	82,325.4	6,435.5	1,074,549.4
1977	-	937,010.3	4,739.1	-	40,301.8	362,571.1	427.5	45,528.6	230,322.5	77,434.6	8,797.9	1,151,020.3
1978	7,711.0	635,040.4	2,413.1	-	18,561.7	569,370.7	-	40,057.5	432,352.6	81,223.7	13,736.9	1,340,877.4
1979	31,058.1	921,876.8	2,188.2	-	29,164.0	707,852.8	-	47,353.8	490,724.5	101,065.5	10,709.0	1,536,438.5
1980	14,760.6	1,437,235.6	1,620.7	-	23,301.4	894,435.6	-	59,561.1	815,405.4	204,185.5	18,389.0	2,763,431.0
1981	7,935.2	1,026,458.4	-	-	23,849.2	989,738.5	-	63,833.6	691,044.4	213,173.4	21,687.1	3,060,681.1
1982	4,374.2	505,542.6	-	-	8,845.2	1,340,456.9	-	304,287.1	824,337.9	218,852.0	22,582.8	3,410,097.5
1983	2,607.0	323,055.0	-	-	8,677.0	1,293,889.3	-	392,544.0	1,022,345.0	318,133.0	51,692.0	3,100,675.2

Note: Total all minerals reflect the sum of metallic and non-metallic minerals only enumerated above. Details do not always add up to total due to rounding.
[1]Includes chromite metallurgical concentrate, cobalt metal, nickel (beneficiated ore), gypsum, cement and other non-metallics.
[2]Gypsum, natural only; data for artificial gypsum not available. Starting 1978 gypsum was added to other minerals.
Source: Bureau of Mines and Geo-Sciences.

2-3 Mining Production Share in Exports

Philippine exports of major 10 commodity groups in F.O.B. value (1955-1984) is shown in the Table-5. For the past several years, export value of mining production has been stabilized, but its share is decreased to the 10 % mark from 17-18 % before, although its export value ranking conflicts with the coconut products to get No. 1.

Table—5 Philippine Exports by Major Commodity Groups: 1955 to 1984 (F. O. B value in million U. S. dollars)

Major commodity group	1955	1960	1965	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984 (Jan-March)
Total	419	535	786	1,142	1,189	1,169	1,837	2,725	2,294	2,574	3,151	3,425	4,601	5,788	5,722	5,021	5,005	1,254
Coconut products	152	177	271	212	254	228	374	609	466	540	761	908	1,024	811	750	590	680	198
Copra	119	139	170	81	114	110	166	140	172	150	201	136	89	47	34	49	4	-
Coconut oil	16	16	69	98	103	84	153	381	231	299	412	621	742	567	533	401	516	157
Desiccated coconut	13	19	20	19	21	18	32	60	30	37	90	82	107	116	102	68	88	26
Copra meal or cake	4	3	12	14	16	16	23	28	33	54	58	69	86	81	81	72	72	15
Sugar and sugar products	111	135	147	196	220	218	294	766	616	456	535	216	240	657	609	445	321	18
Centrifugal and refined sugar	107	133	132	188	212	211	274	737	581	429	512	197	212	624	567	416	299	75
Molasses	4	2	10	8	8	6	19	28	34	24	20	16	27	33	38	25	17	12
Others	*	*	5	*	*	1	1	1	1	3	3	3	1	-	4	4	5	1
Forest products	44	95	195	301	264	235	464	338	260	308	294	362	536	468	469	362	331	58
Logs	33	85	155	243	215	164	304	216	167	135	134	145	144	92	76	78	74	15
Lumber	8	7	8	13	11	10	35	30	27	68	67	85	198	181	126	124	149	24
Plywood	1	2	18	20	24	34	58	26	21	43	41	72	107	111	111	67	76	13
Others	2	1	14	25	14	27	47	66	45	62	52	60	87	84	156	93	32	6
Mineral products	30	37	70	224	224	239	374	518	332	371	501	554	831	1,031	758	532	440	73
Copper concentrates	7	30	47	185	185	191	290	393	212	266	268	250	440	545	429	312	249	35
Gold	...	...	...	...	8	37	40	74	76	65	71	76	103	239	215	169	154	26
Iron ore and concentrates	*	*	2	13	13	9	18	12	13	7	-	-	-	-	-	-	-	-
Chromite ore	10	5	11	9	6	5	9	13	13	15	25	25	23	33	25	15	10	-
Others	13	2	10	17	12	7	17	26	18	19	137	203	265	214	89	36	27	12
Fruits and vegetables	6	25	17	35	41	52	57	91	124	142	157	177	214	365	378	374	327	99
Pineapple products	6	7	12	22	20	21	23	35	41	52	64	74	96	97	101	107	102	26
Banana	*	18	2	6	15	24	28	45	73	76	72	86	100	114	124	146	105	28
Others	*	*	3	7	6	7	6	11	10	14	21	17	18	154	153	121	120	45
Abaca and products	29	43	26	17	15	16	24	46	22	27	29	25	38	31	25	26	25	7
Abaca unmanufactured	28	42	24	15	13	13	20	38	15	18	18	15	25	27	21	20	18	4
Abaca rope	1	1	2	2	2	3	4	8	7	9	11	10	13	4	4	6	7	3
Tobacco and products	4	3	16	15	15	18	27	31	35	29	29	30	33	30	50	49	35	4
Raw tobacco	3	3	15	14	14	17	26	30	34	28	28	29	32	29	48	47	33	4
Cigars and others	1	*	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	1
Mineral fuel and lubricants	...	*	6	17	24	19	16	17	37	34	37	30	42	38	42	33	115	26
Chemicals	1	2	2	5	6	6	10	15	21	26	51	59	112	89	107	98	87	22
Textiles	2	3	5	5	7	9	24	20	22	28	21	31	39	33	69	56	25	7
Miscellaneous manufactures and Others	37	14	39	114	111	124	181	271	357	589	722	1,011	1,463	2,198	2,455	2,449	2,586	650
Re-exports	3	1	2	1	6	4	2	3	2	24	14	22	29	37	10	9	33	21

Source: National Census and Statistics Office.

2-4 Major mining companies

2-4-1 Business Performance of Major Mining Companies (except oil and gas)

The business performance of six (6) major mining companies (1982 and 1983) is shown in the Table -6.

Table—6 Business Performance of Majer Mining Companies: 1982 & 1983

Gross Revenue Rank in the 100 top Corporations		Name of Corporation	Gross Revenue (1,000 Pesos)		Net Sales (1,000 Pesos)		Net Income (1,000 Pesos)	
1983	1982		1983	1982	1983	1982	1983	1982
12	14	Atlas Consolidated Mining & Development Corporation	3,283,456	2,613,393	3,078,568	2,493,941	99,359	(295,408)
18	22	Benguet Corporation	2,012,586	1,460,780	1,814,553	1,291,714	267,091	88,189
21	18	Marinduque Mining & Industrial Corporation	1,917,480	1,723,054	1,912,634	1,715,081	(4,305,028)	(1,958,324)
50	48	Philex Mining Corporation	939,576	714,802	895,214	697,116	291,419	178,404
70	83	Marcopper Mining Corporation	620,880	462,408	606,011	462,408	10,566	(56,588)
86	93	Lepanto Consolidated Mining Corporation	523,021	448,949	523,021	448,949	101,051	27,851

2-4-2 Performance of Major Mining Companies in Each Mineral (except oil and gas)

The business results of main mining companies in each mineral (1982 and 1983) is shown in the Table-7.

Table—7 Performance of Major Mining Companies in Each Mineral : 1982 & 1983

NAME OF CORPORATION	NET SALES (1,000 Pesos)		GROSS REVENUE (1,000 Pesos)		NET INCOME (1,000 Pesos)		TOTAL ASSETS (1,000 Pesos)		PAID-UP CAPITAL (1,000 Pesos)	
	1983	1982	1983	1982	1983	1982	1983	1982	1983	1982
METALLIC ORE MINING										
• COPPER ORE MINING										
ATLAS CONSOLIDATED MINING & DEVT CORP.	3,078,568	2,493,941	3,283,456	2,613,393	99,359	(295,408)	5,443,774	3,974,836	836,108	836,108
PHILEX MINING CORP.	895,214	697,116	939,576	714,802	291,419	178,404	1,281,053	1,156,790	409,105	379,956
MARCOPPER MINING CORP.	606,011	462,408	620,880	462,408	10,566	(56,588)	1,118,339	919,670	388,766	388,766
BASAY MINING CORP.	105,713	142,207	105,713	142,207	(641,895)	(299,592)	1,749,010	1,452,352	276,802	276,802
TOTAL	4,685,506	3,795,672	4,949,625	3,932,810	(240,551)	(473,184)	9,592,176	7,503,648	1,909,781	1,872,632
• GOLD ORE MINING										
BENGUET CORP.	1,814,553	1,291,714	2,012,586	1,460,780	267,091	88,188	3,056,877	2,457,895	108,333	106,313
LEPANTO CONSOLIDATED MINING CO.	523,021	448,949	523,021	448,949	101,051	27,851	1,465,883	1,079,794	385,070	382,913
NORTH DAVAO MINING CORP.	260,839	27,528	262,183	27,779	(56,837)	350	3,138,246	1,987,122	158,300	36,300
APEX MINING CO., INC.	177,591	146,742	180,894	150,281	24,848	11,401	356,608	266,278	60,506	79,329
SURIGAO CONSOLIDATED MINING CO., INC.	121,438	63,461	121,460	64,661	6,023	2,986	229,514	161,199	36,539	35,761
VULCAN INDUSTRIAL & MINING CORP.	84,430	70,674	84,430	71,166	(38,198)	(45,227)	180,144	291,366	107,292	107,290
BENGUET EXPLORATION, INC.	77,374	57,383	77,374	57,383	7,045	4,641	82,718	47,137	25,782	17,852
ITOGON-SUYOC MINES, INC.	68,642	46,170	69,175	46,446	10,762	1,621	51,319	47,338	27,112	27,112
TOTAL	3,127,888	2,154,621	3,331,123	2,327,445	321,785	91,792	8,561,309	6,338,229	926,934	872,870
• METALLURIGICAL CHROMITE ORE MINING										
ACOJE MINING CO., INC.	78,153	54,140	78,153	54,140	(25,409)	(48,105)	153,539	139,270	19,983	19,983
• NICKEL ORE MINING										
MARINDUQUE MINING & INDUSTRIAL CORP.	1,912,634	1,715,081	1,917,480	1,723,054	(4,305,028)	(1,958,324)	20,948,585	13,073,933	935,304	935,304
RIO TUBA NICKEL MINING CORP.	88,761	90,755	95,817	93,418	(3,896)	(8,711)	208,656	178,364	21,000	21,000
TOTAL	2,001,395	1,805,836	2,013,297	1,816,472	(4,308,924)	(1,967,035)	21,157,241	13,252,297	950,304	956,304
NON-METALLIC MINING AND QUARRYING										
• COAL MINING										
PNOC COAL CORP.	410,049	113,016	410,049	113,016	7,500	206	602,323	430,305	135,626	113,700
MALANGAS COAL CORP.	75,616	11,565	75,616	11,565	9,993	517	317,627	238,567	87,210	47,210
SEMIRARA COAL CORP.	70,929	-	70,929	-	2,132	-	2,079,304	-	554,890	-
TOTAL	556,594	124,581	556,594	124,581	19,625	723	2,999,254	668,872	777,726	160,910

2-5 Major Operating Metal Mines

The major producing and operating metal mines in the Philippines for 1984 are shown in the Table-8

Table-8 List of the Major Producing and Operating Metal Mines in the Philippines, 1984

Kind of ore	Name of mine	Name of Company	Deposit type	Ore reserve (MT)	Ore grade	Ore milled	Metal/ Concentrate year	Method of Mining
Au	Atok-Big Wedge	Atok-Big Wedge Mng. Co., Inc. (Operated by Benguet Corp.)	Vein	(Included in Acupan)			256 kg	Cut and fill
"	Masara	Apex Mining Company, Inc.	Vein	383,882	8.875 g/MT Au	1,000 TPD	1,166 kg	Cut and fill
"	Acupan	Benguet Corporation	Vein	1,409,685	5.95 g/MT Au	3,250 TPD	3,300 kg	Cut and fill Top slice
"	*Antamok*	*Benguet Corporation*	*Vein*	*(included in Acupan)*				
"	Thanksgiving	Benguet Exploration, Inc.	Skarn		7.0 g/MT Au (30-35 g/MT Ag) (5.0% Zn)	230 TPD	400 kg	Cut and fill
"	Hijo Gold	North, Davao Mining Corp.	Disseminated	313,544	3.8 g/MT Au		357 kg	Open pit
"	Itogon-Suyoc	Itogon-Suyoc Mines, Inc.	Vein	723,414	4.22 g/MT Au	300 TPD	392 kg	Shrinkage & fill stopping
"	Placer	Manila Mining Corporation	Vein	932,162	4.82 g/MT Au	200 TPD	180 kg	Open pit & Underground
"	Masbate Gold Operations	Atlas Consolidated Mining & Dev't. Corporation	Disseminated Vein	7,041,773	2.13 g/MT Au	3,500 TPD	2,526 kg	Open pit
"	Siana	Surigao Consolidated Mining Co., Inc.	Vein	3,452,495	5.27 g/MT Au	1,000 TPD	577 kg	Open pit
"	Cordon	Vulcan Industrial and Mining Exploration	Vein	272,690	7.00 g/MT Au		66 kg	Underground
"	Olecram	Olecram Mining Corp.	Vein					Underground
Cu	*Amacan Copper*	*North Davao Mining Corp.*	*Porphyry*	*116,637,000*	*0.37% Cu (0.42 g/MT Au) (2.30 g/MT Ag)*	*30,000 TPD*	*21,949 MT*	*Open pit*
"	Batong-Buhay	Batong-Buhay Gold Mines, Inc.				9,000 TPD	7,518 MT	Block caving
"	Toledo	Atlas Consolidated Mining and Dev't. Corporation	Porphyry	835,811,000	0.45% Cu (0.26 g/MT Au)	109,000 TPD	118,069 MT	Open pit & underground
"	*Dizon*	*Benguet Corporation*	*Porphyry*	*75,209,000*	*0.46% Cu (1.07 g/MT Au)*	*19,000 TPD*	*23,450 MT*	*Open pit*
"	Mankayan	Lepanto Consolidated Mining Company	Massive	1,702,370	2.70% Cu (4.21 g/MT Au)	3,100 TPD	9,150 MT	Square set
"	Marcopper	Marcopper Mining Corp.	Porphyry	177,354,949	0.60% Cu (0.04 g/MT Au) (0.50 g/MT Ag)	24,590 TPD	32,732 MT	Open pit
"	Sto. Tomas II	Philex Mining Corp.	Porphyry	180,000,000	0.28% Cu (0.7 g/MT Au) (1-2 g/MT Ag)	27,000 TPD	20,390 MT	Block caving
Cr	Zambales chromite	Acoje Mining Company, Inc.	Metallurgical	3,984,846	18% Cr_2O_3		91,013 MT	
"	Dinagat chromite	Acoje Mining Company, Inc.		632,460	17.6% Cr_2O_3		4,130 MT	
	Bo. Paete, San Narciso, Zambales	Amerasia Management and Dev't. Corporation					4,250 MT	
"		Astromite Mining Corp.					140 MT	
"		Chrome Ore Mineral Expl., Inc.	Metallurgical	1,300,000	48.8% Cr_2O_3		47 MT	
"		Loyalty Mining and Dev't. Corp.	Metallurgical	20,000	49.0% Cr_2O_3		2,276 MT	
"		Mayan Wood Products, Inc.	Metallurgical	55,710	48.56% Cr_2O_3		79,921 MT	
"	Masinloc chromite	Benguet Corporation	Refractory	8,956,000	31.42% Cr_2O_3		115,257 MT	underground & Open pit
"		Philchrome Mining Corp.						
"		Rio Chico Mining Corp./Pacific Shore	Metallurgical	3,322,889	48.00% Cr_2O_3		5,369 MT	
Mn	Caranglas	Vicente Abubo		2,500	48.00% Mn		257 MT	
Ni	Hinatuan Is., Surigao del Norte	Hinatuan Mining Corp.		1,744,000	2.3% Ni (0.09% Co) (11.5% Fe)		2,141 MT	
"	Bo. Rio Tuba, Bataraza, Palawan	Rio Tuba Nickel Mining Corporation		9,607,200	2.30% Ni		352,250 MT	Open pit
"	*Nonc Is. Surigao City*	*Surigao Nickel Refinery (MMIC)*		75,173,000	1.24% Ni (35.65% Fe) (0.11% Co)			

(After BMG, E.G. Domingo, 1985 Manuscript)

2-6 Governmental Mining Organization

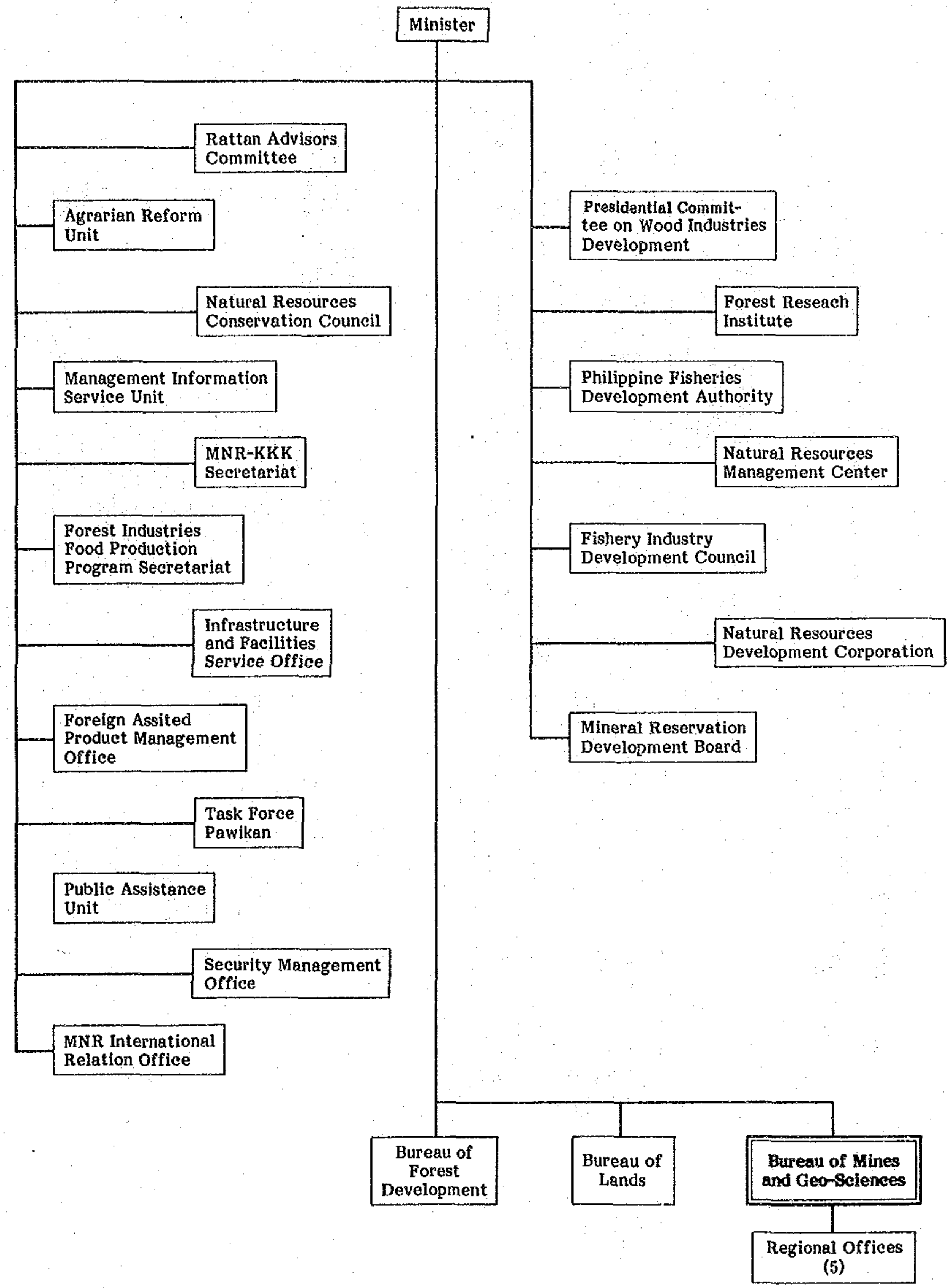
2-6-1 The Cabinet in the Philippines

Fig-2 The organizational chart of the Cabinet

- President
  - Prime minister (CESAR VIRATA)
    - Deputy prime minister (JOSE A. ROÑO)
    - M. of Finance (CESAR VIRATA)
    - M. of Local government (JOSE A. ROÑO)
    - M. of Human settlements (IMELDA R. MARCOS)
    - M. of Foreign affairs (ARTURO TOLENTINO)
    - M. of Defense (JUAN PONCE ENRILE)
    - M. of Justice (ESTELITO MENDOZA)
    - M. of Trade and Industry (ROBERTO ONGPIN)
    - M. of Labor (BLAS F. OPLE)
    - M. of Education (JAIME LAYA)
    - M. of Public works and Highways (JESUS HIPOLITO)
    - M. of Transportation (JOSE P. DANS)
    - M. of Tourism (JOSE D. ASPIRAS)
    - M. of Agriculture and Food (SALVADOR ESCUDERO)
    - **M. of Natural Resources** (RODOLFO DEL ROSARIO)
    - M. of Energy (GERONIMO VELASCO)
    - M. of Health (JESUS AZURIN)
    - M. of Agrarian reform (CONRADO ESTRELLA)
    - M. of Social services (SYLVIA MONTES)
    - S.M. of Media affairs (GREGORIO CENDAÑA)
    - S.M. of Budget (MANUEL ALBA)
    - S.M. of Science (EMIL JAVIER)
    - S.M. of NEDA (VICENTE VALDEPEÑAS)
    - S.M. of PHILCOA (ROLANDO DELA CUESTA)

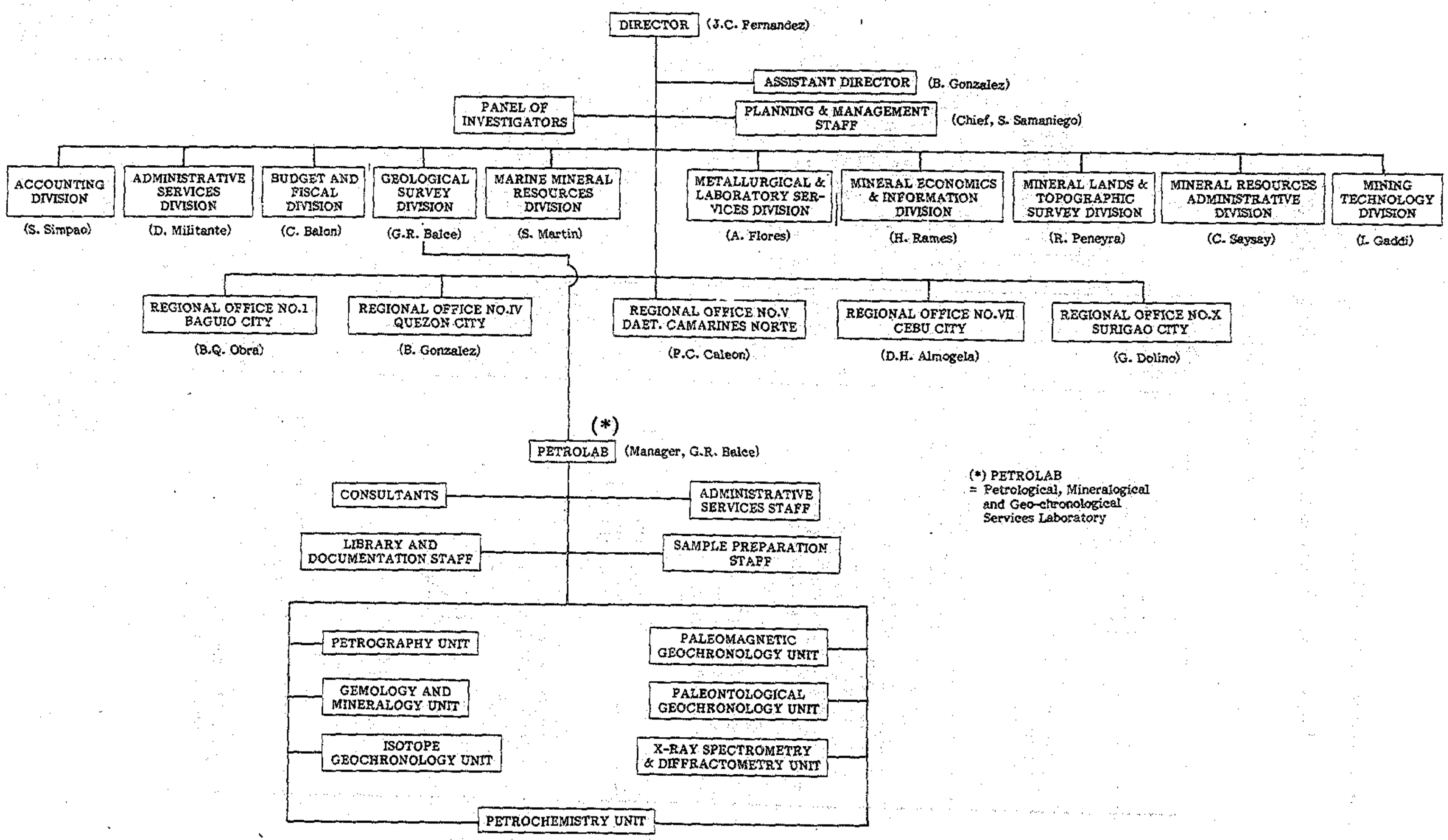
2-6-2 The Ministry of Natural Resources

Fig-3 The Organozational Chart of the Ministry of Natural Resources

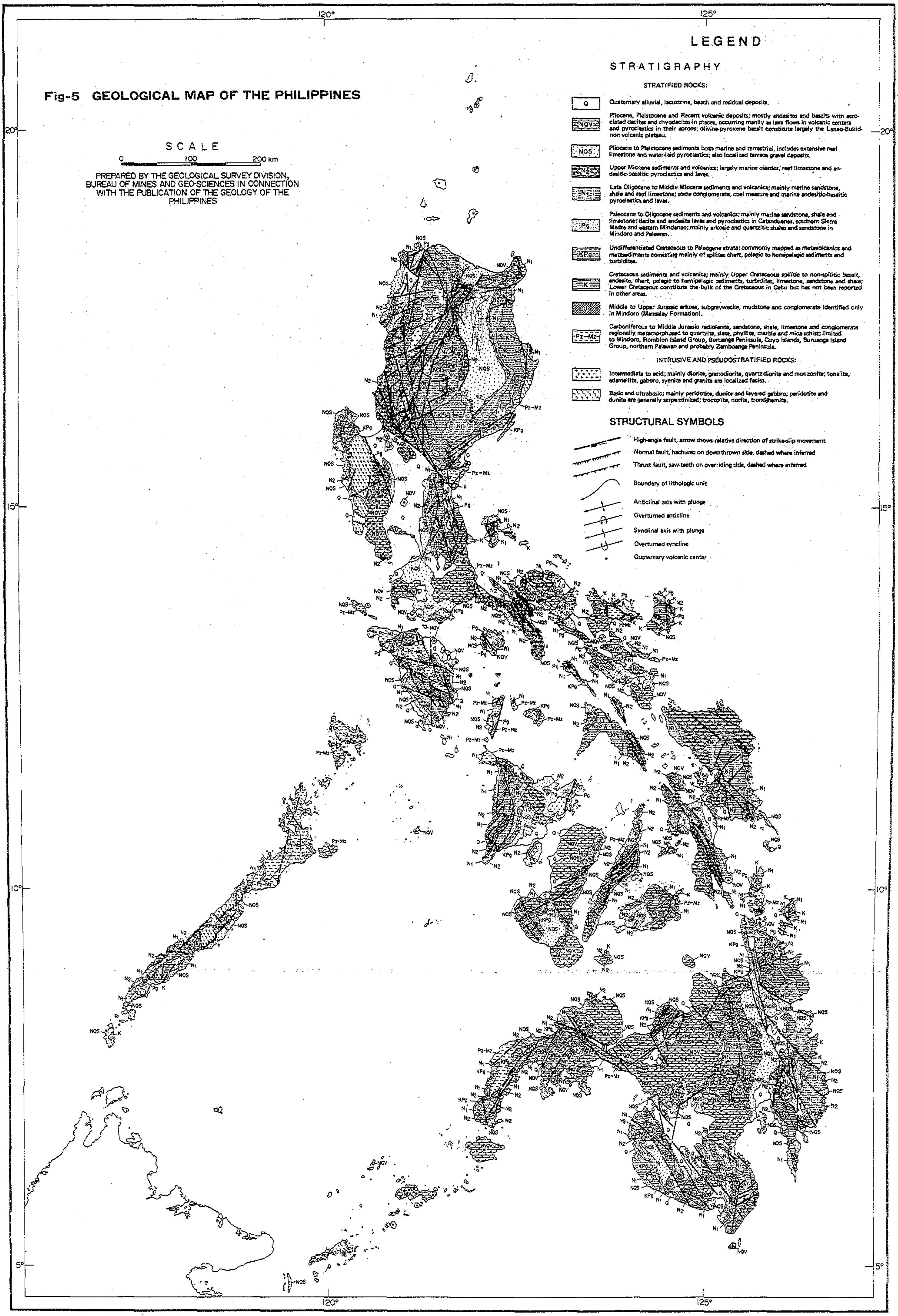


2-6-3 Bureau of Mines and Geo-Sciences

Fig-4 The Organizational Chart of Bureau of Mines and Geo-Sciences



CHAPTER 3. GEOLOGY AND METALLOGENESIS IN THE PHILIPPINES



(After Geology and Mineral Resources of the Philippines Vol. I, Bureau of Mines and Geo-Sciences, 1982)

Chapter 3. Geology and Metallogenesis in the Philippines

3-1 Physiography and Geology

3-1-1 Physiographic Province

The Philippines is an archipelago of 7,100 islands, between 5 and 22 degrees north latitudes, in the southwest margin of the Pacific. It is divisible into four major physiographic provinces (Fig-6)

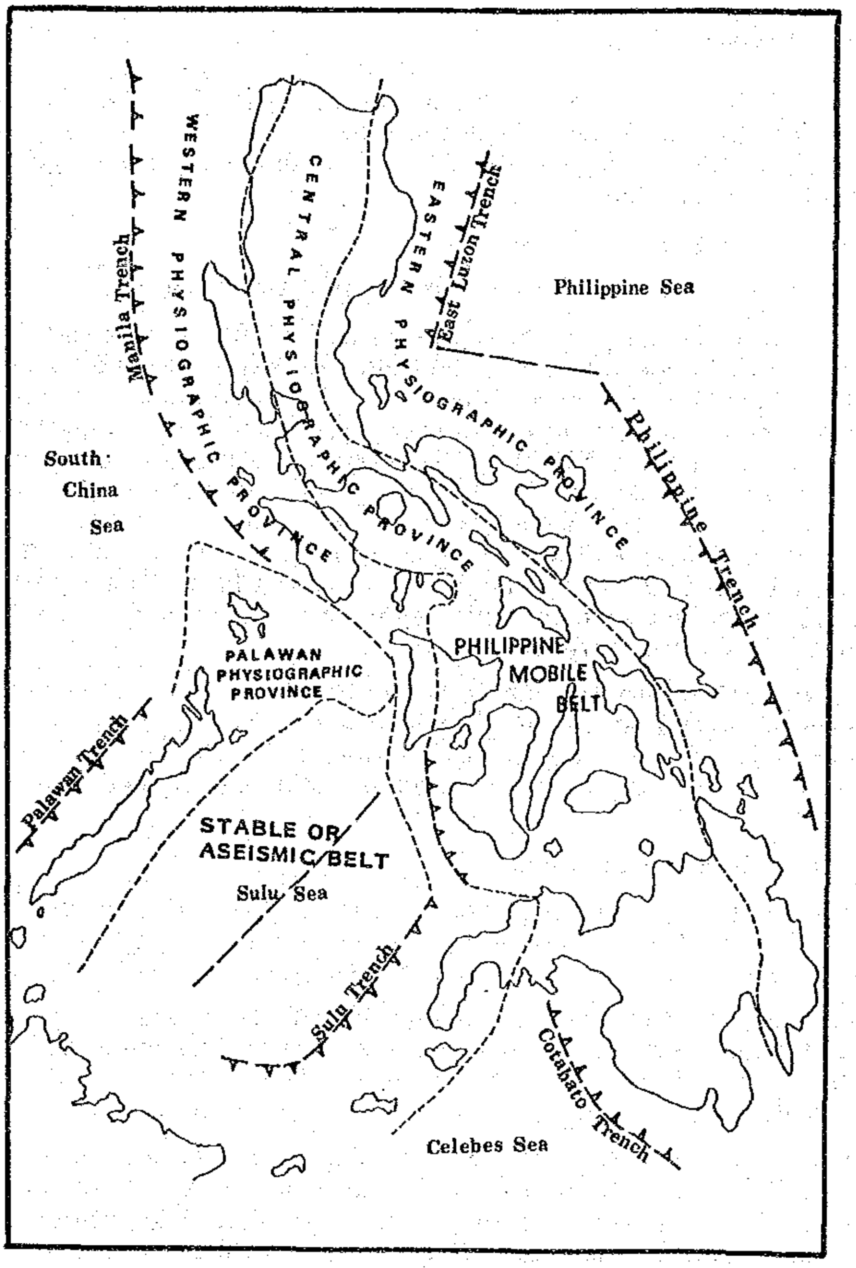


Fig-6 Major physiographic elements in the Philippines
(After G.R. Balce et al., 1981)

Palawan physiographic province and Sulu Sea comprise the "stable or aseismic belt" (Gervasio, 1966), while western, central and eastern physiographic provinces comprise the seismically active "Philippine mobile belt". The "Philippine mobile belt" is bounded on both sides by trenches, while the Palawan physiographic province is bounded on the northwest by the Palawan Trench.

(i) Palawan physiographic province — "Stable or Aseismic Belt"
(ii) Western physiographic province
(iii) Central physiographic province — "Philippine Mobile Belt"
(iv) Eastern physiographic province

3-1-2 Outline of Geology

Fig-5 is the geologic map of the Philippine archipelago, which is summarized and edited by Bureau of Mines and Geo-Sciences in 1982.

The following is the geologic outline of the Philippine archipelago based on Fig-5 according to each physiographic provinces.

(i) Palawan physiographic province

Palawan physiographic province is divisible into two subprovinces.

- The northern, comprising the northern half of Palawan Island, Busuanga Island Group and Cuyo Island Group, is underlain by Early Jurassic basement composed of Carboniferous to Early Jurassic (?) geosynclinal sediments regionally metamorphosed to the low-pressure greenschist facies and deformed mainly during Early Jurassic (Fig-7). This sequence is intruded by granitic plutons of unknown age represented by Kapoas granite in various portions of northern Palawan. In the Cuyo Island Group, the sequence is covered with the Cuyo volcanics of probable Pliocene age. Offshore, it is overlain unconformably by poorly deformed sediments ranging in age from Late Eocene to Recent. Middle Jurassic to Cretaceous continental sediments are probably present at the base of the poorly deformed cover (Fig-7).
- In great contrast to the northern sub-province, the southern sub-province of Palawan is composed mainly of a strongly deformed complex of ophiolite and Paleocene to Miocene marine to continental arkosic to quartzitic clastics and limestone. This complex is covered by thin undeformed Pliocene to Recent sediments.

(ii) Western physiographic province

The western physiographic province constitutes the belt of mountain ranges in the western side of the mobile belt. The mountain ranges are Ilocos, Zambales, Mindoro, western Panay and Zamboanga Peninsula.

- Ilocos Range is composed of a highly deformed complex of ophiolite, Paleogene turbidites and Lower to Middle Miocene basaltic volcanics and sediments. East dipping thrust faults of late Middle miocene age are very prominent. The undeformed cover ranges from Late Miocene to Recent.
- Zambales Range exposes the biggest single mass of ultramafic-mafic rocks as well as the most complete ophiolite sequence in the Philippines. A series of diabase dike complex, back-arc basin-type tholeiitic pillow basalt Hawkins, 1979), and pelagic sediments (Garrison et al., 1979) lie over the ultramafic-mafic mass in the north-western and eastern flanks of the range and constitute

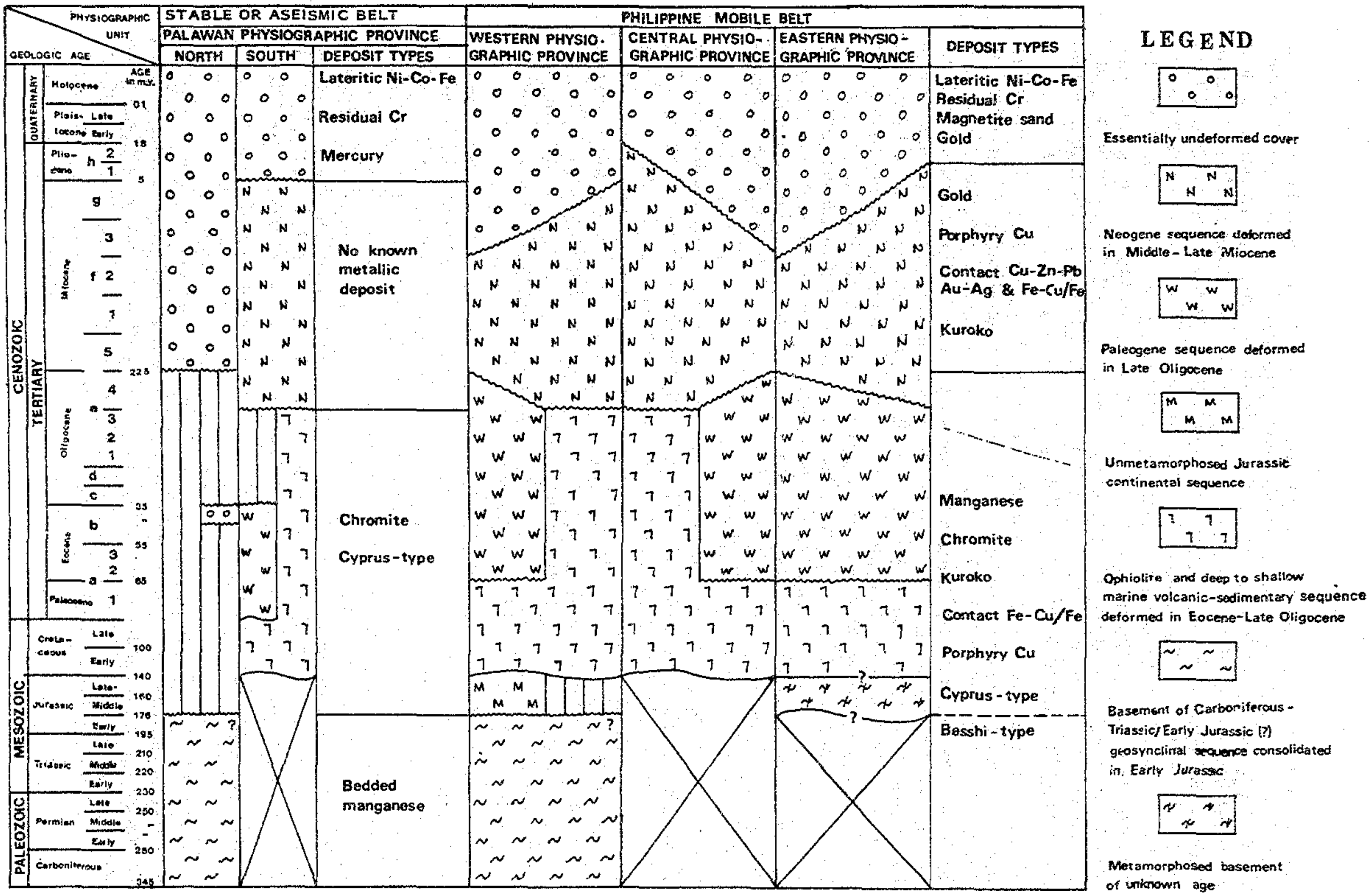


Fig-7 **Tectonostratigraphic Column and Distribution of Ore Deposit Types in The Philippines** (After G.R. Balce et al., 1981) the upper part of the ophiolite sequence. The age of the uppermost part, the Aksitero formation, is Late Eocene to Lower Oligocene. The sequence is intruded by felsic gabbro, quartz diorite and granodiorite plutons in the eastern and northwestern parts of the range. Lower Miocene to Middle Miocene clastic sediments, with large amounts of andesitic pyroclastic components and limestone, cover unconformably the ophiolite and the dioritic to granodioritic plutons. Middle-Late Miocene folding and thrusting are evident in both the eastern and western flanks of range. Undeformed Late Miocene to Quaternary sediments cover the western flank, while Quaternary andesitic pyroclastics and lava flows cover the eastern side. Andesitic to dacitic and rhyodacitic volcanic cones and plugs are also common in the eastern side.

- Mindoro Range has a core of Carboniferous to Early Jurassic (?) basement, overlain unconformably by Middle to Late Jurassic coastal deposits. An ophiolitic assemblage of chert, spilitic basalts, and basaltic wackes of probable Cretaceous to Paleocene age and large ultramafic masses are thrusted eastward against the basement. Quartzdiorite and granodiorite plutons intruding even the ultramafic rocks are distributed along the northwesterly axis of the mountain range. Limited Late Eocene to Late Oligocene limestone units cover unconformably the older rocks, including the granitic plutons. Early Miocene to Late Miocene clastic sediments and limestone skirt the southwestern half of the range. Intense Late Miocene folding of the basinal sediments is evident. Undeformed cover, limited to the range flanks, consists of Pliocene to Recent basaltic to andesitic terrestrial lavas and pyroclastics, tuffaceous shale and sandstone, terrace gravels, reel limiestone and alluvium.
- The western Panay Ranges include Buruanga Peninsula and Antique Range. Buruanga Peninsula is composed almost wholly of the Carboniferous to Early Jurassic continental-type basement. In contrast, Antique Range is composed of a highly deformed complex of Mesozoic to Oligocene ophiolite, overlain unconformably by Early-Middle Miocene reefal limestone and shallow marine clastics. The complex folding and thrust faulting evidently occurred in Late Miocene, when the blueschist-bearing melange, the Paniciuan formation, was emplaced. This tectonic activity was accompanied by limited andesite volcanism. The undeformed cover is Pliocene to Recent.
- Zamboanga Peninsula is similar in many respects to Mindoro, Metamorphosed geosynclinal rocks similar to the known Carboniferous-Early Jurassic basement in Mindoro, constitute the core. An ophiolitic assemblage of spilitic pillow basalts, chert and indurated greywackes, of probably Cretaceous to Paleocene age, and ultramafic rocks are thrusted westward against the basement core. These are overlain unconformably by Early Miocene to Late Miocene sedimentary and volcanic rocks which have been folded in Late Miocene. Intrusion of quartzdiorite and granodiorite plutons occurred sometime in Paleogene, and in Late Miocene. The undeformed cover is Pliocene to Recent.

(iii) Central physiographic province

The central physiographic province is a complex array of ranges and sedimentary basins with highly variable lithology and structure. The metallogenically important physiographic entities are Luzon Central Cordillera-Caraballo Range, Marinduque, Central Masbate-E. Panay-Guimaras Island-SW Negros Belt, Cebu, Bohol, Leyte, Mindanao Central Cordillera, Misamis-Bukidnon Highlands, Northern Zamboanga-Misamis Occidental Highlands and Daguma Range.

- Luzon Central Cordillera is a north-south trending mountain range at the center of northern Luzon. The northwestern portion merges with the Ilocos Range, along a Late Miocene zone of frontal arc-magmatic arc collision. South of this junction, the northern extension of Central Luzon Basin (Ilocos Basin) bounds the western side of the Cordillera. To the east, it is bounded by the Cagayan Basin and the Caraballo Range at the southeast.

  There is hardly any physiographic or geological demarcation between Luzon Central Cordillera and Caraballo Range. They are both composed of a core of probable Cretaceous to Eocene-Oligocene calc-alkaline metavolcanics and metasediments intruded in Oligocene to Early Miocene by synkinematic batholiths of quartzdiorite and granodiorite represented by Agno, Dupax and Palali batholiths (MMAJ-PBM, 1977; Balce, 1978). These rocks are covered unconformably with early Middle Miocene limestone and clastic sediments rich in volcanic facies. Stocks of calc-alkaline quartzdiorite porphyries were intruded in the later part of Middle Miocene in Luzon Central Cordillera. In Caraballo, highly alkaline analcite bearing basalts and pseudo-leucite bearing porphyries were emplaced in Middle Miocene (Baquiran, 1975; Palispis, 1979). Late Miocene to Pliocene strata composed largely of andesitic lavas, pyroclastics and conglomerate are essentially undeformed in the central part of the ranges but steeply tilted basinward on both flanks of the ranges.

- Marinduque Island, south of Luzon, consists of a core of Cretaceous to Eocene metavolcanic and metasedimentary rocks overlain unconformably by Late Oligocene to Early Miocene sediments. Folding along the NW-SE direction and synkinematic quartzdiorite plutonism occurred in Middle Miocene. Undeformed Late Miocene to Recent cover is limited to the western and eastern flanks of the island range. A Pliocene-Pleistocene volcanic cone is present at the southern tip of the island.

- Central Masbate, eastern Panay, Guimaras Island and southwestern Negros constitute a belt of Paleogene diorite-granodiorite batholiths (one K-Ar date: 59 m.y.) intruding presumably Cretaceous to Paleogene metavolcanics and metasediments. Offshore data show that the belt is actually a continuous ridge between the Tertiary Iloilo and Visayan Basins. The Cretaceous to Paleogene rocks are overlain unconformably by Late Oligocene to Middle Miocene clastics and limestone, slightly folded during Late Miocene and intruded by small stocks of quartzdiorite porphyry. Undeformed cover ranges from Late Miocene to Recent.

- Cebu Island, the site of the largest copper mine in Asia, is a NE trending geanticlinal ridge formed during a folding episode in Late Miocene to Pliocene. It became fully emergent since Late Pleistocene. The core is composed of Lower Cretaceous to Paleocene/Early Eocene basaltic to andesitic metavolcanics, metasediments, deep water to reefal limistone and quartzdiorite-granodiorite batholiths intruded in Paleocene to Early Eocene (one K-Ar date: 59 m.y.) These are overlain unconformably by Oligocene to Middle Miocene shallow marine clastics and limestone. Magmatism at the start of Middle Miocene deposited substantial amounts of andesite lavas and pyroclastics in the eastern part of the island. The plutonic equivalent is the Talamban diorite which intrudes Lower Miocene strata. Contemporaneous with Late Miocene-Pliocene geanticlinal development, shallow marine to terrestrial molasse was deposited on the eastern and western flanks of the island. The undeformed cover is mainly Pliocene to Pleistocene reef limestone.

- Bohol Island consists of two NE-NNE trending ridges formed in Late Miocene-Pliocene. The ridge at the islands northwestern edge is a geanticline with basically similar geology as Central Cebu. The ridge at the eastern edge was formed by westward thrusting. The core is composed of strongly foliated metamorphic rocks and serpentinized periodotite. These are thrusted against Lower-Middle Miocene sedimentary rocks. The undeformed cover consists mainly of Pliocene to Pleistocene limestone and lagoonal clastics.
- Leyte Island is divisible into two parts: northeastern and western. The northeastern part is underlain by thrusted slices of slightly to strongly foliated metamorphosed volcanic rocks, serpentinized periodotite and Lower to Middle Miocene sedimentary rocks. These are covered along the ridge flanks by undeformed Late Miocene-Pleistocene shallow marine to terrestrial deposits. The western part is a NW-SE folded belt of Early-Late Miocene sediments and volcanics. Late Miocene volcanic facies dominate in the eastern section where the Philippine Fault passes the fold belt longitudinally. Middle Miocene diorite and thrusted sheets of serpentinized periodotite are disposed in the southwestern section. Pliocene to Pleistocene lavas and pyroclastics constitute the undeformed cover. Andesitic volcanic cones are distributed along the belt where the Philippine Fault passes.
- Mindanao Central Cordillera, a N-S fold belt at the central part of Mindanao Island, is composed of Cretaceous-Paleogene ophiolitic core of mafic-ultramafic rocks, metabasalts, chert and turbiditic metagreywackes. In the northern part, strongly foliated greenschist with pronounced sedimentary structures are thrusted against the ophiolitic materials. Late Oligocene to Late Miocene sedimentary strata with intercalated andesitic volcanic and pyroclastic facies cover unconformably the ophiolitic rocks. Batholiths and stocks of Middle to Late Miocene quartzdiorite are distributed along the axis of the Cordillera. Pliocene to Pleistocene sedimentary rocks along the flanks of the Cordillera are moderately folded. The undeformed cover consists of Late Pleistocene to Recent basaltic to andesitic lavas, pyroclastics, alluvium and terrace gravels. Mount Apo, the highest peak in the Philippines, is at the central part of the Cordillera.
- The Misamis Oriental-Bukidnon Highlands is another metallogenically important region. It is composed of strongly folded Early to Late Miocene sedimentary and volcanic sequence, thrusted sheets of ultramafic rocks, Cretaceous-Paleogene metavolcanics/metasediments and Middle-Late Miocene diorite stocks. These rocks are covered unconformably by Pliocene-Pleistocene limestone and volcanic rocks including the extensive olivine basalt lavas and pyroclastics of the Lanao-Bukidnon plateau.
- The Northern Zamboanga-Misamis Occidental Highlands consist of folded sedimentary and volcanic deposits of Lower to Middle Miocene age. These are intruded by Middle Miocene quartzdiorite batholiths and stocks. Moderately folded Late Miocene to Pliocene undeformed sedimentary cover includes Plio-Pleistocene reef limestone and andesitic lavas and pyroclastics extruded by numerous volcanic cones.
- Daguma Range is a NW-SE trending mountain range transverse the N-S and NE-SW trends of other ranges in Mindanao. It is composed mainly of Cretaceous to Eocene metavolcanics and metasediments overlain unconformably by Early Oligocene to Early Miocene sedimentary rocks. These are intruded by pre-Middle Miocene diorite. Along the northeastern and eastern flanks of the range, folded Middle to Late Miocene rocks are intruded by quartzdiorite batholiths. Slightly

deformed Pliocene-Pleistocene limestone covers the central part of the range. Towards Cotabato Basin, at the northeastern side of the range, Pliocene-Pleistocene sediments are moderately folded. Pleistocene andesite lavas and pyroclastics underlie the volcanic cones in the northwestern part of the range.

(iv) Eastern physiographic province

This physiographic province covers the belt of mountain ranges at the eastern edge of the archipelago, facing the Pacific. It includes Northern Sierra Madre, Southern Sierra Madre, Polillo Island Group, Bicol Peninsula-Catanduances, Samar Island, and the Eastern Mindanao Ranges.

- Northern Sierra Madre in the northeastern seaboard of Luzon Island, is divisible into two parallel belts. The eastern belt is composed of upthrusted masses of ultramafic-mafic rocks, plagioclase-hornblende amphibolite and greenschists derived from well-bedded Cretaceous to Early Eocene pelagic clastics, chert, limestone and interbedded basaltic volcanics (Hashimoto et al., 1978). These are intruded by plagiogranites in the southern portion. Unmetamorphosed equivalent of the rocks converted to greenschist are present in the western part of the belt where they are overlain unconformably by andesitic lavas and pyroclastics with fragments of Oligocene-Early Miocene limestone. The western belt is composed of the essentially unmetamorphosed Cretaceous to Eocene sequence, with significant horizons of manganese and stratiform sulfide deposits. This is intruded by synkinematic batholiths of gabbro, tonalite and granodiorite ranging in age from Eocene to Oligocene (K-Ar ages: 27-49 m.y., MMAJ-PBM, 1977). Oligocene to Middle Miocene clastic sediments, limestone and volcanic rocks deposited in the Cagayan Basin compose the western flank of the range. These basinal deposits are steeply tilted and occur even at 1,500-meter elevations. Undeformed Early-Middle Miocene limestone and clastic sediments cover the ultramafic rocks of the eastern belt. An andesitic Quaternary volcanic cone covers the folded Miocene rocks in the northern tip of the range.
- Southern Sierra Madre has basically similar geology as Luzon Central Cordillera. Late Cretaceous metavolcanics, turbiditic metasediments and limestone, overlain ungreater portion. These are intruded by batholiths of Oligocene diorite (K-Ar age: 36 m.y., Wolfe, 1972). Folded Late Oligocene to Middle Miocene limestone, clastics and volcanics are present along the western flank as well as the central highlands. These are intruded by Middle Miocene diorite (Antonio, 1967). The undeformed cover ranges from Late Miocene to Pleistocene consisting mainly of conglomerate and volcanics. The southern part of the range is covered with basaltic to andesitic lava flows and thick sub-terrestrial pyroclastics related to volcanic centers in the Laguna Lake, Mt. Makiling and Mt. Banahaw.
- Polillo Island Group, east of Southern Sierra Madre, has a basement of metavolcanics and metasediments and small thrusted bodies of serpentinite and mica schists. This is intruded by diorite, which is assigned an Early Eocene age because it is unconformably overlain by Late Eocene-Early Oligocene clastic sediments and limestone. Folded Late Oligocene-Middle Miocene sediments with few intercalated pyroclastics underlie the eastern portion of the main island. The other islands to the east, except Jomalig Island, are underlain by only slightly folded Late Miocene-Pliocene sediments. Jomalig Island is underlain presumably by Cretaceous volcanics. The undeformed cover is maily reefal limestone of Pliocene-Pleistocene age.
- Bicol Peninsula-Catanduanes is composed of three distinct physiographic units: (1) Eastern Bicol Ranges, (2) Bicol Basin and (3) Western Bicol Ranges.

Eastern and Western Bicol Ranges merge in a thrusted junction at the northern end of the peninsula. The northeast ranges include the Caramoan Peninsula and the Paracale-Larap Highlands in northeastern Camarines Norte. These are composed of thrusted slices of greenschists, ultramafic rocks and essentially unmetamorphosed volcanics, clastic sediments and limestone of Late Cretaceous to Eocene age. The greenschists are derived from well-stratified sequences of basaltic volcanics, clastic sediments, chert and limestone of unknown age. These rocks are overlain unconformably by folded Oligocene to Early Miocene sediments and volcanics which are intruded by presumably Middle Miocene diorite as represented by the Tamisan diorite in Camarines Norte. The Paracale diorite-granodiorite batholith which yielded a Middle Miocene K-Ar age (16 m.y.), could actually be Paleogene in age as estimated by Miranda (1977) on the basis of granodioritic pebble occurrences in the Late Eocene Universal formation near the batholith. Towards Bicol Basin are folded Late Miocene to Pliocene sediments with abundant volcanic facies. The undeformed cover includes Pleistocene volcanics from several volcanic cones between Bicol Basin and the Eastern Ranges, and Quaternary alluvium.

Bicol Basin is underlain by folded Early Miocene to Pliocene sedimentary strata with occasional volcanic interbeds. These are covered by undeformed Pleistocene to Recent alluvium and volcanic rocks. The Western Bicol Ranges have practically the same geology as the Eastern Ranges except for the absence of extensive metamorphic rock exposures.

- Samar Island has a core of Late Cretaceous metavolcanics and metasediments with occasional manganiferous beds and chert, and thrusted masses of ultramafic-mafic rocks. These are intruded by Paleogene diorite overlain unconformably by essentially undeformed Early Miocene limestone and clastic sediments. At the central part of the island are extensive deposits of Middle Miocene dacitic and andesitic lavas and pyroclastics containing kuroko-type deposits. Late Miocene to Pliocene clastics and limestone are distributed widely in the northern, eastern and western sides of the Island. These rocks are highly folded in the western part, a downthrown block towards the Visayan Basin.

- The Eastern Mindanao Ranges is divisible into a northern and southern parts. The northern part covers Dinagat and neighboring islands which is composed mainly of upthrusted ultramafic-mafic rocks and Cretaceous-Paleogene (?) metasediments and basaltic metavolcanics apparently constituting the upper member of an ophiolite sequence. Eocene clastics, containing serpentinized periodotite pebbles (Santos-Yñigo and Esguerra, 1961), and limestone occur also as thrusted slices together with the Cretaceous-Paleogene rocks and ultramafic-mafic rocks. Occasional slivers of greenschists, some containing glaucophane (Santos-Yñigo, personal comm., 1980), are thrusted against the ultramafic-mafic rocks. Strongly folded Early-Mddle Miocene clastics and limestone complete the thrusted-folded sequence which is intruded by Middle to Late Miocene quartz-diorite, andesite and dacite. The undeformed cover consists mainly of Pliocene to Pleistocene andesitic volcanics/pyroclastics, conglomerates and reef limestone.

- The southern part of the Eastern Mindanao Ranges has practically the same geology as the northern part (MMAJ-PBM, 1972). However, unlike the northern part the thrusted ophiolite zone is in the western part, i.e., in the Pujada Peninsula. Hornblende-garnet-amphibolite schist is found as thrusted slices in the ultramafic mass at Pujada Peninsula. Middle Miocene diorite-granodiorite batholiths and stocks are more widely exposed in this part of the ranges.

3-2 Tectonic Setting

3-2-1 Crustal Evolution

Stratigraphic and structural information allows to subdivide the relevant geologic time into five (5) major geohistorical episodes (G.R. Balce et al., 1985, manuscript): (i) Carboniferous to Early Jurassic (345 m.y. - 175 m.y.); (ii) Middle Jurassic to Early Eocene (175 m.y. - 46 m.y.); (iii) Late Eocene to Early Oligocene (46 m.y. - 32 m.y.); (iv) Late Oligocene to Middle Miocene (32 m.y. - 11.5 m.y.); and (v) Late Miocene to Recent (11.5 m.y. - present). The boundaries of these episodes are correlated with structural, paleomagnetic and other tectonic information to formulate a total picture of the archipelago's geohistory.

(i) Carboniferous to Early Jurassic Period

The Carboniferous-Early Jurassic (?) or basement stage period covers the mainly miogeosynclinal deposits in the Reed Banks, the northern segment of Palawan physiographic province, Mindoro, Romblon Island Group, Buruanga Peninsula and possibly Zamboanga Peninsula. This consists of presumably Carboniferous (Reyes, 1969; Easton and Melendries, 1963), Permian-Late Triassic (Hashimoto and Sato, 1968 & 1973) and possible Early Jurassic (Fontaine et al., 1979) sedimentary sequences that have been metamorphosed to low pressure greenschist facies and converted to continental-type basement before Middle Jurassic. Probably pre-Middle Jurassic granitic rocks in Palawan and Mindoro (Andal and Caagusan, 1967) are also included.

These areas significantly surround the Sulu Sea. It can be speculated that they were once a part of one continental mass.

Formation of the oldest rock units occurred at a proto-southern China margin before Middle Jurassic and by Late Jurassic, these rock units were consolidated into a continental crust (G.R. Balce et al., 1985, manuscript).

(ii) Middle Jurassic to Early Eocene Period

The Middle Jurassic-Early Focene period covers a wide variety of lighologies and depositional environments, but ophiolites occupy a major lithologic type. This includes the near-shore to continental deposit over a Middle Jurassic continental platform as represented by Mansalay formation in Mindoro; the non-ophiolitic deep to shallow marine basaltic to andesitic volcanics, limestone and clastic rocks of Early Cretaceous to Paleocene in Central Visayas and Central Mindanao.

The ammonite-bearing Mansalay formation was deposited in a continental shelf environment. The continental shelf faced to the east a Mesozoic ocean, with a west-dipping subduction zone bounding the continental and oceanic crusts.

During Late Cretaceous, up to probably the Paleocene, an island arc system existed southeast of the China Continental Margin (G.R. Balce et al., 1985, manuscript). This includes Cebu, Sulu Archipelago and eastern Borneo. Northwestward subduction produced the cretaceous (?) granitic intrusives in Central Cebu and Eastern Borneo and the Paleocene to Oligocene dioritic-granodioritic batholiths in the mobile belt.

(iii) Late Eocene to Early Oligocene Period

The Eocene to Oligocene archipelagic basinal deposits with occasional coal measures are widespread in the Philippine mobile belt and southern Palawan.

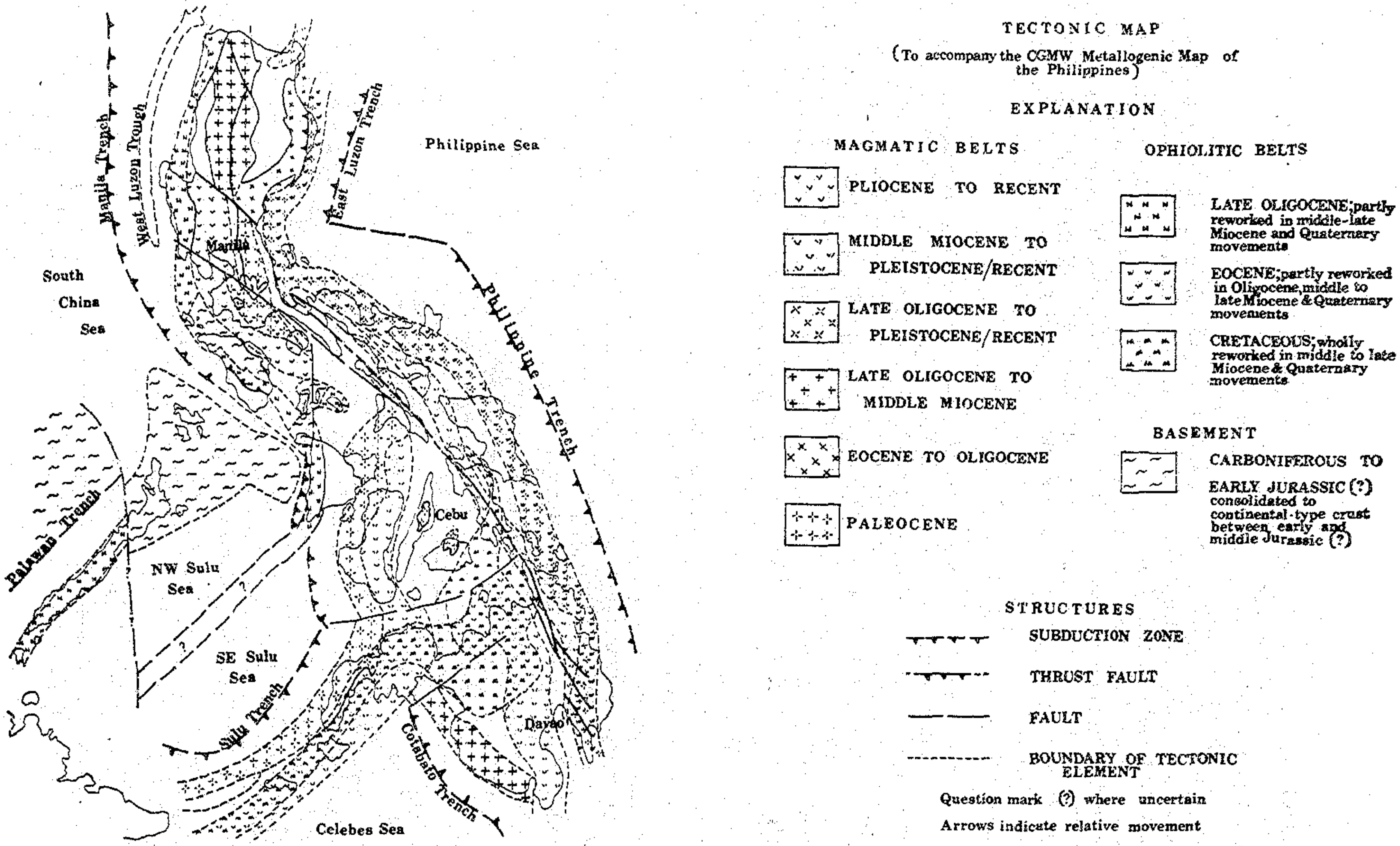


Fig-8 Tectonic Map of The Philippines
(After G.R. Balce et al., 1981)

Continued subduction along this Cebu-Borneo Margin resulted in the opening of Sulu Sea which extended up to Zambales during the Eocene to Early Oligocene time. The Celebes Sea also opened during the Eocene as a result of another northwestward subduction south of the northern arm of Sulawesi and southeast of Davao del Sur and Cotabato. An arc which includes eastern Mindanao and Bicol Peninsula was developing at this time further to the east, concomittant with formation by sea-floor spreading of the West Philippine Sea.

Dioritic-granodioritic batholith activities, continued from above-poeriod, occurred in the mobile belt to Oligocene.

(iv) Late Oligocene to Middle Miocene Period

The Late Oligocene/Early Miocene-Late Miocene/Pliocene period includes mainly archipelagic basinal deposits of the period, large amount of volcanic and pyroclastic rocks and dioritic-granodioritic batholiths and stocks formed mainly in Middle to Late Miocene. The broad time boundaries of this period are reflective of the characteristically variable position of unconformities in archipelagic or island arc environments. The close of this period marks the latest stage of folding of the upper crustal material in the Philippines.

Cessation of spreading in West Philippine, Celebes and Sulu Seas gave way to extension of the continental crust in the South China Margin. Thus the South China Sea was formed by sea-floor spreading from Late Oligocene to Middle Miocene. Westward push due to continued opening of the Pacific Ocean, brought the greater part of the Philippines into collision with the southward moving continental block comprising Northern Palawan, Reed Banks and Mindoro. Eastward subduction along Central Luzon to the northwest side of Sulu Archipelago provided relief to this collision movement up to Middle Miocene. By Late Miocene the eastward subduction jumped to the Manila Trench which had earlier acted as the transform fault border of South China Sea (G.R. Balce et al., 1985, manuscript).

(v) Late Miocene to Recent Period

The Late Miocene/Pliocene-Recent period is represented by the undeformed cover. It includes the widely distributed lava flows and pyroclastics in the volcanic cones and their immediate vicinities in the mobile belt. These Late Miocene-Recent volcanic rocks are mainly andesitic but basaltic and rhyolitic facies are also present here and there. The olivine basalt mantle of the Bukidnon Plateau, in central Mindanao, is notable. Also included in this tectonic stage are the widespread reefal limestone deposits in Central Visayas and many of the coastal areas in the archipelago.

From Late Miocene to Recent, only little changes in the configuration of the archipelago happened. The major loci of movements were the Philippine fault, the Manila Trench, the Philippine Trench and Negros-Sulu Trench. Westward subduction along the Davao-Agusan Trough continued from the earlier periods to the present, thus preserving a subducting slab down to 700 hundred kilometers beneath western Mindanao and Celebes Sea. Subduction along Cotobato Trench was initiated probably in the Pliocene or early Pleistocene.

Fig-9 is a schematic model of the tectonic evolution of the Central Valley Basin of Luzon that has been recently proposed by A.S. Zanoria et. al., 1984.

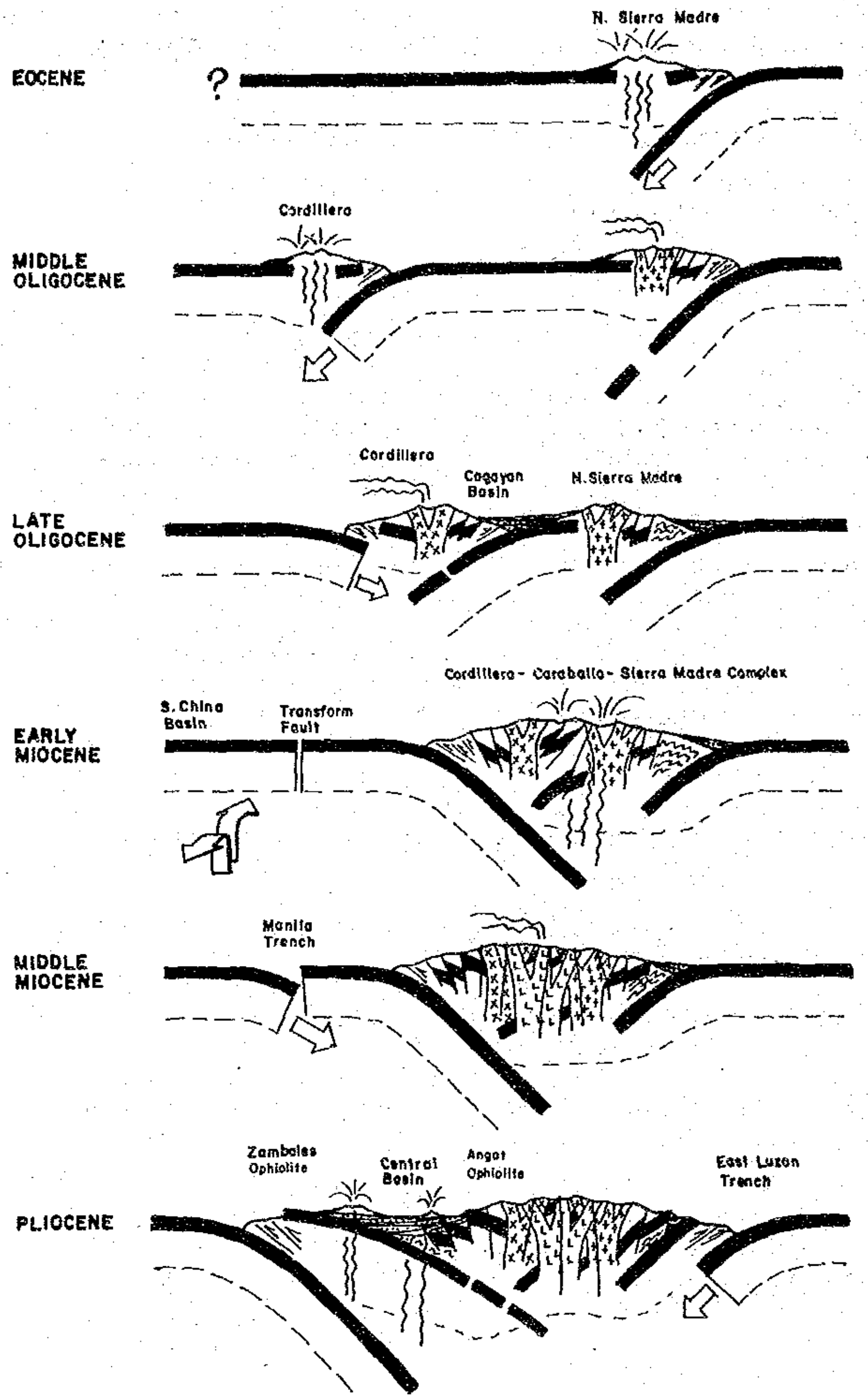


Fig-9 Schematic Model of the Tectonic Evolution of Luzon
(After A.S. Zanoria et al., 1984)

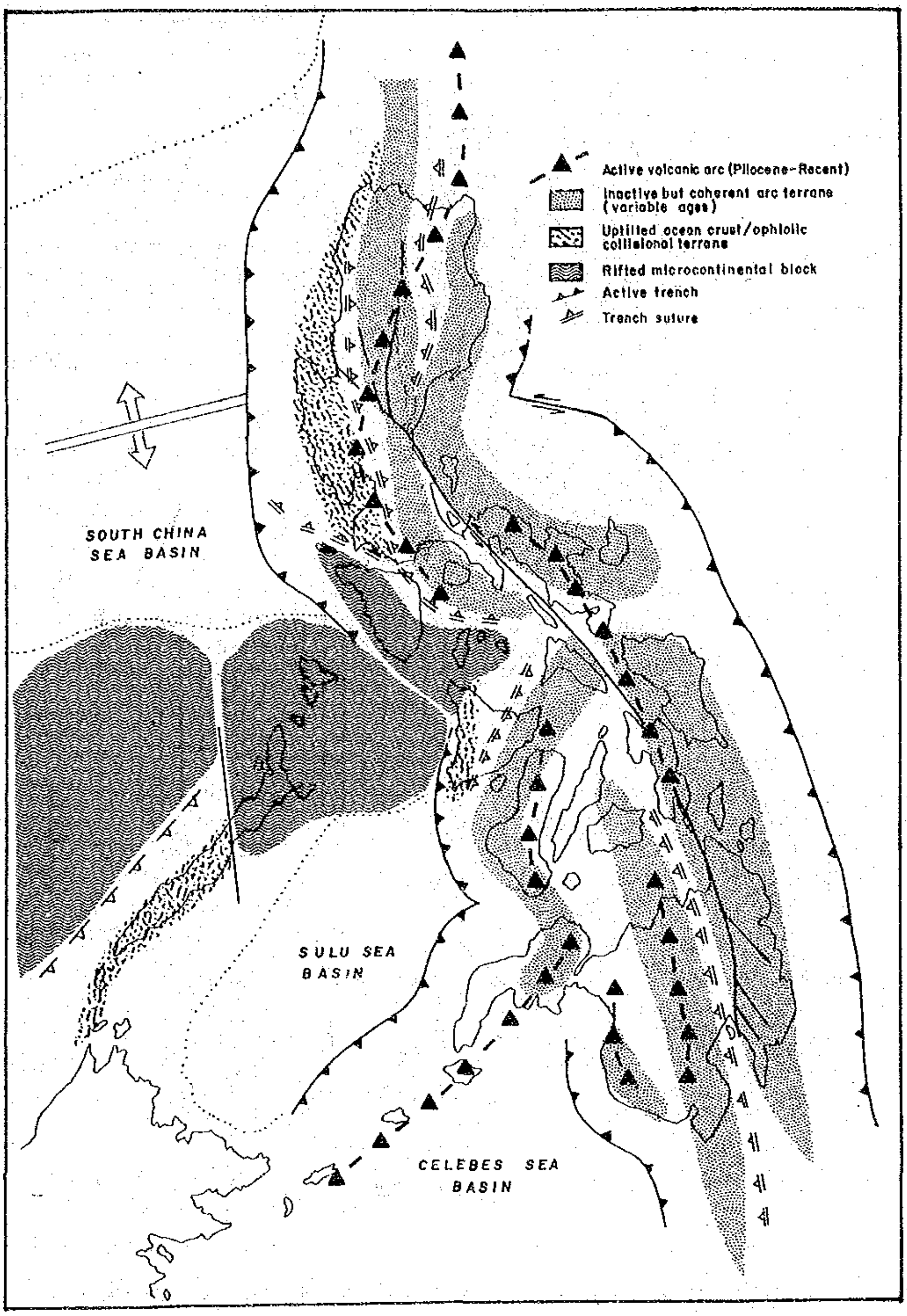


Fig-10 Tectonic Terranes of The Philippines
(After A.S. Zanoria et al., 1984)

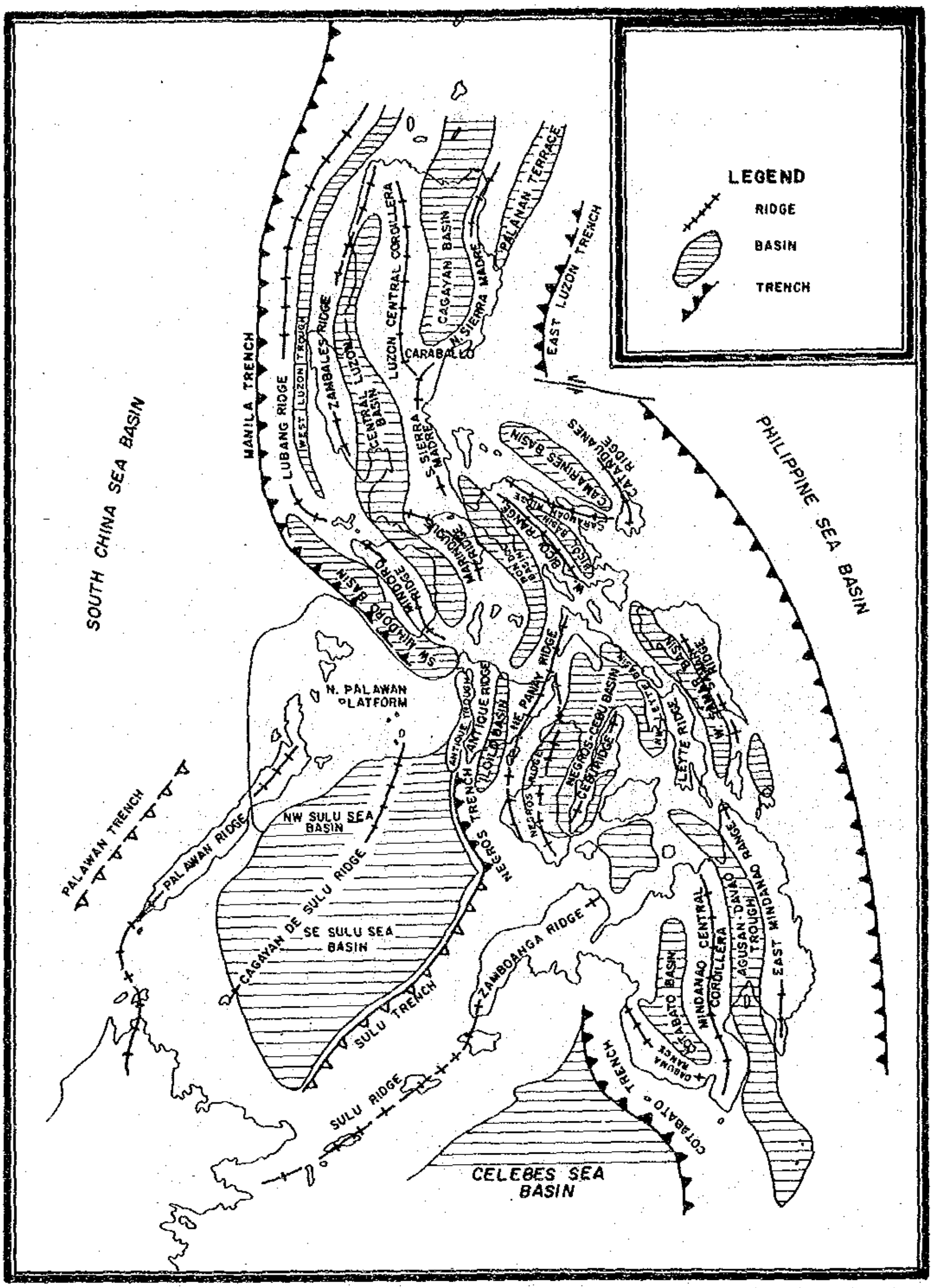


Fig-11 **Ridge and Basin Structure of The Philippines**
(After A.S. Zanoria et al., 1984)

3-2-2 Tectonic Terranes

The Philippines is an amalgamation of various crustal terranes (magmatic arcs, ophiolites, microcontinents) that have coalesced in response to complex and rapidly changing interaction between converging megaplates--three convergent megaplates: the Eurasian Plate in the west; the Philippine Sea Plate in the east; and the Indo-Australian Plate in the south—since the Mesozoic (Fig-10).

Several sets of collided magmatic arcs and trench sutures are interpreted from structural ridges and basins which define the archipelago.

The Philippine archipelago is structurally defined by a series of sub-parallel alternating ridges and basins (Fig-11) that generally follow the trends of adjacent trenches (Balce and Zanoria, 1980). The ridges are geologically varied in nature. These are generally made up of: (a) Plio-Pleistocene volcanic centers whose origins are attributable to the subduction in the adjacent trenches; (b) dioritic stocks and batholiths that have intruded into a generally undifferentiated but predominantly ophiolitic basement; (c) ophiolite blocks; (d) melange; (e) metamorphic massifs and (f) folded sediments.

The basins that separate these ridges are commonly elongated in form and thickly sedimented. However, the structural origins of most of these basins, and their relationship to the adjacent ridges are little understood in most cases.

(i) Ophiolitic terranes

Ophiolitic terranes are interpreted to be the fragments of oceanic crust formed from the magmatic differentiation of upper mantle material at midocean spreading regions. In the Philippines, ophiolites commonly form the primary basement upon which magmatic arcs formed by the subduction process were built up. However, in this setting they are rarely coherent and has generally undergone complex structural deformation and varying degrees of metamorphism. They are commonly referred to as "undifferentiated Cretaceous-Paleogene basement complex" in the literature. The ophiolitic origin of the basement is unmistakable, however, as evidenced by the common association of greenschist-metamorphosed pillow basalts with intercalated deep marine sediments and occasional gabbros and serpentinites. These ophiolitic materials are sometimes tectonically mixed with coarse volcanolithic sediments, pyroclastics and shallow marine clastics that probably represent earlier stages in the development of the island arcs.

A rare example of an essentially coherent oceanic slab exposed on land is the Zambales ophiolite (Fig-12). A complete and continuous sequence from pillow basalts to metamorphic harzburgite is clearly traceable across the section of the ophiolite (Evans and Hawkins, 1982). This extraordinary preservation of the oceanic slab may be attributed to the unique manner of its emplacement related to the suturing of the Central Basin Trench in the east and the initiation of the Manila Trench in the west. The combined effect of downtilting on one side and uplifting on the other may have been a major factor in the unique trapping and preservation of the ophiolite slab.

Another setting for ophiolitic terranes are in the areas of apparently recent colllision. The best examples of this are the Southern Palawan and Antique Regions (Fig-13), both of which are in the zone of collision with the rifted Reed Bank-North Palawan micro-continental blocks (Hamilton, 1979; McCabe, 1982).

(ii) Metamorphic terranes

Metamorphic terranes in the Philippines are differentiated into two types: Pre-Jurassic continental metamorphics, and Post-Jurassic island arc metamorphics (Fig-14).

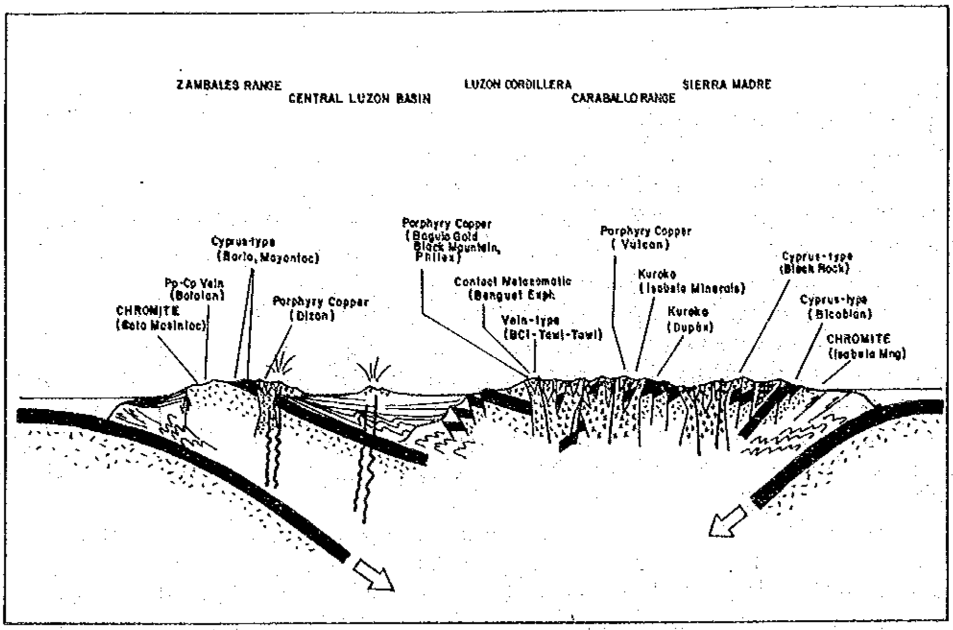


Fig-12 Tectonic Section Across Luzon
(After A.S. Zanoria et al., 1984)

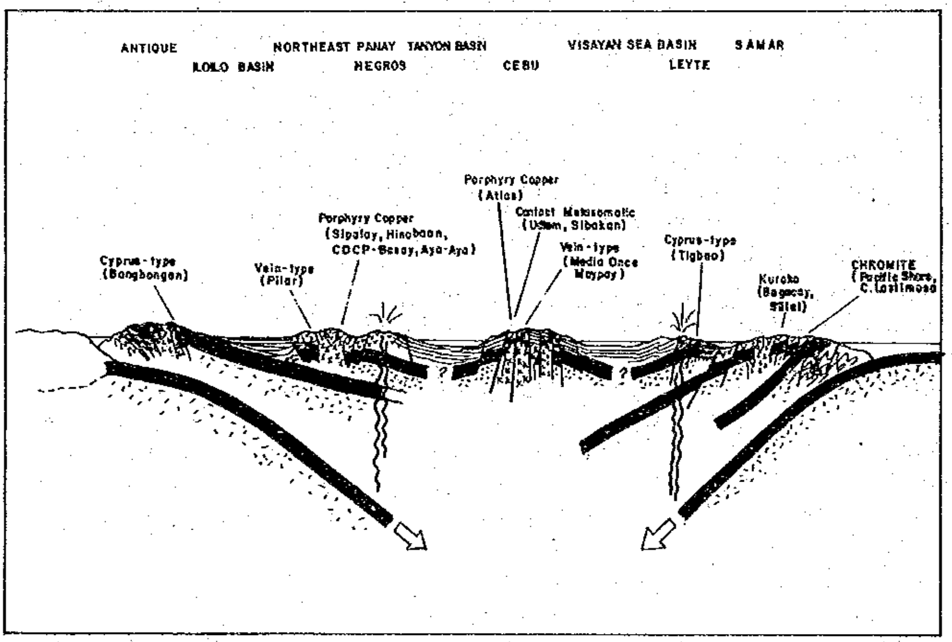


Fig-13 Tectonic Section Across North Palawan-Visayas Region
(After A.S. Zanoria et al., 1984)

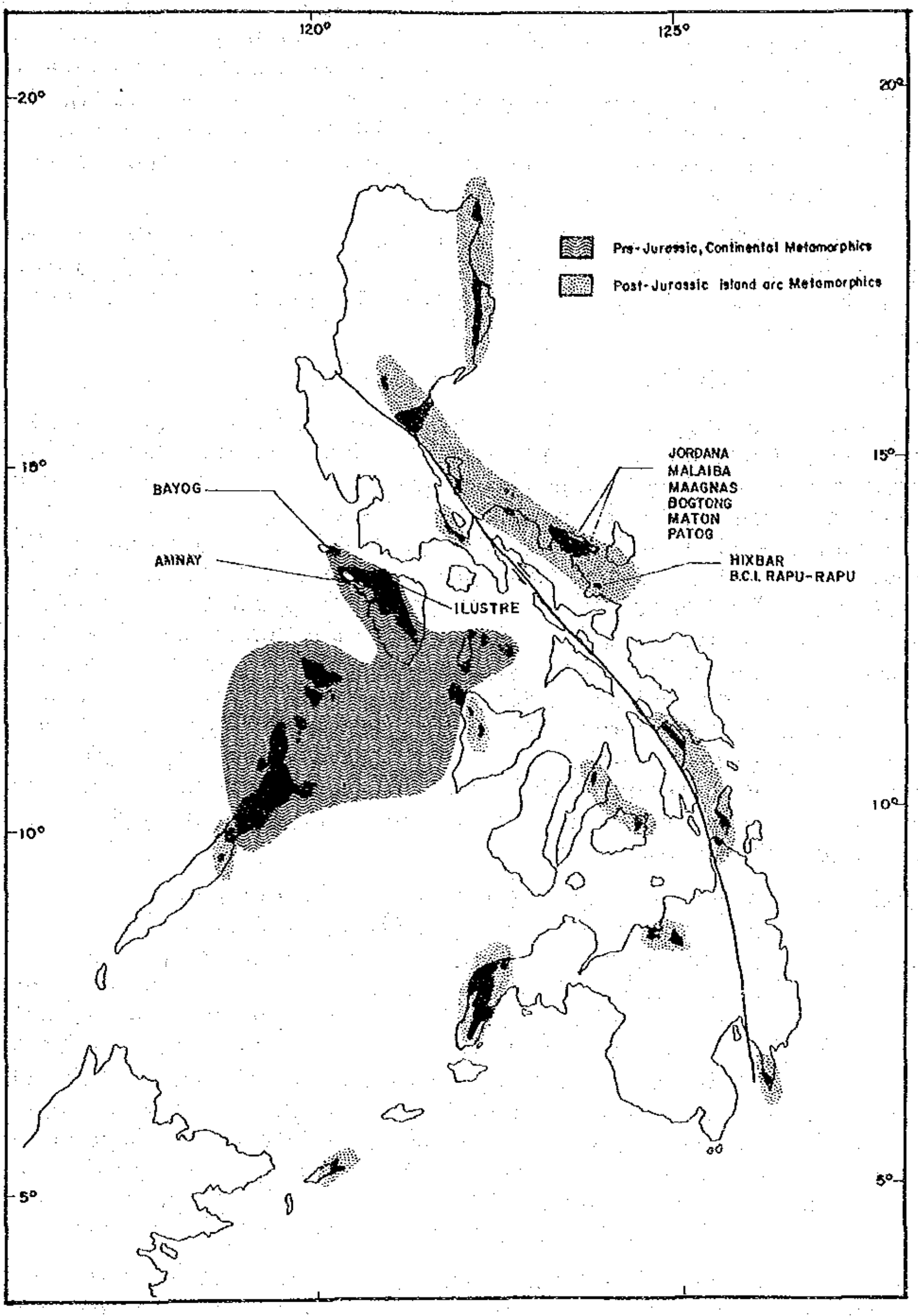


Fig-14 Metamorphic Terranes and Associated Besshi-type Copper Deposits (After A.S. Zanoria et al., 1984)

The first type is best represented by the metamorphic terranes that make up the Reed Banks, North Palawan and Mindoro. These have been shown to be continental blocks drifted away from mainland Asia during the sea floor spreading of the South China Sea Basin during 32-17 m.y.b.p. (Taylor and Hayes, 1980). This type is distinctly characterized by its association with the oldest rocks in the Philippines, its silica-rich composition and its contiguity over a restricted area situated adjacent to the South China Sea Basin.

The second type of metamorphic terranes occur in smaller patches throughout the islands. Their compositions are suggestive of basic to ultrabasic protoliths. Their origin is likely related to deeper sections of old island arcs or to regions of fromer collision.

(iii) Magmatic Arc (Dioritic) terranes

The occurrence of magmatic arcs that are not correlatable in space or time with the active subduction zones are direct indications that the evolution of the archipelago has involved older island arcs systems that have since coalesced together and upon which new magmatic arcs are superimposed. Based on stratigraphic and available radiometric dating (mostly from Luzon), of these dioritic intrusives, several sets of magmatic arcs have been delineated. The delineation is however generalized in nature and may be highly speculative in some parts because of the weakness of available data. It should be mentioned that since the framework of analysis recognizes that these magmatic arcs may have originated from separate and independent subduction systems before their coalescene into the present geography, their corresponding episodes of magmatism may be overlapping. There is no need in trying to define distinct time boundaries applicable for the entire archipelago. It is more important to define better the time range of magmatic activity in each locality so that distinct belts can be identified and the effect of overprinting is differentiated.

The oldest dated dioritic intrusive (Fig-15) is the Lutopan diorite of Cebu which, from most recent radiometric studies, yielded a late Early Cretaceous age (Walther et al., 1981). This intrusive is correlated with similar diorite bodies in northern Bohol (Zanoria et al., 1984). However, the polarity of subduction related to this magmatism is unknown and may be difficult to ascertain due to obliteration of possible indicators. The diorites in northern Sierra Madre have K-Ar ages ranging from early Eocene to early Oligocene (Wolfe, 1981). The age of this terrane makes it distinct from the Luzon Central Cordillera diorites (Late Oligocene-Middle Miocene) and suggests a possible tectonic boundary in the Cagayan Valley Basin that separates the two arc terranes. In the Southern Sierra Madre, a Cretaceous arc has been postulated by Karig (1982), behind which the Late Cretaceous Angat Ophiolite is believed to have formed in a back-arc spreading regime.

Oligocene and Miocene dioritic intrusives are more extensive and make up distinct belts throughout the archipelago (Fig-16). The age of the extensive belt of diorites in the Luzon Central Cordillera is well constrained by stratigraphic and radiometric evidence to range from middle Oligocene to late Miocene. It continues southward to include the intrusives in the Southern Sierra Madre, Batangas and Marinduque Island (Wolfe, 1981), where it terminates against the nose of the North Palawan-Mindoro continental basement.

The diorites in southwestern Negros have been radiometrically determined to be of middle Oligocene age. This correlates with the stratigraphic ages of the diorites in

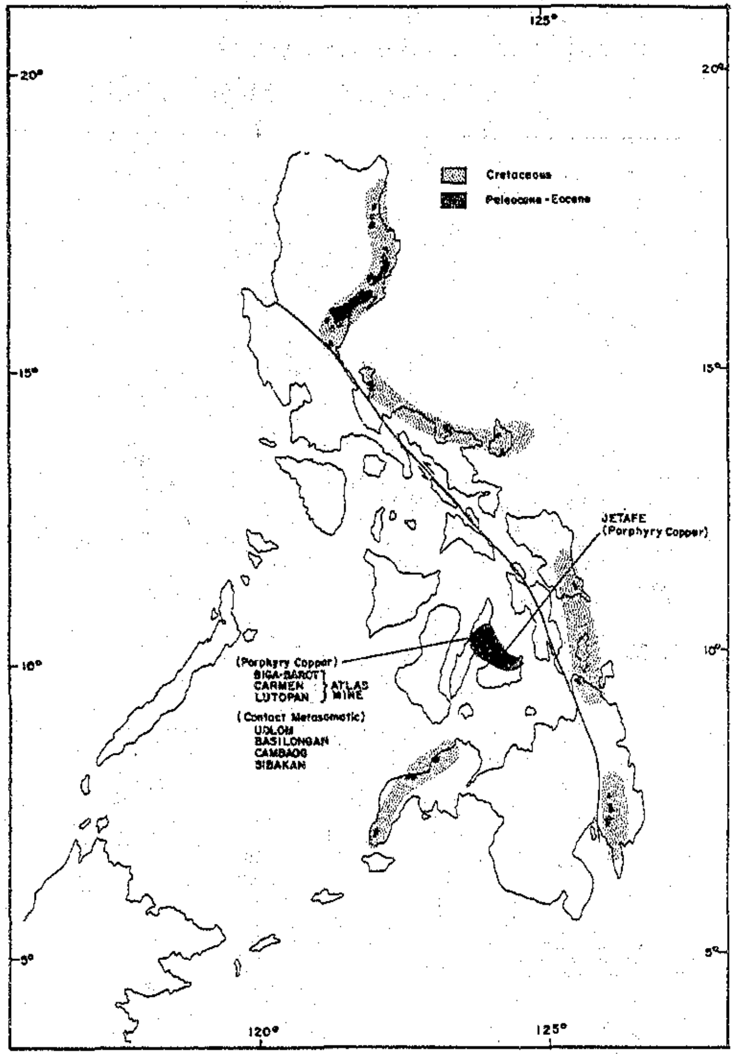


Fig-15 Cretaceous-Paleogene Dioritic Intrusives and Associated Copper Deposits
(After A.S. Zanoria et al., 1984)

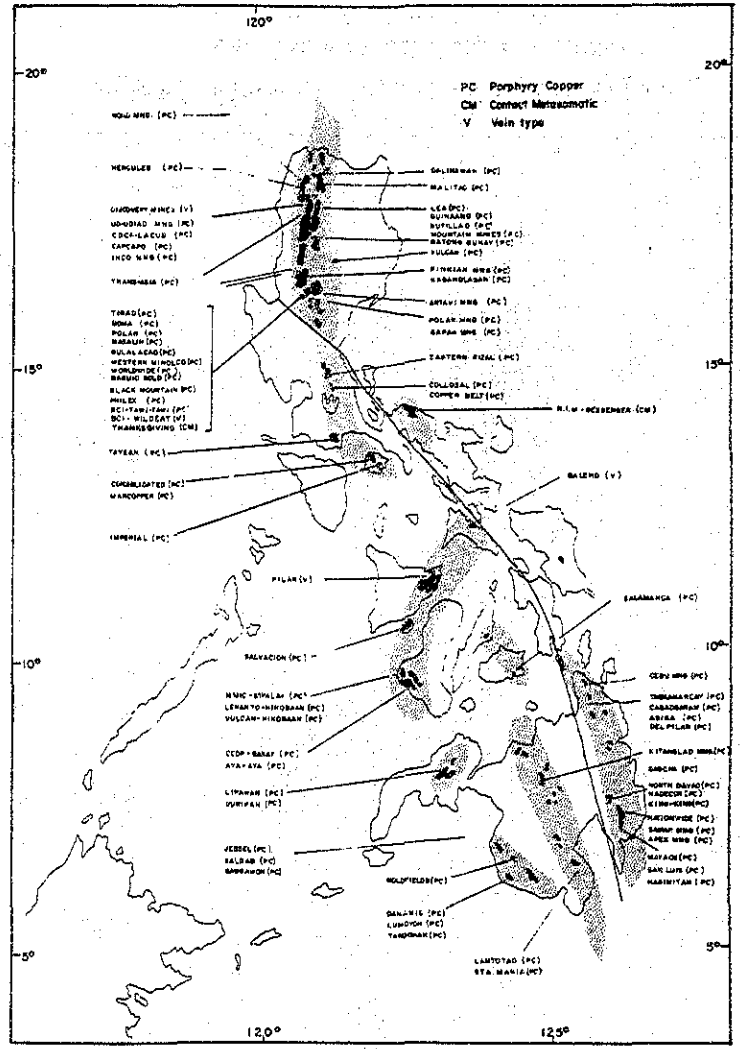


Fig-16 Oligocene-Miocene Dioritic Intrusives and Associated Copper Deposits
(After A.S. Zanoria et al., 1984)

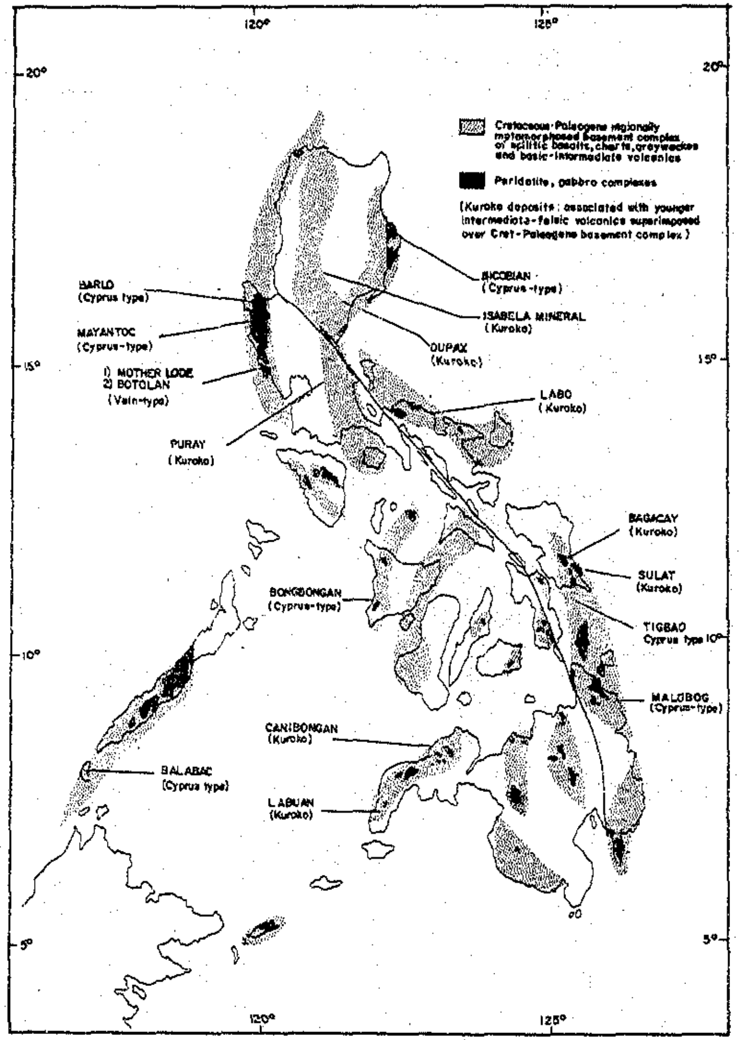


Fig-17 Ophiolitic Terranes and Associated Copper Deposits
(After A.S. Zanoria et al., 1984)

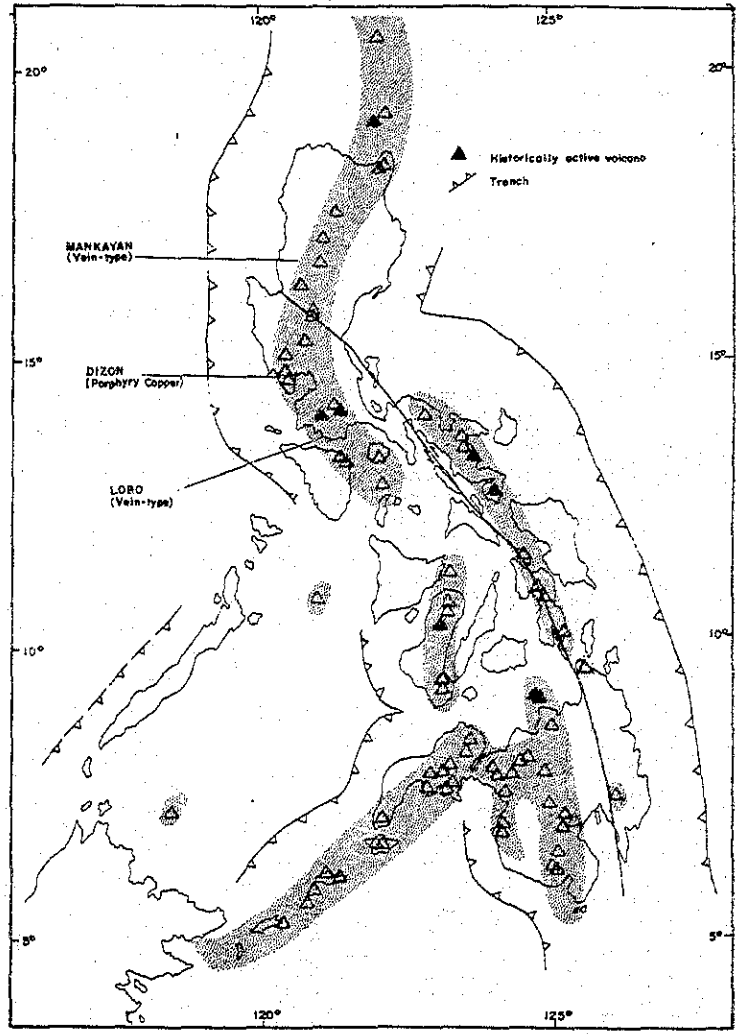


Fig-18 Pliocene-Recent Volcanic Centers and Associated Copper Deposits
(After A.S. Zanoria et al., 1984)

eastern Panay and Masbate, and may continue southward to link up with similarly aged intrusives in northwestern Mindanao. It is considered to correlate this arc with an east-dipping trench whose northern part is now partly buried under the Iloilo Basin and continues southward to connect with the present Negros Trench (Zanoria et al., 1984). This is because the free-air gravity low over the Negros Trench is observed to continue onshore to Panay, following the axis of the Iloilo Basin.

Inasmuch as a similar Oligocene magmatic arc with an east-dipping subduction zone is recognized in Luzon, it is possible to speculate that the two arcs and subduction systems had been contiguous before it collided with the nose of the North Palawan microcontinent in the middle Miocene.

The ages of the diorites in central Mindanao have not been determined. These diorites probably relate with small bodies of Middle Miocene diorite intrusives in Cebu and southern Bohol.

The diorites in eastern Mindanao and southern Leyte are considered together as belonging to the terrane which was accreted unto Mindanao (Cardwell et al., 1980) after the suturing in the Agusan-Davao Basin. The polarity of the subduction associated with this arc is uncertain.

The ages of the diorites in the Cotabato Ridge in Southern Mindanao are also not dear but some of them may be related to the subduction along the Cotabato Trench.

The interrelationship between these various terranes as result of their coalescence and juxtaposition of illustrated by interpretative tectonic sections across the northern, central and southern portions of the archipelago (Figs-12 and -13).

3-3 Ore Deposit

3-3-1 Ore Mineralization

Main ore deposits which were generated, related closely to crustal tectonics, in the philippines are: (i) copper deposits and (ii) chromite deposits.

(i) Copper deposits

Copper deposits in the Philippines, using the plate tectonic framework on the geologic setting of mineral deposits (Mitchell and Garson, 1981), are genetically classified into those of oceanic and island arc origins (Table-9). The first genetic types include the Cyprus-type massive sulfides and the vein-type deposits exclusively found in mafic-ultramagic rocks. The second genetic types, associated with island arc magmatism are the Kuroko, porphyry cooper, contact-metasomatic and vein-type deposits. Metamorphosed equivalants of the massive sulfide deposits, associated with schistose rocks, are the Besshi-type.

The chromite deposits, containing both metallurgical and refractory type ores, are of the podiform type exclusively found in the periodotite-dunite-gabbro portion of the ophiolite terranes.

Table-9 Classification of Philippine copper deposits.

GENETIC TYPE	GEOLOGIC SETTING	ORE MINERAL ASSEMBLAGE
A) OCEANIC		
1. CYPRUS-TYPE	Submarine spilitic basalts and pillow, flows in Cretaceous-Paleogene ophiolitic suites	Massive Py-Cp; subordinate Sp, Bo, Th, Tn; moderate Ag : Au
2. VEIN-TYPE	Gabbroic rocks in Paleogene mafic-ultramafic complex	Po-Cp; subordinate Py; minor Sp
B) ISLAND ARC		
1. KUROKO	Early to Late Miocene felsic volcanic flows and pyroclastics, and intercalated normal sediments	Cp-Sp-Gl-Py; subordinate Bo, Cc, Cv, Th, Tn; moderate to high Ag : Au
2. PORPHYRY COPPER	Cretaceous-Paleogene metavolcanics/metasediments intruded by Cretaceous, Oligocene or Miocene diorite-grano-diorite plutons	Cp-Py-Bo; varying amounts of Sp, Gl, Mo, Mt, Cv, Cc; low Ag : Au
3. CONTACT METASOMATIC	Skarn, Hornfels or Limestone intruded by Miocene dioritic-granodioritic intrusives	Sp-Gl-Cp-Py-Mt; Au-Ag Tellurides moderate Ag : Au
4. VEIN-TYPE		
a) Polymetallic BM Sulfides	Cretaceous-Paleogene metavolcanics/metasediments intruded by Oligocene-Miocene Dioritic-granodioritic plutons.	Cp-Py-Mt-Ht; minor Bo, Co, Cv; low to moderate Ag: Au
b) Copper-Sulfosalt veins	Plio-Pleistocene andesitic-dacitic lava flows and pyroclastics	En-Lu-Th-Tn; varying amounts of CP, Py, Sp, Cc; moderate to high Ag: Au
C) METAMORPHOSED		
1) BESSHI-TYPE	Cretaceous-Paleogene basic and pelitic quartzose Schists	Py-Cp; subordinate to minor amount of Sp, Bo, Cc, Cv; high Ag: Au.

(After A.S. Zanoria et al., 1984)

- Cyprus-type copper deposits

The deposits of this type are found mainly in the ophilotic belts on the eastern and western flanks of the archipelago (Fig-17). Stratigraphically, the deposits are found at the top of ophiolitic sequences composed of spilitic basaltic flows and pillow lavas, tuffaceous interbeds and cherty sediments. The orebodies, normally occurring as lenses concordant to the primary stratification of the host rocks, are composed of massive fine-grained pyrite-chalcopyrite-sphalerite ores with subordinate amount of bornite, chalcocite and tetrahedrite, and minor amounts of silver and gold.

The Barlo Mine, located in the Zambales ophiolitic suite, is a representative of this type of deposit (Figs-12 and -17). The area is underlain by a middle Eocene sequence of basalts, spilites and quartzkeratophyres overlying a thick pyroxenite-gabbro layer which is believed to be a part of an old island arc root (Evans and Eawkins, 1982). The lenticular orebodies are found in the so-called "boulder gouge", which is probably an altered volcanic breccia (Bryner, 1969), composed of hydrothermal clay with boulders of silcified volcanic rocks and pillow basalts. The Barlo orebody is composed of massive pyrite-chalcopyrite-sphalerite-bornite-tetrahedrite ores containing an average of 8-9% Cu, 6% Zn, 60 gm/MT Ag and traces of gold.

Similar deposits of this type are found in Bicobian (Isabela), Mayantoc (Tarlac), Tigbao (Leyte), Malobog (Surigao del Sur) and Balabac (Palawan).

- Vein-type copper deposits in mafic-ultramafic rocks

The mafic-ultramafic complex of the Zambales ophiolite is the host to some copper-bearing quartz veins. Deposits of this type are examplified by the Mindanao Mother Lode Mine and the Botolan Mine in Botolan, Zambales (Figs-12 and -17).

The Botolan Mine is disposed in an area underlain mainly by serpentine and gabbro. Fissure-filling quartz veins, controlled by two strong faults, are developed in massive, unaltered gabrro. The ore minerals, consisting mainly of massive chalcopyrite and pyrrhotite, with lesser amounts of pyrite, occur in the massive quartz veins as disseminations or as replacement of silicified breccia fragments.

- Kuroko-type copper deposits

Kuroko-type deposits are associated with intermediate to felsic lava flows and pyroclastics with intercalations of normal sediments of late Oligocene to late Miocene age. The orebodies occur as massive lense or fragmental breccias conformable with the enclosing bedded host rocks, and as veins/veinlets in the siliceous deeper portions. These deposits have been suggested to be associated with volcanic arcs in tensional stress settings, in contrast to porphyry copper deposits which are associated with compressional settings (Nishiwaki and Ueda, 1980). The presence of both types of deposits in the Philippines has not been adequately explained but this may underscore the fact that different arc terranes have coalesced together into the present archipelago. This is not to discount the possibility that individual arcs may have undergone variable stress conditions during its history.

the Bagacay Mine in eastern Samar is an example of this type of deposit (Figs-13 and -17). The area is underlain by dacitic-andesitic volcanic flows and pyroclastics, carbonaceous sediments and reef limestone, capped by red mudstone. The main orebody, the Guild-Guila, has an irregular bottom underlain by argillized volcanic rocks and overlain unconformably by the red mudstone. Mineralogical zoning is observed, from top to bottom, as follows; (a) chalcopyrite-sphalerite-chalcocite; (b) pyrite-chalcopyrite-sphalerite; and (c) massive pyrite (Bryner, 1969). Accompanying gangue minerals are barite, gypsum and calcite.

Similar deposits are those of the Isabela Mineral (Isabela), Dupax (Nueva Vizcaya), Labo (Camarines Norte), Sulat (Eastern Samar), Canibongan (Zamboanga del Norte) and Labuan (Zamboanga del Sur).

- Porphyry copper deposits

The porphyry copper deposits generally occur close to the axis of geanticlines, within or adjacent to dioritic plutons (Figs-15 and -16). Localization of the deposits are structurally controlled by prominent fault/shear zones, in the intensely fractured apophyses of dioritic stocks and the intruded metavolcanics and metasediments. The orebodies are generally elongate tabular or funnel-shaped, tapering downwards. The ore minerals, occurring mainly as stockworks or disseminations, are chalcopyrite, pyrite and bornite with varying amounts of sphalerite, galena, covellite, chalcocite, magnetite and molybdenite; minor amounts of gold and silver are also present. Average ore grades range from 0.30 to 0.70% Cu and trace amounts to 1.2 g/MT Au. The ores of the Sipalay Mine contain considerably higher molybdenum content (average of 0.10% Mo) and higher silver to gold ratio (35-40:1 compared to the 1-10:1 in the other porphyry copper deposits).

Based on the presumed ages of the associated dioritic intrusives, three main periods of porphyry copper mineralization have been identified: Cretaceous; Oligocene; and Miocene. The first one includes the Biga-Barot, Lutopan and Carmen Mindanao orebodies of the Atlas mine in Cebu, and the Jetafe copper prospects in northern Bohol (Fig-15). The Oligocene deposits are those of the Sipalay, Hinobaan, Vulcan, Basay and Aya-aya mines in southern Negros. Miocene, probably extending up to Pliocene, mineralization formed the deposits of Western Minolco, Sto. Niño, Philex and Kennon mines in northern Luzon; the Taysan deposit in Batangas; Consolidated and Marcopper mines in Marinduque Island; and the North Davao, Nadecor, Sabena and Apex mines in southeastern Mindanao (Fig-16).

Dizon in Zambales, is the youngest known porphyry copper deposit, associated as it is with Late Miocene-Pliocene volcanism related to subduction from the Manila Trench (Fig-18).

- Contact-Metasomatic copper deposits

Deposits of this type are found in skarn, hornfels and/or limestone disposed along the peripheries of intrusive dioritic stocks. The orebodies occur as massive lenses, pods and veinlets localized along the contact zone of the intruded rocks and the intrusive plutons. Contact-metamorphic minerals such as garnet, clinozoisite, amphibole, apatite and cordierite are develped in the skarn-hornfels zone, but conspicuously absent in the intruded limestone bodies. The ores are massive and are composed mainly of sphalerite, pyrite and chalcopyrite with variable amounts of galena, magnetite, hematite and pyrrhotite; small amounts of gold and silver tellurides are also present. Ores of the Thanksgiving mine in the Baguio district (Figs-12 and -16) contain an average of 0.38% Cu, 3.78% Zn, 3.9 g/Mt Au, 34 g/Mt Ag, and trace amounts of cadmium.

Other deposits of this type are found in Camarines Norte and in central Cebu.

- Hydrothermal Vein-type copper deposits

Based on the major mineralogical assemblage, two sub-types have been distinguished: polymetallic base metal sulfide veins of Oligocene to Miocene in age, and copper sulfosalt veins of Pilocene-Pleistocene in age.

The polymetallic base metal sulfide-quartz veins (Fig-16) are genetically associated with the intrusion of diorite-andesite ponphyry stocks and dikes of Oligocene to Miocene in age. The deposits of the Baleno mine in Masbate (Oligocene), the Pilar prospect in northeastern Panay (Oligocene), the Wildcat orebody in northern Luzon (Miocene) and the Samar mine in southeastern Mindanao (Miocene).

The sulfide-quartz veins are developed in the outer peripheries of dioritic-andesitic intrusives and in the intruded rocks within several meters from the contact. The veins are localized along fracture and shear zones developed by regional faulting or as a result of the igneous intrusions. Major ore mineral components are massive to granular chalcopyrite, pyrite, hematite, sphalerite and galena.

Although the copper sulfosalt-bearing quartz veins are proximal to dioritic instrusive bodies, their mineralization is genetically attributed to Plio-Pleistocene volcanism that produced basaltic to andesitic-dacitic volcanic lava flows and pyroclastics. The veins are localized along fault and shear zones as massive fissures and breccia fillings. The ores occur as massive bands and lenses and as replacement in slicified host rock fragments. The major ore minerals are engargite and luzonite with variable amounts of chalcopyrite, pyrite, sphalerite, chalcocite; minor tetrahedrite-tennantite, famatinite and gold-silver telurides are also present.

The deposits of the Makayan mine in northern Luzon and of the Lobo mione in central Luzon belong to this sub-type of vein deposits (Fig-18).

- Besshi-type copper deposits

Deposits of this type have been observed in Mindoro Island, Caramoan Peninsula and Rapu Island in Albay (Fig-14). The deposits occur in basic and pelitic crystalline quartzose schists that have been strongly folded and faulted. The orebodies occur as massive lenses, bands and streaks conformable to the schistosity of the enclosing host rocks. These are generally partly or entirely surrounded by a pyrite halo, especially in the hanging wall side.

The Hixbar mine in Rapu Rapu Island is underlain predominantly by chlorite-epidote schist and quartz-sericite schist. The sulfide orebodies are massive lenses that generally follow the lineation of the host rocks. Relict schistose structures parallel to the schistosity of the wall rocks are observed in some of the ores (Kinkel and Samaniego, 1956) and have been interpreted as possible replacement features. Secondary enrichment zones are sometimes observed in some portions of the deposits. Ores are composed of massive pyrite and chalcopyrite with subordinate to minor amounts of sphalerite, bornite, chalcocite and covellite; minor gold and silver are also detected.

(ii) Chromite deposits

Chromite deposits in the Philippines are exclusively associated with Alpine-type periodotite-dunite-gabbro complexes in ophiolite terranes. These are commonly associated with spilitic basalts, diabases, red cherts and basic metasediments of the ophiolite sequence although the complete sequence is rarely found.

Ultramafic complexes occur in almost all major islands of the archipelago, with an aggregate area occupying about 3.8% of the total land area. The major exposures are generally well-exposed in the western part of the archipelago (Zambales, Mindoro, southern Palawan, Antique and Zamboanga) as well as in the eastern part (Baler, Camarines Norte, Samar, Dinagat, Surigao and Pujada Peninsula) (Fig-19). This has led some workers (Hess, 1948; (Seligman, 1977) to suggest that the eastern and western belts are differentiated genetically. However, there is at present no sufficient constraint on the ages as well as the dates of emplacement of most of the ophiolite bodies to warrant such a generalization. For example, the Zambales ophiolite is now well recognized to be at least of late Eocene in age (Villones, 1980; Bachman et al., 1982) while the Palawan Ophiolite may be inferred to be at least Early Cretaceous based on the age of ferromagnesian shales and cherts intercalated with spilitic basalt flows (Fernandez, 1962; Belandres, 1964) although both are found in the so-called "western belt".

The chromite deposits are typically of podiform type with shapes ranging from tabular, lensoid, pencil-shaped, wedge-shaped to irregular localized mainly within the dunite-harzburgite portion below the gabbro-peridotite transition. Texturally, the ores range from massive, nodular ('leopard type'), brecciated to disseminated. They primarily of chromite with varying amounts of magnetite and ilmenite, and trace amounts of nickel sulfides, platinum and palladium. Secondary minerals such as kammererite and uvarovite are developed along slip planes of shears in the host rock.

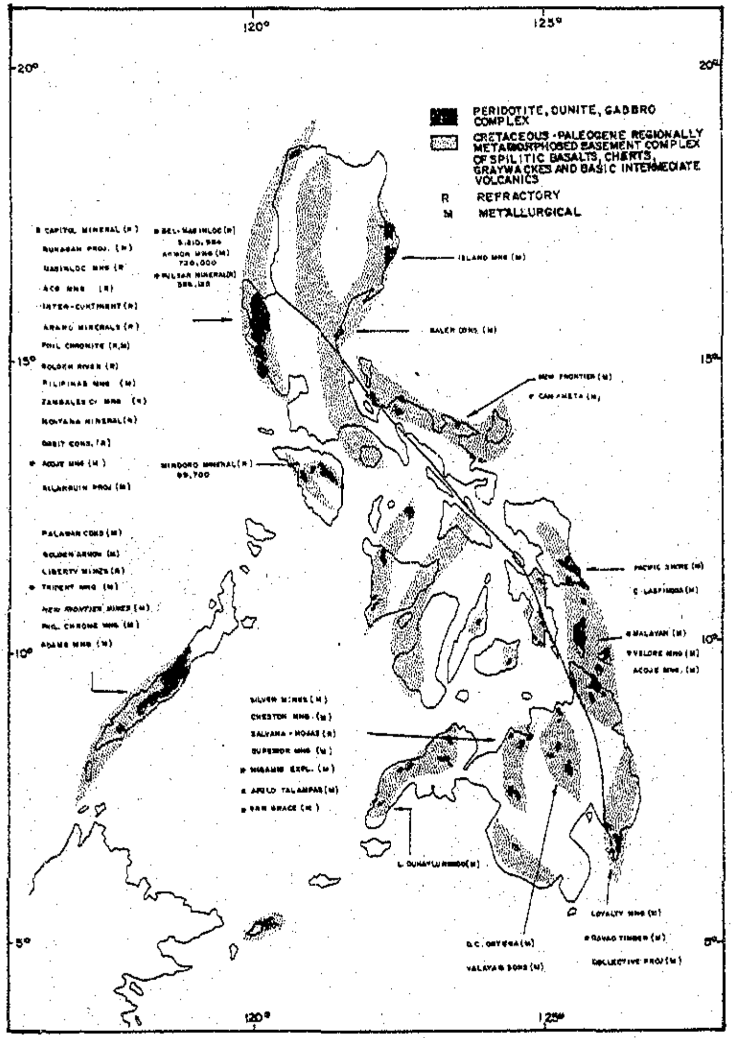


Fig-19 **Ophiolitic Terranes and Associated Chromite Deposits**
(After A.S. Zanoria et al., 1984)

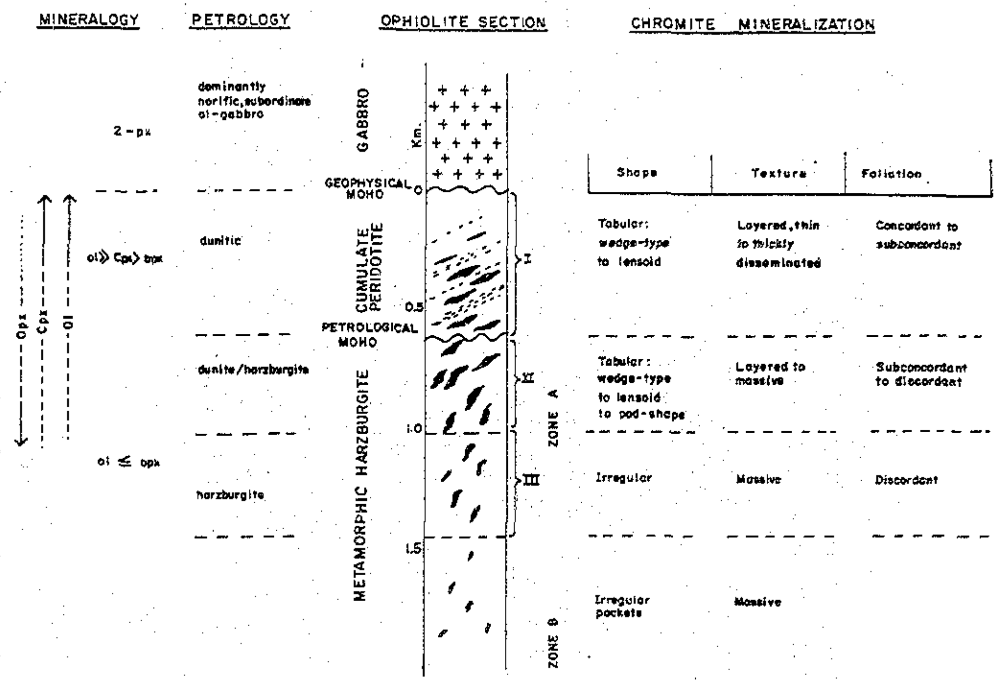


Fig-20 **Straitigraphy and Chromite Mineralization of the Acoje Deposits**
(After A.S. Zanoria et al., 1984)

The largest and the best studied chromite deposits in the Philippines are those in the Zambales area. The Zambales ultramafic complex is divided into two major gabbro-periodotite associations: the Acoje block in the west and the Coto block in the east. The contact between the two units is presently defined by the Lawis Fault, but the age, genetic and structural relations between the two are not clear. The Acoje Block is characterized by the occurrence of metallurgical grade chromite, pyroxenite dikes and association with predominantly noritic gabbro. The Coto block is characterized by the occurrence of refractory grade chromite, mafic dikes and association with olivine gabbros and troctolites. It is the host to the Coto orebody, one of the largest "sackform" deposits in the world, which, by the time it was exhausted, would have produced over 10 million tons of high alumina or refractory ore.

Based on compositional and structural differences, Evans and Hawkins (1982) suggests that the Acoje block is a more depleted ophiolite that may represent primitive island arc crust and upper mantle, while the Coto block, which is less depleted, may represent back arc basin crust adjacent to the aforementioned arc.

In the Acoje mine area, a correlation appears to exist between the size, frequency of occurrence and structure, of the chromite orebodies, and their position in the ophiolite stratigraphy (Fig-20). All of the 32 deposits occur in a zone within 1.4 km below the gabbro-cummulate peridotite boundary (Zone A). The deposits in the upper level, located within the cummulate peridotite horizon, occur in association with a dunitic layer that parallels closely the boundary with gabbro. The deposits in this zone are typically tabular to lensoid bodies, with both layered as well as massive textures and are thinly to thickly disseminated. They display a generally concordant to subconcordant relationship with the structure of the surrounding host rock.

The orebodies in the lower portion of this sections are located within metamorphic peridotite. However, these are always found to be enveloped in an aureole of dunite. The chromite bodies tend to be more irregular in shape, are texturally massive, and generally discordant to layering structures in the surrounding peridotite.

Chromite deposit are also observed to occur in deeper levels of the metamorphic harzburgite (Zone B). These are typically small lenses and pockets that are irregular in shape and massive in texture.

In Coto, chromite zone A appears to be thinner (less 1 km) and most of the chromite deposits are observed to be concordant to subconcordant to structures in the country rock.

3-3-2 Metallogenic Provinces

Considering the association of economic mineral commodities, Philippine ore deposits may be classified into the following commodity groups (Fig-21): Group I-copper-gold (Ag, Pb, Zn, Mo, Fe); Group II-chromite-nickel (Cu, Co, Pt, Fe, Al); Group III-manganese. Group I includes copper and gold as major commodities; while silver, lead, zinc, molybdenum and iron which are, in general, merely associated with copper and gold are minor commodities. Group II includes chromite and nickel as major commodities; with copper, cobalt, platinum, iron and aluminum as minor commodities. Group III includes only manganese which occurs as lone commodity in the deposit with the exception only of those in northern Sierra Madre.

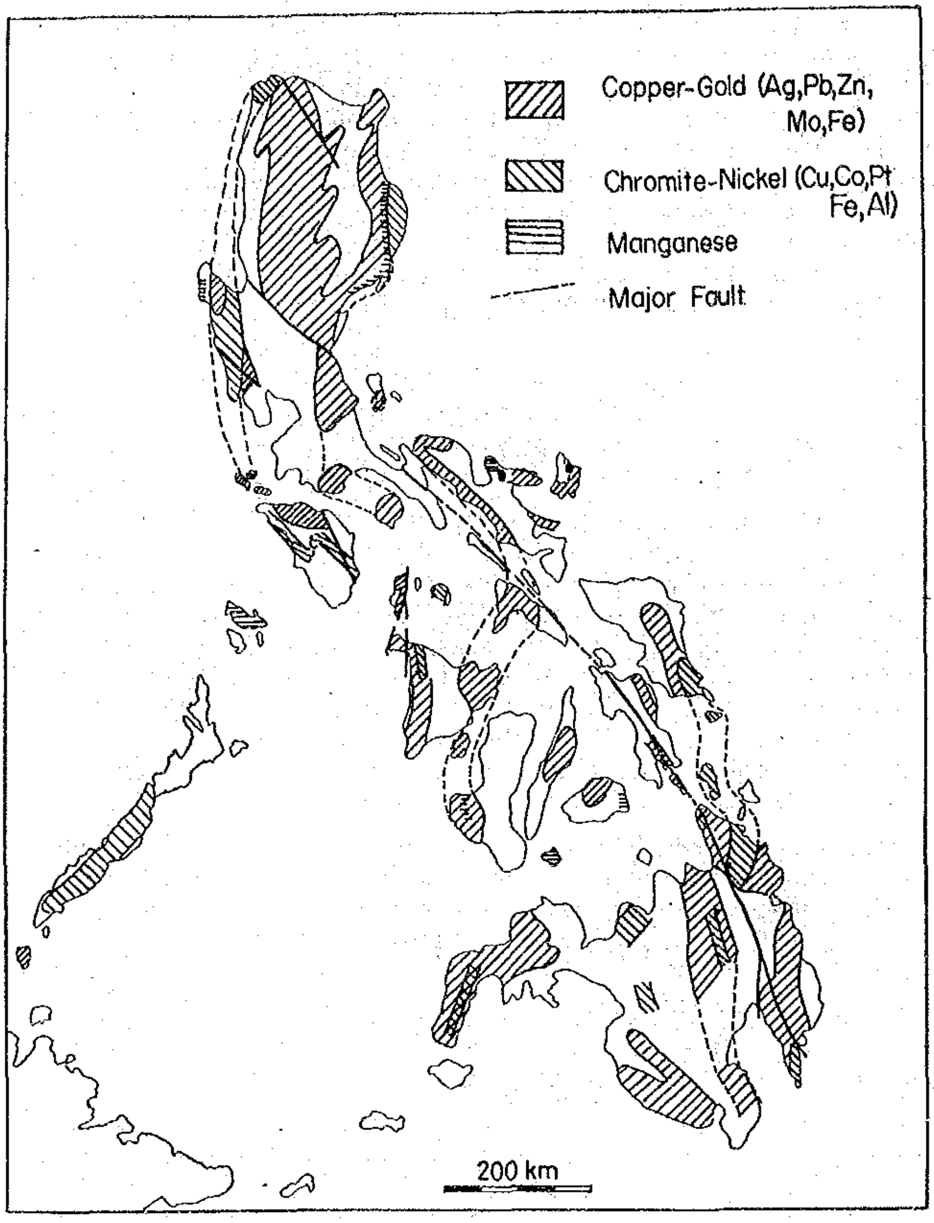


Fig-21 Distribution of Mineral Commodity Groups (in Situ Deposits)
(after G.R. Balce et al., 1981)

Fig-21 shows the distribution of the mineral commodity groups. In general, Group I deposits are concentrated in the central physiographic province of the Philippine mobile belt and Group II deposits are concentrated in the eastern and western physiographic provinces and in southern Palawan. There are, however, significant overlappings of the two groups, particularly in Zambales Range, Antique Range, Zamboanga Peninsula, Mindanao Central Cordillera, Samar Island and the northern segment of Eastern Mindanao Ranges.

In terms of the tectonic belts discussed previously, Group I deposits are confined to the magmatic belts while Group II deposits are confined to the ophiolite belts. Group III, manganese deposits, are present in the two tectonic belts as well as in the basement.

The following are the descriptions of potentials for main minerals, based on each mineral potential maps (Fig-22 ~ Fig-31, Natural Resources Management Center=NRMC, 1980) in the Philippines.

(i) **Copper;**

The Philippines has a total of 4.3 billion M.T. of known copper ore reserves in 1982 (Table-2).

Of the total ore reserves, more than 80% are found in only five (5) mineral districts: SW Negros, Cebu, Baguio Mineral District, Marinduque and Davao del Norte.

The above localities and other areas where copper deposits are known to occur correspond to the identified high mineral potential areas shown in the Mineral Potential Map for copper (Fig-22). An interesting exception is the Sierra Madre which has no sizeable discovered copper deposits but is considered by experts to have high mineral potential (NRMC, 1980). This may be due to the fact that very little exploration work has been done because of the inaccessibility and the prevailing peace and order situation of the area.

(ii) **Gold-silver;**

The potential areas for gold and silver are shown in the Mineral Potential Map for Gold/Silver (Fig-23). Of interest in this map is the potential of Central Leyte. Although there have been no reported gold deposits, experts agreed that the geologic setting is favorable for occurrence of gold deposits, and should be investigated to determine the real potential.

Total gold ore reserves in 1982 were 2,108 million tons (Table-2) in the philippines, however, potential gold ore (only lode type) reserves were estimated 475 million tons (NRMC, 1980), at 2.0 g/t would represent 950,000 kg of metal.

Potential Gold Ore Reserves (LODE)

N and Central Luzon	174 million tons
Visayas/Mindoro	110 million tons
Camarines Region	84 million tons
Mindanao	107 million tons
(NRMC, 1980)	475 million tons

However, the bulk of potential reserve of gold occur as by-product of porphyry copper deposits. These were estimated to total 8.1 million kg of gold metal. Therefore, over-all total potential reserve would amount to 9,000,000 kg of gold metal (NRMC, 1980).

Silver and gold occur together, and the usual ratio of gold to silver occurrence is 1:2. Therefore, if total gold reserves is 9 million kg of metal, silver should has a potential reserve of 18 million kg of metal.

(iii) **Lead-Zinc;**

Total Lead-Zinc ore reserves in 1982 were about 25 million tons (Table-2), however, the outlook for Lead-Zinc deposits in the Philippines is not very bright (Fig-24).

The best known and largest zinc/lead deposit occurs in Ayala, Zamboanga, with ore reserves of 6,118,060 tons. Another deposit occurs in Rapu-Rapu Island with 3,000,000 tons of ore reserves. Other deposits are considerably smaller, and to not reach 1 million tons in reserve (NRMC, 1980).

Zinc and lead deposits are also present as by-products of gold lode veins, of massive sulfide deposits, and of Kuroko deposits.

(iv) **Iron;**

Iron ore deposits in the Philippines are classified into three (3) types: lump iron, magnetite sand iron and lateritic iron.

Fig-25 is potential map of Iron ore, and total Iron ore reserves (1982) in the Philippines is showing in Table-2.

Iron districts for lump ore deposits are Sta. Ines in Rizal; Zamboanga del Sur; Piddig, Ilocos Norte; Camarines Sur; Bulacan.

Sizeable magnetite sand deposits are found in Cagayan, Ilocos Region and Leyte.

Laterite deposits are found in Surigao, Palawan, Camarines, Davao, Isabela and Tawi-Tawi.

(v) **Chromite;**

Sizeable chromite deposits are found abundantly in Zambales, Pangasinan, Tarlac and Palawan. Smaller deposits occur in Camarines Sur, Davao Oriental, Misamis Oriental and Occidental Mindoro.

Areas with potential for chromite occurrences are shown in the Mineral Potential map for chromite (Fig-26). These are not so numerous owing to the limited extent of the associated ultramafic rocks. Among the areas that should merit more exploration work are the Zambales Range, Sierra Madre Mountains, Palawan, Southern Samar and Zamboanga, and Dinagat, Surigao (NRMC, 1980). It should be mentioned, however, that chromite is the least understood of our major mineral resources, and that more research could lead to the discovery of more deposits.

Total chromite ore reserves in 1982 is represented, composing 83.5 million tons of metallurgical grade and 8.1 million tons of refractory grade (Table-2), however, potential ore reserves have been estimated 121.5 million tons (NRMC, 1980), and these deposits should come from the high to intermediate potential areas of Fig-26.

(vi) **Nickel-Cobalt;**

Another major dollar earner for the Philippines are nickel and cobalt deposits.

Major nickel and cobalt occurrences are found in Surigao del Norte, Palawan and Davao Oriental.

Total nickel ore reserves were recently decreasing gradually, and were amounted about 1,752 million tons (Table-2) in 1982, but estimated potential reserves amounted 4,500 million tons (NRMC, 1980) at 0.75% Ni and 0.1% Co, more than double of what has now.

(vii) Manganese;

The over-all picture for manganese reserves in the country is not very bright. Major occurrences of over 100,000 metric tons occur in Bohol, Masbate, Marinduque, Negros Oriental, Palawan, Quezon and Tarlac.

Total Manganese ore reserves in 1982 were 7.5 million tons (Table-2), however, potential ore reserves were estimated to be 50 million tons (NRMC, 1980).

The areas with the biggest potentials are probably Busuanga, Eastern Sierra Madre, Samar, Masbate, Panay, Agusan, Zamboanga, Siquijor and Mindoro (Fig-29).

(viii) Radioactive *minerals*;

The only known reserve of uranium in the Philippines in 1982 is in Camarines Norte, with 90,000 tons at 0.4% uranium (Table-2). Therefore, an estimation on the potential reserve of uranium for the country was not made.

- Experts identified areas which may be worthwhile exploring for uranium (NRMC, 1980). Among those with intermediate potential for uranium occurrence are Cordillera Central, Polilio, Samar and the offshore areas in Northwest Palawan (Fig-30).

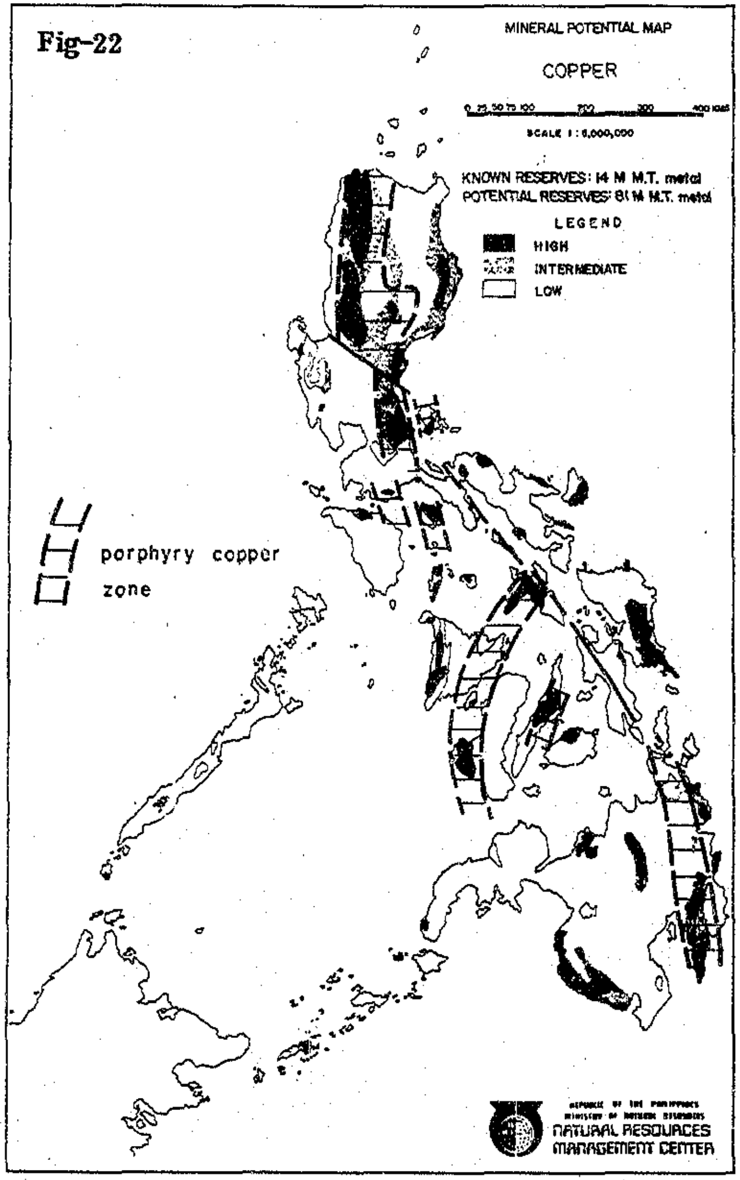


Fig-22

(After Natural Resources Management Center=NRMC, 1980 and G.R. Balce et al., 1981)

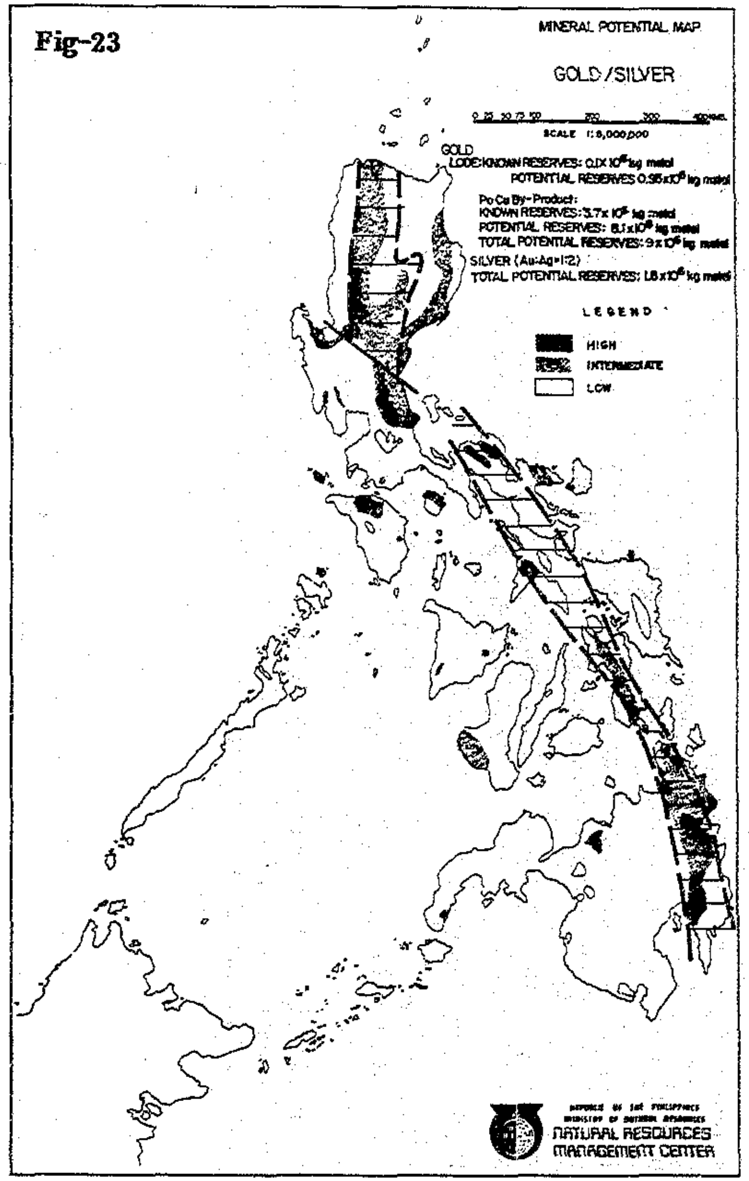
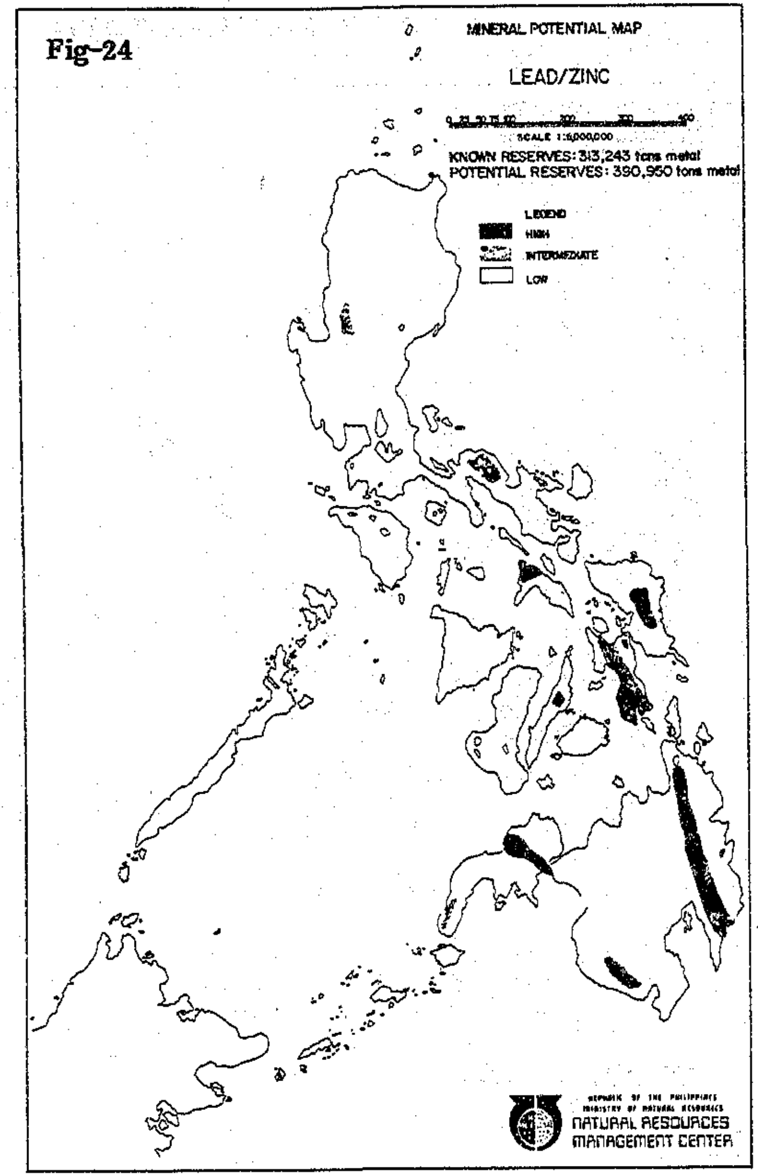


Fig-23

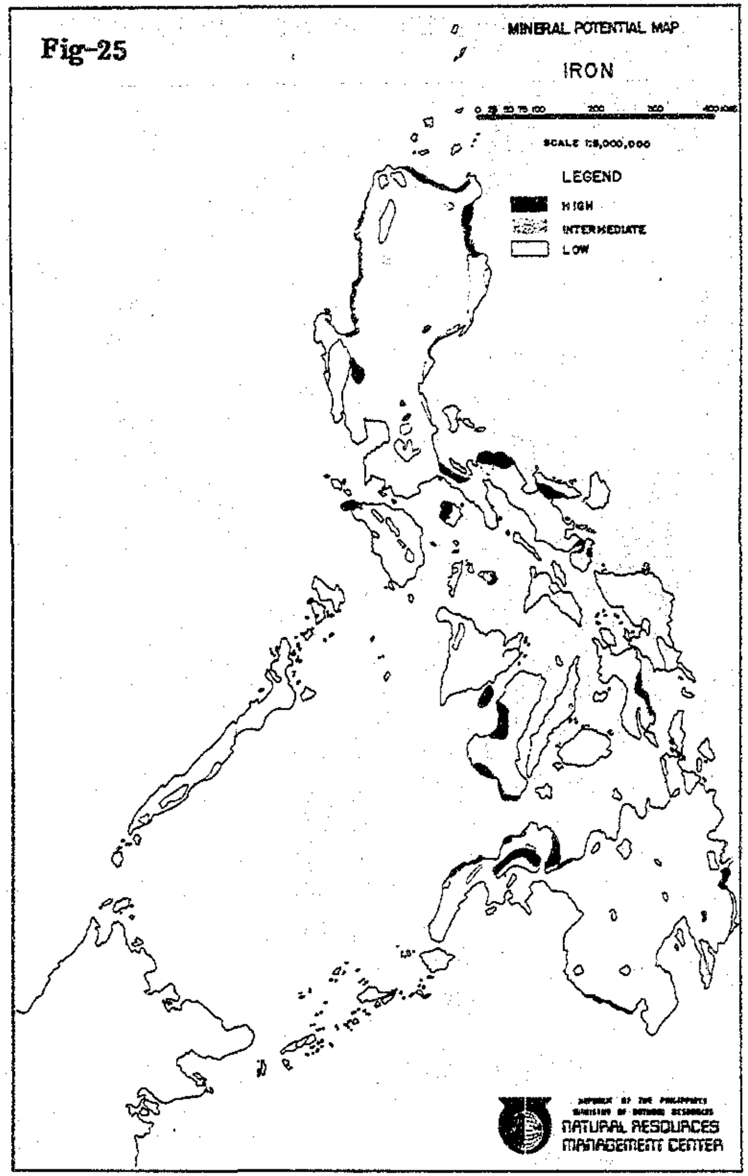
(After NRMC, 1980 and G.R. Balce et al., 1981)

Fig-24



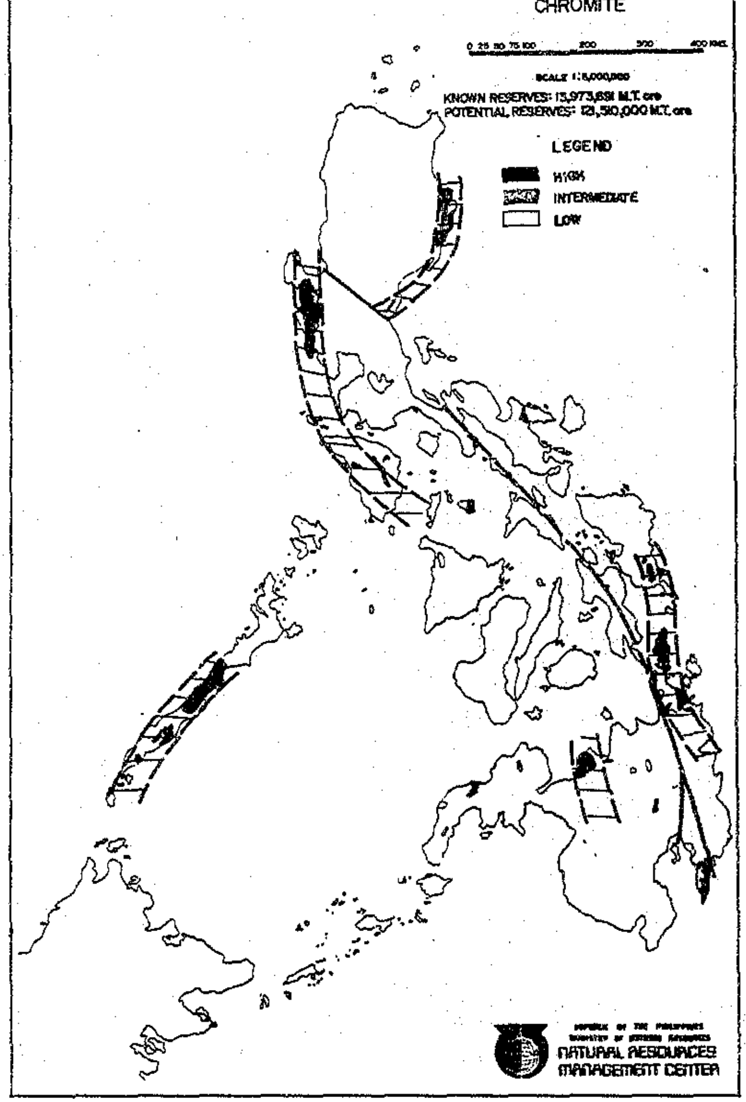
(After NRMC, 1980)

Fig-25



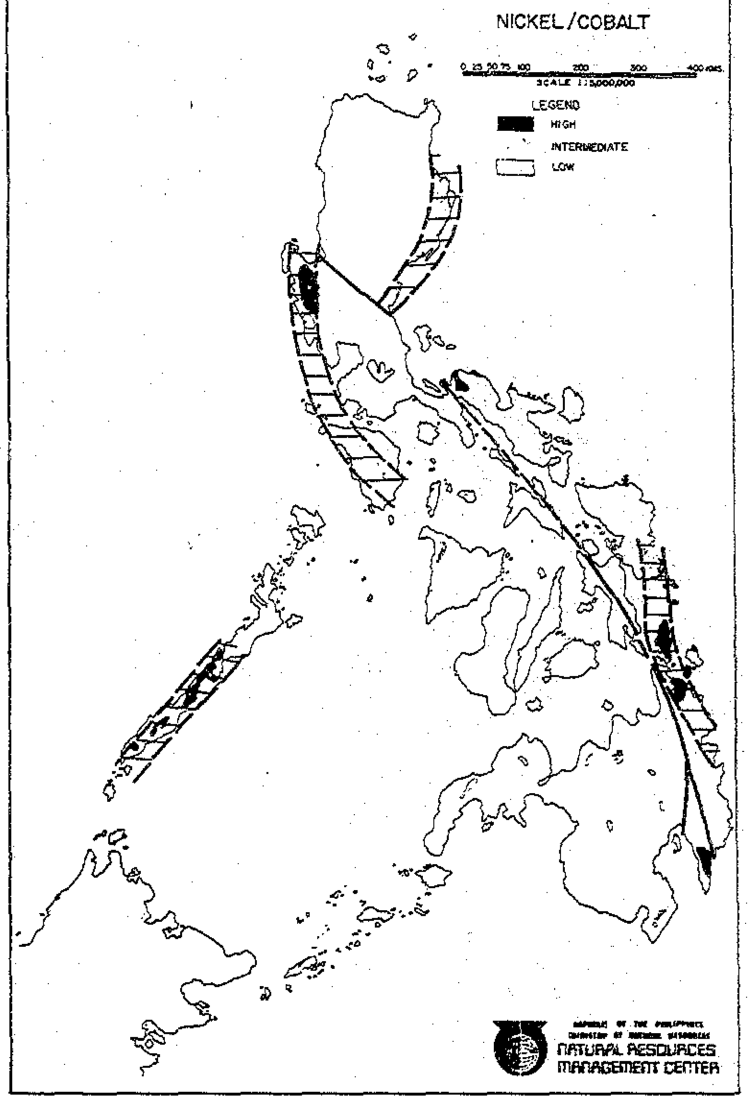
(After NRMC, 1980)

Fig-26



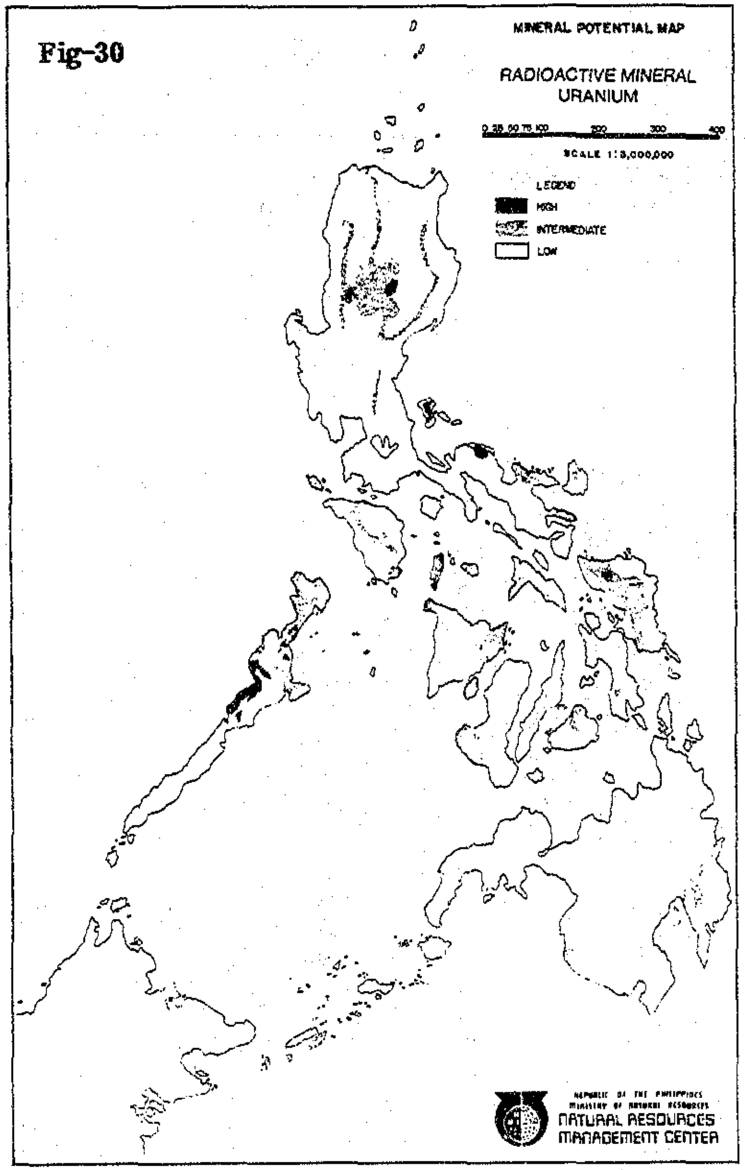
(After NRMC, 1980 and G.R. Balce et al., 1981)

Fig-27



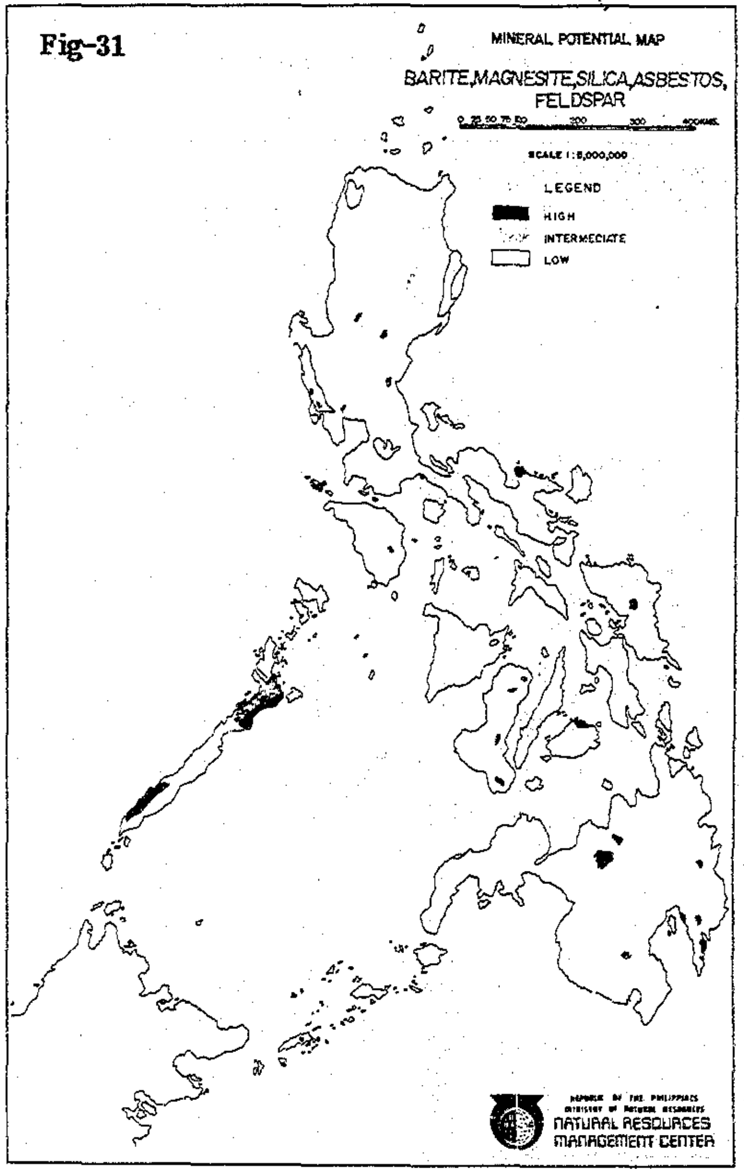
(After NRMC, 1980 and G.R. Balce et al., 1981)

Fig-30



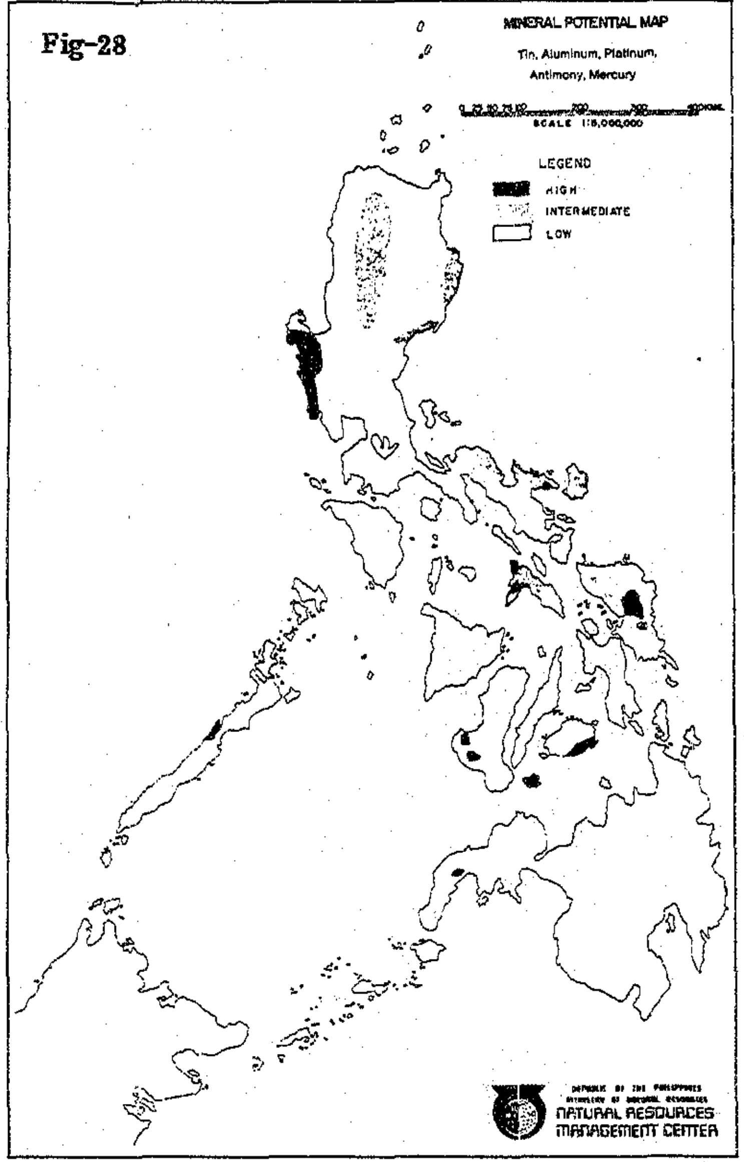
(After NRMC, 1980)

Fig-31



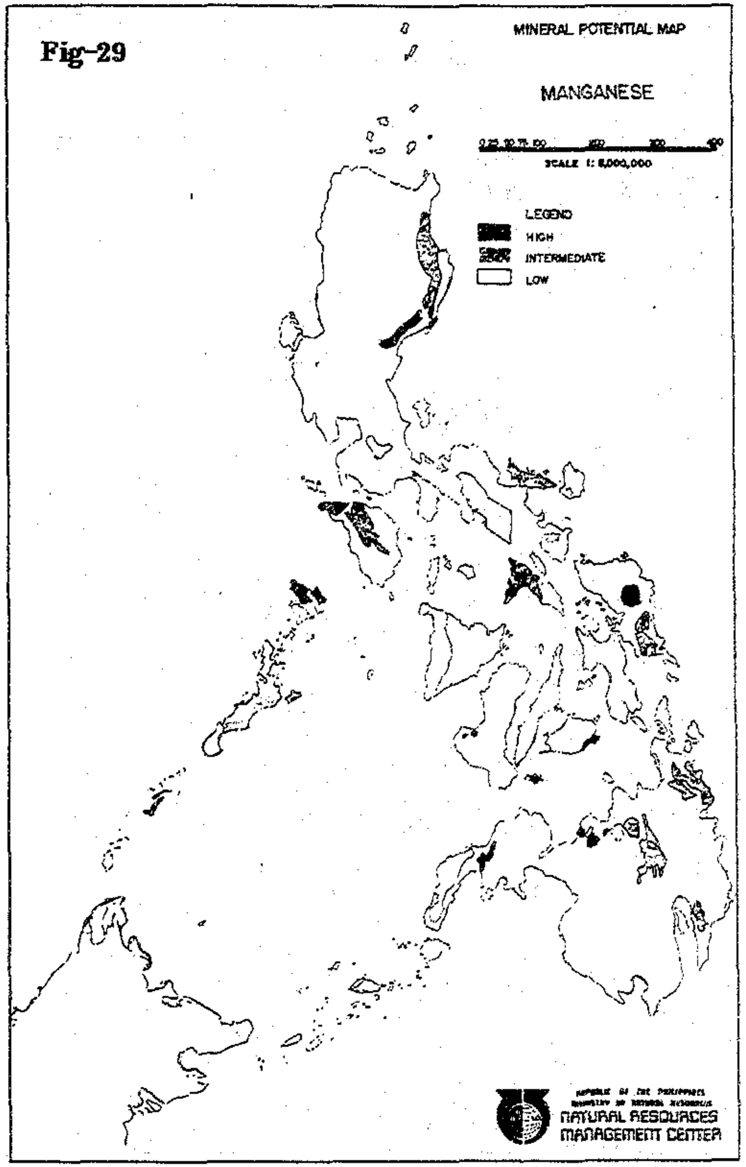
(After NRMC, 1980)

Fig-28



(After NRMC, 1980)

Fig-29



(After NRMC, 1980)