DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

Introducing coal-water-mix fuels to the Philippines

Assessment of project feasibility

Volume 1 - The Philippine coal resource

by

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This report is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards and stratigraphic nomenclature.

1/ U.S. Geological Survey, Denver, CO
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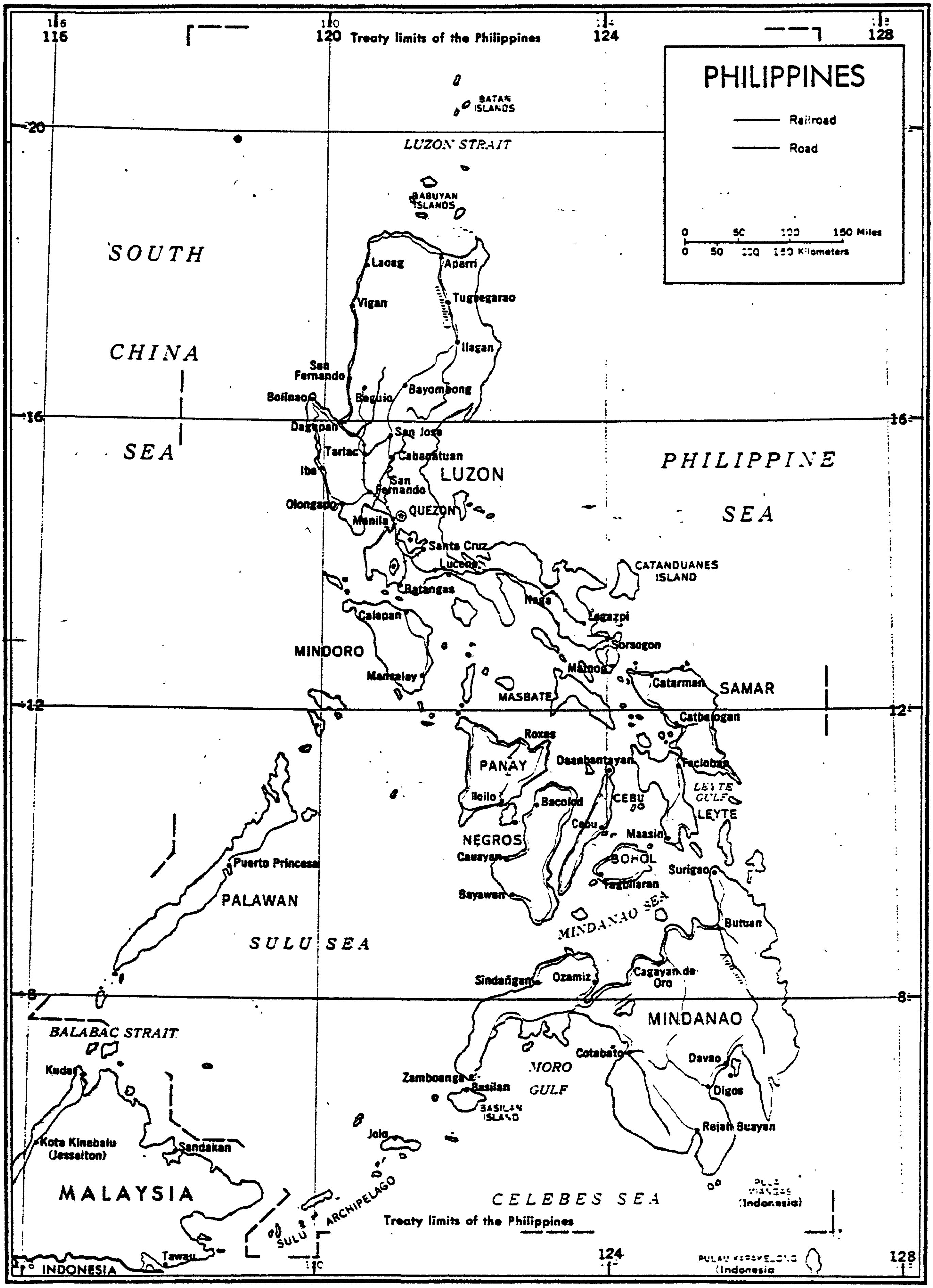

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PREFACE

Involvement of the U. S. Geological Survey (USGS) in the project to introduce coal-water-mix (CWM) fuel into the Philippines began actively in June 1984 when samples of coal from five different areas in the Philippines were received from Brookhaven National Laboratory. The five samples were collected in a prescribed standardized manner by personnel of the Economic Development Foundation, Inc., of Manila in order to allow preliminary decisions about potential sources of indigenous coal for use in CWM fuels. At a meeting of all project participants in August, decisions included plans for collection and evaluation of information about the quantity and quality of Philippine coals. This volume is the result of field, office, and laboratory work during the period August 1984-March 1985 by a large number of research and support personnel of the USGS in Reston, Virginia, and Denver, Colorado. The USGS personnel who performed the project work described in this volume are M. D. Carter, J. H. Medlin, and the team leader, E. R. Landis. Review and editing of reports and coordination of activities with the Office of Energy in the U.S. Agency for International Development (USAID), under whose auspices the investigations were done, were the the tasks of M. J. Bergin.

An executive summary and overview and volumes II through V, which have been prepared by other agencies and contractors involved with the coal-water-mix fuel feasibility study in the Philippines, are available through the agency for International Development library system. These include:

Executive summary and overview by the Agency for International Development

Volume II - Formulation of CWM-fuel from Philippine coals by the Brookhaven National Laboratory

Volume III - Power plant retrofit and performance by Burns and Roe, Inc.

Volume IV - The CWM-fuel supply system by Burns and Roe, Inc. and Development Sciences, Inc.

Volume V - Financial and economic analysis by Development Sciences, Inc.

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From the very beginning, the project to introduce coal-water-mix (CWM) fuels to the Philippines has required and successfully demonstrated close cooperation among all participants. Leadership of the various participating groups has been uniformly excellent, and Purita M. Festin of the Economic Development Foundation (EDF) of the Philippines, Thomas E. O'Hare and Thomas Butcher of Brookhaven National Laboratory (BNL), Morton Gorden of Development Sciences, Inc. (DSI), and Egon A. Kimel of Burns and Roe, Inc. (B&R) deserve special thanks. In particular, the patient and understanding overall leadership of Charles Bliss of the Office of Energy, USAID, is appreciated.

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INTRODUCING COAL-WATER-MIX FUELS TO THE PHILIPPINES

ASSESSMENT OF PROJECT FEASIBILITY

VOLUME 1 - THE PHILIPPINE COAL RESOURCE

1.0 SUMMARY AND CONCLUSIONS

The estimated coal resource potential of the Philippines is 1,600 to 1,700 million metric tons with nearly 200 million tons in the mineable reserve category.

The four areas studied as part of the CWM-fuel project represent about 40 percent of the estimated national resources. The four estimates are (in millions of metric tons):

	Resource potential	Mineable reserves
Semirara	550	79
Sibuguey Peninsula	45 or 50	10 or 11
South Mindoro	100	2.4
Samar	27	6.3

More than 40 percent of the mineable reserves have been estimated for the Island of Semirara by detailed exploration in preparation for present and future open-pit mining. By comparison, the combined estimated mineable reserves of the South Mindoro area, the Sibuguey Peninsula (Lalat and Malangas areas), and the Samar-Leyte area are less than 15 percent of the total estimated mineable reserves of the Philippines. Compared to Semirara, these three other regions range from only partly explored--the Sibuguey Peninsula--to essentially unexplored--South Mindoro and Samar.

In all cases, the quality variations for the coal included in the cited estimated mineable reserves are uncertain.

Two resource figures, both dated 1984, are available for the Sibuguey Peninsula, but neither may include very recent estimates for the Lalat area, which, when reassessed, might increase the mineable reserve figure by about 7 million tons. The estimate for Samar may not include very recent estimates for the Carbon Creek area, which could increase the mineable reserve estimates as much as 5 million tons. All the estimates, except that for Semirara, are conservative.

The coals of the Philippines range in rank from lignitic to bituminous with the bulk categorized as subbituminous C and B. They range in grade from low (1 percent, or less) to high (more than 3 percent) sulfur, and low (less than 8 percent) to high (more than 15 percent) ash.

The Semirara coal, as recently shipped to Luzon for power generation and other uses, such as cement manufacture, has the following quality characteristics in weight percent and heat value in Btu/lb:

	As-received		Air-dried	
	Mean	Range	Mean	Range
Moisture	25.7	23-29	17.6	15-20
Ash	16.4	12-21	17.5	14-22
Volatile matter	29.3	24-31	33.7	31-36
Fixed carbon	27.8	24-31	31.2	27-35
Sulfur	0.5	0.4-0.6	0.6	0.5-0.7
Heat value (Btu/lb)	7138	6627-7630	7981	7232-8679

The weighted arithmetic means of analyses of 22 shipments of Semirara coal received by the National Power Corporation (NPC) in 1984 are similar to the above-cited analytical means. Semirara coal with much less ash and with higher heat value than cited in the above table is represented by two recent analyses; one from a sample collected early in the CWM fuel study from a coal bed exposed in the Unong mine, the other from a sample of a 1,000-ton shipment of "selected Semirara coal" sent to the Calaca generating plant in February 1984. These two samples show 9 and 6 percent ash, and 8,209 and 8,547 Btu/lb, respectively. Both have 26 percent moisture on the as-received basis.

The Semirara coal quality assumed for design purposes in the CWM fuel study is as follows on the as-received basis: 24 percent moisture, 14 percent ash, 33 percent volatile matter, and 7,507 Btu/lb heat value.

So far as can be determined, the estimated mineable reserves of coal in the present or potential mining areas on Semirara are of a quality similar to the assumed design specification analysis just cited. If production were restricted to coal of the quality of the "selected Semirara coal", the mine life--in essence, the mineable reserves--would be decreased by some unknown factor.

The coal of the Sibuguey Peninsula is in demand for cement manufacture and other uses because it is the best quality available in the Philippines and probably in all of Southeast Asia. It is bituminous in rank, low in moisture, and has low to medium sulfur and ash contents.

The coal of the Napisian area in southern Mindoro is of subbituminous B rank, and the relatively few analyses indicate that the coal is high in sulfur and low in ash. The very few analyses from samples of coal in the Siay area, not far from Napisian, indicate a similar coal, except that some samples contain less sulfur.

Many samples of the coal from the Carbon Creek area of southeastern Samar have been analyzed. The coal is of subbituminous C rank, has a high ash content, but a low sulfur content.

Sixteen coal samples collected as part of the CWM fuel study were analyzed for major and minor element content in the ash. Analyses from many more samples are needed for valid characterization of the coal but the samples from Semirara coal, as a group, show the ash to contain more silicon, sodium, and potassium, and less iron and calcium than samples from other areas.

Evaluation of the available information on the quantity and quality of Philippine coals shows that Semirara is the only area in the Philippines with the required estimated mineable reserves of coal to supply the market that a conversion to CWM fuel use would generate immediately. Two of the other three areas that were studied have coal of similar quality to the Semirara coal, but exploration has not advanced sufficiently to allow meaningful evaluation of the potential coal resources of the South Mindoro and Samar areas. The existing and planned mines in the Sibuguey Peninsula of Mindanao could not supply sufficient coal for CWM fuel usage, and at this time, all present and future production is supposedly committed for cement manufacture and other uses.

General and specific deficiencies in coal resource information abound. A new national coal quantity and quality assessment is needed, a program for standardization of coal sampling, handling, storage, preparation, and comprehensive analysis should be initiated, and a coal data management system for coal geology, resource, chemical, and physical information is required. Other more specific needs are obvious. They include:

- A comprehensive quality information program is needed to produce precise and accurate information about the coal of Semirara so that quality of the coal, and the quantity thereof, can be predicted.

- Possible beneficiation of the Semirara coal should be investigated.

- A geologic and resource synthesis of the whole Sibuguey Peninsula should be made, and a feasibility study for mining coal in the Lalat area is needed now.

- A preliminary reconnaissance-type regional study is required to determine how much of southern Mindoro is underlain by coal.

- Feasibility of mining in the Napisian and Siay areas of southern Mindoro should be studied along with the determination of resource potential and coal quality, particularly sulfur content.

- A study of the coal resources of southeastern Samar should be initiated.

2.0 COAL RESOURCES OF THE PHILIPPINES

2.1 Introduction

"Coal in the Philippine Islands was discovered *** in 1827 on Cebu and on Batan Island in Albay Province in 1842. The first coal entries were made on Batan Island in 1847, and the first concession on Cebu was given in 1853. Very little mining was done until after 1890." (Smith, 1924, p. 470). Coal has been reported from 60 or more locations on eight of the principal islands of the Philippines and on as many smaller islands (fig. 1). Coal has been mined, mostly in small quantities, at many places in the country.

Prior to World War II, the energy budget of the Philippines relied heavily on coal for use on the railways, cement manufacture, power for inter-island and ocean-going vessels, electricity generation, and other industrial needs, such as forges and foundries. Pre-war consumption of coal ranged from 282,000 to 500,000 t annually (Bureau of Mines, 1953), but coal production in the Philippines before World War II never exceeded 55 percent of consumption and averaged much less. Coal was imported mostly from Japan, China, and Australia. Coke, of which several thousand tons were used per year, came mainly from Germany and Japan.

After World War II, the Philippines, in common with many other nations, converted to imported petroleum products as energy sources with the resultant decrease in import and domestic production of coal. As early as 1952, however, it was pointed out that "*** imported oil consumes foreign exchange and is to the detriment of the local fuel industry" (ECAFE, 1952).

During the last 20 years, imports of coal, coke, semicoke, and briquettes have been less than 25 thousand tons annually in the Philippines. In the period 1965-1975, the imports came mostly from Japan, and were probably mainly in a prepared form--coke, semicoke, or briquette--rather than as raw coal. In recent years, raw coal from Australia, China, and the Soviet Union has formed part of the imports. Most of this coal has been intended for use in industries such as cement manufacture that have recently converted from oil to coal for energy. With the increase in the price of oil worldwide, the Philippine Government has become interested in increasing domestic coal production and utilization to reduce the amount of imported oil that is used in the country for needs that coal can adequately satisfy. Obviously, the desired situation from a foreign exchange standpoint is the complete substitution of indigenous coal for imported oil.

While the Philippines was a Commonwealth associated with the United States of America, considerable geological research and commodity studies were carried out. Basic geologic work, such as Becker's in 1901 for the U.S. Geological Survey, followed earlier research by the Cuerpo de Ingenieras de Minas. Agencies that were part of the Philippine Government, such as the Mining Bureau established in 1901 and the National Development Company that was active in the 1930's, made studies prior to World War II. After World War II and independence, the Philippine Bureau of Mines conducted

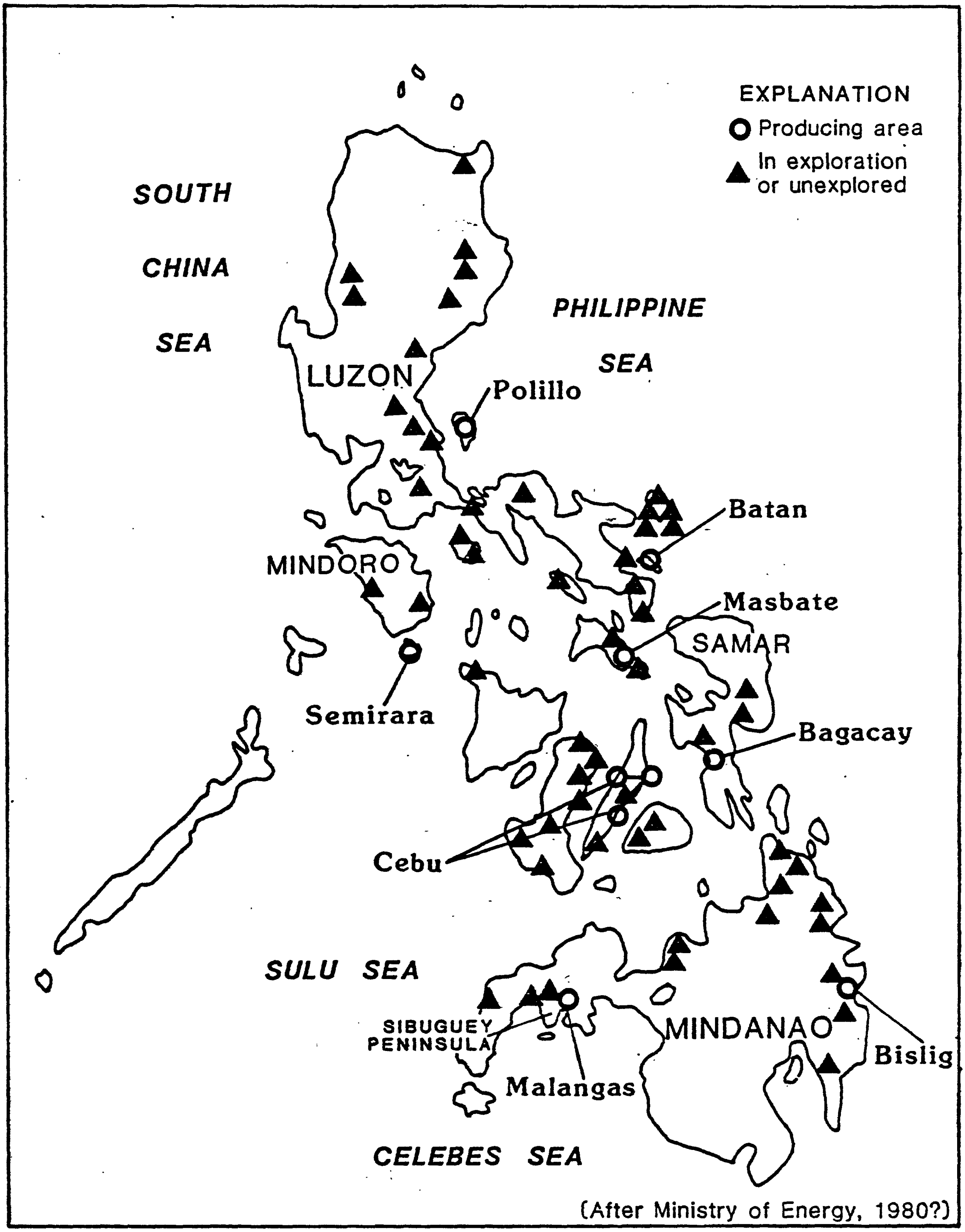

Figure 1. Known and reported coal areas.
(Producing areas updated to 1984)

many coal resource investigations, some with help from counterpart agencies of other countries. Many of the studies were made with the cooperation of personnel of the U.S. Geological Survey under the sponsorship of the Agency for International Development and its predecessor agencies, the U.S. Mutual Security Agency and the International Cooperation Administration. Most of the results of these cooperative studies were published; in many areas, these studies are still the only information available on the coal resources; in some areas newer studies have added information to these basic coal resource studies. The main sources drawn upon for the Selected References listed are only a very small part of the voluminous geologic literature available for the Philippines.

2.2 Geologic Setting

The Philippine Archipelago has a very complex geologic history. The basic relationship of the different islands of the Philippines to each other is only partly understood, and further complications are indicated by the fact that in some cases different parts of islands do not seem to share a common geologic history. In a much larger sense, however, the conclusions of some recent researchers were anticipated by earlier workers. Smith (1924) stated that " *** as has been pointed out by many investigators, the essential geologic unity of the Pacific Basin is well established. *** if we were to flatten out the globe the western coastal margins of the Americas and of eastern Asia would be seen to fall into one line, and that fairly straight, so that really western America and eastern Asia are on the same side of the Pacific."

The coal-bearing rocks reflect the complex history of the Archipelago. Their distribution is poorly understood, they are folded and faulted, and have been intruded by younger igneous rocks. The complex history has resulted in a wide range of coal rank and structurally-difficult mining situations. As expressed by the U.S. Bureau of Mines, 1952, " *** the rise in quality is attributed to igneous and other geological activity which, at the same time, has often broken and displaced the beds making mining extremely difficult *** generally speaking; as the quality of coal increases, difficulties of exploration and development are multiplied." While the preceding statement is generally true, so is the following: "Usually, and fortunately so, the commercial value of coal seams is in direct proportion to the difficulty and expense of mining the coal." (Smith, 1924, p. 381).

Structural deformation in most known coal areas of the Philippines has produced dips ranging from 15° to 90° in the coal-bearing rocks. Bomasang (1984) states that the average degree of inclination is 45° in areas where underground mining is necessary. Faulting, commonly of high-angle tensional and compressional forms, is common and, if undetected, can constitute problems to mining. The coal beds in most areas are relatively thin, but beds as much as 29 m thick are present in some areas. Five of the eight producing areas on figure 1 have underground mines. In the other three areas, Semirara, Batan, and Bagacay, surface mining is done, and the coal beds are not so steeply inclined. The coal in some other parts of the

Philippines, such as eastern Mindanao and northern Luzon, is also amenable to surface mining, and future exploration will locate other areas where recovery of coal is possible by open-pit methods.

Figure 2 shows known coal districts of the Philippines as of 1952, and table 1 summarizes geologic and other pertinent information as of 1940. This summation was complete and valid until less than 10 years ago. A comparison of figures 1 and 2 shows that more coal areas are now known. Although many areas remain unexplored, recent and continuing exploration for coal in the Philippines, particularly in the last 5 years, has added much new data for many of the areas, especially those on Samar, northern Luzon, and eastern Mindanao.

2.3 Quantity

Through the years, many attempts to quantify the coal resources of the Philippines have been made. Neither the philosophy, nor methodology of estimation have been standardized in the Philippines, and most older estimates are not comparable with each other. The Bureau of Energy Development has adopted some workable standards, but they have not been applied nationwide, and many older estimates are still the best available for some areas. In general, the older estimates for Philippine coal resources are much smaller than recent quantifications because of an increased amount of both general geologic data and specific coal quantity information in a few relatively small areas. To date, a comprehensive attempt has not been made to evaluate the overall coal resource potential of the Philippines.

As is shown in table 2, the "possible total amount" of coal in the Philippines was estimated in 1940 to be 10 million metric tons. By 1950, the estimate had increased to 41 million tons (ECAFE, 1952), and by 1973, had increased to 91 million tons (World Energy Conference, 1974). The estimated coal resource potential increased dramatically to about 1,500 million metric tons by 1982 through research by BED, and has remained at about that level to date (table 3).

Comparison of table 2 with table 3 shows that detailed exploration on the 55-km^2 Island of Semirara added about 549 million tons of estimated resources to the total, exploration in Mindanao increased the total by more than 350 million tons, and exploration in northern Luzon (Cagayan Valley) added 336 million tons to the total estimated resource potential.

The areas selected for specific attention in the coal-water-mix (CWM) fuel study are those which seemed to offer the best potential in terms of quantity and/or quality of the deposits. They were Semirara, the Lalat area of the Sibuguey Peninsula of Mindanao, South Mindoro, and the Carbon Creek area of southeastern Samar (see appendices A through D). Table 4 shows the pertinent resource data from table 3.

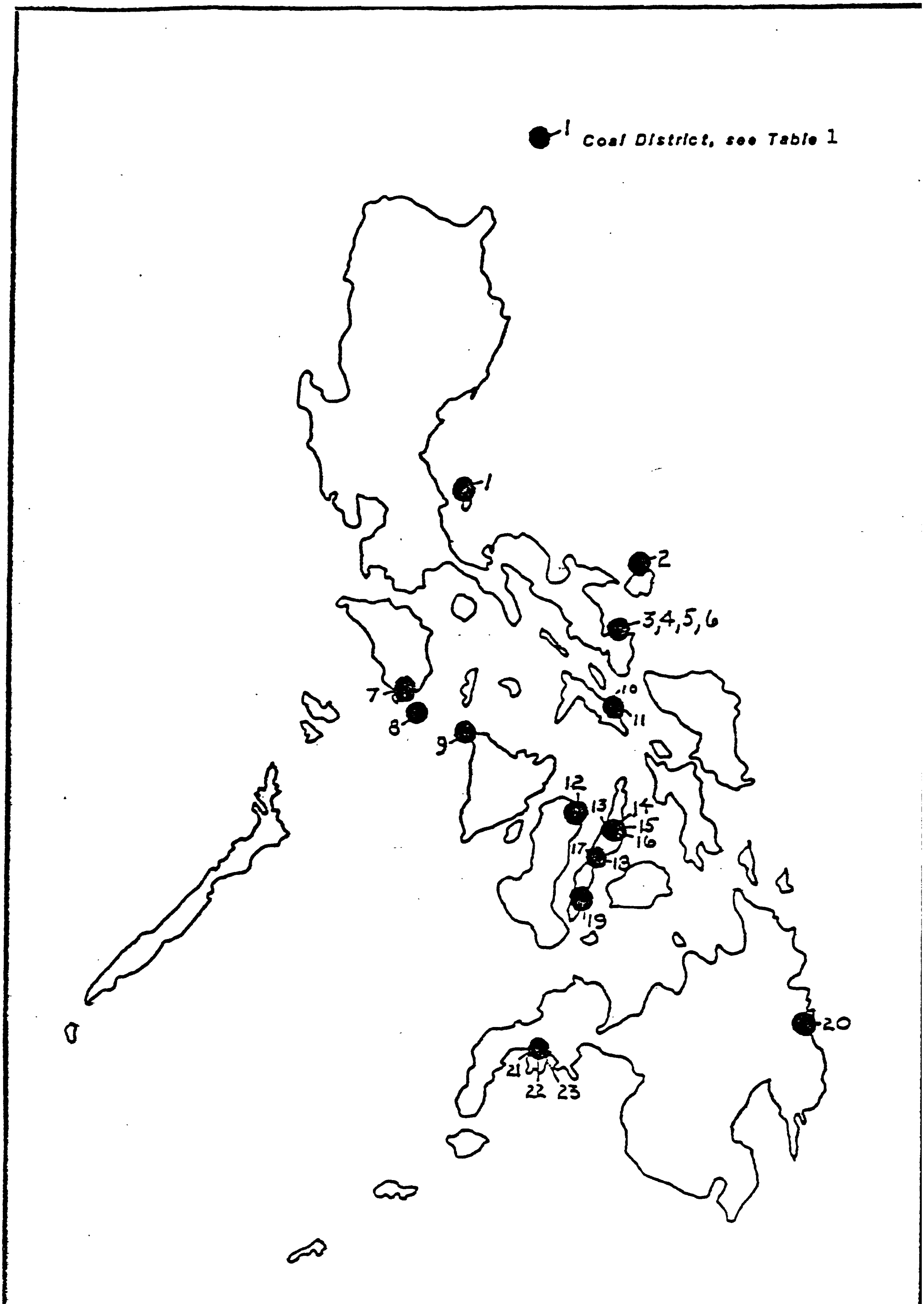

Figure 2. Coal Districts (ECAFE 1952).

Table 1. Philippine Coal Districts.
(modified from Alberding, 1940)

Map Ref. No.	Coal District	Location Island	Harbour Facilities	Distance from Coast (Km)	General Structure	Dip of Coal beds	No. of Coal Beds of Mineable Thickness
1	Polillo	Polillo	Excellent	2 to 4	N-S striking folds; numerous minor faults	5° to 87° Average 48°	4
2	Panganiban	Catan-duanes	Poor (Shallow water and unprotected)	11 to 17	NE striking folds; numerous minor faults	10 to 90° Average 51°	At least 2 lenticular
3	Liguan	Batan	Excellent (Pier already built)	on Coast	E-W striking mono-cline dipping north	145° to 17° Average 16°	2
4	Calanaga	do	Excellent	0.46 to 1.22	N75° striking mono-cline dipping north	15° to 30° Average 21°	At least 2
5	East Batan	do	Excellent	0.21	do	13° to 30° Average 20°	2
6	Gatbo	Luzon	Good (Protected but shallow water--pier already built)	1	(Strata vertical N 20°W)	Vertical	1 (Lenticu-lar)
7	Bulalacao	Mindoro	Fair (deep water but unprotected from southwest monsoon)	6.5	NW plunging anticline	19 °to 70° Average 46°	4
8	Semirara	Semirara	Poor (shallow water and unprotected)	on Coast	Gently dipping strata minor folds	2° to 32° Average 30°	At least 2
9	Buruanga	Panay	Fair (deep water, but unprotected)	2	NW striking folds some overturned	17° to 85° Average 63°	At least 2
10	Nabangig	Masbate	do	do	do	do	3
11	Buyag	do	do	do	do	do	?
12	Escalante	Negros	do	do	do	do	?
13	Cajumayjumayan	Cebu	Harbors unnecessary, coal is consumed locally--excellent harbors present	10 to 12	Folds plunge north-east; faults in Mt. Licos area	3 to 85° Average 40°	4
14	Northeastern Camansi	do	do	do	do	do	3
15	Camansi Proper	do	do	do	do	do	4
16	Mount Licos	do	do	do	do	do	3 (only)one in depth--the Abella)
17	Toledo	do	do	4 to 17	NW plunging anticline	11 to 17° Average 20°	At least 2
18	Uling	do	do	13	NE striking folds Uling-Masaba faults and many minor faults	18 to 72° Average 42°	At least 5
19	Montalongon	do	do	10 to 12	Badly crumpled NW striking folds	3 to 80° Average 35°	At least 2
20	Linsig-Bislig (Mecoupe-area)	Mindanao	Fair (deep water, but unprotected)	1.5	SW or S dipping strata block faulted	2 to 85° Average 22°	2
21	Lalat	do	Excellent	31.5	EW striking folds minor faults	16 to 81° Average 18°	4
22	Lumbong	do	do	2.2	Dome with flanks much faulted	13 to 70° Average 44°	1
23	Deplahan	do	do	2.4	NE striking syncline with diorite intru-sion	27° to 70° Average 36°	2

Table 2. Classification and reserves of Philippine coals. (from Alberding, 1940)

Coal District	Seam	CLASSIFICATION AND COAL BY RANK (Standards of American Society for Testing Materials)	Approximate Tonnages Mined To end of 1939	COAL RESERVES (Metric Tons)			
				Amount Above Stream Level if Weathered Zone Excluded	Possible Amount Below Stream Level	Number of Meters down on Seam	Possible Total Amount
Polillo	Coal No 4 Coal No 3 Coal No. 2 Coal No. 1	High Volatile B Bituminous -- ditto -- Sub-Bituminous A or High Volatile C Bituminous -- ditto --		65,500	1,433 300	110 to 250	1,500 000
Pauganiban	Uncorrelated Coal No. 2 (?) Coal No. 2 Coal No. 1 (?) Coal No. 1	Low Volatile Bituminous Semi-Anthracite Low Volatile Bituminous -- ditto -- -- ditto --		33,800	287,000	50	321 400
Liguan	Seam No. 4 Seam No. 5	Sub-Bituminous A or High Volatile C Bituminous	350,000		1,000,000 ?		1,000,000 ?
Calauaga		Sub-Bituminous B	6,000				
East Batan	Seam 100 Seam 153	Sub-Bituminous C	125,000		441,200 ?		441,200 ?
Gatbo	Seam 204	Sub Bituminous B	6,000	4,400	112 000	00	116,400
Bulalacao	Coal No 4 Coal No. 3 Coal No. 2 Coal No. 1	Sub-Bituminous B Sub Bituminous A or High Volatile C Bituminous -- ditto -- Sub-Bituminous B		17,000	170,000	50	187,000
Semirara	Coal No. 2 Coal No. 1	Sub-Bituminous B -- ditto --	48,300	46,500 (strippable)			1,000,000
Burnanga							
Nabangig	Coal No. 3 Coal No. 2 Coal No. 1	Sub-Bituminous A or High Volatile C Bituminous -- ditto --		8,000	113,000	20 to 70 usually 50	121,000
Buyag							
Escalante							
Cajumayjumayan	G Bed C Bed B Bed A Bed	Sub-Bituminous C Sub-Bituminous B -- ditto -- -- ditto --			1,080,000	80 to 100	1,080,000
Northeastern Camansi	G Bed F Bed E Bed	Sub-Bituminous C -- ditto -- Sub-Bituminous B			504,000	100	504,600
Camansi proper	San Luis No. 5 No. 2 Carmen	Sub-Bituminous A or High Volatile C Bituminous -- ditto -- -- ditto -- -- ditto --	57,000 ?		203,000	100	203,000
Mount Licos	Enriqueta Abella Carmen	Sub-Bituminous A or High Volatile C Bituminous -- ditto -- -- ditto --	63,000				
Toledo	Seams 0 81	High Volatile B Bituminous	9,500 +	28,500	5,000 (at Guila Guila)		33,500
Uling	Landon Seam Footwall Seam Dona Margarita Coal No. 2 Coal No. 1	Sub-Bituminous A or High Volatile C Bituminous Sub-Bituminous B High Volatile B Bituminous Sub-Bituminous A or High Volatile C Bituminous	70,000	750,000 ? (above tunnel) drainage level)		150 to fault	750,000
Mantalongon		Sub-Bituminous A or High Volatile C Bituminous					
Lingig-Bislig (Mecoupe-Area)	Coal No. 4 Coal No. 2	Sub-Bituminous A or High Volatile C Bituminous -- ditto --		66,000 (Strippable) + 53,000	437,000 to 120 Meter Level		556,000
Lalat	Coal No. 1 Coal No. 2 Coal No. 3 Coal No. 4	High Volatile B Bituminous -- ditto -- -- ditto --		100,000	3,000,000		3,100,000
Lumbong	Seam 3 14	High Volatile A Bituminous	113,500	16,000 (strippable)			16,000
Deplahan	No. 1 No. 2	Low Volatile Bituminous Medium Volatile Bituminous					
TOTAL			800,000 Metric Tons				10,000,000

Table 3. Philippine proven coal reserves by category.
(in million metric tons as of September 1984, BED)

		Resource Potential	Positive		Probable		Total In-situ (Positive + 2/3 Probable	Mineable Reserves
A.	SEMIRARA ISLAND	550.00	132.3	+	29.7	=	152.1	79.0
B.	CAGAYAN VALLEY	336.0	40.4		38.2		68.4	58.7
C.	SURIGAO	209.0	36.8		-		36.8	21.1
D.	SAMAR-LEYTE	27.0	4.5		4.3		7.4	6.3
E.	ZAMBOANGA	45.0	27.7		7.4		33.9	10.1
F.	SOUTHERN MINDORO	100.0	3.1		1.4		4.0	2.4
G.	NORTHERN CEBU	50.0-100.00	1.5		0.4		1.8	1.0
H.	CENTRAL CEBU	40.00	2.3		-		3.2	1.4
I.	SOUTHERN CEBU	50.00	3.9		2.4		5.5	3.3
J.	BATAN ISLAND	9.9	5.6		4.0		8.3	4.6
K.	QUEZON PROV. & POLILLO IS.	5.0	0.4		0.4		0.7	0.2
L.	CATANDUANES	4.1	0.6		-		0.6	0.4
M.	NEGROS	4.5	1.0		1.0		1.7	1.0
N.	DAVAO	100.0	0.2		-		0.2	0.1
O.	MASBATE	2.5	0.3		-		0.3	0.2
P.	OTHERS (BOHOL)	-	0.4		0.7		0.9	-
	TOTAL	1,533.0 to 1,583.0	264.9		90.0		324.9	186.8

NOTE:

1. Positive reserves are those sufficiently explored by drilling/and or tunnelling to warrant inclusion in a company's 5-year development/production program. Drill holes are generally spaced at not more than 200 meters apart, and in highly disturbed areas like Cebu, holes are spaced not more than 100 m apart.

2. Probable reserves are those also explored by drilling and/or tunnelling, but still need confirmatory drilling and/or tunnelling. Drill holes are generally spaced at 200 to 400 m apart, except in fairly undisturbed areas like Cagayan.

3. The mineable reserves are computed by multiplying the total in-situ reserves (positive + 2/3 probable) by a mining recovery factor of 60 percent for underground and 85 percent for open pit, except for companies which have conducted studies on its mineable reserves based on mining method, pit limit, etc.

4. Except for Cagayan, Semirara and part of Samar, Batan, and Surigao, all other coal areas are treated as underground coal areas.

Table 4. Resource Potential of CWM Study Areas (Millions of Metric Tons)

	Resource Potential	Total In-situ	Mineable Reserves
Semirara	550	152.1	79.0
Sibuguey Peninsula (Zamboanga)	45	33.9	10.1
South Mindoro	100	4.0	2.4
Samar (Bagacay)	27	7.4	6.3
Total	722	197.4	97.8

Appendix A to this report discusses the elements that are summarized in table 4 for the estimate of resources of the Island of Semirara. The estimates of mineable/recoverable reserves for the one active and two proposed mining areas on Semirara exceed the mineable reserves cited in table 4 by almost 19 million tons. The difference of 19 million tons is not significant because the various estimates of resources and reserves for Semirara were derived in different manners and are not comparable. However, the basic conclusion is that the estimates do indicate that Semirara contains impressive resources and reserves that should be sufficient to support a mining industry of one to five million tons per year for as long as 16 to 80 years, even if future exploration and development do not increase the mineable reserves. While the quantity is expected to be sufficient, the quality of the resources has not been well-defined.

The estimated resources, total in-situ, and mineable reserves for the Sibuguey Peninsula (Zamboanga) cited in table 4 may be largely attributable to the Malangas area. If so, the total estimated resources of the Sibuguey Peninsula may be larger than shown in table 3. According to recent estimates cited in appendix B to this report, the recoverable reserves in the Lalat area alone may be more than 7 million metric tons, enough to allow a production of about 300,000 tons per year for more than 20 years.

The resources and reserves of South Mindoro have been estimated at least seven times (appendix C, this report). The estimated total resources, 100 million tons, are conservative considering the area of potential coal-bearing rocks in the southern part of Mindoro. The reserve estimates of 2.4 million tons cited in table 4 are less than, but of the same order of magnitude as, the 3 million metric tons of reserves estimated for the Napisian area alone, and both are conservative estimates. Despite the fact that coal was first reported in South Mindoro almost 100 years ago, the area must be considered virtually unexplored from a coal resource standpoint.

The estimated resources and reserves cited in table 4 for Samar are probably mainly for the Bagacay area, and, as such, do not include the coal present in the Carbon Creek and adjacent areas in southeast Samar.

During the last 4 years, there have been four resource, or reserve, estimates for the Carbon Creek area (appendix D, this report). None of the estimates are for an area larger than about 1 km^2, and all are conservative. The recent estimates have not been done on a bed-by-bed basis; however, enough information now exists for such an effort to be initiated in order to eventually obtain a meaningful evaluation of the coal resource potential of the area. The estimated "reserves" of the Carbon Creek area are given as between 3.5 and 5.5 million tons. Both numbers are conservative, and further exploration will increase both the size of the known coal area and the estimated resources and reserves.

The basic conclusion from the available data is that at this time Semirara Island is the only predictable source of coal for use in the project to introduce coal-water-mix fuels to the Philippines. None of the other areas studied can at this time supply the amount of coal that will be needed in the planned initial conversion period. Whether or not any of the other study areas will contribute significantly to the CWM fuel technology is dependent on the type, scale, and time-frame of future exploration and development activities that take place.

2.4 Quality

The quality of coal can be measured in many ways, but the three most common expressions are rank, type, and grade. These and other terms pertaining to coal quality classifications are defined and explained in appendix E to this report. In general, all measures of coal quality are intended to allow prediction of a coal's suitability for particular usages.

2.4.1 Philippine coals

Until now, most coal analyses reported in the Philippines have been only proximate analyses supplemented by sulfur and heat value determinations. Very few ultimate analyses have been done, and such other data as forms of sulfur, Hardgrove Grindability Index, ash-fusion temperatures, equilibrium moisture, free swelling index, elemental and oxide composition of the ash, and minor trace element contents have seldom, if ever, been determined (see appendix E). Because of the lack of sampling, handling, and analytical standards, the comparability of the available analyses is always subject to question, and the reported variability of the physical and chemical properties of Philippine coals may well be caused by sample and analytical inconsistencies, as well as inherent differences of the coal itself.

Table 5 is a summary of Philippine coal quality and variability prepared by BED. The source and number of samples are unstated, as well as most other pertinent factors that can influence evaluation of the data. Nevertheless, the table does yield some idea of both the reported differences and the range between coals from different parts of the Philippines. Some of the recorded data apparently does not include newer information. For example, the ash content of Semirara coal is given as ranging from 2 to 9 percent, but recent information indicates

Table 5. Summary of coal quality.
(Air - Dried Basis)
Source : BED

Coal Area / Basin	Moisture %	Ash %	Volatile Matter %	Fixed Carbon %	Sulphur %	Heat Value Kcal / Kg	Coal Rank (ASTM Classification)
SEMIRARA ISLAND	17 - 18	2 - 9	37 - 38	37 - 41	0.5 - 0.7	4440 - 5550	Lignite to subbituminous
CAGAYAN BASIN							
Cauayan, Isabela	14 - 16	15 - 18	36 - 38	25 - 29	0.7 - 1.1	3780 - 4110	Lignite
Maddela, Quirino Prov	8 - 12	8 - 16	41 - 55	28 - 32	N/A	5170 - 5400	Lignite to subbituminous
SURIGAO							
Bislig	12 - 14	11 - 13	31 - 34	34 - 38	0.5 - 1.0	4900 - 5400	Subbituminous
Cuigaquit	8 - 9	17 - 22	37 - 40	28 - 34	2.4 - 3.8	4780 - 5170	Subbituminous
SAMAR - LEYTE	N/A	N/A	N/A	N/A	N/A	4170 - 5280	Subbituminous
ZAMBOANGA	2 - 4	5 - 7	24 - 28	58 - 67	0.4 - 0.9	7060 - 7280	Bituminous to Semi-Anthracite
SOUTHERN MINDORO	6	2 - 3	50 - 53	36 - 39	3.0 - 4.1	6170 - 6280	Subbituminous
NORTHERN CEBU							
Danao - Compostela	6 - 9	5 - 8	40 - 41	38 - 44	0.3 - 1.0	5830 - 6400	Subbituminous
Toledo - Balamban	3 - 4	10 - 13	36 - 39	41 - 46	3 - 5	5170 - 6780	Subbituminous to Bituminous
CENTRAL CEBU	11 - 12	5 - 6	38 - 40	39 - 42	0.3 - 0.5	5400 - 5780	Subbituminous
SOUTHERN CEBU	5 - 6	3 - 6	40	46 - 48	0.4 - 0.6	6670 - 6900	Bituminous
BATAN ISLAND							
East	16 - 19	5 - 6	36 - 37	34 - 36	1.7 - 2.0	4560 - 4940	Subbituminous
West	6 - 10	2 - 7	35 - 37	42 - 47	1.5 - 3.0	5830 - 6280	Subbituminous
QUEZON	5	4	48	42	0.4	7170	Bituminous
POLILLO ISLAND	11 - 14	1 - 6	30 - 35	36 - 42	0.3 - 1.3	5060 - 6110	Subbituminous
CATANDUANES	3 - 7	9 - 15	22 - 25	50 - 55	1.2 - 1.6	5720 - 6720	Bituminous
NEGROS (East)	17 - 19	12 - 13	32 - 34	35 - 37	1.5 - 4.4	4670 - 5060	Subbituminous
DAVAO	18	9	33 - 34	36	0.6 - 1.7	4560 - 6110	Lignite to Subbituminous
MASBATE *	4 - 15	5 - 35	20 - 36	36 - 45	0.7 - 3.2	4440 - 5110	Lignite to Subbituminous

* Data from report by Robertson Research International Limited

N/A Data not available

that some samples may contain as much as 48 percent ash. Other areas, such as the virtually unknown locality called Quezon in the table, are apparently represented by a single analysis.

Complete analytical data on the five samples of Philippine coals collected at the onset of the CWM fuel technology program are presented in appendix F of this report. The samples were collected from five different coal areas in standardized manners specified by William Watson as a result of prior AID-funded studies by Development Sciences, Inc. Thomas Butcher of BNL sent splits of the five samples to the U.S. Geological Survey who analyzed them following the flow diagram presented with the analytical results in appendix F.

The elemental content of major constituents of coal ash were determined for 16 samples of Philippine coal that were submitted to the U.S. Geological Survey laboratories as part of the CWM fuel study. Table 6 shows the elemental content and the derived oxide content for the ash of the 16 samples. Five of the samples are those described above as being collected by EDF personnel in the initial stage of the study; the other 11 samples were obtained in the Philippines by the authors of this volume. Ash in samples from Semirara as a group contain more silicon, sodium, and potassium, and less iron and calcium than most of the other samples. More data is needed to evaluate these possible relationships, some of which may influence utilization.

2.4.2 Coal from Semirara

A bewildering profusion of noncomparable groups of analytical results are available for Semirara coal. The lack of standardized sampling, packing, shipping, storage, and analyses are probable cause for the uninterpretable variability. Three groups of recent samples do, however, present comparable analytical results (table 7). One group of eight samples was collected from run-of-mine coal from different coal shipments prior to ship transport to the National Power Corporation (NPC) generating plant at Calaca and was analyzed by the Semirara Coal Corporation, presumably in a laboratory on Semirara Island. Another group of six samples was analyzed in the NPC laboratory at Calaca subsequent to arrival of coal shipments at the plant. Two samples were from automatic sampling equipment at the generating plant, and four were splits of samples collected by SCC at Semirara. The other group of five samples were splits, in storage, of samples collected from shipments of Semirara coal that had been delivered at the Batangas coal terminal of the Philippine National Oil Corporation Coal Company. These five samples were analyzed in the United States by a laboratory under contract to the U.S. Geological Survey.

All of the samples came from the Unong mine on Semirara Island, and supposedly represent as-shipped-or-delivered samples of the coal actually available for use during the time-period of July to October 1984. All samples were presumably collected in manners attempting to ensure a representative characterization of the particular coal shipments, and all were analyzed in laboratories, presumably using similar equipment and methods. The group analyzed by the U.S. Geological Survey was in storage

Table 6. Analyses of Coal Ash; 16 Philippine Samples
(Elemental weight percents expressed also as oxides)

	Si SiO_2	Al Al_2O_3	Fe Fe_2O_3	Mg MgO	Ca CaO	Na Na_2O	K K_2O	Ti TiO_2	P P_2O_5	Mn MnO
W226576 (U11934) Malangas	19.7 42.2	16.6 31.4	2.9 4.2	1.04 1.75	5.33 7.46	0.70 0.95	0.26 0.31	0.99 1.65	0.25 0.58	0.02 0.03
W226577 (U11935) Bislig	21.8 46.7	14.6 27.6	4.2 6.0	0.68 1.1	4.83 6.76	0.82 1.1	0.18 0.22	0.71 1.2	<0.1 <0.23	0.05 0.07
W226579 (U11937) Cebu	10.9 23.3	4.25 8.03	18.7 26.7	2.67 4.49	7.84 10.98	0.06 0.08	0.20 0.24	0.35 0.58	<0.1 <0.23	0.03 0.04
W226580 (U11938) Bagacay	11.5 24.6	10.9 20.6	19.8 28.3	0.74 1.2	4.98 6.97	0.13 0.18	0.23 0.28	0.53 0.89	<0.1 <0.23	0.08 0.1
W226578 (U11936) Semirara	17.7 37.9	12.5 23.6	4.3 6.1	2.40 4.03	4.90 6.86	1.91 2.58	0.95 1.1	0.73 1.2	<0.1 <0.23	0.05 0.07
W229404 (U11986) Semirara	22.8 48.8	13.7 25.9	2.7 3.9	1.3 2.2	2.6 3.6	2.4 3.2	1.2 1.4	0.72 1.2	0.09 0.2	0.04 0.05
W229405 (U11987) Semirara	23.0 49.2	13.1 24.8	2.4 3.4	2.5 4.2	3.1 4.3	2.7 3.6	1.3 1.6	0.72 1.2	0.1 0.2	0.04 0.05
W229406 (U11988) Semirara	22.8 48.8	14.4 27.2	2.1 3.0	1.9 3.2	3.2 4.5	2.3 3.1	1.2 1.4	0.78 1.3	0.12 0.28	0.03 0.04
W229407 (U11989) Semirara	22.1 47.3	12.5 23.6	2.6 3.7	2.4 4.0	4.2 5.9	2.3 3.1	1.3 1.6	0.60 1.0	0.10 0.23	0.03 0.04
W229408 (U11990) Semirara	23.6 50.5	14.6 27.6	2.5 3.6	1.7 2.9	2.3 3.2	1.3 1.8	1.2 1.4	0.78 1.3	0.12 0.28	0.03 0.04
W229409 (U12002) S.Mindoro-A bed	10.3 22.0	11.0 20.8	4.8 6.9	1.3 2.2	11.0 15.4	0.49 0.66	0.32 0.38	0.21 0.35	0.03 0.07	0.38 0.49
W229410 (U12005) S.Mindoro-B bed	2.8 6.0	3.0 5.7	1.7 2.4	4.6 7.7	18.8 26.3	1.6 2.2	0.16 0.19	0.14 0.23	0.02 0.05	0.38 0.49
W229411 (U12003) S.Mindoro-C bed	14.3 30.6	7.5 14.2	4.7 6.7	2.2 3.7	9.6 13.4	0.19 0.26	0.80 0.96	0.35 0.58	0.03 0.07	0.13 0.17
W229412 (U12004) S.Mindoro-Unc. bed	17.1 36.6	17.5 33.1	7.5 10.7	0.58 0.97	2.9 4.1	0.04 0.05	0.36 0.43	0.17 0.28	0.05 0.12	0.05 0.07
W229402 (U12001) Samar-Carbon Cr	20.1 43.0	21.0 39.7	4.0 5.7	0.38 0.64	0.62 0.87	0.03 0.04	0.01 0.01	1.2 2.0	0.33 0.76	0.03 0.04
W229403 (U12000) Samar-Carbon Cr	20.2 43.2	21.0 39.7	4.8 6.9	0.17 0.29	0.39 0.55	0.01 0.01	0.01 0.01	1.3 2.2	0.1 0.2	0.02 0.03

Table 7. Comparison of 19 Recent Samples From Semirara (weigh percent means)

	Eight Samples Semirara	Six Samples Calaca	Five Samples USGS	Arithmetic Mean	Range
Moisture (as-received)	25.5	26.1	25.3 1/	25.7	23-29
Ash (as-received)		16.9	15.7	16.4	12-21
Volatile matter (as-received)		28.9	29.8	29.3	24-31
Fixed carbon (as-received)		26.7	29.2	27.8	24-31
Sulfur (as-received)		0.5	0.6	0.5	0.4-0.6
Heat value (Btu) (as-received)		7006	7297	7138	6627-76
Moisture (air-dried)	17.1	18.3	17.7 2/	17.6	15-20
Ash (air-dried)	16.7	18.8	17.2	17.5	14-22
Volatile matter (air-dried)	34.8	33.1	32.8	33.7	31-36
Fixed carbon (air-dried)	31.6	29.9	332.2	31.2	27-35
Sulfur (air-dried)	0.6	0.6	0.6	0.6	0.5-0.7
Heat value (Btu) (air-dried) (7 analyses)	8074	7823	8040	7981	7232-86

1/ Modified to equilibrium moisture.

2/ As-received, but partly air-dried during storage prior to analysis.

in plastic bags for about 2 months prior to analysis, but the other two groups were analyzed within days after collection. Because the samples in the U.S. Geological Survey group had obviously lost moisture, the analyses for these are presented in reverse form in table 7, i.e., the as-received analysis is listed as air-dried, and the analyses listed as as-received are the previous result as modified by adjustment to the determined equilibrium moisture. As is shown in table 7, the as-received analysis is perhaps the representative of Semirara coal as available for shipment in conditions that preclude loss of surface moisture. The air-dried analysis perhaps represents Semirara coal available for utilization after storage and/or transportation in conditions that allow loss of surface moisture.

The means and ranges for the 19 samples are compared in table 8 with the weighted arithmetic means derived from analyses of 22 shipments of Semirara coal received during 1984 by the National Power Corporation (NPC). The means and ranges are very similar; the differences are insignificant. These analytical results appear to be valid expressions of the quality of Semirara coal that was being shipped to two different consumers during 1984.

Table 8 also presents the analysis of the initial Semirara sample obtained for the CWM fuel study in May 1984. The sample was collected by EDF personnel, and was obtained by cutting a channel of an entire coal bed 12 m thick at an active mining face at a location selected to be as representative as possible of the mine product at that particular time. The directions for sampling specifically excluded collection from stockpiles, bins, or conveyor belts. Consequently, the sample presumably included non-coal material that was inherent to the coal seam and excluded non-coal material that was extraneous to the coal seam, such as rock above and below the coal bed that might be included in the run-of-mine product.

Also shown in table 8 is the analysis, made at the Semirara Coal Company laboratory, of a sample representing a shipment of "selected Semirara coal" of 1,000 t received at the Calaca generating plant in February 1985. This sample, and the initial sample, may represent the best quality coal that can be produced from the Unong mine on Semirara at this time.

As a base for a set of coal quality specifications for design purposes in the CWM fuel study, there are three obvious alternatives: 1) use the two "best case" analyses, 2) assume that coal available for CWM fuel use would have to be similar to that delivered at Calaca and Batangas in 1984, or 3) select some intermediate values. In fact, in line with the conservative approach of the CWM fuel study, an assumed specification analysis shown on the bottom line of table 8 more nearly approximates the quality of the actual coal delivered in 1984. The coal actually available for ultimate CWM fuel use should be of better quality, particularly of lower ash content and higher heat value, than the assumed specifications cited in table 8. However, with the present available data, it is not possible to predict the ultimate quality of the Semirara coal except within the broad limits discussed here and shown in table 8.

Table 8. Summary of analyses of Semirara coal shipped to National Power Corporation during 1984. (Analytical values in percent, except heat value in Btu/lb.)

	As-Received					Air-Dried				
	Moisture	Ash	Volatile Matter	Sulfur	Heat Value Btu/lb	Moisture	Ash	Volatile Matter	Sulfur	Heat Value Btu/lb
Initial Sample	26	9	32	0.6	8209	--	--	--	--	--
"Selected"	26	6	35	--	8547	20	7	38	--	9276
Nineteen Samples	26 (23-29)	16 (12-21)	29 (24-31)	0.5 (0.4-0.6)	7138 (6627-7630)	18 (15-20)	18 (14-22)	34 (31-36)	0.6 (0.5-0.7)	7981 (7232-8679)
Twenty-two Samples	27 (23-32)	--	--	--	7228 (6610-7919)	17 (14-19)	16 (9-21)	35 (33-?)	0.6 (0.5-0.7)	8223 (7520-9009)
Assumed Specifications	24	14	33	--	7507	--	--	--	--	--

2.4.3 Coals from Sibuguey Peninsula, Mindoro, and Samar

A large number of recent analyses are available for coals of the Lalat and Malangas areas of the Sibuguey Peninsula of Mindanao. The analysis of a sample of Malangas coal collected as part of the CWM fuel study is in appendix F of this report, and many individual analyses and statistical means thereof are presented in appendix B.

The coal in the Lalat and Malangas areas is some of the best quality in the Philippines and Southeast Asia. The calorific value is medium to high; the coal is bituminous in rank, the moisture content is low; the ash and sulfur are within the ranges required by CWM fuel technology and most other potential uses; the coal has a free swelling index of about 5 (on average); and the Hardgrove Grindability Index ranges from 36 to 57, although it sometimes is considerably higher. The area is geologically complex, which complicates mining. This complexity is the result of folding, faulting, and igneous intrusive activity. However, these are also the factors which contribute to the high quality of the coal. The fact that the PNOC-CC is mining coal at Malangas, and planning a new mine at Lalat, indicates that the geologic complexities can be overcome, and mining is possible.

The coal of the Sibuguey Peninsula is in such demand for cement manufacture and other uses, that little or none may ever be available for use in the CWM fuel program unless use priorities and commitments change.

The available coal analyses of samples from South Mindoro are largely from the Napisian area of the Bulalacao region. A few samples from the Siay area of the Bulalacao region are available, and individual samples from two other areas are also available. Descriptions of geology, coal resources, and coal quality of South Mindoro are given in detail in appendix C. The following conclusions can be drawn:

1) The coal of the Napisian area is low in ash (less than 8 percent), high in sulfur (3 percent, or more), and has an apparent rank of subbituminous B.

2) In comparison with the coal of Semirara, the Napisian area coal has similar or lower moisture content, slightly higher volatiles and fixed carbon, significantly lower ash, significantly higher sulfur content, and higher heat value.

3) Almost all sulfur in the Napisian coal is in the organic form, and consequently is not removable by coal preparation methods in use in the world today.

4) The coals of the Siay and other areas in South Mindoro are basically similar to the Napisian coals, but some samples contain much less sulfur than is common in the Napisian coals. Whether this relationship is true, and, if true, whether it is an areal or stratigraphic relationship,

cannot be decided on the basis of presently available quality information.

Despite the fact that the presence of coal in the Carbon Creek area of southeast Samar has been known for only a short period of time, almost 40 coal analyses are available. The individual sample analyses and the coal bed descriptions are in appendix D, this report. The analyses indicate a low to medium sulfur, medium to high ash, subbituminous C coal. However, the analyses are of only limited usability because the samples represent only partially recovered coal beds in cored intervals of drill holes. The average core recovery for 32 samples was 59 percent with a range of 20 to 100 percent. In most coal exploratory drill programs in the United States, 80 percent recovery is the absolute minimum acceptable recovery, and 85 percent is commonly specified in contracts. Coal beds tend to be selectively cored, and when core recovery is only partial, the sample cannot be representative of the interval (bed) that was cored.

Two samples were collected from a surface exposure during the CWM fuel study. These samples indicate that the Carbon Creek coal has a high ash content (more than 15 percent), low sulfur content (1 percent, or less), and is subbituminous C in rank. The as-received moisture content exceeds 20 percent in most of the reported analyses. The two samples collected for the CWM fuel study both have high ash-fusion temperatures.

Until more and better samples become available, it is difficult to adequately classify the coals of the Carbon Creek area of southeast Samar.

3.0 EXPLORATION AND DEVELOPMENT NEEDS

3.1 History of exploration-and-mining

The following succinct statement by Smith (1924) summarizes early exploration and exploitation history.

> "Coal in the Philippine Islands was discovered by Europeans in 1827, on Cebu, and on Batan Island in Albay Province in 1842. The first coal entries were made on Batan Island in 1847, and the first concession on Cebu was given in 1853. Very little mining was done until after 1890. The two most important properties were the Bilbao and Chifladura mines on Batan operated by the Minas de Batan Company and the Compostela and the Camansi mines consolidated by Enrique Spitt on Cebu. These failed and have done nothing since the insurrection. A very comprehensive plan for mining operations on the part of the Government with Enrique Abella, chief of the mining bureau, in charge, was about to be consummated when the insurrection broke out in 1896. In 1904 the United States Army began exploring Batan Island, but never accomplished much, and in 1910 operations ceased by order of the Secretary of War. In 1907 the East Batan Coal Company began operation and did fairly well until 1911, when it went into the hands of a receiver and was bid in by the Government to satisfy its preferred indebtedness. With the coming of the World War and the need for coal at any price the Philippine Coal Mining Company began operations near the old site of the East Batan Company mine, and in 1921, this was the largest coal mine in the Islands. In 1918, the National Coal Company was formed. Its career has been a checkered one, but now, at the end of 1922, it has reached the production stage."

The National Coal Company operated on Cebu, and in 1925 Cebu led the Philippines in coal production. However, domestic production was only about 5 percent of total consumption during the 1920s and early 1930s. Several major mines were closed during that period, and the Bureau of Science listed the lessons to be learned. "In the first place, it must be admitted that coal deposits in the Philippines are irregular in form and outline, and that the coal outcrops are unreliable so that any calculation of tonnage based on them must be made with a great deal of caution. Preliminary estimates of tonnage should serve as a guide for development rather than as basis for exploitation of the mine. In the second place, the structural features of the coal seams and underground structures must be investigated and studied in detail for the proper formulation of mine development and exploitation. In the third place, no transportation system should be built before the amount of proved coal is known." The Philippines are not unique, and the "lessons" are applicable in most coal areas of the world.

During the early 1930s, consumption dropped sharply because of the Great Depression, but as economic conditions improved during the late 1930s, coal was replaced by other fuels, such as oil, and coal consumption did not increase to the levels of the 1920s. Domestic production was 58,888 t in 1925, but subsequent production in most years was about 20 to 25 thousand tons, or about 5 to 8 percent of consumption.

Production slowly increased to more than 61 thousand tons in 1940 and 123 thousand tons in 1949. By 1968, production had decreased to about 32 thousand tons, but has increased steadily since then.

In 1983, Philippine coal production exceeded 1 million tons for the first time. Sources were as follows:

Source	Metric tons
Cebu	326,731 (32 percent)
Semirara, Antique	325,702 (32 percent)
Zamboanga del Sur	246,997 (24 percent)
Surigao del Sur (Bislig)	38,900 (4 percent)
Batan, Albay	33,984 (3 percent)
Masbate	19,043 (2 percent)
Samar	16,377 (2 percent)
Polillo, Quezon	11,842 (1 percent)
Total	1,019,594 (100 percent)

Bomasang, 1984, summarizes present activity as follows:

"Cebu has always been the main source of Philippine coal production. Coal mining has been carried out in Cebu for the last 50 years, although it has been characterized by a very crude mining technology. Due to the limited size of coal deposits and complicated geology, however, Cebu's share of the total national production is expected to go down to only 13 percent by 1990.

Except for open-pit production from Semirara and Batan, the balance of Philippine coal production comes from underground mines. These underground mines generally use room-and-pillar methods, except for those at Zamboanga del Sur and Polillo, which use modified longwall methods patterned after those used in Taiwan. Due to the much higher mining recovery, most underground mines are now planning on switching to longwall.

At Semirara, a 1 million ton per year open-pit mine, the largest in the Philippines, has just been developed as of this writing. The main coal extraction equipment are bucket wheel excavators imported from Australia. At Batan, two open-pit mines with annual capacities from 100,000 to 150,000 tons each are also in operation using conventional earthmoving equipment (trucks, loaders, bulldozers)."

It is anticipated that production will continue to increase, with the bulk of the increased production derived from Semirara.

3.2 General

The present study of indigenous coal quantity and quality that could be used for CWM-fuel technology in the Philippines reveals that the only possible short term source is Semirara Island. A search for other coal supply options revealed scant and incomplete data, revealed uncertainty in the quantity and quality estimates, revealed an inability to easily disaggregate the basic data, and revealed that most of the available data cover only small areas of larger basins about which little is known. Exploration has been focussed on reserve definition rather than basin and national resource delineation, estimation, and assessment. The lack of general availability to both public and private sectors of much of the exploration data hinders the development of Philippine coal resources, and does not encourage and expedite investment in the exploration and development of Philippine coal.

The deficiencies in the coal resource knowledge that is needed to encourage development of Philippine coal resources can be remedied if the following obvious needs are addressed:

1. A new national coal quantity and quality assessment,
2. National standardization for coal sample collection, handling, preparation, and analysis, and
3. A coal data management system to store, retrieve, manipulate, and make available all of the collected coal geology, resource, chemical, and physical data.

If the above-cited needs are addressed, many overall policy and planning problems, and many detailed specific data needs may be satisfied. At the same time, data deficiencies will be revealed and possible solutions will become apparent.

During the progress of the present CWM-fuel technology study, several general and specific data needs became obvious. These data needs are probably representative of the research that is needed to assess the quantity, quality, and potential utilization of Philippine coal resources.

3.3 Semirara

The Island of Semirara has been the subject of an intensive coal exploration program for more than 10 years. The exploration program was conducted and/or evaluated by several different groups. The results of the efforts of the different groups are not strictly comparable, primarily because of the differences in philosophy and methodology in such interpretive efforts as coal resource and reserve estimation. One of the major areas of confusion is in the attempt to understand and predict the quality characteristics of the coals of Semirara. Considering the long-term importance of the Semirara coal in the energy budget of the Philippines, the problems about expectations, prediction, and reality of Philippine coal quality--a continuing problem for more than 130 years--need to be solved. A comprehensive quality monitoring program is obviously needed. At present, determination of heat values supplemented by some proximate analyses and sulfur analyses constitutes almost the complete program. The quality monitoring program must be more comprehensive in order to yield credible information about a much larger suite of coal characteristics. The creation of credible coal quality information is dependent on the establishment and maintenance of a sampling, storage, and handling program designed to yield representative coal quality data. The program should be designed to produce precise and accurate information about the Semirara coal during all stages of exploration, mining, storage, transportation, and utilization. Only in this manner, will the credibility of information about the quality of Philippine coal be established.

A specific need that relates to both general usage of the Semirara coal and specific usage for CWM fuel technology is an investigation of the possible beneficiation of the run-of-mine Semirara coal so as to produce both a lower ash coal and coal with more consistent quality characteristics of all types. Beneficiation can be as simple as hand-picking and washing with water through a hose, to as complex as cleaning plants that employ a variety of gravity-separation and size-separation methods. As a minimum, the Semirara coal should be hand-picked and water-washed. The washing can be accomplished in several ways, but use of plain water in a hydrocyclone or a dense-medium in a cyclone should be considered. Other more complex techniques should be investigated, such a jigs, tables, and other devices that are commonly applied around the world. Froth flotation, a method of separation widely used in some places, may not be usable on the Semirara coal because of the hydrophilic character of most low-rank coals.

3.4 Sibuguey Peninsula

Study of the available information about the coal in the Sibuguey Peninsula indicates that sufficient information now probably exists to allow a geologic and resource synthesis of the whole area to provide a preliminary regional assessment. Such an assessment would allow reasonable predictions and expectations about the quantity and quality of the coal in the area, and would also point out data deficiencies and highlight prospective areas for further exploration.

In the specific case of the Lalat area, the feasibility of mining coal in the drilled development areas should be investigated as soon as possible.

3.5 South Mindoro

This study of the available information about the coal in the southern part of the Island of Mindoro indicates that several investigations are needed to advance our knowledge of the coal resource potential of the area. In common with many of the other coal-bearing areas of the Philippines, the presence of coal in southern Mindoro has been known for 100 years or so, but very little definitive exploration has ever been done. The observations, reports, and facts discussed in appendix C lead to the following recommendations:

1) A reconnaissance-type regional study of the part of southern Mindoro that is known, or is suspected, to contain coal-bearing rocks is needed in order to obtain even a preliminary understanding of the coal resource potential of the area. Recent studies by the Japan International Cooperation Administration and the Philippine Bureau of Mines and Geosciences have established a theoretical stratigraphic and structural framework for Mindoro, and detailed studies of the coal resources are more possible now than previously. This regional study would probably require reconnaissance geologic mapping, stratigraphic traverses, and extensive trenching of outcrops for stratigraphic and lithologic information and samples of rock and coal. If favorable results were obtained, this study would be followed by a study to determine the feasibility of coal development potential.

2) A feasibility study of the mining potential of the Napisian area in the Bulalacao region is needed. Enough information is now, or soon should be, available to allow preliminary evaluation of the development and exploitation possibilities of that area.

3) Exploration work based on trenching and drilling to develop stratigraphic information and yield coal samples for analysis should be initiated in the Siay area of the Bulalacao region. The effort should be aimed at determining the possible resource potential of the area in general, and, in particular, determining whether or not the coals of the Siay area are significantly different in sulfur content from the coals of the Napisian area and, if so, why and how.

3.6 Southeast Samar

The coal resource potential of southeast Samar cannot be evaluated on the basis of presently available information. Coal has been mined in the northern part of the area at Bagacay, and coal has been examined and, in some cases drilled, in several other parts of the region. The estimated resources--which by USGS standards are classified as reserve base--seem very conservative. Most past work has been concentrated in a very few square kilometers of this large island. Even in those areas of greatest density of information, many questions are unanswered. Not only is the quantity of coal unknown, but the quality characteristics need much more definition.

Pre-feasibility studies based on present data supplemented by reconnaissance geologic mapping and stratigraphic studies in conjunction with trenching, and more drilling with better core recovery and complementary geophysical logging should be initiated.

One activity that is possible on the basis of presently available data is a modern detailed categorized bed-by-bed estimate of the coal resource potential of the Carbon Creek area.

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APPENDIX A

COAL IN SEMIRARA, PHILIPPINES

DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

PROJECT REPORT
Philippine Investigation
(IR)RP-22

COAL IN SEMIRARA, PHILIPPINES

Prepared in cooperation with the Government of the Philippines, under the auspices of the Agency for International Development.

1984

COAL IN SEMIRARA, PHILIPPINES

By

J. H. Medlin, E. R. Landis and M. D. Carter
U.S. Geological Survey

The project report series presents information resulting from various kinds of scientific, technical, or administrative studies. Reports may be preliminary in scope, provide interim results in advance of publication, or may be final documents.

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COAL IN SEMIRARA, PHILIPPINES

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U.S. Geological Survey

ABSTRACT

The quantity of coal reportedly available for mining on the Island of Semirara is more than adequate to supply the needs of the proposed coal-water-mix fuel technology. New mines would have to be developed, but the necessary feasibility studies may need to be reviewed in the light of these needs.

The quality of the coal of Semirara remains a major problem both because of the wide range of reported properties and because prediction of the quality is difficult.

INTRODUCTION

A workshop on introducing coal-water-mix (CWM) fuels to the Philippines was held August 20-24, 1984, at Brookhaven National Laboratory (BNL), Upton, New York under sponsorship of the Office of Energy in the Agency for International Development (AID). One of the results of the workshop was selection of coal from the Island of Semirara for further experimental work. An evaluation of the available information about the quantity and quality of Semirara coal was necessitated.

During September and October, information about the coal resources of Semirara was gathered by Carter, Medlin, and Landis of the U.S. Geological Survey (USGS) and Gil C. Guevara of the Economic Development Foundation (EDF) as part of the AID program to determine the potential use of CWM fuels. Unfortunately, most of the required information did not become available until near the end of the USGS team's time in the Philippines. The aid and assistance of Ms. Purita M. Festin and Gil C. Guevara of EDF, Jose V. Jovellanos of the National Power Corporation (NPC), and George B. Baquiran of Semirara Coal Corporation (SCC) are gratefully acknowledged.

GEOLOGY

The Island of Semirara shares a very complex geologic history with the remainder of the Philippine Archipelago. Interpretations of this history and of the active geologic relations are diverse. In general, there is at least some agreement that Semirara is part of a major depositional basin that includes parts of southern Mindoro, Caluya, and other nearby islands, and may (or may not) include part of the northwestern tip of Panay Island. This basin could have been in existence as early as Late Paleozoic time but the recorded history is largely Tertiary and Quaternary with major periods of depression, accumulation of sediments, and uplift during the Cenozoic. There is some evidence that parts of this basin could contain as much as 5,000 m of sediment, largely of middle Cenozoic age. For further details and disparate interpretations the reader is referred to Melendres and Cinco (1940), Guzman (1975), Vergara (1956), Robertson Research International (1977), Bardelosa and Sales (1981), Balce and others (1981), Dames and Moore (1984), and Austromineral (1980 and 1981).

Stratigraphy

Sedimentary rocks of Cenozoic age underlie Semirara Island. Most of the known sedimentary sequence is included in the Semirara Formation of middle to late Miocene age. Both the Lower and Middle Members of the Semirara are composed largely of fine to coarse-grained clastics and are coal-bearing. The Upper Member of the Semirara is marine limestone. The marine Buenavista Limestone of Pliocene age unconformably overlies the Semirara Formation and forms the resistant higher parts of the island. The discontinuity was caused by folding, faulting, and erosion of parts of the Semirara prior to deposition of the Buenavista.

The Semirara Formation is more than 700 m thick based on exploration by Dames and Moore, 1984. An oil exploratory well drilled near the south end of the island penetrated as much as 2,300 m of coal-bearing sedimentary rocks (Baquiran, oral commun., 1984).

Structure

Grossly, the rocks of Semirara form a north-south trending anticlinal structure. Minor folds, some at nearly right angles to the major axis, are superimposed on the main structure. At most outcrops the rocks dip gently westward and southwestward and strike north-northwest to north-northeast.

Deformation of the rocks of the island occurred during at least two distinct time periods. Following deposition of the Semirara Formation the rocks were folded, faulted, and eroded before and/or during depression of the area below sea level and deposition of the overlying marine limestone of Pliocene age. Subsequent vertical changes relative to sea level have raised the island, and further faulting has occurred. Each of the areas on the island where mining has occurred, is underway, or is proposed, is structure-bounded either because beds become too deep to recover or are cut off by faulting.

COAL RESOURCES

Quantity

The number of coal beds underlying Semirara Island, their distribution, their thickness, and their quality varies according to the source document of information. According to the Bureau of Energy Development (BED) at least six coal beds of considerable thickness have been delineated; coal bed Nos. 5 and 6 have been traced and appear to occur consistently in the three major coal areas of Semirara Island: Panian, Himalian, and Unong, (fig. 1).

Vergara (1956) reported that at least six coal beds of considerable thickness were distinguishable from outcrops on Semirara Island. Three of these coal beds are within a sandstone unit and one within a shale unit in the middle member of the Semirara Formation. The two other coal beds (Nos. 5 and 6) are within a shale unit of the lower member of the Semirara Formation. Coal bed No. 6 is reported to be the thickest on Semirara Island, ranging from 40 to 60 cm at Himalian, as much as 4.26 m, excluding three shale partings, at Panian, and 3.74 m at the Limkako pit at Unong.

Since the Vergara study (1956), more detailed mapping, stratigraphic studies, and drilling of the three coal areas have revealed considerably more data on the coal underlying Semirara Island. An open-pit mine has opened at Unong as a result of these more recent studies. The following discussion summarizes these new data.

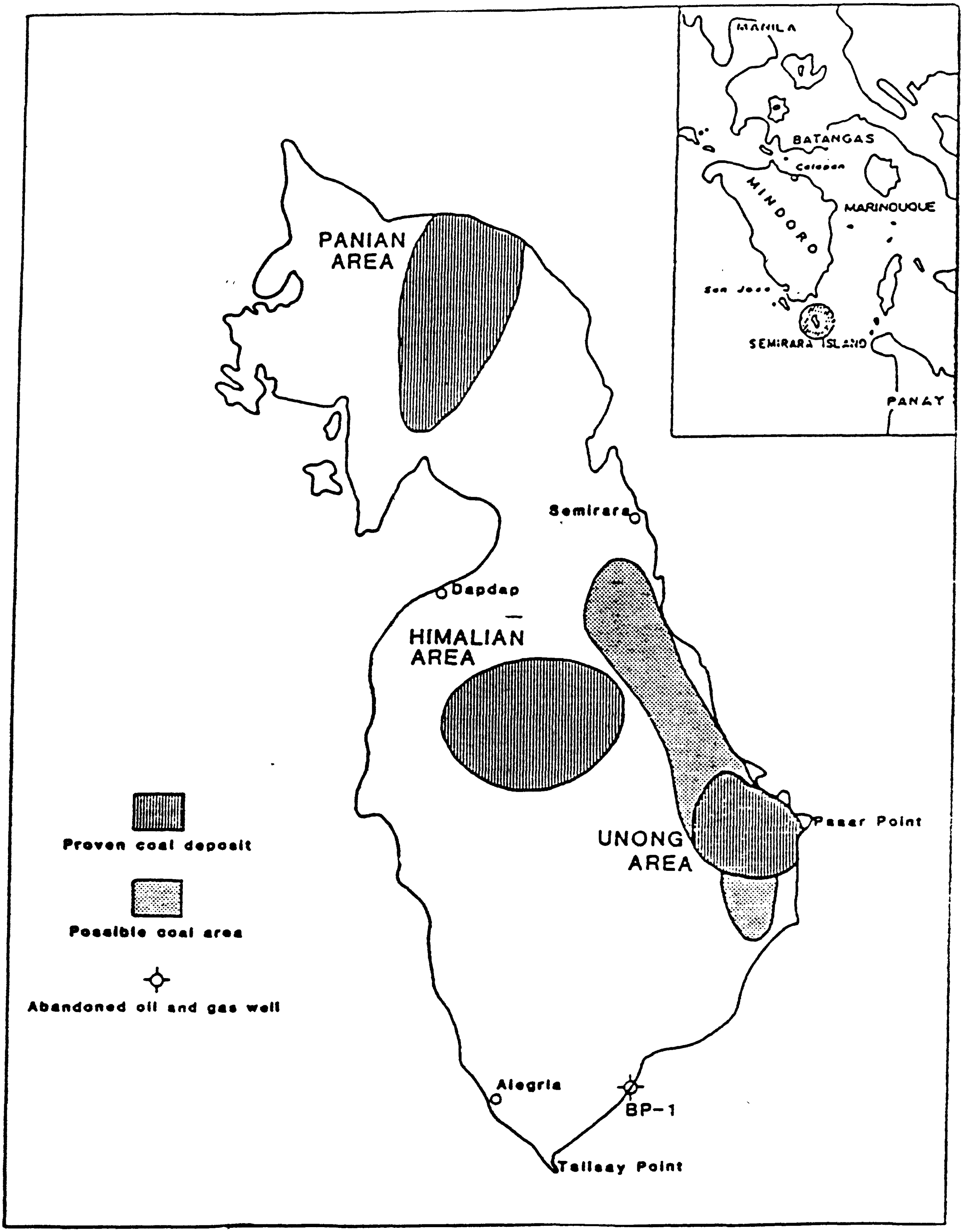

Figure 1. Location map showing proven and possible coal mine areas on Semirara.

Panian Area

The Panian area, approximately 3 km^2, contains 7 continuous coal beds — three major ones. Forty-nine drill holes (12,752 m) on a 250 m grid are the basis for the stratigraphy and reserve esitmates. The reserve estimate by Austromineral (1981) was made on polygonal blocks delineated by the bisectrix between the individual drill holes. Proven and probable (geological) reserves were based on an aggregate of all coal encountered in the drill hole in the center of each block. Recoverable coal includes only that coal that can be mined — thickness cutoff of .3 m. The average aggregate thickness of beds in each block was 38 m. The limit of overburden was 200 m. The density factor was 1.3. The mining ratio is about 6:1 (m^3 of overburden to metric tons of coal).

Himalian Area

The Himalian area includes 13 main coal beds, with 29 non-coal partings. Twenty-five drill holes at 250-meter spacing were used to estimate reserves. The reserves were estimated by Dames and Moore (1984) on a bed-by-bed basis. Isopach and structure maps were prepared. Maximum overburden was 300 m and the mining ratio was 11:1 (m^3 of overburden to metric tons of coal). Dames and Moore calculated and used a density factor of 1.45 for this site. The minimum thickness of mineable coal was .5 m when isolated by more than 54 m of interburden and .3 m when within a main bed. Unfortunately, Dames and Moore did not include detailed information on how or where they calculated their reserves. SCC is therefore in the process of recalculating the reserves of the Himalian area so that they will have a better understanding of what they have to mine.

Unong Area

Unong, 1.6 km^2, began production in 1984 and is currently to the 1 million ton per year rate. There are 7 beds in the deposit, with 1 main bed that is as much as 29 m thick. Seventy drill holes (about 12,000 m total thickness at 250 m spacing) were used to estimate reserves. Reserves were estimated by Austromineral (1980) on a modified triangle-polygon method employing the aggregate thickness of coal in each polygon. Austromineral used a density factor of 1.3 and calculated reserves to a depth of 150 m. The beds range from 3.5 to 29 m in thickness and average 18 m of coal per drill hole and polygon.

Table 1 shows the tonnage estimates from the three feasibility studies and, for comparison, the current estimate by the Bureau of Energy Development (BED). The authors were unable to fit the numbers into the coal classification categories of the U.S. Geological Survey (Wood and others, 1983). In fact, the equivalence of the terms for reserves between the various sources is uncertain and represents only the best guess by the authors of this report. BED defines the following categories.

1. Mineable reserves.--Positive reserves + 2/3 probable reserves multiplied by a recovery factor of 85 percent for open pit; except for areas where companies have conducted studies on their minable reserves based on mining method, pit limit, etc. (all three feasibility studies have done so).

2. Positive reserves.--Those sufficiently explored by drilling and/or tunnelling to warrant inclusion in a company's five-year development/

production program. Drill holes are generally spaced not more than 200 m apart (drilling in the Panian, Himalian, and Unong areas slightly exceeds these limits but are considered proven by the companies and apparently are accepted as positive reserves by BED).

Table 1. Tonnage estimates of coal on Semirara Island[1/]
(in millions of metric tons)

Area	Mineable/ Recoverable Reserves	Positive/ Proven Reserves	Probable Reserves	Resource Potential	Source
1. Panian	45.9	54.7	23.7	---	Austromineral, 1981
2. Himalian	37.5	60.5	--	---	Dames and Moore, 1984
3. Unong	14.5	13.9	3.3	---	Austromineral, 1980
4. Semirara Island (total of 1-3 above)	97.9	129.1	27.0	---	1-3 above
5. Semirara Island	79.0	132.3	29.7	550	Bureau of Energy Development (BED), 1984

[1/]Equivalence of reserve terms between sources is authors' best guess.

3. Probable reserves.--Those also explored by drilling and/or tunnelling, but still need confirmatory drilling and/or tunnelling. Drill holes are generally spaced at 200 to 400 m apart except in fairly undisturbed areas.

BED has not formally defined the term resource potential. However, discussion with Rufino B. Bomasang, Chief, Coal and Uranium Division of BED, indicates that this is comparable to the USGS term resource, and may include all deposits of coal to 2,000 m in depth in such form and amount that economic extraction is currently or potentially feasible. Bomasang indicated that the resource estimate of 550 million metric tons for Semirara was derived from estimates from the Panian, Himalian, and Unong areas, from recent SCC drilling, and from a 1980 oil and gas test hole by British Petroleum at the southeastern tip of the island that showed sequences of Miocene carbonceous shales and coals from approximately 250 to 2500 m in depth (fig. 1).

Quality

The quality of coal can be measured in many ways but the three most common expressions are rank, type, and grade. These and other terms are defined and explained in appendix E to the main report of which this is appendix A. In general, all measures of coal quality are intended to allow prediction of a coal's suitability for particular usages.

Panian Area

Vulcan Industrial and Mining Corporation recently drilled 49 boreholes in the Panian area; the aggregate thickness of these boreholes was about 12,752 m. These boreholes intersected four major coal beds that are described as being lignitic sub-bituminous coal; the aggregate thickness of these beds is about 38 m.

Vulcan performed proximate analyses on 321 coal samples collected from 33 of these boreholes. Analyses for these samples were recorded on an as-received basis; i.e., as-received at the laboratory prior to any processing (ASTM D-3180-74). According to Vulcan, the samples were stored in sealed containers after sampling, and thus the as-received basis should be equivalent to the as-sampled basis. Further, "***proximate analyses on an air-dried basis refer to results obtained after air-drying at ambient atmospheric conditions and subsequent inherent moisture determinations at a temperature of 105 C." The exact atmospheric conditions during individual analysis were not recorded by Vulcan. However, it was concluded from a statistical distribution of all the analyses that the air-drying process created no bias and that the analyses were done under homogeneous conditions.

According to an Austromineral report prepared for Vulcan in 1981, "The average coal quality for the Panian area was determined by using weighted averages of the analyses obtained from individual borehole coal sections, whereby the respective thickness of coal in each borehole and the tonnage of coal pertaining to each individual reserve block served as weighting factors."

The weighted averages of the proximate analyses, according to borehole and on an as-received basis, are given in table 2. The weighted averages of proximate analyses, according to borehole and on an air-dried basis, are given in table 3. The predicted run-of-mine (ROM) analyses for the Panian deposit, calculated as weighted averages of coal blocks, is given in table 4.

Table 5 gives the chemical analysis of coal-ash from the Panian Main Seam. This analysis appears to be normalized to 100 percent and as such is not likely to represent the accurate values for the individual elements. Table 6 presents ash-fusion temperatures for the Panian Main Seam, and table 7 provides data on the average calorific value for individual mining benches for the Panian deposit. Study of table 7 reveals that the heat value will increase as the Panian deposit is developed. Thus, in the first few years of production the heat value of the coal will be less than the predicted average ROM quality given in table 4.

A study of the Panian area by Bardelosa and Sales (1981) for Vulcan revealed the presence of 28 coal beds in the lower member of the Semirara Formation. These coal beds were interspersed over a depth of 300 m; most lie below sea level. The interlayered sediment intervals range from 20 to 50 m. The report gave analytical results for 348 coal samples collected from 49 boreholes. The boreholes covered an area of 250 hectares and had a grid spacing of 250 m. The total aggregate thickness of coal analyzed was 954.1 m. This report indicated that 221 of the coal samples were analyzed both on an as-received and on an air-dried basis; 49 samples were analyzed on an as-received basis only; and 78 samples were analyzed on an air-dried basis only.

Table 2. <u>Weighted averages of proximate analyses for the Panian area on an as-received basis.</u> (Table 3-38, Austromineral Report, 1981).

Drill Hole No.	Total Coal Thk m	Calorific Value Btu/lb	Ash Percent	Moisture Percent	Volatile Matter Percent	Fixed Carbon Percent
D47	26.50	6930	26.58	19.04	58.89	18.50
D48	26.48	7466	16.01	19.60		
D49	25.17	7494	16.65	21.85		
D50	31.56	6410	27.11	19.26		
D51	10.69	6095	33.70	15.61	31.63	19.06
DE47	44.37	6672	25.12	16.58	34.61	23.70
DE48	30.48	8004	18.54	17.85	36.33	27.28
DE49	30.34	6859	26.90	13.20	37.28	22.59
DE50	31.68	7561	17.70	19.11	35.22	27.96
DE51	29.16	7665	21.11	21.11	36.21	26.02
DE52	23.60	6789	28.30	17.00	34.02	20.67
DE53	12.04	8137	15.59	18.67	38.43	27.31
E47	21.89	8175	14.62	15.72		
E48	63.48	7579	24.95	13.48	35.02	26.55
E49	33.37	8379	16.21	14.56	35.95	33.27
E50	23.84	7518	18.57	17.82	36.61	27.00
E51	27.05	7335	22.23	13.44	36.62	27.71
E52	15.27	8319	13.98	14.93	30.10	41.00
E53	28.72	7695	18.32	17.14	35.91	28.51
E54	16.31	8046	16.88	15.67	39.54	27.90
E55-505	43.30	8888	10.73	14.39	37.77	36.81
EF49	31.88	8779	9.63	17.07		
EF50	14.55	8084	13.89	15.46		
EF51	31.03	9252	9.08	15.38	37.13	38.41
EF52	47.48	7345	23.10	16.34	34.61	26.09
EF53	61.19	7648	20.39	12.96	36.01	30.65
EF53-125N-29E	12.50	7168	22.11	15.34	35.93	26.63
EF54	31.12	8299	17.54	13.12	37.69	31.65
EFF53-125N	8.19	6530	26.53	16.29	32.10	25.07
EEF53-125N	22.37	7110	23.96	14.87	35.75	25.43
F52	29.55	7658	19.66	15.09	41.98	23.27
F53	20.72	5273	38.74	12.30	30.07	18.90

Table 3. Weighted averages of proximate analyses and air drying loss for the Panian area on as-received basis. (Table 3-39, Austromineral Report, 1981).

Drill Hole No.	Total Coal Thk m	Calorific Value Btu/lb	Ash Percent	Moisture Percent	Volatile Matter Percent	Fixed Carbon Percent	Air Drying Loss Percent
D47	26.50	7532	28.72	12.18	38.96	20.13	7.82
D48	26.48	7578	16.28	18.37			1.46
D49	25.17	7855	16.95	18.38			4.26
D50	31.56	6646	28.29	16.08			3.75
D51	10.69	6489	35.51	10.58	33.60	20.31	5.65
DE47	44.37	7204	26.83	10.25	37.28	25.64	7.08
DE48	30.48	8504	19.68	12.74	38.58	29.00	5.87
DE49	30.34	7126	27.91	9.90	38.72	23.47	3.70
DE50	31.68	8272	19.26	11.63	38.52	30.59	8.48
DE51	29.16	7903	21.62	14.23	37.30	26.84	2.46
DE52	23.60	7387	30.48	10.03	36.97	22.52	7.77
DE53	12.04	8969	17.08	10.46	42.33	30.13	9.18
E47	21.89	8227	14.73	15.20			0.61
E48	63.48	7807	25.67	10.92	36.02	27.39	2.88
E49	33.37	8683	16.75	11.53	37.24	34.48	3.43
E50	23.84	8215	20.25	10.24	40.00	29.52	8.45
E51	27.05	7603	23.01	10.30	37.96	28.73	3.51
E52	15.27	8692	14.57	11.14	31.42	42.86	4.26
E53	28.72	8315	19.74	10.53	38.92	30.81	7.39
E54	16.31	8444	17.71	11.52	41.50	29.28	4.69
E55-505	43.30	9289	11.18	10.56	39.78	38.48	4.29
EF49	31.88	8919	9.79	15.73			1.58
EF50	14.55	8113	14.20	15.09			0.44
EF51	31.03	9676	9.50	11.50	38.83	40.17	4.39
EF52	47.48	7947	24.77	9.58	37.41	28.24	7.48
EF53	61.19	7946	21.07	9.70	37.37	31.87	3.61
EF53-125N-29E	12.50	7638	23.48	9.87	38.28	28.37	6.07
EF54	31.12	8635	18.21	9.66	39.20	32.94	3.84
EFF53-125N	8.19	7099	28.57	9.23	34.84	27.27	7.71
EEF53-125N	22.37	7491	25.19	10.36	37.62	26.82	5.03
F52	29.55	8078	20.69	10.48	38.83	29.99	5.15
F53	20.72	5535	40.44	8.19	31.03	20.34	4.49

Table 4. Predicted average ROM coal quality of the Panian area as weighted averages of the individual coal beds. (from Austromineral Report, 1981).

Basis	Moisture Percent	Ash Percent	Fixed Carbon Percent	Volatile Matter Percent	Calorific Value Btu/lb
As-received	16.3	20.07	27.23	36.48	7603
Air-dried	11.63	21.36	29.09	37.64	8005

Table 5. Chemical analysis of coal ash from Panian Main Seam. (by XRF, normalized to 100 percent) (from Austromineral Peport, 1981).

	Percent
S_iO_3	18.40
Al_2O_3	31.98
T_iO_2	0.04
Fe_2O_3	27.04
CaO	11.58
MgO	2.12
Na_2O	0.68
K_2O	0.38
P_2O_5	0.04
SO_3	5.96
Others	1.78
	100.00

Table 6. Ash fusion temperature for Panian Main Seam.
(from Austromineral Report, 1981).

Fusion Point	1200 C
Hemisphere Point	1420 C
Melting Point	1460 C

Table 7. Average calorific value for individual benches, Panian coal deposit.
(from Austromineral Report, 1981).

Bench	Mineable reserves, '000t	Percent of reserves	Average Calorific Value Btu/lb, as-received
Pre-stripping			
Bench 3	2,111	4.61	6,499
Bench 1	4,237	9.26	7,210
Bench 2	5,960	13.03	7,077
Bench 3	9,866	21.56	7,506
Bench 4	11,718	25.61	7,497
Bench 5	7,532	16.46	8,574
Bench 5 sublevel	4,337	9.47	8,371
Total	45,761	100.00	7,632(ave.)

Table 8. Coal quality of Panian coal deposits.
(table 5.0, Bardelosa and Sales, 1981; air-dried basis)

Value	Mean	Range	Std. Deviation
Calorific value (But/lb)	8000	7200-8800	+-800
Ash (percent)	20.6	19.6-23.6	+-3(1)
Moisture (105° C, percent)	12.7	8.2-17.2	+-5(1.5)
Fixed Carbon (percent)	28.8	26.4-31.2	+-2.4
Volatile Matter (percent)	41.5	38.0-45.0	+-3.5
Calorific vlaue (Kcal/kg)	4444.4	4000-4889	+-444.4

Of the 28 coal beds, Bardelosa and Sales (1981) indicated that beds numbered 13, 15, and 19 are major; those numbered 12, 14, 17, and 18 are minor; and the remaining 21 are lenticular.

Table 8 shows the coal quality of the Panian beds as given by Bardelosa and Sales (1981) after some sophisticated statistical analyses were performed on the chemical data.

The Austromineral report (1981) concluded that the coal at Panian is low rank subbituminous C, transitional into lignite A. Bardelosa and Sales (1981) concluded that the rank is subbituminous C.

Himalian Area

Dames and Moore, Inc. (1984) recently completed and submitted to Vulcan Industrial and Mining Company a mine feasibility study for the Himalian coal area. This study revealed that there are 13 main coal beds and 29 splits or plys of coal underlying the Himalian area. The stratigraphic succession with coal bed/split/ply identifications and coal bed and interburden thicknesses are given in table 9. Dames and Moore (1984) discerned this stratigraphy by drilling two boreholes (DM #1 and #9) in the Himalian area. Drill hole DM #1 was abandoned prior to reaching the bottom target; subsequently DM #9 was offset a few meters and drilled to a depth of more than 300 m.

Dames and Moore (1984) carefully sampled and "bagged" samples for analyses by an analytical laboratory in Australia. With the completion of the analytical work, a comparison of the coal quality as determined by the laboratory was made with the coal quality data base for the Himalian area held by the Semirara Coal Company (SCC). This comparison revealed major differences in the moisture, ash, fixed carbon, and calorific values. These differences were, for the most part, attributed to the moisture values obtained by SCC. Dames and Moore (1984) concluded that the improper handling of the sample followed by improper moisture determination procedures led to inaccuracies in the ash, fixed carbon, and calorific values.

Table 10 shows chemical data determined by Dames and Moore (1984) on a coal bed basis. The table not only displays proximate analyses, but also gives the crucible swelling index (CSI), Hardgrove Grindability Index (HGI), forms-of-sulfur, ash-fusion temperatures, and the major oxides in the coal-ash. These analyses represent some of the most complete data ever assembled for Philippine coal.

The Himalian coal is subbituminous C (ASTM) according to Dames and Moore (1984).

Unong Area

Coal is produced at the Unong Mine. The feasiblity study for this area, prepared by Austromineral (1980), was reviewed to obtain drilling, stratigraphic, and coal quality data. These data are derived from 79 boreholes with an accumulative thickness of about 14,000 m. It was concluded that there was one major coal bed or coal zone which ranges up to 29 m in thickness; there are several minor coal beds above and below this zone. According to the feasibility study, the upper coal beds have a higher ash content than the main and lower coal beds; the main and lower beds have higher heating values and thus,

Table 9. Himalian deposit coal bed stratigraphy. (from Dames and Moore, 1984).

General Bed Identification	Average Thickness meters	Indicative Thickness meters	Bed/Split/Ply Identification	Semirara Formation Rock Units
A1	5.8		A1A A1B A1C A1D A1E	
Interburden		10		
B1R	0.8		B1R	
Interburden		15		
B1	1.3		B1A B1B	UNIT I
Interburden		15		
B2	1.7		B2A B2B	
Interburden		3		
B3	1.7		B3A	
Interburden		20		
B4	1.5		B4A	
Interburden				
B5	1.0	55	B5A	UNIT II
Interburden				
Interburden				
C1	2.3		C1A, C1B, C1C	
Interburden		15		
C2	7.5		C2A, C2B, C2C	UNIT III
Interburden		5		
C3	7.9		C3A, C3B, C3C, C3D, C3E, C3F	
Interburden		65		UNIT IV
D1	2.2		D1A	
Interburden		10		
D2	3.8		D2A	UNIT V
Interburden		15		
D3	1.5		D3A	

Table 10. Analytical data from Himalian coal prospect and Unong Mine, Semirara Island. Data taken from Dames and Moore (1984) feasibility reports submitted to Semirara Coal Corporation. Himalian data given first using coal seam nomenclature of Dames and Moore (see table 9). Himalian data from Dames and Moore drillholes 1 and 9. Unong Mine information taken from Dames and Moore drillhole 10. Sample identification numbers follow those of Dames and Moore. In places values have been rounded for convenience. Analyses are on raw coal as-received basis. Major and minor oxides determined by XRF on coal ash ignited at 815 C.

Seam	Moisture	Ash	VM	FC	CSI	Cal. Val.	HGI	Tot. S	C	H	N	O	Cl	Rel. Den.	Pyr. S	Sul. S	Org. S	In. Def.	Spherical	Hemisph.	Flow	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	TiO_2	Mn_3O_4	SO_3	P_2O_5
A1	12.0	19.5	36.5	32.0	0	8368	(57) 45	2.2	47.5	3.5	.63	14.6	.01	1.50	.21	.06	1.94	1210	1290	1310	1370	50.	23.9	3.46	7.01	3.53	.35	1.65	.95	.03	9.17	.10
B1R	12.6	24.1	34.2	29.1	-	7277	-	2.17	43.4	3.4	.63	13.7	.01	1.53	-	-	-	1200	1440	1460	1480	54.7	25.5	5.68	3.14	3.06	4.48	1.92	.88	.02	3.66	.03
B2	12.0	20.2	33.7	34.1	0	8205	(59) 42	1.46	47.8	3.6	.75	14.2	.16	1.50	.44	.09	.93	1200	1250	1270	1320	52.7	22.4	6.37	4.52	3.77	1.29	1.65	.88	.04	6.59	.08
B3	13.9	7.3	38.3	40.5	0	9519	(57) 34	1.04	56.3	3.99	.97	16.5	.02	1.41	.14	.03	.87	1170	1200	1210	1240	31.6	12.5	8.68	13.7	3.85	3.97	.97	.54	.10	17.8	.14
B4	10.4	29.2	30.0	30.4	-	7260	(57) 49	1.14	42.1	3.44	.77	13.0	.01	1.56	-	-	-	1220	1420	1430	1440	60.0	24.8	3.98	2.80	2.26	1.49	1.77	.81	.03	2.56	.05
C1 Comp1	13.6	11.4	39.3	35.7	0	9451	-	1.12	54.3	4.07	.93	14.6	.01	1.42	.18	.03	.91	-	-	-	-	47.4	22.3	5.15	5.96	3.79	5.69	1.40	.82	.03	6.43	.11
C2 Comp2	12.6	16.2	35.8	35.4	-	8892	-	.80	51.3	3.53	.98	14.6	-	1.49	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
C2 Comp3	14.3	8.0	37.3	40.0	0	9760	38 (57)	.36	56.0	3.81	1.10	16.5	.10	1.41	.02	.001	.34	1290	1340	1360	1370	46.9	21.5	3.24	5.96	4.05	7.67	1.41	1.12	.02	6.59	.42
C2 Comp4	12.2	21.7	34.0	32.1	-	8188	-	.39	47.0	3.64	.82	14.3	-	1.53	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
C2(21)	14.5	6.7	38.9	39.9	0	9769	(60) 40	.36	57.2	3.89	1.06	16.3	.01	1.38	.02	.002	.34	1160	1210	1230	1260	20.7	15.1	3.02	7.72	5.36	9.55	.71	.65	.38	7.75	.72
C3	14.1	39.8	24.6	21.5	0	5447	-	.34	31.1	2.65	.61	11.4	-	1.72	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
C3 Comp5	11.2	33.4	29.9	25.5	-	6590	-	.41	38.4	3.12	.61	12.9	-	1.67	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
C3 Comp6	13.7	5.1	40.1	41.9	-	10284	(63) 37	.34	59.1	5.19	1.12	15.5	.02	1.41	.013	.002	.325	1220	1280	1290	1300	37.8	15.7	6.03	9.42	5.64	12.7	1.18	.73	.05	9.60	.24
C3 Comp7	11.5	23.0	34.3	30.3	-	8007	-	-	-	-	-	-	-	1.55	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
UNONG SAMPLES FROM BOREHOLE 10 OF DAMES AND MOORE REFERENCE NUMBERS																																
1	10.5	15.9	37.9	35.7	-	9279	(45) 57	1.06	53.9	3.96	.77	14.9	.06	1.47	-	-	-	1140	1270	1320	1360	64.3	14.9	110.0	3.34	2.25	.40	.97	.82	.17	3.08	.08
7	10.5	3.3	44.5	41.7	0	10834	(66) 44	.44	62.3	4.66	.98	17.9	.01	1.34	.088	.019	.33	1350	1370	1390	1510	12.2	13.3	6.35	28.6	15.4	1.86	.18	.95	.73	19.4	.011
12	8.4	39.0	28.8	23.8	0	6151	(48) 80	.56	35.0	3.11	.47	13.5	.01	1.73	.129	.022	.41	1300	+1600	+1600	+1600	54.5	34.3	2.93	1.39	1.90	.42	1.70	1.56	.03	.80	.137

better quality than the upper beds. Analytical data for the Unong area, from a borehole designated BH 10 by Dames and Moore (1984) is shown in table 10 for comparison of anlyses to coal in the Himalian area.

Table 11 gives weighted average analytical data for the lower and upper coal beds and the expected ROM raw coal (lumpy coal, 0-40mm, as-received). The coal rank given in the feasibility study for the Unong area is lignitic subbituminous C. (The authors are not certain of this meaning; perhaps as given for the Panian area, low rank subbituminous C, transitional into Lignite A.) Samples from the Unong mine as analyzed by the USGS reveal a coal rank of subbituminous C.

Table 12 shows a compilation of existing analytical data for the Panian, Himalian, and Unong coal areas. Sources and basis of these analyses are also given in footnotes.

On September 19, 1984, the Philippines National Oil Corporation Coal Company laboratory at Batangas transferred five samples of Semirara coal to the USGS for analysis. The samples were from five different shipments received at Batangas between August 10 and August 14, 1984.

Table 13 shows the analytical results on these samples. The most striking factors in the analyses are the differences between the as-received moisture content and the equilibrium moisture determination. The as-received moisture determination reflects the moisture content of the sample at the time of analysis. The equilibrium moisture determination is an attempt to evaluate the total moisture that the coal might have contained at the time it was recovered from the coal bed in place. Obviously, the as-received moisture analyzed as reported herein is in effect an air-dried moisture content reflecting loss of moisture during mining, transport, and storage of the sample.

The dependence of other determined characteristics on the reliability of the moisture determination of coal samples is shown in table 14, where the analytical results shown in table 13 are modified to reflect the equilibrium moisture determinations. The moist, mineral-matter-free calorific values (Btu/lb) all indicate an apparent rank of subbituminous C for the sampled coal.

Annex A to this report contains analyses of 14 samples of Semirara coal produced at the Unong mine and shipped to National Power Corporation (NPC), Calaca, Batangas between July 29, and October 13, 1984. Eight samples were collected from different shipments and analyzed by Semirara Coal Company (SCC) presumably at a laboratory on Semirara Island. The other six samples were analyzed at the National Power Corporation laboratory at the Calaca generating plant on Luzon. Two of the six samples were collected by the automatic sampling equipment at Calaca and the other four were splits of samples collected at Semirara by SCC. The arithmetic means for the proximate analyses, sulfur contents and heat values for these samples reported as two groups (eight and six) on the as-recieved and air-dried bases are shown in table 15. Also shown for comparison are the means for the five samples or shipments of Semirara coal delivered to the Batangas coal terminal of the Philippine National Oil Corporation Coal Company and analyzed by the USGS. The samples given to the USGS had been in storage and had obviously dried to some extent; therfore, the equilibrium moisture values for these samples indicate that the as-received analyses of the laboratory are actually nearer to being an air-dried basis; and when the reported as-received is modified to reflect the

Table 11. Weighted averages of analytical data for the lower and upper beds and expected ROM coal from the Unong area, (from Austromineral, 1980, calorific values in Btu/lb; ash fusion temperatures in degrees C; HGI no units; all other values in percent).

Lower Beds (air-dried basis, 105°C)

Calorific value	9076
Ash	15.8
Moisture	13.3
Sulfur range (3 values)	0.63-1.88

Upper Beds (air-dried basis, 105°C)

Calorific value	6785
Ash	31.2
Moisture	10.9

Run-of-Mine (ROM) (as-received basis)

Calorific vlaue	>8000 <9000
Ash	16-19
Fixed Carbon	26-29
Volatile Matter	35-41
Moisture	16-19
Total Sulfur	<1
HGI	40-50
Ash Fusion Temperatures	
Hemisphere	1350
Fluid	1410

Table 12. Compilation of existing analytical data for the Panian, Himalian, and Unong coal areas, Semirara Island.

Coal Area	Moisture	Ash	Volatile Matter	Fixed Carbon	Sulfur	Calorific Value, Btu	Coal Rank (ASTM)	HGI	Ash Fusion Temp °C FP	HP	MP
1. Semirara	17-18	2- 9	37-38	37-41	0.5-0.7	7992- 9990	lignite-subbitum.				
2. Semirara											
Dan's Pit	8.3	33	55.6		1.3		subbit C				
Limkako's Pit No. 2	12.8	2.8	56.3		0.5		subbit C				
Limkako's Pit No. 1	11.3	3.7	50.1		0.6		subbit C				
Avellana's Pit	11.2	3.6	52.9		0.9		subbit C				
Panian	11.5	3.5	51.1		0.7		subbit C				
3. Semirara	25-30	6-12	46-52		<1%	8500-10,000	subbit C				
4. Semirara	25.66	32.08	32.08	33.40	0.58	8209	subbit C				
Semirara											
5. Panian Prospect (ROM)	14.0	20.55	36.77	28.42		7819	subbit C	45	1200	1420	1460
6. Panian Prospect											
(as-received) (wt. ave.)	16.30	20.07	36.48	27.23		7603					
(stnd Dev.)	2.39	6.86	5.28	5.63		827					
(air dry basis, wt. ave.)	11.63	21.36	37.64	29.09		8005					
(stnd Dev.)	2.54	7.06	2.60	5.65		822					
7. Panian Prospect (range)	8.2-17.2	19.6-23.6	38-45	26.4-31.2		7200- 8800					
(mean)	12.7	20.6	41.5	28.8		7999					
(stnd. Dev.)	3(1.5)	3(1.5)	3.5	2.4		799					
8. Unong mine											
lower seams	13.3	15.8			0.62-1.88	9076					
upper seams	10.9	31.2				6785					
Ave, ROM, weighted main seam	16-19	16-19	35-41	26-29	<1	>8000 <9000	subbit C	40-50		1350	1410
9. Himalian (SCC database)(AD)											
range	15.9-21.0	9.8-25.8	31.4-36.4	24.5-36.9		6800- 9007					
ave.	19.7	15.1	35.0	30.2		8022					
(SGS, DM 1/9 DH)(AD)											
range	10.4-14.5	5.1-39.4	24.6-40.1	21.5-41.9		6596-10,294	subbit A				

1. ASEAN Coal Development project Inception Report, Montreal Eng. Co., Limited, Fed. 1984, P. 2-31, Air dried basis; Data from BED.
2. Hufnagel, Heinz, Feb. 1977, Philippine Coal Resources: Fed. Inst. for Geosci. and Nat. Res., Hannover, Germany, Moist Air dried basis, 106°; ash, dry basis; VM, dry, ash free basis, 900°C; s, dry basis, tschk meth.
3. BED, Feb. 1983, Report submitted to ASEAN Coal Devel. project: Anal. values quoted on an as-received basis.
4. USGS, 1984, Anal. of coal sample collected as part of CWM from Unong pit as-received basis.
5. Austro mineral, Vienna, Austria, Nov. 1981, Feasibility Rept. on Purian prospect; 321 samples submitted from 33 drill holes to determine ave. ROM Quality/Annum; air dried basis; from ERL and JHM notes.
6. Main seam, Panian.
7. Bardelosa, J.L. and Sales, A.O., 1981, Completion report for the exploration of the Panian coal area; safety factor of 3x(stnd dev.) used to account for disposed nature of moisture and ash. Analyses are on air-dried basis, 348 samples total, 221 as-received and air dried; 49 as received; 78 air dried only.
8. Austrominerals, Vienna, Austria, 1980, Unong mine feasibility study; air dired basis.
9. Dames and Moore feasibility study of Himalias deposit.

Table 13. Analyses of five delivered samples of Semirara coal; collected August, 1984 and analyzed November, 1984.

Field Number: MDC-Phil I
Laboratory Number: U11986

AIR DRY LOSS 10.18 RESIDUAL MOISTURE 8.65

	As-received	Dry	Dry ash-free
PROXIMATE ANALYSIS			
Moisture	17.95		
Ash	16.27	19.83	
Volatile Matter	32.78	39.95	49.83
Fixed Carbon	33.00	40.22	50.17
	100.00	100.00	100.00
ULTIMATE ANALYSIS			
Hydrogen	5.61	4.39	5.48
Carbon	47.05	57.34	71.53
Nitrogen	0.87	1.07	1.33
Sulfur	0.63	0.77	0.96
Oxygen	29.57	16.60	20.70
Ash	16.27	19.83	
	100.00	100.00	100.00
HEATING VALUE (BTU/LB)	8144	9925	12380
FORMS OF SULFUR			
Sulfate sulfur	0.04	0.05	0.06
Pyritic sulfur	0.18	0.22	0.27
Organic sulfur	0.41	0.50	0.63

FREE SWELLING INDEX 0.0

ASH FUSION TEMPERATURES (Reducing Atmosphere)

Initial Deformation	2290 F
Softening Temp.	2370 F
Fluid Temp.	2490 F

EQUILIBRIUM MOISTURE - 25.61%

HARDGROVE GRINDABILITY - 51

Table 13. continued

Field Number: MCD-Phil 2
Laboratory Number: U11987

AIR DRY LOSS 9.70 RESIDUAL MOISTURE 8.77

	As-received	Dry	Dry ash-free
PROXIMATE ANALYSIS			
Moisture	17.62		
Ash	15.71	19.07	
Volatile Matter	33.61	40.79	50.40
Fixed Carbon	33.06	40.14	49.60
	100.00	100.00	100.00
ULTIMATE ANALYSIS			
Hydrogen	5.60	4.41	5.45
Carbon	48.02	58.29	72.02
Nitrogen	0.87	1.05	1.30
Sulfur	0.60	0.73	0.90
Oxygen	29.20	16.45	20.33
Ash	15.71	19.07	
	100.00	100.00	100.00
HEATING VALUE (BTU/LB)	8278	10049	12416
FORMS OF SULFUR			
Sulfate sulfur	0.03	0.04	0.05
Pyritic sulfur	0.15	0.18	0.22
Organic sulfur	0.42	0.51	0.63

FREE SWELLING INDEX 0.0

ASH FUSION TEMPERATURES (Reducing Atmosphere)

Initial Deformation	2300	F
Softening Temp.	2340	F
Fluid Temp.	2440	F

EQUILIBRIUM MOISTURE = 25.90%

HARDGROVE GRINDABILITY INDEX = 47

Table 13. continued

Field Number: MDC-Phil 3
Laboratory Number: U11988

AIR DRY LOSS 9.40 RESIDUAL MOISTURE 9.27

	As-received	Dry	Dry ash-free
PROXIMATE ANALYSIS			
Moisture	17.80		
Ash	18.57	22.59	
Volatile Matter	32.57	39.63	51.20
Fixed Carbon	31.06	37.78	48.80
	100.00	100.00	100.00
ULTIMATE ANALYSIS			
Hydrogen	5.52	4.29	5.54
Carbon	45.38	55.21	71.32
Nitrogen	0.83	1.01	1.30
Sulfur	0.63	0.77	0.99
Oxygen	29.07	16.13	20.85
Ash	18.57	22.59	
	100.00	100.00	100.00
HEATING VALUE (BTU/LB)	7792	9479	12245
FORMS OF SULFUR			
Sulfate sulfur	0.04	0.04	0.05
Pyritic sulfur	0.15	0.18	0.23
Organic sulfur	0.44	0.55	0.71

FREE SWELLING INDEX 0.0

ASH FUSION TEMPERATURES (Reducing Atmosphere)

Initial Deformation	2340	F
Softening Temp.	2600	F
Fluid Temp.	2660	F

EQUILIBRIUM MOISTURE = 23.03%

HARDGROVE GRINDABILITY INDEX = 45

Table 13. continued

Field Number: MDC-Phil 4
Laboratory Number: U11989

AIR DRY LOSS 9.32 RESIDUAL MOISTURE 10.14

	As-received	Dry	Dry ash-free
PROXIMATE ANALYSIS			
Moisture	18.51		
Ash	14.99	18.40	
Volatile Matter	32.93	40.40	49.51
Fixed Carbon	33.57	41.20	50.49
	100.00	100.00	100.00
ULTIMATE ANALYSIS			
Hydrogen	5.71	4.46	5.47
Carbon	47.97	58.86	72.13
Nitrogen	0.87	1.07	1.31
Sulfur	0.63	0.77	0.94
Oxygen	29.83	16.44	20.15
Ash	14.99	18.40	
	100.00	100.00	100.00
HEATING VALUE (BTU/LB)	8302	10188	12485
FORMS OF SULFUR			
Sulfate sulfur	0.04	0.05	0.06
Pyritic sulfur	0.19	0.24	0.29
Organic sulfur	0.40	0.48	0.59

FREE SWELLING INDEX 0.0

ASH FUSION TEMPERATURES (Reducing Atmosphere)

Initial Deformation	2280	F
Softening Temp.	2380	F
Fluid Temp.	2530	F

EQUILIBRIUM MOISTURE - 25.10%

HARDGROVE GRINDABILITY INDEX - 43

Table 13. continued

Field Number: MDC-Phil 5
Laboratory Number: U11990

AIR DRY LOSS 8.24 RESIDUAL MOISTURE 9.36

	As-received	Dry	Dry ash-free
PROXIMATE ANALYSIS			
Moisture	16.83		
Ash	20.55	24.71	
Volatile Matter	32.19	38.71	51.41
Fixed Carbon	30.43	36.58	48.59
	100.00	100.00	100.00
ULTIMATE ANALYSIS			
Hydrogen	5.25	4.04	5.37
Carbon	44.48	53.48	71.03
Nitrogen	0.83	0.99	1.31
Sulfur	0.60	0.72	0.96
Oxygen	28.29	16.06	21.33
Ash	20.55	24.71	
	100.00	100.00	100.00
HEATING VALUE (BTU/LB)	7684	9239	12271
FORMS OF SULFUR			
Sulfate sulfur	0.04	0.05	0.07
Pyritic sulfur	0.11	0.14	0.19
Organic sulfur	0.45	0.53	0.70

FREE SWELLING INDEX 0.0

ASH FUSION TEMPERATURES (Reducing Atmosphere)

Initial Deformation 2590 F
Softening Temp. 2640 F
Fluid Temp. 2710 F

EQUILIBRIUM MOISTURE = 23.88%

HARDGROVE GRINDABILITY INDEX = 46

Table 14. Analyses modified to equilibrium moisture (see Table 13), as-received basis except as noted. (Analytical values in percent except calorific values in Btu/lb.

Sample No.	Moisture	Ash	Volatile Matter	Fixed Carbon	Calorific Value Btu/lb	Calorific Value Moist, mineral-matter-free Btu/lb
U11986	25.61	14.75	29.72	29.92	7383	8781
U11987	28.90	13.56	29.01	28.53	7144	8368
U11988	23.03	17.39	30.50	29.08	7295	8982
U11989	25.10	13.78	30.27	30.85	7630	8964
U11990	23.88	18.81	29.46	27.85	7032	8824

Table 15. Comparison of analyses of nineteen coal samples from Semirara. (Analytical values in percent except heat values in Btu/lb)

	Eight	Six	Five	Arithmetic Means	Range of Means
Moisture (As-received)	25.5	26.1	25.5	25.7 1/	23-29
Ash "		16.9	15.7	16.4	12-21
Volatile Matter "		28.9	29.8	29.3	24-31
Fixed Carbon "		26.7	29.2	27.8	24-31
Sulfur "		0.5	0.6	0.5	0.4-0.6
Heat Value (Btu) "		7006	7297	7138	6627-7630
Moisture (Air-dried)	17.7	18.3	17.7 2/	17.6	15-20
Ash "	16.7	18.8	17.2	17.5	14-22
Volatile Matter "	34.8	33.1	32.8	33.7	31-36
Fixed Carbon "	31.6	29.9	32.2	31.2	27-35
Sulfur "	0.6	0.6	0.6	0.6	0.5-0.7
Heat Value (Btu) " (7 analyses)	8074	7823	8040	7981	7232-8679

1/ Modified to equilibrium moisture

2/ As-received, but partly air-dried during storage prior to anlaysis.

equilibrium moisture values, the resulting analytical format is probably nearly the same as an as-mined (as-received) basis. The analyses of the five samples are listed in that manner for comparison in table 15.

The as-received values for the three groups of samples in table 15 are an attempt to reflect the quality characteristics of the Semirara coal shortly after mining and prior to transport and storage before utilization. The air-dried format is presumably an accurate reflection of the condition of the coal after the coal has lost surface moisture during storage and transport activities.

Among the large number of reported analyses of Semirara coal, these three groups of samples exhibit reasonably good compatibility. The samples probably are a fairly accurate record of the quality of coal that was produced at the Unong Mine on Semirara during a period of about three months in the latter part of 1984. Therefore, the arithmetic means and ranges shown in table 15 are the best expression available for coal recently produced at Semirara. The quality may change in the future because of variability in the characteristics of particular coal beds, because of changes or variability in mining practices, or because of the application of some types of benefication processes.

Analyses of samples of twenty two shipments of Semirara coal received by NPC in 1984 are shown in average and range form in table 16 in comparison with the nineteen samples shown in table 15. Both means and ranges are very similar.

Also shown in table 16 are the analysis of a sample collected from the face of an active mine early in the CWM fuel study and an analysis of a sample from a 1,000-t shipment of "Selected Semirara Coal" received by NPC in February, 1984.

Obviously, the quality of Semirara coal as shipped can range widely in ash content and heat value. The design specifications of Semirara coal assumed for the CWM fuel study are hopefully conservative. Table 16 shows the assumed specifications compared to the four previously discussed analyses and means.

CONCLUSIONS

The coal resource and reserve estimates that have been made for the Island of Semirara were derived in a variety of manners and are not fully categorized to internationally accepted forms. However, the estimates do indicate that Semirara does contain resources and reserves sufficient to support a mining industry of one to five million tons per year for as long as 16 to 80 years, even if future exploration does not increase the estimated mineable/ recoverable reserves. The estimated potential resources of only 550 million tons are conservative considering the number and thickness of coal beds that are known to underlie the island.

Coal produced on Semirara is of low rank (subbituminous C), high moisture and ash content, and generally low in sulfur and heating value. Although the coal reportedly has a wide range in quality, problems assoicated with quality of the coal do not appear to be a deterent to its utilization.

Table 16. Summary of anlayses of Semirara coal shipped to National Power Corporation during 1984. (Analytical values in percent except Heat Vlaue in Btu/lb)

	As-Received					Air-Dried				
	Moisture	Ash	Volatile Matter	Sulfur	Heat Value Btu/lb	Moisture	Ash	Volatile Matter	Sulfur	Heat Value Btu/lb
Initial Sample	26	9	32	0.6	8209	—	—	—	—	—
"Selected"	26	6	35	—	8547	20	7	38	—	9276
Nineteen Samples	26 (23-29)	16 (12-21)	29 (24-31)	0.5 (0.4-0.6)	7138 (6627-7630)	18 (15-20)	18 (14-22)	34 (31-36)	0.6 (0.5-0.7)	7981 (7232-8679)
Twenty-two Samples	27 (23-32)	—	—	—	7228 (6610-7919)	17 (14-19)	16 (9-21)	35 (33-?)	0.6 (0.5-0.7)	8223 (7520-9009)
Assumed Specifications	24	14	33	—	7507	—	—	—	—	—

The following conclusions appear valid:

1) The proximate analyses that are reported for the Semirara coal deposits display very wide variations in values for moisture, ash, volatile matter, and heating content. These variations are at least partly caused by the different methods used in the collection, preparation, and analysis of the samples. Until standardized methods of sampling and analyses are introduced into the coal exploration, production, and utilization processes, there will continue to be doubts about the credibility and reliability of information about Philippine coal quality.

2) Very few ultimate analyses and determinations of forms-of-sulfur, ash fusion temperature, Hardgrove Grindability Indexes, and major and minor element constituants have been made for any of the Semirara coal deposits.

RECOMMENDATIONS

The adaption of coal with such quality as that on Semirara for utilization as a fuel, in particular as a coal-water-mix fuel, will require consideration of a number of choices. The most obvious is to adapt the coal-burning facility to the quality of coal that is, and presumably will continue to be, available. Another choice is to upgrade the available coal in some suitable manner. Upgrading of a mine product may be done through selective mining, mixing of different mine products to try to attain a selected quality, preparation of a product by washing or other processes to reduce undesireable material such as ash, or some other less standard techniques. Some of these options are already being tried on Semirara Coal, and others have been cursorily investigated; all deserve a harder look.

A more complete coal quality monitoring program is needed for the Semirara coal. Standardized sampling proceedures and analysis of coal at critical times following mining and during storage, and more analyses for characteristics such as the complete ultimate analysis, constitution of the coal ash, the grindability index, and ash fusion temperatures are needed now and in the future to aid planning for utilization of the coals of Semirara.

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APPENDIX B

COAL IN THE SIBUGUEY PENINSULA, PHILIPPINES

RP-23

DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

PROJECT REPORT
Philippine Investigation
(IR)RP-23

COAL IN THE SIBUGUEY PENINSULA, PHILIPPINES

Prepared in cooperation with the Government of the Philippines, under the auspices of the Agency for International Development.

1985

COAL IN THE SIBUGUEY PENINSULA, PHILIPPINES

By

J. H. Medlin
U.S. Geological Survey

The project report series presents information resulting from various kinds of scientific, technical, or administrative studies. Reports may be preliminary in scope, provide interim results in advance of publication, or may be final documents.

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COAL IN THE SIBUGUEY PENINSULA, PHILIPPINES

By

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ABSTRACT

Total coal resources on the Sibuguey Peninsula are estimated as 35 million metric tons. The estimate is considered to be conservative, but the resource is sufficient to support production of 200,000 t per year for 30 years. The coal is the best quality in the Philippines, perhaps in all of Southeast Asia. The coal is high volatile bituminous in rank, with low moisture, medium to high calorific value, and low to medium ash and sulfur. A systematic geologic investigation and coal exploratory program is recommended in order to assess the total coal resources available on the Peninsula.

INTRODUCTION

A workshop on introducing coal-water-mix (CWM) fuels to the Philippines was held August 20-24, 1984, at Brookhaven National Laboratory (BNL), Upton, New York under sponsorship of the Office of Energy in the Agency for International Development (AID). One of the results of the workshop was selection of coal from the Sibuguey Peninsula on the Island of Mindanao for further experimental work. An evaluation of the available information about the quantity and quality of Sibuguey coal was necessitated.

During October 1984, information about the coal resources of the Peninsula was gathered by the author and Gil C. Guevara of the Economic Development Foundation (EDF) as part of the AID program to determine the potential use of CWM fuels. The information was obtained from published reports on the geology and coal resources of the area, from a mining feasibility report by the Philippines National Oil Company-Coal Company (PNOC-CC), and from discussions with coal personnel in the company and in the Philippines Government Agencies. The aid and assistance of Ms. Purita M. Festin and Gil C. Guevara of EDF are gratefully acknowledge.

HISTORY OF EXPLORATION AND DEVELOPMENT

The Lalat and Malangas coal areas are shown in figure 1. Brown (1938) made a geologic reconnaissance of the Sibuguey Peninsula for the National Development Company (NDC). The Lalat area was topographically surveyed and geologically mapped between 1952-1955 by Ibanez and others (1956). During 1954-1956 the Philippine Bureau of Mines and the International Cooperation Administration conducted a drilling program, totaling 10 boreholes and 2,650 m, mainly in the Lumbog area, but including the Lalat area. Four other boreholes were drilled in the area in the late 1950's by the United Nations Development Program (Barnsley, 1968). The National Development Company mined a total of 73,000 t from the Sibuguey Peninsula between 1937 and 1951; the company ceased operations. The Cebu Cement Company began mining in the area in July 1951, but abandoned mining in mid-1952; they produced a total of 20,343 t.

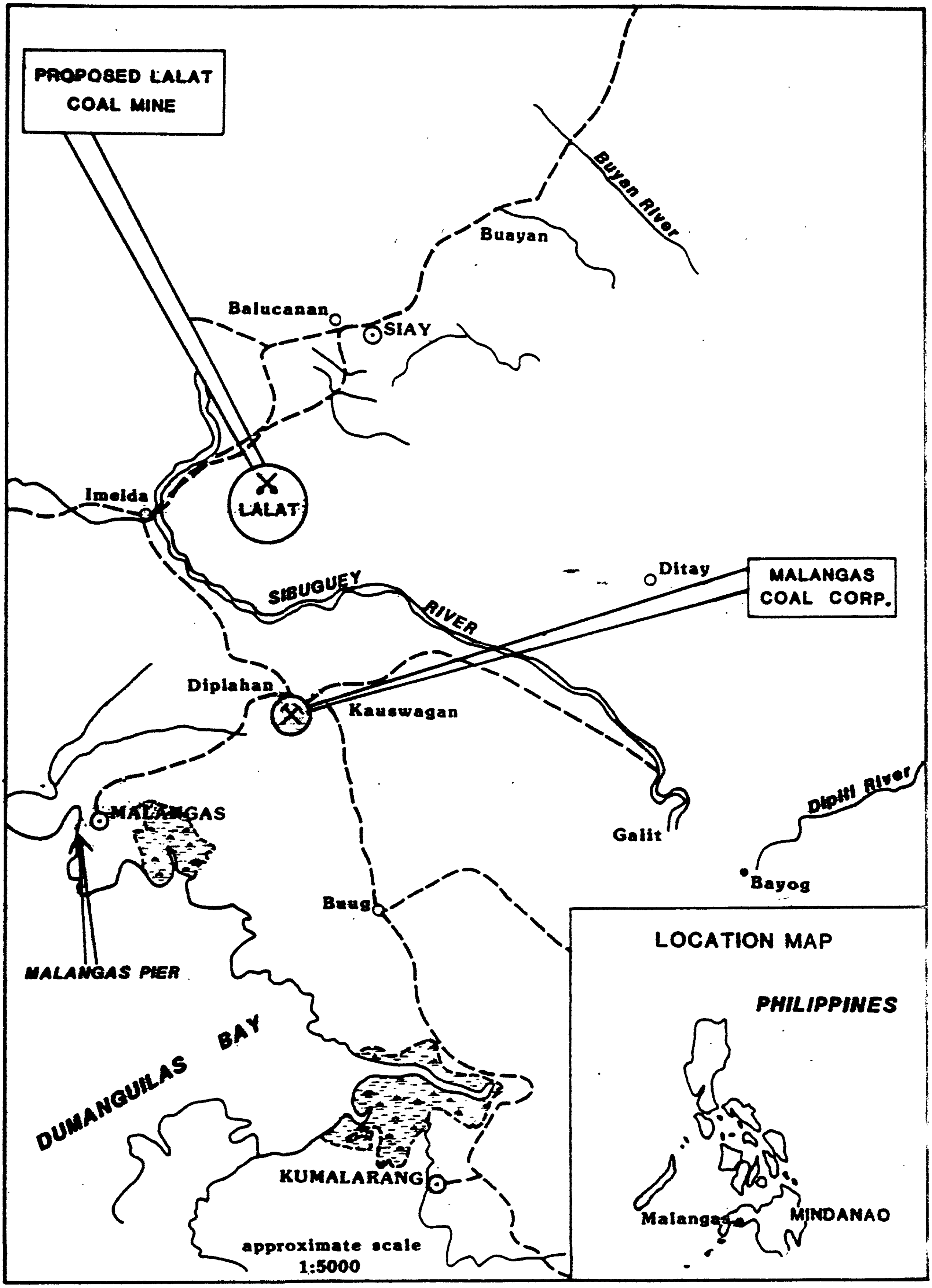

Figure 1. Sketch map of proposed Lalat coal mine

When PNOC-CC assumed an interest in the Lalat area, the company subcontracted the mining to several small companies who extracted the walls and pillows left by prior mining companies. PNOC-CC began recent geologic mapping in the Lalat project area in February 1981. A total of 96 diamond drill holes with an aggregate thickness of 32,360 m were completed between July 1981 and June 1983; drill hole spacings averaged 250 m.

A mini-Sosie seismic reflection survey of 30 line-km length over 11 lines was conducted in April and May 1982 by Layton Scientific Services (Layton Seismic Services, 1982).

The PNOC-CC project development group is presently conducting a pre-mining feasibility study of the Lalat coal deposit.

GEOLOGY

Tectonically, the western Mindanao area is set between the dormant Sulu-Zamboanga Island arc and the active Catabato-West Sangihe arc, which are both eastern dipping subduction zones. The Sulu-Zamboanga arc was active into Quaternary time (Hamilton, 1979).

The northwestern part of the Sibuguey Peninsula is underlain by a basement complex of schist, metasandstone, phyllite, marble, foraminferal limestone, volcanics, and serpentinized peridotite. Unconformably overlying the basement complex to the east is a regressive sequence of lower to middle Miocene shallow marine limestones, mudstones, sandstones, coal measures, and pyroclastics. Upper Miocene to Pliocene volcanoclastic rocks and andesitic basalt flows blanket much of the Sibuguey Peninsula. Quaternary volcanic rocks are limited to the eastern part of the Peninsula.

The economic geology of western Mindanao is poorly known with most of the published material representing only casual reconnaissance. However, several small basins containing good quality coal deposits are found in the area. The deposits are commonly in complex structural settings as a result of post-depositional tectonics.

Stratigraphy

The stratigraphy in the Lalat project area and that in the Malangas Coal Corporation-Diplahan Colliery in an adjacent area to the south is similar. The coal-bearing lower Miocene Lumbog Formation is conformably underlain by the lower Miocene Sibuguey Formation, unconformably overlain by the Miocene-Pliocene Coloy Formation and volcanic flows, and intruded by andesitic sills and dikes. A generalized stratigraphic column is given as figure 2.

Sibuguey Formation

The lower Miocene Sibuguey Formation, the base of the stratigraphic sequence as defined by recent drilling, consists of interbedded white to gray calcisiltite and limestone, dark-gray mudstone, and gray to greenish, fine- to coarse-grained lithic sandstone, all containing brackish to shallow marine fauna in the upper 100 m. Non-fossiliferous sandstone, mudstone, and coal beds less than 0.5 m thick are interbedded with the strata below.

AGE	FORMATION		COLUMN	LITHOLOGY	DEPOSITIONAL ENVIRONMENT	THICKNESS
Recent	Alluvium/Colluvium			clay, sand, gravel	fluvial	10+m
Pliocene-Pleistocene	andesitic-basaltic volcanics			porphyritic andesite basalt and interbedded pyroclastics andesitic intrusives on Lombog and Sibuguey Formations	Terrestrial volcanics	120+m
	Coloy Formation			tuffaceous conglomertic sandstone and mudstone	Terrestrial volcanics waterlain	to 200+m
Lower Miocene	Lumbog Formation	Dumagok Member		interbedded dominant lithic sandstone, mudstone, carbonaceous mudstone and coal beds Bed H Bed G fossil markers above and below G Bed F	Distal fluvial, paralic, rare shallow marine transgressions	270+m
		Gotas Member		tuff, and mudstone	Terrestrial volc.	
		Lalat Member		Bed E interbedded dominant mudstone, fine to coarse grained sandstone, Bed D carbonaceous shale and coal beds Bed C Fossil markers below A and between C and D Bed B Bed A	Distal fluvial paralic with few shallow marine transgressions	120-150m
	Sibuguey Formation			interbedded calcisiltite limestone, mudstone, and sandstone Brackish to shallow marine faunas	Regressive shallow marine	to 350+m

Figure 2. Stratigraphic column of Lalat area

Thickness of the formation exceeds 350 m in the region (Ibanez and others, 1956), although the maximum thickness drilled at Lalat is only 75 m. The Sibuguey Formation is exposed in a 50 to 70 m wide belt along the axial trace of the central (?) Lalat anticline, which is reflected as a topographic low by an unnamed creek east of the Israel fault (fig. 3). The rock types observed in this area are interbedded calcareous mudstones and sandstones.

The top of the formation is normally marked by the first appearance of calcisilties grading to limestone and calcareous nodules. The contact with the overlying Lalat Member of the Lumbog Formation is both gradational and intertonguing.

Lumbog Formation

The lower Miocene Lumbog Formation consists of interbedded fine- to coarse-grained lithic sandstone, mudstone, and coal beds.

Deposition of the predominantly non-marine Lumbog Formation over the marine Sibuguey Formation reflects the general shift in the depositional environment from the shallow marine to fluvial and paralic environments marked by rare transgressive marine sedimentation.

Variable amounts of tuffaceous material in the rocks indicate volcanic activity during the deposition of the formation (especially during the deposition of the Gotas Member). Lateral variations in lithofacies within short distances and occurrence of numerous paleochannels indicate periods of high energy scouring and deposition interspersed with periods of quiescence in which peat swamps developed.

Total thickness of the formation is in excess of 350 m. The formation consists of three conformable members, namely the Lalat, Gotas, and Dumagok.

Lalat Member.—The Lalat Member is the most important coal-bearing unit in the area. It consists of well consolidated and interbedded, gray mudstone, whitish-gray to greenish, fine- to coarse-grained lithic sandstone, carbonaceaous mudstone, and coal beds. Thickness, as measured in drill holes, ranges from 120 to 150 m.

Five main coal beds, designated in descending order, E, D, C., B, and A are present in the Lalat Member. Bed B is in the same stratigraphic position as bed LC-1 at the Malangas Coal Corporation-Diplahan Colliery.

Consistent marker horizons in the stratigraphic sequence are: a siltstone grading to a mudstone bed with plant impressions above bed E, a sandy to silty mudstone with shallow marine bivalues and gastropods above bed C and a thick, medium- to coarse-grained lithic sandstone above bed B. Numberous exposures of the Lalat Member occur in the erosional window around central Lalat.

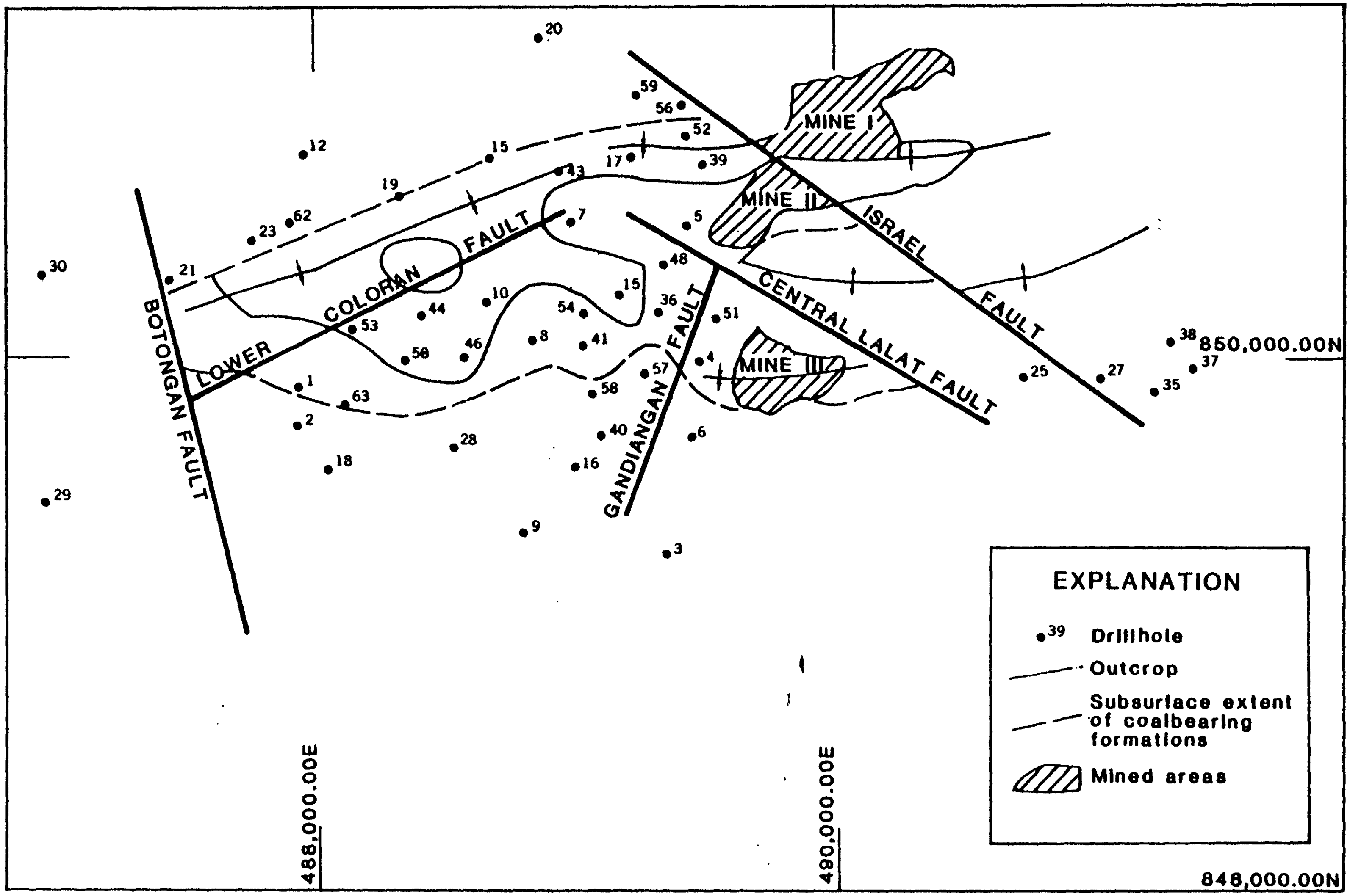

Figure 3. Drillhole locations, fold structures, mined out areas and faults in the Lalat area.

Typical stratigraphic separations within the Lalat Member are as follows:

Stratigraphic Separation	Interval Thickness
Bottom of Gotas Member to roof of bed E	15 to 40 m
Bed E	More than 1.0 m
Floor of bed E to roof of bed D	5 to 10 m
Bed D	Less than 1.0 m
Floor of bed D to roof of bed C	10 to 20 m
Bed C	Less than 1.0 m
Floor of bed C to roof of bed B	15 to 35 m
Bed B	More than 1.0 m
Floor of bed B to roof of bed A	15 to 20 m
Bed A	More than 1.0 m
Floor of bed A to top of Sibuguey Fm.	15 to 25 m

Only beds A, B, and E appear to be of mineable thickness (1.0 m or thicker).

Gotas Member.--The Gotas Member represents a period of relatively intense volcanic activity and is distinguished from the overlying Dumagok and underlying Lalat Members by the relative abundance of volcanic ash and lithic tuff interlaminated with gray-brown mudstones. Its thickness, as observed from drill holes, ranges from 0 to 15 m. The Gotas Member is poorly exposed along a stream a few meters south of drill hole No. 6 (fig. 3).

Dumagok Member.--The Dumagok Member consists predominatly of well-consolidated gray to greenish, fine- to medium-grained lithic sandstone interbedded with mudstones, carbonaceous shales, and coal beds. Three major coal beds, in descending order, are designated H, G, and F. The only coal considered to be mineable is bed H.

Thickness of the Dumagok Member, as measured from drill holes, is in excess of 200 m. The unit is unconformably overlain by the Coloy Formation and andesitic basaltic volcanic rocks.

A typical stratigraphic separation is as follows:

Stratigraphic Separation	Interval Thickness
Roof of bed H to base of Coloy Fm.	Greater than 150 m
Bed H	Minable thickness
Floor of bed H to roof of Bed G	30 to 50 m
Bed G	Less than minable thickness
Floor of Bed G to roof of Bed F	50 to 70 m
Bed F	Less than minable thickness
Floor of bed F to top of Gotas Fm.	10 to 30 m

The Dumagok Member is well-exposed along the old Cebu mining road leading from Mine 3 to Mine 1.

Coloy Formation

The late Miocene-Pliocene(?) Coloy Formation, which unconformably blankets much of the Lalat project area, consists of poorly to moderately consolidated water-laid pyrolclastics and tuffaceous sediments. The pyroclastic rocks range from fine-grained lithic tuff to fine-grained andesitic volcanic breccias. Biotite flakes are abundant in coarse-grained facies. The Coloy Formation is generally massive or indistinctly bedded except for the fine-grained facies which are fine- to medium-bedded, (as in the numerous exposures along Coloy Creek). Thickness of the formation increases westward to more than 200 m.

Structure

The Lalat area is a structural basin about 1.3 km in length and covers a surface area of about 550 hectares or 5 km^2. It is approximately 15 km north of the Malangas Coal Mine (fig. 1), which has a similar general geologic setting. The rocks in the basins have been folded into east-northeast trending asymmetrical anticlines and synclines that locally are steeply dipping.

Complicating the Lalat structural basin are the Bontogan, Lower Coloran, Gandiangan, Central Lalat, and Israel faults (fig. 3). The Botongan, Central Lalat, and Israel faults are northeast-southwest trending structures, whereas the Lower Coloran and Gandiangan faults are northeast-southwest trending features. All are steeply dipping normal or reverse faults; displacement ranges from less than 5 m to more than 100 m. These faults separate the basin into separate coal reserve areas. The basin is bounded on the north and south by subcropping coal-bearing sediments. The structural basin is about 600 m deep (at deepest point) and has more than 100 separate coal beds in the preserved stratigraphic section.

At the Malangas mine the normal and reverse faulting has resulted in displacements ranging from 0 to 150 m. Moreover, volcanic sills and dikes have intruded and, in places, replaced the coal beds. All of these structural features complicate the mining, cause roof and aquifer problems, and complicate the prediction of coal occurrence, distribution, quantity, and quality.

COAL RESOURCES

Lalat Area

Of the ten coal beds present in the Lalat area, only three or possibly four are considered mineable. These beds, in decending order, are the H, E, B, and A, all in the Dumagok or Lalat Members of the Lumbog Formation (fig. 2). Beds E, B, and A are locally affected by andesite intrusive sheets or dikes.

The roof and floor rocks for the major coal beds are generally mudstone. Locally, the roof and floor are sandstone that appears to be associated with peroids of channelization in paralic, nearshore depositional environments. Table 1 provides specific roof and floor rock information on a bed-by-bed basis for beds H, E, B, and A.

Quantity

Table 2 provides a summary of the in-situ coal reserves on a bed-by-bed basis for the Lalat basin. Calculated total reserves are 17.29 million tons of which 11.24 million tons are measured and 6.05 million tons are indicated. According to the PNOC-CC pre-feasibility report, 60 percent (or 10.35 million tons) of the total reserves are in bed B.

Mining reserves (those reserves remaining after required protection pillows around faults, old underground working, bed outcrop or subcrops, development shafts, etc., have been removed) are 8.63 million tons. Approximately 7.33 million tons are considered recoverable at present; this estimate is based on an assumed extraction rate of 85 percent. Potential clean coal reserves of 6.23 million tons are estimated assuming a recovery rate of 85 percent following coal benefication.

Quality

The rank of the Lalat coal beds generally ranges from high volatile B to high volatile C bituminous. However, the coal may locally vary from semi-anthracite to natural coke where it is in contact with the post-depositional andesitic intrusions.

Chemical and physical coal quality data for beds H, E, B, and A are given in tables 3, 4, 5, and 6. The range in raw coal quality (on an air-dried basis) is given in table 7 for these same beds, and table 8 gives statistical data (mean and standard deviation) for the raw coal quality. Data in tables 7 and 8 are derived from tables 3, 4, 5, and 6. All data in tables 3 to 8 are taken from a pre-feasibility report submitted by PNOC-CC to the U.S. Trade Development Program in 1984.

Malangas Area

The coal beds in the Malangas area are in the Lumbog Formation, which has been folded and faulted as in the Lalat area. At Malangas, the Malangas Coal Corporation is currently mining a bed designated LC-1. As mentioned previously, coal bed LC-1 is believed to be equivalent to coal bed B in the Lalat area. At Malangas, a second coal bed designated LA, lies about 20 to 30 m below LC-1. Future plans include mining of the LA bed, but quantity and quality data for the LA coal bed are sparse.

Bed LC-1 averages about 1.5 m in thickness, and does attain 3.0 m in thickness locally. Coal bed LA ranges in thickness from 0 to 1.5 m.

Locally, partings in the coal bed attain 0.5 m in thickness; if these partings are included in the mine product, the quality of the coal will be decreased, or the product will require cleaning to maintain coal quality.

Table 1. Roof and floor rock data for coal beds H, E, B, and A, Latat area. Drillhole numbers are shown on figure 3. (All data taken from PNOC-CC pre-feasibility Report, 1984)

Bed	Roof	Floor
H	Most drillholes show tuffaceous mudstone; sandstone in vicinity of 69, 34, 47, 44, 88, 67, and 10.	Mostly mudstone; sandstone in vicinity of 68, 42, 72, and 43.
E	Predominately mudstone; sandstone roof in minor areas of paleochannels around 95, 87, 90. Bed washed out at 41 by paleochannel.	Predominately mudstone; sandstone at 95, 44, 41, 77, 8, 15, and 70 in the west and 79 in central Lalat.
B	More than 50 percent of the area has thin mudstone roof; less than half has sandstone roof, generally along paleochannels trending ENE around 18, 63, 15, and 34.	Predominately mudstone; sandstone in vicinity of 72, 56, 91, 75, 81, and 77.
A	Predominately mudstone; sandstone in vicinity of 18, 63, 8, 6, 4, 51, and 94 (probably paleochannels).	Predominately mudstone; sandstone in vicinity of 76, 67, and 50.

Table 2. In-situ coal reserves in Lalat Area. Million metric tons. Data from PNOC-CC Pre-feasibility Report, 1984

Bed	Measured	Indicated	Total
H	1.37	0.96	2.33
E	2.00	0.30	2.30
B	6.10	4.25	10.35
A	1.77	0.54	2.31
Total	11.24	6.05	17.29

Table 3. Coal quality data for bed H, Lalat area.
Analytical values in percent except calorific value in Btu/lb.

Drill Hole	Moisture	Ash	Ash DB*	Volatile Matter	Volatile Matter DAF*	Fixed Carbon	Calorific Value Btu/lb	Calorific Value DAF*	Sulfur
4	6.49	7.14	7.6	39.94	46.43	46.43	11561	13390	.21
10	4.0	7.4	7.4	41.4	46.73	47.2	11971	17511	.26
15	3.35	18.81	19.46	32.18	41.34	45.46	11944	13344	.37
17	3.1	13.0	13.4	39.1	44.60	44.8	11870	14148	.40
191	2.68	5.82	5.98	46.27	50.57	45.23	12478	13637	.32
192	4.05	83.57	87.1	—	—	—	—	—	—
193	2.98	10.38	10.70	45.78	52.84	41.50	11694	13497	.41
019comp	3.03	14.82	15.28	42.26	48.45	36.89	10871	12459	—
34	3.23	4.84	5.0	42.73	46.48	49.20	12796	13927	.31
36	4.15	14.62	15.25	37.08	45.65	44.15	11906	14657	.15
39	2.70	9.28	9.5	41.29	47.36	46.73	12156	13736	.24
42	5.06	16.33	17.2	37.58	47.81	41.03	10625	13516	.92
43	3.12	12.74	13.15	39.48	46.97	44.66	10885	12937	.33
44	4.8	9.0	9.5	49.2	57.1	37.0	11283	13089	.49
46	7.5	12.3	13.3	45.9	57.2	34.3	10759	13415	.46
47	3.4	12.3	12.7	45.0	53.4	39.3	11708	13888	.35
50	6.2	9.5	10.1	46.8	55.5	37.5	11289	13391	.32
52	5.1	16.4	17.3	45.5	58.0	33.0	10713	13647	.31
53	4.5	10.3	10.8	46.7	54.8	38.5	11670	13697	.52
54	5.5	24.3	36.3	43.1	60.2	27.1	11755	13765	.35
55	4.8	10.5	11.1	41.1	48.5	43.6	11827	13963	.43
67	4.54	13.43	14.06	38.38	46.79	42.24	10540	12910	.67
68	3.7	6.7	7.0	43.3	48.3	46.3	12572	14031	.23
74	5.7	11.7	12.4	39.6	47.9	43.0	11466	13881	.27
78	2.5	9.0	9.2	40.4	45.6	48.1	12454	13823	.27
79	3.28	3.21	3.32	44.03	42.09	41.48	12926	13823	.16
82	2.59	9.41	9.66	31.98	36.34	56.02	12148	13805	.39
96	3.8	23.6	24.5	31.3	43.1	39.7	9769	13456	.30

* DB= Dry basis
DAF= Dry Ash Free basis

Table 4. Coal quality data for bed E, Lalat area.
Analytical values in percent except calorific value in Btu/lb.

Drill Hole	Moisture	Ash	Volatile Matter	Fixed Carbon	Calorific Value Btu/lb	Sulfur
7	2.14	13.8	36.30	47.74	11734	.26
8	3.10	13.4	37.34	46.13	11623	.23
10	4.78	18.78	40.43	36.01	10962	.44
13	2.16	6.45	39.48	51.91	13248	1.27
14	2.26	24.46	7.46	65.82	10186	.57
15	1.73	7.55	14.93	75.79	99.68	.33
17	2.2	22.1	32.11	44.09	12178	.49
18	5.4	11.1	38.1	45.4	11687	.54
19	2.53	17.9	22.44	46.12	11264	.33
23	3.05	18.2	33.5	45.25	12003	.42
25	1.72	11.92	45.58	40.78	12039	.45
36	2.01	6.89	9.44	81.66	11215	.27
39	1.98	14.71	37.06	46.25	11574	.25
40	6.15	7.42	40.46	45.97	11788	.34
43	2.1	5.3	45.1	47.5	13568	.44
44	3.5	20.33	36.0	40.19	12957	.51
46	3.64	17.30	35.91	43.15	11473	.57
47	2.7	26.7	34.5	36.1	10926	.33
50	5.0	21.9	40.3	32.8	10012	.98
52	1.8	12.9	43.6	41.7	12383	.29
53	4.6	41.8	29.5	24.1	7730	.31
54	3.9	15.8	39.1	41.2	11255	1.35
55	3.13	9.97	37.56	49.34	12314	.50
56	3.66	2.56	42.20	51.88	12935	.29
57	2.99	16.22	37.61	43.18	10911	.30
58	3.43	15.81	37.07	43.19	11724	.35
61	2.5	6.4	41.9	49.2	13257	.39
621	2.2	18.2	34.9	44.7	11030	.28
622	1.1	72.6	—	—	—	—
623	1.9	4.6	39.8	53.7	13309	.25
62comp	2.04	20.12	32.62	45.22	10510	—
63	2.49	10.24	36.07	50.71	12366	.35
65	6.1	7.5	44.8	41.6	11770	.33
67	3.45	17.62	37.40	47.38	11386	.80
68	1.3	5.8	41.8	51.1	13685	.35
70	2.1	9.0	35.6	53.3	12721	.32
76	2.10	8.44	31.34	48.28	11500	.39
77	3.1	6.3	40.0	59.6	13180	.29
78	1.2	10.6	39.8	48.4	12612	.54
79	2.58	4.27	38.38	49.71	12505	.20
81	2.4	3.1	44.0	50.1	13526	.27
82	2.14	16.55	37.26	44.25	11124	.59
83	4.78	6.14	40.31	48.78	11735	.30
85	2.67	12.98	34.95	49.40	12269	.53
87	2.51	5.31	40.13	52.05	13044	.29
89	1.81	7.04	23.90	67.25	13047	.36
92	2.73	12.73	37.96	46.58	11595	.24
93	3.59	4.68	41.73	50.0	12859	.28
94	2.85	10.01	38.89	48.20	12234	.50
95	2.15	12.18	35.49	50.18	12480	.90
96	2.27	13.32	38.82	45.59	10012	.25

Table 5. <u>Coal quality data for bed B, Lalat area (air dried basis)</u>
Analytical values in percent except calorific value in Btu/lb.

Drill Hole	Moisture	Ash	Volatile Matter	Fixed Carbon	Calorific Value Btu/lb	Sulfur
4	5.07	5.07	37.93	51.93	12521	.32
6	3.2	23.3	8.7	64.9	10214	.4
10	2.54	26.57	36.43	34.46	10147	.33
13	1.72	9.76	36.90	51.63	12875	.89
15	2.49	11.84	10.68	74.99	12162	.35
17	1.26	8.86	35.89	51.99	12991	.46
19	0.9	7.6	38.6	52.9	13479	.48
23	4.0	14.4	47.24	34.36	12188	.47
25	1.84	16.87	38.98	38.6	13479	.42
28	2.87	22.58	20.51	54.04	9874	.79
36	2.56	14.77	30.99	51.68	12228	.29
39	3.0	14.03	35.81	47.16	11823	.22
40	4.05	5.68	35.08	55.19	12388	.25
41	2.96	9.66	38.05	49.33	12153	.63
42	2.82	11.34	36.71	49.13	12330	.42
44	2.0	9.9	44.9	42.8	12414	.36
47	5.0	34.3	33.3	27.4	8438	.55
48	4.5	9.7	41.3	45.5	12363	.29
50	7.3	21.7	28.9	42.1	10969	.17
51	4.08	12.68	45.06	38.18	10637	.41
52	3.3	17.0	37.6	42.1	11399	.34
54	3.6	22.1	30.8	43.5	10744	.32
55	1.8	9.1	42.3	46.8	13301	.32
56	2.12	2.72	41.86	53.30	13505	.66
58	2.33	5.93	41.11	49.82	12265	.62
59	3.2	5.9	46.6	44.3	12871	.27
60	2.8	29.7	32.9	34.6	9700	.28
61	3.8	25.8	6.7	63.7	9570	.49
62	1.99	6.08	41.21	50.76	13295	.56
64	2.0	4.2	43.8	50.0	13097	.33
65/1	6.7	5.8	44.6	42.9	11989	.30
65/2	6.3	77.8	—	—	—	—
65/3	5.7	5.7	43.8	44.8	12381	.30
65 comp	6.07	11.4	40.61	—	11280	—
67	1.52	6.76	39.49	52.28	13302	—
70	2.1	5.9	39.8	52.2	13479	.36
71	4.16	31.78	29.71	34.34	8232	1.09
74	2.77	6.72	38.85	52.28	12932	.47
75	3.5	9.1	39.8	47.6	12884	.33
76	1.9	10.4	36.36	51.34	12818	.60
77	2.4	2.9	39.0	55.7	13955	.27
78	0.7	3.7	41.8	53.8	14315	.31
79	2.6	7.4	40.1	49.9	12936	.25
80	2.62	7.89	39.96	49.48	12720	1.19
81	2.1	6.2	40.9	50.8	13350	.39
82	1.98	9.6	39.20	49.22	12745	1.94
83	2.49	8.0	35.48	54.04	12089	.92
84	1.5	6.4	39.8	52.3	13490	.36
85	2.18	10.84	36.45	50.53	12606	.46

Table 5. cont.

Drill Hole	Moisture	Ash	Volatile Matter	Fixed Carbon	Calorific Value Btu/lb	Sulfur
86	2.68	16.41	18.50	62.41	11362	.35
87	2.25	5.85	39.18	52.72	13211	.44
88	1.85	10.49	11.89	75.77	12947	.58
89	1.59	4.78	38.70	54.95	13937	.44
90	2.16	6.15	38.31	53.38	13363	.88
92	3.51	15.61	5.77	75.11	11511	.21
95	1.68	18.11	37.18	51.03	12803	.29
23	5.78	4.71	38.22	51.06	11584	.70

Table 6. Coal quality data for bed A, Lalat area (air dried basis)
Analytical values in percent except calorific value in Btu/lb.

Drill Hole	Moisture	Ash	Volatile Matter	Fixed Carbon	Calorific Value Btu/lb	Sulfur
7/1	2.18	15.10	32.78	49.94	11600	1.03
7/2	4.12	49.34	—	—	—	—
7/3	1.94	17.96	23.90	56.20	11467	.40
17/comp	2.74	27.30	19.00	35.68	7749	—
10	2.54	26.87	12.26	48.13	9892	.27
15	5.37	23.05	41.55	30.05	11437	.43
17/1	2.13	35.24	31.03	31.60	8245	.63
17/2	4.52	78.90	—	—	—	—
17/3	1.06	23.40	31.67	43.87	10620	1.34
17/comp	2.20	38.45	26.8	30.2	7674	—
23	2.11	32.30	33.75	31.94	9180	.76
25	1.60	24.42	32.80	41.18	10406	.42
36	2.33	7.33	10.87	79.47	10846	2.10
39	1.97	18.06	33.13	46.84	11329	1.10
40	4.22	13.58	38.96	45.32	11232	.35
42	2.6	22.59	34.63	40.18	10446	.51
43	3.9	38.0	31.2	27.1	8134	.39
44	3.0	38.4	33.2	25.4	7888	3.44
47	2.3	28.6	33.2	35.9	9729	.59
48/1	3.9	19.8	36.5	39.8	11095	.66
48/2	9.9	73.1	—	—	—	—
48/2	3.6	27.3	35.2	33.9	9568	2.55
48/comp	4.4	31.76	30.01	31.03	8695	—
50	3.3	28.4	35.1	33.2	9403	1.70
52	2.3	19.3	36.2	42.2	11392	1.01
54	4.2	41.5	23.6	30.7	6996	.21
55	2.7	30.4	30.2	36.7	9562	.53
57	3.75	22.82	32.46	40.97	10114	.54
58/1	2.39	14.90	38.43	344.28	11253	2.0
58/2	3.47	30.21	31.66	34.66	8861	.65
59	3.6	16.9	37.7	41.8	11306	.42
62	2.87	36.54	28.68	31.91	8353	1.99
64/1	3.6	34.1	22.3	40	11827	.34
64/2	8.9	78.5	—	—	—	—
64.3	4.0	34.5	30.0	31.0	8486	.29
64/comp	4.34	39.44	21.95	32.65	94.54	—
65/1	3.8	17.4	40.7	38.1	10907	.29
65/2	3.49	16.76	37.70	42.05	10784	2.78
67	2.9	24.5	34.7	37.9	10322	2.42
70/1	0.7	11.9	36.1	51.3	12461	1.09
70/2	3.3	42.1	—	—	—	—
70/3	1.7	26.6	32.7	59.0	10173	1.52
70/comp	1.88	26.9	24.29	39.93	7904	.96
72	3.1	30.3	29.2	37.4	9644	.31
74	2.86	18.15	33.25	45.74	10909	.57

Table 6. cont.

Drill Hole	Moisture	Ash	Volatile Matter	Fixed Carbon	Calorific Value Btu/lb	Sulfur
77	2.75	23.12	5.52	68.61	10142	.61
78/1	1.0	25.7	30.8	42.4	10822	.47
78/2	0.6	21.1	30.7	47.5	11216	3.24
82/1	2.2	23.0	34.2	40.6	10784	—
82/2	4.7	80.7	—	—	—	—
82/3	1.8	17.6	35.7	44.7	11592	.83
82/comp	2.32	27.9	30.7	37.52	9836	-
83	2.1	11.3	37.3	49.3	12061	2.52
86	3.32	22.63	30.72	43.33	10160	1.76
87	4.31	32.70	6.3	56.69	8808	.92
88	2.41	31.56	16.70	49.33	9361	2.03
89	1.9	19.88	40.13	52.05	11463	.47
91	4.32	19.16	35.0	41.52	10373	1.93
92	2.68	38.16	8.97	50.19	7933	.33
06	743	22.05	30.04	40.47	9194	
10	8.61	128.30	32.87	40.22	9507	.26
05	8.61	128.30	32.87	40.22	9527	.26

Table 7. Raw coal quality ranges for Lalat borehole samples air dried basis). Data from ENCC-CC pre-feasibility Report (1984).

Bed	Ash Percent	Volatile Matter Percent	Sulfur Percent	Calorific Values (Btu/lb)
H	6.3-16.5	39.1-49.2	.23- .52	10,713-12,715
E	3.1-41.8	29.5-45.1	.28- .89	7,736-13,526
B	3.7-34.3	6.7-46.6	17- .55	8,438-14,315
A	11.5-41.5	23.6-40.7	.10-3.44	6,996-12,096

Hardgrove Grindability Index ranges from 36-57.

Table 8. Statistical means (X) and standard deviations (S) of Lalat raw coal quality analyses (air dried basis). Samples from ENCC-CC Pre-feasibility Report, 1984).

Bed	Moisture (Percent)		Ash (Percent)		Volatile Matter (Percent)		Fixed Carbon (Percent)		Calorific Value (Btu/lb)		Total Sulfur (Percent)	
	X	S	X	S	X	S	X	S	X	S	X	S
H	4.2	1.3	12.0	5.1	41.1	4.7	92.7	6.2	11,659	740	0.34	0.12
E	2.9	1.2	13.2	7.3	35.5	8.9	49.4	9.7	12,047	1,129	0.42	0.12
B	2.7	1.2	11.8	7.7	35.1	10.0	49.	10.6	12,168	1,356	0.48	0.29
A	3.34	1.67	25.4	8.34	29.16	9.36	41.31	10.33	9,789	1,265	0.88	0.77

Quantity

According to Malangas Coal Corporation personnel, the Malangas mine area has 9,312,000 t of coal in the LC-1 bed. This same bed in the Kauswagan area has 276,000 t of indicated resources and at Little Baquio 1,380,000 t. As mentioned earlier, the Lalat area has 17 million tons in four mineable beds. Therefore, company personnel believe that more than 35 million tons of resources are contained in all coal beds in the Malangas, Lalat, Little Baguio, and Kauswagon areas. These resources are calculated using the polygon method and a greater than 1.0 m thickness cut-off. The mining depth cut-off is not stated.

PNOC-CC is exploring for coal in other places south and west of the four areas mentioned above. They have discovered coal outcrops over most of the Sibuguey Peninsula. About 90 percent of the Peninsula has been geologically mapped at 1:50,000-scale using U.S. Army Map Service maps; PNOC-CC drilling and exploration work is conducted at a 1:5,000-scale.

Quality

The quality of Malangas coal is similar to that in the Lalat area. A detailed compilation of the range in coal quality values for the Malangas area is unavailable, but a review of table 5 prepared for the Lalat area provides an estimate. Table 9 shows quality of coal in a few samples from the Malangas area, which have been reported in various recent studies. These coal quality estimates indicate a high volatile B and C bituminous coal rank, low sulfur, low to medium ash content, and medium calorific value. The conclusion is that the coal underlying west-central Mindanao is some of the highest quality in the Philippines and, perhaps, in Southeast Asia. Moreover, the coal is of metallurgical grade and possesses desirable metallurgical properties.

COAL PRODUCTION

Clean coal production from the Lalat area is planned as 306,000 t/yr. The life of the mine in the three major beds would be about 21 years; or 27 years if the fourth bed is mined. Initial production would be 19,000 t beginning in 1986; full production would be reached in 1989.

Coal production at Malangas, as is indicated by table 10, has been projected to reach 270,000-300,000 t by 1984. Our investigation found that total production for all mines in the area for 1984 may be less than 140,000 t, far less than the projected amount.

CONCLUSIONS

The following conclusions for the Malangas, Lalat, Little Baguio, and Kauswagan areas are believed valid:

—The total resources for the area are estimated as 35 million t. This is certainly a sufficient resource to support production of 200,000 t/yr for 30 years.

—The coal in the area is some of the best quality in the Philippines and Southeast Asia. The calorific value is medium to high; the coal is bituminous in rank; the moisture content is low; the ash and sulfur are low to medium; the coal has a free swelling index of about 5 (on average); and the Hardgrove Grindability Index ranges from 36 to 57, and sometimes may be considerably higher.

Table 9. Compilation of coal quality data for Malangas coal mine and Malangas area. Values in percent, except calorific value which is Btu/lb (Air-dried basis).

	USGS 1/	Australian lab 1/	Asean 2/	Asean 3/
Moisture	1.94	1.9	2-10	2-4
Ash	15.18	13.1	3-10	5-7
Volatile Matter	19.63	19.7	20-32	24-28
Fixed Carbon	63.25	65.3	---	58-67
Total Sulfur	0.49	0.45	0.4-1.5	0.4-0.9
Calorific value	12,909	13,044	10,500-13,000	17,708-13,104

1/ Splits of same sample analyzed by USGS and an unnamed Australian laboratory, 1984.
2/ Data from Dames and Moore (ASEAN Coal Study, 1984).
3/ Data from Asian Development Bank ASEAN Coal Inception Report (1984).

Table 10. Estimated coal supply from Malangas areas predicted by PNOC-CC (from Lalat Prefeasibility Report, 1984). Numbers in thousands metric tons/year

	Malangas Mine	Little Baguio	Inimaco	Lalat	Total
1983	225	45	10	--	280
1984	270	45	10	--	325
1985	285	45	10	--	340
1986	285	45	10	19	359
1987	300	45	10	60	415
1988	345	45	10	128	483
1989	300	45	10	312	667
1990	300	45	10	312	667
1990-2005					667

Data obtained by William I. Watson, Development Sciences Inc., (DSI) indicated that the projections are overly optimistic. In 1984, Malangas mine will produce about 98,000 t (not 270,000), Little Baguio about 20,000 t (not 45,000), and Inimaco about 18,000 t, for a total of 136,000 t (not 325,000).

--The area is geologically complex, which complicates mining. This complexity is due to folding, faulting, and igneous intrusive activity. However, these are the factors which contribute to the high quality of the coal. The fact the PNOC-CC is mining coal at Malangas and planning a new mine at Lalat indicates that the geologic complexities can be overcome and that mining is economically possible.

--More systematic geologic, resource, and coal quality exploration work needs to be done in the entire Sibuguey Peninsula area to assess the total available coal.

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APPENDIX C

COAL IN SOUTH MINDORO, PHILIPPINES

DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

PROJECT REPORT
Philippine Investigation
(IR)RP-20

COAL IN SOUTH MINDORO, PHILIPPINES

Prepared in cooperation with the Government of the Philippines, under the auspices of the Agency for International Development.

1984

COAL IN SOUTH MINDORO, PHILIPPINES

By

M. D. Carter and E. R. Landis
U.S. Geological Survey

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COAL IN SOUTH MINDORO, PHILIPPINES

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ABSTRACT

The estimation of the total coal resource potential of the southern part of Mindoro has no credible basis. The presently accepted estimate of 100 million tons is conservative as is the presently accepted proven reserve estimate of 4 million tons in the Napisian area; both will be increased as exploration proceeds in the area.

The coal of the Napisian area compares favorably with such other coal as that from Semirara with the exceptions of the sulfur content. Samples of the Napisian coal have more than 3 percent sulfur on the average and the sulfur is largely in the organic form. Organic sulfur is essentially non-removable by conventional coal-cleaning processes.

There is some indication that coals from another area in southern Mindoro may contain less sulfur than the Napisian coals; this possibility should be investigated.

INTRODUCTION

A workshop on introducing coal-water-mix (CWM) fuels to the Philippines was held August 20-24, 1984, at Brookhaven National Laboratory (BNL), Upton, New York, under sponsorship of the Office of Energy in the Agency for International Development (AID). One of the results of the workshop was selection of coal from the Island of Semirara for further experimental work. At the same time, it was decided that information about coal from the southern part of the Island of Mindoro should be evaluated to determine if the Mindoro coal is similar to the Semirara coal and could be considered as an additional potential resource for use in CWM fuels applications in the Philippines.

During September and October 1984, information about the coal resources of the southern part of Mindoro was gathered from many sources by E. R. Landis and M. D. Carter of the U.S. Geological Survey (USGS) and Guevara of the Economic Development Foundation (EDF) as part of the AID program to determine the potential use of CWM fuels. The assistance of R. M. Bomasang and Arturo Mori of the Bureau of Energy Development (BED) is greatly appreciated. The aid and cooperation of F. F. Cruz and F. F. Cruz, Jr. was absolutely invaluable. Through the courtesy of the F. F. Cruz Company, the authors visited the area being explored by the Cruz Company at Napisian, north of the settlement of Bulalacao. Four samples were collected from four coal beds ranging in thickness from 1.35 to 2.05 m for analysis and testing for CWM fuel technology purposes. These samples were submitted to the U.S. Geological Survey for complete coal analysis, including tests not routinely made at laboratories in the Philippines. The bulk of each sample was sent to Brookhaven National Laboratories for testing for use in CWM fuel technology.

GEOLOGY

Geologically, the Island of Mindoro is grossly divisible into two parts. In the eastern part, the rocks at the surface are largely pre-Tertiary "basement" rocks, intrusive igneous rocks, or recent alluvium and other unconsolidated material. No coal has been reported in the eastern part. The western part of the Island of Mindoro forms the northeasternmost part of the Palawan sedimentary and tectonic basin (Philippines Bureau of Mines, 1976 and Sali, 1978, as reported by Younse and Glenn, written commun., 1980) and consists largely of rocks of Tertiary age. The contact between the two parts of Mindoro has been variously depicted by different workers as an ordinary sedimentary contact with Tertiary rocks lapping onto the older pre-Tertiary rocks (Japan International Cooperation Agency) (JICA), 1984 a and b), or as a major fault contact with thrusting of the older rocks of the eastern block over the younger rocks of the western block (Gervasio, 1973, as reported by Younse and Glenn, written commun., 1980, Philippine Bureau of Mines and Geosciences, undated geologic map of the Philippines, and Guzman, 1975).

The major differences between these two interpretations can affect subsequent predictions of such factors as the depositional histories of the various rock units of the island, their later tectonic history, and their present distribution and stratigraphic relationships.

Stratigraphy

The stratigraphic relations of the rocks of Mindoro have been interpreted in several manners by past workers. Table 1 is taken from Japan International Cooperation Agency (JICA) (1984b, table 4) and shows rock-unit stratigraphy and nomenclature as proposed and used by various authors, primarily in relatively small parts of Mindoro. The recently completed geological survey of the Island of Mindoro by the Philippine Bureau of Mines and Geosciences and the Japan International Cooperation Agency (1982, 1983, 1984a and b) had as one objective, the development of a regional stratigraphic framework for Mindoro. The JICA stratigraphic framework proposal establishes general relationships and should encourage solution of local stratigraphic and structural problems within the regional framework.

At this time, both local and regional understandings of the stratigraphic position and distribution of the coal-bearing rocks of southern and western Mindoro require further clarification. In their study of the Bulalacao region of southern Mindoro (which includes the Napisian and Siay coal-bearing areas), Weller and Vergara (1955) suggested that two coal-bearing rock units, the Napisian and Pocanil Formations of middle and late Miocene age were separated by the Mato-ang Limestone of middle Miocene age. The Napisian is underlain by the Bulalacao Limestone of early Miocene age. Later work over a larger area by Montero and Kintanar (1961) and Quidayan (1972) (as reported by Robertson Research International, 1977) indicated to them that the rock units recognized by Weller and Vergara were local members of a larger rock unit of Miocene to earliest Pliocene age, which they called the Insulman Formation.

Recent work by the Philippines Bureau of Mines and Geosciences and the Japan International Cooperation Agency (JICA, 1984 a and b) has resulted in the stratigraphic interpretation shown here as figure 1. A somewhat similar

Table 1. Stratigraphic correlation of Mindoro.

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

From: JICA 1984b

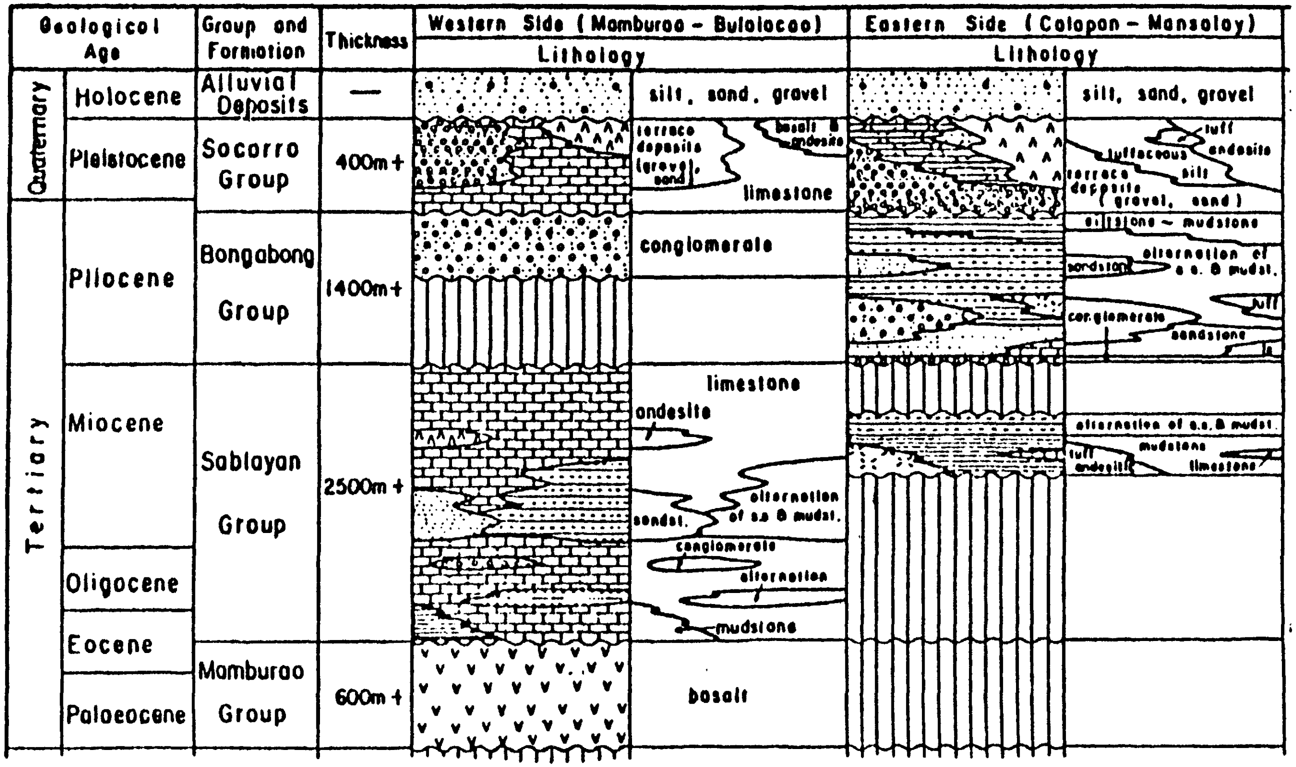

Figure 1. Distribution of lithologies within proposed stratigraphic units.

interpretation had previously been offered by the Philippines Bureau of Mines in 1980 (according to a map prepared to accompany an unseen report by the Philippines Atomic Energy Commission prepared by Gabriel Santos). The cited map shows the Napisian coal measures as laterally equivalent to the Napisian limestone.

Structure

Detailed understanding of the structure of the coal-bearing rocks of southern and western Mindoro awaits better understanding of the local and regional stratigraphy. However, structural attitudes of coal beds and other strata supplemented by study of aerial photographs indicates relatively simple folding with dominant northwest axial orientation accompanied by faulting closely related to the folding.

The coal-bearing rocks dip as much as 50°. Most of the faulting may be high-angle tensional-type. Both the folding and faulting can create mining problems but the problems are not usually insurmountable.

HISTORY OF EXPLORATION AND DEVELOPMENT

Coal has been known in southern Mindoro for more than 100 years. Exploration has revealed hundreds of reported outcrops throughout the coal-bearing strata (see fig. 2 for reported coal occurrences). Major attention has consistently focused on the Bulalacao region, and in most recent years on the vicinity of Napisian Creek. Despite sporadic exploration and development activity, coal has never been successfully produced in southern Mindoro.

In 1879 and 1898, Bulalacao coal was burned on two ships on a test basis. The second trial was reported to compare favorably with coal imported from Australia. In 1889, an application was made for a concession in the Bulalacao region. In 1901, several prospect tunnels were dug, again in the Bulalacao region, but were later abandoned with no measured production. In 1924-25, a small mine was opened in Bolo sitio of Bulalacao but was soon abandoned. Just before World War II, applications were made for 16 permits and leases, but were revoked in 1940 when the Bulalacao region (about 220 km^2) was declared a government reservation. During World War II, the Japanese opened a small mine near Siay but apparently no coal was ever shipped out of the area.

During 1965, the Bacnotan Cement Corporation performed exploratory work in the Napisian Creek area including four drill holes, but to date all resulting data have been kept confidential and, therefore, have had no bearing on any resource estimates of the area.

In 1979, the Construction Development Corporation of the Philippines (CDCP) applied for an exploration contract on 12,000 hectares in the Bulalacao region (see fig. 2). In 1980 CDCP acquired a 1-year contract for reconnaissance on an additional 30,000 hectares extending northwest from the Bulalacao region to the northern reaches of the Labangan River approximately 15 km northeast of San Jose. This contract was not renewed at the end of a year because CDCP

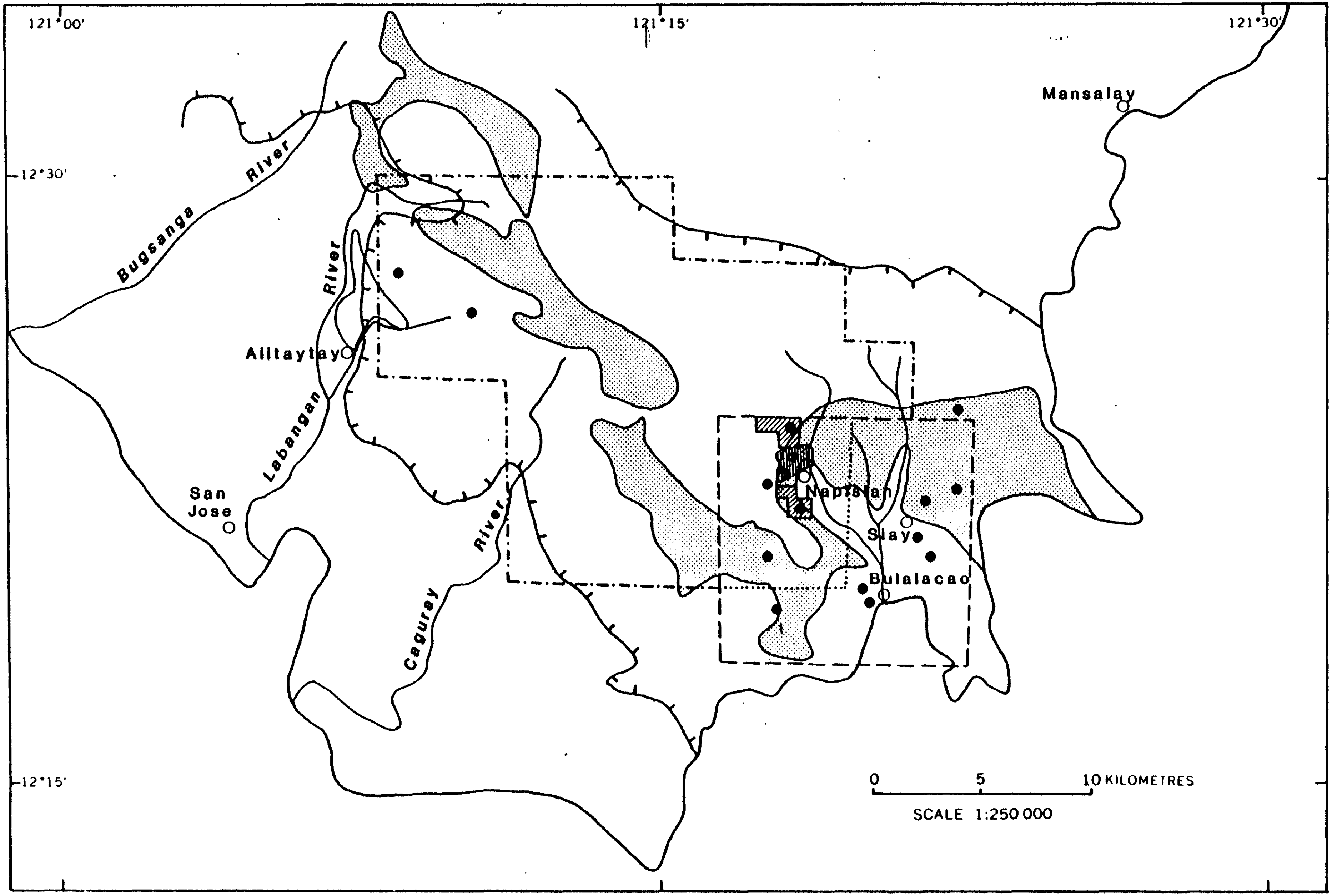

Figure 2. Index map of South Mindoro showing coal-bearing sediments, reported coal occurrences, and various coal exploration contract areas. (Explanation on next page)

EXPLANATION FOR FIGURE 2

Napisian Coal Measures (Santos, 1983)

Coal-bearing sediments (Robertson Research International, 1977)

Reported coal occurrences from various sources

Construction and Development Corporation of the Philippines (CDCP) 12,000-hectare coal exploration contract, 1979-80 (BED files)

CDCP 4,000-hectare coal exploration contract, 1980-82 (BED files)

CDCP 30,000-hectare coal exploration contract, 1980 (BED files)

Area of CDCP proved and probably reserve estimate (CDCP Mining Corporation, 1981)

Area of CDCP possible reserve estimate (CDCP Mining Corporation, 1981).

had not delineated any coal deposits or reserves with large potential. Furthermore, CDCP retained only 4,000 hectares in the northwestern part of the original 12,000 for concentrated exploration and drilling. By May 1981, CDCP had drilled 21 holes, made an estimate of the coal potential, and developed plans for an underground mine in the Napisian Creek area to produce 500 tons per day from mining of multiple beds by modified longwall methods (CDCP Mining Corp., 1981). However, in July 1982, CDCP withdrew their claim, reportedly owing to financial difficulties.

In the same year, Filipinas Systems, Inc. acquired a contract for exploration and development of 15,000 hectares in the Bulalacao region including both the Napisian and Siay areas. Filipinas Systems performed mapping and aerial surveying, trenching and sampling of outcrops, as well as construction of roads and establishment of a headquarters camp. At present its parent company, F. F. Cruz, is conducting further exploratory work on the Napisian Creek area, including both drilling and sampling of coal for chemical analysis.

COAL RESOURCES

Quantity

To date, a comprehensive study has not been made of coal on Mindoro. However, several reports depict the extent and geology of the coal-bearing rocks in southern Mindoro.

Robertson Research International Limited (1977) indicates an area of coal-bearing sediments trending northwestward from southeastern Mindoro (fig. 2). An unpublished set of maps by the Philippines Atomic Energy Commission (Santos, 1983) shows a far more narrow belt of coal measures extending from southeastern Mindoro 35 km northwestward to the northern reaches of the Bugsanga River, about 25 km north-northeast of San Jose (fig. 2). If there is an accompanying text with explanation for these maps, the authors have not seen it.

As part of their compilation of a geological survey of Mindoro, the JICA team (Japan International Cooperation Agency and Metal Mining Agency of Japan, 1983 and 1984b) prepared a simple geologic map of the Napisian area (fig. 3). They also presented the only columnar sections of the Napisian and Siay areas that the authors have seen in publication (figs. 4 and 5). Note that the section for the Napisian area shows eight coal beds while the map traces the outcrop of only three. Although the treatment of coal was apparently incidental to their study, the JICA geologic interpretation provides the most comprehensive pictorial synthesis of coal geology in the Bulalacao area.

Seven estimates have been made for the amount of coal in southern Mindoro; all except the 1977 estimate address only the Bulalacao region. The estimates are as follows:

Year	Area	Thousand metric tons	Basis	Criteria	Source
1898	Napisian and Siay	1,500	Resources	Unknown	Fenton Hill
1913	Bulalacao	4,096	Resources	Unknown	F. A. Dalberg
1940	Napisian	187	Reserves	Unspecified	Melendres & Cinco

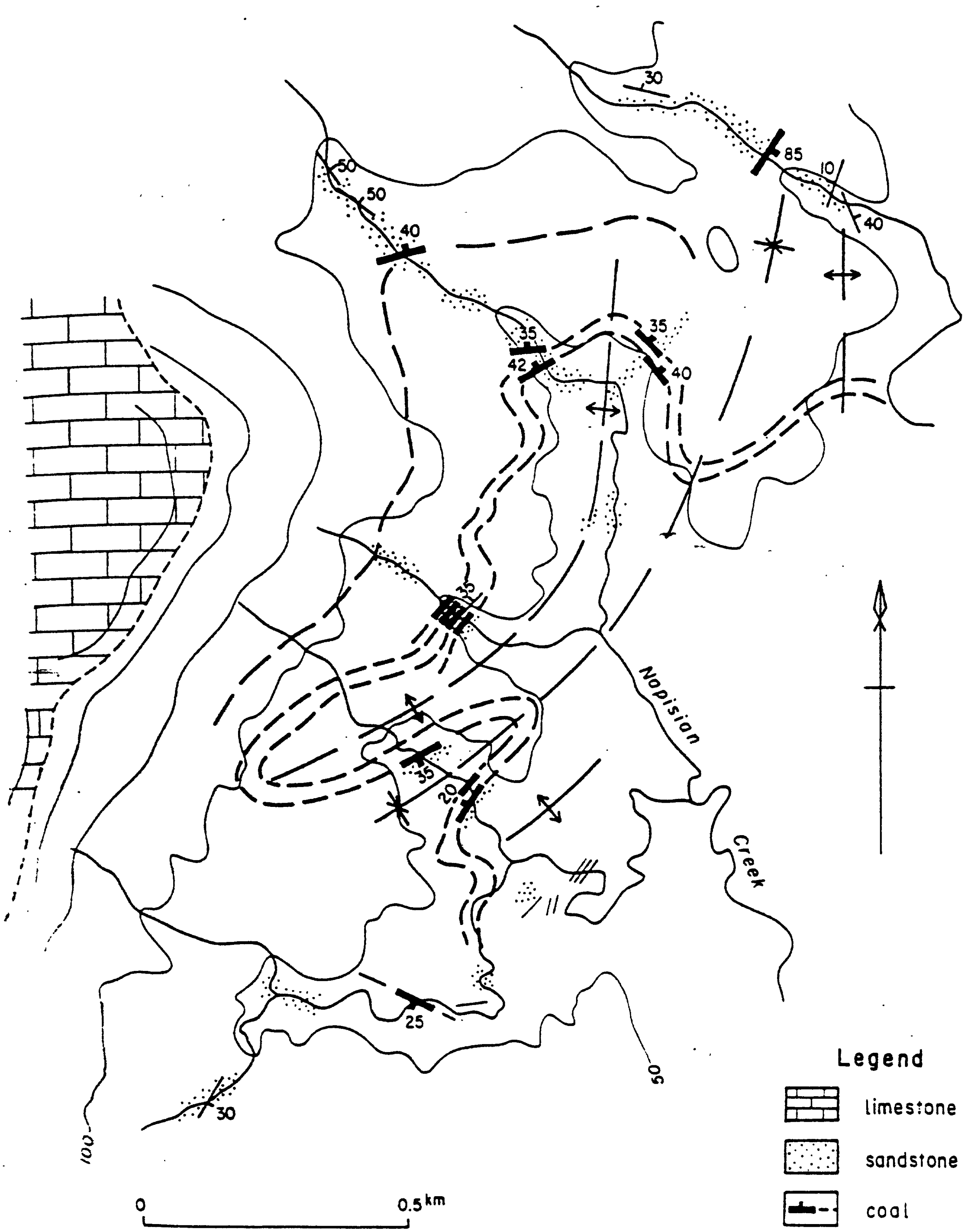

Figure 3. Geologic map of the Napisian area (Japan International Cooperation Agency and Metal Mining Agency of Japan, 1983).

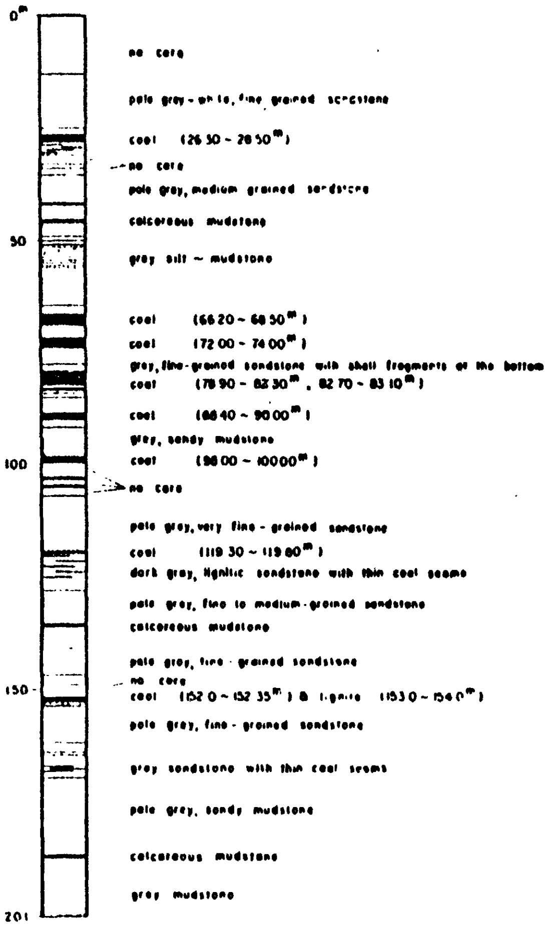

Figure 4. Core log from the Napisian area (Japan International Cooperation Agency and Metal Mining Agency of Japan, 1984b).

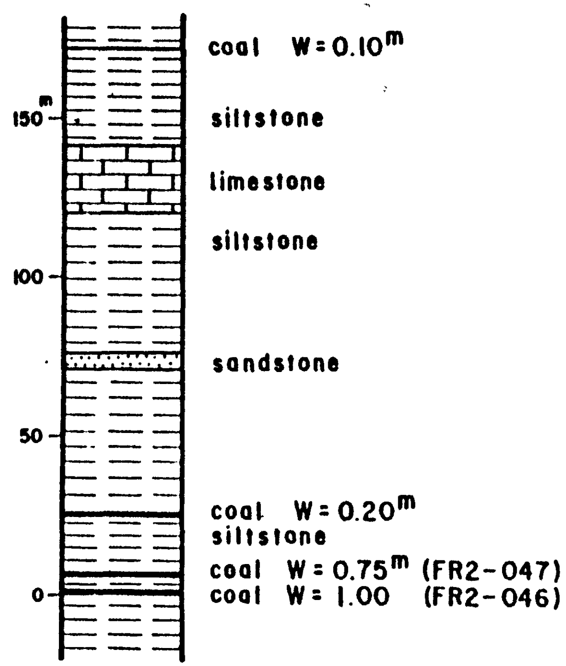

Figure 5. Columnar section of the Siay area (Japan International Cooperation Agency and Metal Mining Agency of Japan, 1983).

1955	Napisian and Siay	7,236	Resources	Specified	Weller & Vergara
1976	Napisian and Siay	5,014	Resources	Unspecified	Argano & de Luna
1977	Southern Mindoro	100,000	Resources	Unspecified	Robertson Research
1981	Napisian	14,696	Resources	Specified	CDCP
1981	Napisian	5,174	Reserve base	Specified	CDCP
1981	Napisian	3,073	Reserves	Specified	CDCP

To facilitate comparison of the various estimates of coal tonnages, the terms resources, reserve base, and reserves used in this report are in accordance with the U.S. Geological Survey Coal Classification System (Wood and others, 1983). Resources are deposits of coal in such form and amount that economic extraction is currently or potentially feasible. Reserve base is that part of the identified resources that meet specified minimum physical and chemical criteria related to current mining and production practices, including those for quality, depth, thickness, rank, and distance from points of measurement. Reserves are that part of the reserve base which could be economically extracted or produced at the time of determination considering environmental, legal, and technical constraints.

Although it has not been clearly stated in each case, it is reasonable to assume that all of the estimates cited above are of resources, except for the 186,940 t reserve estimate of Melendres and Cinco in 1940 and the 5,174,033 t reserve base and 3,073,233 t reserve in the 1981 CDCP mining feasibility study.

It should be noted that until 1981, all estimates were based upon observations at outcrops, trenches, and shallow mines. In fact, until CDCP began drilling in the Napisian area in 1980, correlation of coal beds in southern Mindoro had been nearly impossible. Therefore, all resource estimates had been made on the statistical basis of total thickness of coal beds of potentially minable thickness likely to be encountered within the area of the estimate.

Many of the published and unpublished reports available to previous researchers were destroyed by the fire in the Philippines Bureau of Mines Headquarters in Manila in August 1984. The reports that the authors were able to obtain were from the files of the Bureau of Energy Development (BED) at Fort Bonifacio and at a small library at the Philippines Bureau of Mines Petrolab in Quezon City, both in Metro Manila, Philippines.

The authors were unable to look at the 1898 and 1913 resource estimates. Consequently, the criteria used, if described, are unknown for purposes of this report. Although the 1898 figure is small, the numbers in these two reports are not dissimilar from succeeding tonnage estimates for the Bulalacao area. Melendres and Cinco (1940) indicated that Fenton Hill (1898) described six beds ranging from 1 to 4 m thick and averaging 2 m (see table 2).

The Melendres and Cinco report of 1940 estimated reserves of four minable coal beds ranging from 0.9 to 1.8 m thick and averaging 1.2 m in two localities within a 1.6-km^2 part of the Napisian area. The authors believe that this must be an estimate of reserves as evidenced by the small tonnage, the small

Table 2. Selected coal descriptions in South Mindoro.

Date	Area	Number of beds	Range in thickness (meters)	Average thickness per bed (meters)	Dip (degrees)	Author(s)
1898	Napisian	6	1 -4	2	20-40	Hill
1940	Napisian	4 1/	.9 -1.8	1.2	35	Melendres and Cinco
1955	Napisian	10	.1 -3.0	.6	45	Weller and Vergara
		4 minable	.75	1.02	45	Weller and Vergara
	Siay	7	.1 -1.2	---	45	Weller and Vergara
		3 minable	.75	.85	45	Weller and Vergara
1970	Alitaytayan	2	.61-1.07	.85	20	Fernandez
1976	Napisian	9	.3 -2.85	---	45	Argano and de Luna
		6 minable	.55-1.02	---	(20-70)	Argano and de Luna
	Siay	5	.45-1.2	---	30 (15-65)	Argano and de Luna
1981	Napisian	8	.5 -4.0 2/	1.5	45+	CDCP

1/ Melendres and Cinco state that numerous coal beds occur but only four closely related coal beds deserve consideration.

2/ One (1) thickness of 13 m discounted by authors.

area considered, and the frequent references to "mine workings," "entries," and "yield." Other than a maximum depth of 50 m below drainage, Melendres and Cinco did not state their criteria in the text and, unfortunately, all of the accompanying illustrations and maps were destroyed during World War II.

In their 1955 report, Weller and Vergara were the first to specify in detail the assumptions made in deriving their resource estimates. The estimates were based upon approximately 100 measurements at outcrop in the Napisian and Siay areas. The assumptions given for the Napisian area are representative of the type of assumptions made for both areas:

1. Length of coal area about 3,000 m.

2. At least 10 beds.

3. About 40 percent of coal outcrops are 0.75 m or more thick and average about 1.02 m.

4. About 25 percent of coal outcrops are between 0.35 and 0.75 m thick and average about 0.54 m.

5. Average dip of coal is about 45°.

6. Potential mining limit is 200 m below drainage.

7. Width of estimate is 200 m depth below drainage X cosecant of 45° dip.

8. Specific gravity of coal is 1.3.

The formula for calculation of coal tonnage below drainage was:

length X width X average total bed thickness X percent of beds of category of coal thickness X specific gravity.

A slightly different formula was applied to coal above drainage.

Although not stated in the text, Weller and Vergara (1955) probably used the same criteria for the Siay area where they identified seven beds ranging from 0.1 to 1.2 m thick with three minable beds (more than 0.75 m) averaging 0.85 m thick.

Weller and Vergara (1955) indicated that they were unable to employ standard USGS resource calculation techniques because of uncertain correlation of coal beds.

In 1976, Argano and de Luna conducted a brief investigation for the Philippine Bureau of Mines and Geosciences to reassess the Napisian and Siay areas for possible future exploration and development. Nine correlated beds, ranging in thickness from 0.3 to 2.85 m, were identified in the Napisian area. Six of the beds are minable. In the Siay area five beds of economic significance have thicknesses ranging from 0.45 to 1.2 m. They calculated a resource of 5 million metric tons but presented no discussion of criteria employed other than the application of 1.03 for specific gravity (this is probably a misprint; 1.3 is commonly used for southern Mindoro coal).

In 1977, Robertson Research International Limited (RRI) made a resource estimate for southern Mindoro in excess of 100 million metric tons to a depth of 200 m. RRI indicated that two unpublished reports by the Republic Resources and Development Corporation (Montero and Kintanar, 1961, and Quidayan, 1972) had proved the coal-bearing rocks to be continuous at least as far as the Alitaytayan area, 25 km northwest of Bulalacao. Although the RRI report shows a far larger area of coal-bearing rocks (see fig. 2), the text indicates the area of coal potential to be 25 km in length NW-SE and 5 km in width. The criteria were not specified; however, a simple calculation of 125 km^2 (area) X 1 m (average total coal thickness) X 1.3 (specific gravity) equals 162.5 million metric tons--which is indeed in excess of 100 million.

The first significant subsurface information on the coal was obtained in 1980-81 by CDCP drilling (CDCP Mining Corp., 1981). The company cored 21 holes (totalling 4,349.5 m) in the Bulalacao region. Subsequently, CDCP calculated resources and reserves from 15 holes and numerous outcrops in a small portion of the Napisian Creek area. In all 15 holes from 1 to 8 coal beds were penetrated with an average of 5 beds per hole. The total coal thickness encountered in each hole ranges from 1 to 88 m and averages 12 m per hole. Spacing between the core holes ranges from 50 to 300 m. The holes average approximately 200 m in depth. This afforded CDCP adequate subsurface control to correlate as many as 10 coal beds and to construct cross sections throughout their selected mine site.

Tonnages were estimated by the following criteria specified by BED:

Positive Reserves--Those sufficiently explored by drilling and/or tunneling. Drilled holes are generally spaced at not more than 100 m apart.

Probable Reserves--Those also explored by drilling and/or tunneling but still needing confirmatory drilling and/or tunneling. Drill holes are generally spaced at 200 m apart.

Possible Reserves--Those which are assumed from geological condition or surface outcrops. Observation is spaced at not more than 400 m.

The area of calculation was divided into rectangular blocks wherein each drill hole has an area of influence of 100 m around the hole. The sides of the blocks were drawn parallel to the directions of the strike and dip. Coal less than 0.5 m thick was not included. The sum of all beds 0.5 m and greater intersected per drill hole represented the thickness of that particular drill hole and its rectangle. The formula for deriving minable reserves was: area of rectangle X total coal thickness X specific gravity.

This computation yielded the "positive reserves" of coal in place in the 0.4-km^2 mine site as 3,073,232 t.

Beyond 100 m from a drill hole, CDCP used an average figure of four coal beds per section down to 200 m below the surface and an average thickness of 1 m for each coal bed totalling 4 m of coal per drill hole. On this basis "probable reserves" of 0.4 km^2 adjacent to the mine site totalled 2,100,800 t and "possible reserves" in two nearby areas totalled 9,521,720 t. The north area of 0.9 km^2 was estimated to contain 4,565,600 t, the two south areas of 1.0 km^2 were estimated at 4,956,120 t (see fig. 2 for locations of these estimates).

The above estimates were submitted to BED as a part of the CDCP feasibility study in 1981. BED geologists checked the CDCP assessment and accepted their figures. In fact, BED currently reports resources of southern Mindoro as 100 million metric tons (from the Robertson Research Report, 1977) and proven reserves as 4 million metric tons (proven reserves of CDCP plus two-thirds of their probable reserves).

The tonnage estimates made in the past for southern Mindoro, including the CDCP reserves, have been on the basis of the number and total thickness of coal beds expected to be encountered in the subsurface. This is acceptable for resource estimation, but certainly not for reserves where, in many cases, all of the coal beds in the sequence would not be recovered.

The optimum methodology of resource/reserve estimation requires first the correlation of coal beds, followed by construction of coal isopach (thickness), structure (elevation), and overburden thickness maps for each bed, and, finally, calculation of the tonnage of each bed within the area of concern such as described in the U.S. Geological Survey Coal Classification System (Wood and others, 1983). To date, none of the studies on southern Mindoro have done this. As stated previously, in 1980-81 CDCP became the first to have sufficient subsurface control through their drilling program to allow application of this technique. Current additional drilling by F. F. Cruz should facilitate a proper resource and reserve estimate of the Napisian area on an individual bed basis.

The BED methodology of tonnage calculation followed by CDCP is a valid technique, but should be applied on a bed-by-bed basis--which has not been done as yet in southern Mindoro.

In summary, the RRI resource estimation for southern Mindoro in excess of 100 million metric tons is probably conservative, but far more reconnaissance must be accomplished before a meaningful tonnage estimate can be made. The resource estimates in the Napisian and Siay areas have been small, largely due to lack of subsurface information and bed correlation. Napisian is certainly the most immediately promising area in southern Mindoro. In fact, BED has indicated that the numerous coal beds and thicknesses encountered in the CDCP drill holes are better than the average coal deposits in most of the underground mines around the country and, in addition, that the proven reserve warrants an underground mining operation that could be almost as large as Malangas (BED, written commun., 1980 and 1982). Siay shows some potential for development and has been mined in the past. Other potential minable deposits could be located through additional exploration. The estimates of reserves in the Napisian area appear to be quite conservative. Reserve estimates, however, will always vary with the site chosen, the mining conditions and techniques to be applied, the number of beds to be mined, their thickness and lateral continuity, the quality of the coal, the end use intended, and the marketability, as well as transportation and other logistical considerations.

Quality

The quality of coal can be measured in many ways but the three most common expressions are rank, type, and grade. These and other terms are defined and explained in appendix E to the main report of which this is appendix C. In general, all measures of coal quality are intended to allow prediction of a coal's suitability for particular usages.

A considerable number of analyses of coal from southern Mindoro are available, but sample descriptions and locations, sampling methods, storage and shipment, particular analytical laboratories and most other related facts, are not available. The lack of these data reduce the usability of particular analyses for prediction of coal quality. Nevertheless, statistical appraisal of the available data may indicate some relationships that can be tested by future research.

Melendres and Cinco (1940) presented five analyses of samples from the Napisian area. The five samples came from five separate locations, from four different beds. The lowest of the four "minable" beds Melendres and Cinco found in the area was measured at three places and averaged 94 cm in thickness; the second bed was measured at four places and averaged 100 cm in thickness; the third bed was measured at six places and averaged 180 cm in thickness; the fourth bed was measured at five places, sampled at two places, and averaged 120 cm in thickness. All thicknesses exclude partings and the thickness and selection (without explaining exactly why) of bed number 3 as an "index bed" indicates to the present authors that this bed may be the C bed of present workers (F. F. Cruz Co.) in the Napisian area.

The five samples show the following range and means (in percent except for Btu/lb calorific value) on an air-dried basis:

	Moisture	Volatile matter	Fixed carbon	Ash	Sulfur	Calorific value Btu/lb
Range	16.2-16.8	40.0-43.9	37.7-38.9	2.3-4.9	2.4-3.6	10,235-11,160
Arithmetic mean	16.5	41.9	38.3	3.5	3.0	10,679
Geometric mean	16.5	41.8	38.3	3.3	3.0	10,673

The range of the five samples is remarkably small and consequently the arithmetic and geometric means are almost coincident. Both of the means indicate an apparent rank of subbituminous A coal in the ASTM classification system.

RRI (1977) compiled previous analyses of 22 samples (including the five from Melendres and Cinco (1940) cited above) and sampled three other outcrops presumably representing three separate beds of 112, 122, and 290 cm "between Bulalacao and

Napisian." One early sample (1907) has no sulfur or heating value measurement. The 25 samples show the following range and means (in percent except for Btu/lb calorific value) on an air-dried basis:

	Moisture	Volatile matter	Fixed carbon	Ash	Sulfur	Calorific value Btu/lb
Range	5.8-32.7	34.5-45.4	29.3-48.1	1.3-10.2	0.8-5.5	7,710-11,190
Arithmetic mean	19.6	40.0	35.8	4.5	3.5	9,530
Geometric mean	18.2	39.9	35.5	3.9	3.2	9,450

Despite a significant increase in the range values, the means are very close. The individual analyses indicate a range in apparent ranks of from lignite A to high volatile C bituminous but both of the means indicate an apparent rank of subbituminous B according to the ASTM classification system. The means indicate that the coal is of low ash content (less than 8 percent ash on an as-received basis) and high sulfur (3 percent or more total sulfur on an as-received basis). The analyses are on an air-dried basis, not as-received, but would probably fall within the cited categories.

More recently, seven samples were collected and analyzed during the joint Philippine Bureau of Mines and Geosciences and Japan International Cooperation Agency geological survey of Mindoro Island. Table 3 presents the analyses, on either as-received or air-dried basis (unstated), of the seven samples plus the range and arithmetic and geometric means. Table 4 is a description of the samples. Again, although the range of individual values is quite large, the means are very close and both indicate an apparent rank of subbituminous B according to the ASTM classification system. In contrast to the previously cited 25 samples, these seven samples are of medium sulfur content (more than 1, but less than 3 percent total sulfur on an as-received basis) and are of medium ash content (8 percent to 15 percent ash on an as-received basis). Also noteworthy is the fact that the samples from the Siay area have much less sulfur content than the samples from the Napisian area.

Seven other samples collected in the Napisian area during recent exploration activities of the F. F. Cruz Co. yield a range and means (in percent except for Btu/lb calorific value) as follows:

	Moisture	Volatile matter	Fixed carbon	Ash	Sulfur	Calorific value Btu/lb
Range	18.3-25.1	38.91-43.7	31.7-37.4	1.5-6.2	3.0-3.5	8,675-9,404
Arithmetic mean	21.6	40.8	34.1	3.5	3.3	9,000
Geometric mean	21.5	40.8	34.0	3.2	3.3	8,996

The above values are on the as-received basis. For comparison, the arithmetic mean heat value on an air-dried basis is 9,770 Btu/lb. The apparent rank on the as-received basis is subbituminous C and on the air-dried basis is subbituminous B.

Table 3. Analyses of coal samples collected during JICA study. (JICA 1984a, table A-7 and 1983, p. 64-65)

	As-received or air-dried (?); percent						
Sample No.	Moisture	Volatile matter Percent	Fixed carbon Percent	Ash Percent	Sulfur Percent	Calorific Value Btu/lb	ASTM rank
HRI-204	18.0	39.4	36.0	6.6	(1)	9,452	Sub B
FR2-045	18.7	37.7	32.3	11.3	1.2	7,684	Sub C
FR2-046	16.6	34.9	29.2	19.3	1.0	7,161	Sub C
FR2-047	14.2	40.3	29.4	16.1	1.7	8,766	Sub A
SR2-086	11.1	32.9	28.6	27.4	4.7	6,872	Sub B
SR2-098	15.2	40.5	33.4	10.9	3.4	8,911	Sub B
SR2-099	13.5	43.4	36.8	6.3	4.3	10,083	Sub A
Range	11.1-18.7	32.9-43.4	28.6-36.8	6.3-27.4	1.0-4.7	6,872-10,083	Sub C to Sub A
Arithmetic mean	15.3	38.4	32.2	14.0	2.7	8,418	Sub B
Geometric mean	15.1	38.3	32.1	12.3	2.3	8,344	Sub B

(1) Not reported; assumed 3 percent to derive ASTM rank.

Table 4. Description of coal samples collected during JICA study.

Sample Number HB1-204

Alitaytayan Area, San Jose, Occidental; 13.5 km NE of San Jose

Latitude - 12°26'30" N.

Longitude - 121°09' E.

Two beds, the upper 0.6 m thick and the lower 1.05 m thick with unstated interval between, occur in sequence of interbedded sandstone and carbonaceous silty sediments of the Sablayan Group.

No information about part(s) sampled.

Outcrop sample.

Sample Number FR2-045

Tambargan Area, Bulalacao, Oriental; 4.5 km N. 25 E. of the Siay area in the upper reach of the Talibong River.

Latitude - 12°24'10" N.

Longitude - 12°122'20" E.

No information about bed(s) or thickness sampled.

Outcrop sample.

Sample Number FR2-046

Siay Area, Bulalacao, Oriental; 5 km NE of Bulalacao, in middle reaches of Siay Creek, a western tributary of the Talibong River.

Latitude - 12°21'57" N.

Longitude - 121°21'40" E.

Three beds in siltstone of the Sablayan Group. Beds are 1.0 m, 0.75 m, and 0.2 m thick with siltstone 5 m and 20 m thick between beds. The 1.0-m bed is lowest and is sampled as -046.

Outcrop sample.

Table 4. Description of coal samples collected during JICA study.(continued).

Sample Number FR2-047

Siay Area, Bulalacao, Oriental; 5 km NE of Bulalacao, in middle reaches of Siay Creek, a western tributary of the Talibong River.

Latitude - 12°21'57" N.

Longitude - 121°21'40" E.

Three beds in siltstone of the Sablayan Group. Beds are 1.0 m, 0.75 m, and 0.2 m thick with siltstone 5 m and 20 m thick between beds. The 0.75-m bed is sampled as -047.

Outcrop sample.

Sample Number SR2-086

Napisian Area, Bulalacao, Oriental; 9 km NNW of Bulalacao.

Latitude - 12°22'38" N.

Longitude - 121°18'03" E.

Four coal beds confirmed (seen?), among which two beds are about 2 m thick. Sample -086 represents 0.9-m bed thickness.

Sample from "typical outcrop."

Sample Number SR2-098

Napisian Area, Bulalacao, Oriental; 9 km NNW of Bulalacao

Latitude - 12°22'38" N.

Longitude - 121°18'03" E.

Four coal beds confirmed (seen?), among which two beds are about 2 m thick. Sample -098 represents 2-m bed thickness.

Sample from "typical outcrop."

Sample Number SR2-099

Napisian Area, Bulalacao, Oriental; 9 km NNW of Bulalacao

Latitude - 12°22'38" N.

Longitude - 121°18'03" E.

Four coal beds confirmed (seen?), among which two beds are about 2 m thick. Sample -099 represents 0.7-m bed thickness.

Sample from "typical outcrop."

Coal exploratory drilling by the Cruz and Co. during September and October 1984, produced samples of four beds designated 1, 2A, 2B, and 3, and the samples were analyzed by SGS Far East Limited, a custom laboratory in Manila. The samples came from a location reportedly 100 m north and 40 m east of the Napisian area number 3 where six coal beds are exposed and may represent the upper three outcropping beds (A, B, and C) or may represent a bed above A, and A and B. Analyses (in percent except for calorific value in Btu/lb) of the four samples on an as-received basis are as follows:

		Moisture	Volatile matter	Fixed carbon	Ash	Sulfur	Calorific value Btu/lb
BCM3-Seam 1		21.30	39.34	32.43	6.93	3.36	9,224
BCM3-Seam 2A		18.95	39.67	33.20	8.18	4.90	9,308
BCM3-Seam 2B		17.56	43.59	31.39	7.46	2.84	9,915
BCM3-Seam 3		18.98	40.55	32.94	7.53	3.55	9,467
Range	from	17.56	39.34	31.39	6.93	2.84	9,224
	to	21.30	43.59	33.20	8.18	4.90	9,915
Arithmetic mean		19.20	40.79	32.49	7.53	3.66	9,479
Geometric mean		19.15	40.75	32.48	7.51	3.59	9,475

The means indicate a coal with an apparent rank of subbituminous B, with low ash and high sulfur content.

As listed previously, a total of 11 analyses of samples collected during recent exploration activities of Cruz and Co. are available to date. No locations are available for seven of the samples but presumably all the samples come from the same relatively small area. The earlier seven samples may be all from outcrops, while the later four are from a coal exploratory drill hole. The range and means (in percent except for Btu/lb calorific value) for the 11 samples on an as-received basis are as follows:

		Moisture	Volatile matter	Fixed carbon	Ash	Sulfur	Calorific value Btu/lb
Range	from	17.6	38.9	31.4	1.5	2.8	8,675
	to	25.1	43.7	37.4	8.2	4.9	9,915
Arithmetic mean		20.7	40.8	33.5	5.0	3.4	9,173
Geometric mean		20.6	40.8	33.4	4.3	3.4	9,167

The mean values indicate an apparent rank of subbituminous B and a coal of low ash and high (just barely) sulfur content.

On September 24, 1984, four samples of coal from beds exposed in the Napisian area of southern Mindoro were obtained during a visit by the authors to the F. F. Cruz Company exploration contract area.

Six coal beds are exposed in the creek bottom in Napisian Area 3, which is the area being considered for mining by the F. F. Cruz Company, whose personnel designate these as beds A through F from top down.

A very preliminary mine-plan would put a slope in on bed C and mine beds A, B, and C. Obviously, the other beds would be available for mining also.

Beds A, B, and C were sampled. These are outcrop samples, but the coal beds had been dug-out previously, and were dug-out again for these samples. A column was then collected by using a geologist's pick and a large pick and shovel.

Bed A is 1.5 m thick, no partings, carbonaceous shale roof and floor. Roof 0.5 m +; floor 0.1 m +. Bed B is 1.35 m thick, no partings, 0.2 m carbonaceous shale roof overlain by 2 m + gray claystone and a 0.3 m + carbonaceous shale floor. Bed C has a 0.15 m carbonaceous coaly shale parting separating a 1.2 m upper coal bench and a lower 0.7 m lower coal bench. Roof and floor are carbonaceous shale abruptly grading to gray shale. The sample of Bed C includes the parting on the expectation that the parting would be included in a run-of-mine product. Beds D, E, and F were not sampled.

In Napisian Area 1 west of Area 3 several coal beds are present. They may represent at least in part the sequence of beds exposed in Area 3, but are uncorrelated at this time. The thickest of the exposed beds has 1.53 m coal overlain by 1.0 m of carbonaceous shale and has a light gray claystone roof. The sample collected here represents the 1.53 m coal thickness.

The Cruz Company personnel are doing exploratory drilling north and northeast of Area 3. They reported that they penetrated a seventh coal bed and more importantly feel that the beds, which are inclined steeply where exposed, are dipping at less than 10 degrees in the area where they are drilling.

Table 5 contains the analyses of the four samples described above. Proximate and ultimate analyses, plus other tests defined and described in appendix E to the main report, are listed.

The range and means (in percent except for Btu/lb calorific value) for the four samples listed in table 5 are as follows:

	Moisture	Volatile matter	Fixed carbon	Ash	Sulfur	Calorific value Btu/lb
Range from	21.55	39.38	28.23	4.27	3.63	8219
to	27.72	43.32	31.02	5.46	3.74	9500
Arithmetic mean	23.4	41.88	29.98	4.74	3.68	8999
Geometric mean	23.3	41.85	29.96	4.72	3.67	8986

The above means indicate that the coal is low ash (less than 8 percent), high sulfur (3 percent or more), and has an apparent rank of subbituminous B. Hardgrove Grindability Indexes range from 61 to 72; total sulfur contents are high (more than three percent), and almost all the sulfur is in the organic, essentially unremovable form, none of the coals exhibits swelling (coking) properties.

To date, 15 samples collected recently from the Napisian area have been analyzed and have been cited herein. The analyses are quite similar, allowing for differences in sample handling and packing procedures.

Table 5. Analyses of four coal samples collected September 24, 1984, in the Napisian area, South Mindoro.

Field number: Bed A

Laboratory Number: U12002

AIR DRY LOSS 10.27 RESIDUAL MOISTURE 13.15

	As-received	Dry	Dry ash-free
PROXIMATE ANALYSIS			
Moisture	22.07		
Ash	4.27	5.48	
Volatile Matter	42.64	54.71	57.88
Fixed Carbon	31.02	39.81	42.12
	100.00	100.00	100.00
ULTIMATE ANALYSIS			
Hydrogen	6.31	4.93	5.22
Carbon	51.59	66.21	70.05
Nitrogen	0.69	0.89	0.94
Sulfur	3.63	4.66	4.93
Oxygen	33.51	17.83	18.86
Ash	4.27	5.48	
	100.00	100.00	100.00
HEATING VALUE (BTU/LB)	9120	11702	12380
FORMS OF SULFUR			
Sulfate sulfur	0.04	0.05	0.05
Pyritic sulfur	0.08	0.10	0.11
Organic sulfur	3.51	4.51	4.77

FREE SWELLING INDEX 0.0

ASH FUSION TEMPERATURES (Reducing Atmosphere)

Initial Deformation	2260	F
Softening Temp.	2320	F
Fluid Temp.	2400	F

EQUILIBRIUM MOISTURE = 19.59%

HARDGROVE GRINDABILITY INDEX = 70

Table 5 (continued).

Field number: Bed B

Laboratory number: U12005

AIR DRY LOSS 8.81 RESIDUAL MOISTURE 13.97

	As-received	Dry	Dry ash-free
PROXIMATE ANALYSIS			
Moisture	21.55		
Ash	4.56	5.81	
Volatile Matter	43.32	55.21	58.62
Fixed Carbon	30.57	38.98	41.38
	100.00	100.00	100.00
ULTIMATE ANALYSIS			
Hydrogen	6.52	5.23	5.55
Carbon	53.00	67.56	71.73
Nitrogen	0.68	0.86	0.91
Sulfur	3.68	4.69	4.98
Oxygen	31.56	15.85	16.83
Ash	4.56	5.81	
	100.00	100.00	100.00
HEATING VALUE (BTU/LB)	9500	12109	12856
FORMS OF SULFUR			
Sulfate sulfur	0.01	0.01	0.01
Pyritic sulfur	0.06	0.07	0.07
Organic sulfur	3.62	4.61	4.90

FREE SWELLING INDEX 0.0

ASH FUSION TEMPERATURES (Reducing Atmosphere)

Initial Deformation	2390	F
Softening Temp.	2420	F
Fluid Temp.	2460	F

EQUILIBRIUM MOISTURE = 20.10%

HARDGROVE GRINDABILITY INDEX = 72

Table 5 (continued).

Field number: Bed C

Laboratory number: U12003

AIR DRY LOSS 9.41 RESIDUAL MOISTURE 14.18

	As-received	Dry	Dry ash-free
PROXIMATE ANALYSIS			
Moisture	22.26		
Ash	5.46	7.02	
Volatile Matter	42.19	54.27	58.37
Fixed Carbon	30.09	38.71	41.63
	------	------	------
	100.00	100.00	100.00
ULTIMATE ANALYSIS			
Hydrogen	6.39	5.02	5.40
Carbon	51.34	66.04	71.03
Nitrogen	0.71	0.91	0.98
Sulfur	3.65	4.70	5.05
Oxygen	32.45	16.31	17.54
Ash	5.46	7.02	
	------	------	------
	100.00	100.00	100.00
HEATING VALUE (BTU/LB)	9155	11777	12666
FORMS OF SULFUR			
Sulfate sulfur	0.04	0.05	0.05
Pyritic sulfur	0.13	0.17	0.18
Organic sulfur	3.48	4.48	4.82

FREE SWELLING INDEX 0.0

ASH FUSION TEMPERATURES (Reducing Atmosphere)

Initial Deformation	2190	F
Softening Temp.	2210	F
Fluid Temp.	2430	F

EQUILIBRIUM MOISTURE = 21.07%

HARDGROVE GRINDABILITY INDEX = 61

Table 5 (continued).

Field number: Uncorrelated bed

Laboratory number: U12004

AIR DRY LOSS 13.11 RESIDUAL MOISTURE 16.82

	As-received	Dry	Dry ash-free
PROXIMATE ANALYSIS			
Moisture	27.72		
Ash	4.67	6.45	
Volatile Matter	39.38	54.48	58.24
Fixed Carbon	28.23	39.07	41.76
	100.00	100.00	100.00
ULTIMATE ANALYSIS			
Hydrogen	6.75	5.05	5.40
Carbon	46.62	64.50	68.95
Nitrogen	0.63	0.87	0.93
Sulfur	3.74	5.18	5.54
Oxygen	37.59	17.95	19.18
Ash	4.67	6.45	
	100.00	100.00	100.00
HEATING VALUE (BTU/LB)	8219	11371	12156
FORMS OF SULFUR			
Sulfate sulfur	0.14	0.20	0.21
Pyritic sulfur	0.19	0.26	0.28
Organic sulfur	3.41	4.72	5.05

FREE SWELLING INDEX 0.0

ASH FUSION TEMPERATURES (Reducing Atmosphere)

Initial Deformation	2500	F
Softening Temp.	2630	F
Fluid Temp.	2690	F

EQUILIBRIUM MOISTURE = 25.98%

HARDGROVE GRINDABILITY INDEX = 70

Most of the analyses quoted herein are all basic "proximate" analyses; that is, moisture, volatile matter, fixed carbon, and ash. Also included have been the heat (calorific) value in British Thermal Units per pound or kilogram-calories per kilogram, and that part of the ultimate analysis for sulfur content, which is considered part of the standard analysis. Ultimate analyses which are not performed standardly, report the carbon, hydrogen, oxygen, nitrogen, and sulfur content of the coal; these, and data from the other tests cited above are important in the determination of potential uses of the coal.

CONCLUSIONS

Evaluation of the information available regarding resource quantities of coal in southern Mindoro leads to the following conclusions:

1) A total resource estimate of 100 million tons for southern Mindoro is conservative. However, the relationship of this number to the true total resource potential of southern Mindoro is at this time unknown and unpredictable.

2) Most of the attempts to estimate the reserve and reserve base potential of southern Mindoro are confined areally to small parts of the Bulalacao region, such as the Napisian area.

3) The reserve and reserve base estimates that have been made for the Napisian area are conservative. The Bureau of Energy Development estimate of 4 million tons of proven reserves will be increased as exploration continues.

4) A minimum of seven or eight other areas besides Napisian in southern Mindoro are known or reported to have coal. With the exception of the Siay area, practically no information is available about these other potential sources of coal in South Mindoro.

Evaluation of the information available about the quality of the coal in southern Mindoro is largely based on suites of samples from the Napisian area of the Bulalacao region. A few samples from the Siay area and individual samples from two other areas are also available. The following conclusions can be made:

1) The coal of the Napisian area is low in ash (less than 8 percent), high in sulfur (3 percent or more), and has an apparent rank of subbituminous B.

2) In comparison with the coal of Semirara, the Napisian area coal is similar in moisture content, slightly higher in volatile and fixed carbon contents, significantly lower in ash content, significantly higher in sulfur content, and higher in heat value.

3) Almost all of the sulfur in the Napisian coal is in the organic form, and consequently is not removable by coal preparation methods in use in the world today.

4) The coals of the Siay and other areas in southern Mindoro are basically similar to the Napisian coals, but some samples contain much less sulfur than is common in the Napisian coals. Whether this relationship is true, and, if true, whether it is an areal or stratigraphic relationship, cannot be decided on the basis of presently available quality information.

RECOMMENDATIONS

The stated conclusions, plus other observations and facts cited at other places in the text, lead to the following recommendations:

1) A pre-feasibility reconnaissance-type regional study of the part of southern Mindoro where coal-bearing rocks are, or might be present, is needed before we can obtain even a preliminary understanding of the coal resource potential of the area. One of the objectives of such a study is discovery and definition of problems so that subsequent efforts may lead to solutions, or at least elucidation.

2) A feasibility study of the mining potential of the Napisian area is needed. Enough information is now, or soon should be available to allow preliminary evaluation of the development and exploitation possibilities of that area.

3) Exploration work based on drilling to develop stratigraphic information and yield core samples for analyses should be initiated in the Siay area. This effort should be aimed at determining whether or not the coals of the Siay area are significantly different in sulfur content from the coals of the Napisian area, and, if so, why and how.

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APPENDIX D

COAL IN SOUTHEAST SAMAR, PHILIPPINES

RP-21

DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

PROJECT REPORT
Philippine Investigation
(IR)RP-21

COAL IN SOUTHEAST SAMAR, PHILIPPINES

Prepared in cooperation with the Government of the Philippines, under the auspices of the Agency for International Development.

1984

COAL IN SOUTHEAST SAMAR, PHILIPPINES

By

M. D. Carter and E. R. Landis
U.S. Geological Survey

The project report series presents information resulting from various kinds of scientific, technical, or administrative studies. Reports may be preliminary in scope, provide interim results in advance of publication, or may be final documents.

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COAL IN SOUTHEAST SAMAR, PHILIPPINES

By

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ABSTRACT

The Carbon Creek deposit in southeastern Samar contains 3.5 to 5.5 million metric tons of coal in an area of about one square kilometer. Exploration to date indicates that coal may be present in an area of as much as 15 square kilometers or more. The coal has an apparent rank of subbituminous C and is of low to medium sulfur content and medium to high ash content.

Exploration to define the limits of the area that contains coal should be continued. The quality characteristics of the coal can be further defined if more representative core samples could be obtained.

INTRODUCTION

A workshop on introducing coal-water-mix (CWM) fuels to the Philippines was held August 20-24, 1984, at Brookhaven National Laboratory (BNL), Upton, New York, under the sponsorship of the Office of Energy in the Agency for International Development (AID). Five coals from different parts of the Philippines, selected to cover the range of different qualities of Philippine coals, had been analyzed and tested for slurryability by BNL prior to the workshop. Of those five coals, one from Bagacay on the Island of Samar, was the lowest in rank and had medium ash content and high sulfur. For various reasons, including its low quality, the coal from Bagacay was not considered to be of further interest. In September and October 1984, Landis and Carter visited the Philippines as part of the AID program to assess coal in Semirara and southern Mindoro, and to collect samples for further analysis.

In discussions about the possible utilization of Philippines coals, Governor Zosa of the Development Bank of the Philippines suggested to Ms. Purita Festin of the Economic Development Foundation (EDF) that other coals of Samar, specifically those near Giporlos, southern Samar, might be of higher quality and more usable for CWM fuel use than the Bagacay coal. Subsequently, E. R. Landis, M. D. Carter, and G. C. Guevara of EDF visited both the Bagacay and Giporlos coal areas and collected samples of coal near Giporlos for analysis and CWM fuel testing. The coal areas at both Bagacay and Giporlos are included in the assets of the Marinduque Mining and Industrial Corporation (MMIC), which had recently come under control of the Development Bank of the Philippines.

MMIC presently uses coal from Semirara Island at their Nonoc Island electric power plant. This present investigation will provide limited data on the possibility of substituting coal from southern Samar for the coal now obtained from Semirara.

This work was done in cooperation with the Economic Development Foundation of the Philippines, and would not have been possible without the active support of the Marinduque Mining and Industrial Corporation. In particular, the assistance of G. C. Guevara of EDF and J. R. Castro, Rafael Liwanag, Sheila Redoblado, and A. P. Sabalburo of MMIC were invaluable.

GEOLOGY

The Island of Samar is along the eastern edge of the Philippine Archipelago in the eastern physiographic province (Balce and others, 1981) adjacent to the Philippine trench. According to the geologic map of the Philippines (Philippine Bureau of Mines and Geosciences, undated map) the surface rocks of Samar are mainly sediments and volcanics of late Oligocene to late Miocene age that overlie sediments, volcanics, and ultrabasic intrusives of Cretaceous age. The rocks of Cretaceous age are for the most part metamorphosed. The coal-bearing rocks are in the late Oligocene to middle Miocene sequence that unconformably overlies the rocks of Cretaceous age. Many of the contacts between older and younger rocks are faults of large displacement.

Stratigraphy

Javelosa (1980), in an investigation of the geology of the coal deposits along Carbon Creek, approximately 15 km north of the town of Giporlos, recognized four rock units in ascending stratigraphic sequence: ultramafics of Cretaceous age, metavolcanics and metasedimentary rocks of Cretaceous to Paleocene age, poorly indurated conglomerate of Miocene age, and coal-bearing sediments of Miocene-Pliocene age. The ultramafics are the "basement" rock of the area and consist primarily of serpentine and serpentinized peridotite. The metamorphosed rocks of Cretaceous to Paleocene age are composed of basalt and andesite with interbedded quartz sandstone and tuffaceous clastic rock. The conglomerate of Miocene age was observed in only one small area overlying the ultramafic sequence and is composed predominately of pebble- to boulder-size pieces of ultramafics in metavolcanic and metasedimentary rocks. The coal-bearing rocks appear to rest uncomformably on the ultramafic sequence and to be in fault contact with the metavolcanic and metasedimentary rock sequence (Javelosa, 1980, cross sections, plate 2).

Structure

The geologic map and cross sections of Javelosa (1980) show the coal-bearing rocks as elongated bodies preserved by faulting on one side (eastern) and folding on the other side (western). The coal beds dip eastward and are repeated by normal faulting with relative displacement down on the west. Whether this interpretation is applicable to other nearby areas known or reported to contain coal is unknown at this time.

COAL RESOURCES

Coal has never been produced from the Giporlos area. In fact, the south-eastern Samar area was not recognized as a coal locality until recent years. Now, as is shown on figure 1, coal is present in at least four adjacent areas north of

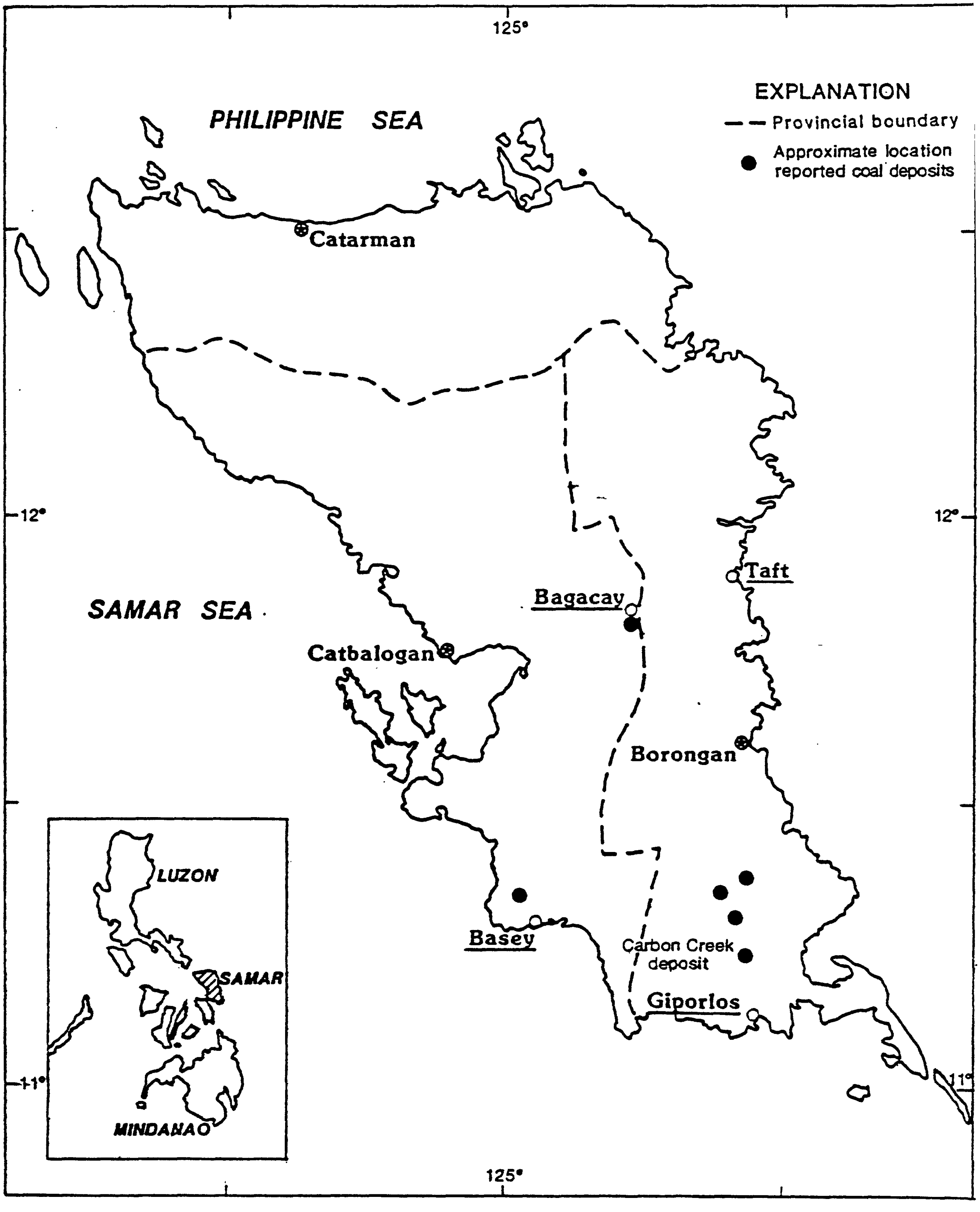

Figure 1. Index map of Samar, Philippines.

Giporlos. According to Javelosa (1980), the Samar Mining Company made reconnaissance exploratory tests by pits and trenches at some unspecified time in the past. Industrial Enterprises, Inc. (IEI) held a service contract on 2,000 hectares along Carbon Creek north of Giporlos from at least 1980 to 1983. IEI conducted exploration, including the drilling of approximately 20 exploratory holes and trenching at more than 60 locations, to prove the presence of the coal. In addition, IEI built an airstrip and set up an office near Giporlos, cleared or improved a 24-km dirt road from the office to the Carbon Creek coal deposit, and constructed a camp with at least five buildings at the site--and appeared to be on the verge of production. However, on August 10, 1983, IEI signed a Memorandum of Agreement with MMIC turning the contract area over to MMIC. No new exploration activities have occurred since that time. MMIC did acquire an additional 1,000 hectares and is in the process of applying for 2,000 more in anticipation of further exploration and development.

Quantity

To date, there have been four tonnage estimates of coal along Carbon Creek in the Giporlos area. They are as follows:

Date	Metric tons	Approximate size of area	Basis	Criteria used	Author
1980	123,145	---	Resource	Some	Javelosa
1982	1,173,597	0.2 km^2	Reserve base	None	IEI
1983	5,495,834	1.0 km^2	Reserve base	Deduced	MMIC
1984	3,485,915	1.0 km^2	Reserve base	Assumed	Bureau of Energy Development and/or MMIC

To facilitate comparison of the various estimates of coal tonnages, the terms resources, reserve base, and reserves used in this report are in accordance with the U.S. Geological Survey Coal Classification System (Wood and others, 1983). Resources are deposits of coal in such form and amount that economic extraction is currently or potentially feasible. Reserve base is that part of the identified resources that meets specified minimum physical and chemical criteria related to current mining and production practices, including those for quality, depth, thickness, rank, and distance from points of measurement. Reserves are that part of the reserve base which could be economically extracted or produced at the time of determination considering environmental, legal, and technical constraints.

Javelosa (1980) calculated resources according to the Philippine Bureau of Mines and Geosciences criteria, which in turn is based upon U.S. Geological Survey methodology. Two minable coal beds were correlated; one up to 3 m thick, the other somewhat thinner, both dipping 30°-40°. The estimate was subdivided into two categories: above drainage and down to 50 m below drainage. Unfortunately, there was no indication of the location or size of the area of estimate. Judging from the small tonnage, the area must have been very small.

The 1982 IEI estimate was obtained by the authors from BED files. The estimate consists solely of a one-page tabulation for 15 subdivisions of a 0.2-km^2 area with total coal thickness X area X specific gravity (1.3) yielding a total of 1,173,597 t, considered by BED to be "proven reserves." Dip of beds is given as 24°-61° NW. Apparently, the coal beds were not correlated for the estimates. The number of beds treated is unknown.

MMIC prepared a reserve estimation of coal in the ground as of July 31, 1983. The company submitted the estimate to BED as a part of their obligation in retaining the exploration contract. In the Carbon I area, the positive reserves were calculated as 5.2 million metric tons and the probable reserves at 0.3 million, giving a total of 5.5 million. The area of estimate was probably about 1 km^2 trending 2.7 km north-south and 0.3 to 0.9 km east-west. An explanation did not accompany the estimate, but as best the authors can determine from the table provided, 25 cross sections were constructed east-west across the deposit; the length of coal along each line of section was multiplied by its average thickness giving a vertical area of coal along each section; this result was added to the calculated area of coal in the next adjacent cross section; the total was divided by 2 to yield the average vertical area of coal between the two adjacent sections; the average area was then multiplied by the distance between the two cross sections giving the volume of coal within the two cross sections; 10 percent of the volume was then subtracted to account for the distortion by the dip of the beds to give the "true volume" of the coal; this volume was then multiplied by 1.35 (the assumed specific gravity for the local coal) to give the tonnage figure for coal in the area between the two cross sections. This method has been applied in the U.S. in areas where coal beds are highly deformed by either folding or faulting, but is a fairly crude method, and is unnecessary in this case where the beds are only moderately folded and faulting has not been shown to distort or duplicate the coal beds.

In November 1983, the Bureau of Energy Development (BED) apparently recalculated, or requested MMIC to recalculate, the reserves using, the authors assume, the standard BED criteria--total thickness of minable coal in the drill hole X its area of influence within a rectangular block X the specific gravity. Once again, only a four-page table was supplied to the authors with no explanation of the criteria or methodology used. In this estimate the reserves of Carbon I total 2.9 million metric tons (all positive reserves). Figures for Carbon II were included with this estimate; 3.4 million metric tons as positive reserves, and 0.2 million metric tons as probable reserves. Following the BED formula, total proven reserves of Carbon I and II were estimated at 3.5 million metric tons (positive reserves + two-thirds probable reserves).

The three tonnage estimates since 1980 have not been made on a bed-by-bed basis; which is the most accurate, most useful, and most valid approach. The method is recommended and followed by the U.S. Geological Survey wherever practicable.

Rafael Liwanag, geologist at MMIC, showed the authors a copy of his 1:3,000-scale work map of the Carbon I area, 17 well logs, 27 cross sections, and the tabulations of the 2 reserve estimates cited above. MMIC has not correlated the coal beds, coal outcrop lines are absent from the map, and few trenching thicknesses are available. The next step should be to correlate the coal beds, project and plot the coal outcrop lines on the surface, construct isopach and structure maps, and prepare a bed-by-bed resource estimate for the Carbon I area. Such an estimate is necessary for meaningful evaluation of the coal resource potential of the area.

To date, all of the tonnage estimates have been conservative, as could be expected considering the lack of data. As the area and detail of exploration increases and as the knowledge of the number and correlation of beds becomes established, the areas of estimate and the number of beds included in the estimate can be expected to increase.

Quality

The quality of coal can be measured in many ways but the three most common expressions are rank, type, and grade. These and other terms are defined and explained in appendix E to the main report of which this is appendix D. In general, all measures of coal quality are intended to allow prediction of a coal's suitability for particular usages.

The earliest mention of the quality of coal in southern Samar that the authors have found is the statement by Robertson Research International, Inc., (1977) concerning four samples that were collected from Basay in southern Samar and Suribao in east-central Samar. Quoting previous works, RRI stated that the coal was reported to be subbituminous B rank with high ash content, and that no additional information was available. Basay is on the coast of southwestern Samar not far from Tacloban, Leyte, and Suribao is a coastal town on the east side of Samar at the mouth of the Suribao River. Coal has been reported both northwest and northeast of Basay (or Basey) but no reports of visits to the coal area(s) were found. No information is available regarding the exact source of the Suribao samples.

Javelosa (1980) recognized two coal beds in his investigation of the coals exposed along Carbon Creek, Barangay Hucnan, Giporlos, eastern Samar, an area of about 1,050 hectares. The investigated area is included in the Coal Exploration Contract Blocks 97 and 57 established by the Bureau of Energy Development. Javelosa described the coal exposed at 22 localities and collected samples for analysis at three of the localities. Javelosa's Bed 1, the thickest of the two beds and stratigraphically oldest, measured as much as 3 m thick, but the base was not exposed. Javelosa's Bed 2 is 2.5 m or more thick at two localities, but is generally thinner than the lower bed, Bed 1. The three samples show the following analyses (in percent and Btu/lb) on the as-received basis:

	Moisture	Volatile matter	Fixed carbon	Ash	Sulfur	Calorific Value Btu/lb	Apparent rank
Bed 2	16.56	24.90	42.37	16.17	0.85	8,580	Subbituminous B
Bed 1	16.19	33.01	23.13	27.67	.83	6,557	Subbituminous C
Bed 1	12.55	26.27	17.87	43.31	.87	5,140	Subbituminous B
Arithmetic mean	15.1	28.1	27.8	29.0	.85	6,759	Subbituminous B
Geometric mean	15.0	27.8	26.0	26.9	.85	6,613	Subbituminous C

The high ash contents of two of the samples may be partly, but not completely, explained by inclusion of all noncoal partings in the coal bed in the sample. The high ash content tends to obscure the true apparent rank and little can be gained by study of these analyses.

In 1980, 13 exploratory drill holes were completed in the Carbon Creek area (MMIC, written commun., 1984). Analyses were made for 32 coal samples collected from coal intervals identified in the drill holes, but use of the analytical results is limited because core recovery averaged only about 59 percent, although the range was from 20 to 100 percent recovery. Table 1 shows the analyses of 31 of the samples; by definition, one of the samples collected in Diamond Drill Hole (DDH) No. 5 is not coal because the ash content is more than 50 percent. The arithmetic and geometric means are equivalent to a high ash (more than 8 percent), medium sulfur (1-3 percent), subbituminous C coal.

During the field visit to Samar, an outcrop in the Carbon Creek deposit was sampled by the authors. The exposed coal is in the upper part of the 18-m thick coal bed penetrated in exploratory drill hole DDH-1, which was drilled in 1980 by IEI. Nine samples of the drilled bed were analyzed (table 1). The present outcrop is only a short distance (probably only a few tens of meters) from the location of the drill hole, and was uncovered by a bulldozer during some pilot recovery operations by IEI. A neat compacted stack reportedly containing about 400 t of coal is near the exposed coal bed.

The sample information is as follows:

Province of Eastern Samar; lat. 11°15'30" N., long. 125°24'45" E.; approximately 20 km north of the town of Giporlos on the southern coast of Samar Island. Sample collected October 2, 1984.

The exposed section is:

Top of coal uncertain
0.7 m Coal, weathered, top uncertain, not sampled
3.8 m Coal, contains several carbonaceous shale partings as much as 0.2 m thick. Sample represents all of sequence. Sample designated as DDH-1 bed Upper.

2.4 m Coal, contains at least two carbonaceous partings as much as 0.1 m thick. Sample represents all of sequence. Sample designated as DDH-1 bed Lower.

0.6 Coal, not sampled.

Base of coal not exposed.

Table 2 gives the laboratory reports of analyses of the two samples described above. The analytical results for the two samples are very similar, and indicate a high ash, low sulfur coal. The moist, mineral-matter-free calorific values in Btu/lb are 8499 and 8365, respectively, and indicate a rank of subbituminous C. Hardgrove Grindability Indexes are 45 and 43; the ash-fusion temperatures are high; total sulfur contents are low (less than one percent), but two-thirds or more of the sulfur is in the organic; not easily removed form; neither coal exhibits swelling (coking) properties.

Table 1. Analyses of IEI samples, Drill Program 1980.

Percent core recovery	Hole No. Depth	Moisture percent	Volatile matter percent	Fixed carbon percent	Ash percent	Sulfur percent	Calorifi Value Btu/lb
65	DDH-1/2-4 m	16.78	37.42	26.88	18.72	3.52	7,452
37.5	DDH /4-6 m	17.34	36.47	23.48	22.71	2.10	6,642
95	DDH /6-6.08 m						
	DDH 6.95-8 m	18.66	35.63	27.56	18.15	1.34	7,200
65	DDH /8-10 m	18.17	35.14	25.60	21.09	1.38	7,074
50	DDH /10-12 m	17.67	33.06	23.72	25.55	.66	6,534
55	DDH /12-14 m	18.59	36.98	29.19	14.93	.96	7,776
40	DDH /14-14.3 m						
	DDH /14.4-16 m	19.84	34.70	30.82	15.24	1.12	7,632
65	DDH /16.8-18 m	21.65	35.68	33.26	9.41	.82	8,352
80	DDH /18-20 m	21.51	34.63	31.83	12.03	1.69	8,064
50	DDH-3/2.24-4 m	19.98	35.92	30.76	13.34	1.52	7,920
41.66	DDH /21.41-24 m	19.01	33.96	26.93	20.10	1.74	7,614
83.33	DDH-4/14.46-17 m	20.76	30.20	27.40	21.44	2.10	6,930
75	DDH /26-28 m	21.19	32.80	33.23	12.78	2.02	8,334
50(?)	DDH /28-29.35 m	22.65	28.82	35.13	13.40	2.32	7,506
66.66	DDH /46.04-46.19 m	21.47	33.18	26.73	18.62	2.31	7,542
46.66	DDH-5/15.78-18 m	22.13	32.68	27.30	17.89	1.09	7,740
71.66	DDH 18-21 m	19.16	34.75	27.58	18.51	1.53	7,560
83.33	DDH /21-24 m	19.13	31.59	24.67	24.61	1.71	7,704
100	DDH-6/46.7-47.08 m	20.53	30.46	27.93	21.08	.43	7,092
50	DDH 54-54.9 m	21.82	33.73	35.20	9.25	.55	8,388
41.66	DDH-7/15.81-18 m	17.81	34.69	27.76	19.74	1.17	7,740
53.33	DDH /18-21 m	16.42	32.89	28.32	21.87	1.14	7,596
66.66	DDH /22.5-24 m	16.85	31.71	22.39	29.05	1.03	6,066
36.66	DDH-8/6-9 m	22.32	34.35	36.26	7.07	.65	9,144
36.33	DDH /25.56-27 m	19.04	36.82	20.21	15.93	.70	8,028
20	DDH 27-30 m	18.63	35.07	28.65	17.65	.95	7,722
66.66	DDH /36.34-36.76						
	DDH 36.96-37.34 m	20.70	33.60	29.17	16.53	.87	7,524
83.33	DDH /39.45-40.13/						
	DDH 40.35-42 m	21.90	36.97	33.58	7.55	0.70	9,144
72.5	DDH /42.24-42.54 m	20.82	32.18	27.87	19.13	1.56	7,560
30	DDH-9/3-5.85 m	17.28	32.69	24.31	25.72	2.07	7,038
20	DDH /7.5-8.5 m	17.14	31.82	24.73	26.31	1.07	6,894
Range from		16.78	28.82	20.21	7.07	.43	6,066
to		22.65	37.42	36.26	29.05	3.52	9,144
Arithmetic mean		19.595	33.89	28.337	17.916	1.381	7,598
Geometric mean		19.5	33.82	28.07	16.94	1.23	7,569

Table 2. Analyses of samples from Carbon Creek collected October 2, 1984.

Sample: DDH-1 bed Upper
Laboratory Number UI2001

AIR DRY LOSS 10.29 RESIDUAL MOISTURE 13.45

	As-received	Dry	Dry ash-free
PROXIMATE ANALYSIS			
Moisture	22.36		
Ash	24.42	31.46	
Volatile Matter	29.06	37.43	54.61
Fixed Carbon	24.16	31.11	45.39
	100.00	100.00	100.00
ULTIMATE ANALYSIS			
Hydrogen	5.73	4.16	6.07
Carbon	35.95	46.30	67.55
Nitrogen	0.64	0.82	1.20
Sulfur	0.75	0.97	1.42
Oxygen	32.51	16.29	23.76
Ash	24.42	31.46	
	100.00	100.00	100.00
HEATING VALUE (BTU/LB)	6261	8064	11765
FORMS OF SULFUR			
Sulfate sulfur	0.05	0.06	0.09
Pyritic sulfur	0.22	0.28	0.41
Organic sulfur	0.48	0.63	0.92

FREE SWELLING INDEX 0.0

ASH FUSION TEMPERATURES (Reducing Atmosphere)

Initial Deformation	2800+ F
Softening Temp.	2800+ F
Fluid Temp.	2800+ F

EQUILIBRIUM MOISTURE = 21.77%

HARDGROVE GRINDABILITY INDEX = 45

(continued).

Sample: DDH-1 bed Lower
Laboratory number UI2000

AIR DRY LOSS 11.53 RESIDUAL MOISTURE 14.39

	As-received	Dry	Dry ash-free
PROXIMATE ANALYSIS			
Moisture	24.26		
Ash	20.09	26.53	
Volatile Matter	30.10	39.74	54.09
Fixed Carbon	25.55	33.73	45.91
	100.00	100.00	100.00
ULTIMATE ANALYSIS			
Hydrogen	5.79	4.07	5.54
Carbon	37.81	49.92	67.94
Nitrogen	0.68	0.90	1.22
Sulfur	0.80	1.06	1.43
Oxygen	34.83	17.53	23.87
Ash	20.09	26.53	
	100.00	100.00	100.00
HEATING VALUE (BTU/LB)	6553	8652	11776
FORMS OF SULFUR			
Sulfate sulfur	0.05	0.06	0.08
Pyritic sulfur	0.19	0.25	0.34
Organic sulfur	0.56	0.74	1.01

FREE SWELLING INDEX 0.0

ASH FUSION TEMPERATURES (Reducing Atmosphere)

Initial Deformation	2800+ F
Softening Temp.	2800+ F
Fluid Temp.	2800+ F

EQUILIBRIUM MOISTURE = 22.33%

HARDGROVE GRINDABILITY INDEX = 43

The nine samples of this particular coal bed collected from the drill hole core (see DDH-1, table 1) all have less moisture, more volatile matter, and greater heat value, and most have more sulfur and less ash than are shown in the analyses in table 2. Some of these differences may be caused by differences in the way samples were packed, handled, shipped, and analyzed, and others might be caused by lateral variation of the coal bed.

The analyses in table 1 are all basic "proximate" analyses--that is, moisture, volatile matter, fixed carbon, and ash, plus heat (calorific) value in British Thermal Units per pound or kilogram-calories per kilogram, and the total sulfur content, which is part of the standard analysis called the "ultimate" analysis. Table 2 also reports ultimate analyses (carbon, hydrogen, oxygen, nitrogen, and sulfur contents) of the coal and provides other data cited above that are important in the determination of potential uses of the coal.

CONCLUSIONS

All of the reserve and resource estimates to date are conservative. None of the estimates were made in a manner that yields estimates categorized according to coal-bed thickness, overburden thickness, or meaningful degree of geologic assurance. All of the estimates are confined to one square kilometer or less. While none of the existing estimates can be categorized in usual and necessary manners, several of the estimates do provide crude credible total estimates. It is probable that there is as much as 3.5 to 5.5 million metric tons of coal present in an area of about one square kilometer in the Carbon Creek area. The area that may contain coal is undefined as yet, but is certainly larger than one square kilometer. The available information indicates that coal has been found in three areas north of the Carbon Creek deposit and these other three areas may be extensions of the Carbon Creek deposit.

Enough information is available to allow generation of resource estimates on a bed-by-bed basis that could be meaningfully categorized by thickness ranges, overburden depth ranges, degree of geologic assurance, and other factors. To date, this form of quantification has not been attempted.

All of the analyses available to date are basically similar and indicate that the coal of the Carbon Creek area in southeastern Samar has a low (1 percent or less) to medium (more than one percent and less than 3 percent) total sulfur content, medium (8 to 15 percent) to high (more than 15 percent) ash content and an apparent rank of subbituminous C.

Only two analyses yield information on the form in which the sulfur is present. Both analyses are of low sulfur samples, and as expectable, most of the sulfur is in the organic form. The samples with greater total sulfur contents may not follow the cited pattern, but definitive analytical data is needed.

An undefinable but large percentage of the ash in the coal samples with higher ash contents is present in the form of non-coal rock material interbedded with the coal. Depending on the physical and chemical characteristics of the non-coal material, a mined product might have less ash content than is shown by many of the available analyses. Such a reduction in ash content might be attained by selective recovery during mining, or by relatively simple washing and hand-picking operations. No washability tests have been done on this particular coal to date, but it is reported that the run-of-mine product at Bagacay in central Samar was up-graded through use of an unsophisticated sizing and washing operation.

The Carbon Creek coal is in many ways similar to coal from Semirara. The Carbon Creek coal may have more ash content, though that relationship is far from positive. The major difference in available samples is the high ash fusion temperatures of the Carbon Creek coal compared to the Semirara coal.

RECOMMENDATIONS

More exploration is needed to define the area in which potential coal resources may be present in southeastern Samar. Surface activities such as geologic mapping based on surface traverses and pits and trenches must be supplemented by exploratory drilling.

In the meantime, a modern detailed categorized bed-by-bed estimate of the coal resource potential of the Carbon Creek area should be initiated.

More detailed analytical information is needed and should be obtained by core drilling. The drilling must be done in such a manner that core recovery is at least 85 percent of the coal sequence that is penetrated. Core recovery in such rocks as coal tends to be unpredictably selective, and the samples that are recovered when core recovery is low are very likely not to be representative of the coal beds that were penetrated.

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APPENDIX E

COAL CLASSIFICATION TERMINOLOGY

CONTENTS

ILLUSTRATIONS

COAL CLASSIFICATION TERMINOLOGY

RANK

Rank is a classification of coals according to their degree of metamorphism, progressive alteration, or coalification (maturation) in the natural series from peat to graphite. Various classifications have been and are being used in various parts of the world. The international classification of hard coals by type and the corollary classification of brown coals, both developed by the United Nations Economic Commission for Europe, require certain determinations such as specific forms of caking and coking determinations, or tar-yield determinations that are not in common usage in the rest of the world. A system in wide use throughout the world, and which is applicable to the coals of the Philippines, is the American Society for Testing and Materials rank classification (ASTM, 1982). Figure 1 shows comparison of the international and ASTM systems. The ASTM system uses heat value and fixed carbon contents as parameters, and recognizes the importance of constitutional (inherent) moisture content in the lower rank, less-metamorphosed coals. These coals, of lignitic and subbituminous rank, are common in North and South America, parts of Africa, and southern Asia. Figure 2 shows the ASTM classification system, and figure 3 compares coals of different ranks as classified by the ASTM system. The ASTM classification specifies that samples used to determine rank must be collected, packed, handled, and analyzed in certain uniform manners, and must be of certain number and distribution collected by particular methods and procedures. In particular, the classification by rank cannot be based on samples from outcrops, or from weathered or oxidized coal. However, such nonstandard samples can be used to indicate the correct relative position in the rank classification system, and these comparative indications are designated "apparent rank."

TYPE

Another form of coal classification, by type, is commonly used in some areas. Type classification is based on the relative amounts of the different megascopically and microscopically coal components, which are derived from different kinds of original plant material. The relative composition of the different components, which are in many ways analogous to mineral components of rocks, bears a definite relationship to the ultimate utilization potential of the coal. In general, type classification of Philippine coals is not possible at this time; this form of investigation has not been routinely applied in the past, therefore, little basic data is available. To the authors' knowledge, a limited amount of unpublished research was done by Robertson Research International (1977); 16 samples from the Unong area of Semirara Island have been studied (Austromineral, 1980), and five samples of Philippines coal have been studied to date by a U.S. Geological Survey researcher (Stanton, written commun., 1984).

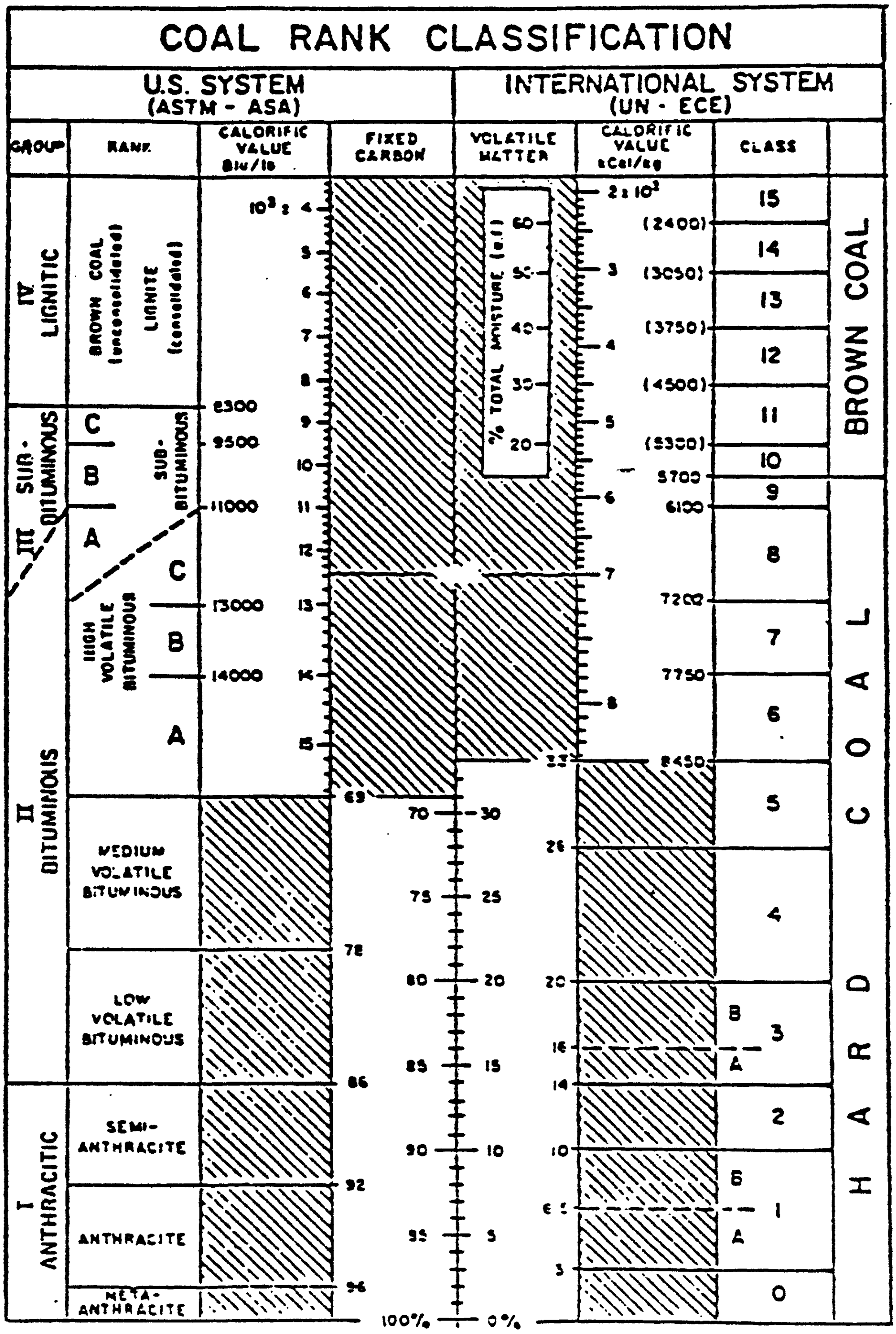


Figure 1. Comparison of coal rank classification.

Class	Group	Fixed Carbon Limits, percent (Dry, Mineral-Matter-Free Basis)		Volatile Matter Limits, percent Dry, Mineral-Matter-Free Basis		Calorific Value Limits BTU per pound (Moist,[B] Mineral-Matter-Free Basis)		Agglomerating Character
		Equal or Greater Than	Less Than	Greater Than	Equal or Less Than	Equal or Greater Than	Less	
I. Anthracite	1. Meta-anthracite	98	—	—	2	—	—	nonagglomerating
	2. Anthracite	92	98	2	8	—	—	
	3. Semianthracite[C]	86	92	8	14	—	—	
II. Bituminous	1. Low volatile bituminous coal	78	86	14	22	—	—	commonly agglomerating[E]
	2. Medium volatile bituminous coal	69	78	22	31	—	—	
	3. High volatile A bituminous coal	—	69	31	—	14 000[D]	—	
	4. High volatile B bituminous coal	—	—	—	—	13 000[D]	14 000	
	5. High volatile C bituminous coal	—	—	—	—	11 500	13 000	
		—	—	—	—	10 500	11 500	agglomerating
III. Subbituminous	1. Subbituminous A coal	—	—	—	—	10 500	11 500	—
	2. Subbituminous B coal	—	—	—	—	9 500	10 500	nonagglomerating
	3. Subbituminous C coal	—	—	—	—	8 300	9 500	
IV. Lignite	1. Lignite A	—	—	—	—	6 300	8 300	
	2. Lignite B	—	—	—	—	—	6 300	

[A]This classification does not include a few coals, principally nonbanded varieties, which have unusual physical and chemical properties and which come within the limits of fixed carbon or calorific value of the high-volatile bituminous and subbituminous ranks. All of these coals either contain less than 46 percent dry, mineral-matter-free fixed carbon or have more than 15 500 moist, mineral-matter-free British thermal units per pound.

[B]Moist refers to coal containing its natural inherent moisture but not including visible water on the surface of the coal.

[C]If agglomerating, classify in low-volatile group of the bituminous class.

[D]Coals having 69 percent or more fixed carbon on the dry, mineral-matter-free basis shall be classified according to fixed carbon, regardless of calorific value.

[E]It is recognized that there may be nonagglomerating varieties in these groups of the bituminous class, and there are notable exceptions in the high-volatile C bituminous group.

Figure 2. Classification of coals by rank, (ASTM, 1982)

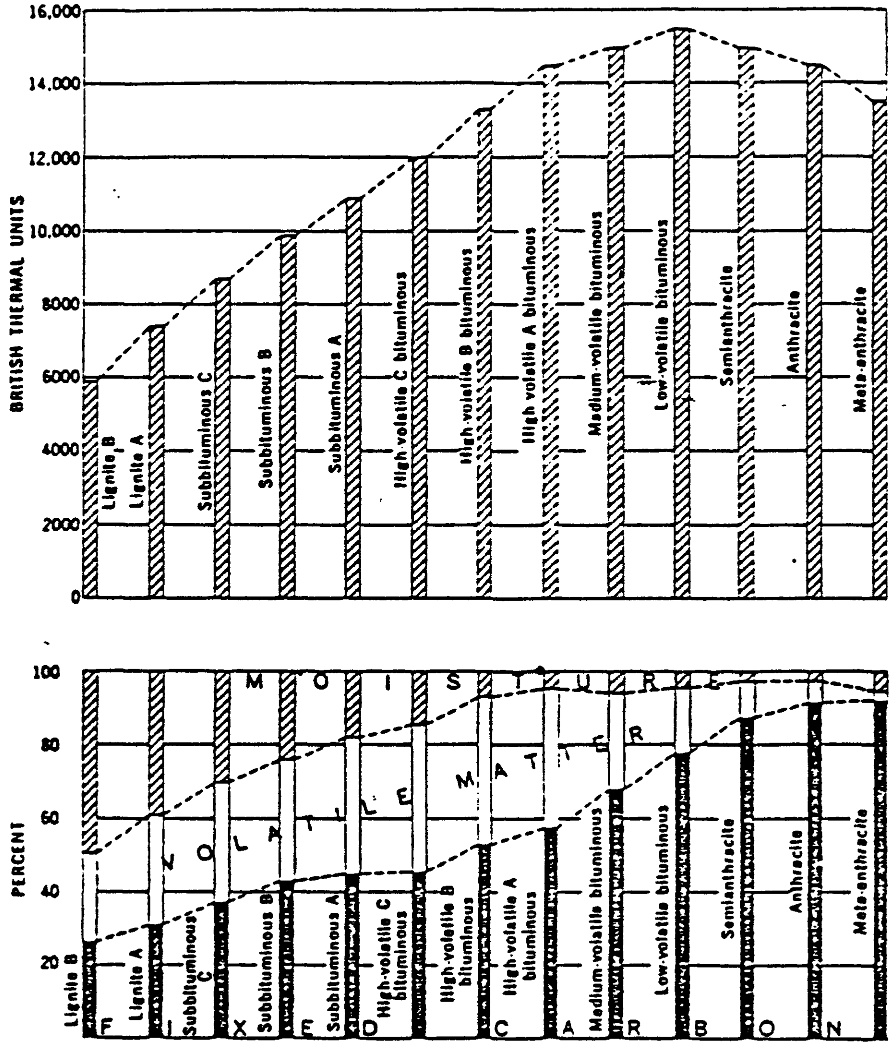


Figure 3. Comparison on moist, mineral-matter-free basis of heat values and proximate analyses of coals of different ranks.

GRADE

Grade classification of coal is commonly based on the amount and form of deleterious constituents that are present in a coal. This classification is complicated by the fact that the definition of "deleterious constituents" is different, depending on the potential utilization, or exact method of use. Of traditional importance in this form of classification are the ash and sulfur contents, both in total and in constituent form. Recently, such disparate properties as grindability and ash fusion temperatures have assumed importance for particular applications, such as coal-water-mix fuel formulation and combustion technology. Another major problem with grade classification is that the definition of the amount of deleterious constituents, or the properties that are undesirable, are subject to change by factors such as variations in mining plans, types of machinery, mining philosophies, or the uses of coal recovery preparation, or beneficiation facilities at some place in the system.

PROXIMATE, ULTIMATE, AND OTHER ANALYSES

Information needed for determining rank, type, and grade of coal are provided by the standard proximate and ultimate analyses and by specific standardized tests for other properties, such as the heat value, Hardgrove Grindability Index, ash fusion temperatures, forms-of-sulfur, equilibrium moisture, free swelling index, and elemental and chemical composition of the coal and coal-ash.

Proximate analyses are those laboratory determinations of the percentage of moisture, ash, volatile matter, and fixed carbon in coal. Ultimate analyses are the laboratory determinations of percentage of hydrogen, carbon, nitrogen, sulfur, oxygen, and ash in coal.

Calorific or heating value of coal is determined in the laboratory, and is expressed in kilocalories per kilogram (kcal/km), or British Thermal Units per pound (Btu/lb).

Proximate analyses were the standard in most large coal-producing countries through the early 1960s. With the introduction of more sophisticated technology, environmental controls, and the ever-increasing effort to increase coal conversion efficiency has come the need for the additional types of analyses. Proximate analyses are now recognized as not sufficient for coal quality characterization. All other cited data are needed in making assessments and judgements on the suitability of a coal for electric power generation, cement making, steel making, and other uses. These chemical and physical data allow the early development of many mining, blending, and cleaning options prior to mining, extraction, and usage. International standards, such as those of the ASTM, have been established to guide methodology and procedures in an attempt to ensure comparability of results of analyses by different researchers and laboratories. Whether and to what degree, comparability is achieved, is always a question.

The Hardgrove Grindability Index (HGI) is a test designed to measure the crushing and pulverizing ease of a particular coal. Its importance is emphasized to some extent during mining, but it is most important in coal preparation prior to cleaning and subsequent utilization. In general, the HGI is rank dependent with the higher rank coals being more amenable to crushing and pulverizing than lower rank coals. The analytical determination of HGI is performed under strict well-defined standard procedures using well-defined equipment. ASTM standards are followed in the United States.

Ash-fusion temperatures are determined on the noncombustible material of coal or coal ash. This empirical test provides a measure of clinkering tendency of the coal ash. The ash-fusion temperatures are determined under strictly controlled conditions and in accordance with well-defined standards (ASTM in United States). Historically, three temperatures are determined: initial deformation, softening, and fluid. Later modifications include softening spherical and softening hemispherical for a total of four temperature determinations. The softening temperature(s) is the one most frequently used. The temperature at which initial deformation, softening, and fluid states occur are determined by the chemical composition of the ash (including the amount and valence state of iron), mineralogical composition of the ash, and whether the determinations are performed in a reducing, midly reducing, or oxidizing atmosphere. The softening temperatures may vary, for a given sample, by as much as 300-400F depending on the atmosphere. Lower softening temperatures are normally obtained in a mildly reducing atmosphere than in a strongly reducing or oxidizing atmosphere.

In many analyses of coal, only the total sulfur content is determined and reported. The total sulfur includes the various forms-of-sulfur, namely: pyritic sulfur, organic sulfur, and sulfate sulfur. The pyritic sulfur occurs in coal as disseminated grains, as concentrations along fracture and bedding surfaces, or as nodules scattered through the coal bed. Pyritic sulfur represents the sulfur that can be partially removed from the coal through the use of various coal-cleaning or beneficiation techniques. Its determination is by standard (ASTM in United States) analytical techniques. Organic sulfur is sulfur chemically bound in the organic structure of coal. It cannot be removed by physical cleaning techniques and as such is normally volatilized and emitted during combustion. Its concentration is determined by difference and as such the determination is indirect. Sulfate sulfur generally occurs in very small amounts in coal; its concentration is a measure of how fresh the coal sample is. A high-sulfate sulfur content indicates weathering or degradation of the coal. Sulfate sulfur is determined by a standard chemical method (ASTM in United States).

Equilibrium or inherent moisture values are critical to the calculation of moist mineral-matter-free calorific (Btu) values for coal-rank classification. This rank classification is of utmost importance in establishing the value of the coal. The difference between the total moisture and equilibrium moisture contents is the surface moisture which may occur as film along fractures, bedding surfaces, and voids. The equilibrium moisture is determined according to ASTM standards.

The free-swelling index (FSI) is a measure of the increased volume of a coal when the coal is subjected to specific heating conditions. The values used to connote this volume increase, or plasticity, of the coal is a scale which ranges from 0 to 10. A low value denotes low-swelling capacity whereas a high value indicates considerable swelling or volume increase properties. The importance of the swelling capacity is in evaluating the coking properties of the coal and in furnace design for power plants, or synthetic conversion units.

The analytical methods for determining the elemental and chemical composition of coal and coal-ash are described in detail in U.S. Geological Survey Circular 735 (Swanson and Huffman, 1976). Tests are conducted on either raw coal or the coal-ash to determine contents of nearly 100 major, minor, or trace elements. Analytical methods include wet chemistry-atomic absorption spectroscopy, X-ray fluorescence spectroscopy, optical emission spectroscopy, spectrophotometry, selective-ion electrode, and neutron activation. The resulting data are fundamental in determining the economic value of the coal, in evaluating environmental effects of mining and utilization of the coal, in determining potential byproduct recovery, and determining adaptability of the coal to beneficiation, gasification, liquefaction, and other technological processes; also, the results may be used to correlate coal beds and to reveal environments of deposition, peat accumulation, and postdepositional processes of coalification (Swanson and Huffman, 1976).

RANGES AND MEANS

Statistical appraisal of coal analyses data commonly takes two forms. Study of the frequency distribution of the data mass can yield a "range," or spread of values. The range is thus an expression of what may be expected as the difference between the smallest and greatest value of a measured physical or chemical property of a material. Grouping by frequency distribution alone is seldom adequate and description of groups of data by numbers that represent the typical values of the individual groups of data is required. These measures of the central tendency, or averages, take several forms.

The arithmetic mean is by far the most commonly used measure of the central tendency because it is easily derived and understood and is fairly reliable. Much less commonly used is the geometric mean because it is not easy to derive and not commonly understood. However, extreme high and low values do not affect the geometric mean as much as they affect the arithmetic mean. In general, the geometric mean will equal or be less than the arithmetic mean, and is usually regarded as a better measure of the central tendency in such groups as percentages.

REFERENCES

American Society for Testing and Materials, 1982, Standard classification of coals by rank: ASTM designation D388-82, p. 238-242.

Austromineral, 1980, Feasibility study, Semirara coal project (Unong Mine), vol. 1, Geology and mine planning: Unpublished report in files of Semirara Coal Company, Philippines

Robertson Research International, Limited, 1977, The Philippines: An evaluation of coal resources: v. I, 231 p., 24 figs., 52 tables; VII, 13 sheets, 4 overlays. Unpublished report in files of Bureau of Energy Development.

Swanson, V. E. and Huffman, Claude, Jr., 1976, Guidelines for sample collecting and analytical methods used in the U.S. Geological Survey for determining chemical composition of coal: U.S. Geolological Survey Circular 735, 11 p.

APPENDIX F

AUGUST 1984 DATA BASE FOR SELECTION OF COAL RESOURCES

CONTENTS

PHILIPPINE COAL RESOURCES

Coal has been known to be present in the Philippines since as early as 1827. Coal has been reported from 50 or more locations in eight of the principal islands and eleven others. Coal has been mined, mostly in small quantities, in many places in the country but until World War II there was more coal imported annually than was produced domestically. Imports decreased drastically during and following World War II, as the energy budget of the country became based on oil. For several years the Philippine government has been actively interested in increasing the domestic coal production to reduce the amount of oil, both domestic and imported, that is used in the country for needs that coal could adequately satisfy.

The resource and reserve potential of the Philippines has been estimated several times in the past. The most recent available estimates are as of sometime in 1982. Listed by coal region, they are:

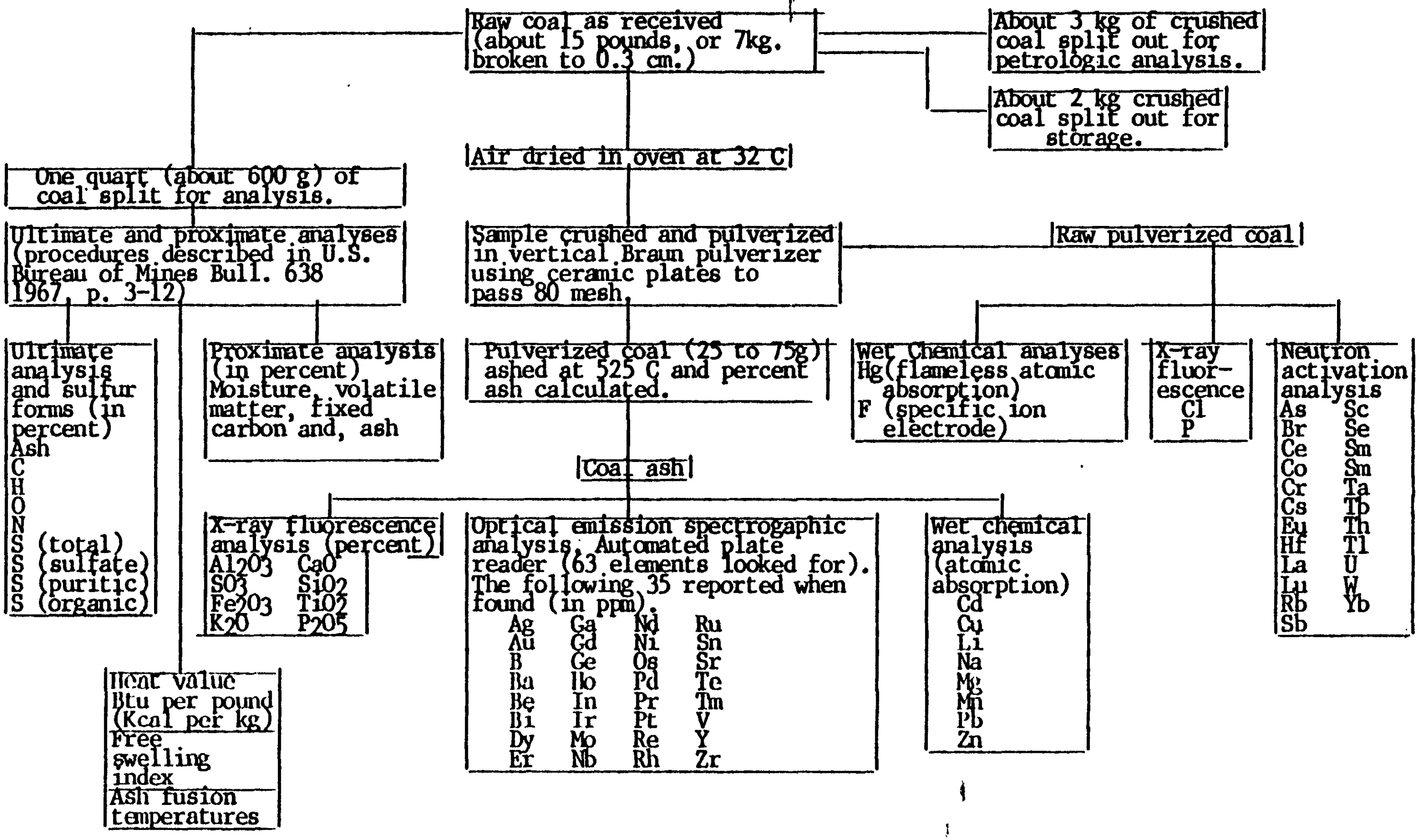
Region	Resource potential (mt)	Proven reserves (mt)
Semirara	550,000,000	131,800,000
South Cebu	50,000,000	5,500,000
Samar	27,000,000	5,200,000
Surigao	189,000,000	19,600,000
Zamboanga del Sur	45,000,000	18,600,000
Cagayan Valley	336,000,000	64,200,000
Polillo-Batan-Catanduanes	16,500,000	8,200,000
South Mindoro	100,000,000	4,000,000
North Cebu	50 to 100 million	1,800,000
Central Cebu	40,000,000	2,400,000
Negras	4,520,000	1,750,000
Davao	100,000,000	208,000
		263,258,000
Total	1,508,020,000	

Plus: 85,799,000 Indicated reserves and 2,290,000 Inferred reserves in addition to proven reserves.

Presumably, these resource and reserve estimates include the results of the coal resource assessment completed in 1977 by Robertson Research International. A large amount of exploration work has been done since 1977 in many of the coal regions and the extent to which new data has modified the RRI results is unknown.

The manner and methods by which the cited resource and reserve estimates were created is also unknown but obviously includes several forms of quantification of geologic information.

The following sections briefly describe the coal regions from which samples were recently collected for coal-water-mix technology purposes.



Flow Diagram for Coal-Sample Analysis

Semirara

Resources and reserves.

Resource potential - 550,000,000 mt

Proven reserves - 131,800,000 mt

Mining method. - Open-pit

Coal quality.

Heating value - 8,500-10,000 Btu/lb

Moisture (As-received) - 25-30%

Ash (As-received) - 6-12%

Production capability.

December 1982 - 44 mt/day

Projected (1985) - 4,300 mt/day

Utilization. - Power generation

Notes.

-Probably only one mine operating at present but several are planned.

-Stupping ratio of 15 to 1. Associated rocks are soft sandstone and shale.

-Strata inclined from 5 to 30 degrees, some coal-occurrence areas are bounded by faults with displacements of as much as 600 meters.

-Six coal beds identified but only lower two are persistent.

-Maximum bed thickness given as 4.6 m but data with samples says 12 m thick bed was sampled.

-Presumably much coal must be mined at elevations below sea level.

Sample analysis.

-Attached is standard coal analysis of sample Semirara, plus analysis revised to equilibrium moisture.

-Coal has apparent rank of subbituminous C and is midway in rank of group.

-Low sulfur, medium ash.

GEOCHEMICAL TESTING

COAL, WATER, AND MATERIALS ANALYSIS

R.D. 2, BOX 124

Somerset, Pennsylvania 15501

Phone: (814) 445-6666 or 443-1671

COAL ANALYSIS REPORT

Client: United States Geological Survey   Date of report: 07/23/84

USGS Lab No.   State: PH   Field ID: SEMIRARA

(W226578)

Lab No. U11936 ***

AIR DRY LOSS 14.73   RESIDUAL MOISTURE 12.81

	As-received	Dry	Dry ash-free
PROXIMATE ANALYSIS			
Moisture	25.66		
Ash	8.86	11.92	
Volatile Matter	32.08	43.16	49.00
Fixed Carbon	33.40	44.92	51.00
	------	------	------
	100.00	100.00	100.00
ULTIMATE ANALYSIS			
Hydrogen	6.51	4.89	5.55
Carbon	47.95	64.50	73.23
Nitrogen	0.91	1.22	1.39
Sulfur	0.58	0.78	0.89
Oxygen	35.19	16.69	18.94
Ash	8.86	11.92	
	------	------	------
	100.00	100.00	100.00
HEATING VALUE (BTU/LB)	8209	11043	12537
FORMS OF SULFUR			
Sulfate sulfur	0.03	0.04	0.05
Pyritic sulfur	0.15	0.20	0.23
Organic sulfur	0.40	0.54	0.61

FREE SWELLING INDEX 0.0

ASH FUSION TEMPERATURES (Reducing Atmosphere)

Initial Deformation	2300 F
Softening Temp.	2370 F
Fluid Temp.	2410 F

USGS COAL ANALYSIS

HOLE NUMBER	FOOTAGE INTERVAL	COAL BED NAME	LAB NUMBER
SEMIRARA	----	----	W226578 U1193[illegible]

PROXIMATE ANALYSIS

	AS RECEIVED TO EM	DRY MMF BASIS
% MOISTURE	25.96	
% ASH	8.82	
% VOLATILE	31.95	49.00
% FIXED CARBON	33.27	51.00
TOTAL	100.00	100.00

ULTIMATE ANALYSIS

	AS RECEIVED TO EM	DRY MMF BASIS
% CARBON	47.97	73.23
% HYDROGEN	6.51	5.55
% NITROGEN	.91	1.39
% SULFUR	.58	.89
% ASH	8.82	
% OXYGEN(diff)	35.20	18.95
TOTAL	100.00	100.00

THE AS RECEIVED TO EM BTU IS 8176

THE EQUILIBRIUM MOISTURE IS 25.96

THE BTU USING THE PARR FORMULA IS 9037 - subbituminous C

South Cebu

Resources and reserves.

Resource potential - 50,000,000 mt

Proven reserves - 5,500,000 mt

Mining method. - underground

Coal quality.

Heating value - 10,900-11,800 Btu/lb

Moisture (As-received) - 4-10%

Ash (As-received) - 5-10%

Production capability.

December 1982 - 192 mt/day

Projected (1985) - 950 mt/day

Utilization. - Power generation and cement

Notes.

-These coal areas in the region.

-Much folding and faulting. Strata inclined as much as 70 degrees though average is much less. Faults with displacements of as much as 1,200 meters.

-At least eight mines and may be more.

-As many as six or more coal beds in any one area. Maximum thickness listed is 4 meters and average mined may be 2 meters or less.

Sample analysis.

-Attached is standard coal analysis of sample South Cebu, plus analysis revised to equilibrium moisture.

-Coal has an apparent rank of high-volatile B bituminous.

-Medium sulfur, low ash.

-Sample from Luvimun Cebu Mining Corp. mine but this company has two contract areas (two mines?), one in the northern part and one in the southern part of the South Cebu coal region.

-Almost 2,500 tons of coal from Luvimun at Batangas coal terminal July 1983. Reported heat value of 10,865 Btu/lb.; possible apparent rank of high-volatile C bituminous.

-This sample seems a little high in heat value and may not represent the average coal of the region.

GEOCHEMICAL TESTING

COAL, WATER, AND MATERIALS ANALYSIS
R.D. 2, BOX 124
Somerset, Pennsylvania 15501
Phone: (814) 445-6666 or 443-1671

COAL ANALYSIS REPORT

Client: United States Geological Survey   Date of report: 07/23/84

USGS Lab No.   State: PH   Field ID: SOUTH CEBU

(W226579)
Lab No. U11937 **

AIR DRY LOSS 6.18   RESIDUAL MOISTURE 3.99

	As-received	Dry	Dry ash-free
PROXIMATE ANALYSIS			
Moisture	9.93		
Ash	4.43	4.92	
Volatile Matter	42.35	47.02	49.45
Fixed Carbon	43.29	48.06	50.55
	------	------	------
	100.00	100.00	100.00
ULTIMATE ANALYSIS			
Hydrogen	6.35	5.82	6.12
Carbon	67.96	75.45	79.35
Nitrogen	1.52	1.68	1.77
Sulfur	1.74	1.93	2.03
Oxygen	18.00	10.20	10.73
Ash	4.43	4.92	
	------	------	------
	100.00	100.00	100.00
HEATING VALUE (BTU/LB)	12212	13558	14259
FORMS OF SULFUR			
Sulfate sulfur	0.04	0.04	0.04
Pyritic sulfur	0.77	0.85	0.89
Organic sulfur	0.93	1.04	1.10

FREE SWELLING INDEX 1.0

ASH FUSION TEMPERATURES (Reducing Atmosphere)

Initial Deformation	2050 F
Softening Temp.	2130 F
Fluid Temp.	2160 F

USGS COAL ANALYSIS

HOLE NUMBER	FOOTAGE INTERVAL	COAL BED NAME	LAB NUMBER
So. CEBU	----	----	W226579 U11937

PROXIMATE ANALYSIS

	AS RECEIVED TO EM	DRY MMF BASIS
% MOISTURE	5.57	
% ASH	4.64	
% VOLATILE	44.40	49.45
% FIXED CARBON	45.39	50.55
TOTAL	100.00	100.00

ULTIMATE ANALYSIS

	AS RECEIVED TO EM	DRY MMF BASIS
% CARBON	67.81	79.35
% HYDROGEN	6.34	6.12
% NITROGEN	1.52	1.77
% SULFUR	1.74	2.03
% ASH	4.64	
% OXYGEN(diff)	17.96	10.73
TOTAL	100.00	100.00

THE AS RECEIVED TO EM BTU IS 12802

THE EQUILIBRIUM MOISTURE IS 5.57

THE BTU USING THE PARR FORMULA IS 13523 - high volatile B bituminous

Bagacay (Samar)

Resources and reserves.

Resource potential - 27,000,000 mt

Proven reserves - 5,200,000 mt

Note: There are two contract areas on Samar and the quantity estimates above are for Samar in total. No separate numbers for the two areas are available. Indicated reserves of 4,319,897 mt have also been estimated for Samar.

Mining method. - Open-pit; maybe some underground

Coal quality.

Heating value - 7,500-9,500 Btu/lb

Moisture (As-received) - 10-25%

Ash (As-received) - 9-13

Production capability.

December 1982 - 0

Projected (1985) - 890 mt/day

Utilization. - Power generation and cement

Notes.

- There are two contract areas on Samar; one in West Samar and one in East Samar. Separate companies. In latest list available both contracts are shown as Exploration. The Bagacay area in West Samar may be much more developed than the Giporlos area in East Samar.

- Several coal beds in each area, as much as 12 meters very locally but average thickness is much less.

- Stripping ratios of 20 to 1 to 8 to 1.

- Strata inclined up to 10 degrees in Bagacay area and up to 50 degrees in Giporlos area.

- No mention of faulting

Sample analysis.

-Attached is standard coal analysis of sample Bagacay, plus analysis revised to equilibrium moisture.

-Coal has an apparent rank of lignite A.

-Medium ash, high sulfur.

-Much more information may exist about coal in Samar; perhaps created by World Bank - funded exploration program.

GEOCHEMICAL TESTING

COAL, WATER, AND MATERIALS ANALYSIS

R.D. 2, BOX 124

Somerset, Pennsylvania 15501

Phone: (814) 445-6666 or 443-1671

COAL ANALYSIS REPORT

Client: United States Geological Survey   Date of report: 07/23/84

USGS Lab No.   State: PH   Field ID: BAGACAY

(W226580)

Lab No. U11938 **

AIR DRY LOSS 24.02   RESIDUAL MOISTURE 11.97

	As-received	Dry	Dry ash-free
PROXIMATE ANALYSIS			
Moisture	33.11		
Ash	11.78	17.61	
Volatile Matter	28.23	42.20	51.22
Fixed Carbon	26.88	40.19	48.78
	------	------	------
	100.00	100.00	100.00
ULTIMATE ANALYSIS			
Hydrogen	6.70	4.47	5.43
Carbon	37.19	55.60	67.48
Nitrogen	0.46	0.69	0.84
Sulfur	5.44	8.13	9.87
Oxygen	38.43	13.50	16.38
Ash	11.78	17.61	
	------	------	------
	100.00	100.00	100.00
HEATING VALUE (BTU/LB)	6662	9959	12087
FORMS OF SULFUR			
Sulfate sulfur	0.04	0.06	0.07
Pyritic sulfur	1.91	2.86	3.47
Organic sulfur	3.49	5.21	6.33

FREE SWELLING INDEX 0.0

ASH FUSION TEMPERATURES (Reducing Atmosphere)

Initial Deformation	2250 F
Softening Temp.	2360 F
Fluid Temp.	2400 F

USGS COAL ANALYSIS

HOLE NUMBER	FOOTAGE INTERVAL	COAL BED NAME	LAB NUMBER
BAGACAY	----	----	W22658 U1193

PROXIMATE ANALYSIS

	AS RECEIVED TO EM	DRY MMF BASIS
% MOISTURE	32.27	
% ASH	11.93	
% VOLATILE	28.58	51.22
% FIXED CARBON	27.22	48.78
TOTAL	100.00	100.00

ULTIMATE ANALYSIS

	AS RECEIVED TO EM	DRY MMF BASIS
% CARBON	37.13	67.48
% HYDROGEN	6.69	5.43
% NITROGEN	.46	.84
% SULFUR	5.43	9.87
% ASH	11.93	
% OXYGEN(diff)	38.37	16.39
TOTAL	100.00	100.00

THE AS RECEIVED TO EM BTU IS 6745

THE EQUILIBRIUM MOISTURE IS 32.27

THE BTU USING THE PARR FORMULA IS 7694 - lignite A

Bislig (Surigao del Sur)

Resources and reserves.

Resource potential - 169,000,000 mt

Proven reserves - 18,901,085 mt

Mining method. - Open-pit (?) and Underground

Coal quality.

Heat value - 7,000-10,000 Btu/lb

Moisture (As-received) - 8-20%

Ash (As-received) - 5-30%

Production capability.

December 1982 - 19 mt/day

Projected (1985) - 2,950 mt/day

Utilization. - Power generation and cement

Notes.

-Two power plants proposed for the region by 1985. Two units of 75 MW.

-Complex geologically, both folded and faulted. However, reported inclinations of Strata are not as great as many other areas.

-As many as 20 coal beds identified.

-Much exploration has been done in last few years and the cited quantity estimates do not reflect this new information.

Coal analysis.

-Attached is the standard coal analysis of the Bislig sample. Also attached is the analysis revised according to the equilibrium moisture.

-Apparent rank is subbituminous, B.

-Medium ash, low sulfur

-The amount of coal in the region represented by this sample is unknown. The available data indicates a range of apparent rank from subbituminous B to high-volatile B bituminous. Also a wide range in sulfur content.

-Coal from Bislig at Batangas Coal Terminal in July 1983 was rated at 9,600 Btu/lb, slightly higher rank than the sample.

GEOCHEMICAL TESTING

COAL, WATER, AND MATERIALS ANALYSIS

R.D. 2, BOX 124

Somerset, Pennsylvania 15501

Phone: (814) 445-6666 or 443-1671

COAL ANALYSIS REPORT

Client: United States Geological Survey   Date of report: 07/23/84

USGS Lab No.   State: PH   Field ID: BISLIG
(W226577)

Lab No. U11935 **

AIR DRY LOSS 9.76   RESIDUAL MOISTURE 10.14

	As-received	Dry	Dry ash-free
PROXIMATE ANALYSIS			
Moisture	18.92		
Ash	14.49	17.87	
Volatile Matter	30.73	37.90	46.15
Fixed Carbon	35.86	44.23	53.85
	------	------	------
	100.00	100.00	100.00
ULTIMATE ANALYSIS			
Hydrogen	5.83	4.58	5.58
Carbon	50.29	62.02	75.51
Nitrogen	0.94	1.16	1.41
Sulfur	0.57	0.70	0.85
Oxygen	27.88	13.67	16.65
Ash	14.49	17.87	
	------	------	------
	100.00	100.00	100.00
HEATING VALUE (BTU/LB)	8742	10782	13128
FORMS OF SULFUR			
Sulfate sulfur	0.01	0.01	0.01
Pyritic sulfur	0.20	0.25	0.30
Organic sulfur	0.36	0.44	0.54

FREE SWELLING INDEX 0.0

ASH FUSION TEMPERATURES (Reducing Atmosphere)

Initial Deformation	2530	F
Softening Temp.	2620	F
Fluid Temp.	2660	F

USGS COAL ANALYSIS

HOLE NUMBER	FOOTAGE INTERVAL	COAL BED NAME	LAB NUMBER
BISLIG	----	----	W226577 U11935

PROXIMATE ANALYSIS

	AS RECEIVED TO EM	DRY MMF BASIS
% MOISTURE	18.96	
% ASH	14.48	
% VOLATILE	30.71	46.15
% FIXED CARBON	35.84	53.85
TOTAL	100.00	100.00

ULTIMATE ANALYSIS

	AS RECEIVED TO EM	DRY MMF BASIS
% CARBON	50.29	75.51
% HYDROGEN	5.83	5.58
% NITROGEN	.94	1.41
% SULFUR	.57	.85
% ASH	14.48	
% OXYGEN(diff)	27.88	16.64
TOTAL	100.00	100.00

THE AS RECEIVED TO EM BTU IS 8737

THE EQUILIBRIUM MOISTURE IS 18.96

THE BTU USING THE PARR FORMULA IS 10362 - subbituminous B

Malangas (Zamboanga del Sur)

Resources and reserves.

Resource potential - 45,000,000 mt

Proven reserves - 18,600,000 mt

Mining method. - Underground

Coal quality.

Heating value - 10,500-12,900 Btu/lb

Moisture (As-received) - 2-10%

Ash (As-received) - 3-10%

Production capability.

December 1982 - 190 mt/day

Projected (1985) - 1,300 mt/day

Utilization. - Power generation, cement and non-energy (?)

Notes.

-Complex geologically. Many folds with strata inclined as much as 45 degrees and many faults in some areas. Igneous intrusion possible cause of generally higher rank than most Philippine coals. Six coal areas delineated in the region.

-Older mining area, but most meaningful exploration relatively new.

-As many as eight coal beds identified in any one area. Beds as thick as 4 m but average is less than half that.

-Additional 1,300,000 mt listed as indicated reserves.

Coal analysis.

-Attached is the standard analysis of sample Malangas. Also attached is the analysis revised to the equilibrium moisture.

-Apparent rank is medium volatile bituminous.

-High ash (just barely), low sulfur.

-FSI of 5 indicates medium coking ability.

-Malangas coal at Batangas Coal Terminal in July 1983 listed as 11,454 Btu/lb, indicating (probably) a high volatile bituminous coal.

-With this complicated geologic history, the coal rank and accompanying characteristics could have a wide range.

GEOCHEMICAL TESTING

COAL, WATER, AND MATERIALS ANALYSIS

R.D. 2, BOX 124

Somerset, Pennsylvania 15501

Phone: (814) 445-6666 or 443-1671

COAL ANALYSIS REPORT

Client: United States Geological Survey   Date of report: 07/23/84

USGS Lab No.   State: PH   Field ID: MALANGAS

(W226576)

Lab No. U11934 **

AIR DRY LOSS 0.83   RESIDUAL MOISTURE 1.11

	As-received	Dry	Dry ash-free
PROXIMATE ANALYSIS			
Moisture	1.94		
Ash	15.18	15.48	
Volatile Matter	19.63	20.02	23.69
Fixed Carbon	63.25	64.50	76.31
	------	------	------
	100.00	100.00	100.00
ULTIMATE ANALYSIS			
Hydrogen	4.42	4.28	5.06
Carbon	72.92	74.36	87.98
Nitrogen	1.94	1.97	2.33
Sulfur	0.49	0.50	0.59
Oxygen	5.05	3.41	4.04
Ash	15.18	15.48	
	------	------	------
	100.00	100.00	100.00
HEATING VALUE (BTU/LB)	12909	13165	15577
FORMS OF SULFUR			
Sulfate sulfur	0.00	0.00	0.00
Pyritic sulfur	0.02	0.02	0.02
Organic sulfur	0.47	0.48	0.57

FREE SWELLING INDEX 5.0

ASH FUSION TEMPERATURES (Reducing Atmosphere)

Initial Deformation	2600	F
Softening Temp.	2680	F
Fluid Temp.	2720	F

USGS COAL ANALYSIS

HOLE NUMBER	FOOTAGE INTERVAL	COAL BED NAME	LAB NUMBER
MALANGAS	----	----	W226576 U11934

PROXIMATE ANALYSIS

	AS RECEIVED TO EM	DRY MMF BASIS
% MOISTURE	2.10	
% ASH	15.16	
% VOLATILE	19.60	23.69
% FIXED CARBON	63.15	76.31
TOTAL	100.00	100.00

ULTIMATE ANALYSIS

	AS RECEIVED TO EM	DRY MMF BASIS
% CARBON	72.94	87.98
% HYDROGEN	4.42	5.06
% NITROGEN	1.94	2.33
% SULFUR	.49	.59
% ASH	15.16	
% OXYGEN(diff)	5.05	4.03
TOTAL	100.00	100.00

THE AS RECEIVED TO EM BTU IS 12888

THE EQUILIBRIUM MOISTURE IS 2.1

THE BTU USING THE PARR FORMULA IS 15431 - medium volatile bituminous

Analyses of five delivered samples of Semirara coal; collected August, 1984 and analyzed November, 1984.

Field Number: MDC-Phil 1
Laboratory Number: U11986

(W229404)

AIR DRY LOSS 10.18 RESIDUAL MOISTURE 8.65

	As-received	Dry	Dry ash-free
PROXIMATE ANALYSIS			
Moisture	17.95		
Ash	16.27	19.83	
Volatile Matter	32.78	39.95	49.83
Fixed Carbon	33.00	40.22	50.17
	100.00	100.00	100.00
ULTIMATE ANALYSIS			
Hydrogen	5.61	4.39	5.48
Carbon	47.05	57.34	71.63
Nitrogen	0.87	1.07	1.33
Sulfur	0.63	0.77	0.96
Oxygen	29.57	16.60	20.70
Ash	16.27	19.83	
	100.00	100.00	100.00
HEATING VALUE (BTU/LB)	8144	9926	12380
FORMS OF SULFUR			
Sulfate sulfur	0.04	0.05	0.06
Pyritic sulfur	0.18	0.22	0.27
Organic sulfur	0.41	0.50	0.63

FREE SWELLING INDEX 0.0

ASH FUSION TEMPERATURES (Reducing Atmosphere)

Initial Deformation	2290 F
Softening Temp.	2370 F
Fluid Temp.	2490 F

continued

Field Number: MCD-Phil 2
Laboratory Number: U11987

(W229405)

AIR DRY LOSS 9.70 RESIDUAL MOISTURE 8.77

	As-received	Dry	Dry ash-free
PROXIMATE ANALYSIS			
Moisture	17.62		
Ash	15.71	19.07	
Volatile Matter	33.61	40.79	50.40
Fixed Carbon	33.06	40.14	49.60
	100.00	100.00	100.00
ULTIMATE ANALYSIS			
Hydrogen	5.60	4.41	5.45
Carbon	48.02	58.29	72.02
Nitrogen	0.87	1.05	1.30
Sulfur	0.60	0.73	0.90
Oxygen	29.20	16.45	20.33
Ash	15.71	19.07	
	100.00	100.00	100.00
HEATING VALUE (BTU/LB)	8278	10049	12416
FORMS OF SULFUR			
Sulfate sulfur	0.03	0.04	0.05
Pyritic sulfur	0.15	0.18	0.22
Organic sulfur	0.42	0.51	0.63

FREE SWELLING INDEX 0.0

ASH FUSION TEMPERATURES (Reducing Atmosphere)

Initial Deformation	2300	F
Softening Temp.	2340	F
Fluid Temp.	2440	F

continued

Field Number: MDC-Phil 3
Laboratory Number: U11988 (W229406)

AIR DRY LOSS 9.40 RESIDUAL MOISTURE 9.27

	As-received	Dry	Dry ash-free
PROXIMATE ANALYSIS			
Moisture	17.80		
Ash	18.57	22.59	
Volatile Matter	32.57	39.63	51.20
Fixed Carbon	31.06	37.78	48.80
	100.00	100.00	100.00
ULTIMATE ANALYSIS			
Hydrogen	5.52	4.29	5.54
Carbon	45.38	55.21	71.32
Nitrogen	0.83	1.01	1.30
Sulfur	0.63	0.77	0.99
Oxygen	29.07	16.13	20.85
Ash	18.57	22.59	
	100.00	100.00	100.00
HEATING VALUE (BTU/LB)	7792	9479	12245
FORMS OF SULFUR			
Sulfate sulfur	0.04	0.04	0.05
Pyritic sulfur	0.15	0.18	0.23
Organic sulfur	0.44	0.55	0.71

FREE SWELLING INDEX 0.0

ASH FUSION TEMPERATURES (Reducing Atmosphere)

Initial Deformation	2340	F
Softening Temp.	2600	F
Fluid Temp.	2660	F

continued

Field Number: HDC-Phil 4
Laboratory Number: U11989

(W229407)

AIR DRY LOSS 9.32 RESIDUAL MOISTURE 10.14

	As-received	Dry	Dry ash-free
PROXIMATE ANALYSIS			
Moisture	18.51		
Ash	14.99	18.40	
Volatile Matter	32.93	40.40	49.51
Fixed Carbon	33.57	41.20	50.49
	100.00	100.00	100.00
ULTIMATE ANALYSIS			
Hydrogen	5.71	4.46	5.47
Carbon	47.97	58.86	72.13
Nitrogen	0.87	1.07	1.31
Sulfur	0.63	0.77	0.94
Oxygen	29.83	16.44	20.15
Ash	14.99	18.40	
	100.00	100.00	100.00
HEATING VALUE (BTU/LB)	8302	10188	12485
FORMS OF SULFUR			
Sulfate sulfur	0.04	0.05	0.06
Pyritic sulfur	0.19	0.24	0.29
Organic sulfur	0.40	0.48	0.59

FREE SWELLING INDEX 0.0

ASH FUSION TEMPERATURES (Reducing Atmosphere)

Initial Deformation	2280	F
Softening Temp.	2380	F
Fluid Temp.	2530	F

continued

Field Number: MDC-Phil 5
Laboratory Number: U11990

(W229408)

AIR DRY LOSS 8.24 RESIDUAL MOISTURE 9.36

	As-received	Dry	Dry ash-free
PROXIMATE ANALYSIS			
Moisture	16.83		
Ash	20.55	24.71	
Volatile Matter	32.19	38.71	51.41
Fixed Carbon	30.43	36.58	48.59
	100.00	100.00	100.00
ULTIMATE ANALYSIS			
Hydrogen	5.25	4.04	5.37
Carbon	44.48	53.48	71.03
Nitrogen	0.83	0.99	1.31
Sulfur	0.60	0.72	0.96
Oxygen	28.29	16.06	21.33
Ash	20.55	24.71	
	100.00	100.00	100.00
HEATING VALUE (BTU/LB)	7684	9239	12271
FORMS OF SULFUR			
Sulfate sulfur	0.04	0.05	0.07
Pyritic sulfur	0.11	0.14	0.19
Organic sulfur	0.45	0.53	0.70

FREE SWELLING INDEX 0.0

ASH FUSION TEMPERATURES (Reducing Atmosphere)

Initial Deformation	2590 F
Softening Temp.	2640 F
Fluid Temp.	2710 F

Analyses of four coal samples collected September 24, 1984, in the Napisian area, South Mindoro.

Field number: Bed A

Laboratory Number: U12002

(W229409)

AIR DRY LOSS 10.27 RESIDUAL MOISTURE 13.15

	As-received	Dry	Dry ash-free
PROXIMATE ANALYSIS			
Moisture	22.07		
Ash	4.27	5.48	
Volatile Matter	42.64	54.71	57.88
Fixed Carbon	31.02	39.81	42.12
	100.00	100.00	100.00
ULTIMATE ANALYSIS			
Hydrogen	6.31	4.93	5.22
Carbon	51.59	66.21	70.05
Nitrogen	0.69	0.89	0.94
Sulfur	3.63	4.66	4.93
Oxygen	33.51	17.83	18.86
Ash	4.27	5.48	
	100.00	100.00	100.00
HEATING VALUE (BTU/LB)	9120	11702	12380
FORMS OF SULFUR			
Sulfate sulfur	0.04	0.05	0.05
Pyritic sulfur	0.08	0.10	0.11
Organic sulfur	3.51	4.51	4.77

FREE SWELLING INDEX 0.0

ASH FUSION TEMPERATURES (Reducing Atmosphere)

Initial Deformation	2260	F
Softening Temp.	2320	F
Fluid Temp	2400	F

(continued).

Field number: Bed B

Laboratory number: U12005

(W229410)

AIR DRY LOSS 8.81 RESIDUAL MOISTURE 13.97

	As-received	Dry	Dry ash-free
PROXIMATE ANALYSIS			
Moisture	21.55		
Ash	4.56	5.81	
Volatile Matter	43.32	55.21	58.62
Fixed Carbon	30.57	38.98	41.38
	100.00	100.00	100.00
ULTIMATE ANALYSIS			
Hydrogen	6.52	5.23	5.55
Carbon	53.00	67.56	71.73
Nitrogen	0.68	0.86	0.91
Sulfur	3.68	4.69	4.98
Oxygen	31.56	15.85	16.83
Ash	4.56	5.81	
	100.00	100.00	100.00
HEATING VALUE (BTU/LB)	9500	12109	12856
FORMS OF SULFUR			
Sulfate sulfur	0.01	0.01	0.01
Pyritic sulfur	0.05	0.07	0.07
Organic sulfur	3.62	4.61	4.90

FREE SWELLING INDEX 0.0

ASH FUSION TEMPERATURES (Reducing Atmosphere)

Initial Deformation	2390	F
Softening Temp.	2420	F
Fluid Temp.	2460	F

(continued).

Field number: Bed C

Laboratory number: U12003

(W229411)

AIR DRY LOSS 9.41 RESIDUAL MOISTURE 14.18

	As-received	Dry	Dry ash-free
PROXIMATE ANALYSIS			
Moisture	22.26		
Ash	5.46	7.02	
Volatile Matter	42.19	54.27	58.37
Fixed Carbon	30.09	38.71	41.63
	100.00	100.00	100.00
ULTIMATE ANALYSIS			
Hydrogen	6.39	5.02	5.40
Carbon	51.34	66.04	71.03
Nitrogen	0.71	0.91	0.98
Sulfur	3.65	4.70	5.05
Oxygen	32.45	16.31	17.54
Ash	5.46	7.02	
	100.00	100.00	100.00
HEATING VALUE (BTU/LB)	9155	11777	12666
FORMS OF SULFUR			
Sulfate sulfur	0.04	0.05	0.05
Pyritic sulfur	0.13	0.17	0.18
Organic sulfur	3.48	4.48	4.82

FREE SWELLING INDEX 0.0

ASH FUSION TEMPERATURES (Reducing Atmosphere)

Initial Deformation	2190	F
Softening Temp.	2210	F
Fluid Temp.	2430	F

(continued).

Field number: Uncorrelated bed

Laboratory number: U12004

(W229412)

AIR DRY LOSS 13.11 RESIDUAL MOISTURE 16.82

	As-received	Dry	Dry ash-free
PROXIMATE ANALYSIS			
Moisture	27.72		
Ash	4.67	6.45	
Volatile Matter	39.38	54.48	58.24
Fixed Carbon	28.23	39.07	41.76
	100.00	100.00	100.00
ULTIMATE ANALYSIS			
Hydrogen	6.75	5.05	5.40
Carbon	46.62	64.50	68.95
Nitrogen	0.63	0.87	0.93
Sulfur	3.74	5.18	5.54
Oxygen	37.59	17.95	19.18
Ash	4.67	6.45	
	100.00	100.00	100.00
HEATING VALUE (BTU/LB)	8219	11371	12156
FORMS OF SULFUR			
Sulfate sulfur	0.14	0.20	0.21
Pyritic sulfur	0.19	0.26	0.28
Organic sulfur	3.41	4.72	5.05

FREE SWELLING INDEX 0.0

ASH FUSION TEMPERATURES (Reducing Atmosphere)

Initial Deformation	2500	F
Softening Temp.	2630	F
Fluid Temp.	2690	F

Analyses of samples from Carbon Creek collected October 2, 1984.

Sample: DDH-1 bed Upper
Laboratory Number UI2001

(W229402)

AIR DRY LOSS 10.29 RESIDUAL MOISTURE 13.45

	As-received	Dry	Dry ash-free
PROXIMATE ANALYSIS			
Moisture	22.36		
Ash	24.42	31.46	
Volatile Matter	29.06	37.43	54.61
Fixed Carbon	24.16	31.11	45.39
	100.00	100.00	100.00
ULTIMATE ANALYSIS			
Hydrogen	5.73	4.16	6.07
Carbon	35.95	46.30	67.55
Nitrogen	0.64	0.82	1.20
Sulfur	0.75	0.97	1.42
Oxygen	32.51	16.29	23.76
Ash	24.42	31.46	
	100.00	100.00	100.00
HEATING VALUE (BTU/LB)	6261	8064	11765
FORMS OF SULFUR			
Sulfate sulfur	0.05	0.06	0.09
Pyritic sulfur	0.22	0.28	0.41
Organic sulfur	0.48	0.63	0.92

FREE SWELLING INDEX 0.0

ASH FUSION TEMPERATURES (Reducing Atmosphere)

Initial Deformation	2800+ F
Softening Temp.	2800+ F
Fluid Temp.	2800+ F

(continued).

Sample: DDH-1 bed Lower
Laboratory number UI2000

(W229403)

AIR DRY LOSS 11.53 RESIDUAL MOISTURE 14.39

	As-received	Dry	Dry ash-free
PROXIMATE ANALYSIS			
Moisture	24.26		
Ash	20.09	26.53	
Volatile Matter	30.10	39.74	54.09
Fixed Carbon	25.55	33.73	45.91
	------	------	------
	100.00	100.00	100.00
ULTIMATE ANALYSIS			
Hydrogen	5.79	4.07	5.54
Carbon	37.81	49.92	67.94
Nitrogen	0.68	0.90	1.22
Sulfur	0.80	1.06	1.43
Oxygen	34.83	17.53	23.87
Ash	20.09	26.53	
	------	------	------
	100.00	100.00	100.00
HEATING VALUE (BTU/LB)	6553	8652	11776
FORMS OF SULFUR			
Sulfate sulfur	0.05	0.06	0.08
Pyritic sulfur	0.19	0.25	0.34
Organic sulfur	0.56	0.74	1.01

FREE SWELLING INDEX 0.0

ASH FUSION TEMPERATURES (Reducing Atmosphere)

Initial Deformation	2800+ F
Softening Temp.	2800+ F
Fluid Temp.	2800+ F

USGS COAL ANALYSES

USGS COAL ANALYSIS

HOLE NUMBER	FOOTAGE INTERVAL	COAL BED NAME	LAB NUMBER
MDC-Phil 1	------	------	U11986

PROXIMATE ANALYSIS

	AS RECEIVED TO EM	DRY MMF BASIS
% MOISTURE	25.61	
% ASH	14.75	
% VOLATILE	29.72	49.83
% FIXED CARBON	29.92	50.17
TOTAL	100.00	100.00

ULTIMATE ANALYSIS

	AS RECEIVED TO EM	DRY MMF BASIS
% CARBON	42.66	71.52
% HYDROGEN	6.13	5.48
% NITROGEN	.79	1.33
% SULFUR	.57	.96
% ASH	14.75	
% OXYGEN(diff)	35.10	20.71
TOTAL	100.00	100.00

THE AS RECEIVED TO EM BTU IS 7383

THE EQUILIBRIUM MOISTURE IS 25.61

THE BTU USING THE PARR FORMULA IS 8781

Continued

USGS COAL ANALYSIS

HOLE NUMBER	FOOTAGE INTERVAL	COAL BED NAME	LAB NUMBER
MCD-Phil 2	----	----	U11987

PROXIMATE ANALYSIS

	AS RECEIVED TO EM	DRY MMF BASIS
% MOISTURE	28.90	
% ASH	13.56	
% VOLATILE	29.01	50.40
% FIXED CARBON	28.53	49.60
TOTAL	100.00	100.00

ULTIMATE ANALYSIS

	AS RECEIVED TO EM	DRY MMF BASIS
% CARBON	41.44	72.03
% HYDROGEN	6.37	5.45
% NITROGEN	.75	1.30
% SULFUR	.52	.90
% ASH	13.56	
% OXYGEN(diff)	37.36	20.33
TOTAL	100.00	100.00

THE AS RECEIVED TO EM BTU IS 7144

THE EQUILIBRIUM MOISTURE IS 28.9

THE BTU USING THE PARR FORMULA IS 8368

Continued

USGS COAL ANALYSIS

HOLE NUMBER	FOOTAGE INTERVAL	COAL BED NAME	LAB NUMBER
MDC-Phil 3	-----	-----	U11988

PROXIMATE ANALYSIS

	AS RECEIVED TO EM	DRY MMF BASIS
% MOISTURE	23.03	
% ASH	17.39	
% VOLATILE	30.50	51.19
% FIXED CARBON	29.08	48.81
TOTAL	100.00	100.00

ULTIMATE ANALYSIS

	AS RECEIVED TO EM	DRY MMF BASIS
% CARBON	42.49	71.32
% HYDROGEN	5.88	5.54
% NITROGEN	.78	1.30
% SULFUR	.59	.99
% ASH	17.39	
% OXYGEN(diff)	32.87	20.84
TOTAL	100.00	100.00

THE AS RECEIVED TO EM BTU IS 7295

THE EQUILIBRIUM MOISTURE IS 23.03

THE BTU USING THE PARR FORMULA IS 8982

Continued

USGS COAL ANALYSIS

HOLE NUMBER	FOOTAGE INTERVAL	COAL BED NAME	LAB NUMBER
MDC-Phil 4	-----	-----	U11989

PROXIMATE ANALYSIS

	AS RECEIVED TO EM	DRY MMF BASIS
% MOISTURE	25.10	
% ASH	13.78	
% VOLATILE	30.27	49.51
% FIXED CARBON	30.86	50.49
TOTAL	100.00	100.00

ULTIMATE ANALYSIS

	AS RECEIVED TO EM	DRY MMF BASIS
% CARBON	44.09	72.13
% HYDROGEN	6.15	5.47
% NITROGEN	.80	1.31
% SULFUR	.58	.94
% ASH	13.78	
% OXYGEN(diff)	34.60	20.15
TOTAL	100.00	100.00

THE AS RECEIVED TO EM BTU IS 7630

THE EQUILIBRIUM MOISTURE IS 25.1

THE BTU USING THE PARR FORMULA IS 8964

Continued

USGS COAL ANALYSIS

HOLE NUMBER	FOOTAGE INTERVAL	COAL BED NAME	LAB NUMBER
MDC-Phil 5	-----	-----	U11990

PROXIMATE ANALYSIS

	AS RECEIVED TO EM	DRY MMF BASIS
% MOISTURE	23.88	
% ASH	18.81	
% VOLATILE	29.46	51.41
% FIXED CARBON	27.85	48.59
TOTAL	100.00	100.00

ULTIMATE ANALYSIS

	AS RECEIVED TO EM	DRY MMF BASIS
% CARBON	40.71	71.03
% HYDROGEN	5.75	5.37
% NITROGEN	.76	1.31
% SULFUR	.55	.96
% ASH	18.81	
% OXYGEN(diff)	33.42	21.33
TOTAL	100.00	100.00

THE AS RECEIVED TO EM BTU IS 7032

THE EQUILIBRIUM MOISTURE IS 23.88

THE BTU USING THE PARR FORMULA IS 8824

Continued

USGS COAL ANALYSIS

HOLE NUMBER	FOOTAGE INTERVAL	COAL BED NAME	LAB NUMBER
Bed A	-----	-----	U12002

PROXIMATE ANALYSIS

	AS RECEIVED TO EM	DRY MMF BASIS
% MOISTURE	19.59	
% ASH	4.41	
% VOLATILE	44.00	57.88
% FIXED CARBON	32.01	42.12
TOTAL	100.00	100.00

ULTIMATE ANALYSIS

	AS RECEIVED TO EM	DRY MMF BASIS
% CARBON	53.23	70.05
% HYDROGEN	6.15	5.22
% NITROGEN	.71	.94
% SULFUR	3.75	4.93
% ASH	4.41	
% OXYGEN(diff)	31.75	18.86
TOTAL	100.00	100.00

THE AS RECEIVED TO EM BTU IS 9409

THE EQUILIBRIUM MOISTURE IS 19.59

THE BTU USING THE PARR FORMULA IS 9897

Continued

USGS COAL ANALYSIS

HOLE NUMBER	FOOTAGE INTERVAL	COAL BED NAME	LAB NUMBER
Bed B	-----	-----	U12005

PROXIMATE ANALYSIS

	AS RECEIVED TO EM	DRY MMF BASIS
% MOISTURE	20.10	
% ASH	4.64	
% VOLATILE	44.12	58.62
% FIXED CARBON	31.14	41.38
TOTAL	100.00	100.00

ULTIMATE ANALYSIS

	AS RECEIVED TO EM	DRY MMF BASIS
% CARBON	53.98	71.73
% HYDROGEN	6.43	5.55
% NITROGEN	.69	.91
% SULFUR	3.75	4.98
% ASH	4.64	
% OXYGEN(diff)	30.50	16.83
TOTAL	100.00	100.00

THE AS RECEIVED TO EM BTU IS 9675

THE EQUILIBRIUM MOISTURE IS 20.1

THE BTU USING THE PARR FORMULA IS 10210

Continued

USGS COAL ANALYSIS

HOLE NUMBER	FOOTAGE INTERVAL	COAL BED NAME	LAB NUMBER
Bed C	-----	-----	U12003

PROXIMATE ANALYSIS

	AS RECEIVED TO EM	DRY MMF BASIS
% MOISTURE	21.07	
% ASH	5.54	
% VOLATILE	42.84	58.37
% FIXED CARBON	30.55	41.63
	-------	-------
TOTAL	100.00	100.00

ULTIMATE ANALYSIS

	AS RECEIVED TO EM	DRY MMF BASIS
% CARBON	52.13	71.03
% HYDROGEN	6.32	5.40
% NITROGEN	.72	.98
% SULFUR	3.71	5.05
% ASH	5.54	
% OXYGEN(diff)	31.59	17.54
	-------	-------
TOTAL	100.00	100.00

THE AS RECEIVED TO EM BTU IS 9295

THE EQUILIBRIUM MOISTURE IS 21.07

THE BTU USING THE PARR FORMULA IS 9905

Continued

USGS COAL ANALYSIS

HOLE NUMBER	FOOTAGE INTERVAL	COAL BED NAME	LAB NUMBER
Uncorrelated	-----	-----	U12004

PROXIMATE ANALYSIS

	AS RECEIVED TO EM	DRY MMF BASIS
% MOISTURE	25.98	
% ASH	4.78	
% VOLATILE	40.33	58.24
% FIXED CARBON	28.91	41.76
TOTAL	100.00	100.00

ULTIMATE ANALYSIS

	AS RECEIVED TO EM	DRY MMF BASIS
% CARBON	47.74	68.95
% HYDROGEN	6.64	5.40
% NITROGEN	.65	.93
% SULFUR	3.83	5.54
% ASH	4.78	
% OXYGEN(diff)	36.36	19.19
TOTAL	100.00	100.00

THE AS RECEIVED TO EM BTU IS 8416

THE EQUILIBRIUM MOISTURE IS 25.98

THE BTU USING THE PARR FORMULA IS 8870

Continued

USGS COAL ANALYSIS

HOLE NUMBER	FOOTAGE INTERVAL	COAL BED NAME	LAB NUMBER
DDH-1 bed Lower	-----	-----	U12000

PROXIMATE ANALYSIS

	AS RECEIVED TO EM	DRY MMF BASIS
% MOISTURE	22.33	
% ASH	20.60	
% VOLATILE	30.87	54.09
% FIXED CARBON	26.20	45.91
TOTAL	100.00	100.00

ULTIMATE ANALYSIS

	AS RECEIVED TO EM	DRY MMF BASIS
% CARBON	38.77	67.95
% HYDROGEN	5.65	5.54
% NITROGEN	.70	1.22
% SULFUR	.82	1.43
% ASH	20.60	
% OXYGEN(diff)	33.45	23.86
TOTAL	100.00	100.00

THE AS RECEIVED TO EM BTU IS 6720

THE EQUILIBRIUM MOISTURE IS 22.33

THE BTU USING THE PARR FORMULA IS 8640

Continued

USGS COAL ANALYSIS

HOLE NUMBER	FOOTAGE INTERVAL	COAL BED NAME	LAB NUMBER
DDH-1 bed Upper	-----	-----	U12001

PROXIMATE ANALYSIS

	AS RECEIVED TO EM	DRY MMF BASIS
% MOISTURE	21.77	
% ASH	24.61	
% VOLATILE	29.28	54.61
% FIXED CARBON	24.34	45.39
TOTAL	100.00	100.00

ULTIMATE ANALYSIS

	AS RECEIVED TO EM	DRY MMF BASIS
% CARBON	36.22	67.55
% HYDROGEN	5.69	6.07
% NITROGEN	.64	1.20
% SULFUR	.76	1.42
% ASH	24.61	
% OXYGEN(diff)	32.08	23.77
TOTAL	100.00	100.00

THE AS RECEIVED TO EM BTU IS 6308

THE EQUILIBRIUM MOISTURE IS 21.77

THE BTU USING THE PARR FORMULA IS 8588

Analyses of Coal Ash; 16 Philippine Samples
(Elemental weight percents expressed also as oxides)

	Si SiO_2	Al Al_2O_3	Fe Fe_2O_3	Mg MgO	Ca CaO	Na Na_2O	K K_2O	Ti TiO_2	P P_2O_5	Mn MnO
W226576 (U11934) Malangas	19.7 42.2	16.6 31.4	2.9 4.2	1.04 1.75	5.33 7.46	0.70 0.95	0.26 0.31	0.99 1.65	0.25 0.58	0.02 0.03
W226577 (U11935) Bislig	21.8 46.7	14.6 27.6	4.2 6.0	0.68 1.1	4.83 6.76	0.82 1.1	0.18 0.22	0.71 1.2	<0.1 <0.23	0.05 0.07
W226579 (U11937) Cebu	10.9 23.3	4.25 8.03	18.7 26.7	2.67 4.49	7.84 10.98	0.06 0.08	0.20 0.24	0.35 0.58	<0.1 <0.23	0.03 0.04
W226580 (U11938) Bagacay	11.5 24.6	10.9 20.6	19.8 28.3	0.74 1.2	4.98 6.97	0.13 0.18	0.23 0.28	0.53 0.89	<0.1 <0.23	0.08 0.1
W226578 (U11936) Semirara	17.7 37.9	12.5 23.6	4.3 6.1	2.40 4.03	4.90 6.86	1.91 2.58	0.95 1.1	0.73 1.2	<0.1 <0.23	0.05 0.07
W229404 (U11986) Semirara	22.8 48.8	13.7 25.9	2.7 3.9	1.3 2.2	2.6 3.5	2.4 3.2	1.2 1.4	0.72 1.2	0.09 0.2	0.04 0.05
W229405 (U11987) Semirara	23.0 49.2	13.1 24.8	2.4 3.4	2.5 4.2	3.1 4.3	2.7 3.6	1.3 1.6	0.72 1.2	0.1 0.2	0.04 0.05
W229406 (U11988) Semirara	22.8 48.8	14.4 27.2	2.1 3.0	1.9 3.2	3.2 4.5	2.3 3.1	1.2 1.4	0.78 1.3	0.12 0.28	0.03 0.04
W229407 (U11989) Semirara	22.1 ~~47.3~~	12.5 23.6	2.6 3.7	2.4 4.0	4.2 5.9	2.3 3.1	1.3 1.6	0.60 1.0	0.10 0.23	0.03 0.04
W229408 (U11990) Semirara	23.6 50.5	14.6 27.6	2.5 3.6	1.7 2.9	2.3 3.2	1.3 1.8	1.2 1.4	0.78 1.3	0.12 0.28	0.03 0.04
W229409 (U12002) S.Mindoro-A bed	10.3 22.0	11.0 20.8	4.8 6.3	1.3 2.2	11.0 15.4	0.49 0.66	0.32 0.38	0.21 0.35	0.03 0.07	0.38 0.49
W229410 (U12005) S.Mindoro-B bed	2.8 6.0	3.0 5.7	1.7 2.4	4.6 7.7	18.8 25.3	1.6 2.2	0.16 0.19	0.14 0.23	0.02 0.05	0.38 0.49
W229411 (U12003) S.Mindoro-C bed	14.3 30.6	7.5 14.2	4.7 6.7	2.2 3.7	9.6 13.4	0.19 0.26	0.80 0.96	0.35 0.58	0.03 0.07	0.13 0.17
W229412 (U12004) S.Mindoro-Unc. bed	17.1 36.6	17.5 33.1	7.5 10.7	0.58 0.97	2.9 4.1	0.04 0.05	0.36 0.43	0.17 0.28	0.05 0.12	0.05 0.07
W229402 (U12001) Samar-Carbon Cr	20.1 43.0	21.0 39.7	4.0 5.7	0.38 0.64	0.52 0.37	0.03 0.04	0.01 0.01	1.2 2.0	0.33 0.76	0.03 0.04
W229403 (U12000) Samar-Carbon Cr	20.2 43.2	21.0 39.7	4.8 6.9	0.17 0.29	0.39 0.55	0.01 0.01	0.01 0.01	1.3 2.2	0.1 0.2	0.02 0.03