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GEOTHERMAL POWER DEVELOPMENT IN THE PHILIPPINES

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Abstract

The generation of electric power to meet the needs of industrial growth and dispersal in the Philippines is aimed at attaining self-reliance through availment of indigenous energy resources. The Philippines by virtue of her position in the high-heat flow region has in abundance a number of exploitable geothermal fields located all over the country. Results indicate that the geothermal areas of the Philippines presently in various stages of exploration and development are of such magnitude that they can be relied on to meet a significant portion of the country's power need.

Large scale geothermal energy for electric power generation was put into operation last year with the inauguration of two 55-MW geothermal generating units at Tiwi, Albay in Southern Luzon. Another two 55-MW units were added to the Luzon Grid in the same year from Makiling-Banahaw field about 70 kilometers south of Manila. For 1979 alone, therefore, 220-MW of generating capacity was added to the power supply coming from geothermal energy. This year a total of 220-MW power is programmed for both areas. This will bring to 443-MW of installed generating capacity from geothermal energy with 3-MW contributed by the Tongonan Geothermal pilot plant in Tongonan, Leyte, Central Philippines in operation since July 1977.

Financial consideration of Philippine experience showed that electric power derived from geothermal energy is competitive with other sources of energy and is a viable source of baseload electric power. Findings have proven the technical and economic acceptability of geothermal energy resources development.

To realize the benefits that stem from the utilization of indigenous geothermal resources and in the light of the country's ever increasing electric power demand and in the absence of large commercial oil discovery in the Philippines, geothermal energy resource development has been accelerated anew. The program includes development of eight fields by 1989 by adding five more fields to the currently developed and producing geothermal areas.

Introduction

In view of the current energy crisis that grips many countries of the world today, attention has been focused on the development and utilization of non-fossil and alternate indigenous energy resources. One of these promising resources of indigenous energy which the Philippines has in abundance is the island arc related geothermal energy (Fig. 1). The Philippines by virtue of her position in the high-heat flow region that characterizes the orogenic zone of oceanic to oceanic convergent plate boundaries of the Western Pacific, has a number of commercial and promising geothermal fields scattered over the length of the archipelago. Consequently, the country has embarked on massive geothermal development program that is now paying off with the operation of 165-MW power plant in Tiwi, Albay, 110-MW power plant in Bay, Laguna and 3-MW power pilot plant in Tongonan, Ormoc, Leyte. This will be followed by additional units in the same area, others in the Palimpinon-Dauin fields of Southern Negros, Mambucal field of Northern Negros, and Manito field in Albay. By the end of this year the total geothermal generating capability of the Philippines is 446-MW making her the second largest user of geothermal energy in the world. (Table 1)

Geothermal energy in a broad sense is the heat from the earth as manifested in several forms as hot intrusive rocks, volcanoes, geothermal reservoirs, and geopressured rocks. Of these only the geothermal reservoirs associated with recent hot intrusive rocks and volcanism have thus far been harnessed for electrical power generation.

High temperature geothermal energy has two forms. Dry steam field (vapor dominated

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system) exemplified by Lardarello geothermal fields of Italy and the Geysers of Western United States are easily exploited with conventional technologies. With the pioneering research done by New Zealand in hot-water system, exemplified by their Wairakei and Broaldland fields, utilization of this geothermal field is now an accepted reality. This is the type of geothermal system found in the Philippines.

STATUS OF GEOTHERMAL PROJECT DEVELOPMENT

At present, there are eight geothermal fields in the country in advanced stages of exploration and development as shown in Fig. 2. The priority areas for exploration and development were determined largely on the strength of the surface thermal manifestationsas the initial basis. This is but a practical rationale borne out by the fact that the hot springs, hot grounds and other related phenomena are positive indications of a concealed source of geothermal fluid, located hopefully at an economically drillable depth.

Tiwi hot spring in Albay Province, one of the most popular spots in Luzon, became an easy first choice, followed by Los Baños in Makiling-Banahaw, Tongonan Valley in Leyte, Palimpinon-Dauin in Southern Negros, Mambucal in Northern Negros, the Manat-Amacan geothermal fields in Davao Province, Daklan-Bokod in Benguet and Manito in Albay.

Tiwi Geothermal Project

The geothermal possibilities of Tiwi in Albay were first to be investigated by the government in 1964 through the Commission on Volcanology with financial assistance from the National Science Development Board. The area is presently being developed by the National Power Corporation. Drilling of production wells by the Philippine Geothermal, Inc., a subsidiary of Union Oil Company of California, for the National Power Corporation is going on smoothly and more than fifty wells have been completed so far. By the end of the year, the combined capacity of the project will be two hundred twenty megawatts while the proven capacity of the area is five hundred fifty five megawatts.

Makiling-Banahaw Project

The region hugging the aprons of Mt. Makiling and Mt. Banahaw and the lowland between them studded with diatremes or maars are at present undergoing active development by National Power Corporation with Philippine Geothermal, Inc. carrying out the deep drilling operations. More than fifty-two wells have been drilled to date. Similar to Tiwi the field will have a combined generating capability of two hundred and ten megawatts this year.

Leyte Geothermal Project

The Leyte Geothermal area is undergoing active exploration and development by PNOC-EDC with the assistance of the New Zealand government. Nineteen production wells have been drilled to date. A three megawatt pilot plant is presently in operation in the area since July, 1977. By 1982 the area will have a combined generating capacity of 112.5 megawatts, enough for the envisioned power needs of the proposed copper smelter and the provinces of Leyte and Samar.

Negros Geothermal Projects

The geothermal area of Southern Negros is located at the Palimpinon-Dauin sector of Negros Oriental. Under the New Zealand assistance program PNOC-EDC has completed ten exploratory wells. A three megawatt pilot power plant will be operational by September of this year.

Mambucal prospect of PNOC-EDC is situated at the Northern Sector of Negros Island. Geologic investigation, geochemical studies, magnetic and resistivity surveys and exploration wells indicate sufficiently high temperature at depth and point to favorable underground characteristics. Two intermediate exploration wells have been completed so far.

Davao Geothermal Project

The area of interest has many impressive thermal manifestations clustered in four groups namely Manat, Masara, Amacan, and Maraut. Twenty-five thermal gradients wells drilled at an average depth of one hundred twenty-two meters were sited on the basis of geology, geochemical and geophysical surveys. Results showed a broad thermal anomaly in the area.

Manito Geothermal Project

PNOC-EDC started full scale exploration program at Manito in Albay. Two exploratory wells were drilled on the basis of favorable geological, geochemical, and geophysical surveys. The two exploratory wells drilled along the flow regime confirmed the presence of high temperature geothermal fluids.

Daklan-Bokod Geothermal Area

The area under consideration by the Bureau of Energy Development with the assistance of the Italian government is in Daklan, Bokod, Benguet. Seven exploration gradient wells with average depth of one thousand feet have been drilled so far and preliminary data show impressive geothermal fluids at depth.

GEOTHERMAL IMPLICATIONS OF PHILIPPINE GEOLOGY

From the geologic setting of the Philippines and vulcanism that had occured in the archipelago since Tertiary time with its consequent resulting volcanic rock units, the following general evaluation of their geothermal implications may be considered:

1. The potential geothermal areas of the Philippines will be found in the concave side of the volcanic fronts of plutonic and volcanic rocks of calc-alcalic to alkalic series (Fig. 2, Datuin & Uy, in Press);

2. The vicinity of non-active volcanoes of Pliocene or Quarternary age like Malinao (Tiwi geothermal field), Makiling and Banahaw (Mak-Ban geothermal field), Cuernos de Negros (Southern Negros geothermal fields), and many others that dot the archipelago from north to south offer the most promising areas for geothermal exploration and development;

3. The crystalline rocks and their derivatives that will predominate at the geothermal areas will most likely be sodic to intermediate in composition and will in general be intercalated with relatively thin normal clastic sedimentaries and/or reef limestone lenses;

4. The reservoir rocks will be found either in hydrothermally altered pyroclastic and clastic sedimentary beds, highly fractured formations, and andesitic or dacitic pyroclastic flows;

5. Lava flows will invariably provide capping rock over the reservoir rocks. Geophysically, therefore, many geothermal reservoir areas will be characterized by resistivity lows underneath high resistivity values that are correlatable to relative magnetic highs;

6. Arcuate faulting brought about by the amassed weight of volcanic edifice, and/or recession of magmatic materials or pressure will provide to some degree the structural control that may delineate the reservoir areas. In some areas, as in geothermal areas located close to the Philippine fault zone (Leyte geothermal field), structural control may be provided by the zone itself or secondary faults formed as a consequence of major fault displacements;

7. Except where the geothermal area is the result of convective heat transfer from magma chamber itself as in the case with volcanic craters, the geothermal area will most likely be the result of ground water circulating in fractured formations heated by conduction from the magma chamber;

8. Considering the thickness of Tertiary and recent volcanics in studied areas of the archipelago, and based on thermodynamics considerations, the productive zones will in general be between 3500-6000 feet. Minor steam horizons may exist at much shallower deposits, however; and

9. The rate of recharge of geothermal fields in the Philippines may be expected to be high considering the Island's high annual rainfall. This condition would insure a longer productive life of the field.

COST OF GEOTHERMAL POWER DEVELOPMENT

Recent evaluation and quantitative studies showed geothermal energy for power generation is a viable source of baseload electric power. The utilization of available natural steam is, therefore, considered as major alternative for providing incremental generating capacity as well as for replacing oil thermal plants which have become expensive to operate.

TABLE NO. 3

Comparative Generating Cost of Different Power Plants*

	Cost/KWh
Hydro (Pulangui IV)	7.18
Coal fired Local	21.11
Imported	29.59
Geothermal Manito	30.94
Hi-Viscosity Thermal Plant	30.14
Bunker C Oil Thermal Plant	39.51
Diesel Thermal Plant	49.26
Nuclear Plant	31.25

*Summarized from IPAD, NPC, February 8, 1980

GEOTHERMAL POWER PROGRAM

In order to maximize the benefits from the utilization of indigenous geothermal resources, the government's ten year program for geothermal exploration and development aims at 14018.5MW of generating capability by the year 1989. (Table Nos. 2 and 3). The program includes the development of eight fields by 1989 adding five more fields to the currently developed and producing fields at Tiwi, Makiling-Banahaw, and Tongonan Valley. The five fields targeted for development are Daklan-Bokod, Benguet; Manito, Albay; Mambukal-Mandalagan, Negros Occidental; Palimpinon-Dauin, Negros Oriental; and Manat-Masara, Davao del Norte. (Tables 4 and 5)

TABLE NO. 4

Geothermal Generation Expansion Program

MW	LOCALITY
1979 - 223MW existing	Tiwi, Makban, Tongonan
1980 - 223MW	Tiwi, Makban, Palimpinon
1981 -	
1982 - 335.0MW	Tiwi, Tongonan, Palimpinon
1983 -	
1984 - 37.5MW	Tongonan
1985 - 220MW	Tiwi, Makban
1986 - 37.5MW	Tongonan
1987 -	
1988 - 110MW	Tiwi, Makban
1989 - 75.0MW	Mambugal, Tongonan
1990 - 147.5MW	Tiwi, Manito, Makban, Mambucal

The steam availability is expected to be 1,975MW by 1989 assuming the present success ratio in geothermal production drilling.

POSSIBLE RESEARCH & DEVELOPMENT DIRECTION

The occurrence of numerous hotsprings throughout the Philippines indicates that the country is well endowed with geothermal resources and suggests that all possible methods of utilization of this energy be investigated. Scattered throughout the archipelago are a number of thermal fields of probable geothermal importance and little known thermal spots that could have geothermal significance.

Lindal enumerated the nonelectrical uses of geothermal steam as shown in Table Nos. 6 and 7. The utilization of geothermal energy in any of these forms, however, is not without its share of technological problems. Researches along the suggested topics should be encouraged.

In the Philippines geothermal energy is presently used for salt-making and grain-drying. Projects on the utilization of thermal field for fish canning, refrigeration and air-conditioning are also being studied.

Research should be directed to accurate evaluation of other potential geothermal areas by correlation with magma generation, structural setting of geothermal fields and association of rock type and mineral alterations. This study should lead to a geothermal reservoir models.

The use of binary system in power generation to utilize low heat subsurface waters should be pursued rigorously. If proven economically viable, this method could find applicability in tapping low-temperature hotsprings in our small island communities.

The utilization of geothermal energy in any form is not without its share of problems. Some of these are environmental problems which should be defined and evaluated in order to insure an environmentally compatible development of geothermal resources. Basically, the possible impact on the environment due to geothermal utilization are, ground subsidence because of extraction of fluid from the subsurface, and chemical-thermal pollution because of disposal and discharge of effluent. The problem of scaling, most often by carbonates or silica, high-acidity of geothermal fluids and the attendant corrosion can be minimized by proper research and development program. These problems are, however, not inherent to all geothermal fields, but are specific only in certain areas and in some cases specific only to some steam wells of a particular area.

Hardware used in geothermal exploration and development are carry overs from the oil industry. Some are therefore found to be insufficient to cope with head pressure and chemical conditions peculiar to geothermal operations.

Geothermal energy is relatively a newcomer in the energy field though earth-heat can be said as old as the earth. Its state of the art has not reached the sophistication of oil and gas technologies.

Benefits of Geothermal Development

The benefits that can be reaped from the development of the country's geothermal resources in this context are varied and far reaching.

The use of geothermal energy as a substitute will reduce the amount of oil importation for power generation and thus a corresponding decrease in the drain of the country's dollar reserves. It is estimated that if the target of 1975 MW by 1989 of geothermal power capacity is attained, it would mean an annual savings of about $5.235M in oil importation at $30.00/barrel of oil and at 90% load factor.

The Philippines may be considered as an industrially developing country. To sustain a planned annual gross national product of 7 to 8 percent, there is need for new and additional industries to establish themselves in the island. Geothermal energy could provide a significant amount of their energy requirements. With cheaper geothermal power available to industry in areas removed from traditional center of industrial development, and with proper incentives, it is hoped these conditions would attract industries to set themselves up in such areas. This certainly will be in consonance with the basic national policy to meet the needs of industrial development and dispersal.

Many areas of the Philippines have yet to enjoy the benefits of electricity. Total electrification of the country is, therefore, another pressing program of the government. Through the National Electrification Administration much is being done toward this end with the establishment of electric cooperatives. However, many of the cooperatives operate small diesel generation plants. Development of geothermal power and the installation of island grids will greatly boost the total electrification program.

It is fortunate that the geothermal areas of the Philippines are fairly well distributed throughout the country. The geothermal field of Leyte when developed, for example, could supply electrical power to the entire provinces of Leyte and Samar, two identified economically depressed areas. Electrification will mean to these provinces upliftment of their economic status through more job opportunities, home industries and increased earnings. For smaller islands where geothermal energy could be tapped, the feasibility of putting up generating units of 100 to 1000KW capacity is under consideration.

Summary

The geothermal potential of the Philippines is being tapped in the desire to attain self-sufficiency in energy through availment of indigenous energy resources. Eight areas, in various stages of exploration and development are being worked simultaneously.

The development of an indigenous energy is anticipated to reduce the drain of the country's dollar reserves, fill the needs for industrial development and dispersal, contribute to the total electrification effort, and uplift certain economically depressed areas of the country.

Truly, it may be said that the presence of large geothermal energy in the islands is indeed providential in the light of the energy crisis that grips the nation today and the urgency of warding it off permanently.

References

1. Arturo P. Alcaraz, Geothermal Exploration and Development in the Philippines. Paper read before the Circum-Pacific Energy and Mineral Resources Conference, Hawaii, 26-30 August 1974

2. Rogelio Datuin, 1977 Geothermal Resources of the Philippines, Status of Geothermal Projects Development, and the Geothermal Power Development Program. The National Security Review, Vol. IV, September 1977, pp. 3-16

3. Rogelio Datuin and Fernando L. Uy Quaternary Volcanism and Volcanic Rocks of the Philippines. Journal of the Geographical Society of the Philippines. In Press.

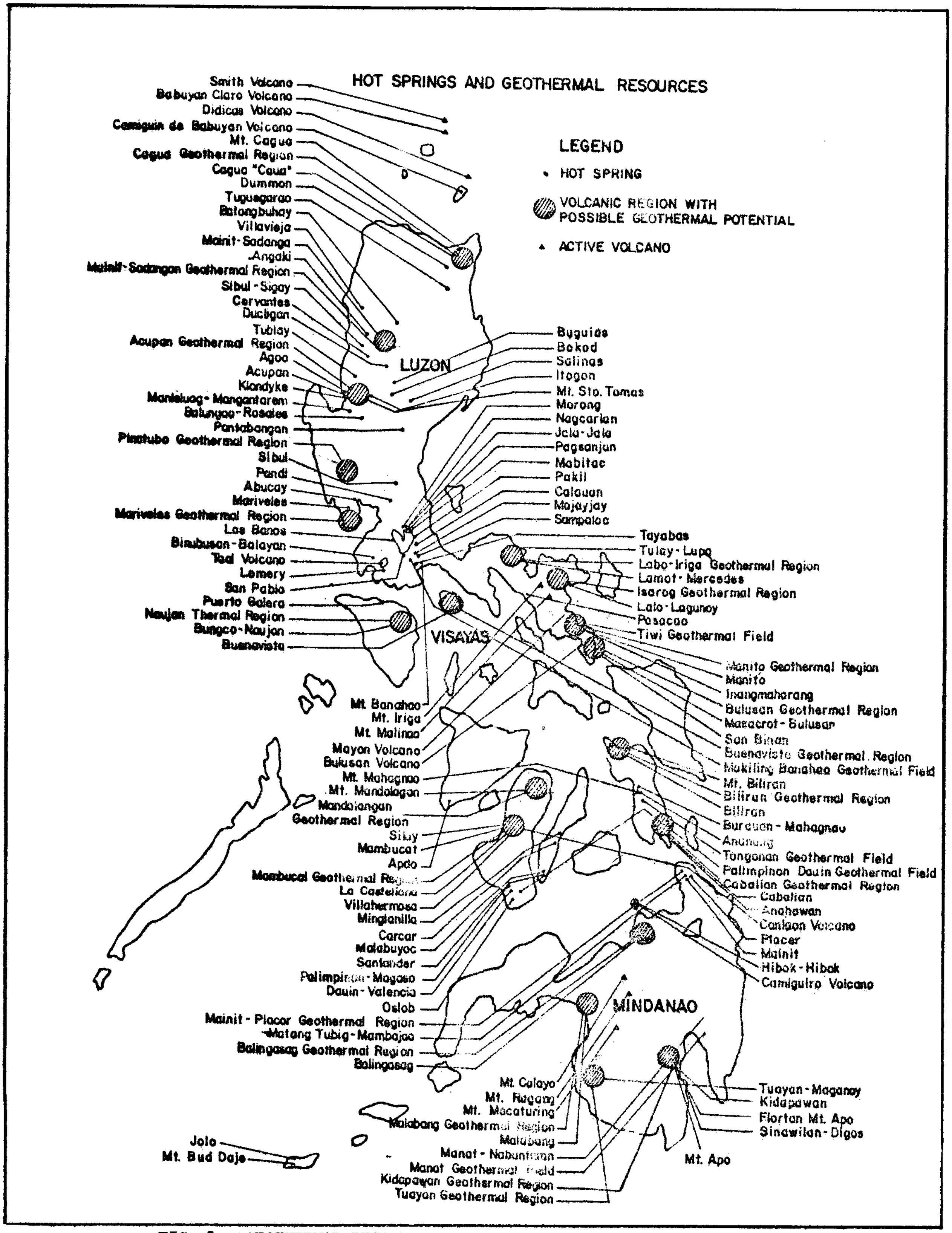

FIG. 1 - GEOTHERMAL RESOURCES OF THE PHILIPPINES

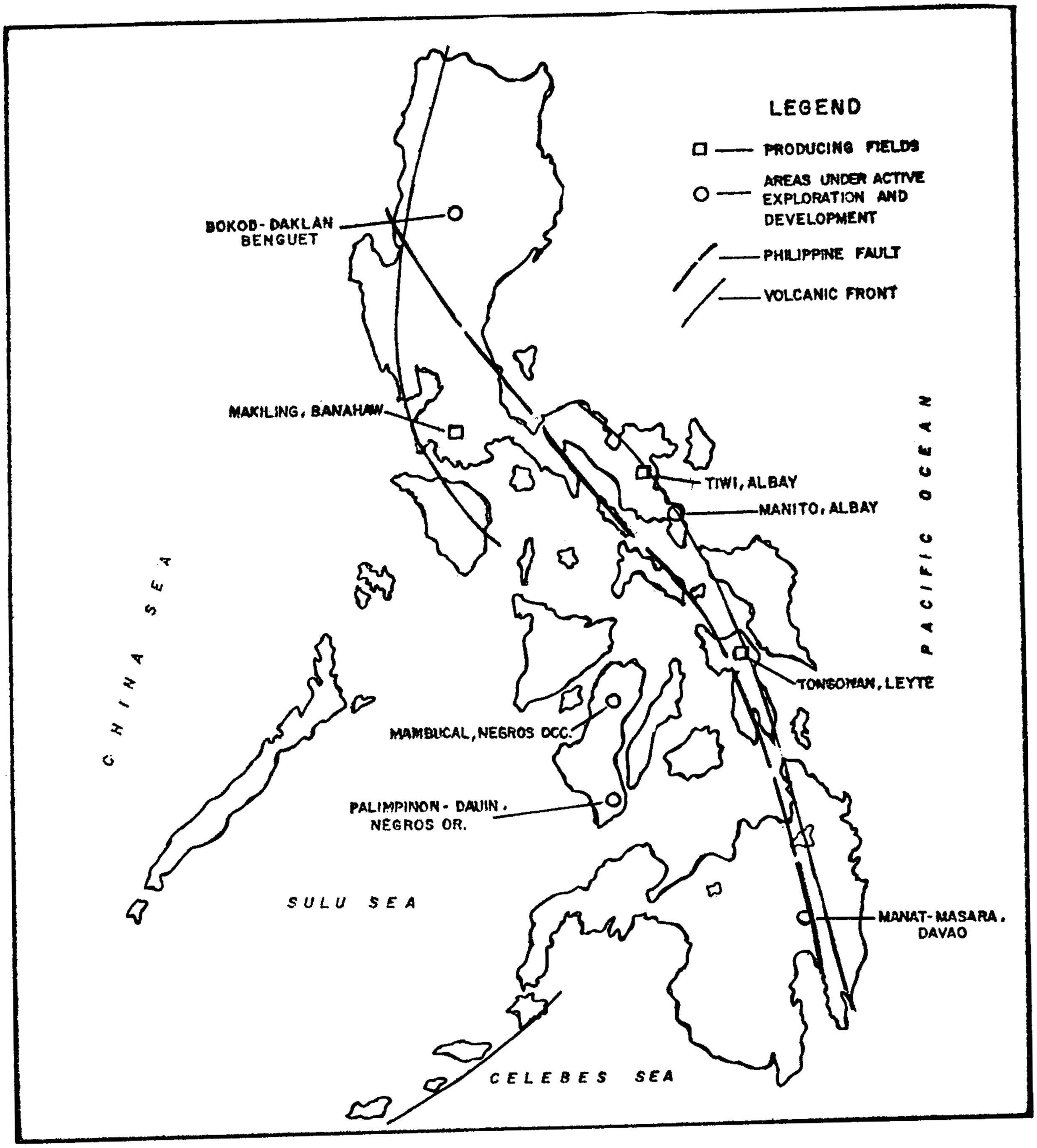

FIG. 2 — GEOTHERMAL AREAS UNDER ADVANCE EXPLORATION AND DEVELOPMENT

TABLE NO. 1

COMPARATIVE GEOTHERMAL ELECTRICAL GENERATING CAPACITY OF THE WORLD IN 1977 AND WHAT IS PLANNED BY 1982

COUNTRY	1977[1/] (MWe)	RANKING	1982[2/] (MWe)	RANKING
UNITED STATES	502	1	1,409	1
ITALY	417.6	2	481.6	3
NEW ZEALAND	202	3	302	4
JAPAN	169	4	244	5
MEXICO	75	5	180	6
EL SALVADOR	60	6	95	7
ICELAND	32.5	7	62.5	8
USSR	5	8	28	12
PHILIPPINES	3	9	548	2
TAIWAN	0.6	10	5.6	15
TURKEY	0.5	11	15	13
NICARAGUA	-	-	35	9
CHILE	-	-	30	10
INDONESIA	-	-	30	11
KENYA	-	-	15	14
TOTAL	1,467.2		3,480.7	

(Source of Information: Dr. Donald E. White, USGS)

1/ Installed Capacity

2/ Definitely committed; with completion dates scheduled up to 1982

TABLE NO. 2

COMPARATIVE COST OF GEOTHERMAL POWER DEVELOPMENT IN THE PHILIPPINES

	PROJECT	COST/KW	CAPACITY (MW)	TOTAL COST (MP)	DATE OF 1st ROLL
1.	Tiwi Units 1-2 (2 x 55 MW)	5281	110	580.90	#1 12/15/78 #2 5/10/79
	Steam Production	2332		256.62	
	TOTAL	7613		837.52	
2.	Tiwi Units 3-4 (2 x 55 MW)	5527	110	608.01	#3 12/20/79 #4 4/ 8/80
	Steam Production	2332		256.62	
	TOTAL	7859		864.63	
3.	Mak-Ban Units 1-2 (2 x 55MW)	4662	110	512.8	#1 3/30/79 #2 5/30/79
	Steam Production	2332		256.62	
	TOTAL	6994		769.42	
4.	Palimpinon Pilot Units 1-2 (2 x 1.5 MW)	4453	3	13.36	#1 8/80 #2 9/80
	Steam Production	2500		7.5	
	TOTAL	6953		20.86	
5.	Tongonan Units 1-3 (3 x 37.5 MW)	7392	112.5	831.66	#1 5/82 #2 8/82 #3 11/82
	Steam Production	3891		437.80	
	TOTAL	11283		1269.46	
6.	Palimpinon Units 1-3 (3 x 37.5 MW)	6129	112.5	689.55	#1 11/82 #2 2/83 #3 5/83
	Steam Production	2651		298.30	
	TOTAL	8780		987.85	
7.	Tiwi Units 5-6 (2 x 55 MW)	4531	110	498.41	#5 4/82 #6 7/82
	Steam Production	2522		277.50	
	TOTAL	7053	775.91		
8.	Mak-Ban Units 3-4	5296	110	582.59	#3 5/80 #4 8/80
	Steam Production	2332		256.62	
	TOTAL	7628		839.21	

($1 = ₱7.50)

TABLE NO. 5

Geothermal Power Development Program

Year	Cumulative No. of Fields	No. of Wells	Cumulative Geothermal Steam Availability (MW)	Cumulative Probable Geothermal Reserves (MW)
1979 (existing)	3	95	560	10
1980	4	60	805	40
1981	4	68	1,055	110
1982	4	76	1,315	180
1983	5	84	1,565	240
1984	6	80	1,820	300
1985	7	51	1,975	350
1986	7	36	1,975	470
1987	8	34	1,975	580
1988	8	34	1,975	700
1989	8	29	1,975	820
TOTAL	8	647	1,975	820

TABLE NO. 6

Possible Non-Electrical Uses of Saturated Steam

Saturated Steam

°C	Uses
200	
190	
180	Evaporation of highly concentrated solutionn Refrigeration by ammonia absorption Digestion in paper pulp, kraft
170	Heavy water via hydrogen suphide process Drying diatomaceous earth
160	Drying fish meal Drying timber
150	Alumina via Bayer's process
140	Drying farm products at high rates Food canning
130	Evaporation in sugar refining
120	Fresh water by distillation Most multiple-effect evaporations, concentration of saline solution
110	Drying and curing light aggregate cement slabs
100	Drying organic materials, seaweeds, grass, vegetables, etc. Washing and drying wool

Conventional power production

Required temperatures (approximate) of geothermal fluids for various applications

A - Saturated Steam

Source: B. Lindal, "Industrial and Other Applications of Geothermal Energy"

TABLE NO. 7

Possible Non-Electrical Uses of Hot Water

Hot Water

120	Fresh water by distillation Most multiple-effect evaporation, concentrations of saline solution
110	Drying and curing light aggregate cement slabs
100	Drying organic materials, seaweeds, grass, vegetables, etc. Washing and drying wool
90	Drying stock fish Intense de-icing operations
80	Space heating Greenhouses by space heating
70	Refrigeration (lower temperature limit)
60	Animal husbandry Greenhouses by combined space and hotbed heating
50	Mushroom growing Balneological baths
40	Soil warming
30	Swimming pools, biodegration, fermentations Warm water for year-round mining in cold climates De-icing
20	Fish matching and farming

Required temperatures (approximate) of geothermal fluids for various applications.

B - Hot water

Source: B. Lindal, "Industrial and Other Applications of Geothermal Energy"