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GEOTHERMAL STUDY OF TONGONAN SPRINGS, ORMOC CITY, LEYTE*

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ABSTRACT

The Toñgonan springs are located between the "Bao Fault" and the "East Fault". There are more than one hundred boiling springs that occur at the intersections of major faults and subsidiary fractures and joints in andesite and sedimentary rocks. One-meter temperature probe-hole survey on the geothermal ground indicates tremendous heat underneath the area.

The temperature of thermal waters from six major boiling springs ranges from 93° to 100° C. Their total estimated heat discharge is 801,000 kilo-calories per minute (total mass discharge is 10,400 liters per minute and the maximum temperature of river water fed to the springs is 23° C) or the equivalent of about 55,900 kilowatts.

Field observations and partial chemical analysis of water samples indicate that most of the hot spring waters are fed from the surface or are meteoric water and little comes from depth. Evidences indicate that the heat is of magmatic origin.

INTRODUCTION

Location and Accessibility

The hot springs are located within barrio Toñgonan, 12.5 kilometers northeast of Ormoc City and 11 kilometers southeast of Kananga, Leyte. The area lies between long 124°38"18' and 124°39"50'E and between lat 11°07"03' and 11°07"53'N.

Ormoc City is serviced by steamships daily from Cebu City and thrice a week from Manila. Airplane service from Manila via Cebu City is limited to three times a week.

Previous Investigation

The hot springs area was first studied during the reconnaissance geological mapping of northern Leyte conducted intermittently by the Bureau of Mines between 1953 and 1960 (J. Pilac, 1965 unpublished).

In 1962, Dr. Clarence Allen, geophysicist of the California Institute of Technology together with Messrs.

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J. Pilac and Eleuterio Gamus, both Supervising Geologist II of the Bureau of Mines, flew over the hot springs area. In May 1965, Messrs. Elpidio C. Vera and Francisco A. Comsti, Asst. Director and Chief Geologist of the Bureau of Mines, respectively, made a brief visit to the area and recommended that the region be studied in detail for possible geothermal power development.

Present Investigation

The present study was undertaken as part of the Bureau of Mines program of canvassing geothermal resources for possible domestic and industrial use. Accordingly, the objectives of the survey are:

1. To study the physical nature of the hot springs and determine their possible origin;
2. To delimit the geothermal areas with the use of one-meter temperature probe-hole method;
3. To assess the feasibility of converting the steam resources into electric power; and
4. To prepare the area for future drilling exploration.

The detailed survey work of the area was carried out in three field work periods from November, 1965 to June, 1966 by Messrs. Pedro Estupigan[1], Juan Olaivar[2] and the writer. Plane table topographic mapping and one-meter temperature probe-hole survey were conducted by Estupigan and Olaivar, respectively, while the writer did the geological mapping. During the second and third field work periods, Mr. Juanito Fernandez[3] and party made a geophysical study of the same geothermal area.

Acknowledgment

The writer is indebted to Mr. Juan E. Pilac for his many suggestions and guidance during the course of the field work. Messrs. Alfredo Magpantay and Sesinando Samaniego, both Supervising Geologist II, likewise offered helpful advises during their brief visit to the area.

The chemical analyses of rocks and spring water samples were made by the personnel of the Analytical Laboratory Services Section of the Bureau of Mines' regional office at Cebu City. Credit is due the Petrography and Mineralogy Section of the Geological Survey Division for the petrographic examination of a number of rock samples.

PHYSIOGRAPHY

The area includes a relatively flat river valley, a rolling upland and a

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mountainous terrain with elevations ranging from 150 to more than 1,000 meters above sea level.

The mountainous area rises abruptly from the relatively flat terrain east of the Bao River, the principal drainage system of the area. It is characterized by steep slopes, sharp peaks, narrow ridges and deeply-dissected valleys.

The rolling upland area consists of low hills and small conical knobs with elevations ranging from 250 to 400 meters above sea level that extend several kilometers west-northwest and east of the valley.

The Bao River Valley where most of the hot springs are located, is about two kilometers long and half a kilometer wide and is bordered by hilly uplands to the east and west. North and south of the ovoid lowland are rugged mountainous areas.

The valley appears to be a graben that had developed from the collapse of a sliver between two major faults. Recent adjustment of the fault blocks and flush-floods during rainy seasons have caused Bao River to alternately shift its course from east to west, thus small islands of sand and gravel are formed.

GEOLOGY

Stratigraphy

The oldest rocks in the area are volcanic extrusives of probable Middle Miocene age (Pilac, 1965 unpublished). Unconformably overlying the extrusives is a series of tuffaceous sedimentary rocks composed of conglomerates with interbedded sandstone and shale. Unconsolidated terrace gravel and river-deposited silt, sand and gravel constitute the alluvial mantle.

Volcanic Rocks — The extrusive volcanic rocks are mostly massive andesite occasionally intercalated with tuffaceous sediments, volcanic breccia and pyroclastic materials. Megascopically, the andesites are porphyritic and coarse to medium-grained whereas the volcanic breccias are made up of angular pieces of light-colored porphyritic fragments, felsite and rounded scoriaceous blocks cemented by tuffaceous materials. Near thermal springs and along the major faults these extrusive rocks are hydrothermally altered to sticky aluminous clay with a characteristic brick-red to purplish-red hue.

Under the microscope, the texture is pilotaxitic, some intersertal and others show a glassy groundmass. Principal minerals are andesine, labradorite, hornblende and pyroxene. Magnetite, chlorite, epidote and calcite are assessory minerals.

Sedimentary Rocks — Interbeds of conglomerates, sandstones and shale of probable Pliocene age unconformably overlie the volcanics, which also serve as their immediate provenance.

The sedimentary rocks are poorly sorted but are fairly-cemented. Silica and tuffaceous materials are the main cementing materials.

Recent Deposits — The deposits are made up of poorly sorted sand, silt, clay, organic materials, lenses of gravel and rubble. The constituents are mainly of volcanic derivative and the deposits form a series of low benches that adjoin the rolling and hilly volcanic terrain.

Structures

Faults — Three major faults herein named "Bao Fault", "Central Split Fault" and "East Fault" were mapped in the area (Plate I). They are approximately parallel to each other with a N 30° W trend. The Bao Fault is a prominent segment of the Philippine Fault Zone, a system of closely interrelated sympathetic faults that passes from Mindanao to Luzon Island[4] The latter fault system shows dominantly left-lateral movements believed to have occurred extensively during the Miocene Orogeny. Recent readjustments, however, are mostly gravity type.

Bao Fault — From Lake Danao (Plate I) the Bao Fault passes through the western side of Bao River Valley to several kilometers northwest of the geothermal area. On the ground the fault is markedly expressed by steep saddle backs, by the aligned trend of faceted slopes, conical knobs, mountain peaks and pinnacles and by a system of feather joints. The adjacent area is characterized by the hydrothermal alterations of the rocks chiefly by hot water and steam and by extensive weathering.

Central Split Fault — The Central Split Fault is traceable from immediately southeast of Lake Danao where it splits from the Bao Fault and extends several kilometers north. Observations on the fault face at the headwaters of Banat-i Creek indicate a right lateral movement.

Ground morphology is well expressed by aligned mountain peaks, steep saddle backs, conical knobs, relatively straight ridges and faceted slopes. The western side of the fault shows zones of intense crushing and shearing which favorably gave rise to numerous hot springs and steaming areas.

East Fault — This fault is the least prominent among the three major faults. It is a gravity type that resulted from the latest readjustments along the two other major faults. The west block has moved down with respect to the east block.

[4] Tectonic Map of the Philippines, 1963.

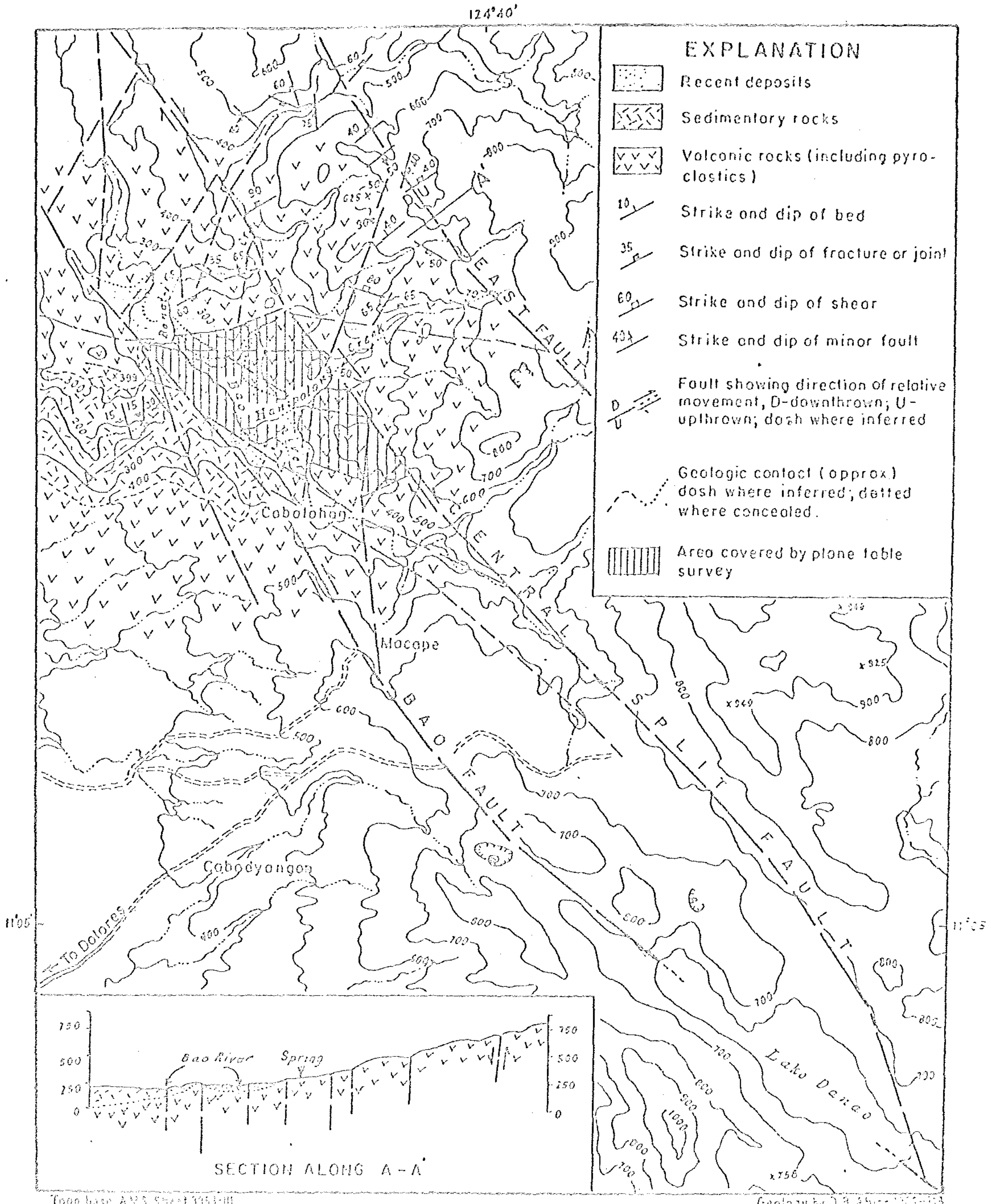

PLATE I – GEOLOGIC MAP AND SECTION OF TOÑGONAN HOT SPRINGS AREA ORMOC CITY, LEYTE

Scale

Contour interval 100 Meters

Other Structures—Secondary structures that developed as a result of transcurrent movement along the major faults consist of minor faults, joints and fractures that generally trend northwest to west and dip steeply to the north. Except for the two small parallel faults along Bao River, the minor structures are at various angles to the major faults. In most places, fault intersections are the favorable sites of thermal springs.

A high angle fault that trends north-northwest lies on the east side of Banat-i Creek. This fault appears to have resulted from the right-lateral movement of the Central Split Fault. The thermal springs emerging from both sides of the fault are probably fed from it.

The large thermal ground in Paril area is attributed to a high angle fault and other cross faults. Two minor faults in the vicinity trend northwest and west from the Central Split Fault.

The tuffaceous clastics intercalated with the extrusive rocks have bedding trends ranging from N5°E to 45°E and dip 30° to 50° to the northwest. Beddings in the Pliocene sedimentary rocks trend N30°-50°E with moderate dips to the west.

THE HOT SPRINGS

The numerous hot springs in Barrio Toñgonan are distributed in an area approximately 2.3 square kilometers within the Bao River Valley.

The geothermal areas are divided into four groups, namely: Bao Hot Spring, Banat-i Hot Spring, Hanipolong Hot Spring and Paril Hot Spring groups (Plate II).

The temperature of individual springs was measured with the use of a maximum thermometer graduated to 200°C. Where possible, the water discharges were calculated in liters per minute by the floating cork method. A cork is dropped at a particular point along the discharge path and timed as it traveled through a pre-determined distance along a ditch and across a weir whose area has been previously measured. One meter temperature-hole probing was undertaken to determine the ground temperature in areas covered by plane table mapping.

Bao Hot Spring Group — The Bao hot spring group is situated at the Bao River valley in the western portion of the mapped area. Most of the thermal springs in this group are found near the western margin of the valley and along the east bank of the southeastwardly flowing section of Bao River where they are impressively aligned over a stretch of 250 meters (Plate II). The springs occur at the intersections of major faults and their se-

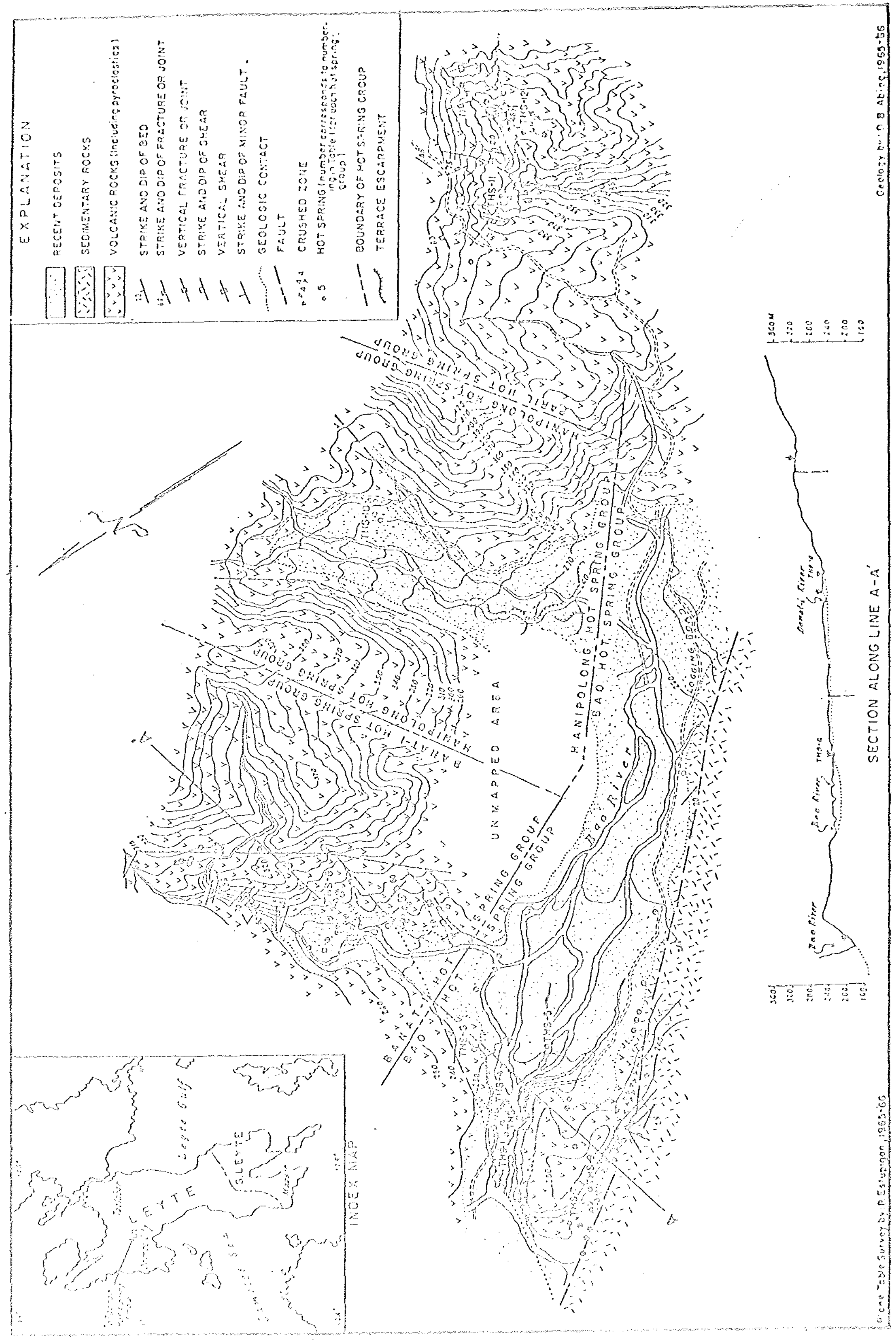

PLATE II—DETAILED GEOLOGIC MAP AND SECTION OF TOÑGONAN HOT SPRINGS AREA, ORMOC CITY, LEYTE

condary fractures.

THS-1 (Toñgonan Hot Spring Number 1) lies a few meters from the river. The seepage comes out of a small gravel-filled vent. The water temperature is 99° to 100° C. The spring discharges about 377 liters per minute which spouts to a height of 25 centimeters.

THS-2 is several meters southeast of THS-1 and is topographically several centimeters above it. It occupies a large area and includes all the nearby smaller springs. The water temperature is 99° to 100° C. The calculated total discharge is 374 liters per minute which spout to a height of 30 centimeters above the vent.

THS-4 is several meters southeast of THS-2 and is a geyser-type hot spring with an orifice about one meter across. The periodic spouting or cyclic thermal activity is believed to be controlled largely by the rising of deep-seated thermal water and steam and the supply of underground cold water.

The activity of the geyser during flood seasons is characterized by approximately six minutes of quiscence, steaming and faint bubbling followed by about five minutes of bubbling, rumbling and spouting and finally by tremendous overflow (Fig. 1). However, during the dry season the periodic activity recorded 11 minutes of quiscence and 4 minutes of bubbling, and spouting with surface overflow. During the height of a flood the geyser was temporarily inactive when the river bank nearly overflowed. Little steam was emitted and faint subsurface rumbling occurred at the vent. Inactivity was suspected to be due to the oversupply of ground water feeding the spring, while the pressure beneath the surface remained constant. However, the temperature of the overflow (99°—100° C) before and after the flood was maintained.

THS-5 is a perennial steam-belcher located in an island of sand and gravel. It is the most accessible spring in the area and includes several smaller ones. The total discharge is estimated to be 230 liters, per minute. This rate noticeably decreases during rainy seasons. The water temperature is constant from 99° to 100°C.

THS-6 ensues from hydrothermally altered volcanic rocks within an area approximately 30 square meters (Fig. 2). The biggest spring in this group is on a vertical cliff where boiling water is periodically thrown-off from a seemingly inclined well. This and several smaller springs in the vicinity give a mass discharge of about 3,000 liters per minute.

THS-7 is situated on the western bank of Bao River and with other boiling springs occur along

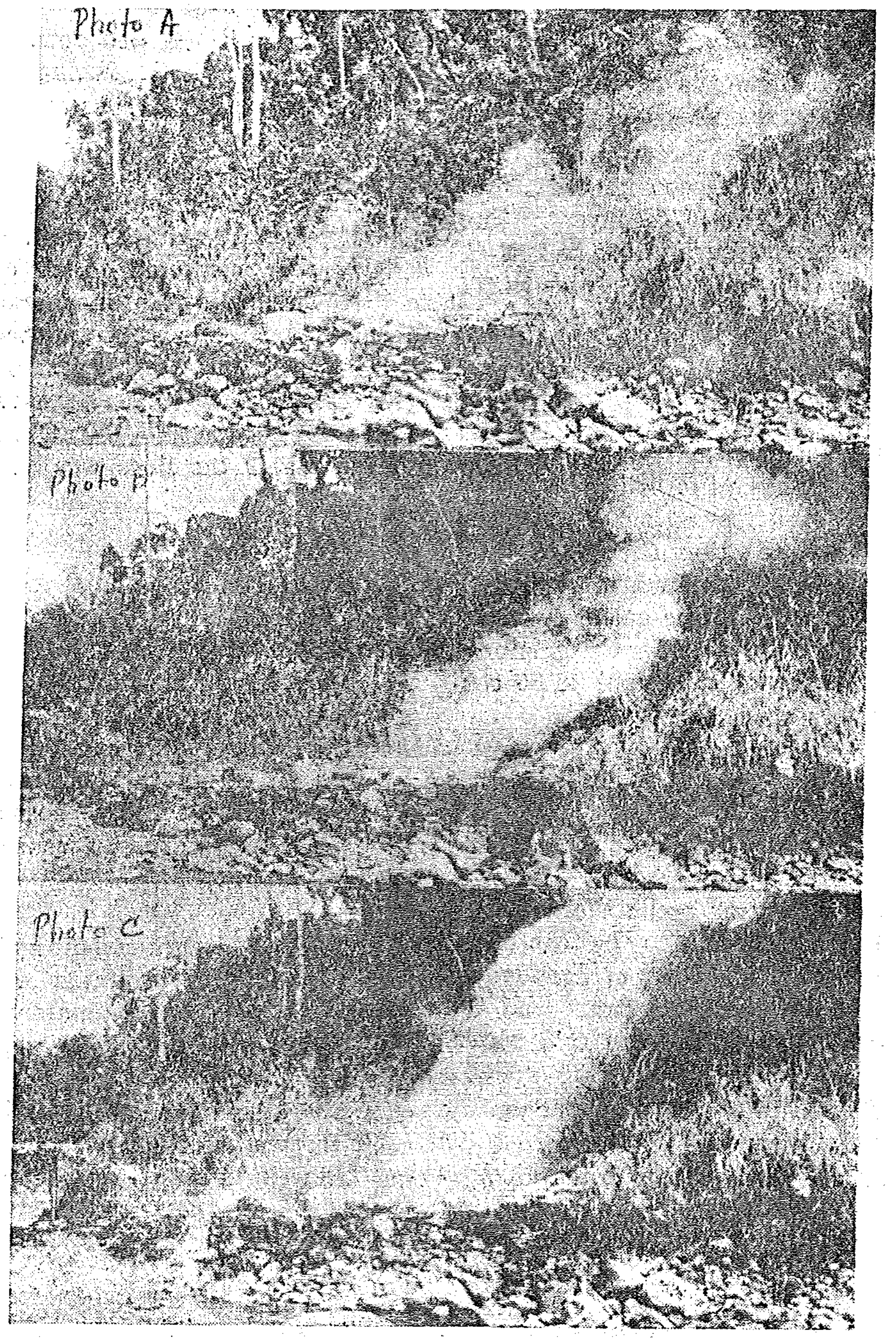

Fig. 1 Geyser spring (THS-4) showing stages of cyclic activity. Photo A — steam starts to emit, Photo B — boiling water starts to show up and Photo C — boiling water overflows the vent.

Fig. 2 Hot springs in hydrothermally altered volcanic rocks. Photo A — geyser-like spring (THS-6) discharges about 3,016 liters per minute. Bubbling and spouting come from inclined vent. Fallen trunk of tree has slightly silicified bark. Photo B— bubbling muddy springs adjacent to Photo A at left side. Local depressions are location of muddy hot water springs.

Bao Fault over a stretch of 250 meters in conglomerates, volcanic rocks and gravel deposits (Figs. 3 & 4). It has the largest mass discharge calculated at 3,680 liters per minute at almost boiling temperature. The second largest spring in this group is about 110 meters farther northwest and is characterized by tremendous bubbling and rumbling which could be heard from a distance. Several other boiling springs emerge at the intersections of structures and around the edges of loosely cemented boulders and cobbles.

THS-9 is on the western margin of the river valley and aligned with THS-7 and the other groups of springs. Like the other boiling springs in the area it discharges large volumes of clear water but has no surface overflow.

Banat-i Hot Springs Group – The Banati-i hot spring group lies on the southwestern side of Banat-i Creek and is east of the Bao group. Several boiling springs are concentrated in an area approximately 150 meters wide between the Central Split Fault and the junction of Banat-i Creek and Bao River.

THS-8 is the largest in the group with a mass discharge of 2,716 liters per minute. Included are several areas of steaming ground, thermal pools and geyser springs issuing from silica-cemented gravel deposits. Several smaller ones emanate from hydrothermally altered volcanic rocks under thick bushes and along gullies and depressions further north, east and south of the area. At the downthrown side of the Central Split Fault near the headwater of Banat-i Creek is a small area of altered volcanic rocks that emit sulfurous gas.

It appears that the Central Split Fault is the primary structure that controls the distribution of the thermal springs, however, smaller structures sympathetic to the major fault serve as channel ways for hot water and steam.

Hanipolong Hot Spring Group – This hot spring group lies in the upper portion of Hanipolong Creek. The hot springs are located in gravel deposits within a graben bounded by the East Fault and the Central Split Fault.

The hot springs in this group are not as impressive as those in the other groups. The hot spots on the west bank of Hanipolong Creek have very small discharges and occur in a comparatively smaller area. Deposits of sulfur were noted around the hot springs and steaming ground.

THS-10 situated about 100 meters east of the creek, is an oval muddy pool measuring about four meters long and three meters wide. Hot water spouts at irregular intervals from the northernmost por-

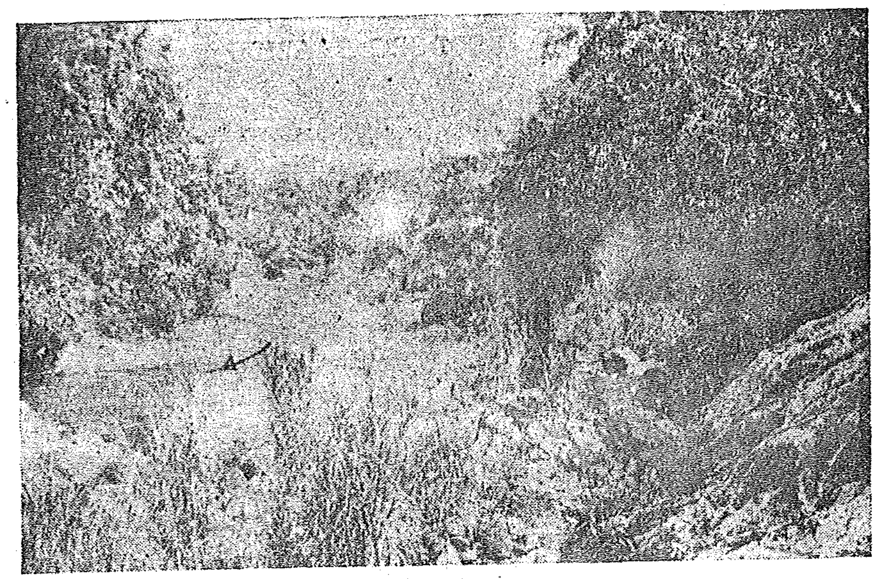

Fig. 3 Southeastward flowing (see arrow) portion of Bao River. At right side of the river from foreground is about 250 meters stretch of beautifully aligned boiling springs and steaming ground. The biggest discharge calculated in one of the springs is 3,680 liters per minute. The river is traversed by the Bao Fault Zone. Relative movement is left-lateral.

Fig. 4 Close-up of the largest boiling spring (THS-7) on the east bank of the southeastward flowing portion of Bao River with an estimated discharge of 3,680 liters per minute. The underlying rock is conglomerate that is made up of locally derived andesite rocks.

tion of this pool. Deposits of sulfur and melanterite are also found around spring vents and within the steaming grounds.

Paril Hot Spring Group — This spring group lies in the southern portion of the mapped area at the headwaters of Paril Creek, a southwesterly flowing tributary of Bao River. Several boiling springs and a large thermal ground in altered andesite are included in this group.

THS-11 is the largest in the group and discharges a considerable volume of boiling water. About 1.5 meters from the spring is a whistling vent which releases great amounts of heated steam. Small boiling springs are found along gullies and depressions while steam emanates from hydrothermally altered rocks along gulley walls. Deposits of melanterite and sulphur are found around vents and within around spring vents.

THS-12 embraces a comparatively larger area south of THS-11 and includes several boiling springs and steaming spots. Deposits of sulphur and melanterite are also found around spring vents.

CHEMICAL ANALYSIS OF HOTSPRING WATERS AND THEIR IMPLICATIONS

Results of chemical analyses of water samples from the various hotsprings in the area are shown in Table I. The water samples were collected from the surface during one seasonal period, hence the effect of seasonal changes on the chemical composition was not determined. Furthermore, the writer is aware that the chemical composition of surface water samples will not be identical with those of the underground inasmuch as cooling, loss of steam, interactions with the country rocks being traversed, oxidation, P-T variance and other parameters will certainly affect the original concentration of the elements.

Table I shows a marked increase in salt content (Na, K, Cl), silica, total solids and pH values of water samples taken from hotsprings at lower altitudes compared with those taken from much higher elevations (plus 100 meter-elevation difference).

The high salt content requires a logical explanation. Most of the hotsprings at low elevations are within the Bao River Valley. The values imply that within the low regions extensive dumping or precipitation of ions took place. This condition is further evinced by the higher solids content of the water samples from the aforesaid areas. The precipitation of ions can be attributed to one or a combination of the following factors:

1) Presence of catalysts and contaminants within the region

TABLE I

CHEMICAL ANALYSIS OF WATER SAMPLES FROM THE TONGONAN HOT SPRINGS

Sample No.	CONSTITUENTS DETERMINED (Parts per Million)														
	pH	CO_3	HCO_3	H_2S	Cl	Si	Fe	Al	Ca	Mg	Na	K	SO_4	Suspended solids	Total solids
Bao Hot Spring Group															
THS-1	8.35	32.09	14.33	0.37	3407.0	128.43	0.08	2.80	76.51	2.67	1557.30	662.82	88.57	162.8	620.37
THS-2	8.70	ND	48.17	0.18	3483.0	126.34	0.42	1.62	75.81	1.23	1634.84	635.11	92.34	13.5	6424.2
THS-4	7.95	32.09	8.02	0.28	3441.0	133.42	0.037	3.73	82.20	4.98	1466.43	726.33	90.21	61.6	6353.7
THS-5	8.05	28.65	10.89	0.37	3486.0	130.48	0.022	5.85	83.98	2.76	1635.51	708.00	91.61	58.4	7769.7
THS-6	7.80	ND	46.99	ND	3194.0	107.29	0.08	7.35	87.72	4.30	1391.35	715.90	81.90	8.8	5835.1
THS-7	8.15	45.27	7.16	0.13	2994.0	149.94	0.231	3.48	69.04	6.67	1431.39	600.93	84.53	7.1	5304.0
THS-9	8.45	ND	44.16	0.55	3433.0	122.97	0.263	2.84	95.02	2.14	1507.84	651.61	92.83	20.4	6275.0
Banati-i Hot Spring Group															
THS-8	8.74	ND	43.58	1.02	3082.0	129.74	0.42	2.63	66.94	1.14	1476.70	552.86	80.41	38.9	5746.4
Manipolong Hot Spring Group															
THS-10	2.80	ND	ND	ND	7.35	67.02	19.61	6.82	24.40	13.93	13.66	3.28	500.57	438.0	721.1
Paril Hot Spring Group															
THS-11	7.20	ND	103.14	0.14	10.53	47.23	2.94	1.14	107.05	39.24	44.62	8.32	435.30	61.3	1048.2
THS-12	4.30	ND	5.44	0.14	7.06	97.91	21.09	9.55	98.21	28.16	44.15	11.44	41.73	430.5	600.4

ND — Not Detected

(perhaps within Bao River or within the water table) which could easily affect the concentration of elements particularly silica.

2) Steam loss and cooling will, correspondingly, entail concentration and precipitation.

3) Loss of pressure. The level of Bao River may correspond to a critical pressure area where precipitation can drastically take place.

4) Variation in sub-surface temperature which can change concentration of elements.

5) Rise and fall of pH values due to loss of steam, dilution or even oxidation.

6) Kind and extent of hydrothermal alterations.

7) Nature of the underlying bedrock.

8) Ionic exchange due to dilution of surrounding meteoric water.

These factors can be the causes of the differences existing now between the two types of hotspring waters, although other subsurface factors can easily affect the concentration of elements.

The high chlorine content may be attributed to volcanic exhalations which are common in the region.

Samples from THS-10 and THS-11 have abnormally high sulfate contents than any other sample. The presence of sulfur deposits and some pyrite mineralization particularly along major structures in the area may explain for these values. Water samples from THS-10 and THS-12 are acidic compared with samples from the other springs which are essentially alkaline. Also, they have higher Fe and Al values which altogether may be explained by the presence of pyrite within springs.

POSSIBLE ORIGIN OF THERMAL WATER

Most of the hot spring waters are believed to be fed from the surface or are meteoric water and little comes from depth. The water is discharged along fractures in volcanic rocks hence, under high temperature and pressure. The original composition of the water is appreciably modified by interaction with the country rocks as it rises to the surface.

Heat is believed to be induced by local thermal anomalies, such as the presence of an intrusive mass or volcanic activity, through conduction and convection. Banwell (1955) also attributed "high temperature gas, principally water vapour at 1,000°C escaping from molten or semi-molten rock (magma) at a considerable depth." Another possible source of heat is subterranean damming of heated steam confined along the major fault zone. Heat release by recrystallization processes due to burial alterations and other chemical reactions are also effective mechanisms which propagate heat.

ONE-METER TEMPERATURE PROBE-HOLE SURVEY

Procedure

A N 35° W base line was laid down by plane table. Pickets and grid lines at 50-meter intervals were established.

A temperature-contour pattern at one-meter depth was obtained by probing each point with the use of a one-inch diameter iron bar. In certain instances, mid-station probing (25-meter points) was made to determine temperature fluctuations between 50-meter points. The temperature of each probe hole was read at 5-minute intervals with a maximum thermometer. The recorded temperatures were plotted on a topographic drainage map from which isothermal contours at 20-degree centigrade intervals were drawn (Plate III).

In some hot springs the temperature goes as high as 102°C when the thermometer is dipped one foot below the vent. This indicates that the thermal gradient is higher at depth. The observed temperature of most boiling springs before and after the rainy days remained the same.

Results

Bao Hot Spring Group — Results of the temperature probe indicate the presence of isothermal peaks aligned with the hot spring distribution. The thermal peaks on both sides of Bao River trend northwest, following the distribution trend of the springs in the area. The temperature probing further indicates that the area is traversed by structures sympathetic to the major faults and that there is spotty temperature gradient. The Bao hot spring group has the largest number of thermal springs and the biggest thermal ground which could be a major source of geothermal power. In terms of hot water discharge, density of thermal areas and proximity to major structures this group may be considered as the most promising area for geothermal exploration. The hot spots are probably interconnected at depth inasmuch as they are localized along related structures.

Banat-i Hot Spring Group — The temperature probe survey indicates five isothermal peaks with temperatures above 80°C. Three of these thermal peaks trend north whereas the other two run northwest and northeast. Thermal grounds with temperatures above 80°C occupy large areas mostly underlain by hydrothermally altered volcanic rocks.

As in the case of the Bao hot spring group, the distribution of thermal peaks indicates that the alignment of hot springs is related to and (or) controlled by structures.

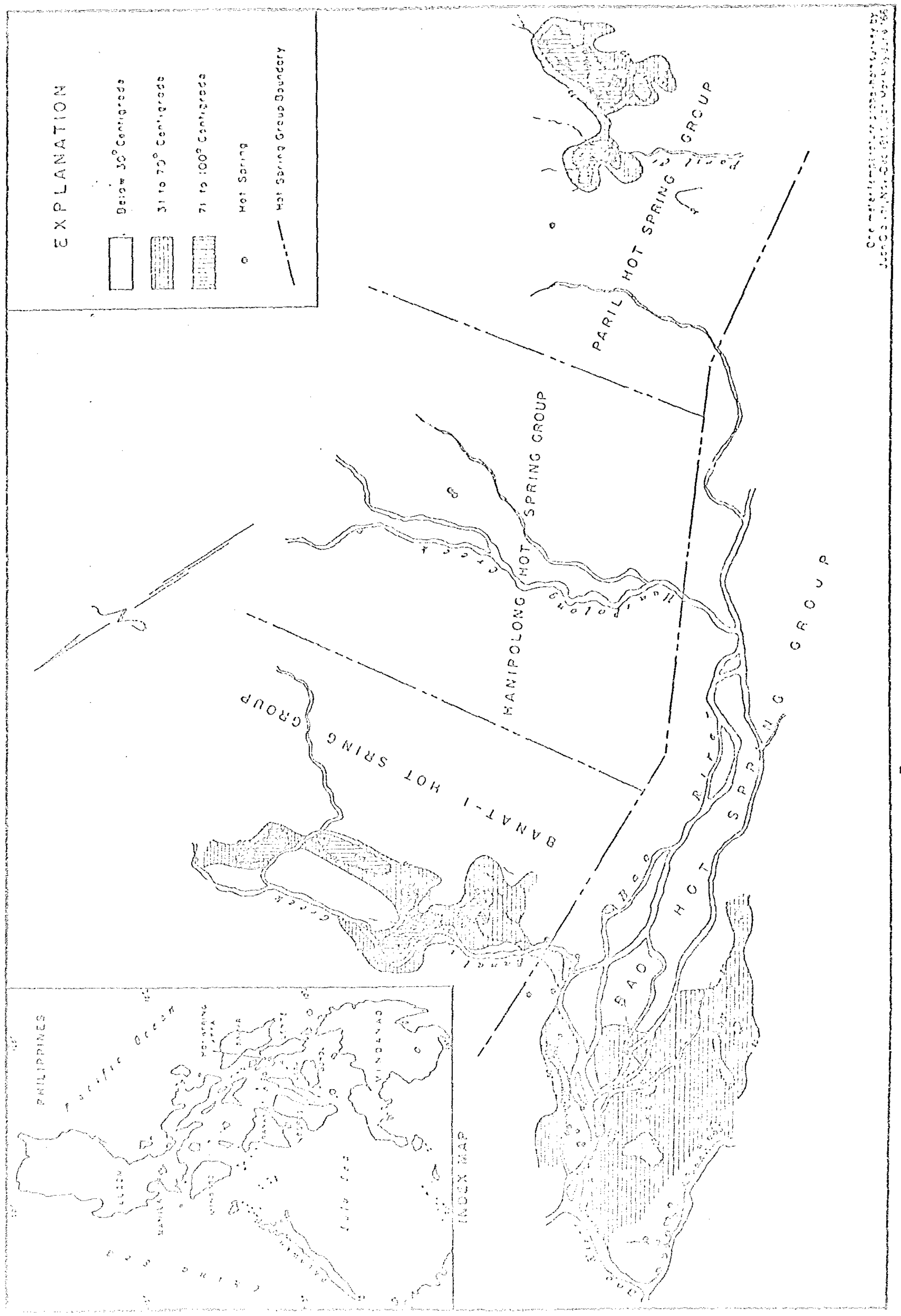

PLATE III - ISOTHERMAL MAP OF TOÑGONAN HOT SPRINGS AREA, ORMOC CITY, LEYTE

This is demonstrated in the northwestern part of the area where a north-northwest trending right--lateral fault was delineated. The temperature gradient is likewise indicated. The two spring groups are interconnected at depth. The main structure that controls the distribution of the hot springs is a northwest-trending high angle gravity fault. The other structures are related to the Central Split Fault.

TABLE II
TEMPERATURE, HOTWATER DISCHARGE, AND HEAT OUTPUT OF SIX MAJOR BOILING SPRINGS IN TONGONAN AREA

Hot Spring Nos	Temp °C	Water Discharge Lt/Min	Heat output K-cal/Min
Bao Hot Spring Group			
THS-1	98 — 100	337	25,949
THS-2	98 — 100	374	28,794
THS-5	99 — 100	231	17,787
THS-6	98 — 100	3,016	232,232
THS-7	99 — 100	3,679	283,283
Banat-i Hot Spring Group			
THS-8	99 — 100	2,716	212,982
T O T A L		10,353	801,027

probably inter-connected at depth and the heat emitting from them originates from the same source.

Hanipolong Hot Spring Group — This area showed the least thermal surface features; however, it is believed that the area is connected at depth with the main geothermal region underlying the Bao River Valley further north. Such being the case, the area may also prove to be important.

Paril Hot Spring Group — The isothermal map shows a comparatively large area with a probed temperature of over 90°C. Several small isothermal peaks are believed to be

POWER POTENTIALS

The Toñgonan hot spring area can be considered a good source of geothermal power as evidenced by the numerous boiling springs and tremendous emission of steam. The amount of heat that escapes from the area is considered to be the minimum quantity available for utilization. If the thermal gradient in the area is steep, a temperature very much above boiling may be tapped from a hundred feet below the surface. In each of the four areas discussed, the heat output may be increased by drilling exploration. Based on rough calculations of heat discharges (Healy,

1960) from six (6) boiling springs with measurable hot water discharges a total of 801,000 kilo-calories per minute (55,900 kilowatts equivalent) is available. This power equivalent although not enough to drive heavy machineries is just a small portion of the total stored thermal energy. The power that could be harnessed from this area is more than enough to supply the requirements of the more than 1 million inhabitants (Bureau of Census and Statistics, 1965) of Leyte. Samar, the island nearest to Leyte, could also be served.

Among the four hot spring areas the Bao area is the largest and the most impressive in terms of location and thermal power potentials. All of the 55,900 kilowatts equivalent were calculated from Bao and Banat-i areas which are adjacent to each other. Hanipolong and Paril areas were not included in the calculation. Other prospective geothermal areas were uncovered by ground magnetometer and resistivity surveys conducted by J. Fernandez (1968). If all these areas are considered, the overall estimate of power would run to a few hundred thousand kilowatts equivalent.

CONCLUSION AND RECOMMENDATIONS

The Toñgonan spring area is a potential source of hydrothermal energy. However, further exploration work should first be undertaken in the area before it could be finally assessed of its economic potentiality.

Drill sites should be selected and the work systematically planned and carried out. The best drill sites are in the vicinities of the hot springs and thermal grounds within the areas embraced by the four hot spring groups. The largest of these areas lies within the valley from the latitude of the Bao-Maihaw river junction to the Paril area.

Since geophysical probing has been useful in delimiting certain potential thermal areas, the same survey can be conducted in neighboring areas to determine the lateral extent of the geothermal grounds prior to any drilling program. Geophysical findings (Fernandez, 1968) show that the stream deposits in the valley (8 m thick) overlie hydrothermally altered volcanic rocks or what is here considered as the thermal layer which has been estimated as over 200 meters thick.

After all the necessary geological and geophysical researches have been accomplished, drilling probes will certainly provide the following information:

1. Depths of drill holes that will give the necessary temperature and pressure for large scale thermal power generation.

2. Thermal gradient in the area.

3. Valuable subsurface data such as the possible sources of heat and thermal water, extent of hydrothermal alteration at depth, favorable thermal layers, and others.

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