THE REPUBLIC OF THE PHILIPPINES

REPORT ON ACUPAN-ITOGON GEOTHERMAL DEVELOPMENT

FIRST PHASE SURVEY

OCTOBER 1983

JAPAN INTERNATIONAL COOPERATION AGENCY

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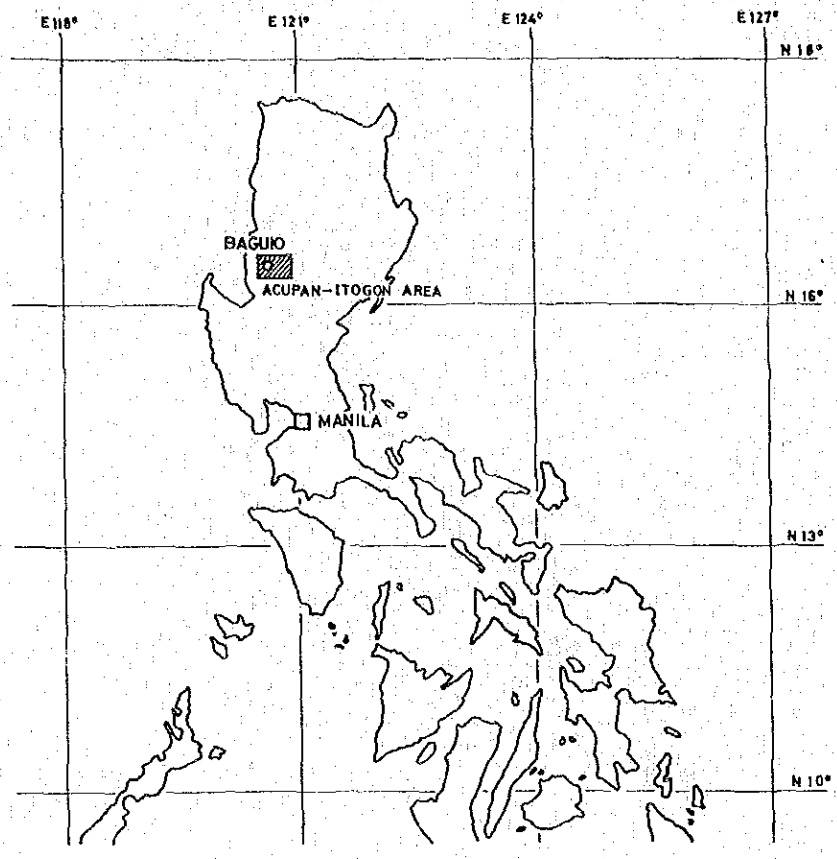
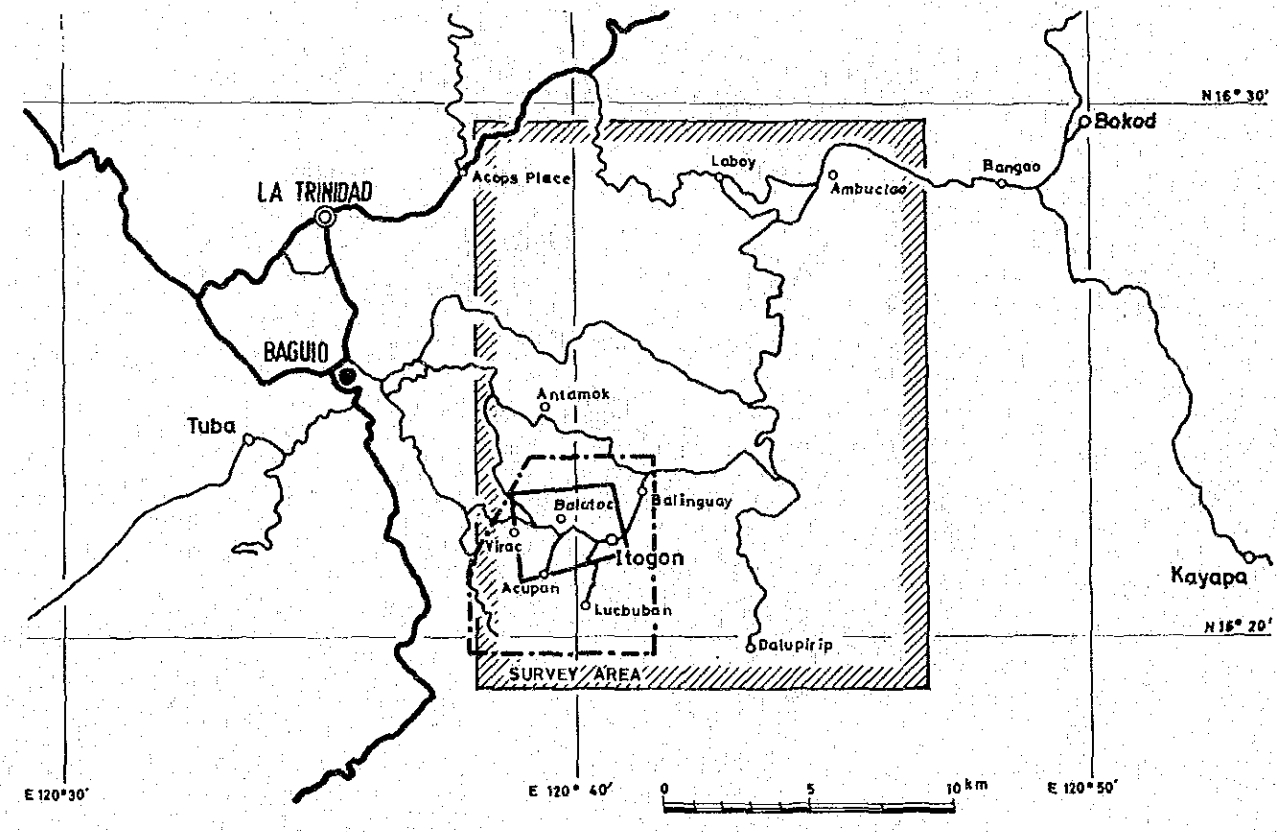
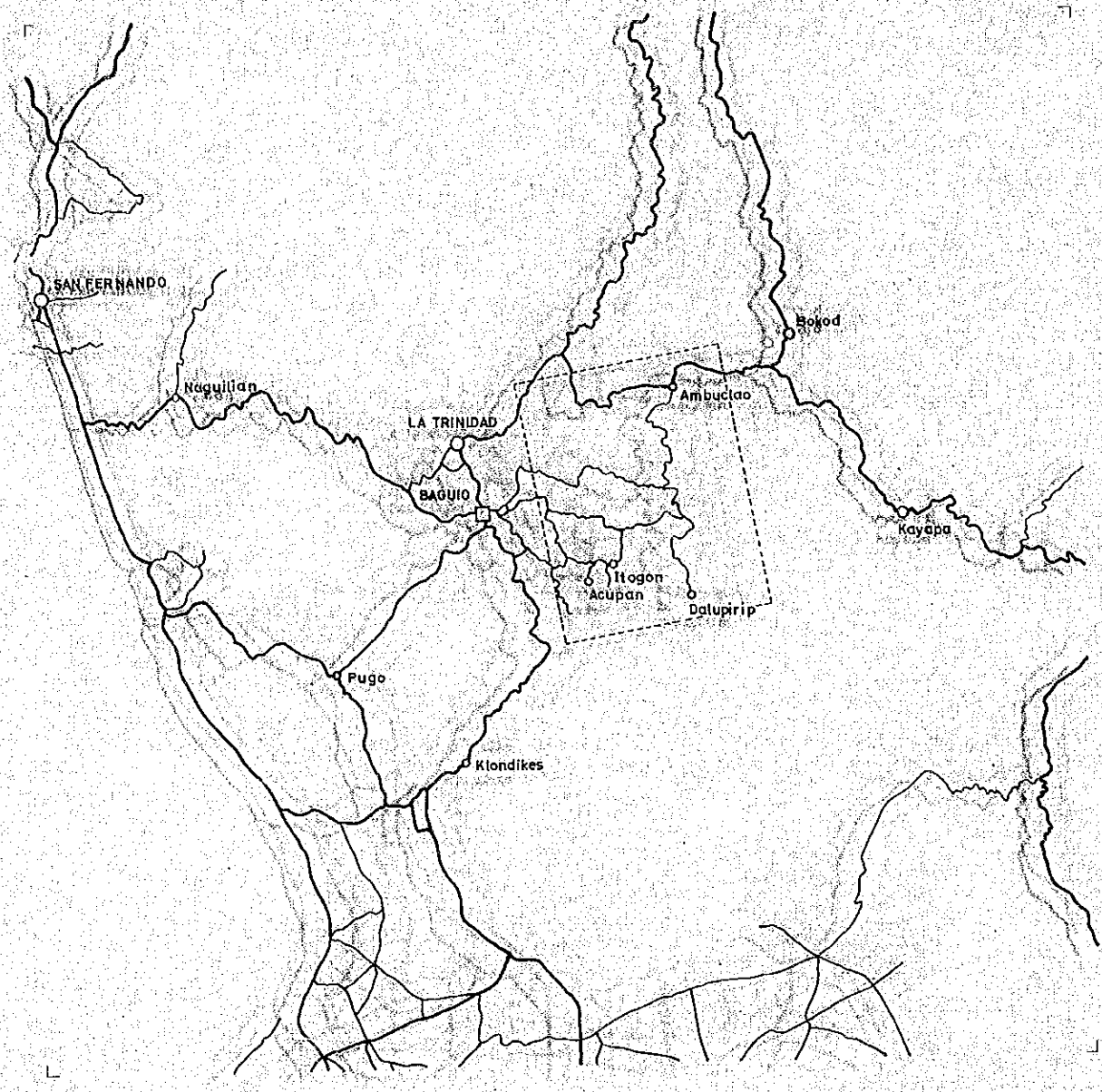


LOCATION MAP OF ACUPAN-ITOGON AREA

PROVINCE OF BENGUET

REPUBLIC OF THE PHILIPPINES

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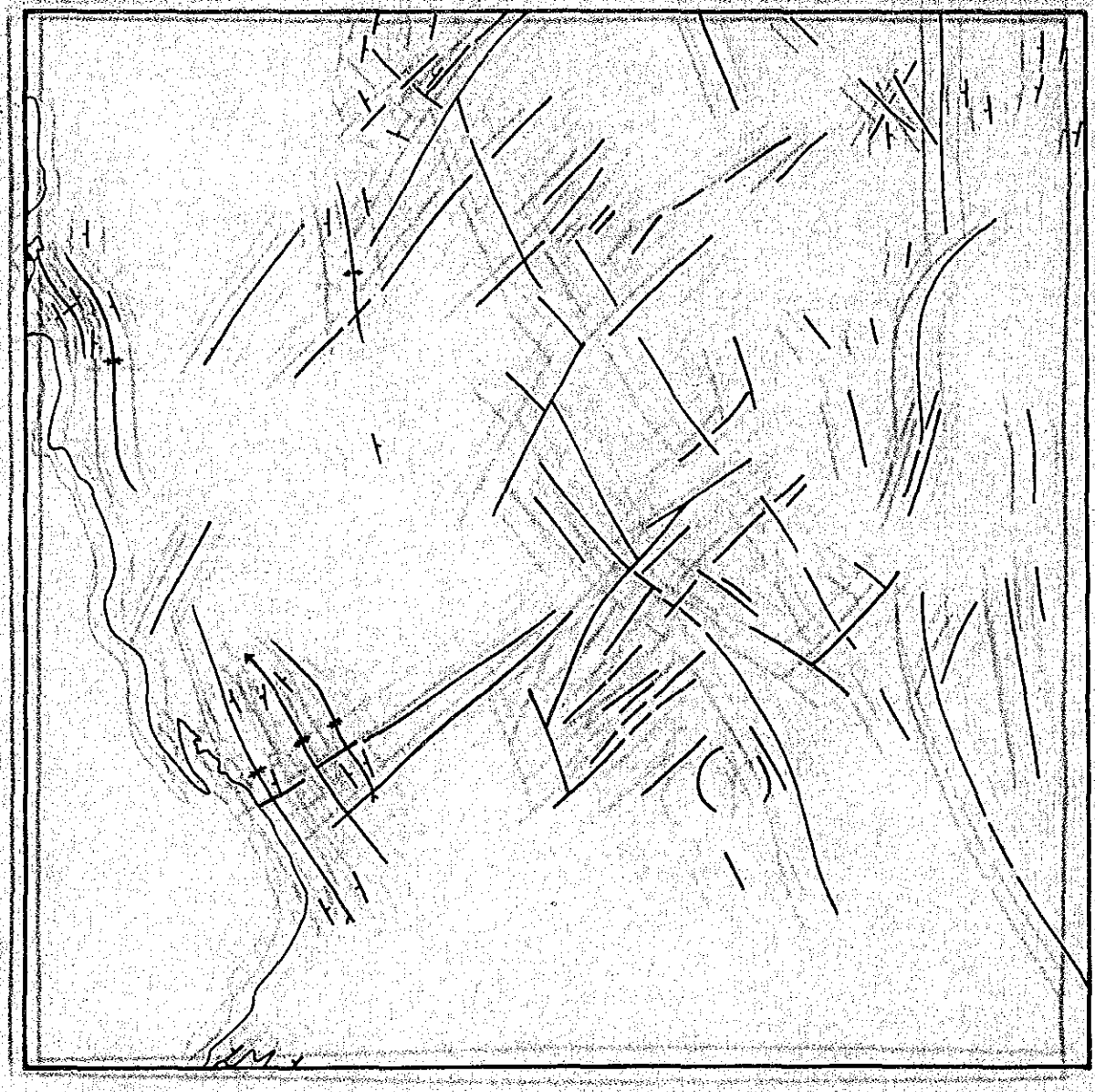

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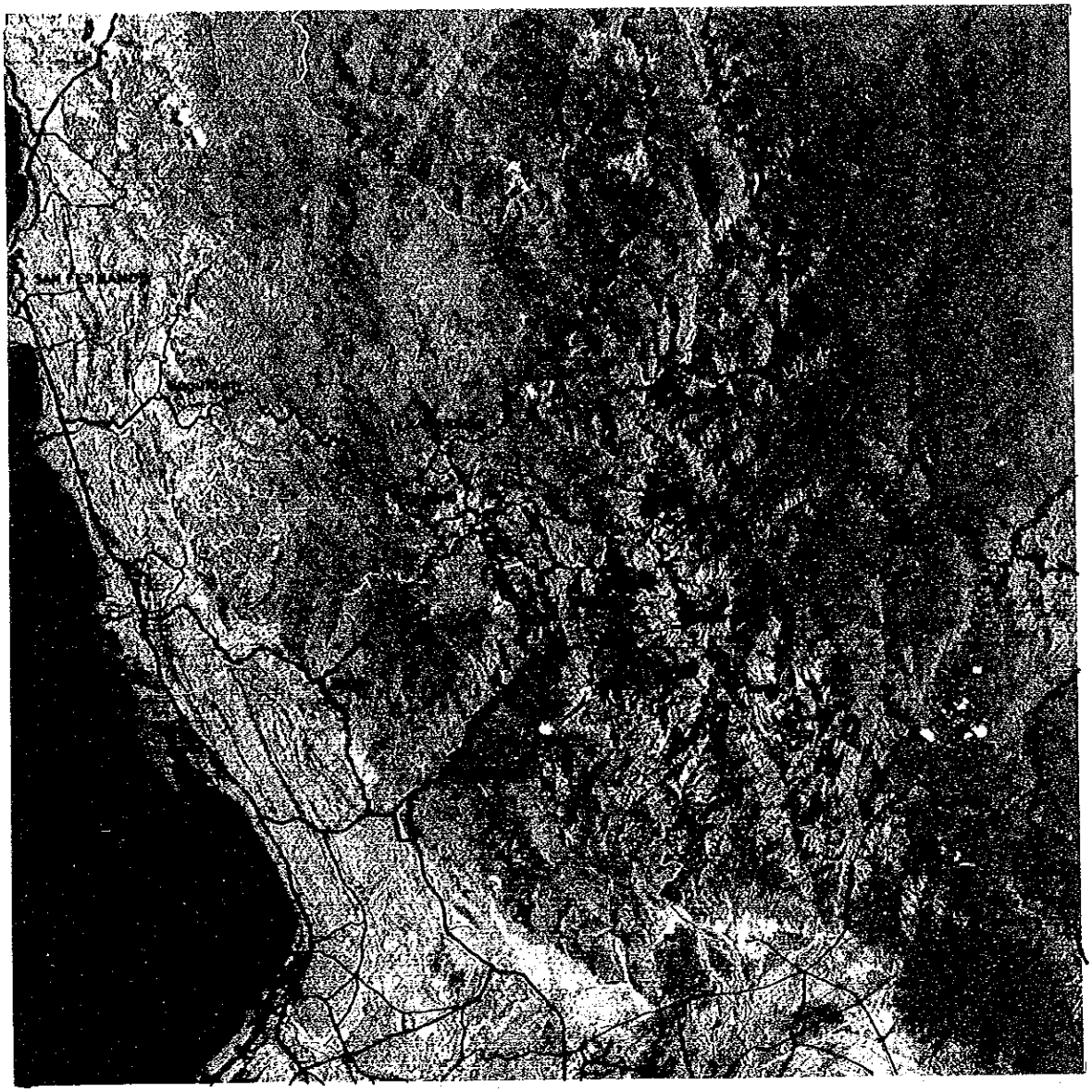

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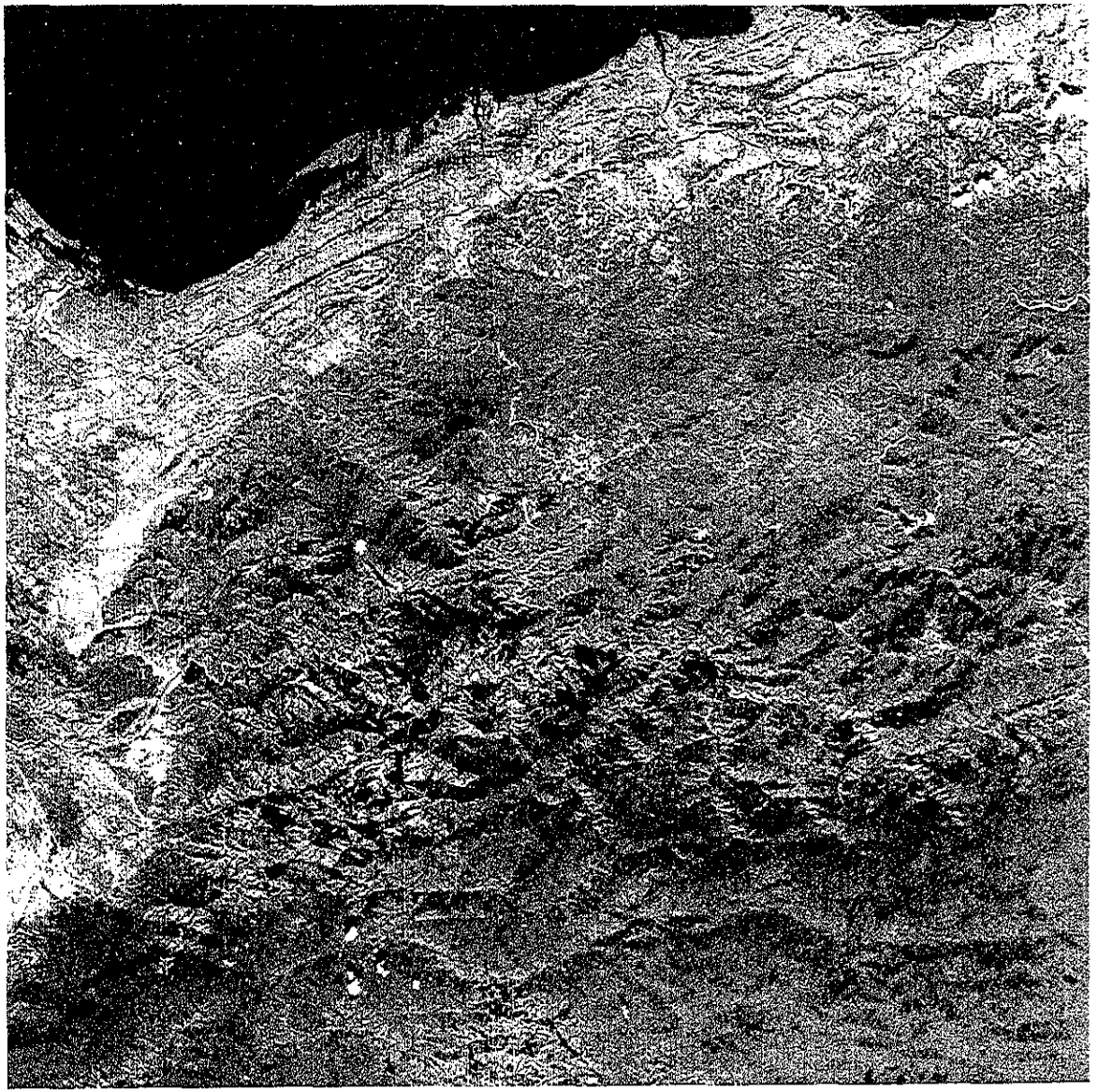

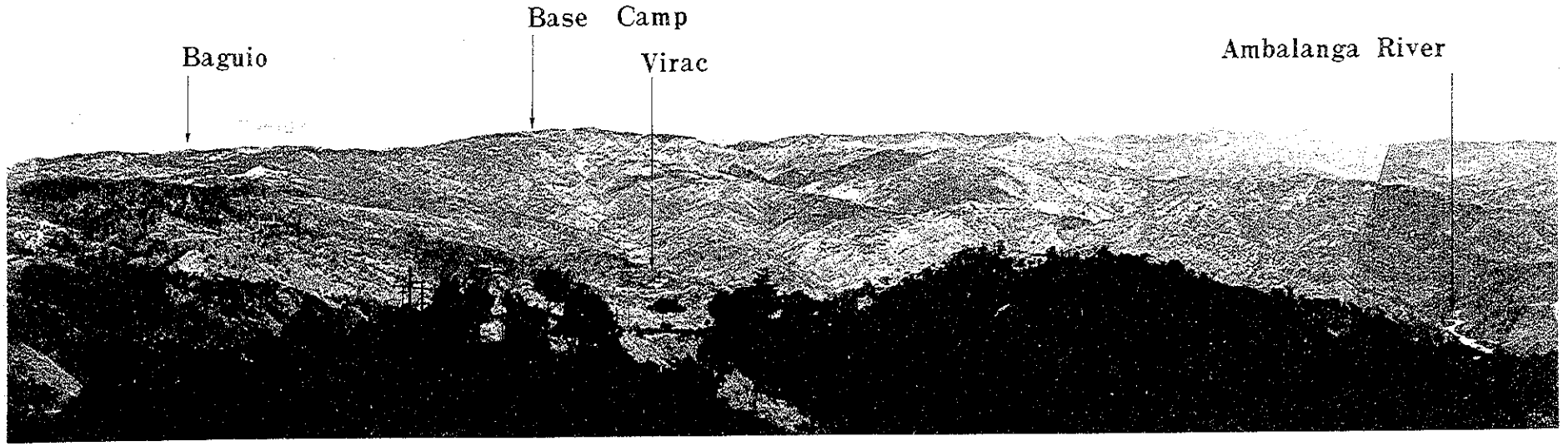

Perspective View of Acupan-Itogon

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CHAPTER 1 INTRODUCTION

CHAPTER I INTRODUCTION

1–1 Objective of the Survey

The Government of Japan in response to the request of the Government of the Republic of the Philippines has conducted the reconnaissance survey by means of geological, geochemical and geophysical explorations in Acupan-Itogon geothermal area, where the strong geothermal resources are expected to exist, in order to verify the geothermal reservoir structure as well as to select the most-promissing gradient drill sites for the next phase of the survey.

1–2 Members of the Survey Team

Team Leader	Mr. Yasunori Sakai Mitsubishi Metal Corporation	Geologist
Geological Survey (Subleader)	Mr. Eiyu Matsunaga Mitsubishi Metal Corporation	Geologist
Geological Survey	Mr. Keiji Nakano Bishimental Exploration Co., Ltd.	Geologist
Geochemical Survey	Mr. Kenji Wakita Bishimental Exploration Co., Ltd.	Geochemist
Analytical Survey	Mr. Masahiro Nara Bishimental Exploration Co., Ltd.	Analyst
Geophysical Survey (Subleader)	Mr. Asahi Hattori Bishimental Exploration Co., Ltd.	Geophysicist
Geophysical Survey	Mr. Hiroshi Fukuda Bishimental Exploration Co., Ltd.	Geophysicist
Geophysical Survey	Mr. Manabu Kaku Bishimental Exploration Co., Ltd.	Geophysicist
Geophysical Survey	Mr. Kazuto Matsukubo Bishimental Exploration Co., Ltd.	Geophysicist

COUNTERPART

Project Manager (Division Chief, Geologist)	Mr. Alfredo C. Troncales
Sr. Geophysicist	Mr. Edgardo S. Aguas
Geophysicist	Mr. Francisco A. Benito
Mining Engineer	Mr. Rene A. Villarosa
Geologist	Mr. Narciso V. Salvania
Geologist	Mr. Romeo R. Tena
Geologist	Ms. Helene G. Aniceto
Geologic Aide	Mr. Leonardo U. Elemia
Geologic Aide	Mr. Velario D. Mata
Sr. Geochemist	Mr. Zalzon C. Espino
Sr. Geochemist	Ms. Rosario D. Mosqueda
Sr. Geochemist	Ms. Evelyn M. Napoles
Geochemist II	Ms. Mona Lisa V. Agoncillo
Sr. Electrical Engineer	Mr. Rodelio T. Palabasan
Sr. Mechanical Engineer	Mr. Josefino C. Adajar
Monitoring Engineer	Mr. Manuel R. Panagsagan
Sr. Geodetic Engineer	Mr. Francisco Palabrica
Geodetic Engineer	Mr. Jose L. Cuaresma
Geodetic Engineer	Mr. Valentino Noble II
Geodetic Engineer	Mr. Allan O. Loleng
Geodetic Engineer	Mr. Cesar U. Dacanay
Cartographer	Mr. Ben P. Ignacio

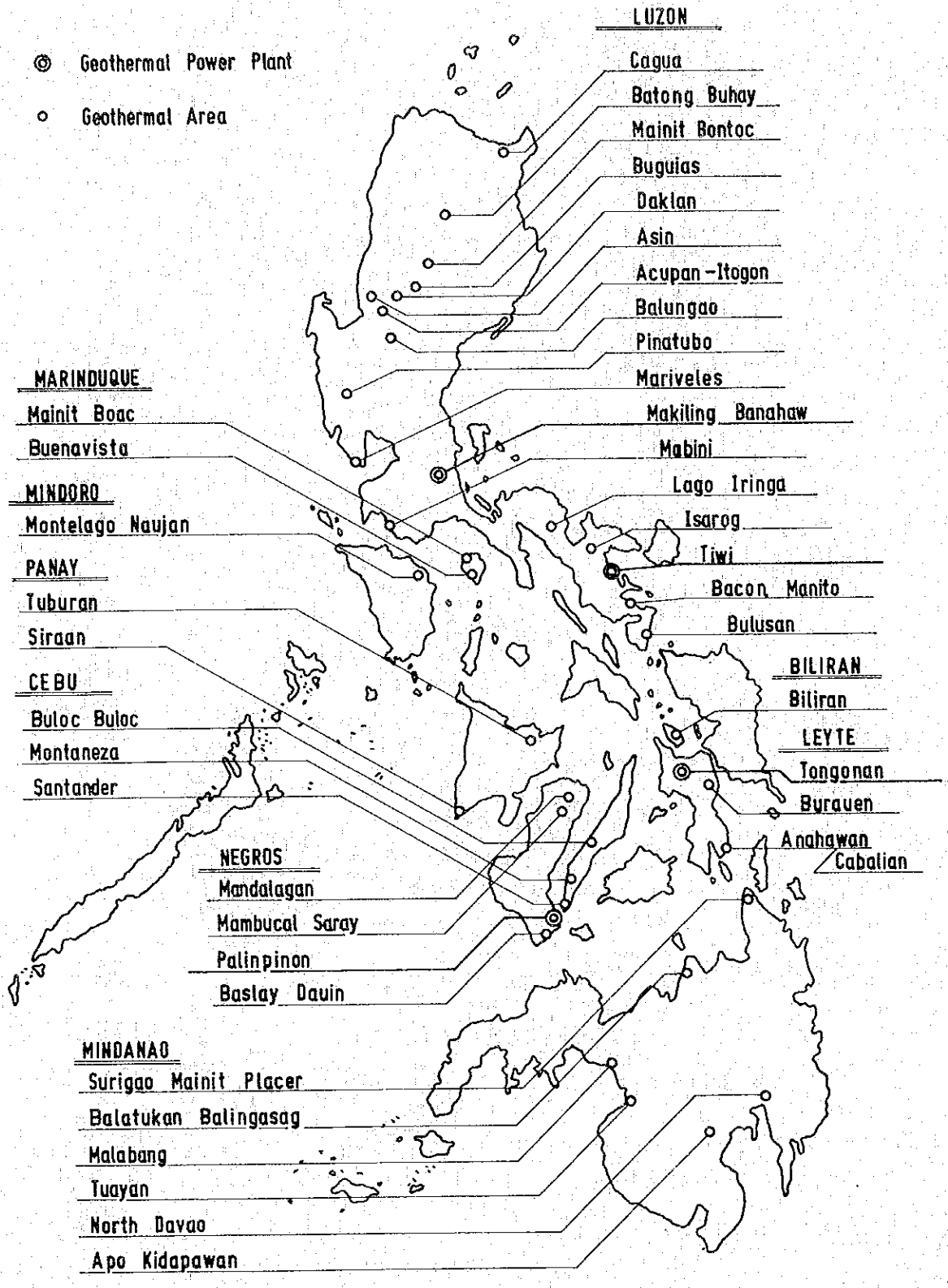
1–3 Itinerary of the Japanese Survey Team

No.	Date	Day	Schedule
	1982		
1	Aug. 8	Sun.	Team Leader, Geological Survey Team Tokyo Lv. → Manila Ar.
2	9		A courtesy call on the Japanese Embassy, JICA, BED
3	10		Arrange for the survey at BED
4	11		Providing of the equipments
5	12		Manila → Baguio
6	13		Preliminary inspection of the survey area
7	14		Beginning of the geological survey
8	15	Sun.	Team Leader Baguio → Manila
9	16		Report
10	17		Manila → Tokyo
11	18		
12	19		
13	20		
14	21		
15	22	Sun.	
16	23		
17	24		
18	25		
19	26		
20	27		
21	28		
22	29	Sun.	
23	30		
24	31		
25	Sep. 1		
26	2		
27	3		
28	4		
29	5	Sun.	
30	6		
31	7		Geochemical survey team Tokyo → Manila
32	8		
33	9		Manila → Baguio
34	10		Beginning of the geochemical survey
35	11		
36	12	Sun.	
37	13		
38	14		
39	15		
40	16		
41	17		
42	18		
43	19	Sun.	
44	20		
45	21		
46	22		
47	23		
48	24		
49	25		
50	26	Sun.	

No.	Date	Day	Schedule
51	27		Team Leader, Geophysical, Analytical survey team Tokyo Lv. → Manila Ar.
52	28		Report to the Japanese Embassy, JICA, BED
53	29		Team Leader Manila → Baguio
54	30		Excursion
55	Oct. 1		Team Leader, Geological, Geochemical team Baguio → Manila
56	2		Geophysical team Manila → Baguio
57	3	Sun.	Beginning of the geophysical survey
58	4		Discussion
59	5		〃
60	6		Geological, Geochemical team Manila → Tokyo Team Leader Manila → Baguio
61	7		
62	8		
63	9		
64	10	Sun.	
65	11		Team Leader Baguio → Manila
66	12		Report the interim report
67	13		Manila → Tokyo
68	14		
69	15		
70	16		Analytical survey team Manila → Tokyo
71	17	Sun.	
72	18		
73	19		
74	20		
75	21		
76	22		
77	23		
78	24	Sun.	
79	25		
80	26		
81	27		
82	28		
83	29		
84	30		
85	31	Sun.	
86	Nov. 1		
87	2		
88	3		
89	4		
90	5		
91	6		
92	7	Sun.	
93	8		
94	9		
95	10		
96	11		
97	12		
98	13		
99	14	Sun.	

No.	Date	Day	Schedule
100	15		
101	16		
102	17		
103	18		
104	19		
105	20		
106	21	Sun.	
107	22		
108	23		
109	24		
110	25		Geophysical survey team Baguio → Manila
111	26		
112	27		Team Leader Tokyo → Manila
113	28	Sun.	
114	29		Arrange the survey data
115	30		〃
116	Dec. 1		General discussion on geology and geophysics
117	2		〃
118	3		Discussion on the result of the survey
119	4		Final report to the Japanese Embassy, etc.
120	5	Sun.	Team Leader, Geophysical survey team Manila → Tokyo

CHAPTER 2 GEOTHERMAL ACTIVITIES IN PHILIPPINES



Geothermal Resource Area in the Philippines

CHAPTER 2 GEOTHERMAL ACTIVITIES IN THE PHILIPPINES 1982

The Philippines is presently generating 556 megawatts of electricity from the geothermal fields of Tiwi in Albay, Makiling-Banahaw in Laguna, Tongonan in Leyte and Southern Negros. The bulk of the power generated comes from Tiwi and Mak-Ban which produce 330 MWe and 220 MWe, respectively. The two fields, located in Luzon Island, are operated by the Philippine Geothermal Inc. (PGI) and National Power Corporation (NAPOCOR). The remaining 6 MWe comes from the 3-MWe pilot plant in Tongonan and the two 1.5-MWe units in Southern Negros. The development of Tongonan and Southern Negros is undertaken by the state-owned Philippine National Oil Company-Energy Development Corporation (PNOC-EDC) with technical assistance from the New Zealand government. These two fields expected to be on a full scale power generation by 1983, will produce an additional 225 MW of electricity (i.e. 112.5 MW from each field). This will boost the geothermal power generation to 781 MW (Fig. I–2–1).

Aside from the four geothermal fields (Tiwi, Mak-Ban, Tongonan, and Southern Negros) undergoing advanced stages of development, other Potential areas are being investigated and explored by both private and government entities. PNOC-EDC is engaged in various phases of exploration in Bacon-Manito in Sorsogon-Albay; Biliran Island and Burauen in Leyte; Mt. Pinatubo in Zambales; Mambucal in Northern Negros; Montelago in Oriental Mindoro; and in North Davao.

Similarly, CALTEX Philippines and TOTAL/POGEI are probing the potentials of Batong-Buhay in Kalinga-Apayao and Mt. Labo in Camarines Norte-Camarines Sur, respectively.

Geoscientific studies are being undertaken in Acupan-Itogon in Benguet by the Bureau of Energy Development (BED) and the Japanese International Cooperation Agency (JICA) prior to the drilling of 7 shallow gradient wells in 1983.

A total of 287 geothermal wells has been drilled as of December 1982 with a rated power generating potential of 1,377 MW.

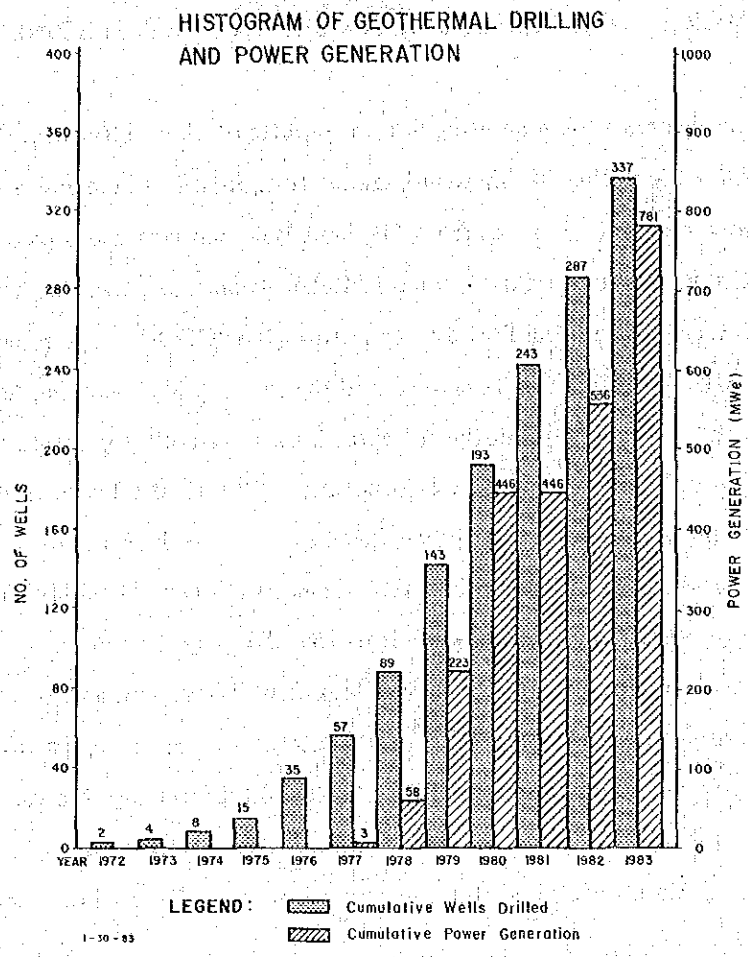


Fig. I–2–1 Histogram of Geothermal Drilling and Power Generation

2–1 Development and Production Stage:

TIWI Geothermal Field, Albay

The field is being operated by PGI and NAPOCOR. Since the start of development drilling in 1972 (Fig. I–2–2), a total of 95 wells have been drilled, eighty-five (85) of which have a combined power potential of 511 MW (Table I–2–1). The field presently contributes 330 MWe to the Luzon Power grid.

Development drilling for a fourth power plant to generate another 110 MWe has been temporarily suspended until the resource of a newly discovered area (Sadurong), located southeast of the present borefield, has been delineated by detailed geoscientific work.

MAK-BAN Geothermal Field, Laguna

The field is likewise operated by PGI and NAPOCOR. A total of 83 wells (Table I–2–1) have been drilled in the area since 1974 (Fig. I–2–3). Fifty-five (55) of these wells are commercial wells with a proven power potential of 352 MW, eighteen (18) are for reinjection while the remaining 10 are dry wells.

On-going activities in the field include production drilling with one rig in operation (Table I–2–3) and construction of the third power plant to house units 5 and 6. The power plant, geared for commissioning in 1984, is to produce 110 MWe of electricity. Programmed to be operational by 1985 is another 110 MWe power plant.

TONGONAN Geothermal Field, Leyte

A total of fifty (50) wells have been completed as of December 1982 with a rated power capacity of 336 MW (Fig. I–2–4) coming from 40 wells.

The first 37.5-MWe unit of the 112.5-MWe power plant (Leyte I) will be commissioned in March 1983. This power plant is expected to generate at full capacity by mid-1983.

The major thrust of PNOC-EDC's work program in Tongonan for 1983 will be development drilling to supply steam for Leyte II (2 x 55 MWe). Ten directional wells will be drilled in the area with an aggregate depth of 29,228.89m. Two (2) rigs will be utilized in the drilling operation (Table I–2–3).

Construction of the steam gathering and effluent disposal system of Leyte II will start in late 1983.

Six (6) km. of new roads will be constructed and fourteen (14) cellars will be made ready by the end of 1983 as options for drilling sequences to be formulated in the course of operations.

On the one hand, the southeastern section of Tongonan will be subject to detailed geological and geochemical mapping for three (3) activity-months to complete the surficial data of the entire Tongonan field.

SOUTHERN NEGROS Geothermal Field

As of December 30, 1982, a total of thirty-six (36) wells (Fig. I–2–5) have been completed in the area with twenty three (23) wells producing 138 MW (Table I–2–1).

The already installed three 37.5-MWe generating units of Palimpinon I is programmed for commissioning before the end of 1983. Meanwhile, construction of the power plant's steam gathering and effluent disposal system is underway.

Similarly, development drilling for the next power plant (Palimpinon II) that will generate another 112.5 MWe, is now in full swing with five (5) rigs in simultaneous operation (Table I–2–3). Targetted for 1983 is sixteen (16) deviated wells to serve as production or reinjection wells for the proposed plant. Construction of the steam gathering and effluent disposal system for this plant will commence in December, 1983.

Civil works to support the Palimpinon II development drilling include construction of 3 km. of roads, widening and preparation of several sites to accomodate 12 cellars as strategic target pads.

2–2 Advance Exploration Stage:

BACON-MANITO Geothermal Area

As of December 30, 1982, ten (10) wells have been completed in the area. Of these, six (6) are producing with a total rated power potential of 33 MW (Table I–2–2).

Table I–2–2 Advance Stage of Exploration

	MANITO	BILIRAN	DAKLAN	NORTH DAVAO	NORTHERN NEGROS
1. Total Wells Drilled	10	3	5	2	3
2. Total Depth (M)	20,600	7,322	12,641	2,653	2,943
3. Average Depth of Well (M/well)	2,060	2,441	2,528	1,326	981
4. Proven Power Potential (MW)	33	7	–	–	–

Table I–2–1 Production and Development Stage (1982)

	TIWI	MAK-BAN	TONGONAN	SOUTHERN NEGROS
1. Total Wells Drilled	95	83	50	36
2. Total Depth	144,801	165,307	105,437	95,339
3. Average Depth (M/well)	1,524	2,025	2,109	2,648
4. Number of Productive Wells	85	55	40*	23**
5. Number of Non-Producing Wells	10	10	1	9
6. Number of Re-injection Wells	0	18	9	4
7. Number of Wells to be tested	0	0	8	3
8. Power Generating Capacity From Steam Producing Wells (MW)	511	352	336	138
9. Average Capacity of Producing Wells (MW/well)	6	6.4	8.4	6
10. Installed Power Capacity	330	220	3	3

* includes 8 reinjection wells
** includes 1 reinjection well

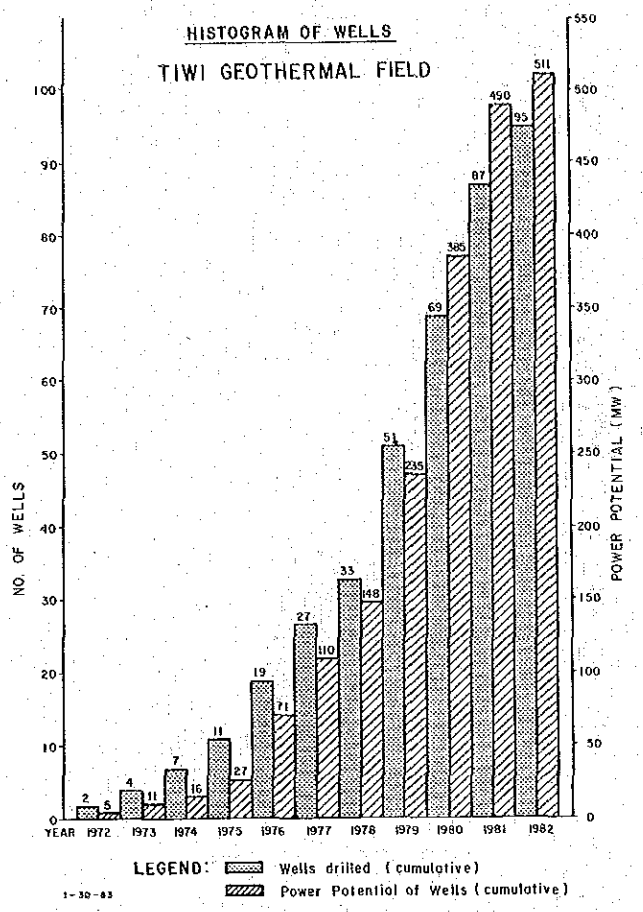


Fig. I–2–2 Histogram of Wells, Tiwi Geothermal Field

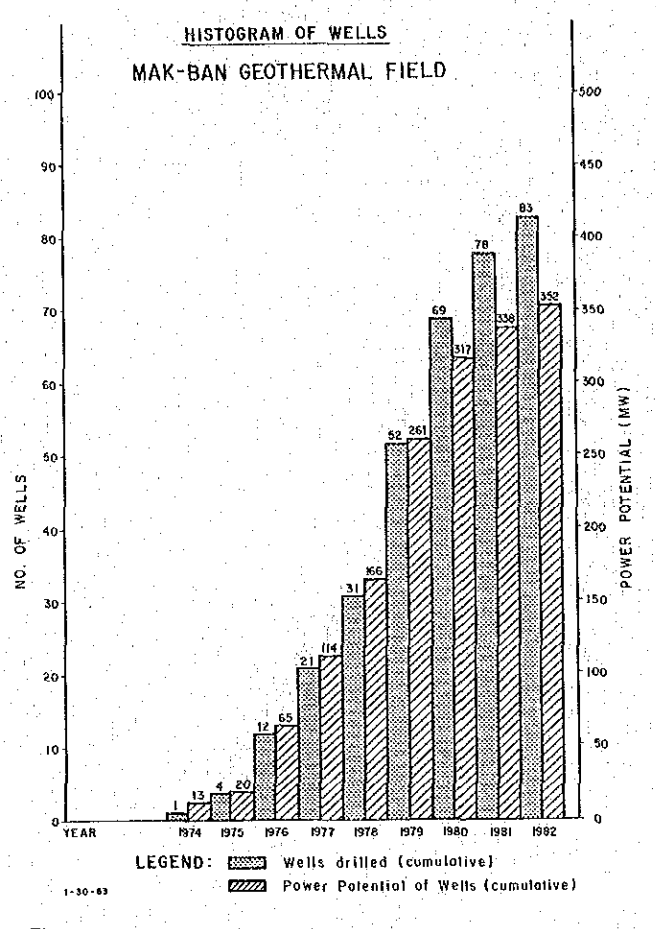


Fig. I–2–3 Histogram of Wells, Mak-Ban Geothermal Field

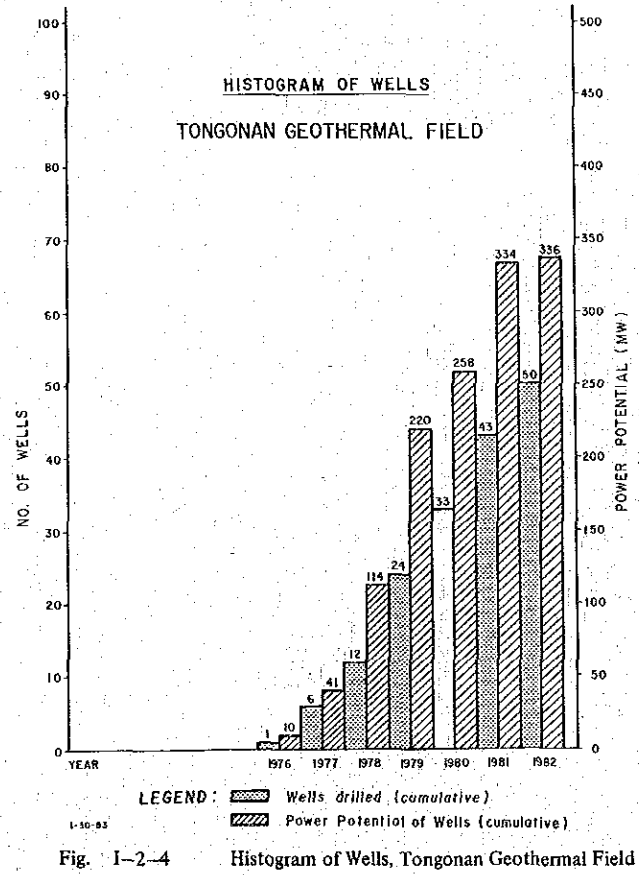


Fig. I–2–4 Histogram of Wells, Tongonan Geothermal Field

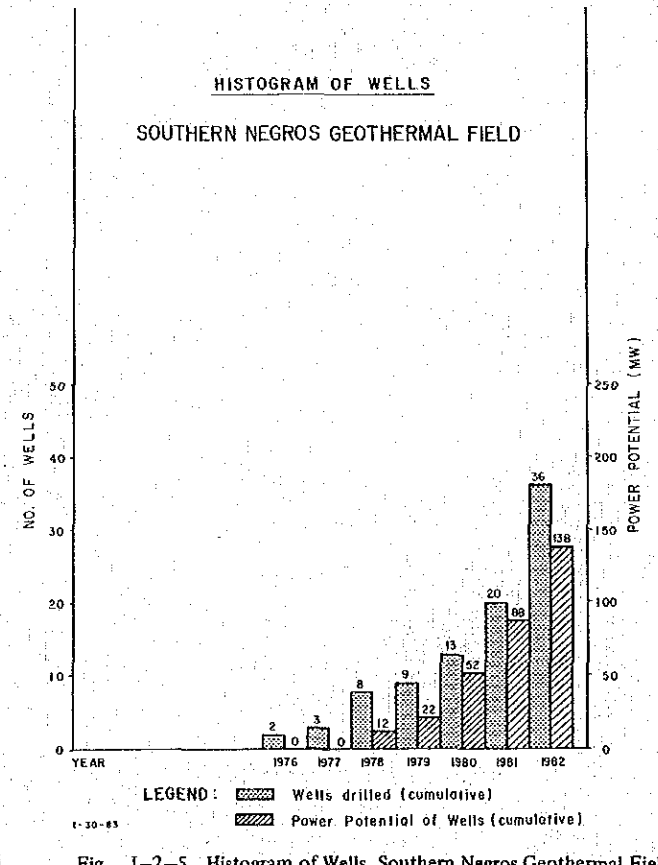


Fig. I–2–5 Histogram of Wells, Southern Negros Geothermal Field

With the very promising results obtained from the deep exploratory wells drilled in 1982 and CN-1 in 1981, the Rig #3 of EDI (Table I–2–3) will be utilized to drill development wells for the proposed 110-MWe power plant due to be commissioned in 1986. Five (5) directional wells, each one with a programmed depth of 2743.07 m., are to be completed in 1983. Infrastructure work to support drilling will involve the preparation of seven drill sites and the construction of 6 km. of access roads.

BILIRAN ISLAND, Leyte

Since the start of deep exploratory drilling in March 1982, three (3) wells have been completed. Two of these wells (BN-2 and -3) were successfully discharged with a total rated power capacity of 7 MW, while the BN-1 was unable to sustain discharge. Monitoring and testing of these wells will be undertaken in 1983 for purposes of evaluating the resource. In addition, three (3) months will be allotted for the completion of the detailed geology of the island and another 3 months for the gravimetric survey.

NORTH DAVAO

The geoscientific work completed in 1982 in Amacan consisted of reconnaissance and detailed geological surveys covering 257 km^2 and vertical electrical sounding over 32 stations.

Drilling of three (3) 2590.7 m. deep exploratory holes is scheduled for 1983 after evaluation of previous geoscientific surveys and tests and studies of the three shallow wells drilled in 1978 revealed the likely existence of a deeper geothermal resource in the area.

NORTHERN NEGROS

In Mambucal, reconnaissance and detailed geological and geochemical surveys over 190 km^2 were conducted in 1982.

For 1983, PNOC-EDC has programmed the drilling of two (2) deep exploratory wells in the area to verify the existence of a deeper geothermal resource suggested by the two shallow wells drilled in 1978.

2–3 Preliminary Exploration Stage:

BURAUEN, Leyte

Three (3) drill sites were proposed in this area after extensive geoscientific work in 1981 and 1982 by PNOC-EDC. Drilling will commence after the mobilization of EDI Rig #7 from Baslay Dauin (Southern Negros).

Vertical electrical soundings and Schlumberger resistivity surveys will be conducted in 1983 to firm up the geophysical characteristics necessary to support exploratory interest in the area.

BATONG-BUHAY, Kalinga, Apayao

CALTEX, Philippines has partially fulfilled its work obligations under a non-exclusive geothermal exploration permit granted last February 10, 1982. Geological, geochemical and geophysical surveys were carried out over an area of 40,000 hectares. In addition, five (5) shallow temperature gradient wells were drilled in the area which gave significant high temperature gradients. At an average depth of 244 m, the wells registered a temperature range of 70°C to 178°C. Four of the wells self-discharged. The permit has been extended by BED to June 1983 to give CALTEX sufficient time to conduct additional resistivity surveys within the area of interest.

MT. LABO, Camarines Norte

A one-year non-exclusive geothermal exploration permit was granted last March 23, 1982 to the TOTAL Exploration/Philippine Oil and Geothermal Exploration Inc. (TOTAL/POGEI) to undertake geoscientific exploration over an area of 120,000 hectares. They have completed the reconnaissance geological, geochemical and geophysical surveys in the area. Semi-detailed geochemical, soil sampling for mercury analysis and resistivity work are still underway.

MT. PINATUBO, Zambales

PNOC-EDC has conducted reconnaissance to semi-detailed geological and geochemical surveys covering 400 sq. km. Geophysical surveys involving Schlumberger resistivity work were also carried out with completion of 129 vertical electrical sounding stations.

MONTELAGO, Mindoro Oriental

Reconnaissance geological and geochemical surveys covering an area of 940 sq. km. were conducted in 1982 by PNOC-EDC.

Table I–2–3 Drilling Rig Location

(1983)

A. TONGONAN, Leyte

1. PNOC-EDI's Rig #2 (Wilson Mogul)
2. PNOC-EDI's Rig #8 (EMSCo D3)

B. SOUTHERN NEGROS

3. PNOC-EDI's Rig #1 (Romanian)
4. PNOC-EDI's Rig #4 (National 610)
5. PNOC-EDI's Rig #6 (National 610)
6. PNOC-EDI's Rig #5 (National 610)
7. Richter Rig #8 (National 110)
8. PNOC-EDI's Rig # (IDECo H-525); Baslay Dauin area

C. MAK-BAN, Laguna

9. Richter Rig #6

D. BACON-MANITO, Sorsogon-Albay

10. PNOC-EDI's Rig #3 (IDECo 725)

E. NORTH DAVAO

11. PNOC-EDI's Rig #9 (National 370)

A wide ranging Schlumberger resistivity survey and deep vertical electrical soundings are programmed for 1983.

ACUPAN-ITOGON, Benguet

In connection with the suspended exploration work in Buguias Geothermal Project, in June 1981, the Acupan-Itogon geothermal Prospect area was selected as alternate site for the continuous implementation of the Bureau of Energy Development-Japan International Cooperation Agency (BED-JICA) Technical Arrangement on Geothermics.

On March 1982, a new technical arrangement was signed between BED and JICA for the Acupan-Itogon project. The work program under this new arrangement was implemented in August 1982.

Reconnaissance geological and geochemical surveys were carried out over an area of 300 sq. kilometers. In addition, semi-detailed geophysical investigation consisting of gravity, magnetic and dipole-dipole resistivity surveys were also undertaken in the area.

2–4 Geothermal Exploration Permits:

Two (2) geothermal exploration permits were granted early this year (Table I–2–4) to CALTEX, Philippines and TOTAL-POGEI in Batong-Buhay and Mt. Labo Geothermal Areas respectively.

NEGOTIATIONS:

1. PNOC-EDC has submitted an application for a geothermal exploration permit for 15 prospect areas (Table I–2–4). Of the fifteen (15) areas, only eleven (11) are being considered by BED since three (3) are already committed in the proposed 4th year extension of the Philippine-Italian Technical Agreement while one (1) has a pending application filed by Ultrana Nuclear and Minerals Corporation.
2. BED is still waiting for the approval of the proposed 4th year extension of the Philippine-Italian Technical Cooperation Program on Geothermics. The program will cover two years of preliminary evaluation and detailed geoscientific studies on new prospective areas. The areas to be investigated include Pinatubo in Zambales; Mainit-Placer in Surigao del Norte; Kidapawan in North Cotabato; and Lake Wood in Zamboanga del Sur.

OUTLOOK FOR 1983:

In terms of geothermal power production, the Philippines is expected to generate an additional 225-megawatts of electricity. The additional power will come from the PNOC operated geothermal fields in Tongonan (112.5 MWe) and Southern Negros (112.5 MWe).

Fifty (50) vertical and directional wells will be drilled in 1983 to further increase the geothermal power potential.

In the exploration side, seven (7) shallow gradient wells will be drilled in the Acupan-Itogon area under the BED-JICA Technical Agreement. On the other hand, deep geothermal wells will be drilled in North Davao and Northern Negros to verify the existence of a geothermal resource.

Table I–2–4 Application List for Geothermal Exploration Permit

I. APPROVED GEOTHERMAL EXPLORATION PERMIT IN 1982

A. CALTEX, Philippines

1. Batong-Buhay, Kalinga-Apayao

B. TOTAL Exploration – POGEI

1. Mt. Labo, Camarines Norte

II. GEOTHERMAL AREAS UNDER NEGOTIATION FOR EXPLORATION IN 1982

A. PNOC-EDC

1. Panay, Antique
2. Balingasag, Misamis Oriental
3. North Davao
4. Northern Negros
5. Anahawan, Southern Leyte
6. Montelago, Oriental Mindoro
7. Mabini, Batangas
8. Mt. Arayat, Pampanga
9. Mt. Balungao, Pangasinan
10. Irosin-Bulusan, Sorsogon
11. Malindang, Misamis Occidental

B. BED-ELC

12. Mt. Pinatubo, Zambales
13. Mt. Apo, Davao
14. Mainit, Surigao

C. ULTRANA NUCLEAR AND MINERALS CORPORATION (UNMC)

15. Buhi-Isarog, Camarines Sur

PART II PARTICULARS

CHAPTER 1 GEOLOGICAL INVESTIGATION

CHAPTER 1 GEOLOGICAL INVESTIGATION

1–1 Purpose and Methods of the Geological Survey

The geological investigation of the Acupan-Itogon area (300 km^2) was carried out basically to analyze the regional structures controlling the movement of the geothermal fluid. The geological/structural results in conjunction with the geochemical and geophysical data are used to:

(1) delimit the probable reservoir and

(2) select the sites for deep exploratory drilling.

Two methods were used in the survey:
(Fig. II–1–1).

(1) Analysis of satellite and air photos. The interpretation of satellite photos was done over a total surface area of 9,000 km^2 which included the areas of Acupan-Itogon, Buguias, (surveyed last year) and Daklan. The exercise defines structures, lineaments and the main geological subdivisions over the coverage. On the other hand, the air photo interpretation outlined the distribution of alteration zones.

(2) Reconnaissance Geological Survey (300 km^2). Geological Survey (300 km^2). Geological mapping was conducted along 220 km of survey routes to collect information on the regional stratigraphy and geological structures. More than 300 rock samples were taken along the reconnaissance routes, 220 of which were brought to Japan for thin section microscopy, radio chronological measurements and other supplementary analyses.

1–2 Geological Setting

The northern part of Luzon Island, where the investigated area is located, lies between two oceanic troughs. It constitues an island are of type III (Sugimura and Ueda, 1973) characterized by deep focus earthquakes and Quaternary volcanoes.

The geological structure of Northern Luzon is basically made up of anticlinorium and synclinorium blocks arranged in the North-South direction. Arranged in succession from east to west are the Sierra Madre anticlinorium, the Cagayan synclinorium, the Cordillera Central anticlinorium and the Ilocos synclinorium; they are limited to the South by the Central Plain. The framework of the area was formed as a result of structural movements that occurred from Lower to Middle Cenozoic and was completed during late Cenozic by block movements.

The investigated area is located in a region called Baguio gold district, characterized by the occurrence of majority of the gold deposits as well as porphyry copper deposits. Therefore, may investigations have been made on its geology (Smith, 1905; Dickerson, 1923; Leith, 1938;

Corby et al, 1952;Schaffer, 1954;Durkee & Pederson, 1961; Peña, 1969; Peña & Reyes, 1970; Wolfe, 1972; Francisco et al., 1974; Hashimoto, 1975; BCI, 1976; MMAJ & JICA, 1977; Balce et al., 1979; Kanno, 1981; JICA, 1982; Santos, 1982) and its ore deposits (Schafer, 1937; Livingston, 1939; Worley, 1967; BCI, 1976; Sawkinds et al., 1979) (Table II-1-1). One major problem that directly concerns geothermy arises from differing opinions of these authors on the question of the age of the Balatoc Plug which is related to gold and silver mineralizations and hot spring activity. According to BCI (1976), the Balatoc plug was emplaced in the Quaternary, whereas, Balce et al. (1979) gave it a late Tertiary age. A resolution on the age of the volcanic rocks related to the present geothermal system was one of the important matters undertaken.

The investigated area consists of metamorphic, volcanic, sedimentary and intrusive rocks. Stratigraphically, the following formations are distinguished; the Dalupirip metamorphic rocks and the Pugo group (metavolcanics and metasediments), both of pre-Neogene age; the Zigzag volcanics, Klondyke group of sediments and Rosario group of sediments of late Tertiary age; and the Pleistocene Balatoc plug and terrace deposits. With regards to the intrusive rocks, besides the plutonic rocks of the so-called Agno Batholith, intrusions consisting of plutonic, hypabyssal and volcanic rocks are found at several places. Some of them are closely related to the porphyry copper or gold-silver mineralizations.

1-3 Satellite and Airphoto Interpretation

The Photo Interpretation was carried out to define the lineaments and the geological units of the area.

1-3-1 Interpretation of Satellite Photos (photograph on first page)

The analysis was aimed to compare the geologic studies of the investigated area with those of the adjacent areas of Buguias and Daklan, where geothermal indications are already known, in order to obtain, on a relatively large scale, data about the potential geothermal reservoir. Black-and-white imagery (at the scale 1/1,000,000 and 1/250,000 for each band) obtained from Landsat image using three bands (4,5,7) on 70 m/m reflex film (ID No. E-2456-01345) of multispectral scanner and false color imagery were used.

The area of study is located between N150°50' and N16°48', and between E120°15' and E121°55' covering about 8000 km^2.

The mode of analysis is as follows: (1) the drainage system is first drawn; (2) the lineaments and their attitudes are defined; and (3) the geologic units are delineated using several criteria such as color, types of water-course, density of the drainage system, roughness and resistance.

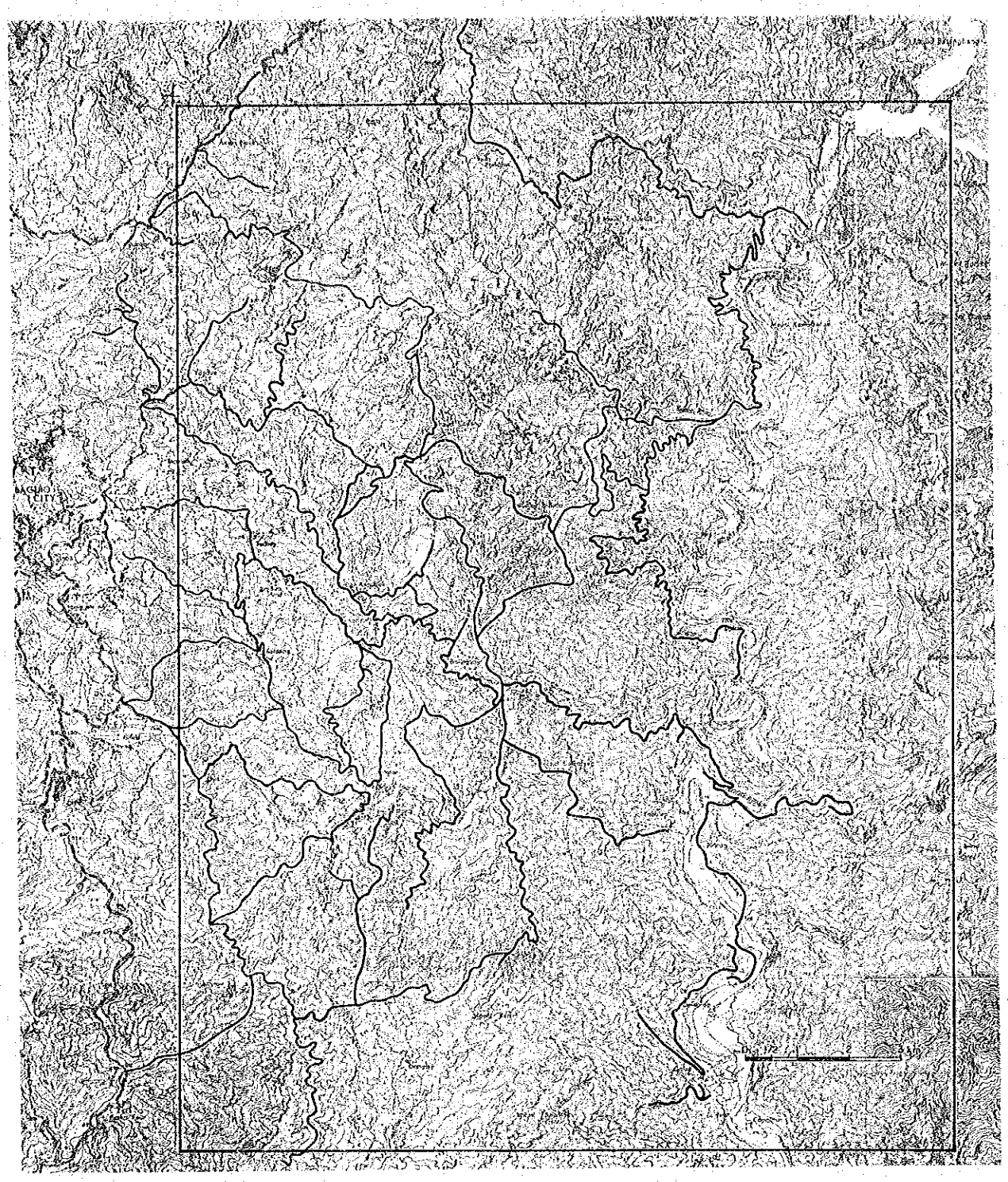
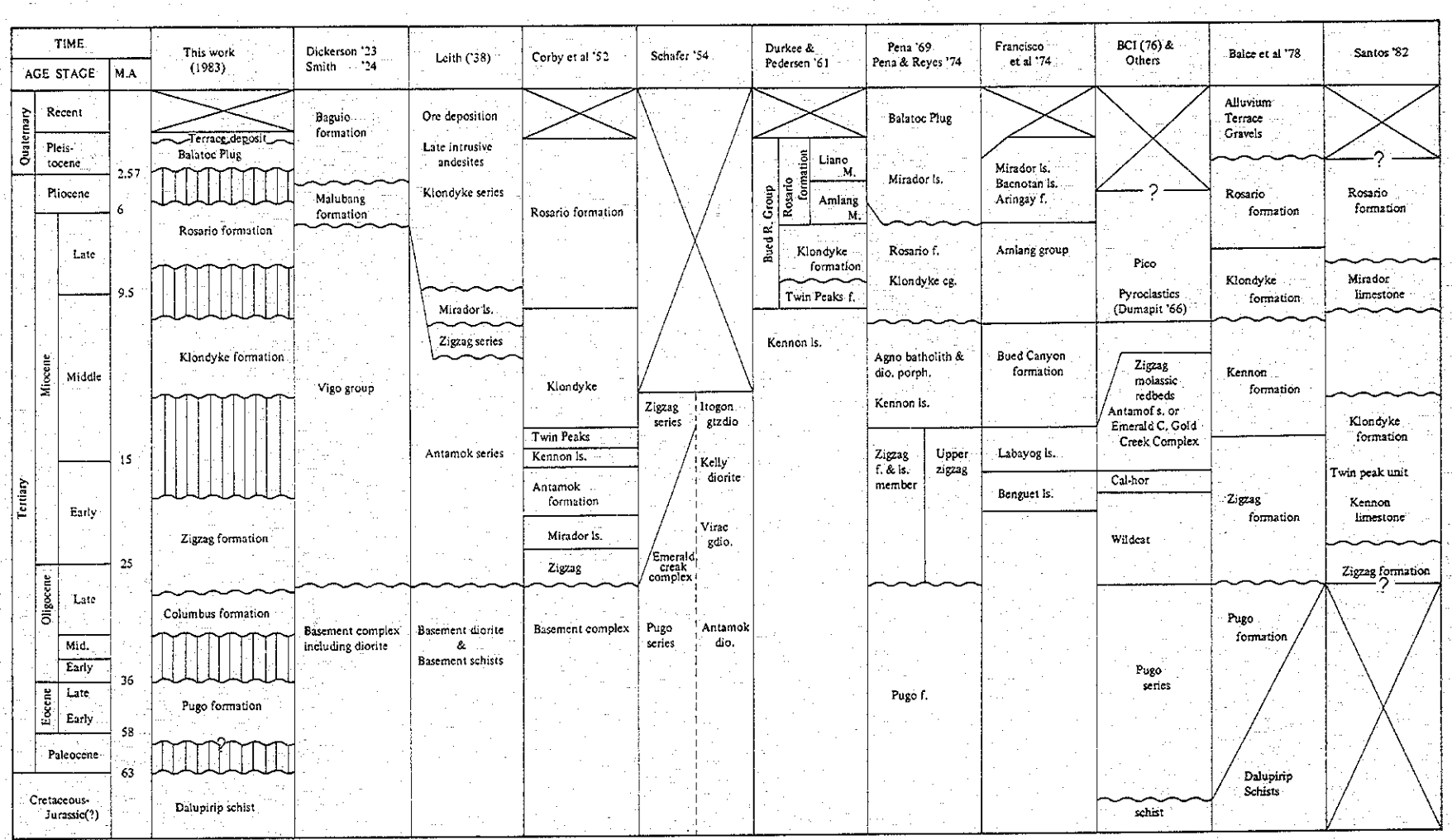


Fig. Ⅱ-1-1 Coverage of Geological Survey

Table II–1–1 Correlation of Rock and Stratigraphic Names



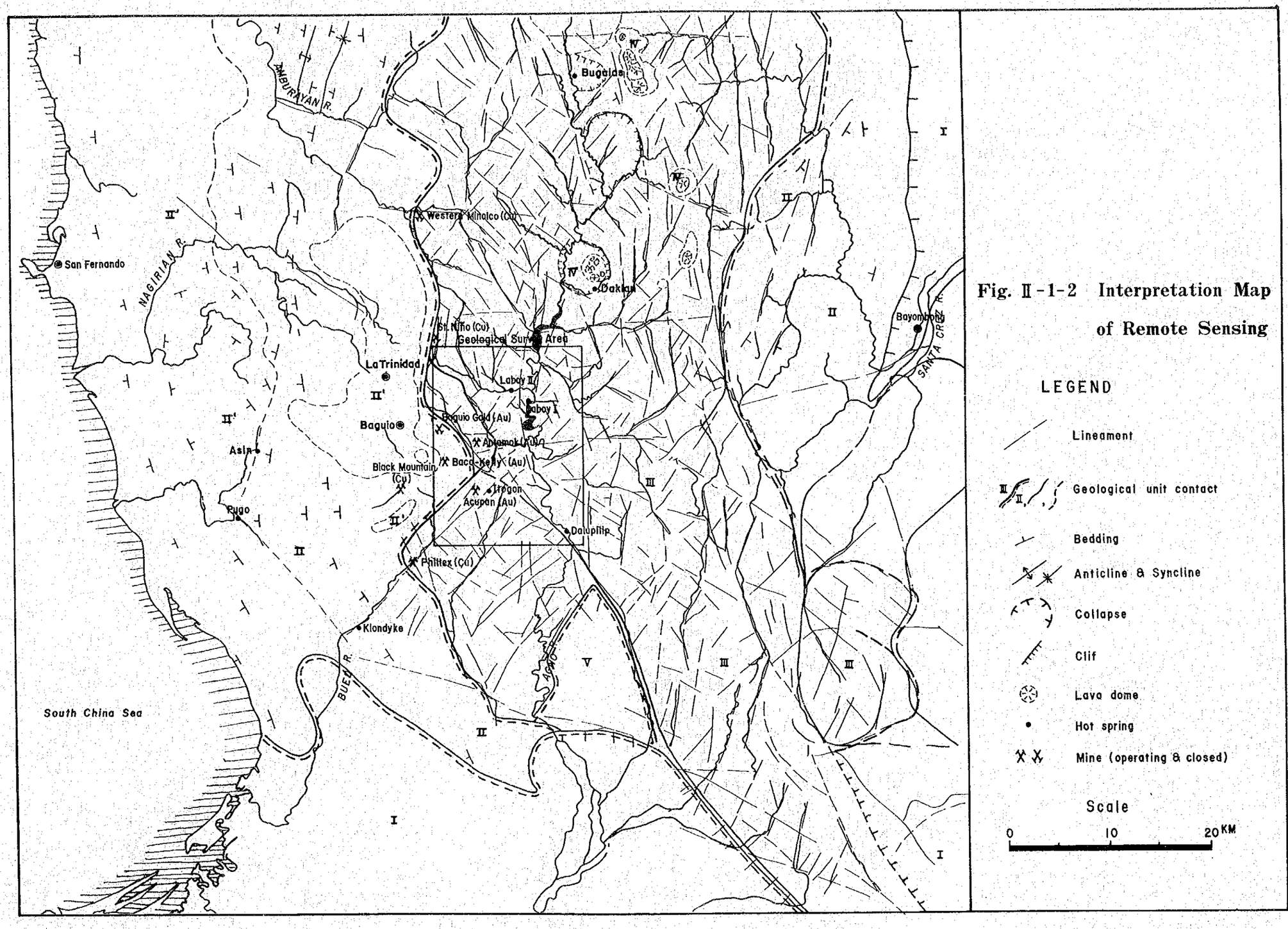


Fig. Ⅱ-1-2 Interpretation Map of Remote Sensing

Six (6) units, including a sub-unit II', are distinguished in the area. (Fig. II–1–2). The correspondence between these units and those from existing geological maps are:

Geological Unit I : Quaternary (sediments);
Geological unit II : Middle Miocene – Pliocene;
Geological unit II' : Pliocene
Geological unit III : Cretaceous to Lower Miocene, (Plutonic rocks);
Geological unit IV : Quaternary (volcanics);
Geological unit V : Cretaceous (metamorphics).

Unit II, straddling unit III on both sides, exhibits lineaments different from the third one. The contact of these units has a N–S orientation.

Geological unit I: this unit is distributed: (a) an the southern part of the investigated area; (b) in the Central Plain of Luzon; and (c) along Cagayan Valley in the northeastern side of the area. The features include: (a) brown in false-color imagery corresponding to cultivated lands: (b) rivers show sinuous contours; (c) high drainage system density; (d) lineaments do not appear very clearly; (e) texture is smooth; and (f) the degree of resistance very small. This unit covers zones of low altitude composed of horizontally bedded Quaternary sediments.

Geologic unit II: this unit appears (a) on the eastern side of the analyzed area; (b) as an elongated zone along Cagayan Valley; and (c) as a zone elongated in the N–S direction on the western side. Its characteristics are: (a) red – brown in false-color imagery, and generally covered by forests, locally by plantation; (b) rivers show parallel course with the drainage system relatively loose; (c) the lineaments run North-South, and cuesta morphologies may be seen; the stratifications revealed by these cuestas strike N–S and dip either West or East; and (d) the roughness is high, and the degree of resistance is intermediate. This unit covers lowlands as well as mountain areas and consists of Upper Tertiary formations folded on a large scale and tilted toward the West.

Geological unit II': this unit covers unit II and is distributed in the mountain areas of the western part of the analyzed region and along the western coastal area. It is red in false-color imagery and corresponds to forests or plantations. The rivers show tree patterns with shallow valleys; the drainage density is relatively high. Lineaments do not appear clearly. The roughness is low, and the degree of reistance is small. This forms highlands with loose plateau morphologies and it cuts the stratification of unit II located above it. It corresponds to the limestone and other rocks of Upper Tertiary age.

Geological unit III: this unit is distributed on a N–S elongation, in the central part of the