

PRELIMINARY SURVEY FOR THE  
 GEOTHERMAL DEVELOPMENT PLAN  
 IN THE REPUBLIC OF THE  
 PHILIPPINES

JAPAN INTERNATIONAL COOPERATION  
 AGENCY

L E G E N D

— PROJECTED DEPTH OF RESERVOIR  
 WITH TEMPERATURE 220°C  
 (ASSUMING CONSTANT GRADIENT)

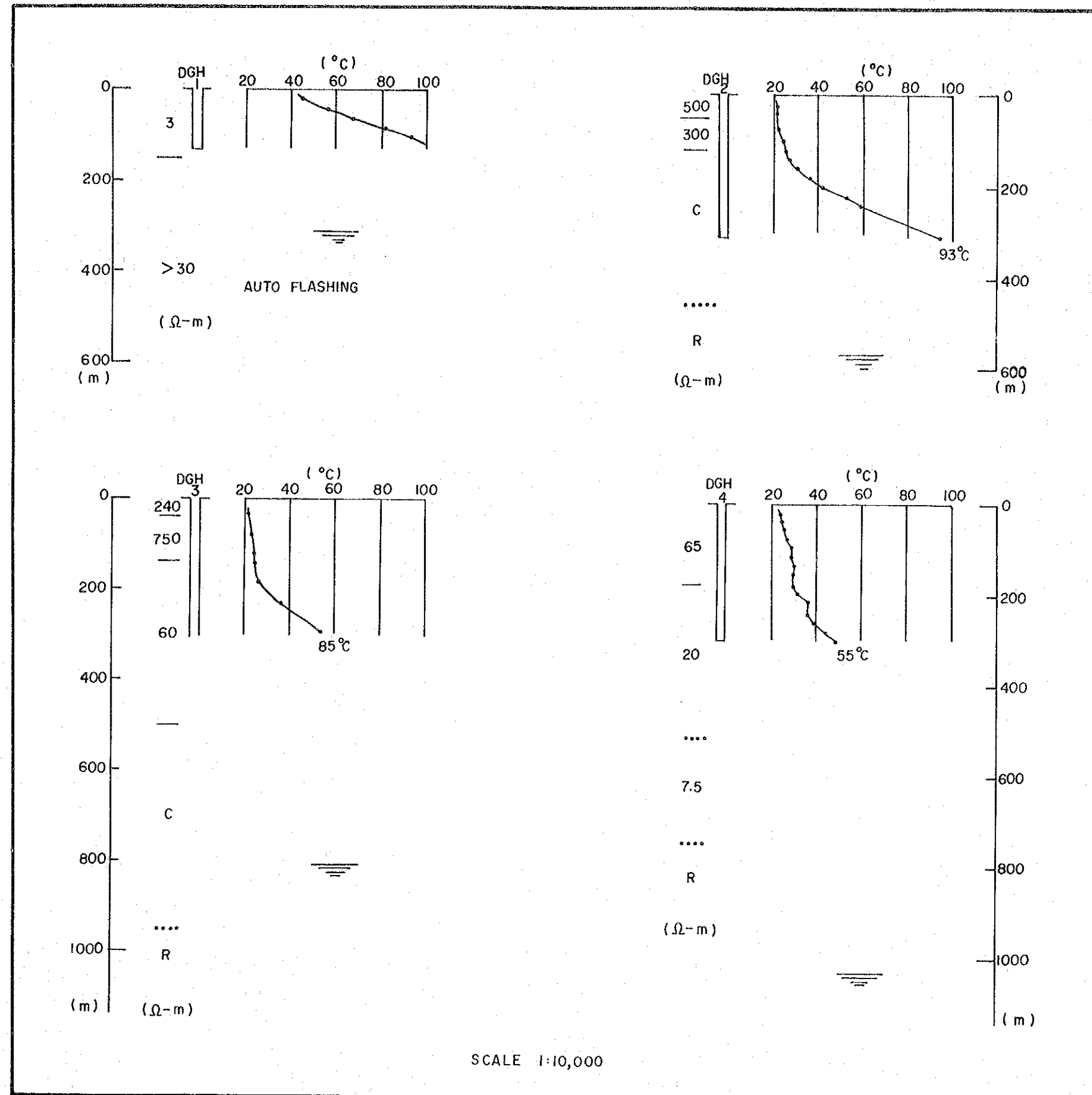


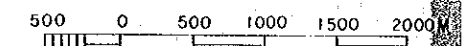
Fig 4.29 THERMAL GRADIENT VS. RESISTIVITY (after BED's data)

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GEOHERMAL DEVELOPMENT  
IN THE REPUBLIC OF  
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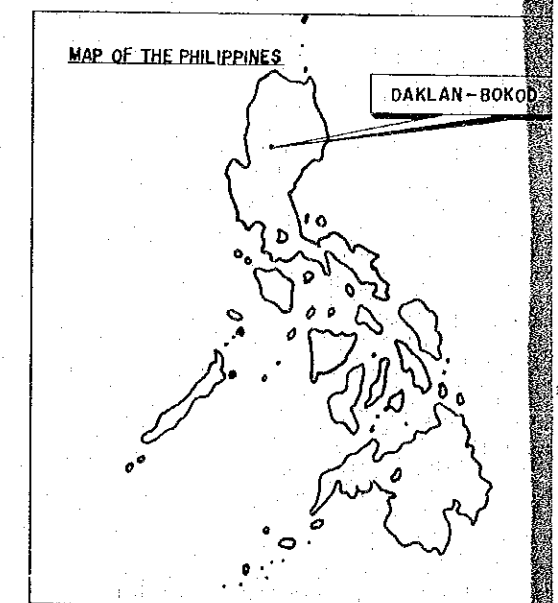
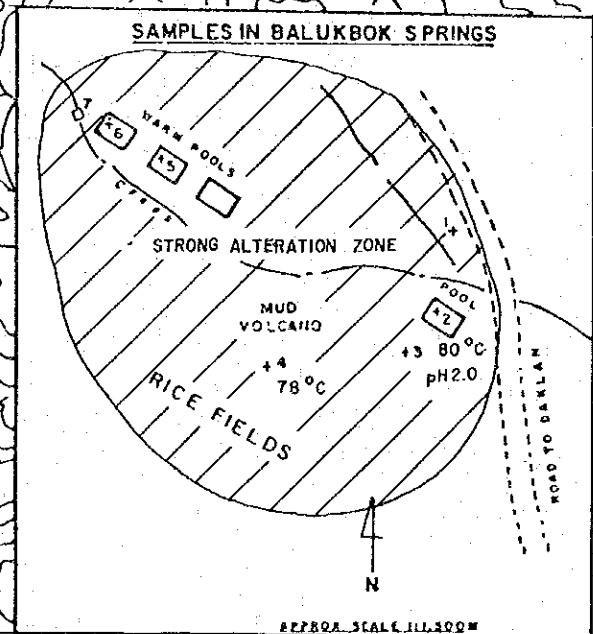
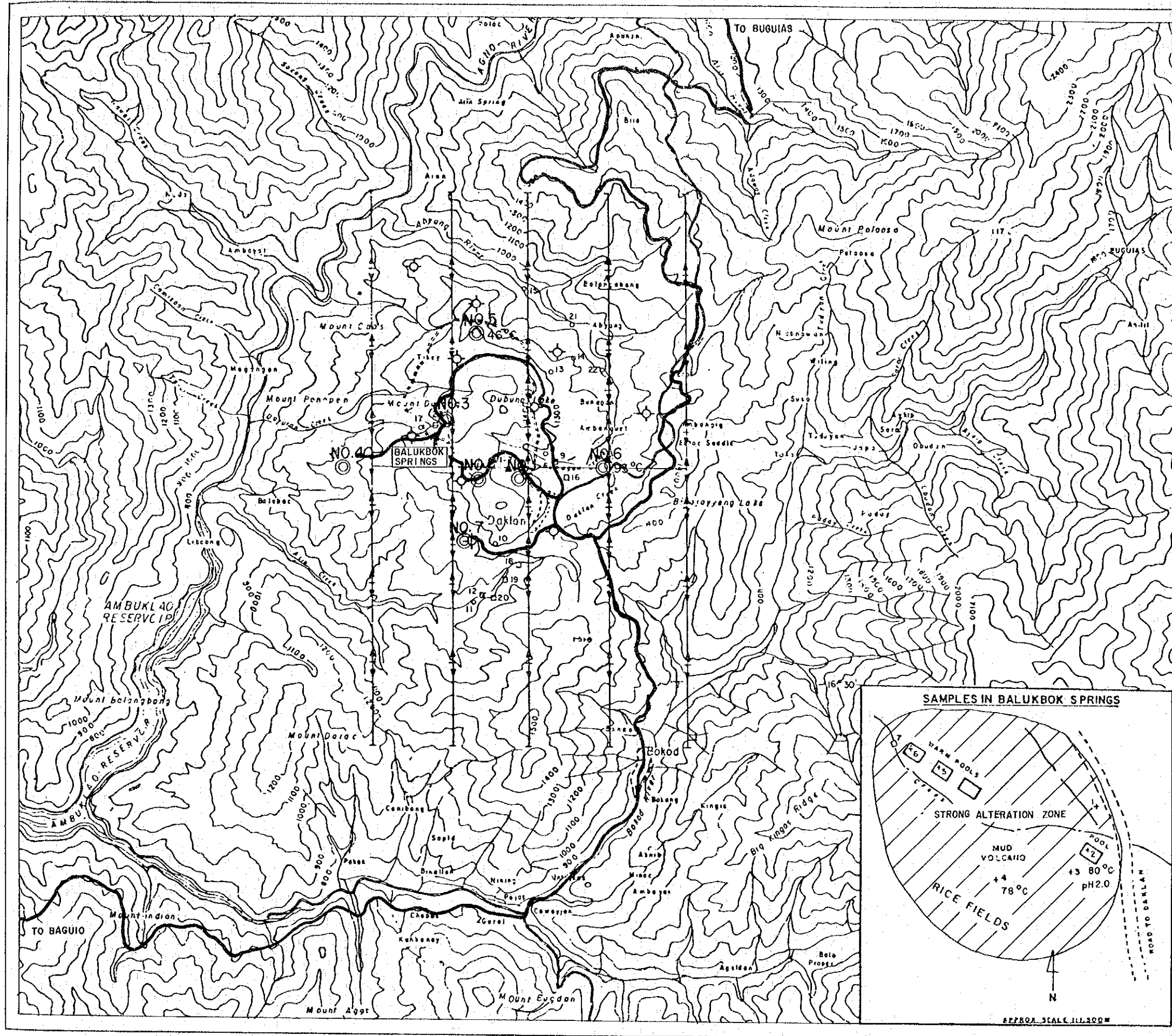
JAPAN INTERNATIONAL COOPERATION  
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LEGEND

- + FUMAROLE CONDENSATE
- WARM / HOT SPRING
- RIVER OF COLD SPRING
- ↔ PROPOSED VERTICAL ELECTRICAL SOUNDING (TOTAL HOLES TO BE DECIDED ON THE BASIS OF THE RESULTS)
- ⊕ PROPOSED LOCATION OF GRADIENT HOLE (TOTAL HOLES TO BE DECIDED ON THE BASIS OF THE RESULTS)
- ROUTE BY JEEP
- ⊙ EXECUTED GRADIENT HOLE



SCALE 1 : 50,000



INDEX MAP

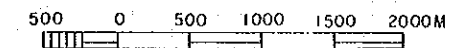
Fig 4. 3 ROUTE MAP IN DAKLAN AREA (after BED's original data)

PRELIMINARY SURVEY FOR THE  
GEOTHERMAL DEVELOPMENT PLAN  
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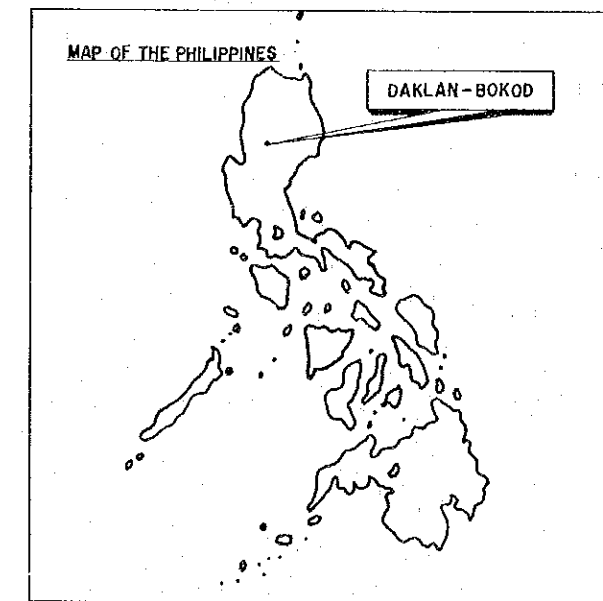
JAPAN INTERNATIONAL COOPERATION  
AGENCY

LEGEND

- + FUMAROLE CONDENSATE
  - WARM / HOT SPRING
  - RIVER OF COLD SPRING
  - ↔ PROPOSED VERTICAL ELECTRICAL SOUNDING (TOTAL 41 SOUNDINGS)
  - ⊕ PROPOSED LOCATION OF GRADIENT HOLE (TOTAL 11 HOLES, 4 MORE HOLES TO BE DECIDED ON THE BASIS OF THE RESULTS)
  - ROUTE BY JEEP
  - ⊙ EXECUTED GRADIENT HOLE
- } WATER SAMPLE



SCALE 1: 50,000



INDEX MAP

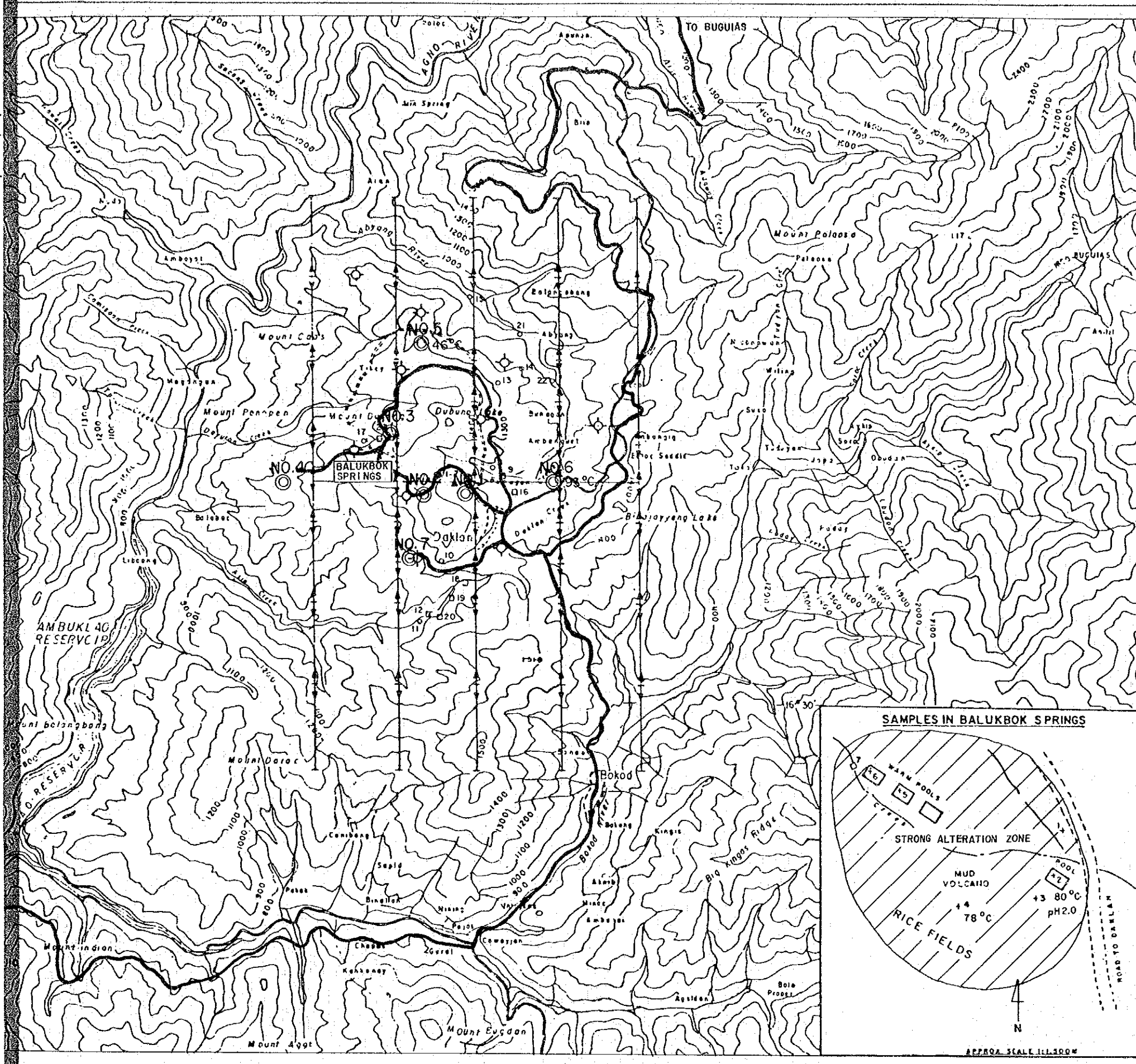


Fig 4. 3 ROUTE MAP IN DAKLAN AREA (after BED's original data)

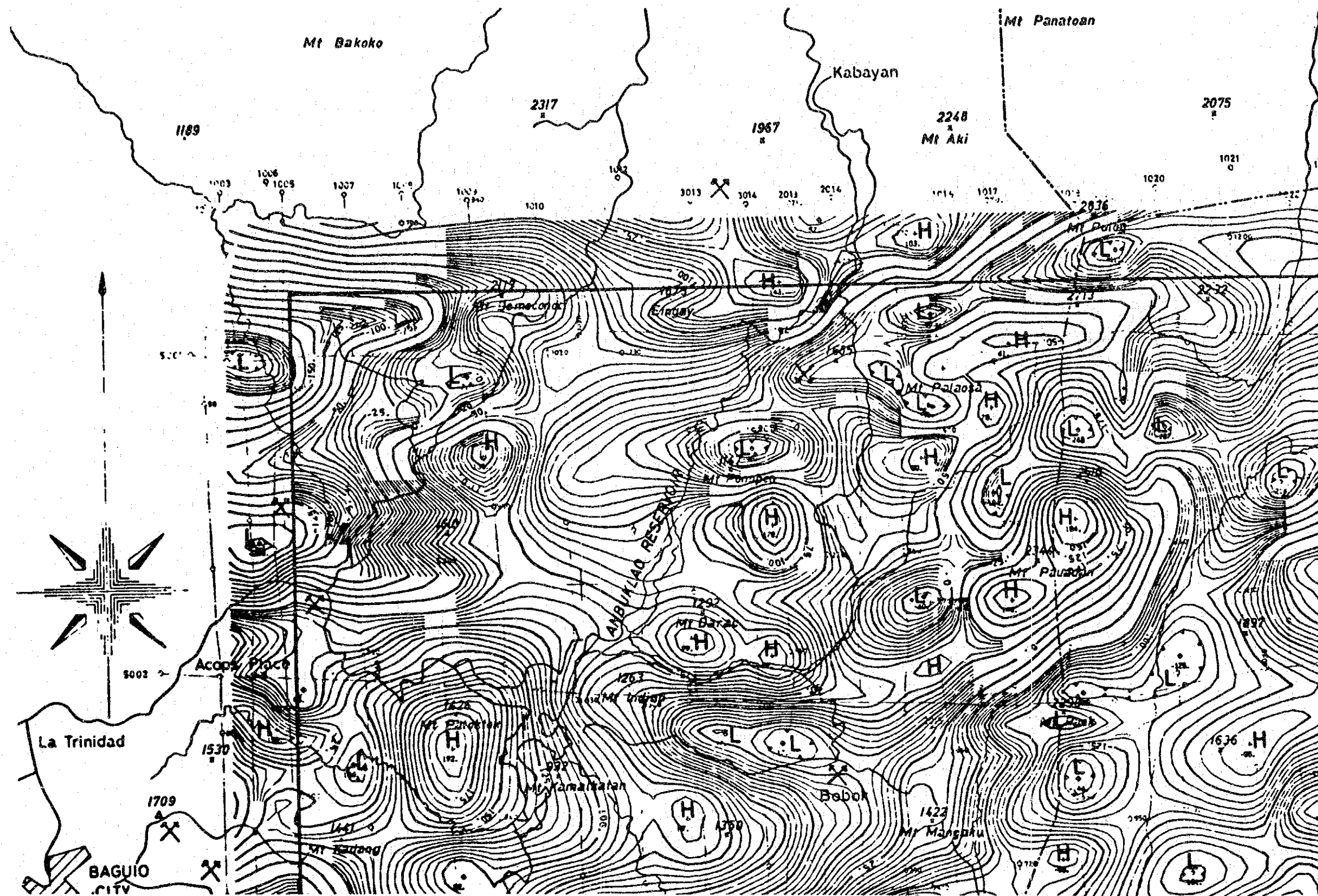


Fig. 4.4 Aero-Magnetic Map, ( by MMAJ )



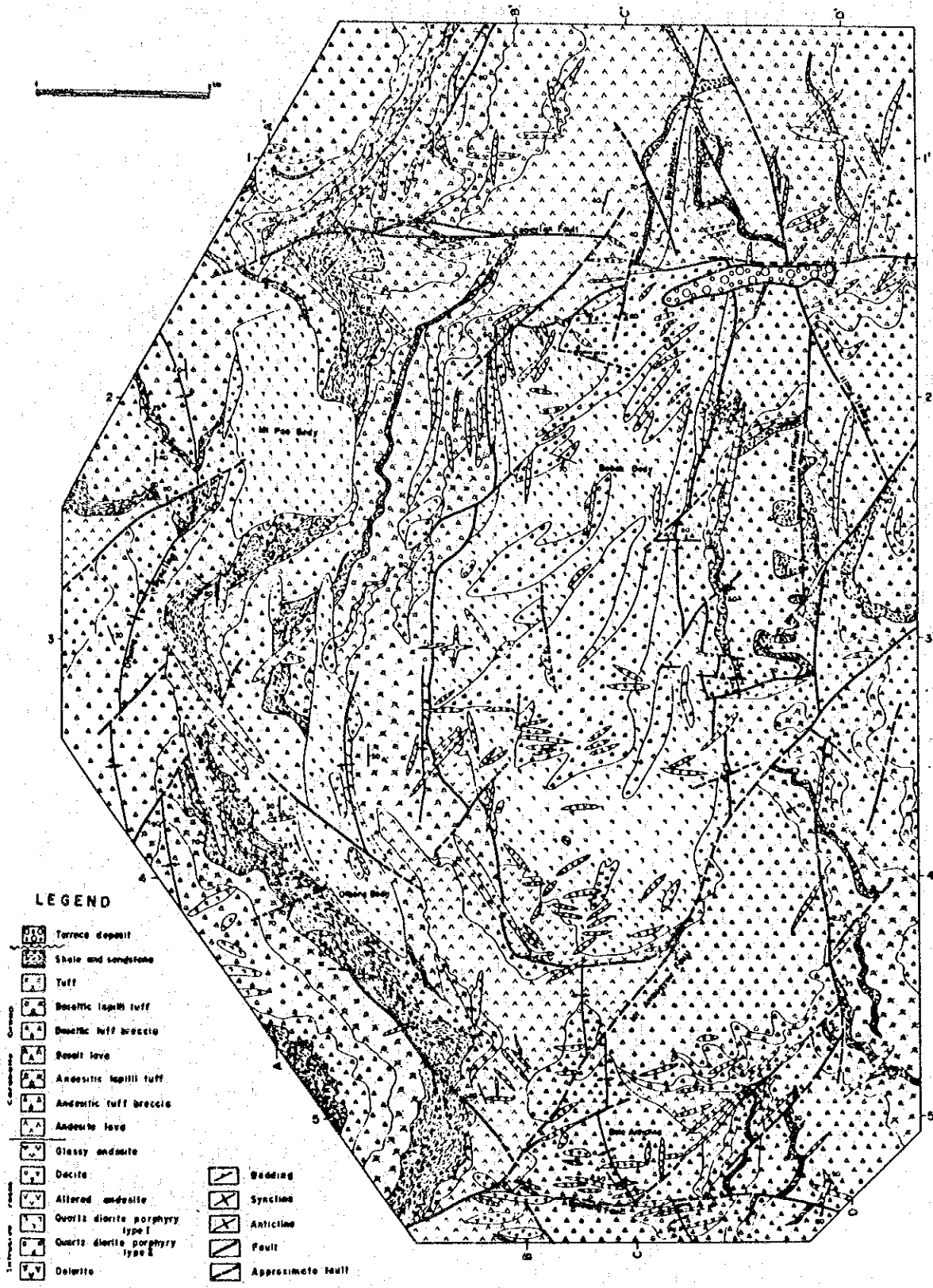


Fig. 4.5 Geological map of Bokod area (by MMAJ)



資 料 5

BUGUIAS 地域資料

- 資料5.1 Preliminary Assessment of Buguias(pp.3)
- Fig.5.2 Route Map in Daklan And Buguias Area
- Fig.5.3 Route Map in Buguias Area
- Fig.5.4 Flight Line Map Of Aerophoto Necessary For  
Photogeology
- Fig.5.5 Area of Aero-magnetic Survey





## 資料 5. 1

### 4.4 BUGUIAS, Benguet

Location and Accessibility. The buguias thermal area (See Plate 0806) is located in the barrio of Mainit, Buguias, Benguet. The hot springs are found mainly along the Asin-an River with other manifestations in its immediate vicinity. Barrio Mainit is accessible from Baguio City, via a tortuous two hour ride along the infamous Mountain trail to the Municipality of Abatan, from there it is another thirty minutes ride via a winding third class dirtroad. Manila is only a four hour drive from Baguio City travelling thru a first class National Highway.

Topography. The area is in the lower Loo Valley of the Benguet Province. Gently rolling hills and exemplifies the moderately rough terrain. The surrounding countryside is very rough and is characterized by steepwalled river valleys, deep precipices and high domes with elevations varying from 1200 to 2319 meter a.s.l.

Power Market. The power market in the immediate vicinity of the area is confined to the mining industry and the local populace. Several large mining ventures are present in the area with activities ranging from the active exploration to the bustling development and producing stages. The Lepanto Inc. gold and copper mine exists only 20 kilometers from Abatan town proper and can be expected to be a big user of the power in the near future. The power lines can also be connected to the proposed nation grid of NPC. As a whole the power market potential is very promising.

Geologic Setting. The Buguias thermal area is underlain by Miocene sedimentary rocks composed of conglomerates, sandstone, wacke and siltstone - shale sequences.

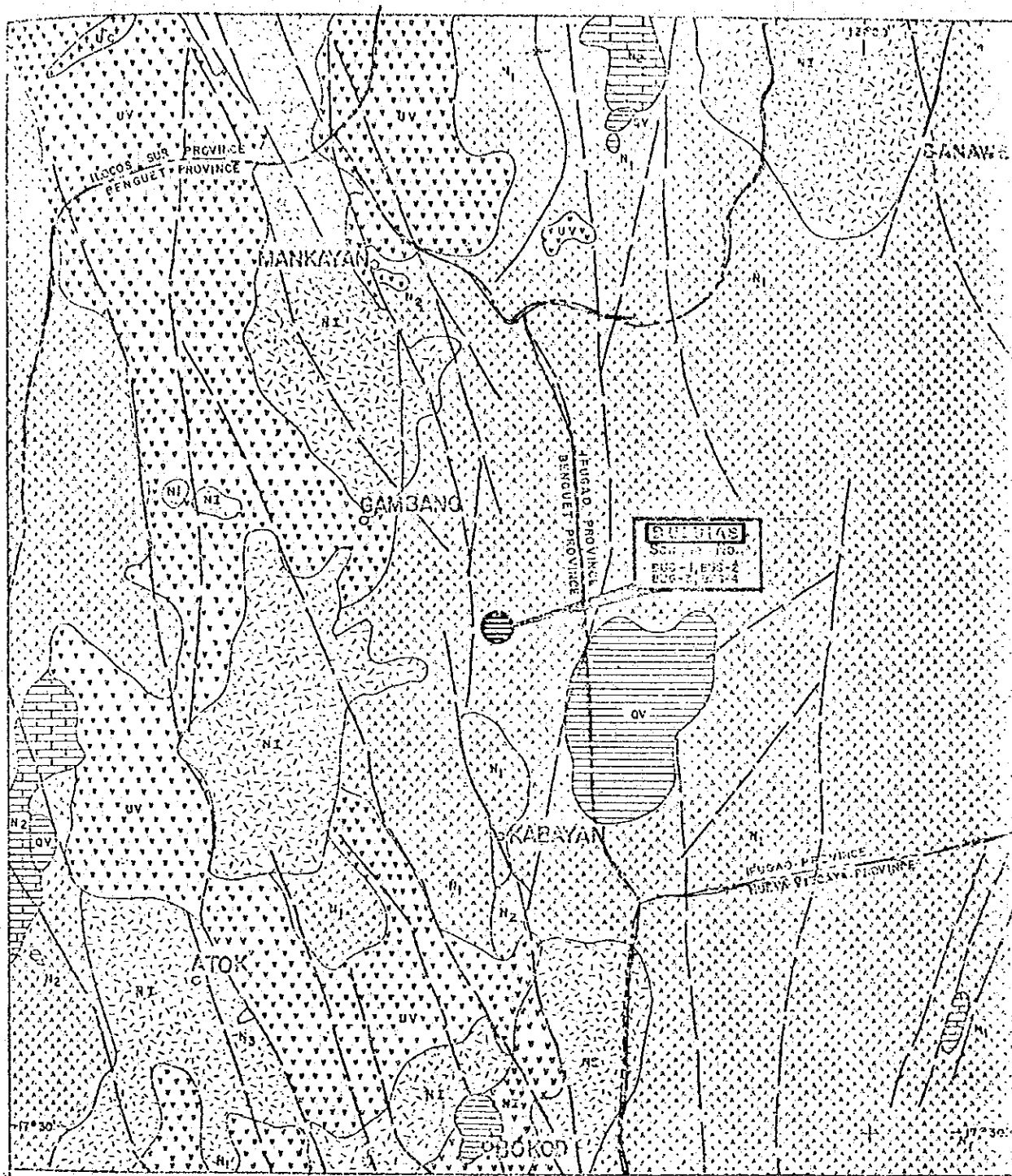
A Quaternary volcanic plug is located approximately 10 kilometers away from the observed thermal manifestations which could be the possible heat source.

The overall geologic setting is encouraging with the presence of a probable heat source and permeable reservoir rocks.

Thermal Manifestations. The thermal manifestations occur along two tributaries of the Loo Valley River. The first hot spring is located under a bridge before entering the barrio proper of Manrit, it emanates from intensely altered metamorphosed sedimentary rocks. The temperature was recorded at 63°C with a pH 7.0 and a total flow of 1-2 liters/second. The second tributary is the Asinab creek, and here the thermal manifestations are spread along its banks, with  $\text{SiO}_2$  and  $\text{CaCO}_3$  deposited in the immediate vicinity. The hot spring temperature recorded varied from 60-67°C and a pH 6.5 was observed.

The geochemistry of the hot springs were very encouraging with  $\text{SiO}_2$  and Na-K-Ca geothermometer giving source temperatures ranging from 150°C to 240°C respectively.

Evaluation. Further, geoscientific work is recommended to be conducted in the very near future. The presence of a promising heat source leads to the consideration of high priority in the nationwide assessment program.



**BUGUIAS**  
 Sheet No. 1  
 ENG-1, ERS-2  
 EUG-1, EUG-4



5000 0 5000 10,000 M.  
 SCALE 1:250,000

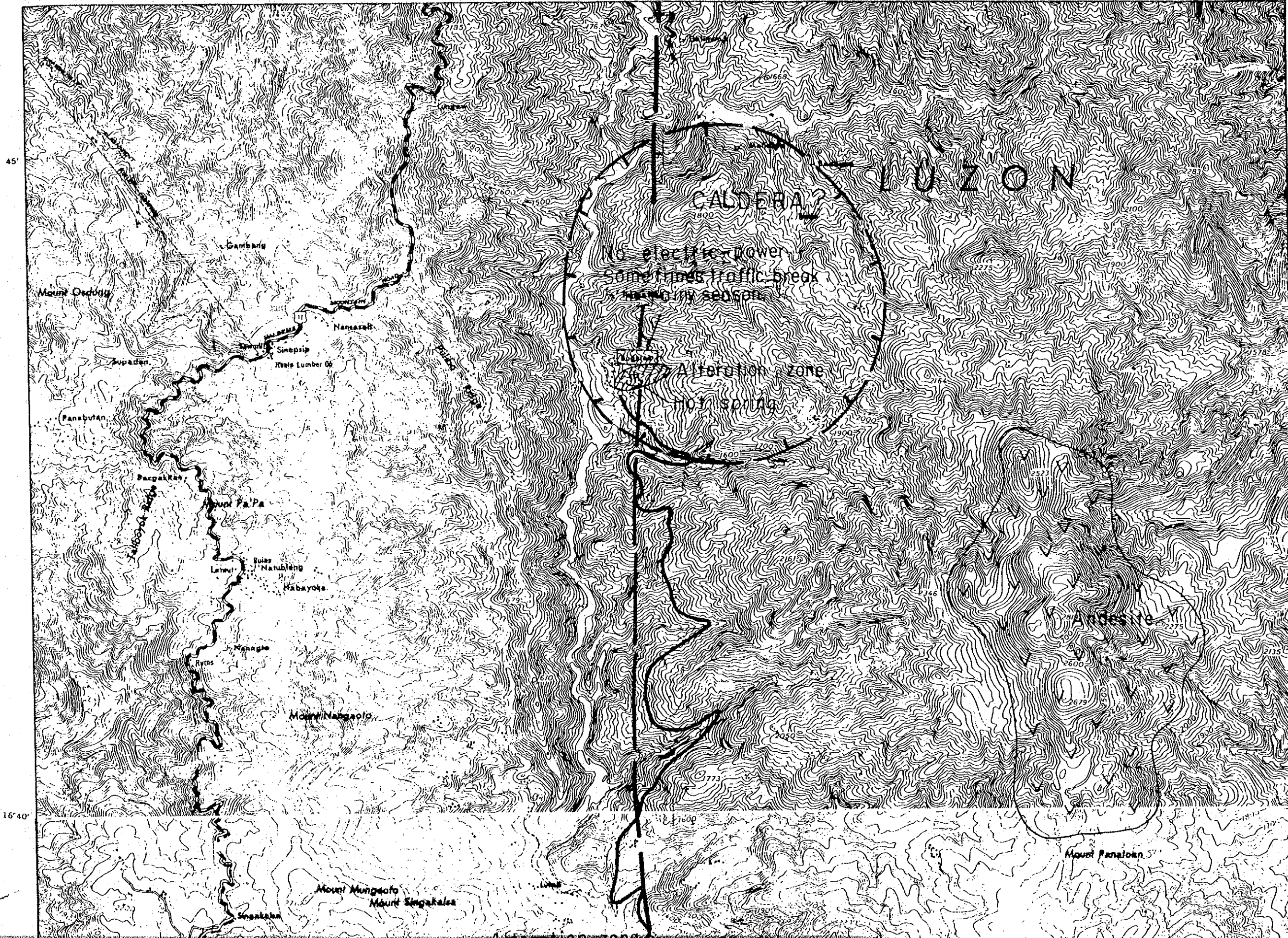
PHILIPPINE-ITALIAN TECHNICAL COOPERATION PROGRAM-STAGE	
BUREAU OF ENERGY DEVELOPMENT -- ELC ELECTROCONSULT	
GEOLOGICAL MAP OF BUGUIAS (Benguet Northern Luzon)	PLATE 0806
DRN.	DECEMBER 1978





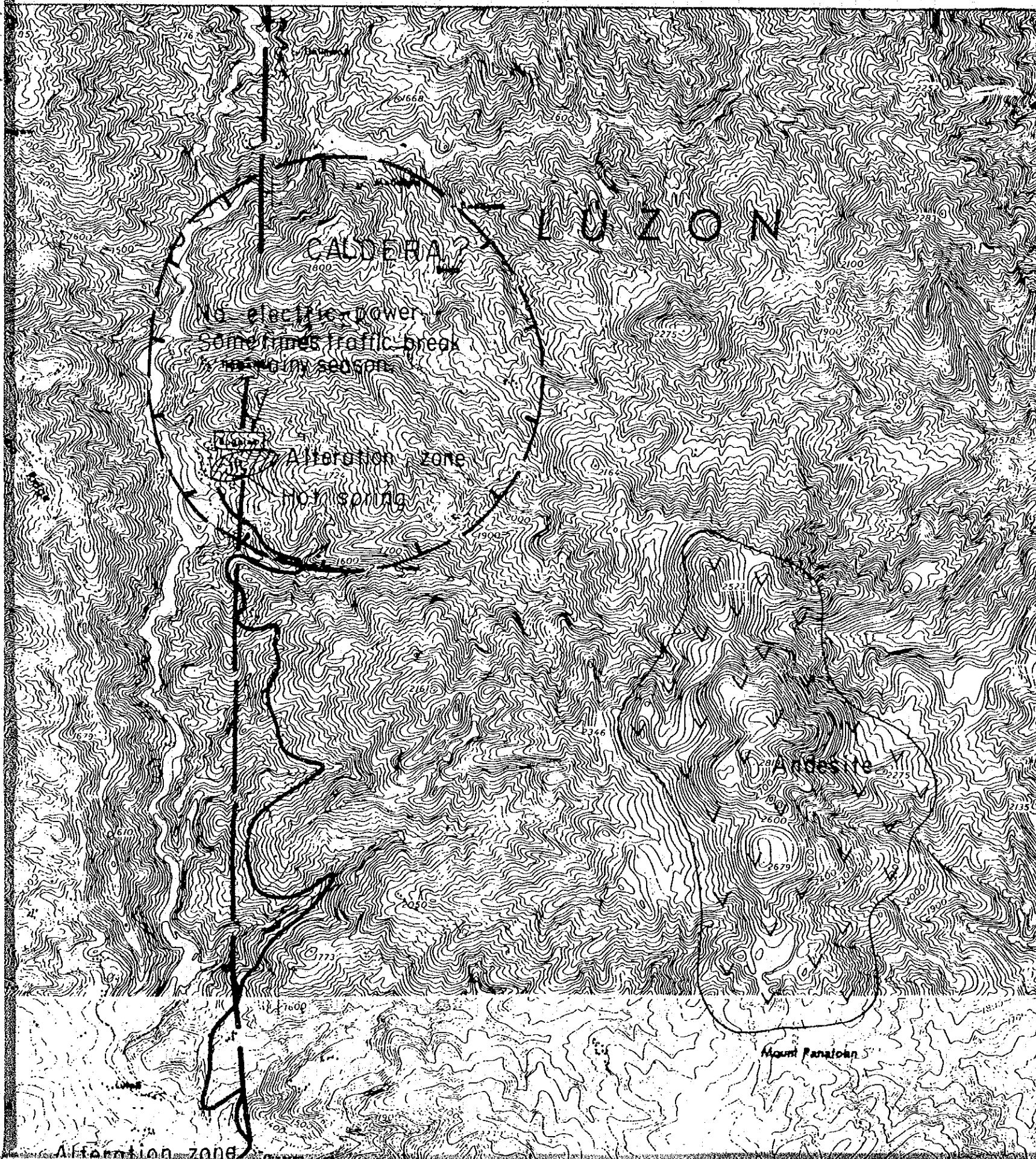
PRELIM  
GEOLOGICAL  
MAP OF  
THE  
PHILIPPINES

JAPAN INTERNATIONAL  
AGENCY

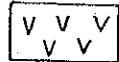
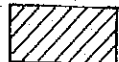







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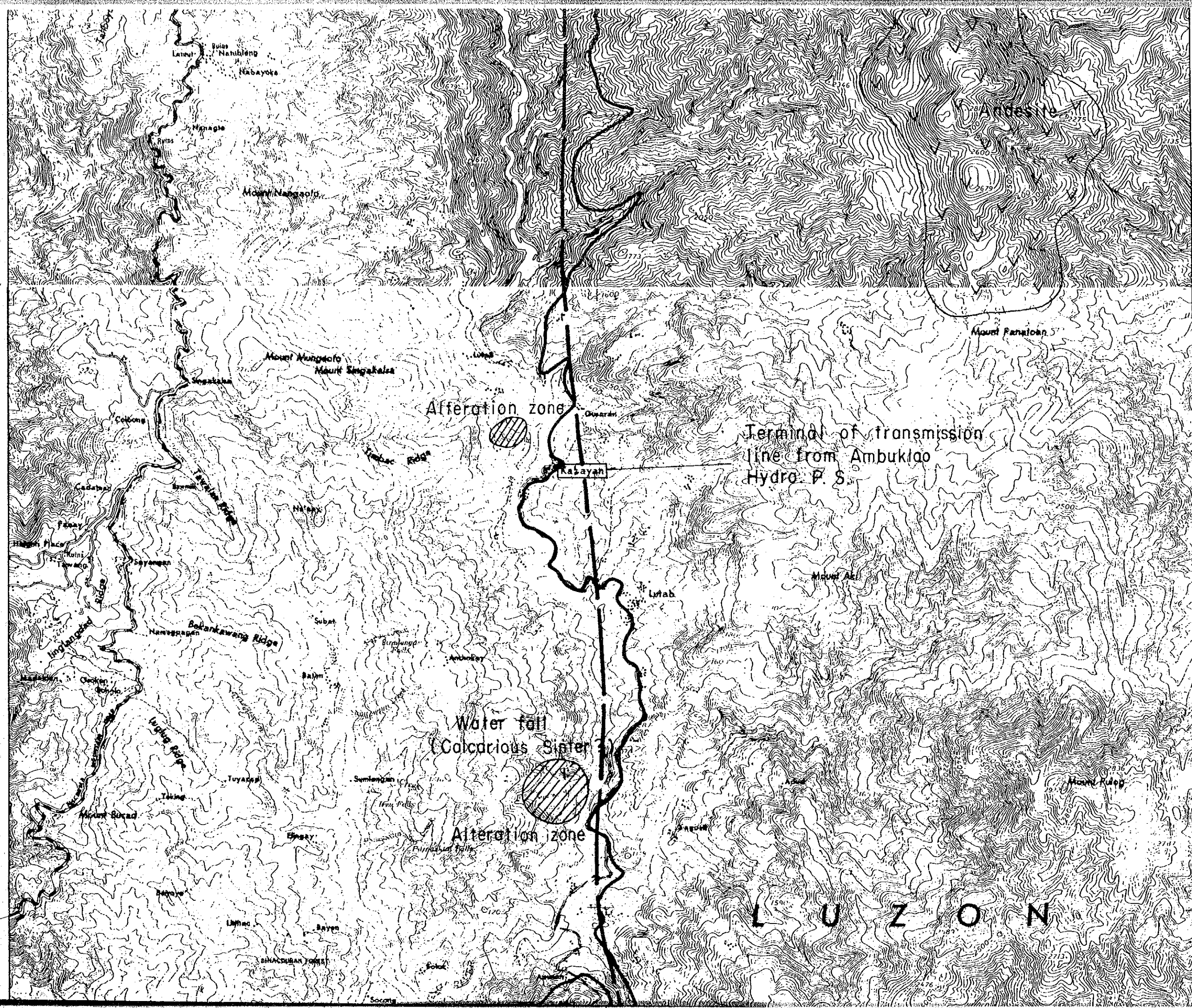
LEGEND

-  ANDESITE
-  ALTERATION ZONE
-  HOT SPRING
-  ESTIMATED FAULT
-  CALDERA
-  ROUTE FOR SURVEY
-  CAMP



16°40'

35'



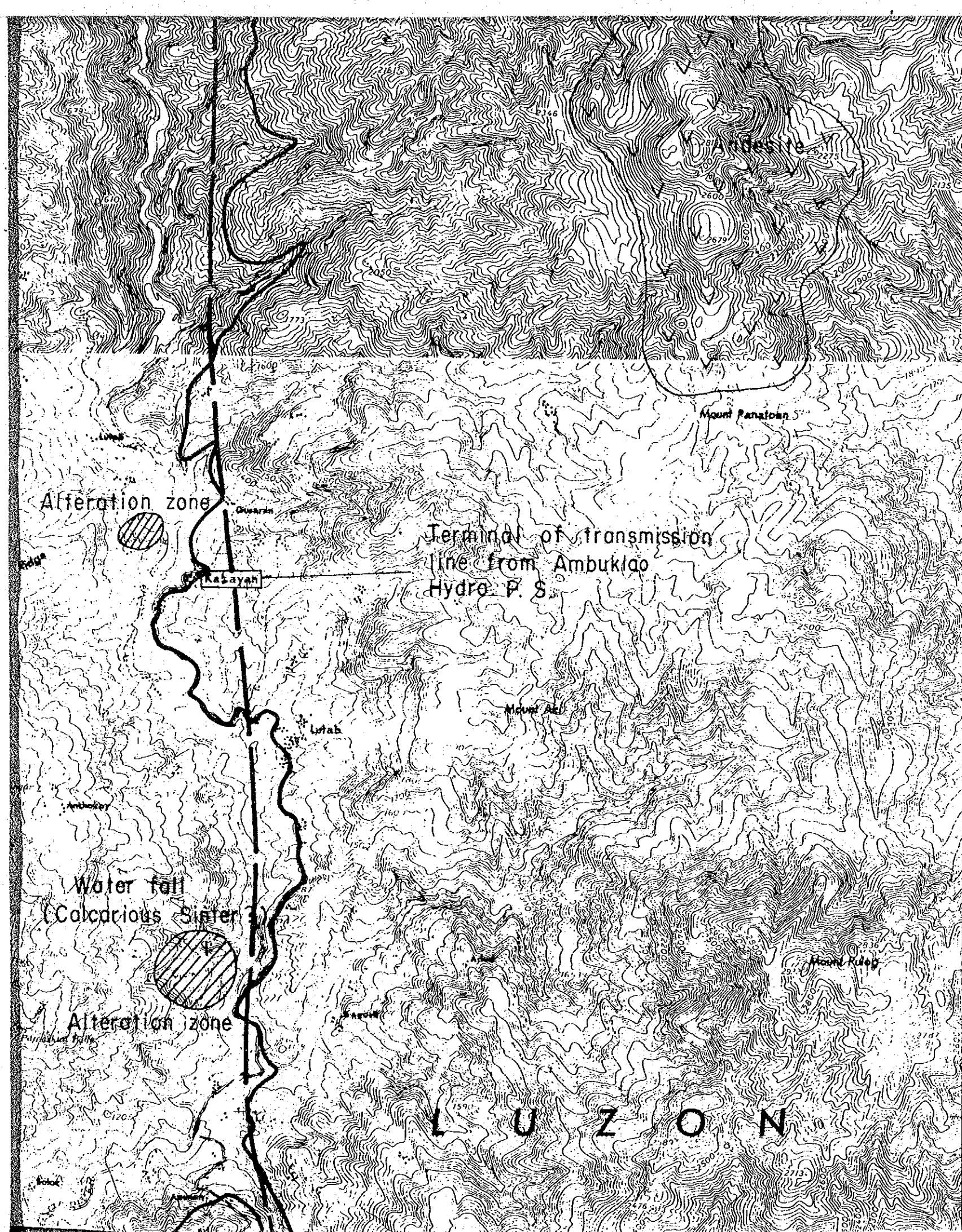
Terminal of transmission  
line from Ambuklao  
Hydro P. S.

Alteration zone

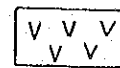
Water fall  
(Colcarious Sister)

Alteration zone

LUZON



LEGEND



ANDESITE



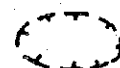
ALTERATION ZONE



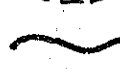
HOT SPRING



ESTIMATED FAULT



CALDERA



ROUTE FOR SURVEY



CAMP

ATON 20 22  
ADUAPAN 4 22

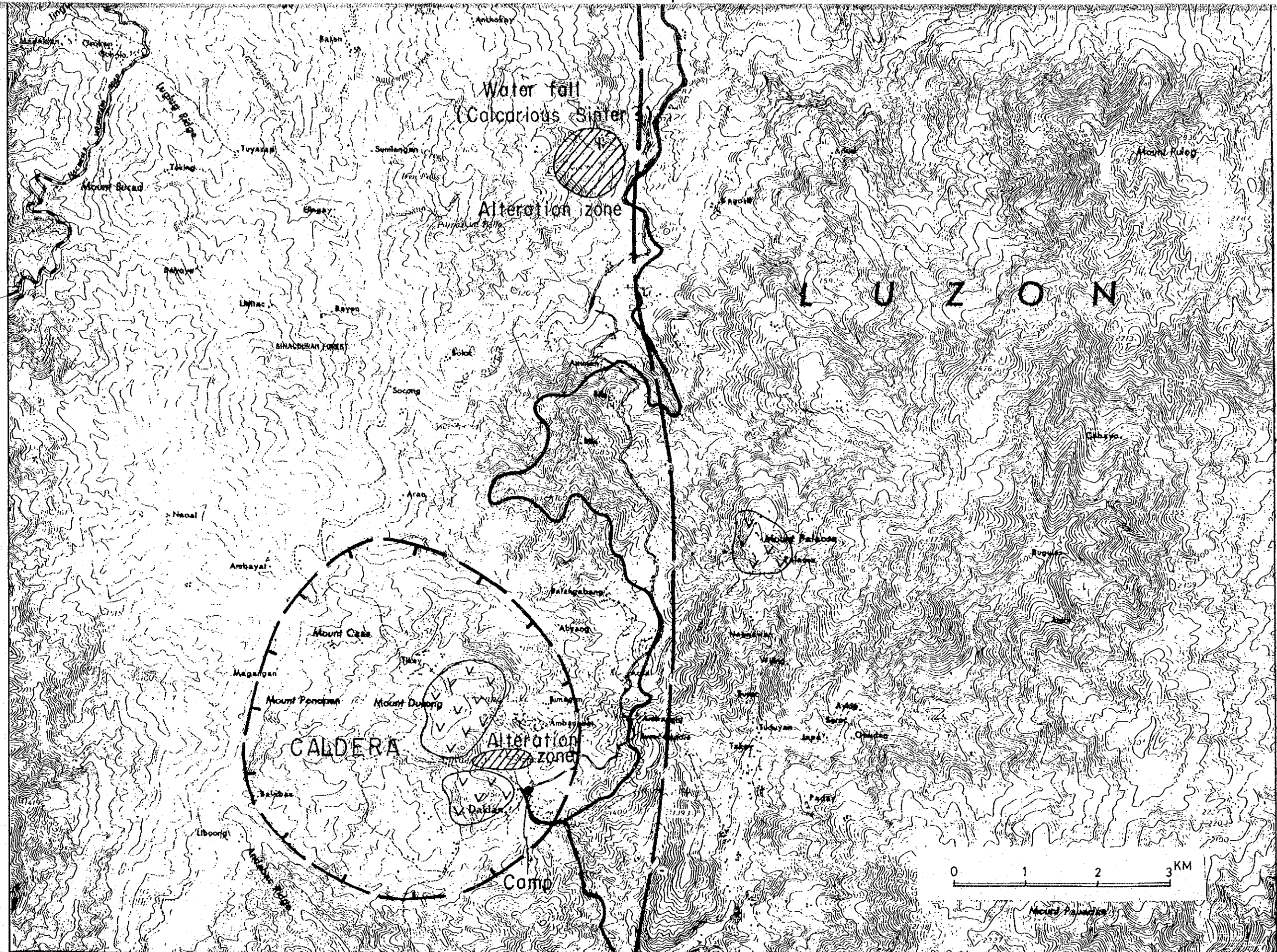


Fig 5.2  
ROUTE MA

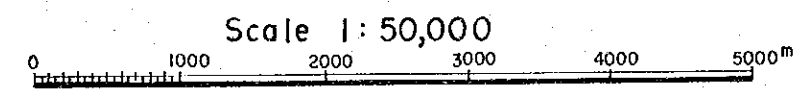
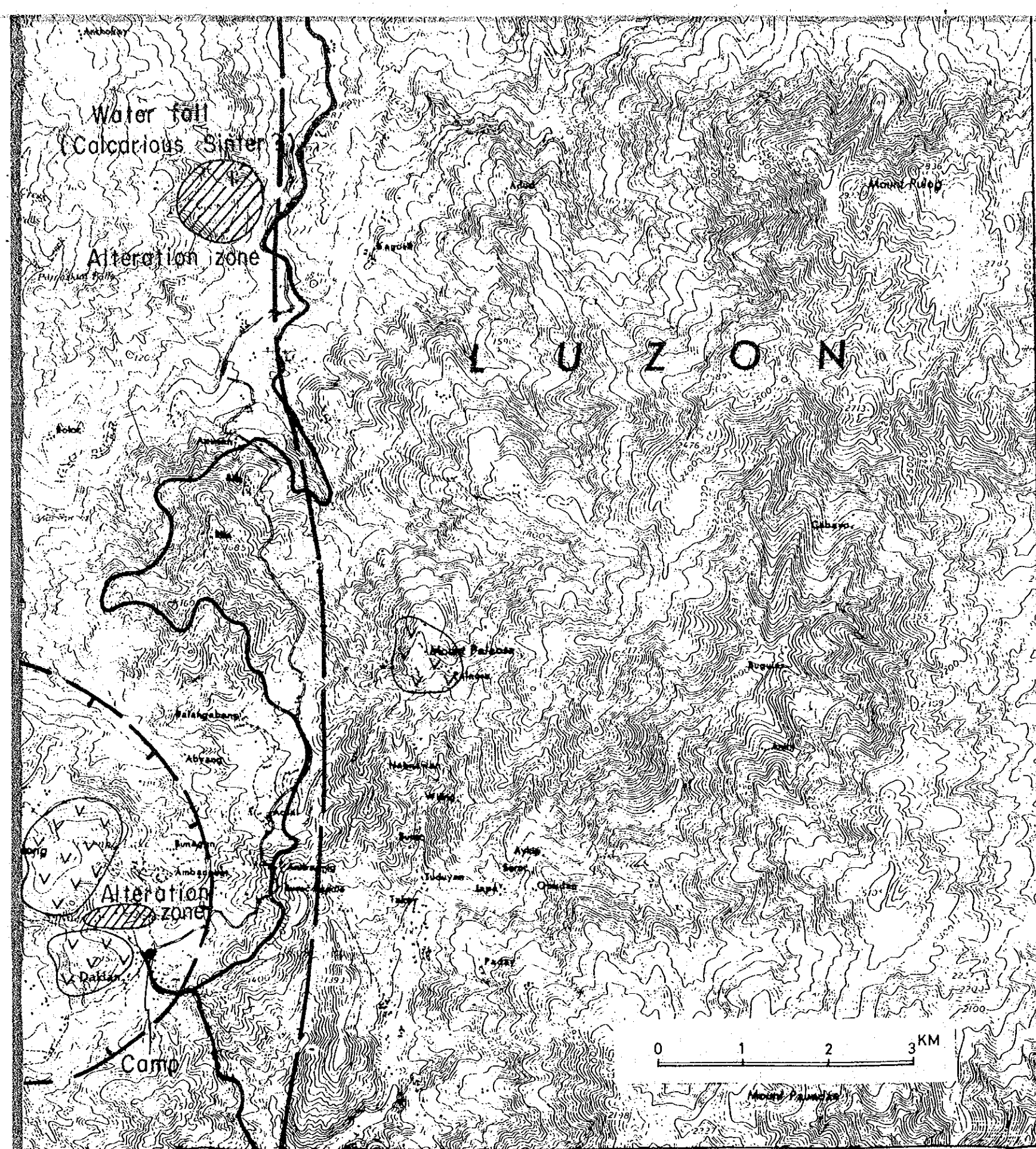
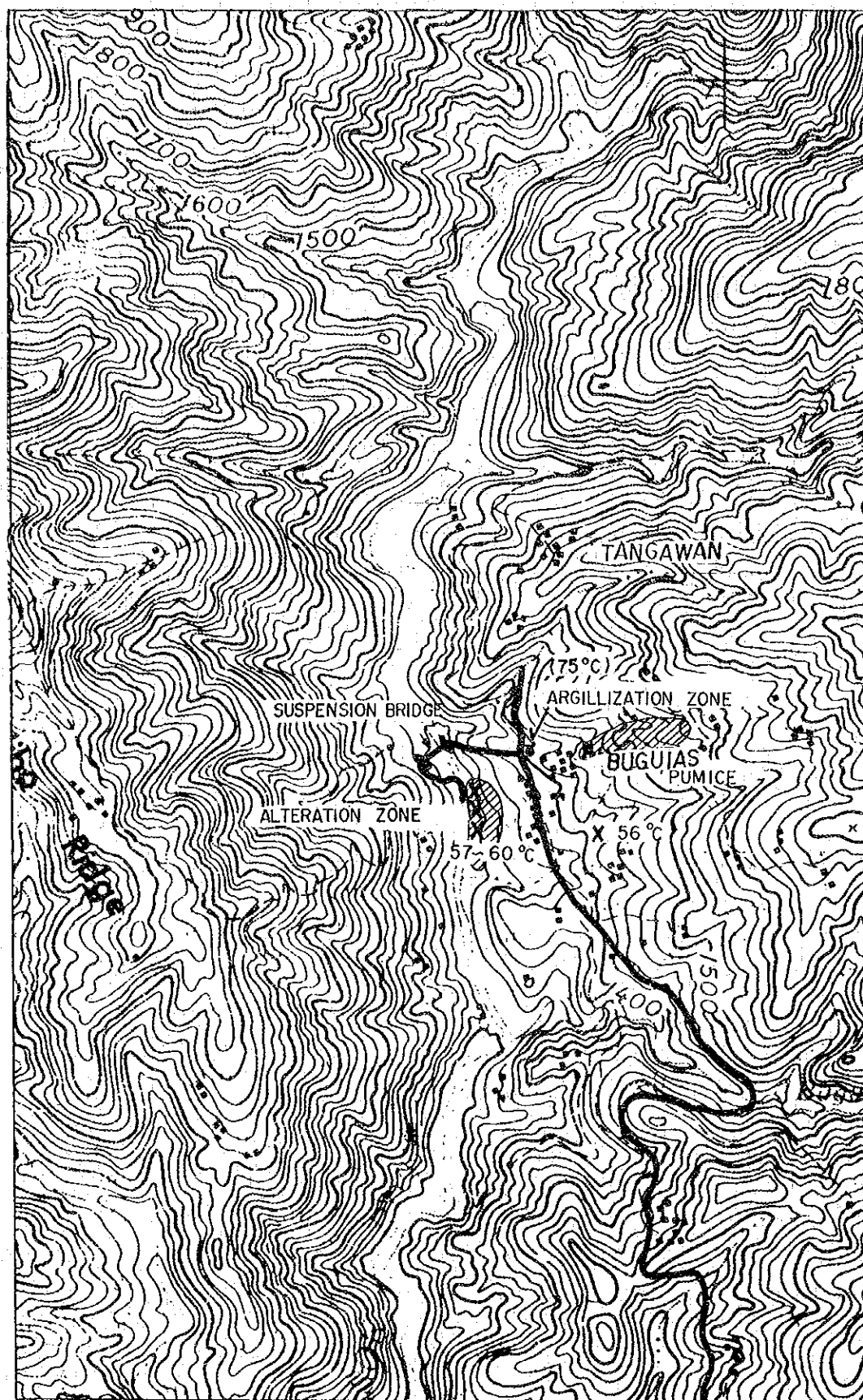


Fig 5.2  
ROUTE MAP IN DAKLAN AND BUGUIAS AREAS

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Scale 1: 25,000

L E G E N D





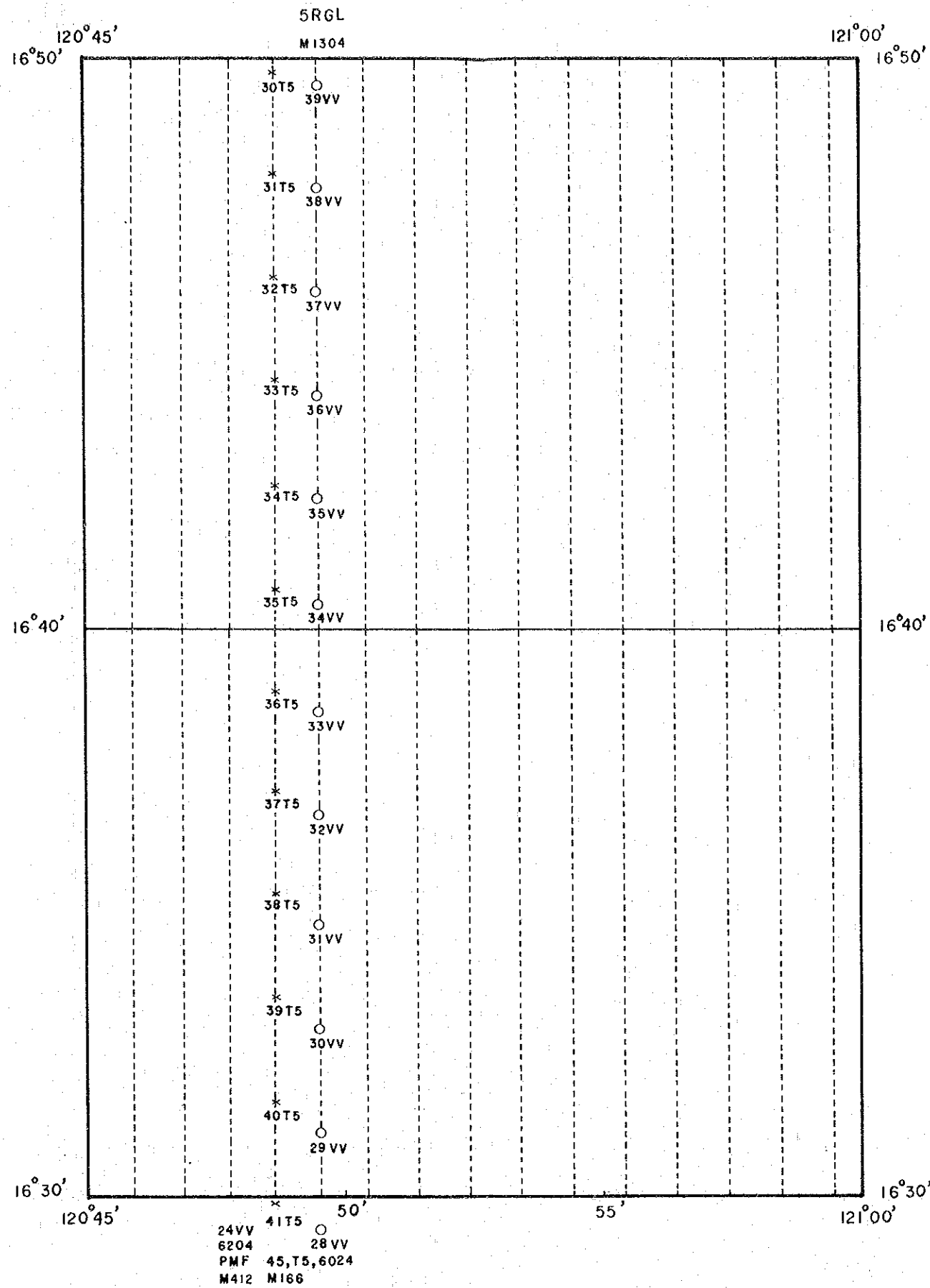
-  ALTERATION ZONE
-  ARGILLIZATION ZONE
-  HOT SPRING
-  ROAD

Fig 5.3 ROUTE MAP IN BUGUIAS AREA



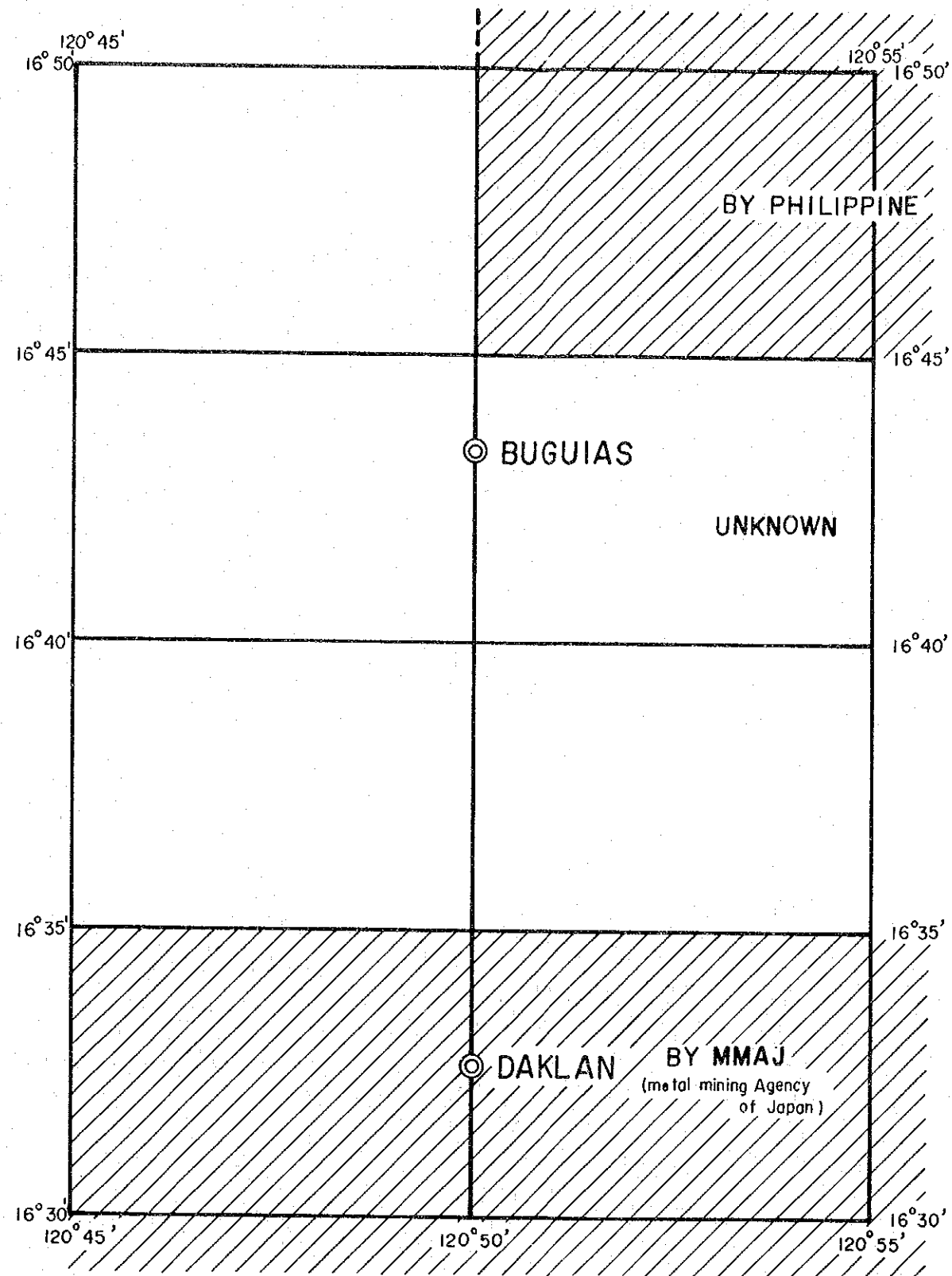
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PHILIPPINES

JAPAN INTERNATIONAL COOPERATION  
AGENCY

L E G E N D

- 120°45' 121°00'
- 16°50' 16°30'
- 120°45' 121°00'
- REQUESTED AREA  
FOR THE PHOTO GEOLOGY
- X 38T5 INDEX NO. OF AEROPHOTO
- PROPOSED FLIGHT LINE
- M1304 KNOWN FLIGHT LINE NO.

Fig 5.4 FLIGHT LINE MAP OF AEROPHOTO NECESSARY FOR PHOTO GEOLOGY



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L E G E N D


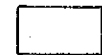
-  SURVEYED
-  UNKNOWN

Fig 5.5 AREA OF AERO MAGNETIC SURVEYS





資 料 6

MONTELAGO 地域資料

資料 6.1 Preliminary Assessment of Montelago (pp.28)

Fig.6.2 Route Map in Montelago Area



資料6 . 1

REPUBLIC OF THE PHILIPPINES

PRELIMINARY ASSESSMENT  
OF  
MONTELAGO  
(ORIENTAL MINDORO)

Bureau of Energy Development  
Ministry of Energy

Manila, February 1979  
PHILIPPINES

4	FUTURE WORK PROGRAM	4-1
4.1	Activities	4-1
4.2	Proposed Sites of Shallow Gradient Holes	4-3

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APPENDIX II     BIBLIOGRAPHY

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PLATE 1003	Location of Electrical Soundings
PLATE 1004	Profile of Electrical Soundings
PLATE 1005	Isoresistivity Plan Map (200 meters)
PLATE 1006	Isoresistivity Plan Map (500 meters)
PLATE 1007	Isoresistivity Plan Map (750 meters)
PLATE 1008	Isoresistivity Plan Map (1000 meters)
FIGURE 1	Square Diagram of Nauhan Waters
FIGURE 2	$t^{\circ}/Cl$ and $T^{\circ}/SiO_2$ Relationship for the Nauhan Springs
FIGURE 3	Relation Between $Na/K$ and $Na-K-Ca$ Geothermometers

## 1 SUMMARY AND CONCLUSION

Montelago geothermal area appears to be related to the waning stage of the Plio-Quaternary volcanic activity in Mindoro Island which is characterized by the extrusion of voluminous andesite lava and pyroclasts. The period of volcanism in the area was concluded by the generation of series of parasitic domes along the NW basal section of Mount Nauhan. The Quaternary volcanic rocks cover an area of about 250 square kilometers. They overlie a thick sequence of Oligo-Pliocene marine sediments intercalated with reefal limestone lenses. The marine clastics fill the eastern Mindoro basin which assumes a lenticular depression extending from Lake Nauhan to Calapan area.

The east Mindoro basin is bounded at the west by a regional northwest trending fault cutting along the long axis of the island and block-faulted by subsidiary sub-parallel fractures with easterly normal vertical displacement. A second set of fault system trending almost perpendicular to the NW regional structure appears to be conjugate faults related to the sub-parallel NW fractures.

The surface thermal activities are primarily manifested by hot springs and bubbling pools which occur along the eastern shoreline of Lake Nauhan and along the eastern seashore of Buloc-Buloc Bay.

The manifestation along Nauhan Lake is characterized by hot water bubbling activity and several minor seepages oozing along cracks and joints. The temperature of the springs range from 60°C to 84°C with a total discharge of a few liters per second.

The Buloc-Buloc Bay appears to be a collapsed structure formed by the past volcanic activity in the area. The bay is a part of the eastern fringe of the narrow isthmus that links Mount Pola in the south to Mount Nauhan in the north.

The two bubbling areas in Euloc-Buloc which are 1,500 meters apart are totally underwater during high tide. The temperature of the ground where the gas bubbles come out ranges between 31°C and 59°C with approximate discharge of hot water about a liter per second.

Aside from the two main thermal areas, there is no other manifestation observed around the vicinity of Nauhan. However, near the town of Nauhan, approximately 13 km. northwest of the hot springs, shallow water wells have encountered warm water with a temperature of 32°C at a depth of about 30 meters suggesting a possible anomalous heat flow in the area.

Chemistry of the hot springs indicates sodium chloride-type water which contains about 7,000 ppm chloride. The Na-K-Ca and silica geothermometers reflect a moderately high base temperature of the source which ranges from 190°C to 200°C. The possibility of strong groundwater dilution of the thermal fluid cannot totally be discounted as this lessens the degree of accuracy of metal cations ratio. The warm artesian flow from water wells drilled in the flood plain of Nauhan indicates a large influx of groundwater underneath the volcanoclastics of Mount Nauhan.

Geoelectrical soundings carried out over the area have indicated significant low resistivity anomaly towards the northern side of Mount Nauhan where an anomalous heat flow is revealed by the shallow water wells. Geoelectrical interpretation of the 31 soundings undertaken in the area are however still preliminary.

At the present stage, there is no definite conclusion on the possible potential of Montelago geothermal area inasmuch as the surface thermal manifestation is limited to small hot water discharge and likewise the chemistry of the hydrothermal fluid indicates a moderate base temperature of the source. However, the geological setting and results of georesistivity survey appear to be favorable to warrant the drilling of shallow gradient holes in the area.

The shallow exploratory holes to be conducted in the area will give a better understanding on the subsurface condition of the thermal area in order to reach a sound assessment on its potential.



## 2 INTRODUCTION

### 2.1. Scope of Work

Following a reconnaissance work undertaken in Montelago geothermal area, a decision was made to carry out a preliminary assessment programme with the following objectives:

- a. Undertake detailed geologic mapping over the area of interest in order to define the structural system, stratigraphic sequence of underlying formation and volcanological setting of the area;
- b. Interpret the groundwater circulation scheme and estimate the base temperature of the hydrothermal fluid by a detailed study of the springs and surface waters;
- c. Conduct a georesistivity survey over the area of interest based on the significant geological and geochemical results;
- d. Establish a preliminary geothermal model and evaluate on a qualitative basis the potential of the area and the nature of the deep geothermal fluids;
- e. And present a pre-feasibility study program with emphasis on gradient hole drilling if the results of the preliminary assessment are significant to warrant further investigation in the area.

This assessment campaign is a part of the technical cooperation program between the Philippine Ministry of Energy and the Italian Government to evaluate the geothermal resources of the Philippines. This technical agreement is being implemented by the Bureau of Energy Development and the ELC-Electroconsult, S.p.A., Milano.

## 2.2 Implementation of the Campaign

At the onset of the present program, there was practically no available technical information on the location of the reported hot springs along Lake Nauhan. Moreover, the geology of the area was studied on a regional level which was included as part of the regional geology of Mindoro Island (refer to Philippine Geologic Map (1:1,000,000) - Plate 1002-A).

Detailed geologic, hydrogeological and geochemical surveys covering an area of 90 square kilometers were carried out in a period of 4 months from July - October 1978. This was followed by georesistivity survey (Schlumberger array) which was completed in February 1979.

In the course of the implementation of the work program undertaken in Montelago geothermal area, utmost cooperation was extended to the survey party by the local residents. In particular, we wish to extend our appreciation to Mayor Manuel Margos, Councilor Pedro Tolentino and Mr. Jose Legaspi of Nauhan for their continuous support and assistance.

## 2.3 Location and Access

The Montelago geothermal area is located north of Lake Nauhan in Oriental Mindoro with geographical coordinates of 13°10' - 13°20' North latitude and 121°15' - 121°30' East longitude. The area stretches from the municipality of Nauhan to Pola town proper. It is bounded to the northwest by the Tablas Strait and to the southwest by Nauhan Lake (Plate 1001).

The province is accessible from Manila to Calapan by a daily flight of PATI Airline or by ferry boats from Batangas City. A second class all weather road connects Calapan to Nauhan and this is accessible in one hour. The last 15 kilometers stretch connects Nauhan to the thermal areas by a winding barangay road cut along the eastern coastal area of Nauhan. The road is passable only during dry season by ordinary jeep. An alternative access to the area is by pump boat passing through Butas River - the discharge channel of Lake Nauhan to the sea.