THE REPUBLIC OF THE PHILIPPINES

BUREAU OF ENERGY DEVELOPMENT

REPORT ON BUGUIAS GEOTHERMAL DEVELOPMENT

FIRST PHASE SURVEY

SEPTEMBER 1981

JAPAN INTERNATIONAL COOPERATION AGENCY

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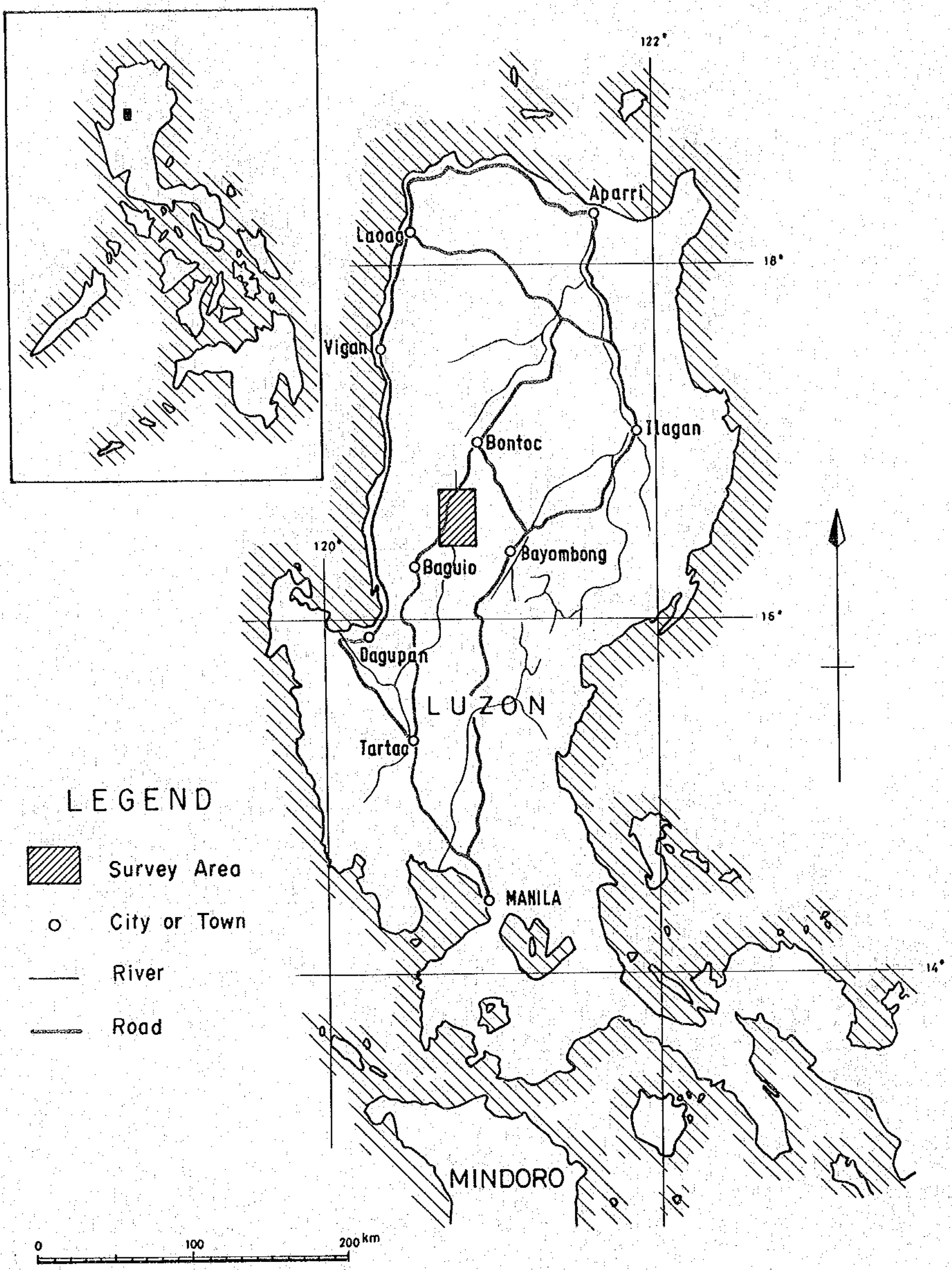
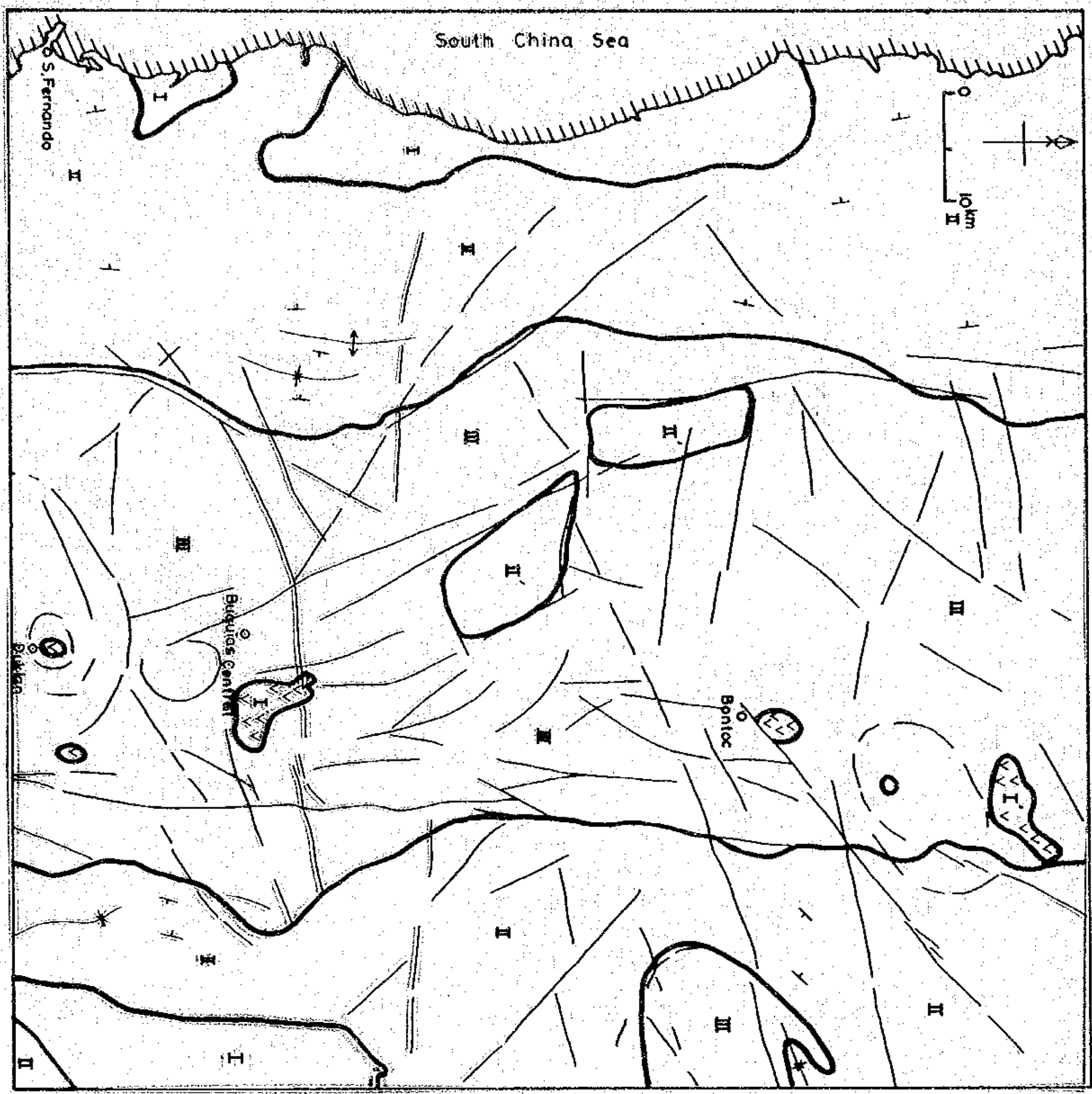


Fig I-1-1 LOCATION OF THE SURVEY AREA



Legend

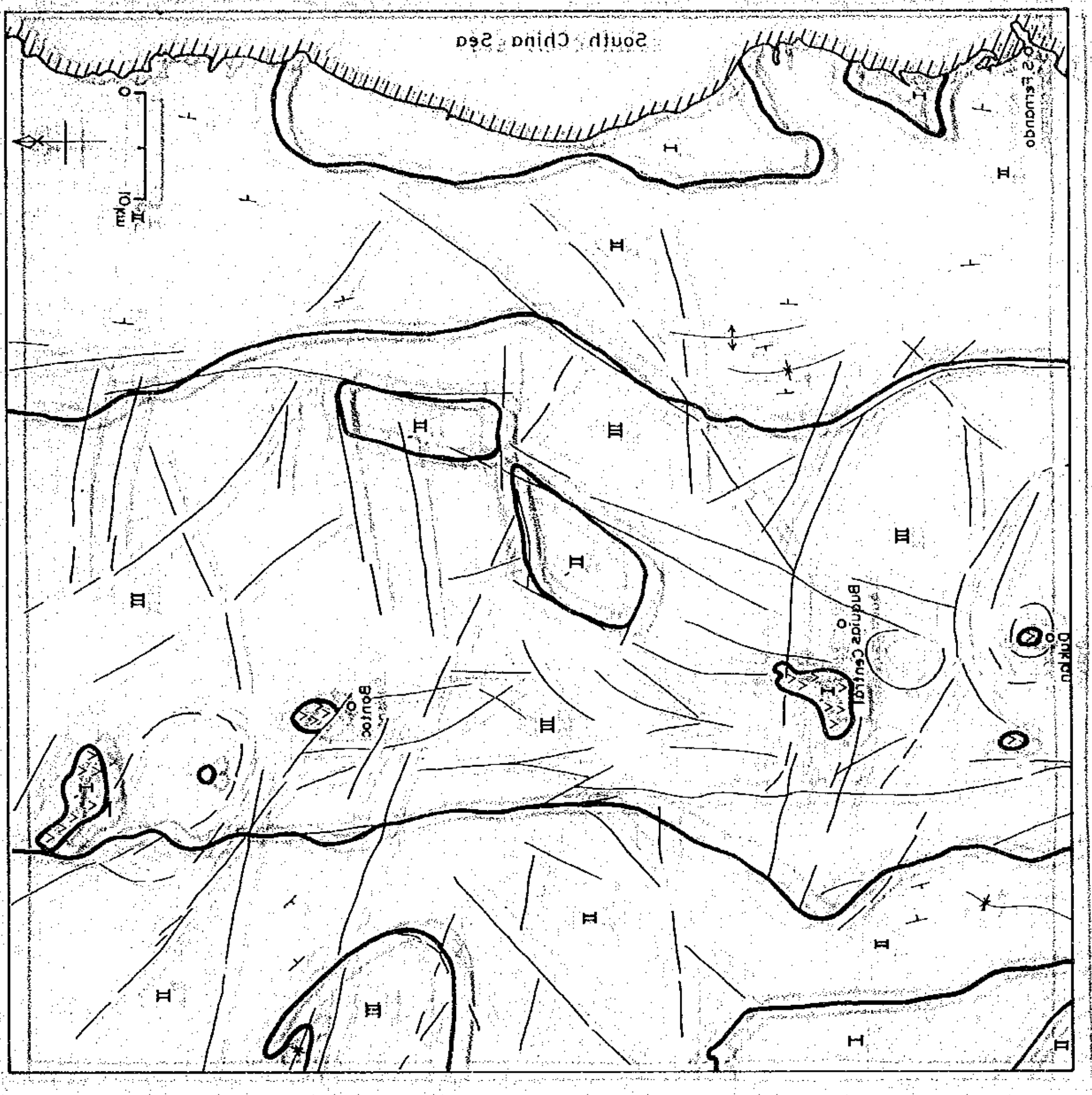
I, II, III ; Geological unit

; Geological unit boundary

; Lineament

; fold axis

; bedding



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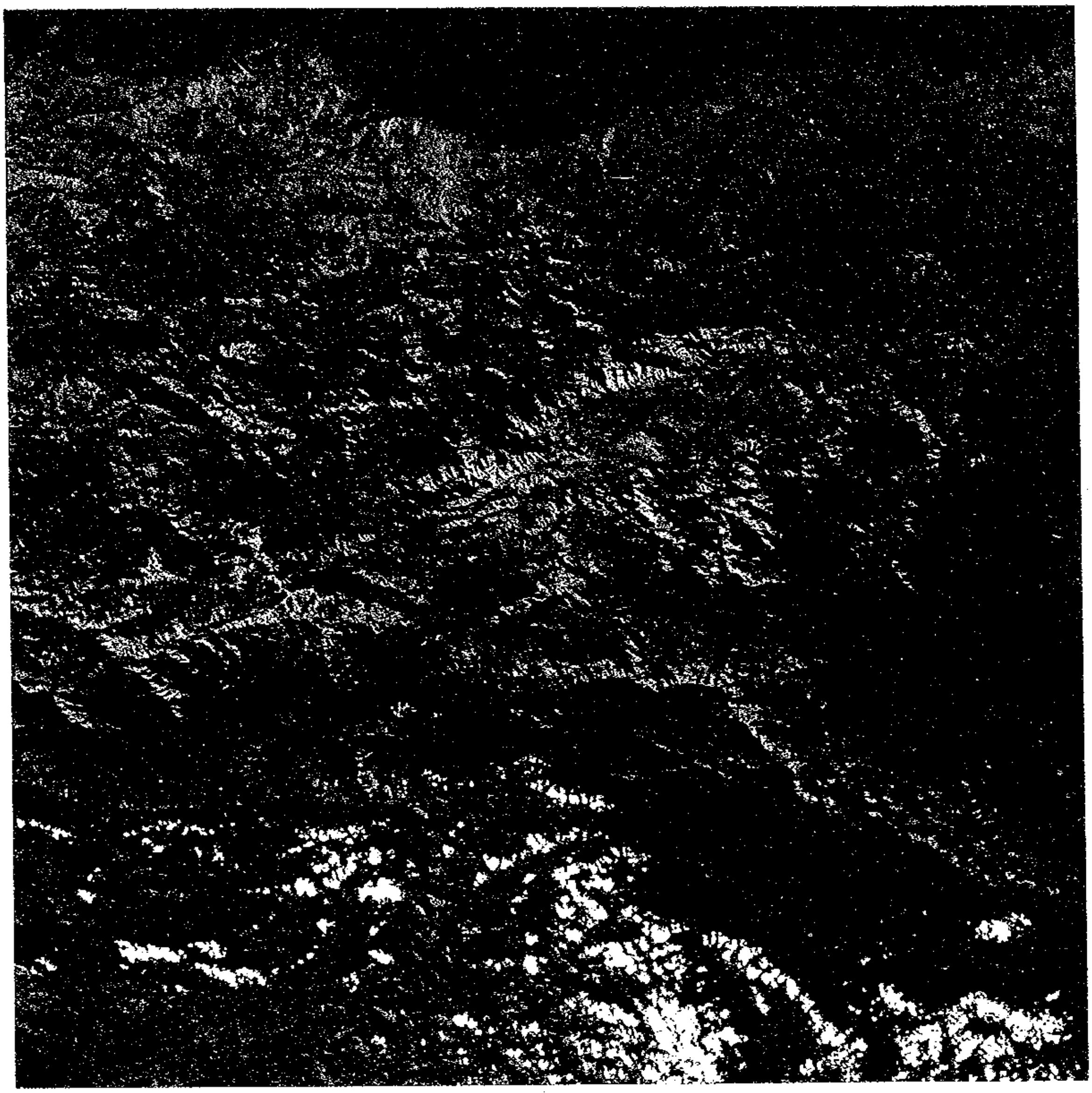

Perspective View of Buguias Central and Mt. Lusab

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PART — I GENERAL

CHAPTER 1 INTRODUCTION

1–1 Objective of the Survey

The Government of Japan, in response to the request of the Government of the Philippines, has conducted a geological, geochemical and geophysical exploration survey in the Buguias geothermal area in Benguet province, where promising geothermal reservoirs are expected to exist. The results of this survey should verify the existence and extent of these geothermal reservoirs, as well as to select the most promising core-drill sites for the next phase of the survey.

1–2 Details of the Survey

The Republic of the Philippines, being volcanically a similar country to Japan, and located in the "circum-pacific fire belt", shows good potential for geothermal development in many areas. Since 1973, the exploration and development of potential geothermal resources have been carried out, with the technical assistance of Italy, New Zealand and the USA. Since the oil crisis of 1970, exploration and development have been accelerated and four geothermal power plants at Tiwi, Makiling-Banahaw, Palimpinon and Tongonan were constructed. The Philippines moved to second place among countries engaged in geothermal energy production behind USA, edging out Italy, and had a total capacity of 446MW in 1980.

According to the ten-year energy program of the Government of the Philippines, underground exploration, with the requisite surface-exploration activities, are programmed to bring the total number of deep wells drilled to 692, by 1989, in the two geothermal areas including Daklan. With the above background, the Government of the Republic of the Philippines has requested the Government of Japan to supply technical assistance for geothermal exploration in six areas, including Buguias. In response, the Government of Japan has assigned the project to the Japan International Cooperation Agency (JICA), and in the period 2 March ~24 March of 1980, JICA dispatched the preliminary survey team of five members to the Philippines, with Mr. K. Watanabe as its leader.

From the four potential geothermal areas; Daklan, Montelago, Buguias and Mabini, this order of geothermal potential was chosen; Daklan, Buguias, Montelago, Mabini, in which Daklan and Montelago are under exploration with the technical help of the Italian Government. Therefore the JICA team was requested to select Bugias, in the northern area of Daklan.

This survey was planned and executed in accord with an "Implementing Arrangement and

Minutes of Meeting", agreed between the Government of the Philippines and the preliminary sruvey team of JICA.

This survey is the first phase of a three year program.

1–3 Members of the Survey Team

Team Leader	Mr. Yasunori Sakai Mitsubishi Metal Corporation	Geologist
Coordinator	Mr. Kazuhiro Yoneda Japan International Cooperation Agency	
Team Sub-leader	Mr. Asahi Hattori Bishimetal Exploration Co., Ltd.	Geophysicist
Geochemical Survey	Mr. Yasuhiro Kubota Mitsubishi Metal Corporation	Geologist
Geophysical Survey	Mr. Hiroshi Fukuda Bishimetal Exploration Co., Ltd.	Geophysicist
Geological Survey	Mr. Keiji Nakano Bishimetal Exploration Co., Ltd.	Geologist
– do –	Mr. Takao Maeda Bishimetal Exploration Co., Ltd.	Geologist
Geophysical Survey	Mr. Manabu Kaku Bishimetal Exploration Co., Ltd.	Geophysicist

Counterpart (Bureau of Energy Development – BED)

Project Manager Acting Div. Chief	Mr. Alfredo C. Troncales
Senior Geologist	Mr. Elmer H. Ibarra
Supervising Geochemist	Mr. Zalzon Espina
Geothermal Engineer	Mr. Edgar S. D. Olympia
Geologist II	Mr. Conrado C. Panem
Chief Geophysicist	Mr. Edward S. Bernard
Senior Geophysicist	Mr. Egai S. Aguas
Geologist	Mr. Romeo R. Tena

Geologist	Mr. Narciso V. Salvania
Geologist	Miss Helene G. Aniceto
Geologic Aides	Mr. Benjamin Mata
Geologic Aides	Mr. Leonardo U. Elemia

1–4 **Itinerary**

No.	Date	Day	Schedule
1	1981 Jan. 20	Tue.	Tokyo Lv. ~ Manila Ar.
2	21		A courtesy call on the Japanese Embassy, BED etc.
3	22		Make arrangements with BED
4	23		Make arrangements with BED and purchase the goods.
5	24		Manila Baguio
6	25	Sun.	Buguio Buguias
7	26		Around of inspection at the survey area
8	27		Beginning of the survey (Reconnaissance geological and gravity surveys)
9	28		
10	29		
11	30		Team Leader : Buguias ~ Baguio
12	31		– do – : Baguio ~ Manila
13	Feb. 1	Sun.	– do – : Report to BED
14	2		
15	3		
16	4		
17	5		
18	6		
19	7		
20	8	Sun.	
21	9		
22	10		
23	11		
24	12		
25	13		
26	14		
27	15	Sun.	
28	16		
29	17		

No.	Date	Day	Schedule
30	1981 Jan. 18		
31	19		Mr. Y. Kubota : Tokyo Lv. ~ Manila Ar.
32	20		– do – : A courtesy call on BED etc.
33	21	Sun.	– do – : Manila ~ Baguio
34	22		– do – : Baguio ~ Buguias
35	23		(Beginning of geochemical survey)
36	24		
37	25		
38	26		(Beginning of semi-detailed geological survey)
39	27		
40	28		
41	Mar. 1	Sun.	
42	2		Team leader : Tokyo Lv. ~ Manila Ar.
43	3		– do – : Arrangements with BED
44	4		– do – : Manila ~ Baguio
45	5		– do – : Baguio ~ Buguias
46	6		
47	7		
48	8	Sun.	Finish the survey.
49	9		Arrange the survey data
50	10		– do –
51	11		Buguias ~ Baguio
52	12		Baguio ~ Manila
53	13		Arrange the survey data and pack the equipments
54	14		Calculate the data and export the equipment
55	15	Sun.	Calculate the data
56	16		Write up the interim report
57	17		– do –
58	18		Report the interim report
59	19		A courtesy call on the Japanese Embassy, BED etc.
60	20		Manila Lv. ~ Tokyo Ar.

PART－Ⅱ PARTICULARS

CHAPTER I GEOLOGICAL SURVEY

Chapter 1

Geological Survey

1–1 Purpose and Method of Survey

1–1–1 Purpose of Survey

The geological survey was conducted covering a total area of 330 Km^2 in order to investigate the geological structures related with the geothermal system in the area. The main objective of the survey this year was to determine the potential area for the future development.

For this purpose the 1st Phase of the geological survey was to establish the stratigraph and to clarify the geological structure associated with the regional geothermal system, i.e., the fundamental date, fracture system, geothermal alteration products and the volcanism in the area.

1–1–2 Method of Survey

At the main outcrops, detailed descriptions were made lithologically and stratigraphically in order to correlate and interpret geological structures. (Fig. II–1–1, Table II–1–1, II–1–2) A topographical map of 1:15,000 was used for the survey. A total of 300 rock samples were collected in the course of the field survey, wherein 200 specimens were brought to Japan for chemical analysis, microscopic observation, X-ray diffraction and radiometric dating. The observation of aerial photographs and landsat images were correlated with the field survey results.

The survey results were compiled on a geological map with a scale of 1:25,000 with profile sections. The map was reduced to 1:50,000 as inclosure to this text.

1–2 Outline of Geology

Northern Luzon Island forms an arcuate structure, bounded by the Philippine Sea on the east and the South China Sea on the west. The island lies between the elongated northern part of the Philippine Trench and the Manila Trench, wherein deep earthquakes and volcanism generated by subduction of crustal slabs (Fig. II–1–2, Jolle de Boer et. al., 1980).

The basic features of the geological structures in Northern Luzon are characterized by a series of anticlinorium and synclinorium trending north to south. From east to west, these are: Sierra Madre anticlinorium, Cagayan Valley synclinorium, Cordillera Central anticlinorium, and Ilocos Basin synclinorium.

The Buguias geothermal field is located on the southern part of Cordillera Central anticlinorium (Fig. II–1–3). Quaternary volcanism of Northern Luzon is distributed along Cordillera Central and Sierra Madre anticlinoriums. The known geothermal manifestations in Cordillera Central are in Kalinga-Apayao, Bontoc, Daklan-Buguias area and Itogon-Acupan area.

The geology of Cordillera Central is composed of crystalline rocks of late Cretaceous, basic volcanics of lower Paleogene with the normal sediments, basic to acidic volcanics of uppermost Paleogene to Lower Miocene accompanied by limestone and Quaternary acidic volcanics (MMAJ, JICA 1977).

The geology of Buguias area consists of Buguias formation, a new name, which is composed of basic volcanics in uppermost Paleogene to lower Miocene and Loo formation which is composed of Quaternary acidic volcanics and intrusive rocks. The geological structure of Buguias area is complicated because of the combination of folds and faults. The trend of major structure shows N-S direction with minor ones trending NW-SE and EW.

1–3 Photogeology

Landsat images depend on 4–5–7 band image film (70 sq mm) taken by multi-spectral scanner of satellites. The imagery black and white are reproduced in scales of 1:1,000,000, 1:500,000 and 1:250,000. The images were analysed for lineaments of geological units and location of Quaternary volcanics.

In the analysis of aerial photographs, 1:20,000 scale was used in an area of 500 Km^2, including the surrounding areas of Buguias. The analysis was done for outline of stratigraphy, geological structure, and distribution of Quaternary volcanics especially the existence of ring structures related to its activity.

1–3–1 Analysis of Landsat Images (Fig. II–1–4)

The geological units analyzed by landsat images were classified into five units, I, I′, II, II′ and III. The lineaments are trending N-S, NW-SE, NE-SW and E-W as shown in Fig. II–1–4.

° Geological Unit:

Geological unit I is located along the coast line and at the lowland of Cagayan Valley, where it forms flat plain topography.

In this unit, the lineament is not well developed because the unit was estimated to be composed of normal sediments of Quaternary member. Unit I′ appears to scatter in vegetated mountainous Cordillera Central. The surface of the area is fairly smooth in moderate hills

Table II–1–1 Coverage of Geological Survey

	Area Covered	Length of Survey Routes
Reconnaissance Survey	330 Km^2	240 Km
Semi-detailed Survey	80 Km^2	70 Km

Table II–1–2 List of Laboratory Work

	Analysis pcs.
Thin Section	30
X-ray Diffractometer	72
Radiometoric Dating (C^{14})	1
do (Fission track)	2
Chemical Analysis (whole rock)	11
do (sinter)	7
do (water)	10
Small Foraminifera	13

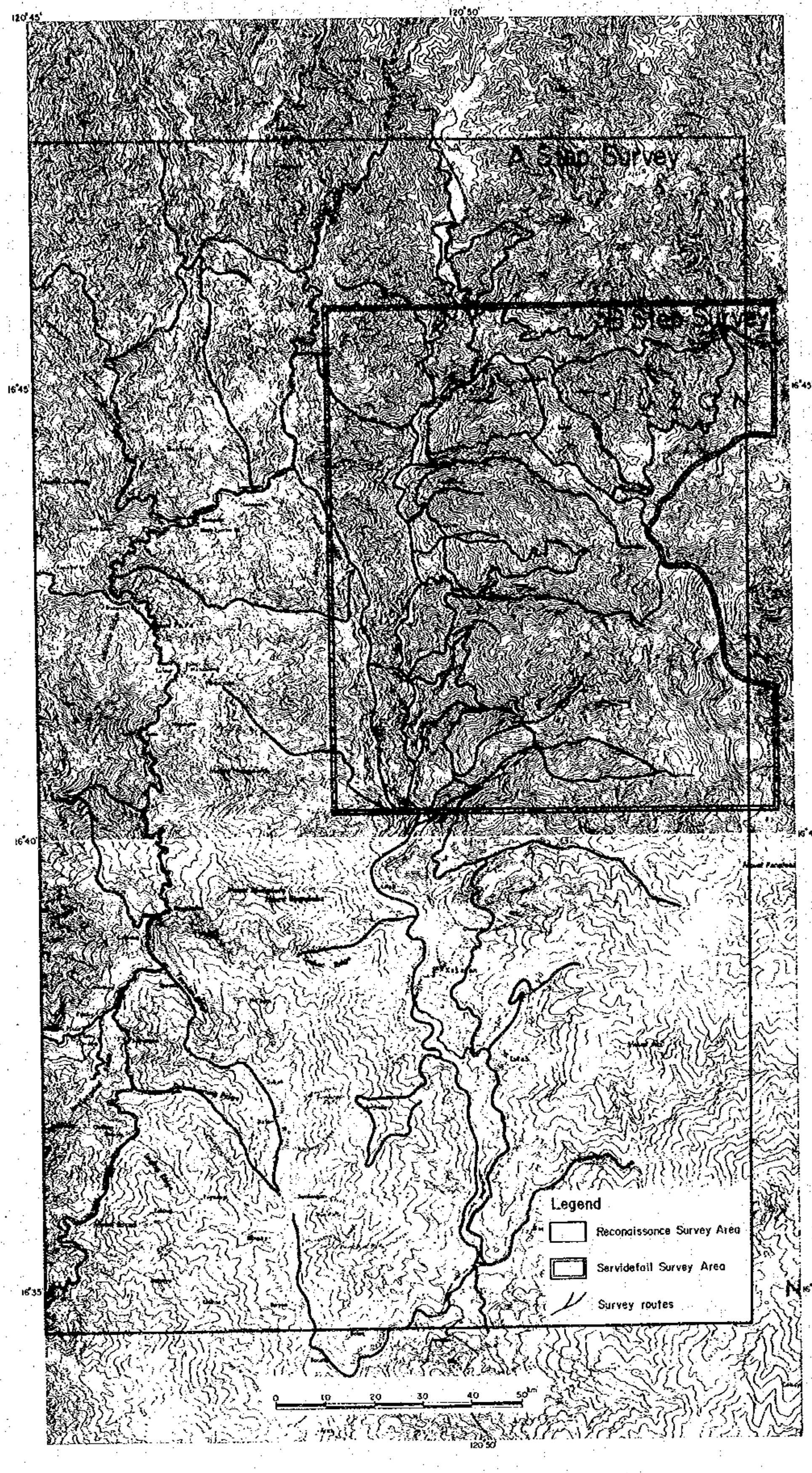


Fig. II–1–1 Coverage of Geological Survey Route

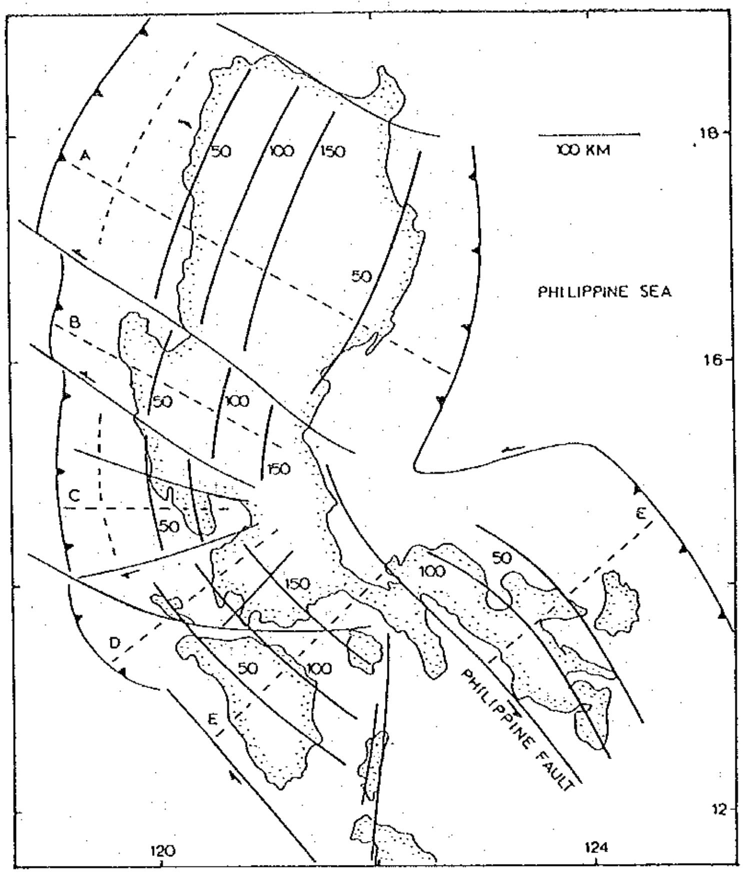


Fig. II–1–2 Depth Contours of Upper Surface of Subducting Crustal Units

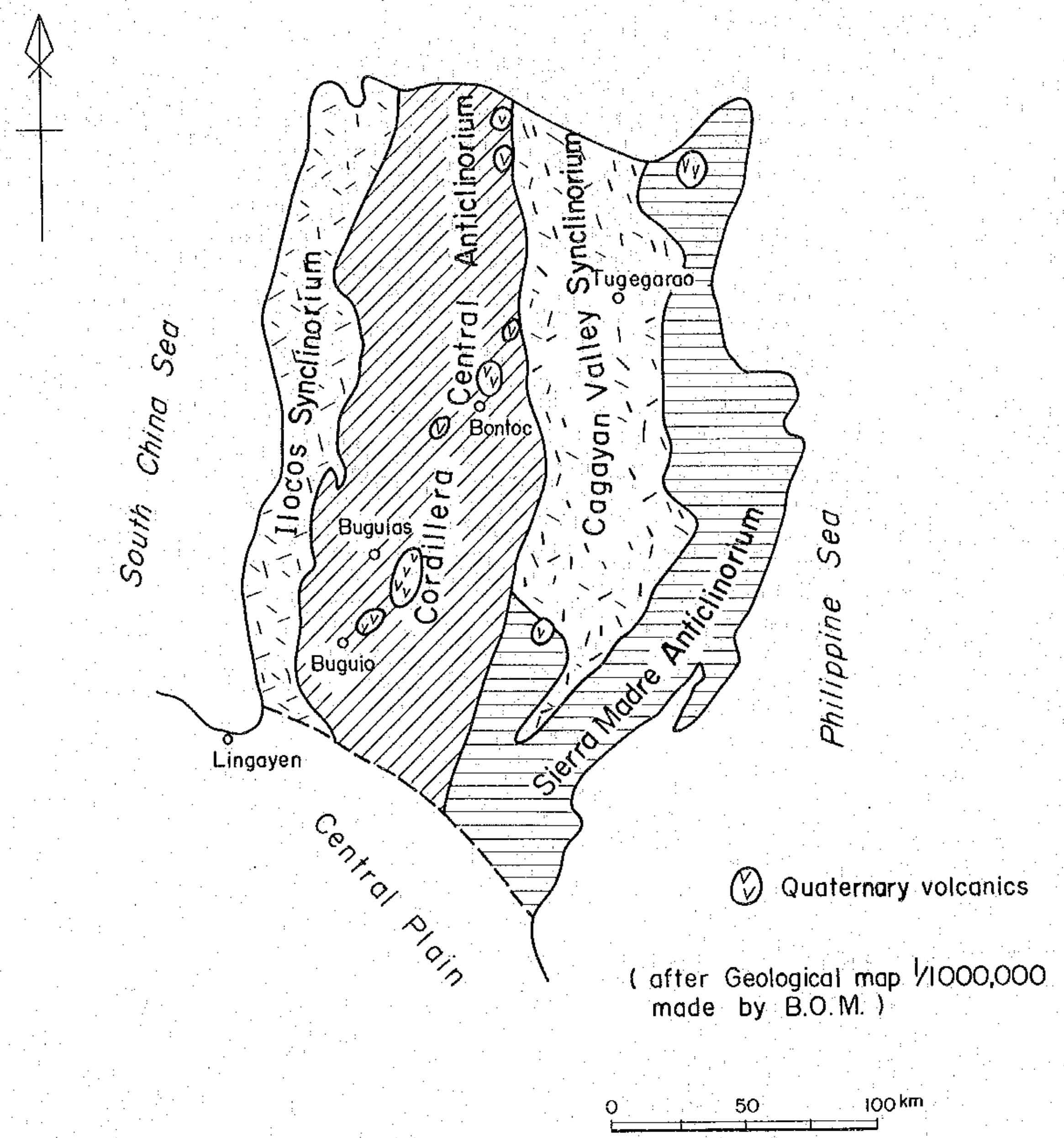
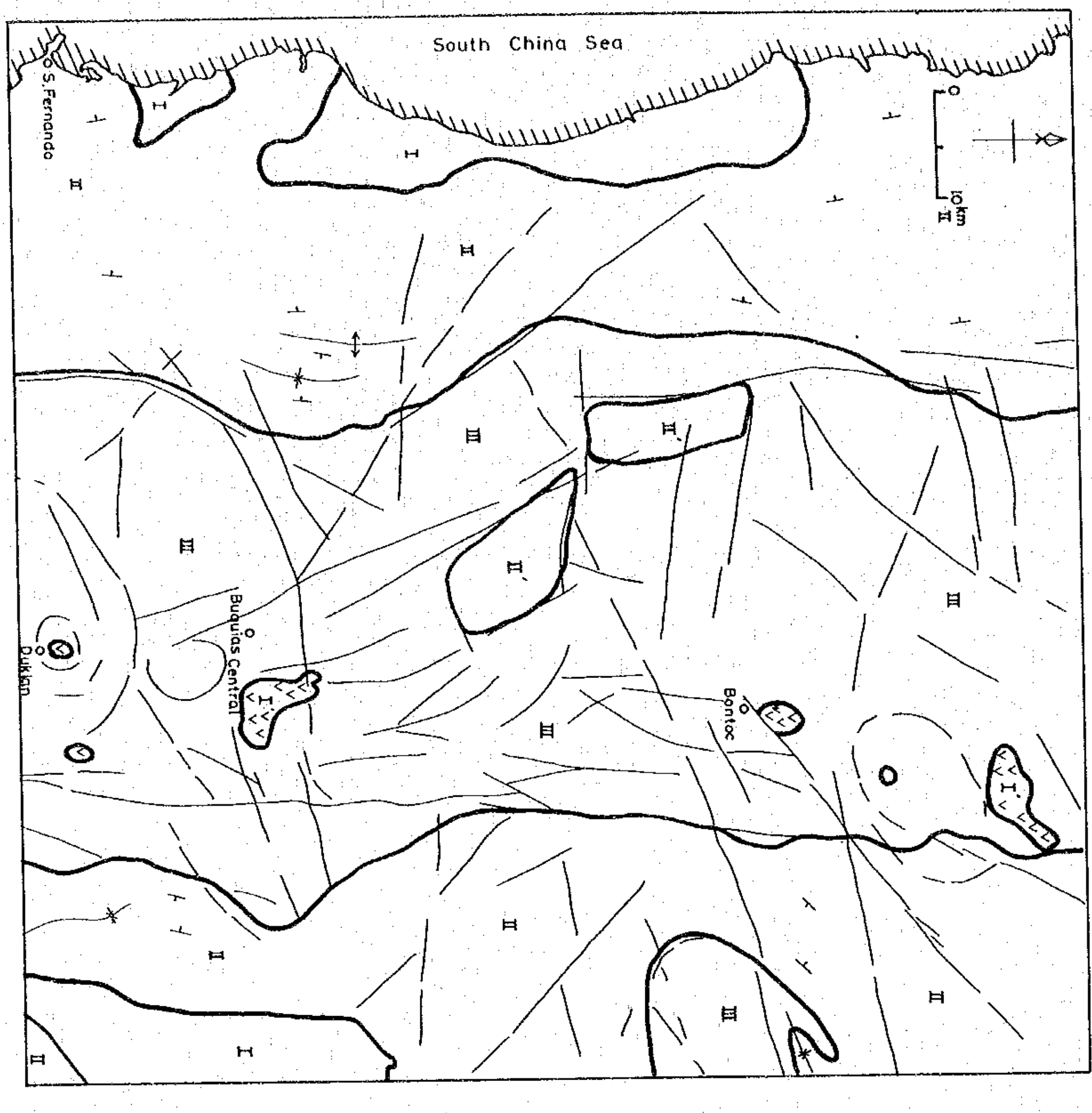


Fig. II–1–3 Tectonic Map of the Northern Luzon



Legend

I , II , III	; Geological unit		; fold axis
	; Geological unit boundary		; bedding
	; Lineament		

Fig. II–1–4 Interpretation Map of Landsat Image

in contrast to the steep rough topography of the surrounding area. Several convex shaped lava hills were considered to be Quaternary lava dome. These lava dome are distributed in the northern part of Bontoc, the biggest of which are in the eastern part of Buguias and in Daklan area.

Geological Unit II develops on both wings of Cordillera Central and is covered with thick vegetation. The surface is fairly smooth and drainage system is well developed showing parallel pattern. Moderate to variable resistance to erosion is evidenced by the presence of a topographic cuesta in a N-S trend. The structure illustrates beddings and folds, thus unit is assumed to be composed of normal sediments with well bedded members, one of which is mainly deposited as a molasse sediment during the uplifted epoch of Cordillera Central on its both edges in Neogene of Tertiary.

Geological Unit II' is enclosed within geological unit III, forming an inner basin. The surface is smooth and is mainly covered with forest and cultivated land. Drainage system is not well developed and resistance to erosion is weak. This unit is considered to be composed of coarse sedimentary materials deposited in a collapsed basin in the later stage of geological Unit II to the early stage of Unit I.

Geological Unit III forms the core of Cordillera Central and is distributed within the Cordillera Central. The surface is slightly coarse and resistance to erosion is fairly strong. The topography shows a deep V shaped valley.

The drainage is well developed showing parallel to sub-trellis patterns. Some bedding formations were recognized. However, complicated geological structure is shown in this unit.

o Lineaments

Lineaments are not well observed in geological Unit I, but are well developed in Unit III, trending N-S, NW-SW, NE-SW, E-W and showing ring structure. The lineament trending N-S is located in Cordillera Central and is well developed in both wings at the eastern part of Cordillera Central with the same direction as the geological formations. A crisscrossed relation between the N-S trending and the other lineaments is observed. A detailed examination of the relation among lineament directions revealed that the N-S trend develops from older to younger stage in the area. The typical lineament of N-S trend in the area is observed at about 20 Km east of Buguias, stretching north to south over 100 Km and is likewise correlated to the direction of Northern Luzon Island Arc.

The lineament trending NW-SE developed on the western part of Cordillera Central and is of the same age as the N-S trend.

The lineaments trending E-W and NE-SW are observed to crosscut Cordillera Central and elongate over 50 Km in some cases. These are considered as part of the transcurrent faults of the Cordillera Central anticlinorium.

The NW-SE trending lineament is located at the marginal parts of Cordillera Central but is rather inextensive.

The ring-like lineaments are observed at about 10 Km north of Bontoc and are about 15 Km in diameter.

At the southern part of Buguias, a ring form lineament with a diameter of 5 Km is observed. Furthermore, concentric ring-form lineaments are also detected in Daklan and are approximately 20 Km in diameter.

1–4 Stratigraphy

The stratigraphy of the survey area is grouped into three (3) formations, Oligocene to Lower Miocene, Upper Miocene, and Quaternary. Previous geological surveys of the area did not classify or indicate nomenclature for the formations, thus the survey party has identified Buguias, Loo, and Bodo from lower to topmost formation respectively. (Table II–1–3, Fig. II–1–5, II–1–6, II–1–7)

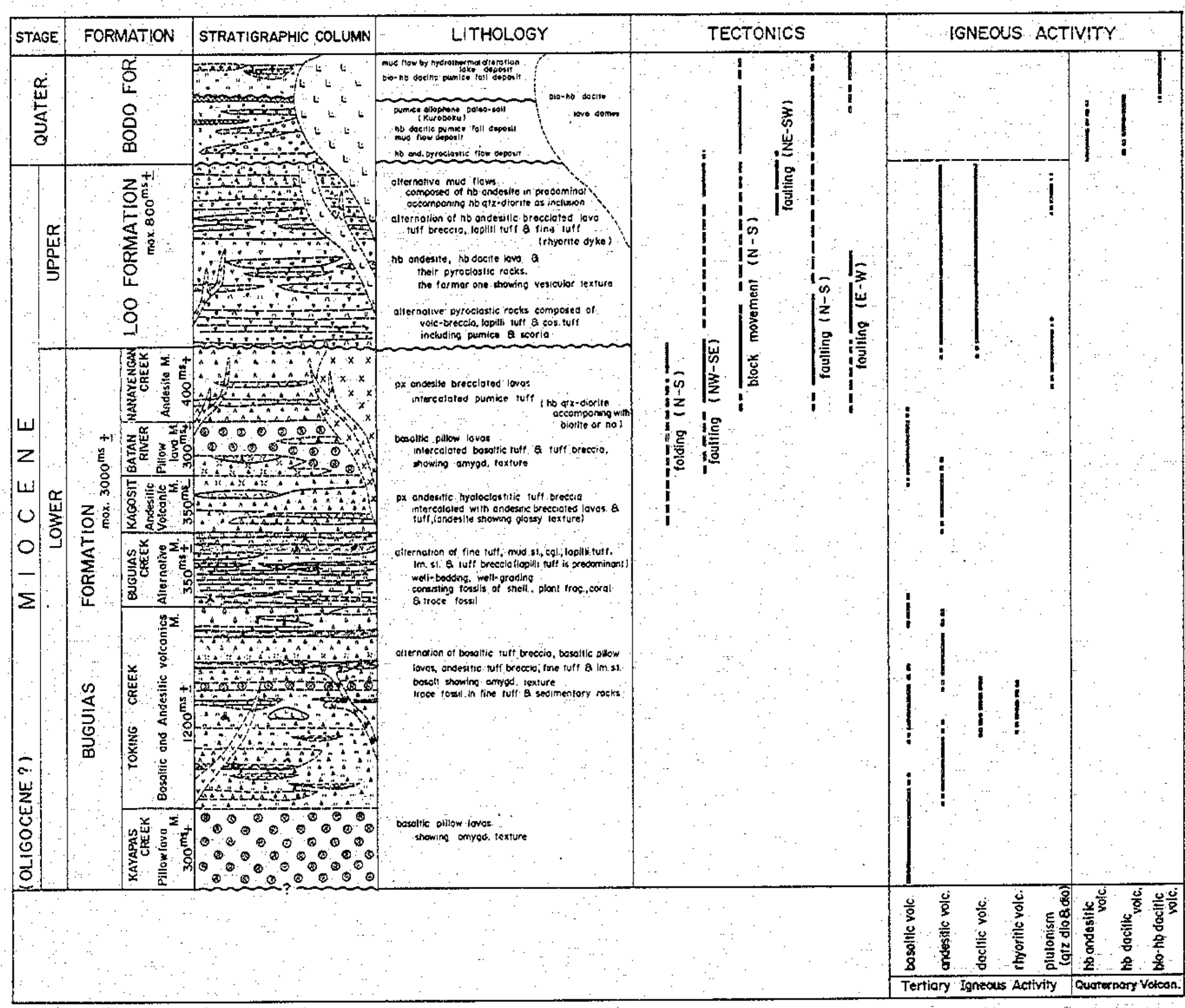
1–4–1 Buguias Formation

This formation is distributed all over the survey area, composed predominantly of basaltic to andesitic pyroclastic rocks, lava and alteration of tuff and mudstone.

Pillow structure is often observed in basaltic and andesitic lava and it is divided into two (2) horizons, lower and middle, in the formation. The lava and pyroclastic rocks are characterized by phenocrysts of pyroxene. The pyroclastics are tuff breccia, hyaloclastites and lapilli tuff, and are often replaced with calcareous substances in their matrix. Dacite and rhyolite lava flows are also observed at some places. The alteration of normal sediments intercalated with conglomerate, wherein greenish metavolcanic gravels presumed to be from the basement are noted. The trace fossils are often observed in the alternation of calcareous sediments and pyroclastics. This evidence shows that the environment of deposition would be under the condition of shallow sea water.

The thickness of Buguias formation reaches about 3,500 m. Planktonic and benthoic foraminiferas are are embedded in tuff. Index fossils are not observed in the formation. Therefore, it is difficult to determine the depositional age of the formation, however, it is

Table II–1–3 Generalized Stratigraphic Section in the Survey Area



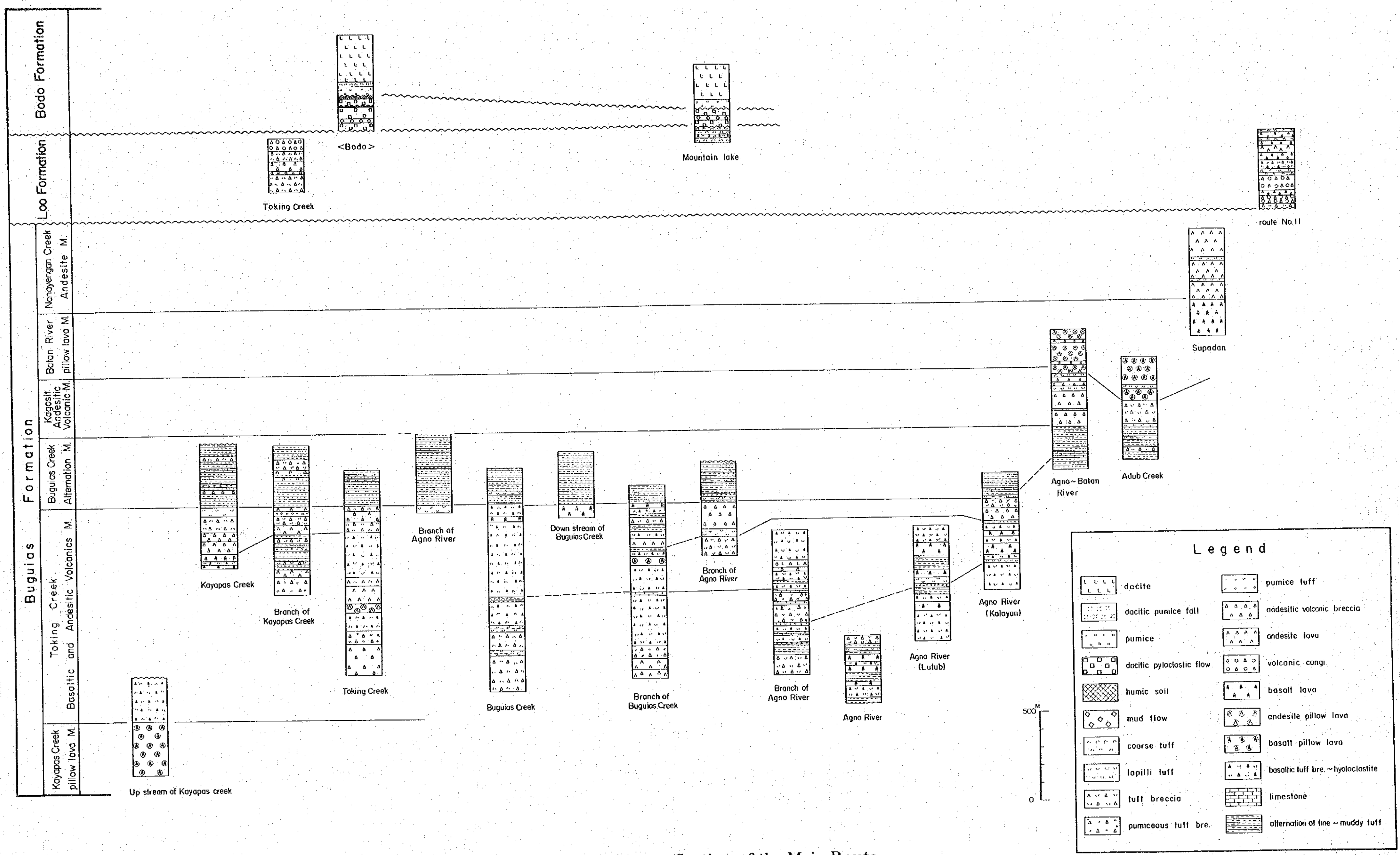


Fig. II–1–5 Columnar Section of the Main Route

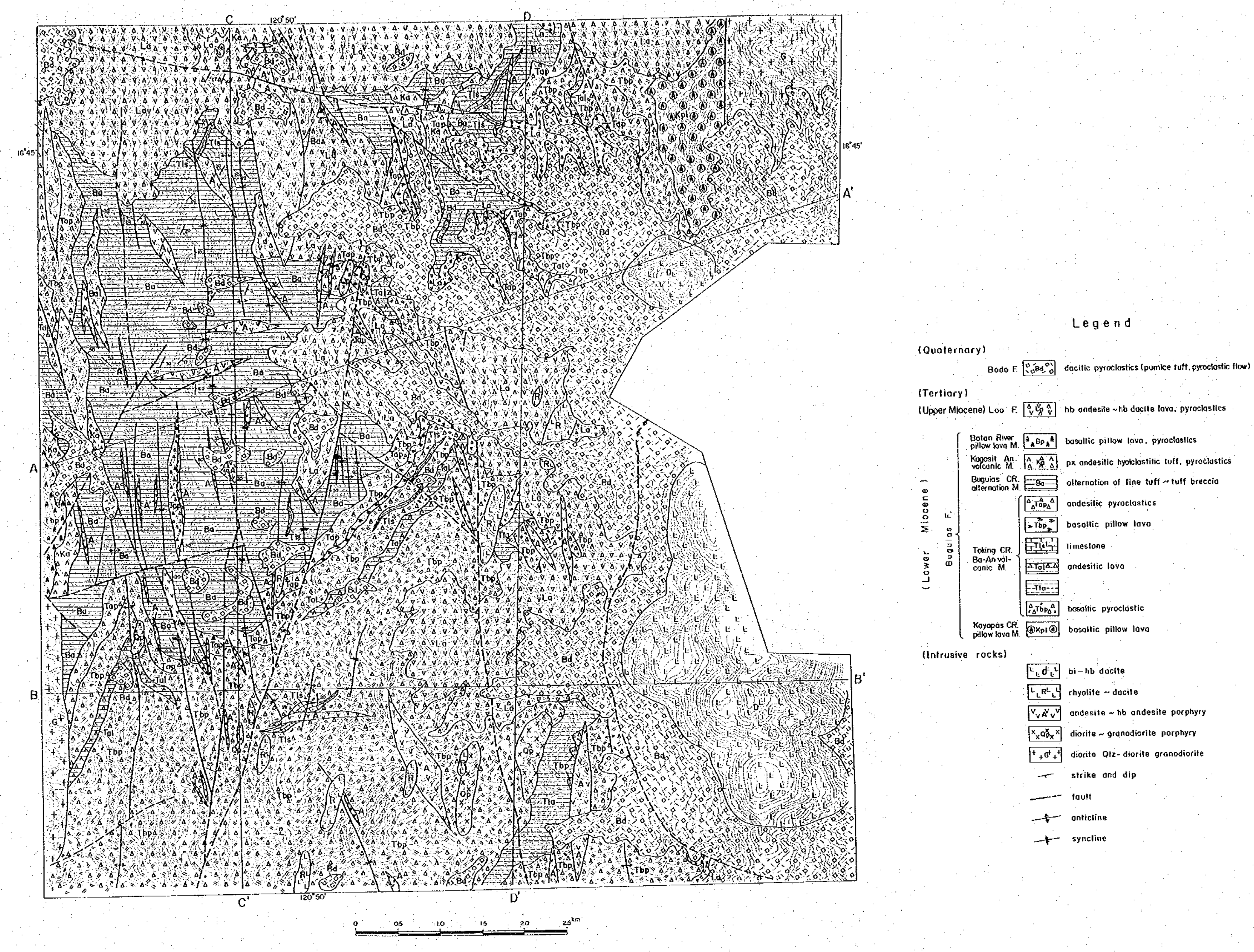
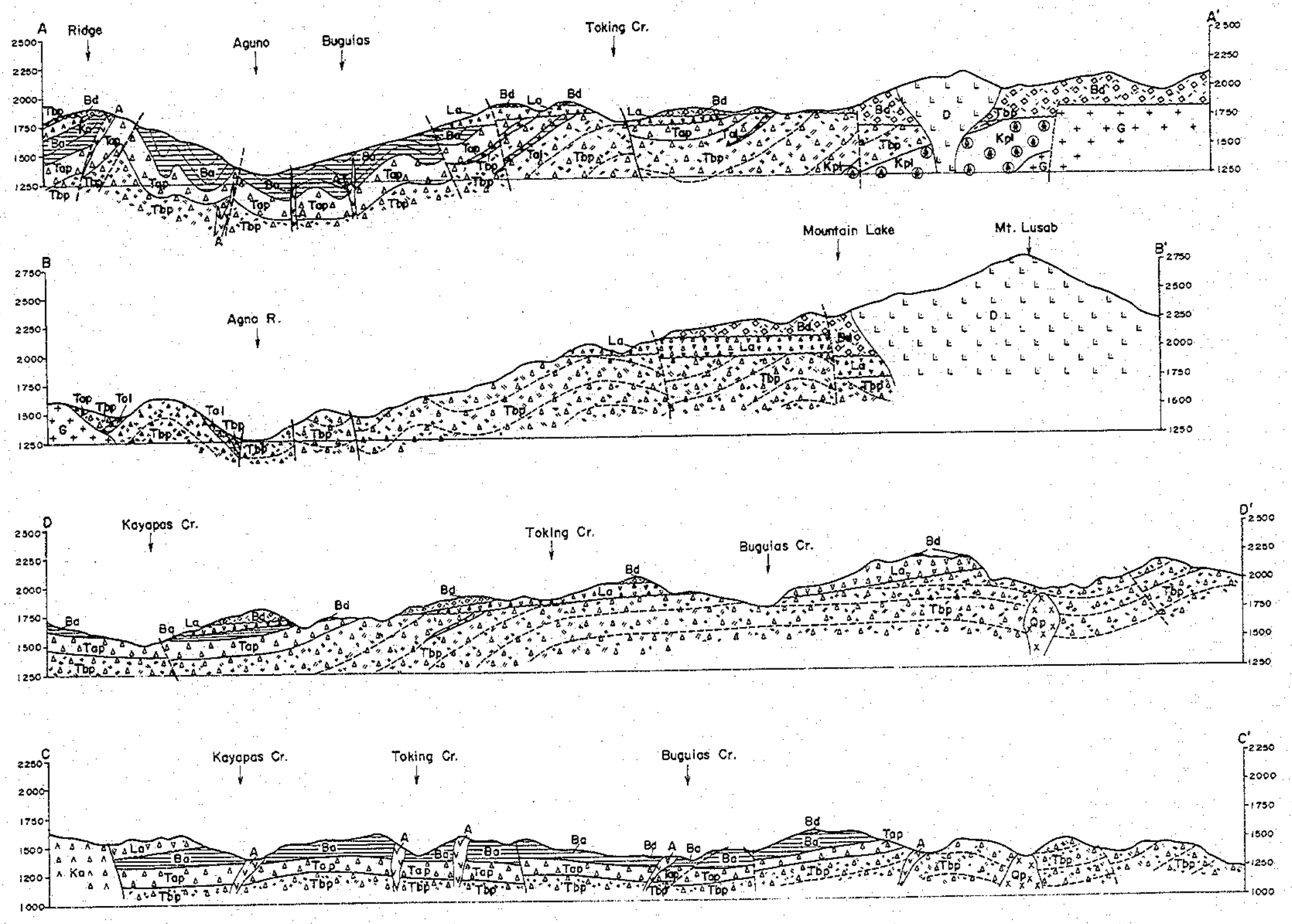


Fig. II–1–6 Geological Map of Semidetailed Survey



Geological Profiles of Fig. II–1–6

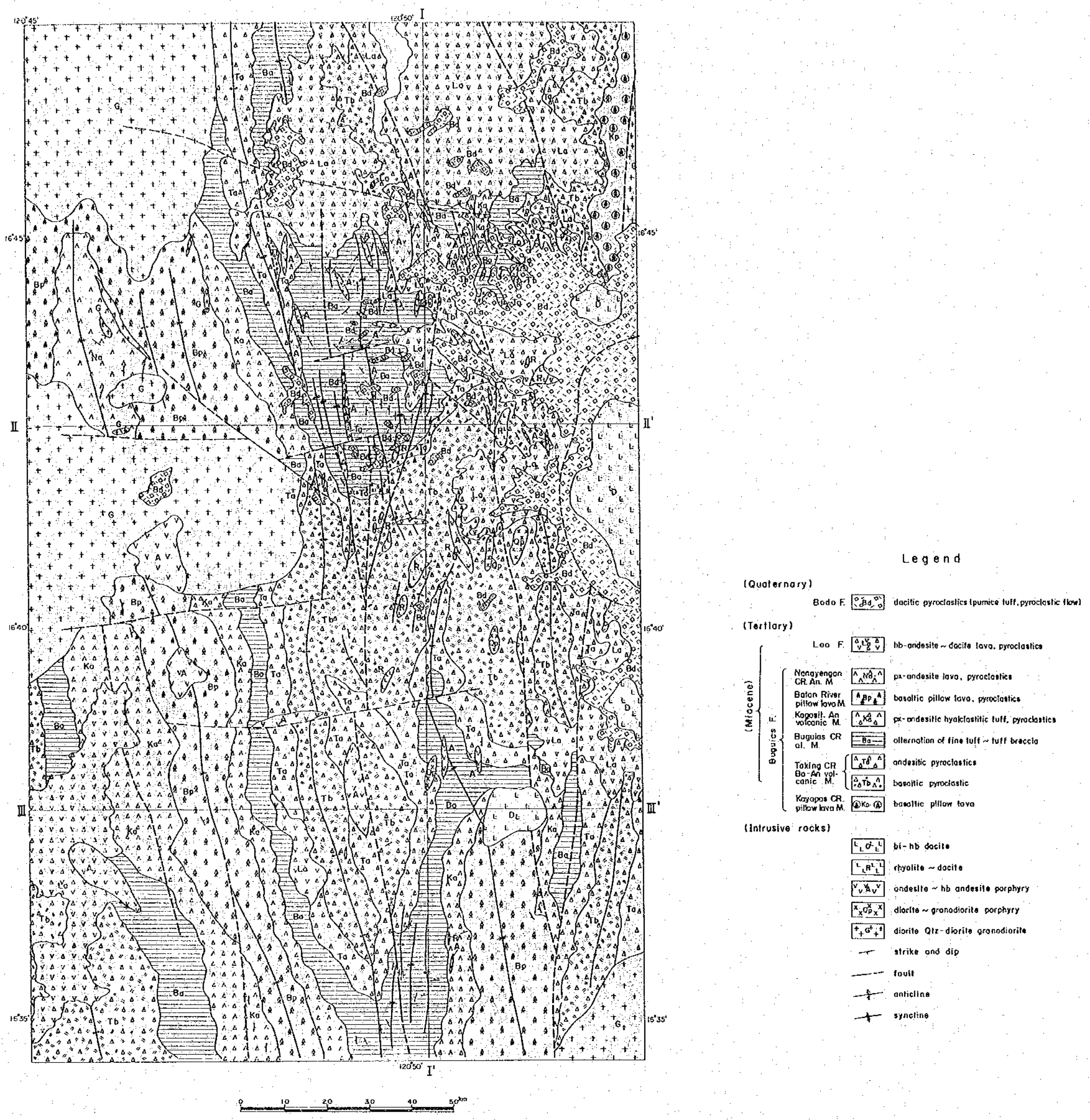


Fig. II-1-7 Geological Map of Reconnaissance Survey