REPORT ON EXPERT TEAM OF JAPAN DISASTER RELIEF TEAM (JDR) ON THE EARTHQUAKE IN PHILIPPINES OF JULY 16, 1990

AUGUST 1990

JAPAN INTERNATIONAL COOPERATION AGENCY

(JICA)

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Preface

This document summarizes the report of the Expert Team of the Japan Disaster Relief Team (JDR) which was dispatched from July 29 to August 7, 1990 to provide guidance and advice on emergency restoration and post-earthquake measures for the stricken area in the northern part of Luzon which suffered serious damages from the Philippine Earthquake on July 16, 1990.

In addition to the June, 1989 report of the Expert Team on the Spitak Earthquake in the Armenian Soviet Socialist Republic in the USSR and others, published since the start of the Japan Disaster Relief Team, it is believed that this report will not only contribute to planning a full-scale restoration and rehabilitation program, but will also significantly serve as a reference for measures to prevent disasters in many disaster-prone countries frequently suffering from earthquakes.

We wish herewith to express our deepest respect to the members of the Expert Team, led by Dr. Tsuneo Okada, Director General of the Institute of Industrial Science, the University of Tokyo, who investigated in detail the state of the damages caused by the earthquake at the stricken area, where traffic and communications immediately after the disaster were very difficult, and provided advice on emergency measures and rehabilitation from the disaster, and who provided proposals for disaster countermeasures based on accumulated experience and technical know-how in our country, as well as to the Japanese Embassy in the Philippines, the JICA Philippines Office, and the participants at the site, all of whom provided significant assistance to the field investigation.

August, 1990

Sekai Nishino
Vice President,
Japan International
Cooperation Agency

Table of Contents

1. Introduction

An earthquake of M=7.7 with an epicenter on Luzon Island, the Republic of the Philippines occurred at about 4:26 P.M. (local time; same as Japan time) on July 16, 1990.

In view of the heavy damage of this earthquake, the Government of Japan immediately decided on July 17 to dispatch a medical team (July 17-24) and a rescue team (July 18-26) in accordance with the Law concerning the Dispatch of Japan Disaster Relief Team (promulgated and enforced on September 16, 1987). Subsequent to the dispatch of these, the Japanese Government dispatched a survey team of eight experts for ten days from July 29 to August 7 in response to a Philippines government request (July 25) for the dispatch of an expert team.

We, as the expert team, collected information from Philippine sources and took field surveys and also separately conferred with rehabilitation activity leaders in disaster-stricken areas. Furthermore, we prepared an interim report (English) there, generally describing the earthquake and its damage and recommended immediate measures for rehabilitation from the earthquake disaster, and briefed about 60 Philippine experts including the Secretary of Public Works and Highways on this basis the day previous to our return to Japan, August 6.

Our present report contains survey results obtained from 10 days stay and is a recapitulation largely derived from the interim report and was made after our return. However, it was hurriedly prepared from limited data because the Philippine Government authorities had desired an early submittal of this report. So, we request your understanding that, depending on further accumulation of data, corrections or additions may be necessary in some of its parts.

Our field activities were greatly aided by the Philippine Government by having its officials accompany us in our field surveys, providing Air Force transport, supplying us with the results of past surveys and otherwise. The Philippine Government agencies that contacted us directly were mainly the Department of Public Works and Highways and the Institute of Volcanology and Seismology but we also received much information from local offices, city halls, etc. everywhere, thus facilitating our research.

Our activities as the expert team were assisted by not only the Japanese embassy in Manila, the JICA office in Manila but also by JICA-dispatched long-term experts in the Philippines. Locally operating Japanese companies were especially helpful by allowing their resident officials to accompany us in our field surveys and cooperating in our preparation of the interim report data.

It can be said that this report has been made possible by the collaboration of us specialist teams and these people. Here we would like to express our heartfelt thanks for the cooperation extended to the team by all agencies concerned.

In the Republic of the Philippines, which, like Japan, has many earthquakes but whose recurrence interval between disastrous earthquakes is relatively long, and technical know-how in the damage of modern structures are not so much accumulated and manuals on the methods of damage assessment and rehabilitation are not necessarily enough. We sincerely hope that the application of our disaster evaluating methods based on our experiences in earthquake disasters and our recommendations concerning the emergency repair of damaged structures and the methods of future rehabilitation will help the Philippine rehabilitation effort as soon as possible after its recent loss of many precious lives and immense property damage.

August 17, 1990
Tsuneo Okada,
Leader,
Japan Disaster Relief Expert Team

2. Purposes

The purposes of the Expert Team included the following:

1) Collection of information on the entire earthquake disaster including the characteristics of the earthquake.

2) Survey on causes of damage to buildings, bridges, roads, etc.

3) Survey on the usability of remaining facilities: namely,
   a) Necessity of off-limits action for buildings
   b) Possibilities of reuse of bridges, buildings, etc.

4) Technical guidance on emergency measures or permanent measures for disaster-stricken districts: namely,
   a) Presentation of a short-term rehabilitation plan and extraction of places
   b) Provision of technical information useful in planning rehabilitation
   c) Listing of necessary materials and equipment (materials and heavy equipment)

To accomplish these purposes, six groups were formed, as in Chapter 4, and took field surveys according to the itinerary indicated in Chapter 3.

To help in the understanding of subsequent chapters, a map showing the names of important places and administrative boundaries in Luzon Island is given in Figure 2.1.

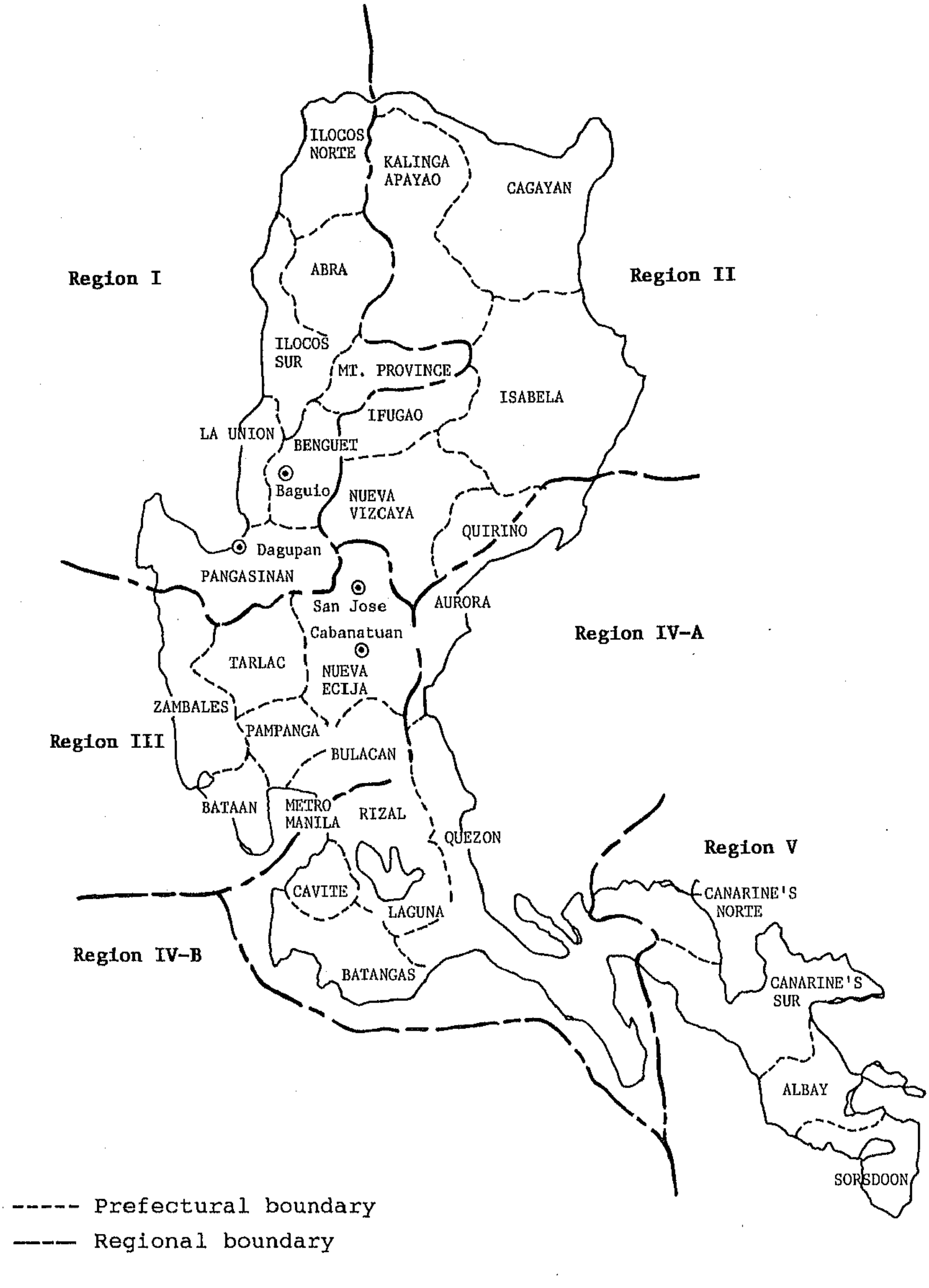


Figure 2.1 Administrative regions and boundaries in Luzon

3. Itinerary

July 29 (Sun)

8:00 Conferred at Narita Airport, attended by Planning Official Suzuki, Technical Cooperation Section, Economic Cooperation Bureau, Ministry of Foreign Affairs and others concerned.

10:15 Left Tokyo (PR-431).

14:30 Arrived at Manila. Met by First Secretary of Japanese Embassy Ikeda, etc.

19:30 Dinner party given by Mr. Miyamoto, Representative, JICA Office.

22:30 Team meeting at Nikko Manila Garden Hotel.

July 30 (Mon)

8:30 Conferred at the embassy.

10:00 - 11:00 Courtesy call to Ambassador Tanaka.

13:30 Meeting including Philippine counterparts at JICA Office.

14:30 Start of survey activities by each group.

(General Inspectorate Group)

15:20 Courtesy call to the Department of Public Works and Highways.
Briefed by Undersecretary Encarnacion and others on the status of damage.

17:00 Courtesy visit to the Philippine Institute of Volcanology and Seismology.
Briefed on the earthquake by Director Bunonbayan and Asst. Prof. Nakata of Hiroshima Univ. (Stay at Nikko Manila Garden Hotel.)

(Roads - Group 1)

15:00 Left Manila.

18:00 Inspected damage in Cabanatuan City.

19:00 Arrived at Cabanatuan (kms113). (Stay at a village inn.)

(Roads - Group 2)

14:55 Left JICA office in Manila.
Survey on North Superhighway and Pampanga River viaduct. Proceeded north via Capas and Tarlac.

18:04 - 25 Survey on San Isidro Bridge (kp149+511.2).
Turned back from this point and proceeded to Dagupan via Tarlac and Lingayen.

20:40 Arrived at Dagupan. (Stay at Victoria Hotel.)

(Bridge group)

15:00 Left Manila.
Surveyed Candaba viaduct and Bamban bridge

20:30 Arrived at Dagupan via Tarlac.

21:00 Supper; Group meeting. (Stay at Victoria Hotel.)

(River and dam group)

15:00 Left Manila.

15:30 Conferred at the dam safety measures section of the NIA head office (Quezon). (Section chief, etc.)

19:00 Conferred at the NIA Pampanga River upper reaches irrigation office (Cabanatuan). (Director C.B. Pirones, etc.)

19:30 Arrived at Cabanatuan. (Stay at Hotel La Parira Inn.)

(Building group)

15:00 Meeting on judgement of damaged buildings with study cooperators.

19:00 Preparation for field survey.

July 31 (Tue)

(General Inspectorate group)

8:00 Left Biramoa Air Force Base for Baguio.

9:20 Landed at San Fernando Airport because of inclement weather in Baguio.

11:20 Visited local office of the Department of Public Works and Highways (San Fernando).
After being briefed by Director Parayano on damage, proceeded to Baguio via Naguilian Road in a car provided for our use.

15:00 Arrived at Baguio.
Inspected Park Hotel, Nevada Hotel, Hyatt Terrace Hotel and other damaged buildings.

16:30 Arrived at Hakuun Sanso and joined with the building group.
Conferred after supper. (Stay at Hakuun Sanso.)

(Roads - Group 1)

7:45 Left Cabanatuan.

9:15 Arrived at San Jose.
Surveyed damage in the San Jose (kms160) - Digdig (kms183) section of the Pan-Philippine Highway (Filipino-Japanese Friendship Highway). (Used a 4-wheel-drive car.)

17:30 Arrived at San Jose. (Stay at Olympic Drive-inn.)
Group meeting (an hour).

(Roads - Group 2)

8:10 Left Dagupan.
Met with the city engineer (Mr. Adelfo M. Oviedo) and visited the city's Task Force Rehabilitation Office.

9:45 Surveyed Magsaysay Bridge, took photographs of damaged buildings in the city and surveyed Boring point No.3.

11:20 Surveyed Barangay Pugo and collected soil samples.
(Mr. Alfredo G. Tangco, project manager of DPWH, Region 1, accompanied the group from the city engineer's office to here.)
City interior.
Moved to Carmen Bridge via Urdaneta.

15:38 - 17:25 Surveyed Carmen Bridge, visited an detour bridge construction site field office and took soil samples.

18:10 Arrived at Dagupan. (Stay at Victoria Hotel.)

(Bridge group)

7:50 Left Dagupan.
Surveyed Calvo Bridge, Hector Mendoza detour bridge and Sison (Carmen) Bridge. (Had to turn back several times due to road disruption.)

15:30 Discussed with DPWH engineers (District Deputy Chief Valencelina, Engr. Nisa and Engr. Rosario) at the Sison Bridge field office. Surveyed San Isidro Bridge and Cojuanco Bridge.

20:15 Arrived at Dagupan.

21:00 Supper; group meeting. (Stay at Victoria Hotel.)

(River and dam group)

7:55 Left Cabanatuan.

8:00 Conferred at the NIA Pampanga River upper reaches irrigation office (Cabanatuan). (Office director and others.)
Took a fault survey at Rizal.
Surveyed damage to Diversion Channel No.1 of the Pampanga River irrigation canal.

11:40 Conferred at the NIA Pantabangan Dam Office (Director J.S. Trenchino and others). Surveyed Pantabangan Dam, Aya Dam and Mashiwai Dam.

21:00 Arrived at Tarlac via Cabanatuan. (Stay at Hotel Jecsons.)

(Building group)

4:00 Gathered at Nikko Manila Garden Hotel.

8:15 Inspected Building in Dagupan.

15:50 Inspected Buildings in Baguio.

18:00 Arrived at Hotel.

August 1 (Wed)

(General Inspectorate group)

8:00 Left Hakuun Sanso.

9:00 Visited local office (Trinidad) of the Department of Public Works and Highways.
Briefed by Manager Blancas on the status of damage. (Accompanied by State Congressman Avaros.)

10:00 Visited Baguio City Hall.
Paid a courtesy visit to Mayor Bagunos and was then briefed by Engr. Julian on damage caused in Baguio City.

11:00 Visited the Office of the Benguet District Engineers.
Was briefed by Manager Batac on damage in Benguet State.

12:00 Inspected buildings in the city (Sky World, Baguio Univ., FBR Hotel, etc.) and the site of rehabilitation work on the Marcos Highway.

14:00 Met with Governor Bagnosen of Benguet State at Hakuun Sanso.

14:30 Left Baguio.

18:00 Arrived at Dagupan.

(Roads - Group 1)

7:00 Left San Jose.
The Pan-Philippine Highway (Filipino-Japanese Friendship Highway).
Surveyed the status of damage between Digdig (Kms183) and Aritao (Kms236) (4-wheel-drive car, walk (Kms192-Kms206), use of locally rented car)

18:00 Arrived at Bayonbon (Kms265). (Stay at Sports City Hotel.)

(Roads - Group 2)

8:00 Left Dagupan.
Explored the area on the right bank of the Pantal River.

9:00 Took soil samples near the left-bank abutment of the Magsaysay Bridge. Proceeded north via the Dagupan-Bonuan-San Fabian Road. Surveyed the status of a road settlement beside the Lingayen Gulf Links (kp217+500) in the meantime.

9:40 Surveyed Manggueragday Bridge.

10:20 Surveyed Longas Bridge.

10:30 Surveyed points of settled banking near the Longas junction.

10:35 - 11:08 Surveyed Cayanga Bridge.

11:40 To Kennon Road via Rosario.

12:20 - 15:40 Surveyed Cayanga Road (up to the point of a bus fall at STA 224+500; walked part of this section.)

16:18 Took photographs of the city hall and other collapsed buildings in Agoo City.

16:58 - 19:00 Surveyed Marcos Highway. Changed to MPWH Regional Office's jeep at KM 226+400 and proceeded to KM 273.

20:30 Arrived at San Fernando. (Stay at Crista Del Mar Hotel.)

(Bridge group)

7:15 Left Dagupan.

Surveyed the Uyong Bridge. There was hardly any damage. So, returned to Dagupan City without going beyond.

Inspected Gayaman, Quintos, Magsaysay and Bolosan Bridges.

Inspected bridges from Dagupan to San Fernando; Inspected Manggueragday, Embarcadero, Aloragat, Bani North and Cupang Bridges.

17:30 Arrived at San Fernando. (Stay at the Crista Del Mar Hotel.)

19:00 Supper, group meeting.

(River and dam group)

7:35 Left Tarlac.

At Paniqui, surveyed damage to the Tarlac River's embankments, revetments and water gauging station.

9:10 Conferred at the DPWH Aguno River Flood Control System Office (Rosales). (Manager J.N. Rigor and others)

Inspected damage to a gabion manufactory. Surveyed damage to Agno River embankments at Urbiztondo and Bayambang.

16:10 Conferred at the Region I Office (Dagupan) (manager and others). River survey in Dagupan.

21:00 Arrived at San Fernando (Pampanga Province). (Arrived at a hotel.)

(Building group)

6:15 Inspected Buildings in Baguio.

15:25 Arrived at Dagupan.

21:00 Arrived at Nikko Manila Garden Hotel.

August 2 (Thu)

(General Inspectorate group)

7:00 Inspected damage in Dagupan.

9:00 Courtesy call to the mayor of Dagupan City. Briefed by Mayor Hon. Liberato D. Redyna Sr., Mr. Rosario and others and discussed rehabilitation.

12:00 Inspected Calvo and Carmen Bridges.

14:30 Visited the Office of District Engineers. Briefed by Manager Banarg on the status of damage.

15:00 Left Roserio City. Inspected damage to the Filipino-Japanese Friendship Highway up to Dalton Pass after proceeding via Umingan and San Jose Cities. (Met with Nakata team of Hiroshima Univ.)

21:00 Arrived at San Jose via Tarlac.

(Roads - group 1)

7:00 Left Bayombong. The Pan-Philippine Highway (Filipino-Japanese Friendship Highway). Surveyed the status of damage in the section between Aritao (Kms236) and San Jose (Kms160). (Used locally rented car, walked and then used a 4-wheel-drive car.)

16:00 Arrived at San Jose.

18:00 Arrived at Tarlac. (Stay at the Grand Mars Hotel.)

(Roads - group 2)

8:30 Left San Fernando.
Met with Mr. Alfredo M. Parayno (Director, IV) at the Region-1 Office, DPWH. Proceeded to Baguio, accompanied by a local office technician (Mr. Foronda).
Surveyed the Naguilian Road.

11:50 Visited the regional office of Baguio.

13:30 - 14:15 Inspected the Marcos Highway (up to kp277).

14:50 - 16:20 Inspected the Kennon Road (up to the Benguet Mine, vicinity of kp238+500). Took photographs of damaged buildings in the city.

19:20 Arrived at San Fernando. (Arrived at the China Sea Hotel.)

(Bridge group)

7:40 Left San Fernando.
Inspected the Pagdalagan and Luggit Bridges.
Inspected the Naguilian Road.
Inspected bridges between San Fernando and Agoo.
Bauang II, Bauang I, Caba, Aringay and Tabora Bridges.
Inspected the Agoo-Baguio Road.
Inspected Principe and Rabon Bridges.
Inspected the Kennon Road.

17:30 Arrived at San Fernando.

19:00 Supper and group meeting. (Stay at the Crista Del Mall Hotel.)

(River and dam group)

6:55 Left San Fernando.

7:40 Conferred at the DPWH Pampanga River Flood Control System Office (Apalit). (Manager E.B. Dizon and others)
Surveyed the Francis Watergate and the Sapang Maragul Lock.
Surveyed damage to Pampanga River embankments at Apalit and Arayat.
Proceeded via San Fernando and Apalit.

17:15 Conferred at the NAPOCOR Angat Dam Office (manager and others).
Surveyed the Angat Dam.
Proceeded via San Jose and Del Monte.

22:00 Arrived at Manila. (Stay at the Manila Garden Hotel.)

(Building group)

8:50 Left Nikko Manila Garden Hotel.

9:40 Inspected Buildings in Manila.

20:00 Dinner.

August 3 (Fri)

(General Inspectorate group)

7:00 Left San Jose.
Inspected the Digdig fault along the Filipino-Japanese Friendship Highway leading to Dalton Pass (Puncan and Digdig).
Met with Nakata team of Hiroshima Univ.

16:00 Observed fault in Rizal.

17:00 Surveyed the Christian College in Cabanatuan.

22:30 Arrived at Manila.

(Roads - group 1)

6:45 Left Tarlac.

10:00 Inspected damage in Dagupan.

12:00 Inspected the status of damage in and around Rosario.

19:00 Returned to Manila.

(Roads - group 2)

8:50 Left San Fernando.

9:00 Visited the Region-I Office, DPWH.
Surveyed Pawan and Santa Rita Bridges. Proceeded to Dagupan via Agoo.

12:00 Interview survey on duration of sand jet from local inhabitants in Dagupan and on the right bank of the Pantal River.

14:10 Similar interview survey in heavily damaged areas in Dagupan and the left bank of the river.
Proceeded via Tarlac.

20:30 Arrived at Manila. (Stay at Nikko Manila Garden Hotel.)

(Bridge group)

7:10 Left San Fernando.
Took photographs of damaged buildings in Agoo.
Inspected bridges on the Filipino-Japanese Friendship Highway via Dagupan, Tarlac, Santa Rosa and San Jose.
Cayangan, Manicla, Tayabo and Sicsican Bridges.

16:00 Met with DPWH engineers at the District Engineers Office.
Inspected Luna Bridge.

20:10 Arrived at Manila. (Stay at Nikko Manila Garden Hotel.)

(Rivers and dams group)

7:15 Left Manila.

8:15 Flew to the Binga Dam by helicopter from the Manila PNOC Helipat.

9:40 Arrived at the Binga Dam.
NAPOCOR Binga Powerplant.
Conferred with Manager J.C. Rico.
Surveyed the Binga Dam.

11:05 Arrived at the Ambuklao Dam.
Conferred with Mr. A.L. Aguila, Supt. on Duty.
Surveyed the Ambuklao Dam.
Proceeded via the NAPOCOR San Manuel Substation.

14:30 Arrived at the NAPOCOR Main Office (Quezon).
NAPOCOR Hydropower Engineering Department.
Conferred with Mr. P.C. Dino, division chief.

16:45 Arrived at Manila. (Stay at the Manila Garden Hotel.)

(Building group)

9:05 Inspected damaged buildings in Manila.

13:00 Inspected damaged buildings in Quezon.

17:00 Inspected damaged buildings in Makati.

(Entire team)

23:30 - 3:00 Meeting at Nikko Manila Garden Hotel

August 4 (Sat)

(General Inspectorate group)

8:00 Surveyed the Digdig fault by helicopter.

(Entire team)

Consolidated data for a local report.

19:30 Dinner given by the embassy (Mr. Yagi, Ikeda, etc.).

August 5 (Sun)

(Entire team)

Consolidated data for a local report.

19:30 Dinner given by local cooperators.

(Road Groups I and II)

8:23 Left Manila.

Surveyed roads around Baguio and the Pan-Philippine Highway (Filipino-Japanese Friendship Highway) by helicopter.

12:50 Arrived at Manila.

August 6 (Mon)

A.M. Prepared and consolidated data for a local report, at the JICA office.

14:00 Briefing for DPWH at the DPWH Office. More than 50 persons were present including Secretary Estuar, Undersecretary Encarnacion and other DPWH officials, officials from NIA (National Irrigation Agency), the National Park Operation, local constructionists' association and consultants' association, Team Leader Okada and members of the team, Embassy Secretary Ikeda and long-term JICA experts.

19:30 Party held by the Japan Disaster Relief Team at the Nikko Manila Garden Hotel. More than 50 persons attended including DPWH Undersecretary Encarnacion Team Leader Okada and Embassy Secretary Ikeda.

August 7 (Tue)

7:00 Left Manila (NW-004).

12:30 Arrived at Tokyo.

13:00 Conferred at Narita.
Planning Official Suzuki of the Technical Cooperation Section, Economic Cooperation Bureau, Ministry of Foreign Affairs and others concerned were present.

4. Members and Inspection Group Members

1) Members of the Expert Team, Japan Disaster Relief Team

Team Leader Tsuneo OKADA
Professor and director general, Institute of Industrial Science, University of Tokyo
(General)

Team members Toshiro YAMADA
Director, Earthquake Disaster Countermeasures Division, Disaster Prevention Bureau, National Land Agency
(Disaster countermeasures and earthquake disasters in general)

Akiomi SHIMAZU
Director, Construction Method and Equipment Department, Public Works Research Institute, Ministry of Construction
(Roads and machines)

Yasushi SASAKI
Director, Earthquake Disaster Prevention Department, Public Works Research Institute, Ministry of Construction
(Earthquake disaster prevention)

Michio OKAHARA
Head, Foundation Engineering Division, Structure and Bridge Department, Public Works Research Institute, Ministry of Construction
(Bridges)

Shinsuke NAKATA
Head, Building Engineering Division, International Institute of Seismology and Earthquake Engineering, Building Research Institute, Ministry of Construction
(Buildings and earthquake engineering)

Yoshihiro KINUGASA
Director, Seismo Tectonic Research Division, Environmental Geology Department, Geological Survey of Japan, Ministry of Trade and Industry
(Seismology and ground disasters)

Yoshiharu YONEYAMA
Staff, Tsukuba International Center, Japan International Cooperation Agency (JICA)
(Activity coordination)

2) Composition of Groups

(1)	General Inspectorate group	Tsuneo OKADA Yoshihiro KINUGASA Yoshiharu YONEYAMA Crispin B. Banaag Jr. (DPWH)
(2)	Roads - Group I	Akiomi SHIMAZU Roger F. David (DPWH) Zosimo G. Alberto (DPWH) Kuniaki NAKAMURA (Long-term JICA expert)
(3)	Roads - Group II	Yasushi SASAKI Simplicio Pestano (DPWH) Tatsuo TAKEUCHI (Long-term JICA expert)
(4)	Bridge group	Michio OKAHARA Joel Surot (DPWH) Virginia Damaso (DPWH) Armenio E. Hayson (DPWH) Ryoji Hagiwara (Long-term JICA expert)
(5)	River and dam group	Toshiro YAMADA Nelson Livara (DPWH) Tetsuaki IWAKIRI (Long-term JICA expert)

(6)	Building group	Shinsuke NAKATA
		Wilfredo Lopez (DPWH)
		Rogelio Isturis (DPWH)
		Koichiro HIRAI (Long-term JICA expert)

(Local cooperators)

Norio UMEDA	(General Inspectorate group)
Shin SATO	(")
Jun ONISHI	(Roads-Group I)
Mineo ENDO	(Roads-Group II)
Tetsu NAKAGAWA	(")
Mitsumasa MITANI	(Bridge group)
Yoshihiro MOTOKI	(River and dam group)
Satoru MIZUNO	(Building group)
Masayuki MATSUSHIMA	(")
Michio SUGIMOTO	(")
Takehiko KATO	(")
Yukio MIZUNO	(")
Motochika FUKUOKA	(")
Masaki KIMURA	(")
Shinji TAKEMOTO	(")

5. Outline of Damage

5.1 Seismic Environment of the Republic of the Philippines

5.1.1 Seismic Activity

The Republic of the Philippines and Japan are situated in the Cirum-Pacific Seismic zone. Both countries suffer from intense seismic activities and have experienced severe damage owing to a large number of destructive earthquakes.

The earthquakes in the Philippines are into (1) earthquakes caused by subduction of plates at such deep sea trenches as the Philippine trench, the East Luzon trench and the Manila trench, and (2) earthquakes caused by dislocation of active faults such as the Philippine Fault. Figure 5.1.1 shows these trenches and major active faults.

Figure 5.1.2 shows the earthquakes epicenters during the period from 1960 to 1988. Figure 5.3 shows earthquakes with a magnitude greater than 6.0 and/or those of seismic intensity scale higher than 6 the seismic intensity scale used in the Philippines is based on Rossi-Forel scale as described in Table 7.1.1.

Remarkable detructive earthquakes in recent years are shown in Table 5.1.1. Among them, most casualities in the Mindanao earthquake were caused by tsunamis associated with the earthquake.

Along the Philippine fault, large earthquakes of magnitude greater than 6.8 occurred repeatedly century (Figure 5.1.4). Allen (1975) described that the Ragay Earthquake of magnitude 7.0 in 1973 had accompanied left-lateral strike-slip displacement as much as 3.2m on the surface.

As shown in Figure 5.1.4, no destructive earthquake has not occurred in the central part of Luzon island since 19th century. The earthquake of July 16th took place on this part of the Philippine Fault. With recent low micro-seismic activity shown in Figure 5.1.2, this part of the Philippine Fault could be regarded as a "Seismic Gap."

Although, the Philippines has very high seismic activity and experienced many destructive earthquakes repeatedly in the recent past, only 15 seismic observation stations are operated by the Philippine Institute of Volcanology and Seismology (PHIVOLCS). Furthermore, data from these observation stations are not telemetered yet.

Strong motion observation, which is indispensable for earthquake-proof design codes and appropriate earthquake-proof design, is not sufficient.

Five strong motion seismographs had been installed in the Philippines but all of them were not in operation at the time of the earthquake of July 16th for lack of recording paper. Consequently, no strong motion record was obtained on this earthquake.

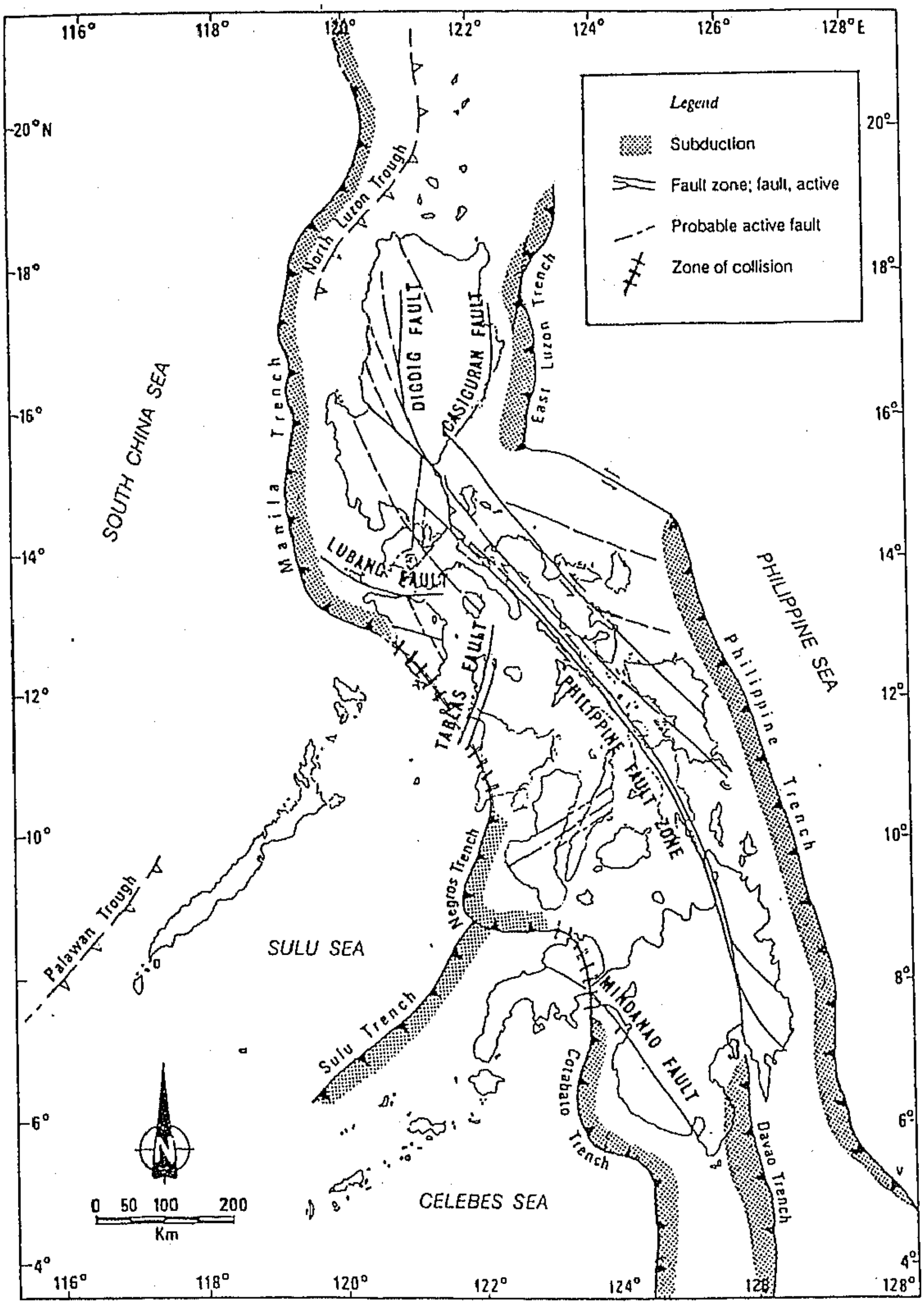


Figure 5.1.1 Trenches and Major Active Faults in the Philippines and its Surroundings (PHIVOLCS Pamphlet)

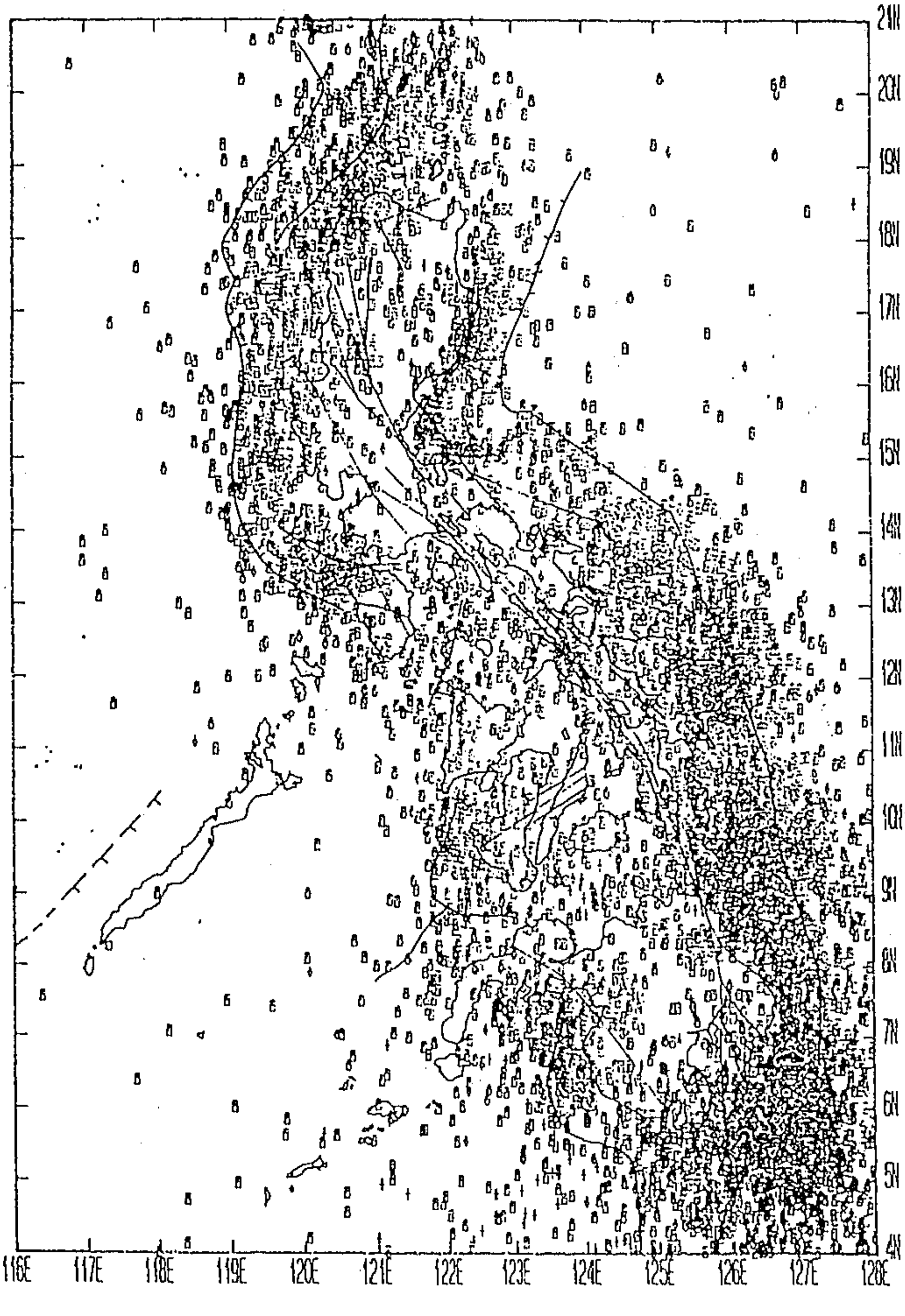


Figure 5.1.2 Distribution of Micro-Earthquake Epicenters in the Philippines and its Surroundings from 1960 to 1988 (PHIVOLCS Pamphlet)

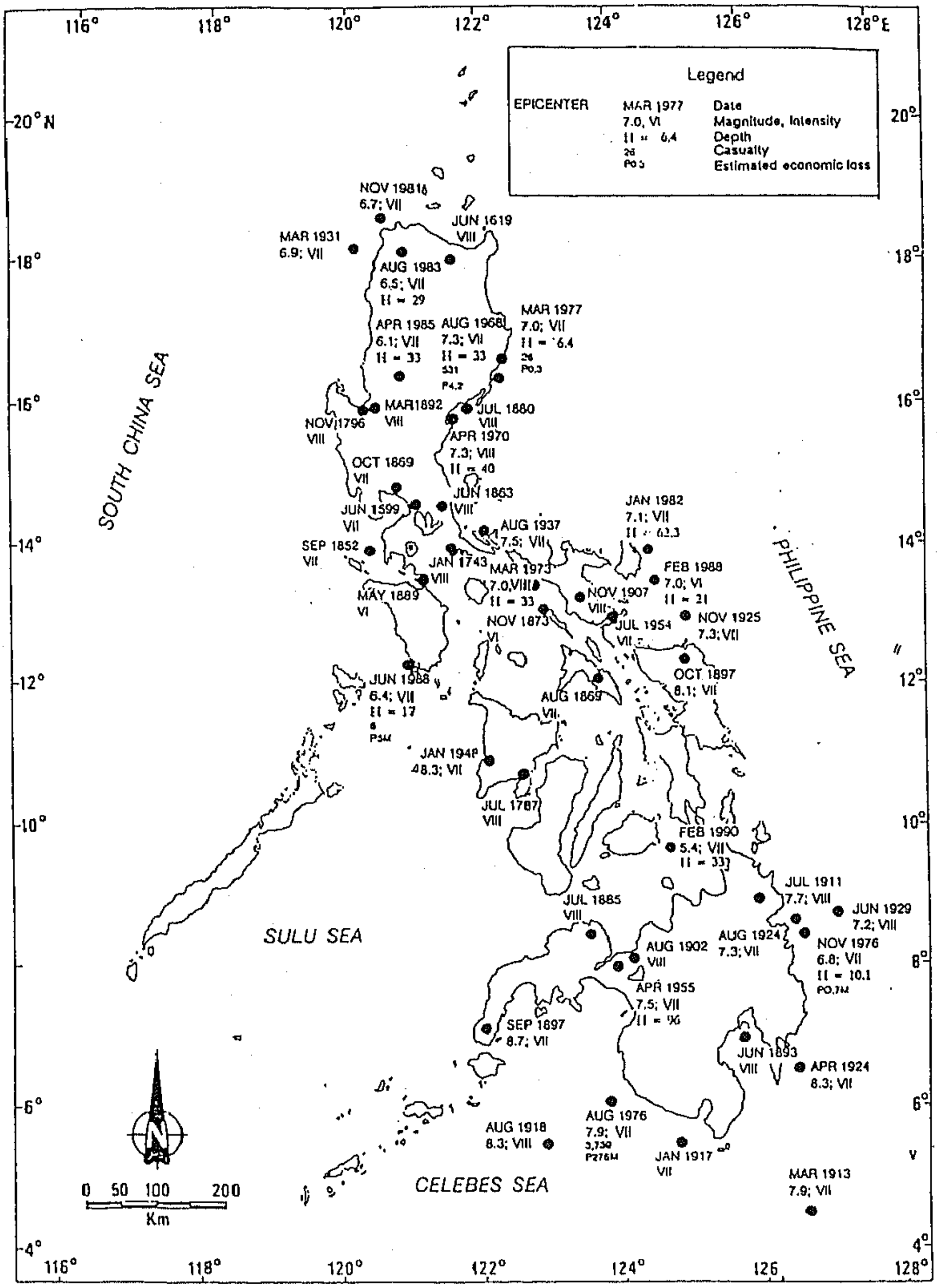


Figure 5.1.3 Major Earthquakes which have occurred in the Philippines and its Surroundings (M>6.0 and/or intensity>V1, 1599 - 1988) (PHIVOLCS Pamphlet)

Table 5.1.1 Destructive Earthquakes and their impacts in the Philippines (PHIVOLCS pamphlet)

DATE	EPICENTER	INTENSITY	MAGNITUDE	CASUALTY/INJURED	
01 Jul. 1954	Bacon, Sorsogon	VII	8.3	13	101
01 Apr. 1955	Lanao, Mindanao	VII	7.5	291	713
02 Aug. 1968	Casiguran, Aurora	VII	7.3	270	600
07 Apr. 1970	Baler, Quezon	VII	7.3	15	200
17 Aug. 1976	Moro Gulf, Mindanao	VII	7.9	3,739	8,000

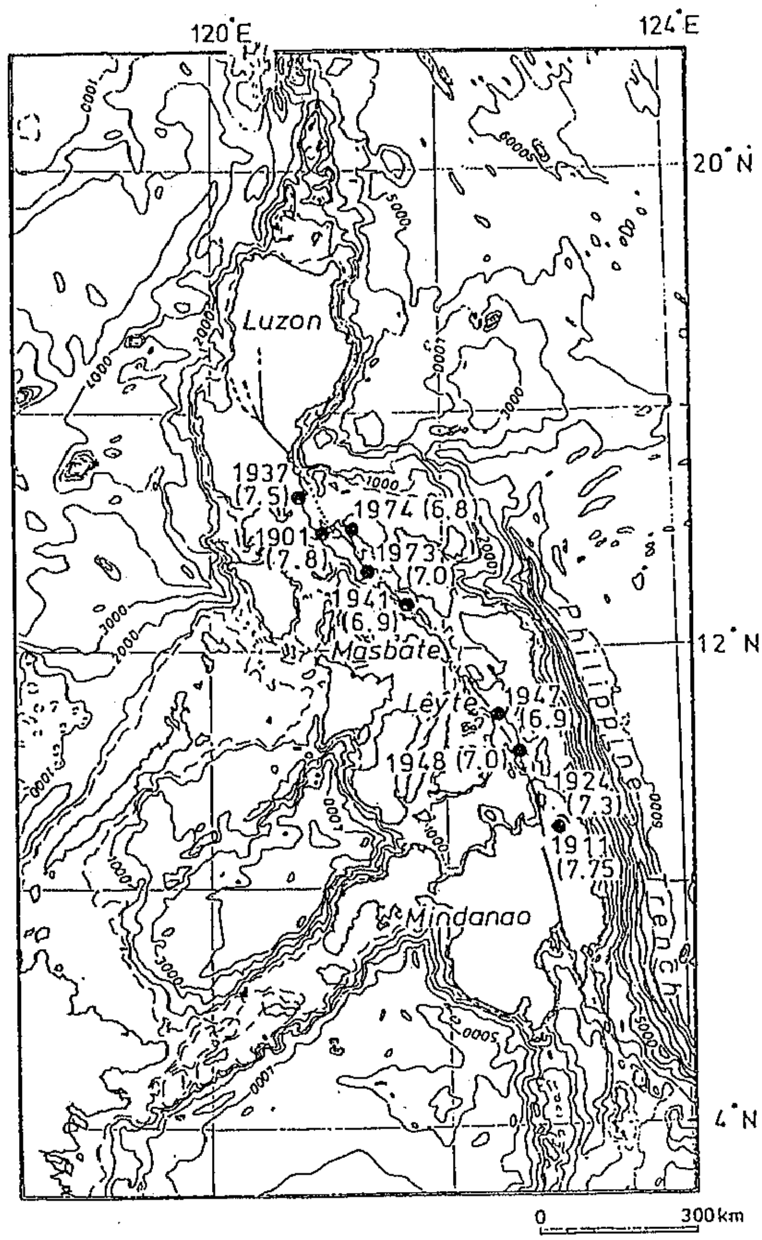


Figure 5.1.4 Distribution of Earthquake Epicenters along the Philippine Fault (Hirano et al., 1986)

5.1.2 Disaster Prevention

(1) Disaster prevention

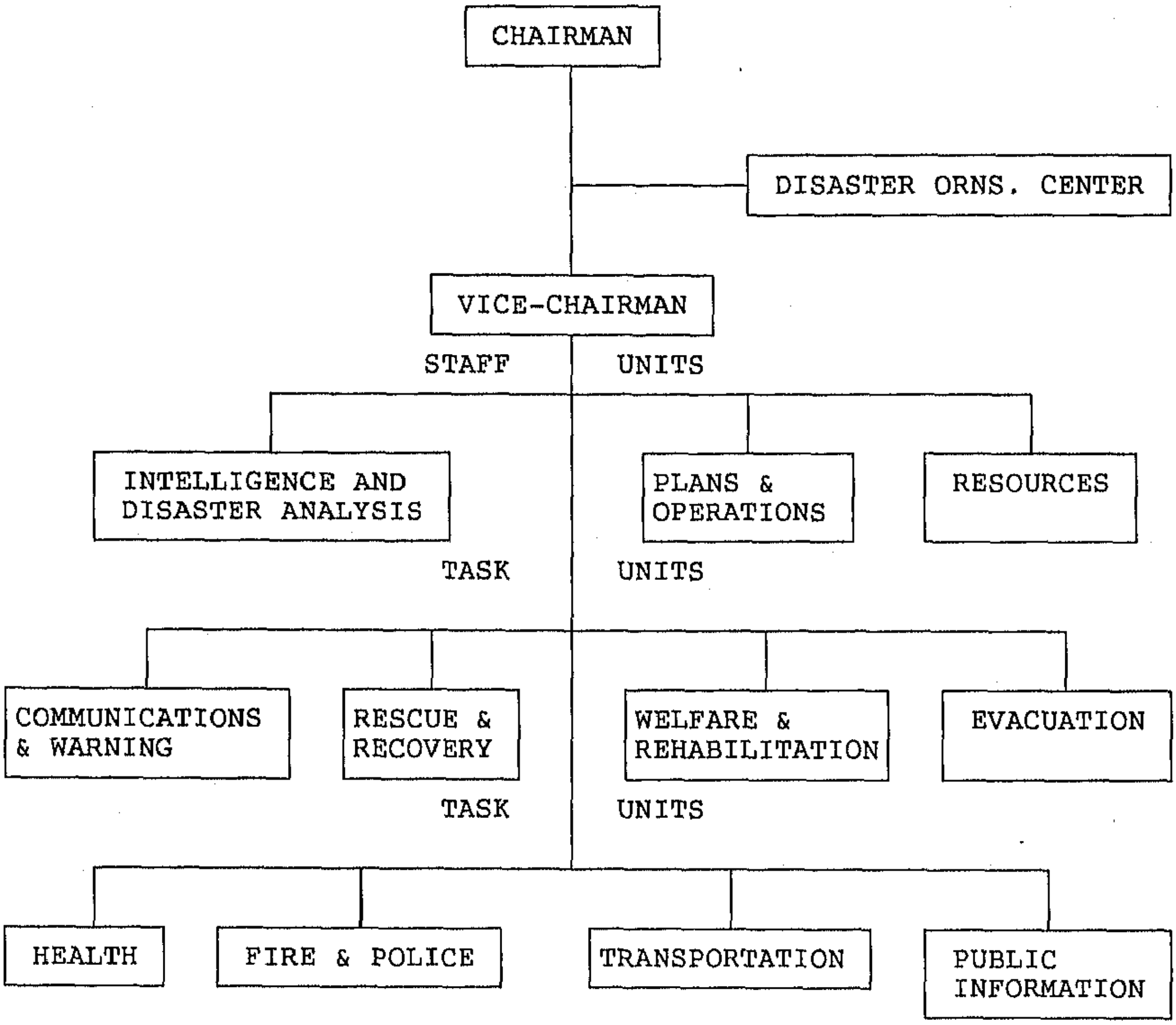
The followings are the Philippines' disaster prevention system and disaster countermeasures according to the data investigated by the International Engineering Consultants Association (Japan).

The Philippines is an area where disasters due to typhoons, earthquakes, and volcanic eruptions are apt to occur. More than 400 lives per year were lost (average from 1970 to 1986) due to damages from typhoons and floods. The Philippines has experienced many wars, thus developed the disaster prevention, restoration and relief systems over a long time.

On the basis of the Presidential Decree No. 1566, the Philippines disaster prevention system mainly consists of the National Disaster Coordinating Council (NDCC) (with members of ministers, chiefs, etc. of government ministries and agencies), the hierarchical Disaster Coordinating Council (DCC) (disaster prevention organization for regions, cities and towns) and the Office of Civil Defense (OCD).

The OCD is an organization to control emergency system, in case of emergency sharing roles of defense, fire fighting, relief, etc. in individual regions, cities and towns. Organization of the DOC planned by the NDCC is promoted by the OCD.

Figure 5.1.5 shows functions and the organization system of the DCC, and Table 5.1.2 shows the related organs in the disaster prevention, restoration and relief.



Source: [Report of the Disaster Countermeasures Seminar Vol.8, "The Current System of Disaster Preparedness and Prevention in the Philippines"], Dec., 1984.

Figure 5.1.5 Functions and Organization System of the DCC

Table 5.1.2 Primary Organizations related to the Disaster Prevension, Restoration and Relief

Name	Jurisdiction
NDCC (National Disaster Coordinating Council) DCC (Disaster Coordinating Council)	Disaster prevention, disaster countermeasures
OCD (Office of Civil Defense)	Disaster prevention, disaster countermeasures, civil defense.
DPWH (Department of Public Works and Highways)	Flood countermeasures
PAGASA (Philippine Atmospheric, Geophysical and Astronomical Services Administration)	Disaster monitoring, forecasting & warning (storm and flood)
PHIVOLCS (Philippine Institute of Volcanology and Seismology)	Disaster monitoring, forecasting & warning (volcanic eruption, earthquake, landslide, etc.)
Health Intelligence Service	Disaster monitoring, warning (infectious disease)
Philippine Coast Guard	Coast contamination monitoring, salvage and lifesaving
CDRC (Civil Defense Regional Center)	Delivery of information on disaster, restoration and relief
COWS (Committee on Warning System) EBS (Emergency Broadcasting Systems)	Issue and delivery of disaster warnings
CDOC (Civil Defense Operation Center) DOC (Disaster Operation Center)* MIAA (Manila International Airport Authority) MRCC (Manila Rescue Coordinating Center) Philippines Military	Relief and restoration
DSWD (Department of Social Welfare and Development) PNRC (Philippine Red Cross) Non Governmental Organizations	Delivery of relief goods

Note *: Relief organ in the DCC

(2) Disaster countermeasures

1) Preparedness

The disaster preparedness in the Philippines are categorized into (1) national land conservation works such as flood control, road disaster countermeasures and volcanic sabo works under the DPWH and (2) development and reinforcement of disaster prevention organization, disaster prevention exercise, education and publicity activities on disaster prevention under the OCD. PAGASA and PHIVOLCS play major roles in forecasting and observation activities.

DPWH promotes flood control of the major rivers in the country and disaster countermeasures in principal roads.

As to the volcanic sabo works, DPWH aids in MAYON volcanic sabo works and related works. As to the other countermeasures against volcanic disasters and earthquakes, PHIVOLCS observes volcanos and earthquakes, compiles hazard maps, and develops predicting technology.

The Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA) performs observation, forecasting and warning activities for disasters such as typhoons, floods, high waves, droughts, and landslidings as well as studies on prevention and reduction of natural disasters.

OCD plays a main role in reinforcement of disaster prevention organization and disaster prevention exercise. OCD gives opportunities for the personnel engaged in disaster prevention activities to have the periodic disaster prevention exercises, issues the manuals and pamphlets related to the disaster prevention, and performs the campaign activities.

To promote public self-consciousness of disaster countermeasures, the first week in July every year is designated as Natural Disaster Consciousness Week by Presidential announcement. This has been started since July, 1989.

2) Emergency measures

The organization related to the disaster emergency measures in the Philippines is formed primarily by the aforementioned NDCC and local DCCs. The Civil Defence Operation Center in OCD is a 24-hour system. It collects disaster warnings and disaster informations, makes plans of relief and emergency restoration works and gives advice to the related organizations. The Disaster Operation Centers (DOC) established in local and regional DCCs do relief and emergency restoration activities in cooperation with the related organizations such as the Philippines Red Cross and Military.

If a severe disaster (under the conditions of disaster periods of more than 1 week, damages of more than 30% of population, etc.) occurs, the President issues Declaration of a State of Calamity and performs relief activities.

Execution of relief activities is monitored by the NDCC through the OCD, and if necessary, the Ministry of the Budget assists with funds under the permission of the Presidential Office.

Supply of the relief goods is to be performed primarily by the Ministry of Social Welfares and the Philippines Red Cross.

3) Restoration

As to the restoration works, the action group of the NDCC, in cooperation with the OCD, performs coordination of the workds and recommends the priority in budgets. All agencies related to the restoration works are to get the permission of this action group.

The priority in the restoration works is as follows:

a. Benefit or qualitative or quantitative impact to the damaged area

b. Usefulness on prompt execution of fund and technical support by the related domestic organizations

c. Rebuilding and restoration of facilities directly supporting production activities

d. Public facilities and public works required to be restored for the people in the damaged area as soon as possible

The action group makes the restoration work plans and budgets according to the above-mentioned standards and get the permission of the President through the chairman of the NDCC. The Ministry of the Budget is to take the necessary budgetary measures for the work execution agencies. The NDCC is to perform inspection of the restoration works through the OCD and to submit a report to the Presidential office via the chairman of the NDCC.

(3) Disaster countermeasures laws and system

Presidential Decree No. 1566 in 1978 is the disaster countermeatures basic law in the Philippines. This Decree describes activities on disaster preparedness, relief and restoration measures. Table 5.1.3 shows the major items. Table 5.1.4 shows major disaster countermeasures laws and systems in the Philippines.

Table 5.1.3 Major Items of Presidential Decree No.1566*

Classification	Major activities
Preparedness	. Planning of disaster countermeasures . Establishment and reinforcement of disaster prevention organization . Education and training of personnel engaged in disaster prevention activity . Preparation of disaster prevention activity guideline . Execution of disaster prevention exercise . P.R. for disaster prevention . Reservation of emergency goods such as foods and medicines . Reinforcement of disaster monitoring and warning network
Relief	. Securing evacuation areas and distribution of exclusive teams for evacuation lead . Emergency measures for injured persons, and transportation to medical facilities . Rationing of relief goods such as foods and clothes to victims . Searching for missing persons . Emergency works . Examination of damages . Securing emergency transportation system
Restoration	. Recheck of damages . Request and supply of relief persons and relief goods necessary for restoration . Restoration activities such as restoring works for damaged facilities

Note) *: "Presidential Decree No.1566 - Strengthening the Philippine Disaster Control, Capability and Establishing the National Programme on Community Disaster Preparedness" June, 1978.

Table 5.1.4 Major Laws and Systems related to disaster prevention

Item	Name	Purpose
Basic laws	Presidential Decree No.1566/1978	Basic laws for disaster countermeasures
Prevention related	Philippine Building code/1977	Building design standards
	Regulation No.81 for Metro Manila District	Land use standards and regulations
	Town Planning Guidance and Standards	
Manuals	Calamities and Disaster Prevention Plan 1987	Defines responsibilities of NDCC, DCC and ministries during the disaster (including the war)
	Procedures and Criteria for Recommending the Declaration of a State of Calamity in Disaster-striken Areas	Defines standards for disaster declaration by the President and execution method of relief activities
	Draft Provincial/City/ Municipal Disaster Preparedness Plan	Disaster prevention plans of the local and regional DCCs countermeasures against floods, storms, diseases, maritime affairs, aviation disasters, tidal waves (tsunami), droughts, etc.
	A Manual of How to Assess Disaster Damage and Impact 1982	Disaster damage examination manuals

(4) Measures taken during this earthquake

Expert term did not have enough time to systematically examine the measures taken by the Philippines governmental agencies during this earthquake. However, the followings describe the informations fragmentarily obtained during the site examination.

* About 50 persons worked in the branch office of DPWH in Baguio. However, reorganization to cope with emergency measures was established July 20.

* The chief of the office was out due to an official trip at that time, therefore, no measurable system against the disaster was taken until the roads to Baguio were opened.

* On the other hand, the day after the earthquake occurrence, works started for emergency roads opening and examination of damages. Thus the Naguilian road was opened July 19.

* According to the information obtained from the Task Force office for disaster countermeasure in Dagupan, various measures to ensure the safety of the people's livelihood were taken as shown in Table 7.3.3 of Chapter 7.3.

* According to the information obtained from Region-1 office, they are familiar with typhoon and storm damages, but not familiar with earthquake disasters. So, they think the countermeasure manuals against earthquakes are helpful, if available.

* It seemed there were some missing damage sites in the temporary damage inventory list offered by the DPWH. Some remarkable damages on the bridges and the embankments were missed since they were observed only from the road sides. Therefore, some damages of the piers, abutments and foundations of the bridges which could be found when get beneath girders seemed not to be reported. It is thought helpful for the Philippines to introduce Japanese expierence in technologies such as the examination methods for damages, the reporting formats, and the evaluation methods concerning the residual strength in case of an earthquake disaster.

5.1.3 Seismic Design

(1) Civil engineering structures

According to the recent "Design Guidelines Criteria and Standards by DPWH 1988" (hereafter referred to as guideline), aseismatic design is to be applied to civil engineering structures such as dams, tanks, and bridges. Detailed procedures and methods of seismic design are not shown there.

Detailed information on bridges is given in the "National Structural Code of the Philippines, Vol.II, Bridges by the Association of Structural Engineers of the Philippines, 1987" (hereafter referred to as the code). This paragraph describes the seismic design of bridges.

1) History of seismic design

The seismatic design of bridges before 1970 is unknown.

Seismic design was performed on the basis of the guideline issued in 1970. It is specified that 10% of the dead load must be considered as the minimum seismic intensity.

According to the guideline (1972), it is specified that the actual seismic design is to be performed on the basis of "Earthquake Engineering for the ILZGAN-BUTAN ROAD in the Island of Mindanao-Philippines by the Asian Development Bank" issued in 1972.

From 1988, it is specified that 10% (dead load + 1/2 live load) is to be considered as the design earthquake force in the revised guideline above.

Actual seismic design is done on the basis of the aforementioned code issued in 1987.

2) Seismic design method (as per code in 1987)

Seismic design for those areas predicting earthquake occurrence is to be done by considering the relation to active dislocations of the object areas, ground response with the ground and bridges, etc.

Calculation methods include the equivalent static load method (seismic intensity method) and the response spectrum method. The latter is specified as follows.

For almost equal underground layer rigidity, design earthquake force (EQ) is calculated using the following equation.

$$EQ = C \cdot F \cdot W$$

Where, F = Compensation factor for each structure (1.0: one-pole type bridge legs, 0.8: Rigid-frame piers)

W = Dead load

C = Value more than 0.1 of combined response factor

Value C is obtained using the maximum acceleration (A) of the foundation, thickness of offshore lamination layer to foundation, and inherent cycle (T).

If the aforementioned data (maximum acceleration of foundation, etc.) are unknown, the following equation can be used to calculate EQ.

$$EQ = 0.10\ (W + L/2)$$

Where, W = Dead load

L = Live load

The response spectrum method is to be used for calculation of complicated structures.

Load for designing transportation limit facilities, is as follows:

EQ = 0.25 x DL - (shearing force generated on pole due to earthquake force)

Where, DL = Reaction force on upper work to be considered for design

(2) Buildings

In the Philippines, the following two standards are used at present for the design and execution of buildings.

1. "The National Building Code of the Philippines." (NBCP), version 1990

2. "National Structural Code of Philippines." (NSCP), version 1988

Item 1 includes overall building standards with specifications as to building confirmation applications, administration, approval, inspection, fire prevention, illumination, ventilation, sanitation, electricity, etc. The building standards in Item 1 contain no descriptions as to aseismic design. Item 2 (NSCP) above specifies buildings and structures design standards, including aseismatic design standards, for wooden structures, steel structures, concrete structures and masonry structures.

Design standards, concrete work standards, aseismatic design analysis, and design methods are specified for concrete structures. Design seismic force is referenced from the "Recommended Lateral Force Requirements and Commentary" issued by the Structural Engineers Association of California (SEAOC) of the United States, which has the following history.

First edition	1959
First edition with commentary	1960
First edition revised	1963
Second edition without commentary	1966
Second edition with commentary	1967
Second edition with commentary and addendum	1968
Third edition with commentary	1973
Fourth edition with partial commentary	1974
Commentary for fourth edition	1975
Fourth edition revised	1980

In the Philippines, the history of employing the above standards is as follows.

Establishment of Manila city aseismatic design standards	1959
Proposal for employing SEAOC, by the Philippines Structural Engineering Society	1966
Establishment of aseismatic design standards on the basis of UBC and ACI	1972
Second edition	1981
Third edition	1986

In Manila, earthquake damages occurred in 1968 and 1970, and Standards of the SEAOC type were issued from the Department of Public Works and Highways in 1972. After that, in the U.S., activities arose starting in 1973 to revise the seismic force factor CS, and the present Philippines Code includes these revised propositions. The U.S. revised propositions are included under the Philippines heading in the "Earthquake Resistant Regulations: A World List-1980" (issued by IAEE).

The reinforcement arrangement regulations for buildings are as in the U.S. ACI standards. However, they comply with ACI318-63. ACI318-71, as revised in the U.S., was not incorporated into the main body of the NSCP 1988 version, but is described in an appendix. This means that the revised design standards for horizontal-reinforcements as per the

"Appendix A - Special Provisions for Seismic Design" for special rigid frame structures are not actively taken into consideration.

There are many buildings which received severe damages in Baguio which were built in the 1970's, and most of these damaged buildings are as per the old regulations.

As a 1983 version (Sixth edition), an NSCP explanatory issue called "Structural Design Data and Specifications" is on the market, and it recommends the use of ACI318-77 mentioned above. In the United States, the Uniform Building Code, version 1988 includes limits of story drift angle for building mechanisms. If they are to be applied to such a large scale earthquake which occurred this time, it will be necessary to strengthen existing aseismatic standards.

In the case of the buildings constructed based on the Japanese standards, even buildings designed by the old Japanese standards, have a base shear coefficient of 0.25 for the frame structure. In the case of those following the new Japanese standards after 1981, this value is more than 0.30. If the buildings are built as per the Philippines aseismatic standards based on the U.S. standards, the base shear coefficient of a frame structure is about 50% of those which follow the old Japanese standards.

When contrasting this earthquake's building damages with designs according to the existing Philippines standards, while taking ease of execution into consideration, we think that it is necessary to provide revised standards which are close to the Japanese standard.

5.2 Outline of Damage

This earthquake is characterized by a wide variety of damages over a wide area.

The damages as of July 29, 1990 are summarized as follows.

Casualty	1,641
Injured	3,441
Missing	969
Destroyed houses	25,369
Partially destroyed	61,077

Table 5.1 shows summary of damages by the region.

The largest number of casualties and injured were reported in Baguio City in Benguet Province. Most of them were caused by collapse of high rise buildings such as hotels. Also, collapse and fire occurred simultaneously at Export Product Area caused serious loss of lives. A large number of passengers on the bus driving on the Kennon Road were involved in landslides and reported to be dead.

As far as the site investigation evidenced, serious damage to the buildings was observed in the southern half of the La Union Province on the coast and west to the Benguet Province.

Nuevavizcaya Province is located in the east of Benguet Province and numerous landslids occurred on steep slopes in mountainous regions. However, the reason for the large number of casualties is not specified.

Most of the casualties in Cabanatuan City were caused by the collapse of Christian College. Collapse of building in the public market was also reported. Though this city is close to the other damage was not substantial.

In the cities along the Lingayen Gulf including Dagupan City, severe damage occurred by soil liquefaction. In Dagupan City, the ground surface sunk about 1 to 1.5m over a wide area, and a large number of buildings sunk and/or inclined.

Damaged bridges were found over a wide area, and among the 39 bridges examined, following damages were observed from a view point of load capacity.

Fallen bridges	6 (including 1 temporary bridge)
Seriously damaged	6
Partially damaged	8
Slightly damaged	8

In addition, breakages on approaching section were commonly, even though their strength were not affected, observed.

Damages to roads were observed at many places, especially on the Pan Philippines Highway which is the main road in the northern part of Luzon island, as well as on the Kennon Road, the Marcos Highway and the Naguilian Road to Baguio. Among these roads, only the road was transpassable for one way traffic. Others were closed even though intense restoration works at the time of inspection, resulting in serious obstacles to daily life as well as to rescue and restoration activities. Because of it being in rainy season, there were high potentials of the secondary disasters such as slope failures even after the immediate restoration works have been done.

River facilities were damaged over a long distance especialy in the Aguno River system and sinking, cracking and breakage of embankments, and damages to parapet and revertment were observed. Though there were little damage along the Banbang river, severe damage to the embankment of the river was observed on the west side of Mt. Arayat.

The damages on dams were very serious. Cracking, sinking and sliding of embankment were observed on the Anbukraw Dam and Binga Dam in the Agno River System, and Pantabangan Dam and it's reverse control the Masaiway Dam, of the Pampanga River System.

Total damages were not obtained in detail. However, President Aquino announced that the final figure may reach 10 to 15 billion pesos (65 to 97.5 billion yen).

Figure 5.2.1 shows an outline of the distribution of damage according to site survey.

In general, most of the damages are concentrated in a triangular area enclosed by Baguio, Dagupan and San Jose. This area is situated on the north-west side of the earthquake surface fault and is arrests the attention in terms of mode of the fault movement.

Table 5.2.1 Statistics of Damages (as of 5:00 p.m., July 29)

	DEAD	INJURED	MISSING	HOUSES DAMAGED TOTALLY	HOUSES DAMAGED PARTIALLY
CAR	845	1,880	395	7,886	12,013
Benguet	312	496	20	4,001	3,445
Baguio City	385	1,101	235	3,668	8,205
Kalinga Apayao	5	5	0	16	20
Abra	5	75	1	33	139
Ifugao	8	203	0	166	192
Mt. Province	0	0	0	2	12
Unspecified Areas	130	0	139	0	0
Region I	345	695	336	7,359	21,906
La Union	100	200	25	3,409	6,954
Pangasinan	54	35	288	2,756	8,916
Dagupan	13	37	23	1,172	5,960
San Carlos City	2	2	0	11	62
Ilocos Sur	3	5	0	11	14
Unspecified Areas	173	416	0	0	0
Region II	211	322	194	2,561	5,078
Cagayan	2	5	0	0	5
Nueva Vizcaya	208	313	194	2,561	5,073
Quirino	1	4	0	0	0
Region III	230	489	44	7,563	22,080
Nueva Ecija	88	250	14	1,856	11,603
Cabanatuan	112	147	29	9	665
San Jose City	16	15	0	157	214
Palayan City	4	4	0	3	32
Tarlac	9	54	0	5,510	9,480
Pampanga	1	6	1	28	85
Angeles City	0	13	0	0	1
N C R	10	55	0	0	0
Quezon City	8	1	0	0	0
Pasay City	0	18	0	0	0
Manila	2	36	0	0	0
TOTAL	1,641	3,441	969	25,369	61,077

Table 5.2.2 Statistics in damaged facilities relating to DPWH
(Materials of DPWH)

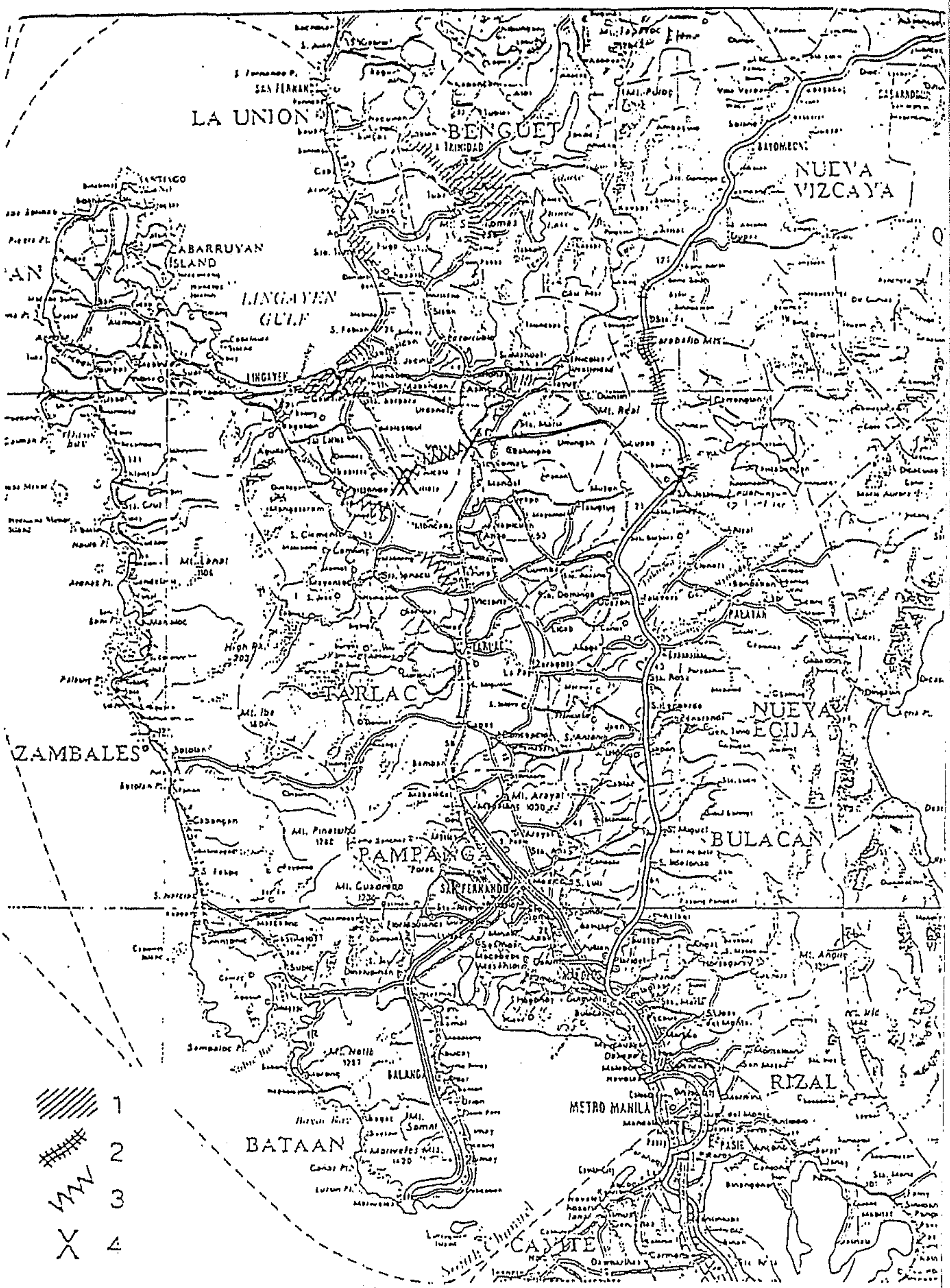
Estimates of repair and rehabilitation works of infrastructure damaged by earthquake.

Department of Public Works and Highways

Summary

As of Date/Time: July 26, 1990

Category	NCR	CAR	Region I	Region II	Region III	Regional IV-A	Total
Roads and Bridges	a. 4,000,000.00 b. 19,288,000.00	a. 98,750,000.00 b. 279,350,000.00	a. 9,700,000.00 b. 470,45,000.00	a. 14,135,000.00 b. 231,665,000.00	a. 55,767,000.00 b. 1,269,371,000.00	a. b. 1,360,000.00	a. 182,352,000.00 b. 2,271,479,000.00
School Buildings	a. 5,300,000.00 b. 22,009,640.00	a. 40,000.00 b. 6,000,000.00	a. b. 68,200,000.00	a. b.	a. b. 9,125,000.00	a. 1,118,000.00 b. 3,105.00	a. 6,818,400.00 b. 108,439,610.00
Hospital/ Public buildings	a. b. 2,385,000.00	a. 300,000.00 b. 600,000.00	a. b. 11,510,000.00	a. b.	a. b. 7,810,000.00	a. b.	a. 300,000.00 b. 22,305,000.00
Flood control/ Shore protection	a. b.	a. 300,000.00 b. 1,700,000.00	a. b. 800,000.00	a. b.	a. b. 5,803,000.00	a. b.	a. 300,000.00 b. 8,303,000.00
Water supply system	a. b. 86,350.00	a. b. 40,000.00	a. b.	a. b.	a. 250,000.00 b. 300,000.00	a. 15,000.00 b. 40,000.00	a. 265,000.00 b. 466,350.00
TOTAL	a. 93,000,000.00 b. 43,768,990.00	a. 99,750,000.00 b. 287,690,000.00	a. 9,700,000.00 b. 550,955,000.00	a. 14,135,000.00 b. 231,665,000.00	a. 56,017,000.00 b. 1,292,409,000.00	a. 1,133,000.00 b. 4,505,000.00	a. 190,350,000.00 b. 2,410,992,990.00
GRAND TOTAL	53,068,990.00	387,440,000.00	560,655,000.00	245,800,000.00	1,348,426,000.00	5,639,000.00	2,601,027,990.00



1: Damaged buildings (areas where damaged buildings occurred frequently)
2: Damaged roads (ruinously disaster-striken areas, such as those with impassability)
3: Damaged river facilities (damaged and broken embankments)
4: Damaged bridges (locations of fallen bridges)

Figure 5.2.1 Approximate distribution of main damages (see Chapter 7 for details)

6. Recommendations Based on Field Reconnaissance

As described previously in Chapter 5, the characteristic features of the seismic damage this time are: 1) that the damaged area is spread over a wide range, 2) that the types of damage suffered were divergent and 3) that about 5m lateral slip faults in the horizontal direction appeared on the ground surface over long distance (confirmed at least approx. 50km). The main affected area was roughly within a triangle with one side approx. 50-60km connecting Baguio, Dagupan and San Jose, with damage found scattered to Cabanatuan City and colonies along the Japan - Philippine Friendship Highway.

The types of damage are roughly divided into 2 types i.e. 1) ground failure and 2) collapse of structures by shaking. The ground failure included: a) sinking and tilting of buildings and damage to infrastructures such as bridges due to soil liquefaction as well as damage to pavement and b) damage to roads centered around collapsed slopes.

In order to achieve high efficiency in a limited period, an expert team was divided into 6 groups, as described in Chapter 4, and dispatched on field surveys. Because they set it their main object to make technical recommendations for recovery, the expert team members discussed with relevant persons and made comments regarding recovery, at appropriate occasion at sites.

Recommendations are compiled on each type of structures and were included in a tentative report. They were explained at a briefing meeting held by the Department of the Public Works and Highways on August 6. In the following, they are classified by urgency. Detailed background of them are given in Chapter 7.

6.1 Items Desired to be Urgently Acted on

1) Diagnosis, repair and reinforcement of damaged buildings

As previously described, damaged buildings may be roughly divided into a) those with columns, beams, walls, etc., destroyed or cracked (mainly in Baguio and Agoo City) and b) those sunk, tilted or floated as a whole, although the structural damage to the buildings themselves from liquefaction of ground are slight (mainly in Dagupan City).

a) Of the buildings which suffered damage from vibration, those which collapsed need to be quickly demolished, while making detailed examinations, for later estimation of the causes of the damage. Those which averted collapse, but were damaged in some way, should be judged on the degree of damage. They should be categorized into those which will be usable after repair or reinforcement and others which should be disposed of rapidly. As for the methods of judgment on the degree of damage, the repair and reinforcement to be used at this time, the methods which have already been developed in Japan may be employed, after adjusting or correcting them, as appropriate, to the actual situations of buildings in the Philippines.

b) Damage from liquefaction of ground at this time is similar to that experienced in Niigata City, Japan, in 1964. In Niigata City, recovery of more than 300 reinforced concrete buildings was undertaken by reerecting them by means of oil jacks and reinforcing their foundations. The recovered buildings are still in use now. The methods developed and adapted at that time seem to be applicable to the situation in Dagupan City.

2) Construction of temporary dwelling houses
In the area, such as Baguio and Dagupan cities that were severely damaged by the disaster where general housing buildings collapsed completely, it is considered to be necessary to construct simple housing facilities to be used in place of those that cannot be used as dwelling houses due to collapse, etc., and to provide them as the

temporary housing to residents in areas where it is difficult to maintain healthy conditions. Since this kind of response is very slow compared to the case of an earthquake disaster in Japan, many people are still living in tents even during the rainy season at the time when this field survey was performed. Consequently it is considered that temporary dwelling houses must be constructed immediately.

3) Diagnosis, repair and reinforcement of bridges suffering from the disaster

Trunk roads connecting the northern part of Luzon to Manila include 2 routes i.e., the Japan - Philippine Friendship Highway and the Manila North Road. In the former, some impassable zones still remain due to the existence of a large quantity of collapsed sediment. In the latter, because the Carmen Bridge fell down, a bypass through Lingayen has been provided. Many bridges suffered from the disaster along the Manila North Road which is left as only one road, including this bypass road, connecting the northern region of Luzon to Manila and its peripheral roads. There are even some bridges among them for which danger of advancing damage has caused them to fall under the load of traffic of heavy vehicles. Considering this road's importance as a trunk road, it goes without saying that the diagnosis on degree of damage and repair and reinforcement of damaged bridges are necessary for rapid recovery of transportation means. As a result of field surveys on 39 bridges at this time, bridges which suffered high degrees of damage were found to be 12, including 6 bridges which fell down. Concerning 10 bridges among them, practical proposals on immediate countermeasures and a full-scale recovery plan were offered in the tentative report.

Of the remaining bridges suffering from the disaster which were not diagnosed this time because of time restrictions, diagnosis should be conducted soon.

In this report, details including results of examinations carried out thereafter are described in Chapter 7.

4) Setting of urgency bypasses and erection of emergency temporarily erected bridges

The diagnosis, repair and reinforcement described in the previous item are one set of countermeasures to be urgently taken, but substantial time will be required before their completion. As a stop-gap measure to be taken in the meantime, setting urgency bypasses and erecting emergency temporary bridges are necessary. Such actions have already been taken to some degree, and it looks as if emergency recovery has become efficient to some extent, but further treatment of the whole range of damaged roads and of all damaged bridges will be necessary.

5) Measures for prevention of drifting of bridges, etc., by running down sediment and logs

At the Second Puncan Bridge on the Japan - Philippine Friendship Highway, danger of the bridge being set adrift by running sediment and logs was observed. At the Carmen, Calvo, Manicla and Magsaysay Bridges which fell down, girders which fell down have been left as they are, impeding passage of flowing water during floods. Some measure to remove them quickly needs to be taken.

6) Early opening of 3 routes to Baguio

Among the 3 main routes to Baguio, only the Naguilian Road has been opened. However, along this route, substantial lengths of road are left where only one-way traffic is available because of large scale collapses and potential disasters resulting from rain falls in the future. It should be an urgent business to hasten the opening of the Marcos Highway. The remaining 2 routes, which have relatively short impassable sections, can be quickly repaired providing at least 2 routes which lead to Baguio.

For this purpose, larger numbers of heavy duty machines for removal of collapsed sediment should be provided.

In the opened road, it is desired to keep watching and to control traffice volume to prevent a secondary disaster from occurring.

7) Emergency recovery of river embankments and dams

Early execution of emergency recovery of the damaged parts of embankments and dams which suffered from the disaster is necessary. This is because the rainy season has set in. Further, after the season is over, full-scale permanent recovery work needs to be done.

8) Study for acquiring basic data for future recovery plans

In proceeding with the above-described countermeasures, records on the planned processes and methods of their execution, etc., should be left, such that they will serve not only as mere records of recovery of this time's disaster but as data for reference in planning countermeasures for the future.

6.2 Items for which Quick Action is Desired to be Taken

The items for which quick action is desired to be taken are as follows.

1) Summary and analysis of the actually damaged state

2) Setting of standard structures for estimation of the intensity of ground shaking and investigation on their damage

3) Diagnosis of resistance to earthquake of important buildings and their reinforcements, which did not suffer from the disaster.

4) Diagnosis of resistance to earthquake of bridges and their reinforcements which did not suffer from the disaster.

5) Extract danger spots in river dykes and their reinforcements.

6) Estimation of outflow of sediment and prediction of its effects
   - Actual utilization of aerial photography is effective. -

7) Judgment on degree of danger from rainfall disaster to residence area and buildings located on slopes and monitoring.

8) Monitoring of changes in dams

9) *Investigation of damage on tailing dams and examination of* necessary steps

Of these items, those of 1) and 2) need to be done, before demolishing damaged structures. Particularly, taking note of the fact that an entire absence of a strong shaking record in this earthquake notably hinders the progress of earthquake-proofing measures for structures. Quantitative estimation of the magnitude of ground shaking everywhere should be made from observation of the actual state of damage, granted that arrangement of a strong motion observation network will be undertaken over a long period of time, as described later. For example, estimating the intensity of the ground motion during the event from the degrees of damage to bus-stop structures placed along roads and their distribution may be contemplated for this purpose.

With regard to such structures as buildings and bridges, etc., as mentioned under 3) and 4), analysis of their resistance to ground shaking and reinforcing measures corresponding to their importance and necessity are needed. This is to provide against future earthquakes, even for sections where the intensity of ground motion was low. For this purpose, various methods which have already been developed in Japan will be applicable. Items of 5) and 6) are desirable as measures to be taken in the future and those of 7) and 8) are useful as measures over a somewhat longer term. Item 9) was not investigated this time.

6.3 Items for which Actions should Desirably be Taken Over the Long Run

Items for which actions should desirably be taken over the long run are as follows:

1) Observation of earthquake and strong ground motion

2) Investigation on fault activity

3) Reexamination of earthquake-proof design standards, etc., for buildings

4) Reexamination of earthquake-proof design standards, etc., for bridges

5) Reexamination of earthquake-proof design standards, etc., for dams

6) Reinforcement of the disaster prevention measures along the slopes of the Japan-Philippine Friendship Highway and review of the alignment around its damaged sections.

7) Review of alignment of the Kennon Road

8) Reinforcement of facilities for disaster prevention along the Marcos Highway and the Naguilian Roads

9) Examination of redevelopment plans of areas of Dagupan City where the sinking rate is larger (migration)

10) Set-up of a facility managing and operation manual for abnormal time and training
    - Breakdown of plan for prevention of disaster -
    Include inspection and recovery manuals

11) Establishment of a system for recovery from damage

7. Field Survey Results

7.1 Earthquake, Geology and Ground Conditions

7.1.1 Earthquake

(1) Main shock

A summary of this earthquake determined by the U.S. Geological Survey (USGS) is as follows. All data are tentative values and might be changed hereafter.

1) Origin time: 16:26 July 16, 1990 (local summer time, same as Japanese standard time)
2) Location of focus: Lat. 15.42°N, Long. 121.12°E, depth "shallow"; near Cabanatuan, approx. 100km north-northeast of Manila
3) Magnitude: 7.7

The Philippine Institute of Volcanology and Seismology (PHIVOLCS) judges that this earthquake was a multiple shock consisting of the following two events:

1) Location: Cabanatuan, M7.7, Depth 60km
2) Location: Baguio, M7.6, Depth 10km (2 min. after the former event)

(2) Distribution of seismic intensity

The seismic intensity distribution map prepared by PHIVOLCS is shown in Figure 7.1.1. In the Philippines, the Rossi-Forel's seismic intensity scale is used as a basis, wherein a 9 stage intensity scale (Table 7.1.1) is applied.

A seismic intensity distribution (Rossi-Forel's 10 stage intensity scale) as estimated by the investigating team, from information obtained by interview and from the conditions of damage, is shown in Figure 7.1.2. Although the surveyed areas were limited, and other limitations were imposed, it is shown that the occurrence of high seismic intensity was limited to the areas like Dagupan and Baguio, located northwest of the epicenter.

(3) Aftershocks

Even at the time of the field survey, at Baguio, strong aftershock activities continued, and being felt several times a day. The major aftershocks are listed below:

July 17th	04:45, M5.1
July 18th	03:06, M5.8
July 18th	06:14, M6.3
July 18th	17:00, M6.0
July 21st	00:11, M5.6

The aftershock distribution within two weeks after the main schock is shown in Figure 7.1.3. This map shows that the aftershock activities were much more intense in the vicinity of Baguio than the vicinity of Cabanatuan where the main shock was located.

(4) Fore-shocks and premonitory phenomenon

No fore-shocks were observed by the PHIVOLCS's observation network, nor any data or reports concerning premonitory phenomenon were obtained. As a long term precursor, the seismic activities in the seismic source region of this earthquake had been low, as indicated in Figure 5.1.2, and therefore, it may be able to be pointed out as "Seismic Gap".

7.1.2 Geology

(1) Summary of geology

Figure 7.1.4 shows a geological map of Luzon and its vicinity. This map clearly indicates that Luzon is roughly divided into a northern part and a central part by the Philippine Fault which run from the northern part of the Lingayen Gulf to the Dingalan Gulf.

The central part of Luzon is roughly divided into the Central Valley, the South Sierra Madre Mountains on the eastern side and the Zambales Range on the western side. The Central Valley is composed of Pliocene-Pleistocene deposits. The South Sierra Madre Mountains and the Zambales Range are composed of a complex of igneous, sedimentary and metamorphic rocks and other Miocene or younger sedimentary rocks surrounding this complex.

The northern part of Luzon is roughly divided into the Northern Sierra Madre Mountains on the eastern side and the Cordillera Central Range on the western side. Further, in the northern half of the northern part of Luzon, these two are divided by the basin between them, which is called the Cagayan Valley Basin. The Cordillera Central Range is composed of Mesozoic metamorphic rocks with granitic rocks intruding into them, overlain by the Cenozoic sedimentary rocks. In the Cagayan Valley Basin, Pliocene or younger sedimentary rocks are widely distributed.

(2) The Philippine Fault

The Philippine Fault, which separates Luzon into its northern and central parts is a prominent fault running over an extension of 1,200km. The average slip rate of this fault is estimated to be 1.5-5m per one thousand years (Hirano et al., 1986). On the basis of its length and activity, the Philippine Fault is comparable with the San Andreas Fault on the West Coast in the U.S.A., the Alpine Fault running through New Zealand, the Atacama Fault in Chile, South America, and the Median Tectonic Line in Japan.

The recurrence intervals of the great earthquakes associated with the Philippine Fault is estimated as to 1,600 to 5,300 years based on the average slip rate of the fault and the amount of displacement associated with the most recent earthquake on it (Hirano et al., 1986). Based on the average slip rate and magnitude of this earthquake (M:7.7), a recurrence interval of 800 to 2,800 years can be obtained, but further study based on the detailed investigation of the fault is needed.

The Philippine Fault is divided into four segments running side by side each other at the central part of Luzon (Figure 7.1.5). Among them, fault displacements associated with the earthquake were observed along the segment running from Rizal to Digdig, which is called as the "Digdig Fault". Because no information about displacements accompanying this earthquake was obtained and because of time restrictions, a field survey was not conducted with regard to other segments.

Fault displacements were confirmed at many places along the Pan Philippine Highway, which runs north from San Jose. Because the fault line runs a part westward from the road beyond the KM183 + 600 distance mark (approx. 12km north of Digdig), and because the road beyond KM194 was impassable, a field survey could not be conducted. Between San Jose and Rizal, no notable fault displacements, cracks, etc., were recognized by observation from a helicopter. In the area spreading southeast from Rizal to the vicinity of Bongabon, distinctive fault displacements crosscutting paddy fields were recognized even by helicopter observation. Surveys could not be carried out over the region further southeast of Bongabon due to the flying time limits for the helicopter (Figure 7.1.6).

Figure 7.1.7 shows the points along the Pan Philippine Highway where fault displacements were confirmed. At most of the places shown in this map, left-lateral strike-slip displacements of approx. 5m were observed, while vertical slips were at a maximum, 1.3m west side subsidences. At each points where a fault line crosses a road, the road its-self was displaced, and at the same time, breakage of the pavement surface was recognized over a range of 2-5m in width. In the vicinity of the KM173, where the fault line and the road are nearly parallel, large scale collapsing of the road shoulders was found.

In the places where the fault line passes through grassland, mole-track shaped cracks of 2-5m in width were observed. The cracks manifest themselves in a right stepping an echelon arrangement, which represents a left lateral strike-slip.

In the places where the fault line passes paddy fields, submergence on the down-thrown side due to vertical slip was evident. Strike-slip displacement appeared as deformation of levees. In some parts, discolorations of the ground surface were observed along the fault line, which seem to be marks of water or sand blow conditions.

7.1.3 Ground Conditions

As described above, the central and northern parts of Luzon are divided into many geological zones; the geology and ground conditions differ from one geological zone to the next. In this section, the ground conditions in the vicinities of Baguio and Dagupan, where damages were most noticeable, are described.

(1) Baguio

Figure 7.1.8 shows a geological map of Baguio and it's vicinity. In this area, the Cretaceous basic rock complex distributes as the basement. The Halway Creek Formation consisting of the Eocene basalt, conglomerate, etc. covers the complex. These are overlain by the Miocene Zigzag Formation with interbeded limestone layer called the Kennon Limestone. And further more, there distributes the Klondyke Formation which mainly consists of clastic materials derived from late Miocene andesite.

What is worth paying attention to in connection with the earthquake disaster is that this area is a mining area with the existence of limestone.

Most of the rocks in this area have been subjected to hydrothermal alteration in various degree, accompanying with the mineralization, and hence been subjected to deep weathering. The limestone in this area have also been weathered deeply and turned in to Terra Rossa. In some places, the weathering has reached several tens of meters. Furthermore, the existence of sinkholes should be pointed out in the area where limestone distributes. A sinkhole as big as 2.5km in diameter is known to exist west of La Trinidad (UNDP, 1987). To explain the evidences such as the intense damage in Baguio and non-uniform distribution of damage even in the city of Baguio, the ground conditions described above should be taken into account, but the relationships between individual damages and ground conditions were not clarified by the field investigation within the very limited time.

(2) Dagupan

Most of the damages in Dagupan are attributable to soil liquefaction. Dagupan is situated at the northwestern end of the Central Valley and developed on the delta at the mouth of the Agno River.

In the eastern and northern parts of the Central Valley, where the fan deposits fed from surrounding mountainous regions are distributed, the ground conditions are considered to be relatively good. On the other hand, in the vicinity of Dagupan, unconsolidated deltaic deposits are developed. The thickness of the deposits may reach around 100m, even limited to the deposits since last Ice Age alone. In this connection, the damages in Dagupan should not be considered to be the result of liquefaction solely, but rather should be considered to have been brought by the amplification of the ground shaking by the thick unconsolidated deposits. The liquefaction is the result of strong ground shaking to the materials susceptible, not only the result of the existence of the materials. Detailed further investigations are desired.

7.1.4 Recommendations

Based on the results of the field investigation described above, the following recommendations might be made for the restoration of the damages and for earthquake hazards mitigation in future.

(1) Survey of the ground conditions

As described above, most of the damages by this earthquake were controlled by the local ground conditions. In this connection, much attention should be paid for the ground conditions to specify the individual cause of the damage and also for restoration and future development.

(2) Survey of the earthquake fault

This earthquake was accompanied by the displacement of the Philippine Fault and damages are classified into the damages due to ground shaking and those due to fault displacement. In this connection, attention should be paid for the relationship between the damages and faulting to specify the individual cause of the damage and also for restoration. Also, study of the active faults in the Philippines, not only the Digdig fault which accompanied with this earthquake, are necessary for the future earthquake prediction, hazards mitigation and planning of the development.

(3) Seismic observation

Although the earthquake prediction is still in the state of the art, public education and awareness on the earthquake phenomena based on the scientific observation and research are indispensable to implementing the earthquake countermeasures. In this connection, intensification of seismic observation and promotion of the basic research on earthquake are recommended.

(4) Strong motion observation

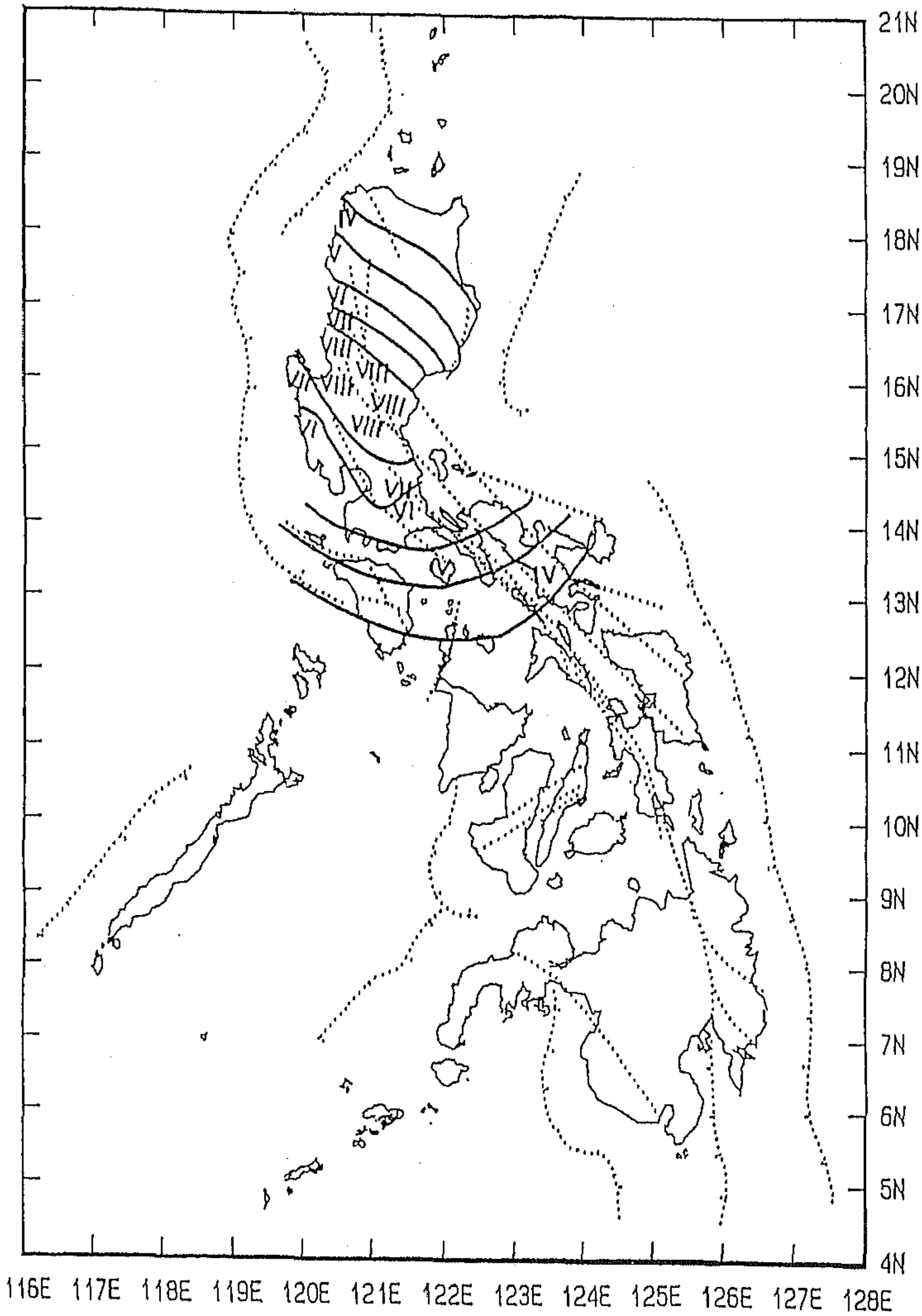
Since no strong motion record was obtained on this earthquake, it is highly recommended that an observation network for strong motion be installed to improve the seismic design codes and establish the seismic design properly.

References

Hirano, S., Nakata, T. and Sangawa, A. (1986): Fault Topography and Quaternary Faulting along the Philippine Fault Zone, Central Luzon, the Philippines. Jour. Geogr. (Chigaku Zasshi), Vol. 95, p.71-93. (in Japanese with English Abs.)

U.N.D.P. (1987): Geology and Mineralization in Baguio area, Northern Luzon. Technical Report, No. 5, DP/UN/PHI-85-001/5, 83p.

Bureau of Mines and Geo-Sciences (1982): Geology and Mineral Resources of the Philippines. Vol. 1, Geology. Bureau of Mines and Geo-sciences, 406p.



ISOSEISMAL MAP OF
THE 16 JULY 1990 EARTHQUAKES

Figure 7.1.1 Seismic intensity distribution (the intensity scale for this figure is described in Table 7.1.1)

(Courtesy of PHIVOLCS)

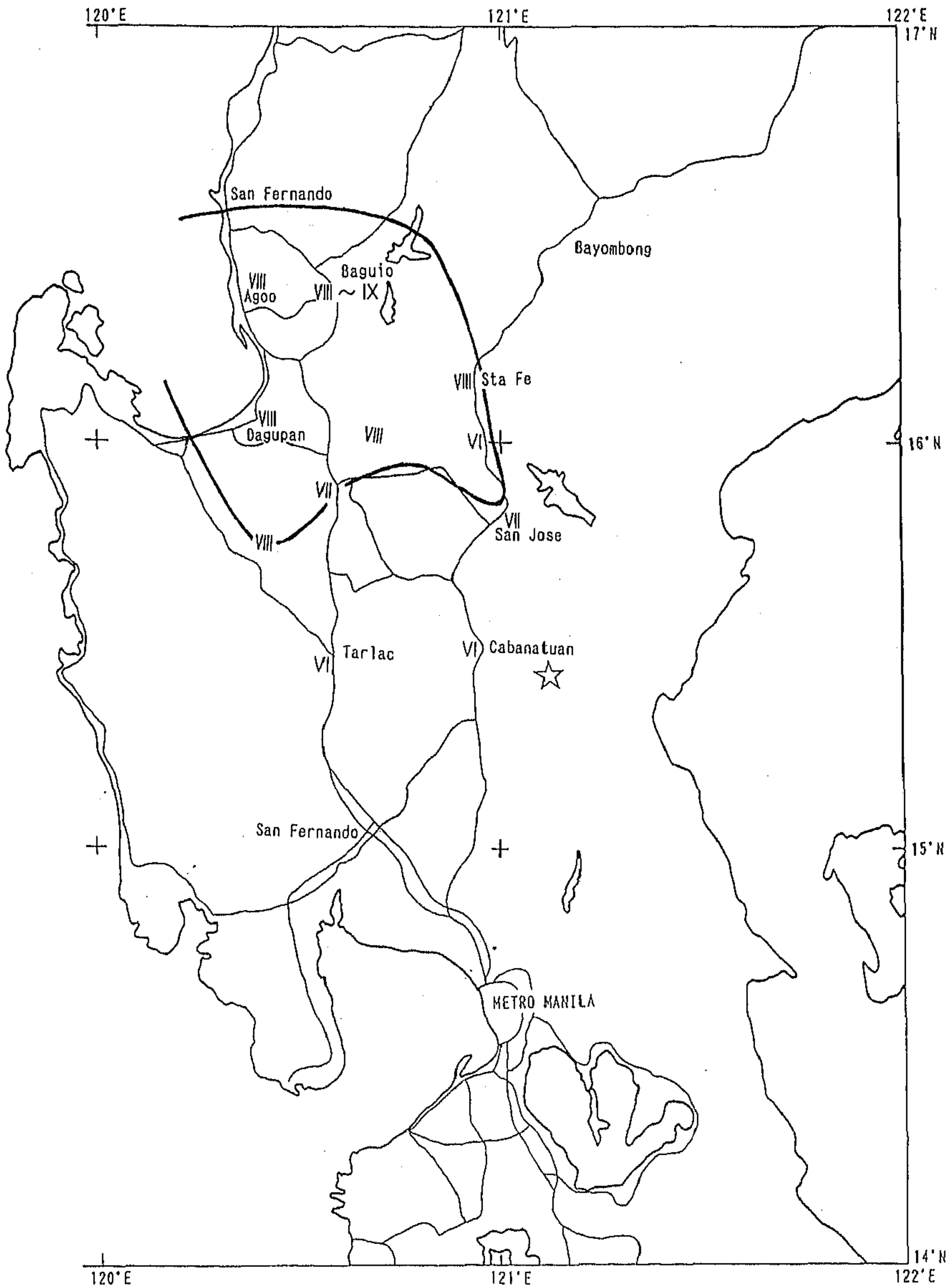
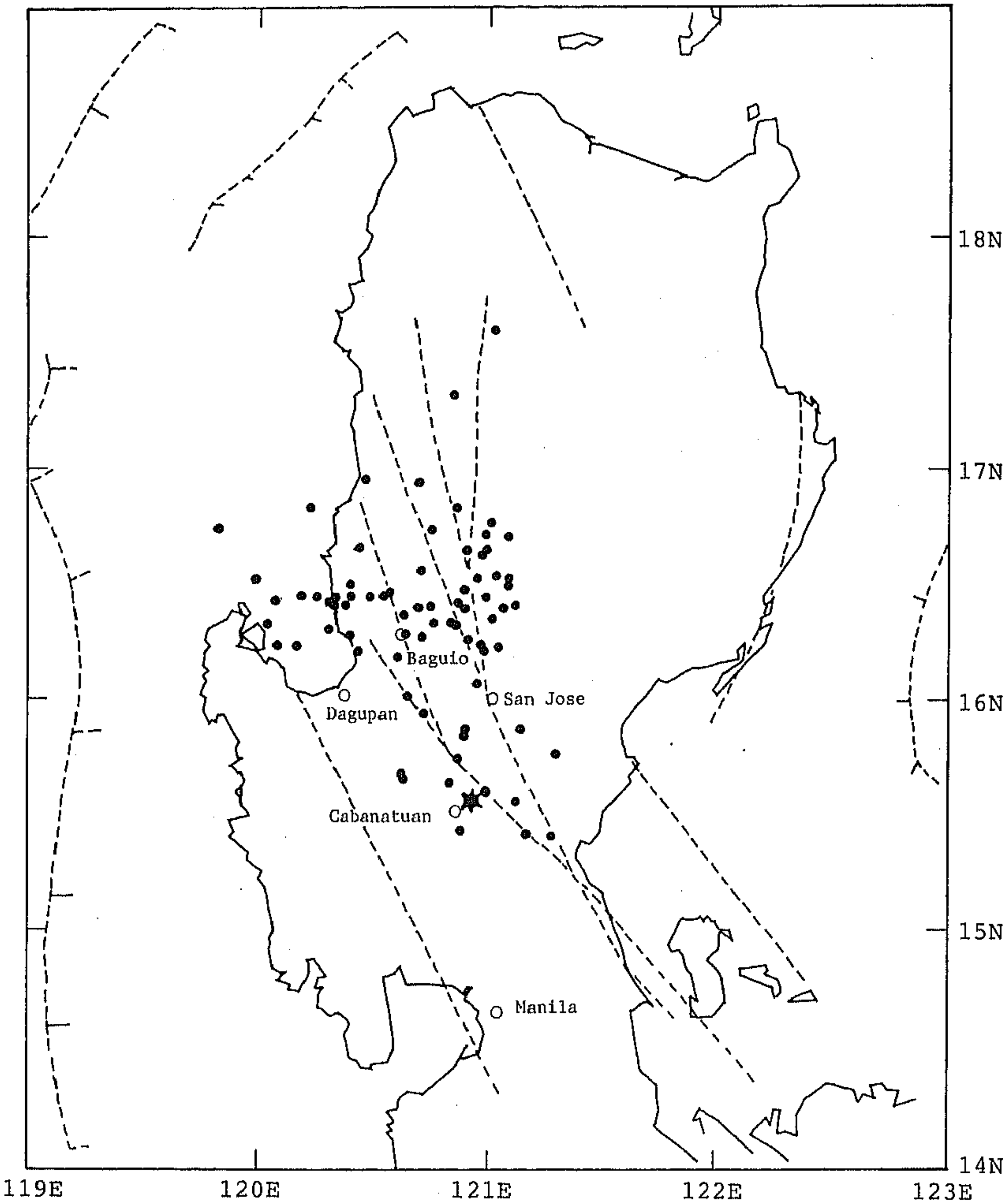


Figure 7.1.2 Seismic intensity distribution by this Investigation Team (Rossi-Forel intensity scale)



AFTERSHOCKS DISTRIBUTION OF
THE 16 JULY 1990 EARTHQUAKES

Figure 7.1.3 Distribution of aftershocks within two weeks after the main shock

(Courtesy of PHIVOLCS)

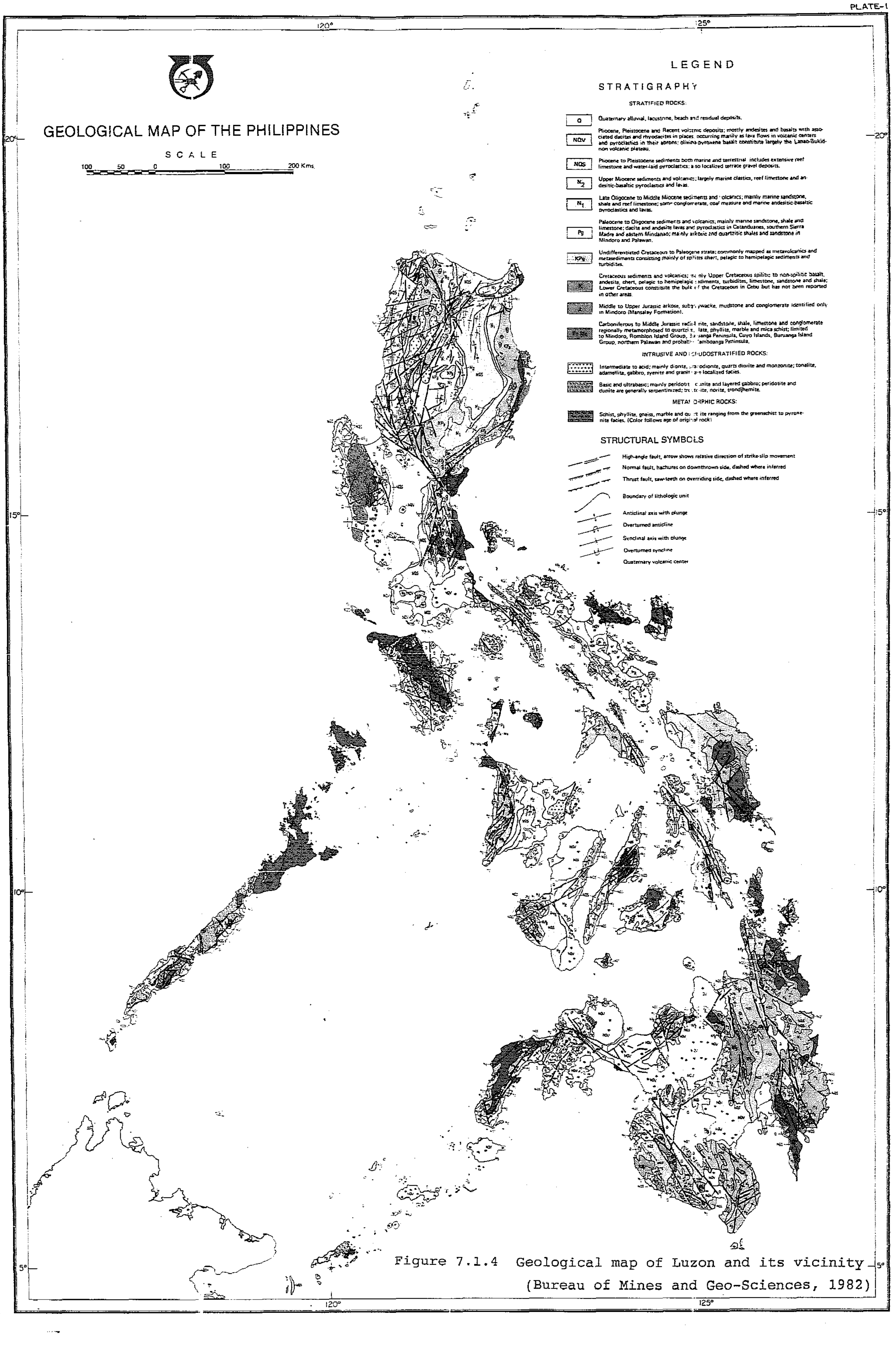


Figure 7.1.4 Geological map of Luzon and its vicinity (Bureau of Mines and Geo-Sciences, 1982)

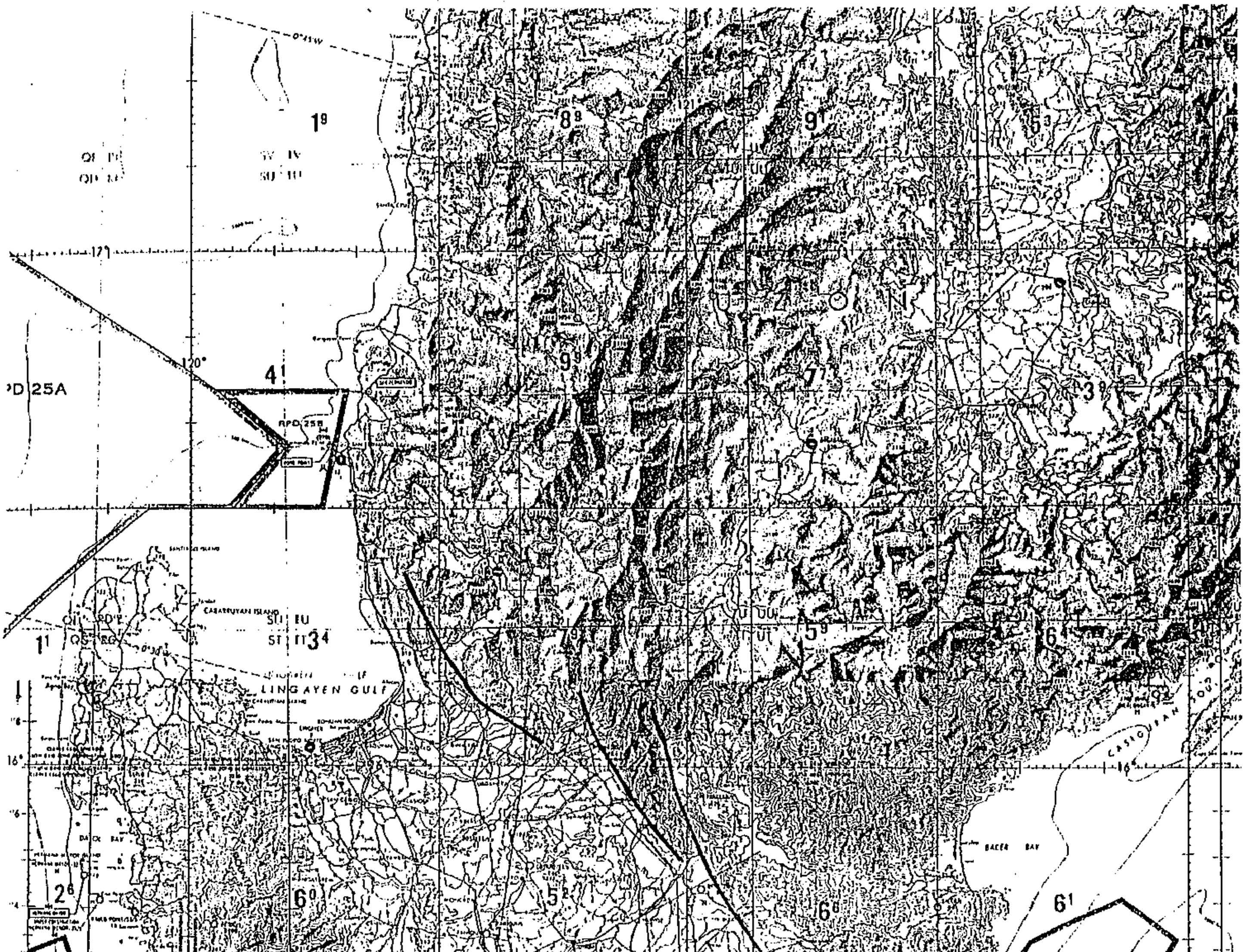


Figure 7.1.5 The Philippine Fault at the central part of Luzon

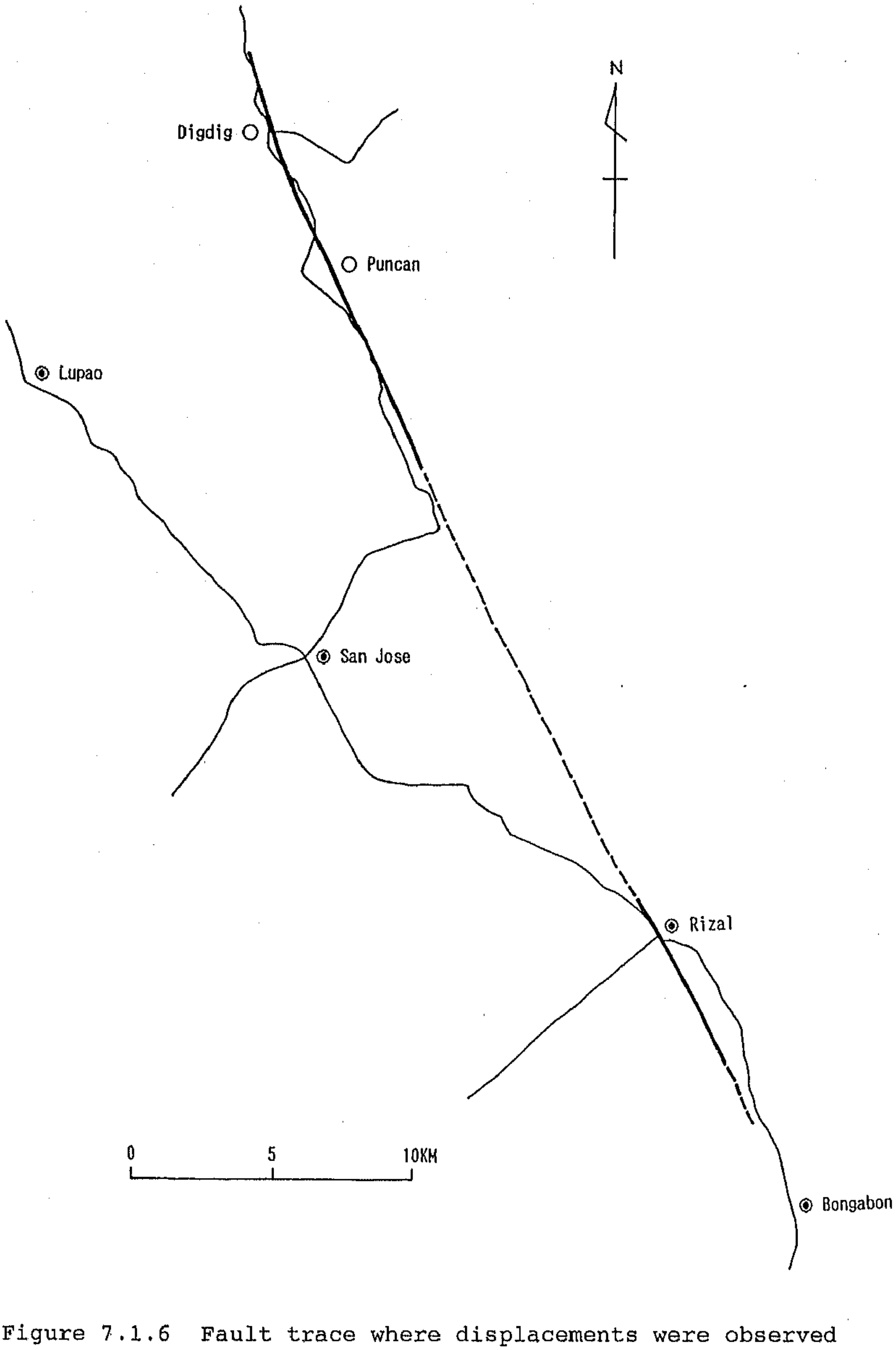
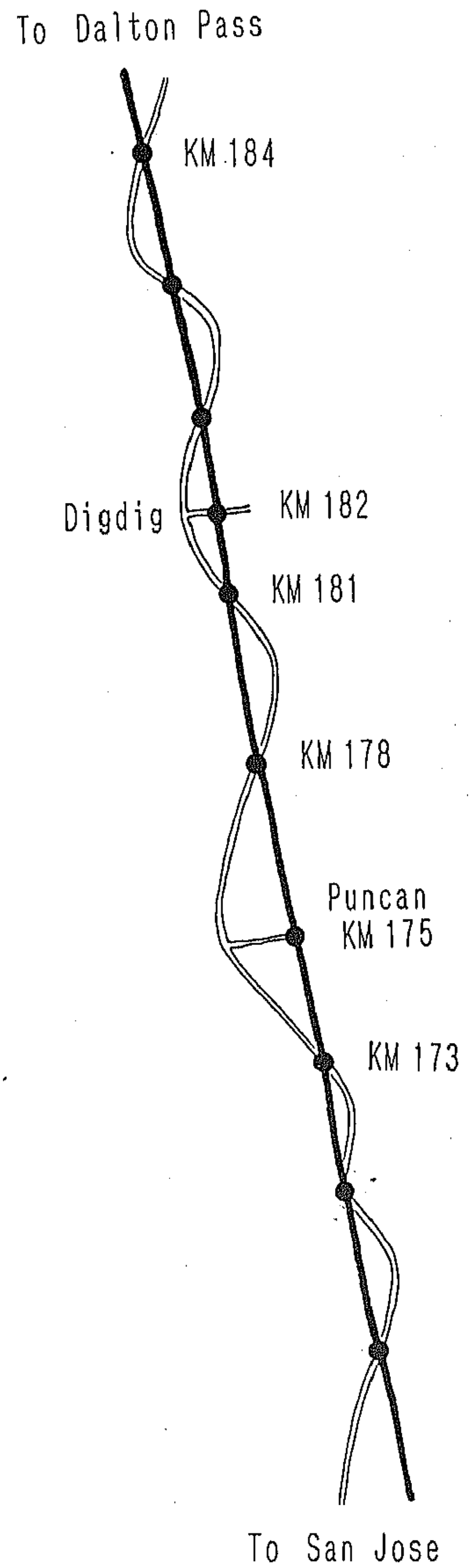


Figure 7.1.6 Fault trace where displacements were observed (thick line)



(not to scale)

Figure 7.1.7 Locations along the Pan Philippine Highway where fault displacements were observed

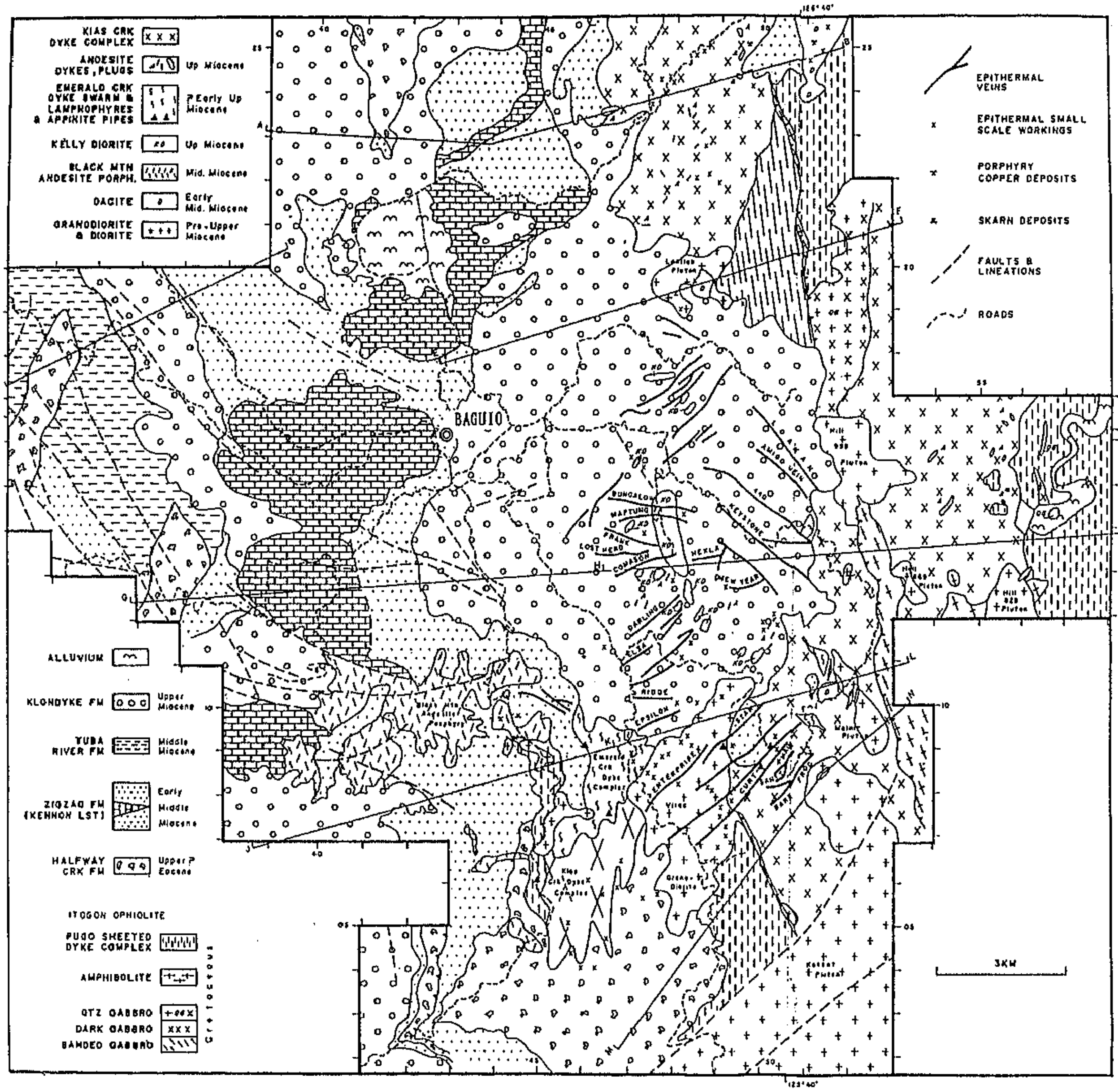


Figure 7.1.8 Geological map of Baguio and its vicinity (UNDP, 1987)

Intensity scale	Description
I	**Hardly Perceptible Shock.** Felt under favorable conditions, only by an experienced observer or a person with high sensitivity.
II	**Extremely Feeble Shock.** Felt by some people at rest or in the upper floors of tall buildings.
III	**Very Feeble Shock.** Felt by several persons at rest. Duration and direction of ground vibrations may be perceptible. Dizziness or nausea may be experienced by a few.
IV	**Feeble Shock.** Felt generally by people indoors; by few people outdoors. Hanging objects swing slightly. Frames of houses creak.
V	**Moderate Shock.** Felt generally by everyone. Hanging objects swing freely. Tall vases and unstable objects are overturned. Light sleepers are awakened.
VI	**Fairly Strong Shock.** Generally wakens those who are asleep. Some people are frightened enough to rush out of buildings. Hanging objects like lamps and small potted plants oscillate. Very old or poorly-built houses and other man-made structures are slightly damaged.
VII	**Strong Shock.** Overturns moveable and unstable objects like bookshelves and drawers. Well built houses may be slightly damaged; old or poorly-built structures, considerably damaged. Some cracks may develop in fishpond dikes and road surfaces. Some landslides may occur in mountain slopes and along steep banks.
VIII	**Very Strong Shock.** Causes panic among people. Trees are shaken strongly. Some buildings may be partially or totally destroyed. The flow of springs and conditions of wells change (e.g., drying up of wells). Sand and mud are ejected from fissures in soft grounds to form "*sand boils*". Cracks form in concrete dikes of fishponds. Small landslides and rockfalls occur.
IX	**Extremely Strong Shock.** Causes widespread panic among people in the affected area. Many buildings are partially or totally destroyed. Ground fissures and sand boils form. Subsidence may occur in some sites, especially those on soft grounds. Major landslides and rock falls occur.

Table 7.1.1 Seismic intensity scale adopted in the Philippines

(PHIVOLCS pamphlet)

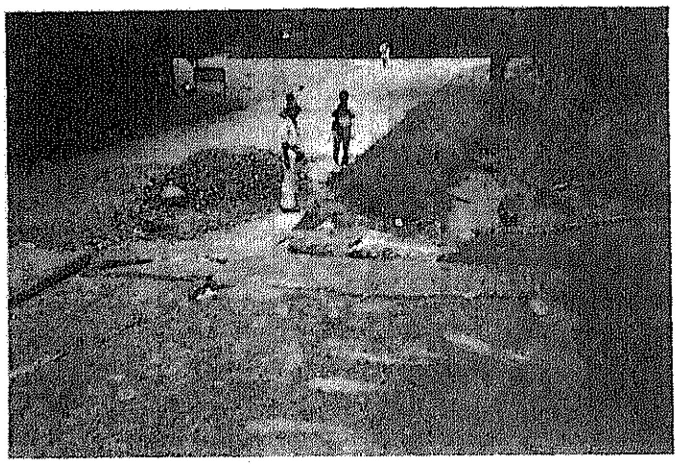


Photo 7.1.1 Earthquake Fault at Digdig. Left-lateral offset at this location is about 5m.

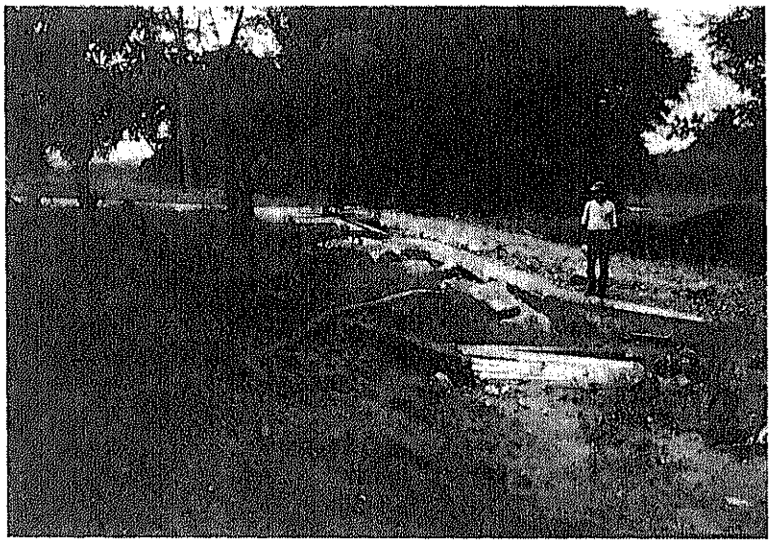


Photo 7.1.2 Earthquake Fault at Digdig. Vertical offset of east side up-thrown is about 1.3m.

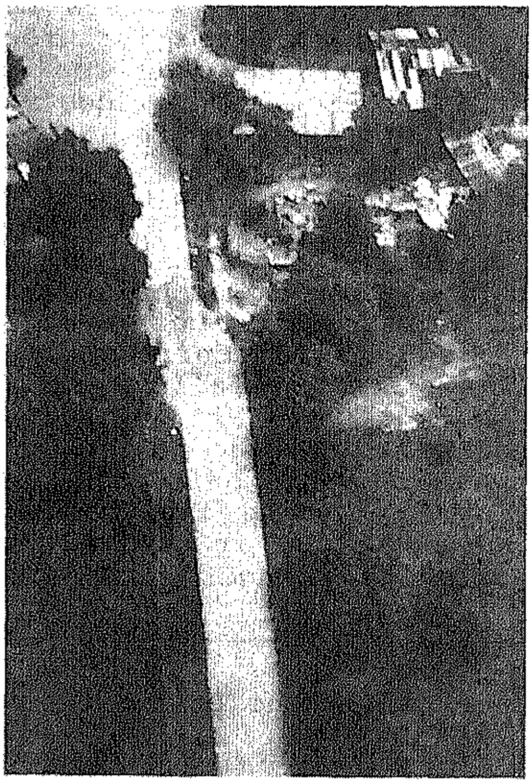


Photo 7.1.3 Earthquake Fault at Digdig, from helicopter. Fault is visible from upper right corner to middle of the left side of the photo.

Photo 7.1.4 Earthquake fault crossing the Pan Philippine High Way at KM181 shown by arrows.

Photo 7.1.5 Earthqake fault crossing the Pan Philippine High Way at KM181. Fault is recognized as an echelon cracks on the grass land.

Photo 7.1.7 Earthquake fault crossing the Pan Philippine High Way at KM181. Cracks on the road surface are evident on the fault.

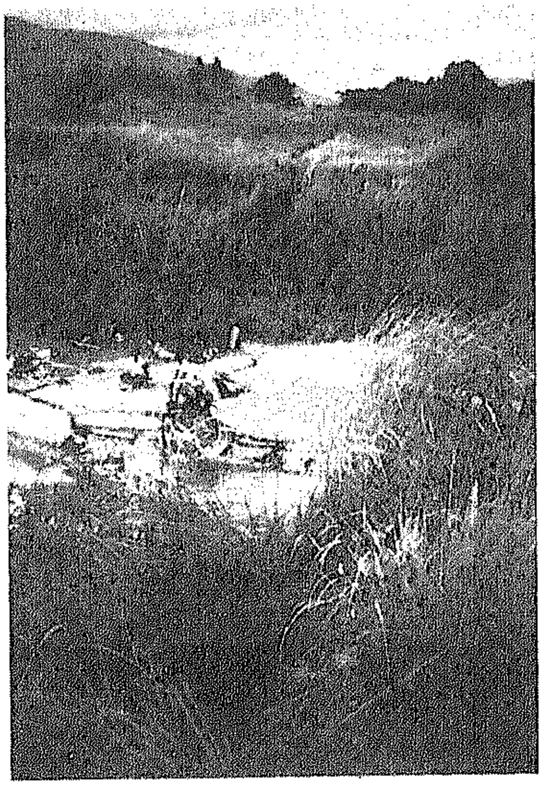
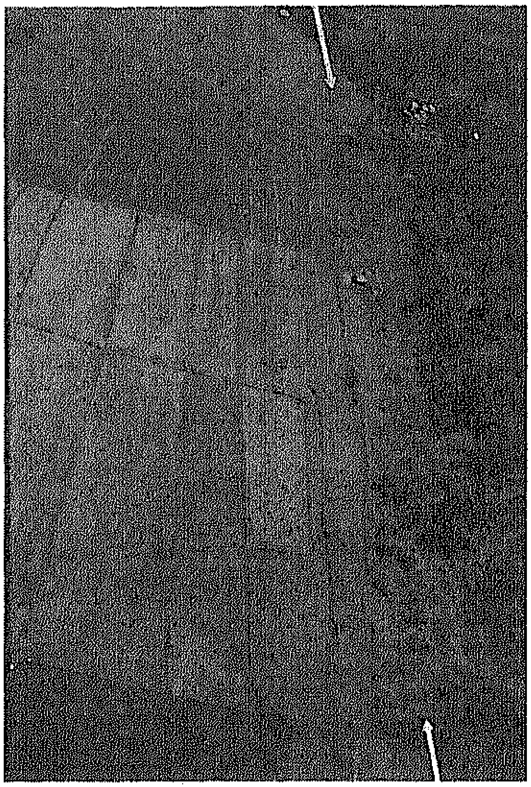


Photo 7.1.6 Earthquake fault crossing the Pan Philippine High Way at KM181. An echelon cracks across the road showing left-lateral movement.

Photo 7.1.8 Fault in the south of Puncan, indicated by arrows.



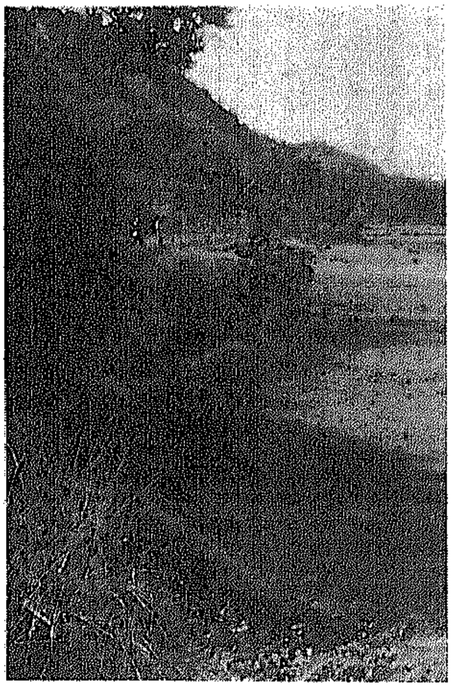


Photo 7.1.9 Fault in the south of Puncan. Mole track shaped cracks are characteristic at this point.

Photo 7.1.10 Fault in the south of Puncan. Lateral offset is shown by two triangles.

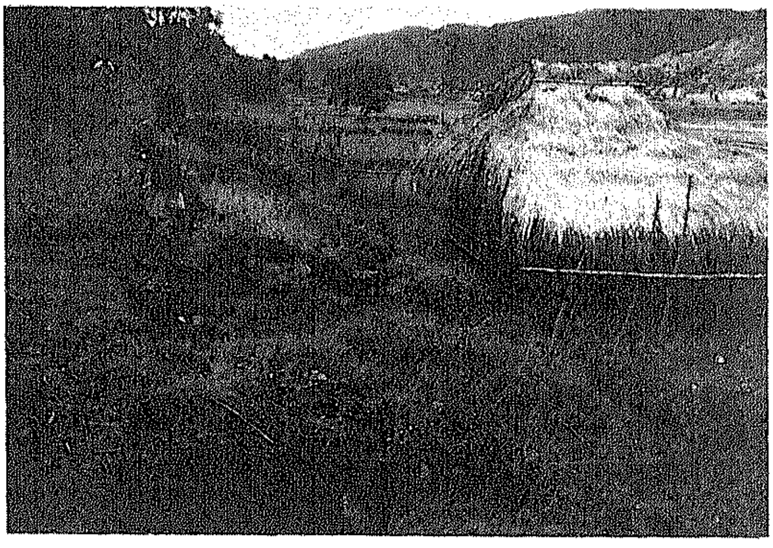


Photo 7.1.11 Fault in the south of Puncan. The scarp in the middle shows the vertical displacement. No damages to the cottage are visible.

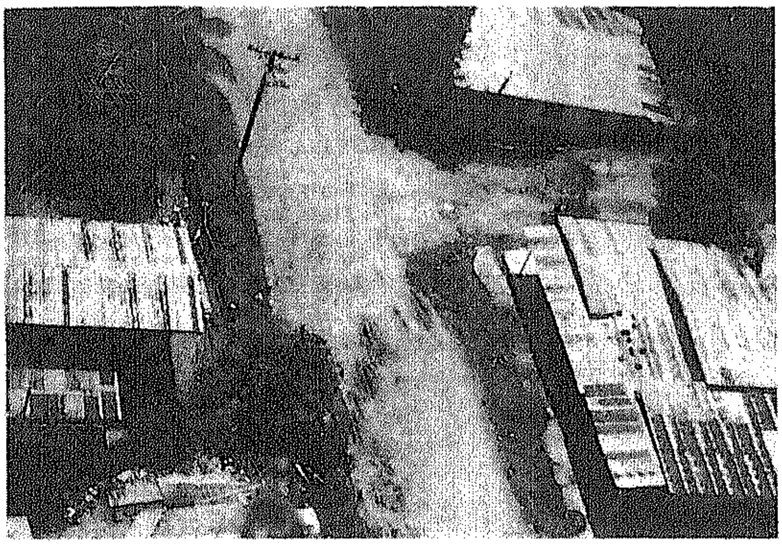


Photo 7.1.13 Fault passing through Rizar. Left-lateral offset of the road.

Photo 7.1.12 Fault passing through Rizar, indicated by arrows.

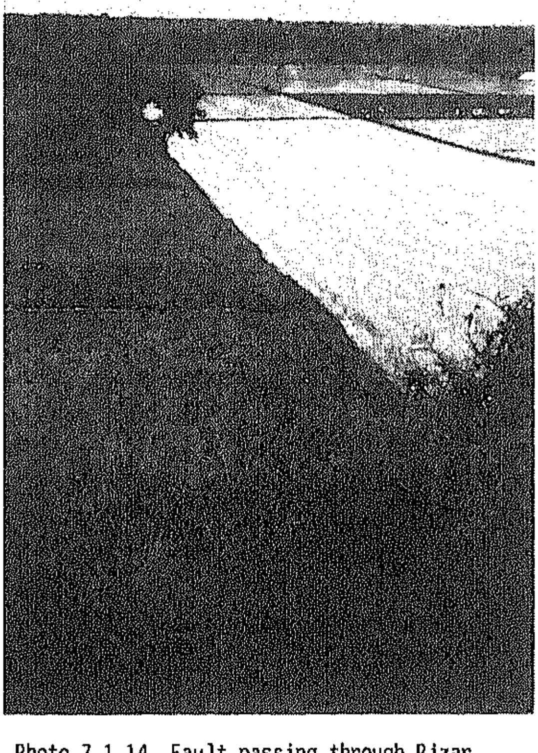


Photo 7.1.14 Fault passing through Rizar. Passing through paddy field.

Photo 7.1.15 Fault passing through Rizar. Lateral and vertical offsets are visible.

Photo 7.1.16 Fault passing through paddy field in the vicinity of Rizar. Lateral offset is visible clearly as the displacements of levees.

Photo 7.1.17 Fault passing through paddy field in the vicinity of Rizar. Down thrown side of the fault is submerged.

Photo 7.1.18 Fault passing through paddy field in the vicinity of Rizar. Right stepping an echelon cracks, characteristics to the left-lateral displacement, are evident.

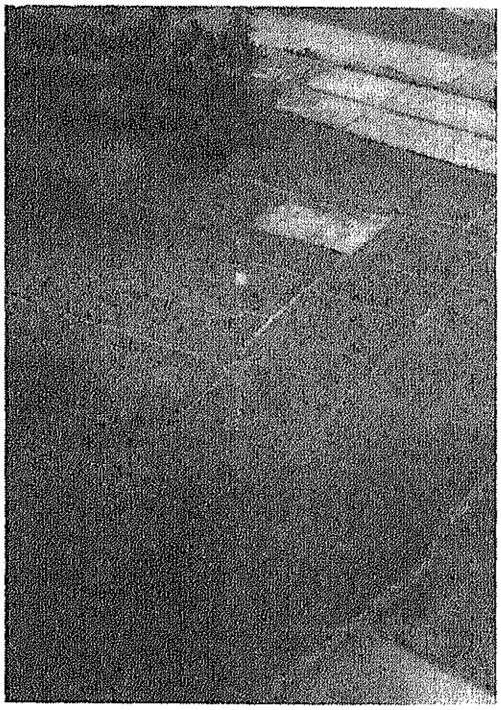


Photo 7.1.19 Fault passing through paddy field in the vicinity of Rizar. Water or sand blows are recognized along the fault trace.