REPORT OF JAPAN DISASTER RELIEF TEAM

(EXPERT TEAM)

ON THE EARTHQUAKE

IN

REPUBLIC OF INDONESIA

OF

DECEMBER 12, 1992

MARCH, 1993

JAPAN INTERNATIONAL COOPERATION AGENCY
(JICA)

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PREFACE

On December 14, 1992, the Government of Japan decided to provide emergency disaster relief services, based on the request of the Government of the Republic of Indonesia, for the earthquake and tidal wave damage which occurred on December 12, 1992 resulting from an earthquake which had its epicentre 36 kilometres offshore from the town of Maumere in the centre of the Indonesian island of Flores.

The Japan International Cooperation Agency, in response to the request of the Government, dispatched a Japan Disaster Relief Team (expert team), headed by Professor Katsuyuki Abe, Eathquake Researve Institute, University of Tokyo, to the Republic of Indonesia from December 20 to 30. The expert team provided technical advice regarding emergency measures and restoration, and suggestions for prevention of future disasters. The team members have summarized their field activities in this report, prepared after their return to Japan.

I hope that this report will serve to assist the Republic of Indonesia in their plans for permanent disaster relief and restoration to be made in the future, and will contribute toward further development of friendly relations between the two countries.

At this opportunity I wish to express my deepest appreciation for all concerned who have expended a great cooperation and assistance in the disaster relief activities.

March, 1993

Sekai Nishino, Vice President
Japan International Cooperation Agency

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I. INTRODUCTION

I. INTRODUCTION

The main shock of the earthquake occurred at 1:29 PM (local time) on December 12, 1992, having a surface wave magnitude of 7.5 (Ms). The epicenter was located about 40 km northwest of Maumere, Flores Island, the Republic of Indonesia. According to aftershock data, the rupture zone was inferred to extend about 100 km to the east of Flores Island. The country suffered severe damage from the strong ground motion and large tsunamis.

In view of the heavy damage from this earthquake, the Japanese government decided to offer immediate relief supplies worth U.S.$ 0.5 million through Japan International Cooperation Agency (JICA).

The Indonesian government requested Japan to dispatch an expert team mainly specializing emergency measures, in which Japan, one of the most earthquake-stricken countries, has the most advanced expertise in the world.

In response to this request, the Japanese government immediately started the selection of experts in cooperation with Ministry of Construction, National Land Agency, Ministry of Education and other agencies concerned, and decided to dispatch immediately a Japan Disaster Relief Team (Expert Team) through JICA during a period form December 20 to 30. This decision was made under the Law concerning the Dispatch of the Japan Disaster Relief Team. The present team consists of 8 experts covering fields of seismology, architecture, civil engineering and emergency countermeasures.

We, as the quick response team, collected information from Indonesian sources and took field survey in Flores Island. The meetings were held with rehabilitation-activity leaders in disaster-stricken areas. Furthermore, we prepared an interim report in English. It describes the earthquake, its damage, and immediate measures for rehabilitation from the earthquake disaster. This report with 23 recommendation items was handed to Coordinating Minister for People's Welfare in Jakarta on December 28 prior to the team's return to Japan.

The present report contains our survey results obtained during the stay, some analyses made later in Japan, and recommendations based on the interim report. Since it was hurriedly prepared from limited data, we request your understanding that, depending on further accumulation of data, corrections or additions may be found necessary in some of its parts.

We were greatly aided by BAKORNAS PB and various agencies of the Indonesian government for the necessary arrangement to facilitate the team activities in Indonesia. We were indebted to local authorities in Flores Island for their generous and efficient support of the activities of the team. Their contributions were crucial to the success of the mission. Our activities as the expert team were assisted by the Japanese Embassy in Jakarta and the JICA Office in Jakarta. A JICA-dispatched long-term expert and his co-worker cooperated fully with the team in the field survey. Our works have been made possible by the collaboration of our team members and these people. We would like to express our sincere gratitude to all these people concerned.

We really hope that the disaster rehabilitation efforts of Indonesia will be helped by this report concerning the application of our disaster evaluating methods based on our experiences in earthquake disasters, our recommendations for the emergency repair of damaged structures and the methods of future preparedness. Finally we sincerely hope that Indonesian people recover from the present disaster as soon as possible.

March, 1993

Katsuyuki Abe (Team Leader)

Japan Disaster Relief Team (Expert Team)

II. MEMBERS AND ITINERARY

II. MEMBERS AND ITINERARY

1. Members

Photo 1.1 Members of Japan Disaster Relief Team and Co-workers at Maumere
Front row, from left to right:
K. Kawashima, T. Uda, K. Abe (team leader), S. Nakata.
Rear, from left to right:
H. Maruyama, K. Mano (JICA expert), T. Akagiri, K. Hamada, T. Fujii, E.T. Putranto (co-worker)

Japan Disaster Relief Team (Expert Team) Earthquake in Indonesia

	Name	Occupation	Assignment
Leader	Mr. Katsuyuki ABE	Professor, Earthquake Research Institute, University of Tokyo	Leader
Member	Mr. Kazuo HAMADA	Director for Solid Earth Science Division, National Research Institute for Earth Science and Disaster Prevention (NIED)	Earthquake Prediction
	Mr. Tomomitsu FUJII	Director of Earthquake Disaster Countermeasure Division, Disaster Prevention Bureau, National land Agency	Earthquake Disaster Countermeasures and Civil Engineering
	Mr. Shinsuke NAKATA	Head of Testing and Evaluation Department, Building Research Institute, Ministry of Construction	Structural Engineering
	Mr. Kazuhiko KAWASHIMA	Head of Earthquake Engineering Division, Earthquake Disaster Prevention Department, Public Works Research Institute, Ministry of Construction	Earthquake Engineering Bridge Structure
	Mr. Takaaki UDA	Head of Coastal Engineering Division, River Deparment, Public Works Research Institute, Ministry of Construction	Coastal Engineering
	Mr. Takekazu AKAGIRI	Head of Second Geographic Division, Geographic Departmet, Geographical Survey Institute, Ministry of Construction	Geological Hazard, Landslide
	Mr. Hideaki MARUYAMA	Office of The President, Japan International Coopration Agency	Coordination (General)

2. Itinerary

Date	Time (local)	Matter for Investigation
20 Dec. (Sun.)	13:00 – 18:40	Tokyo → Jakarta
	20:00 – 22:00	Meeting with Embassy of Japan and JICA
21 Dec. (Mon.)	08:30 – 09:35	Ministry of Public Works
		(Mr. Kartomo : Secretary)
	10:00 – 12:00	Minister of Mining and Energy Ministry
		(Director General : Dr. Adjat Sudradjat)
		Ministry of Social Welfare
		(Director for Disaster Affairs : H.R. Djajusman)
	13:00 – 15:00	Embassy of Japan
	15:30 – 16:30	Press Release to Japanese Media
	17:00 – 18:00	Ambassador of Japan
	18:30 – 20:30	JICA Meeting
22 Dec. (Tues.)	04:30	President Hotel → Airport
	10:08 – 14:50	Jakarta → Maumere
	16:20 – 16:45	Maumere → Babi Island
	16:45 – 17:05	Survey (Babi Island)
	17:05 – 17:30	Babi Island → Maumere
23 Dec. (Weds.)	07:10 – 07:30	Maumere → Ende
	07:30 – 12:00	Survey (Ende)
	14:50 – 15:15	Ende → Maumere
	16:00 – 18:00	Survey (in and around Maumere)
24 Dec. (Thurs.)	09:00 – 11:00	Bupaty of Sikka
	11:00 – 18:00	Survey (in and around Maumere)
25 Dec. (Fri.)	09:00 – 17:00	Survey (in and around Maumere)
	17:00 – 19:00	Bupaty of Sikka
26 Dec. (Sat.)	14:15 – 20:00	Maumere → Jakarta
	20:45 – 23:00	Meeting with Embassy of Japan and JICA
	23:00 –	Report Making
27 Dec. (Sun.)	06:00 –	Report Making
28 Dec. (Mon.)	09:00 – 09:30	Ambassador of Japan
	10:00 – 10:30	Presentation of the Report to the Minister
	11:00 – 15:00	Meeting with related organization in Indonesia
	16:00 – 17:30	Press Release to Japanese Media
	18:00 – 20:00	Meeting with Ambassador
29 Dec. (Tues.)		Meeting with Minister of Public Works
30 Dec. (Weds.)	22:00 – 07:00	Jakarta → Tokyo

III. SURVEY REPORTS AND RECOMMENDATION

III. SURVEY REPORTS AND RECOMMENDATION

1. The Main Shock and Aftershocks

1.1 Summary of Flores Island: the site of the disaster

Flores Island is a narrow, long island extending from the east to the west with a 12 – 70 km width and 360 km length belonging to the Indonesian Island Arc. Approximately 1.4 million people live on Flores Island. There are impressive volcanoes, beautiful lakes, and forests. The island is counted as one of the most beautiful places to visit in Indonesia.

According to modern plate tectonics, the island is located on the Asian plate along the plate boundary between the Asian and the Indo-Australian plates where the Indo-Australian plate subsides approximately northward beneath the Asian plate (Fig. 1.1).

Flores Island is geologically young and active because of the present time subduction of the plate. The surface geology of the island consists primarily of Quaternary and Tertiary volcanic rocks and includes several volcanoes covered with younger Quaternary, volcanic products.

1.2 Seismic Activities and the Earthquake Disaster in Indonesia

The main island arc of Indonesia is situated on a seismically active belt on the earth. This activity is based on the subduction of the Indo-Australian plate beneath the Asian plate.

Figure 1.2 shows earthquakes of magnitude greater than or equal to 7 which caused damage to Indonesia, occurred since 1900, and which took place within the region (10°N – 20°S, 90° – 130°E). Table 1.1 shows selected destructive earthquakes with $M \geqq 7$ which have occurred in and around Indonesia since A.D. 1900.

In the 90 year period preceding 1990, the total number of deaths caused by earthquakes with or without tsunamis was 983. Out of the 983 deaths, 790 (80%) were caused by tsunamis associated with the earthquakes. All of the disastrous earthquakes which caused more than 100 casualties were associated with tsunamis. On 12 December 1992, an earthquake occurred off the north coast of Flores Island and generated tsunamis. As a consequence the total number of casualties reached 2080 as of 26 December 1992. The 1992 disastrous event caused the greatest number of casualties experienced since 1900.

It must be recognized that earthquakes and associated tsunamis are very disastrous for the people of Indonesia.

1.3 The 12 December 1992 Earthquake Near Flores Island

The earthquake occurred on 12 December 1992 off the north coast of Flores Island where there had been no earthquake with magnitude greater than or equal to 7 since A.D. 1900. The source parameters were calculated as follows:

	BGM (revised)	USGS	HARVARD C.M.T.
Origin time	5:29:28.0 (UT)	5:29:27.1 (UT)	5:29:56.9 (UT)
Location	8.63°S 121.90°E	8.48°S 121.93°E	8.34°S 122.37°E
Depth	44 km	36 km	15 km
Magnitude	Mb=6.8±0.4	Ms=7.5	Mw=7.8
Mechanism		Pxis:351° Plunge:15°	MO=6.4×10^{27} STRIKE; DIP; SLIP NP1: =61; =32; =64 NP2: =272; =61; =106 (BEST DOUBLE COUPLE)

BGM: Meteorology and Geophysical Agency, Ministry of Communication, Indonesia.
USGS: United States Geological Survey
HARVARD C.M.T.: HARVARD UNIV. CENTROID, MOMENT TENSOR SOLUTION.

The epicenter of the main shock and some aftershocks recorded by the USGS are illustrated in Fig. 1.3. Their distribution suggests that the initial break began at the west end of the focal zone and that the rupture propagated 100 km to the east-northeast direction. This earthquake was considered a low angle reverse fault and was thought to be caused by a back-arc thrust behind the arc rather than the subduction of the Indo-Australian plate. The back-arc thrust is recognized and illustrated in the seismotectonic map of Indonesia issued from the Geological Research and Development Center in 1992 (Fig. 1.4).

1.4 Aftershock Activities

Aftershock activities have been monitored by using temporary, portable stations installed in Maumere City on Flores Island where a great deal of damage has been reported. The city is probably the closest urban center to the source area. The stations are operated by Geological Research and Development Center, Ministry of Mines and Energy. The number of aftershocks counted at the temporary stations are decreasing as of December 22 as shown in the next table. Also there is a tendency towards a decrease in the size of the aftershocks with time.

Date	Frequency	The maximum magnitude
December 13, 1992	34	6.0
14	28	5.5
15	18	4.9
16	11	4.0
17	18	5.7
18	9	3.0
19	7	4.5
20	6	4.6
21	4	4.5
22	4	4.5

Such decreasing in the number and size of the aftershocks implies the end of the present seismic activities.

The spatial distribution of the aftershocks is, however, not well determined yet because of insufficient instrumentation, although detailed spatial information on aftershock activity is extremely important.

1.5 Recommendation

Regarding the present seismic activities information on the location of the main shock and aftershocks is insufficient.

Denser seismic observation networks are required to locate the hypocenters with good accuracy. They should consist of three-component sets of seismometers equipped with telemetry systems for quick data processing. Broad-band seismic stations are also important to understand the earthquake mechanism.

It is recommended to install strong motion accelerographs on the ground and on structures for evaluating strong ground motion and structural response.

Table 1.1 Selected Destructive Earthquakes with M=7 or more which Caused Damaged to the Indonesian People

Year	MD	hm	Lat	Long	M	Dead	Tsunami	Remarks
1907	625	1754U	2.0	96.3	7.8		T	Indonesia (Sumatra): Gunung Sitoli (Nias)
1909	603	1841U	-2.5	101.5	7.5	200	T	Indonesia (Sumatra): Korintji Djambi (Ms=7.3)
1913	314	845U	4.5	126.5	8.3	some		Indonesia: Sangihe Is.
1914	625	1906U	-4.0	102.5	8.1	many		Indonesia (Sumatra): Benkulen Ms=7.6
1921	911	401U	-11.0	111.0	7.5		T	Indonesia (Java) (Ms=7.5)
1931	210	634U	-5.3	102.5	7.1	18		Indonesia (Sumatra)
1932	514	1311U	0.5	126.0	8.3	5		Indonesia: Molucca Passage Ms=8.0
1933	624	2154U	-5.5	104.7	7.5	76		Indonesia (S.E. Sumatra): Liwa (Ms=7.5)
1936	823		5.0	95.0	7.3	91		Indonesia (N.W. Sumatra)
1938	519	1708U	-1.0	120.0	7.9	8	T	Indonesia (Celebes): Dongala, Mambala (Ms=7.6)
1950	1008	323U	-3.7	128.2	7.6		T	Indonesia: Ceram Is. (Ms=7.4)
1950	1102	1527U	-6.5	129.5	8.1		T	Indonesia: Banda Sea (mB=7.4)
1963	1104	117U	-6.8	129.6	8.2			Indonesia: Banda Sea (mB=7.8)
1964	402	111U	5.8	95.6	7.0	110	T	Indonesia (Sumatra)
1965	124	11U	-2.4	126.0	7.5	71	T	Indonesia: Ceram Sea, Sanana (Sulu) (Ms=7.5)
1968	810	207U	1.4	126.2	7.6		T	Indonesia: Molucca Passage (Ms=7.5)
1968	814	2214U	0.1	119.7	7.4	392	T	Indonesia (Celebes)
1977	819	608U	-11.1	118.5	8.0	189	T	Indonesia: (Sumbawa Is. Eq.) (Ms=8.1)
1990	418	1339U	1.1	122.8	7.4	3		Indonesia (Celebes): Bolaang-Gorontara a

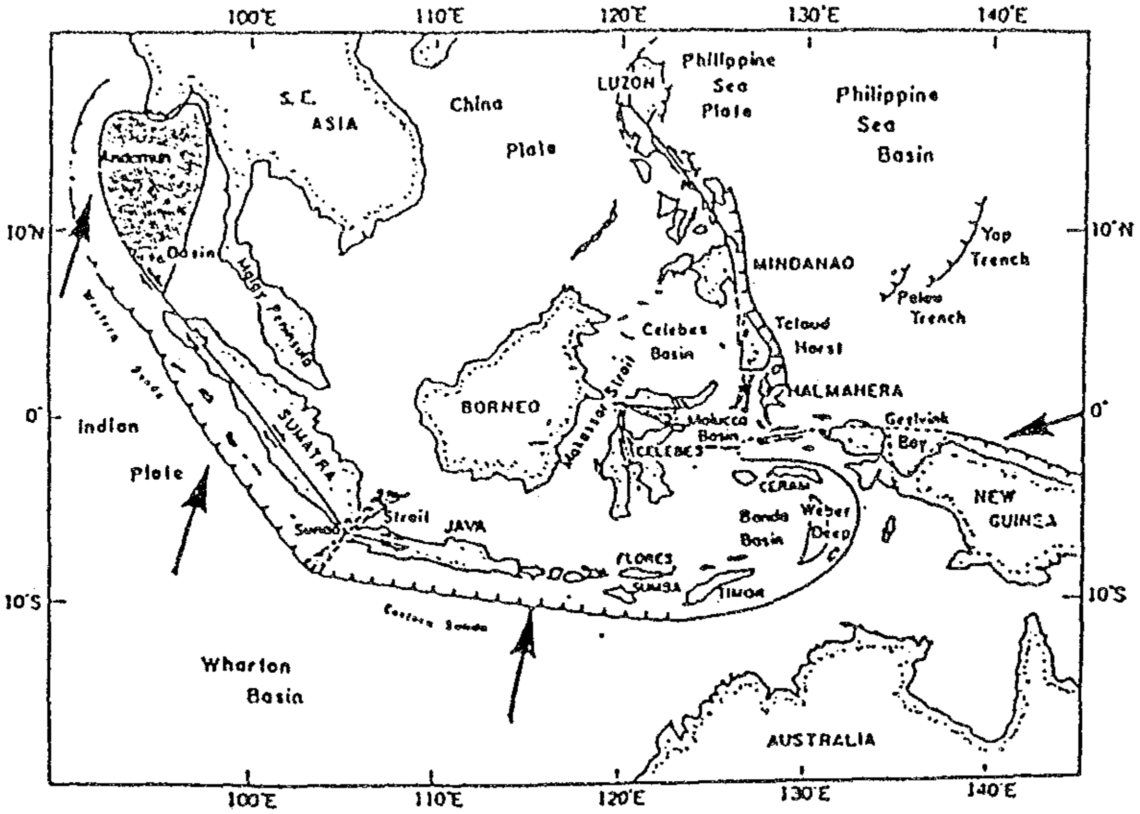


Fig. 1.1 Tectonics of the Indonesian Island Arc Region
Arrows Indicate the Direction of Plate Movements

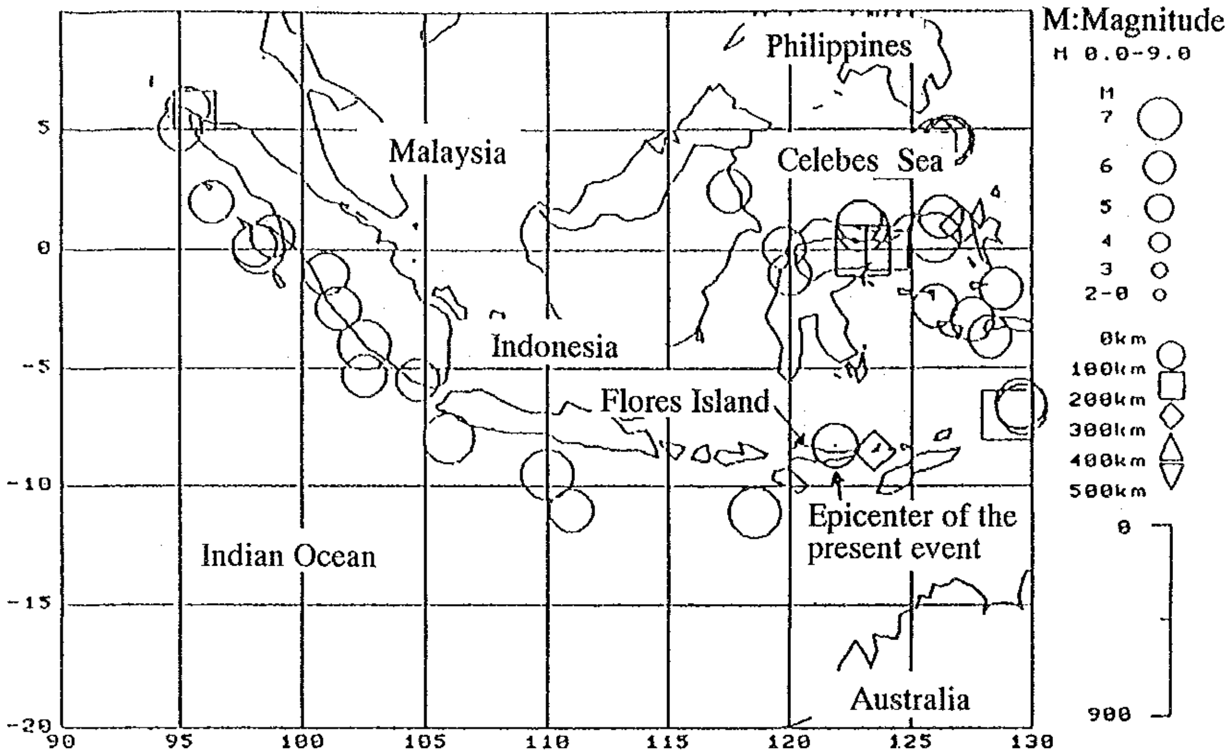


Fig. 1.2 Selected Destructive Earthquakes with M=7 or More

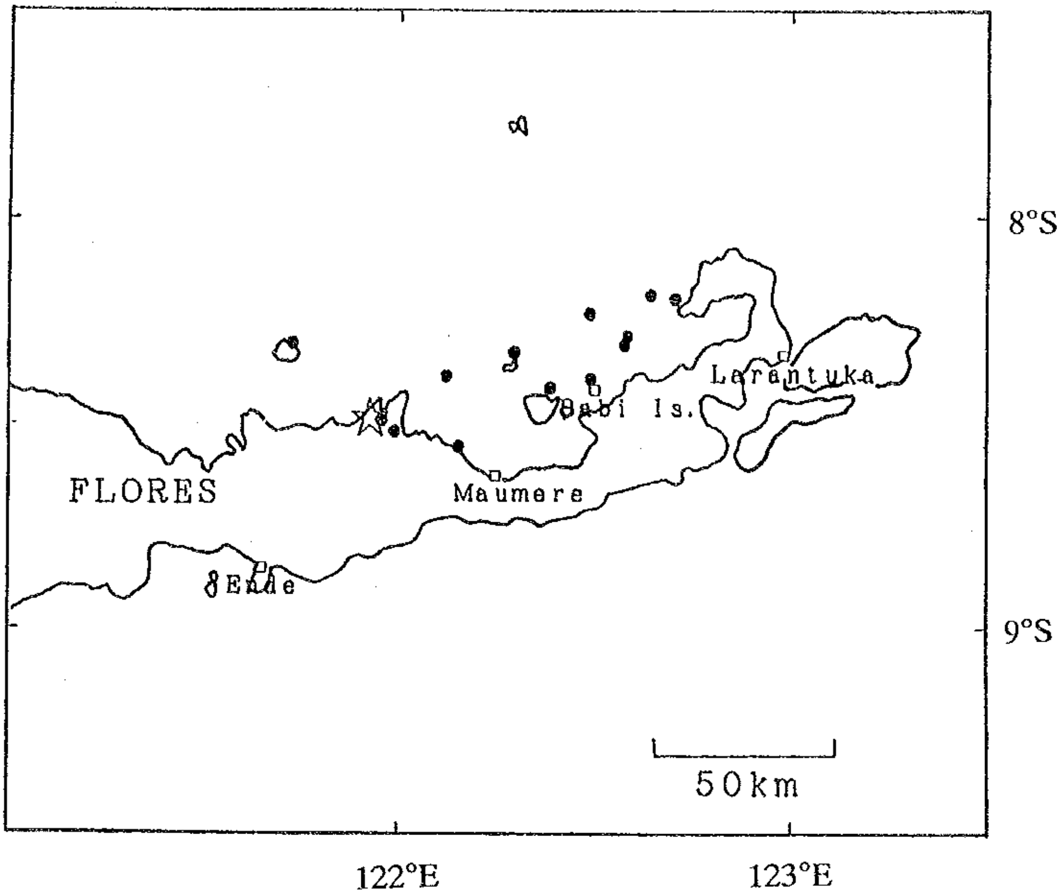


Fig. 1.3 Epicenters of the Main Shock (☆) and some aftershocks (●) Recorded by the USGS

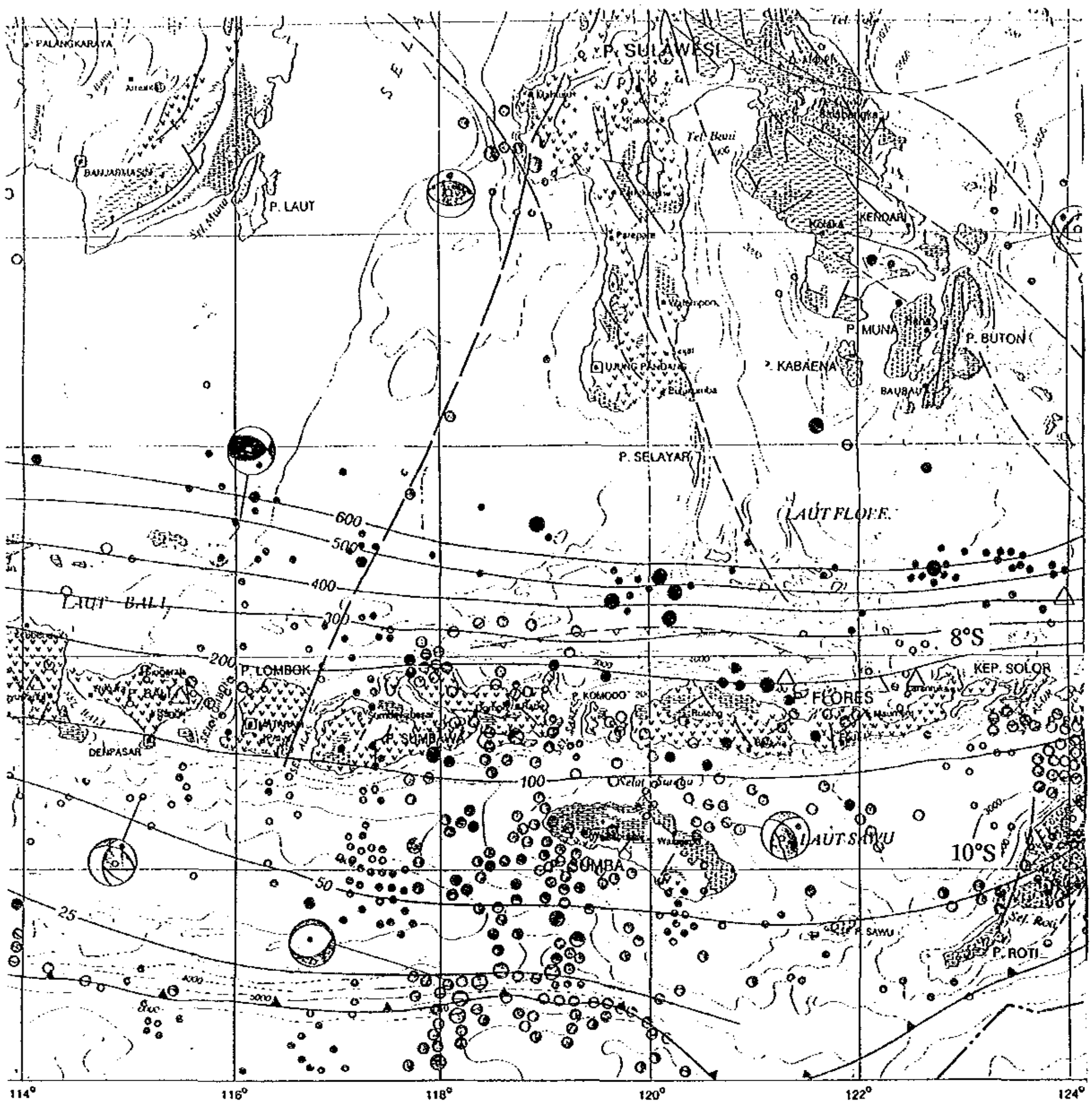


Fig. 1.4 Seismotectonic Map Issued from the Geological Research and Development Center in 1992

Circles indicate the epicenters of earthquakes with M=5 or more during the last decade in Indonesia. Contour lines show the depths of the Wadati and Benioff zone in kilometers.

The symbols ▽ ▽ ▽ illustrate the thrust fault, which is located off the north coast of Flores Island (118 – 122°E, 8°S).

2. Overall Damage

2.1 Outline

Extensive damage was developed in the Eastern part of Flores Island. Major damage was concentrated in the each area of Sikka and Ende Regency, where the epicenter was so much close to. There were some damages observed in the each area of Ngade and Flores Timur Regency.

Those damage due to the latest earthquake can be roughly divided into four main classes as follows;

Damage due to
1. Earthquake shock
2. tsunami
3. Liquefaction
4. Landslide

However, it is difficult to classify clearly into each type of damage because in practice damage often occurred with complex factors.

Typical damages are as follows:

(1) The damage due to the earthquake shock was developed in so many buildings, including governmental offices, charchs or mosks, school facilities, people's houses and others.
There are over thirty thousands (30,000) buildings damaged by shock. At least the half of those buildings were totally or partially collapsed.
Damage to buildings by the earthquake is mostly on the buildings made of bricks or stone masonry. Furthermore totally or patilly collapsed or heavily damaged buildings can be seen not only in the urban area of Maumere or Ende but also in the wide area of Sikka or Ende Regency.

(2) Extensive coastline on the northern part of Flores Island or on the islands located on Flores Sea was damaged by the tsunami.
Damage by tsunami extends over at least one hundred (100) kilo-meters along the northern coast of Flores Island. Damage in the Wuring area and Babi Island of Maumere Regency and the east area of Flores Timur Regency on the Flores Island are remarkably bigger than others. The death toll by tsunami were figuared up to 87, about 750, about 200, respectively. And totally, there are over thousand persons killed by tsunami, and eventually the number of the death by tsunami came up to almost half of the deaths.

(3) Phenomenon of soil liquefaction occurred extensively along the seashore of the northern part of Sikka or Ende Regency. Soil liquefaction mostly occurred in the place where no one lived. But buildings and others were heavily damaged by soil liquefaction around the coast line on the city area of Maumere. There are many tilting buildings or cracked roads observed near here.

(4) The main road between Maumere and Ende is located in the mountainous area and several parts of that road (about twenty (20) places) were hit by landslides caused by the earthquake. Because of that, the road traffic was torn into pieces here and there, and it cannot be used for going through.
Because of that, the amount of transport to Ende from Maumere is said to be limited.

(5) There is no damage on the runway of Maumere Airport (Waioti Airport, runway length one thousand and four hundreds forty-seven meters [1,470 m]) and Ende Airport (runway length nine hundreds meters [900 m]). Therefore, both airports are available now. However, each control tower was heavily damaged. Both towers have not been available yet.

(6) Maumere port pier can be used as usual, though some part of shore protection work was hit by shock or tsunami and suffered for slight damage.

(7) Damage information by the Army Headquarters in Maumere (Waioti) Airport is as shown in Figure 2.1 and Table 2.1.

(8) The using number in the tables and each paragraph are not authorized. Therefore, there are difference number of the damage in the description.

Table 2.1 Overall Damge

Regency	Population ('85)	Area	Human Damage				Building Damage				
			Dead	Injured		Missing	Office	Church Most	People House	School	Others
				Heavy	Light						
	(Prs)	(km^2)	(Prs)	(Prs)	(Prs)	(Prs)	(house)	(house)	(house)	(house)	(house)
Sikka	236,691	1,731.9	1,457	252	1,256	8	56	47	10,200	324	4
Ende	212,349	2,046.6	229	106	227	–	344	193	13,804	281	154
Ngada	188,353	3,037.9	18	2	4	–	67	45	1,194	100	68
Flores Timur	267,295	3,079.2	376	15	241	61	26	22	2,920	80	50
Total	904,688	9,895.6	2,080	375	1,728	69	493	307	28,118	785	276

Notice 1. Human damage (Dead) in Flores Timur includes about 200 victims by Tsunami.
2. Building damage (Housing) includes figures of houses partially damaged.

Source: Army's Headquarters for Emergency Activities in WAIOTI Airport in Maumere.
(Figures table which was prepared for the review to President in 23 Dec. 1992.)

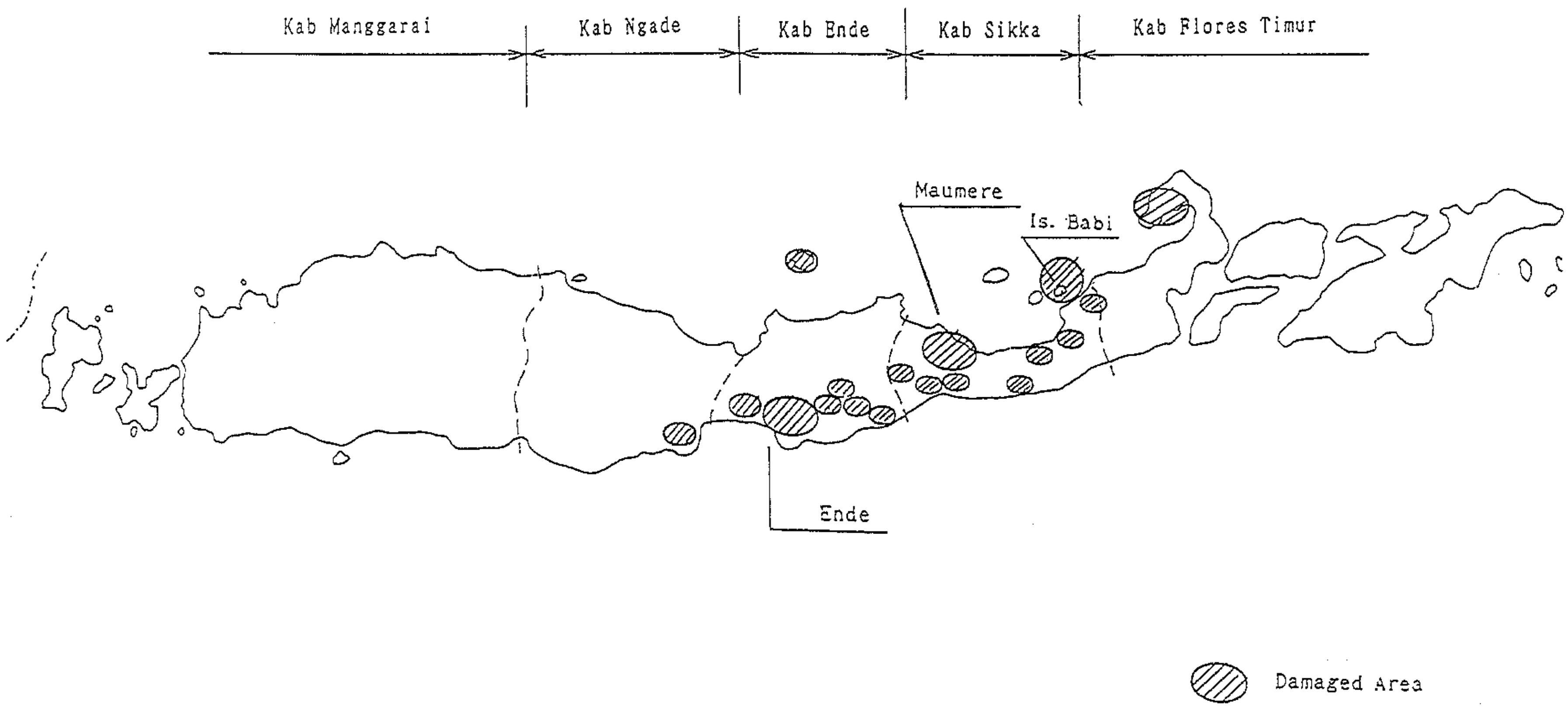


Fig. 2.1 Damaged Area

2.2 Damage in Sikka Regency

(1) Sikka Regency suffered the most serious damage. Damage was developed over almost whole area of this regency. About one thousand and one hundred (1,100) lives were lost and the number of totally collapsed buildings came up to more than about eight thousands (8,000).

(2) Maumere Sub-Regency (including Alok Sub-Regency), which is the main part of Sikka Regency, had suffered serious damage. Nine hundreds and thirty-three (933) lives were lost and the number of totally collapsed buildings reached over four thousands (4,000) and partially damaged buildings came up to three thousands one hundred and ninety-nine (3,199). These were the figures as of 8PM, 23th Dec., 1992.

(3) Remarkable damage in Maumere occurred on the buildings which were built in the main part of the town. The town spreads over the alluvial fun formed by the River Kalimati. Soil liquefaction occurred around these area. Most buildings which collapsed or suffered heavy damage are in the type of masonry structures.

(4) Conspicuous damage due to tsunami occurred in Wuring, located in the western outskirt of Maumere urban area, and also in Babi Island. The figure of the dead came up to eighty-seven (87) in Wuring and about seven hundreds and fifty (750) in Babi Island, respectively. Furthermore, missing on Babi Island was said to be from fifty to one hundred (50–100) persons. There are no persons living on Babi Island now.

(5) The main road connecting with Maumere and Ende is located in the mountainous area and was reported to be hit by many landslides caused from the earthquake. As a result, about Twenty-one (21) places were cut off and the road cannot be used for passing through. Especially, about fourteen kilo-meters (14 km) road section between Muni and Ende have suffered serious damages and eleven (11) places were cut off here and there.

(6) In Maumere, a number of main wells had been destroyed. Because of that, the water supply could not be used for three days after earthquake occurrence. And service reduction of supply is more than half before the earthquake occurrence. These were the figures as of 24th Dec., 1992.

(7) The situation of damage is as shown in Table 2.2.

2.3 Damage in Ende Regency

(1) Damage was developed in the extensive area of Ende regency. Many buildingds collapsed by shock and damages due to landslides also occurred.

(2) The shock was more violent at the northern part of this regency, but the damage was small because population was little. Remarkable damage can be seen in the area of Ende Sub-Regency and its vicinity.

(3) In the urban area of Ende Sub-Regency, the number of the dead came up to fifty-seven (57) and the damage to people's houses reached to three thousands six hundreds and thirty-seven (3,637).

Table 2.2 Overall Damage in Sikka Regency

23 Dec. 1992

Sub-Regency	Human Damage			Building Damage								
	Dead	Injured		Govrnment Office			Civil Office			Church & Mosk		
		Heavy	Light	Totaly Collapsed	Heavy	Light	Totaly Collapsed	Heavy	Light	Totaly Collapsed	Heavy	Light
	(Prs)	(Prs)	(Prs)	(house)	(house)	(house)	(house)	(house)	(house)	(house)	(house)	(house)
Paga	14	7	14	-	71	14	67	45	38	-	3	2
Lekebai	7	9	27	57	4	2	1	2	-	8	2	1
Lela	13	16	64	12	13	9	4	7	12	4	2	1
Nita	16	42	116	15	22	5	36	5	8	3	8	1
Alok	142	205	1,155	10	41	10	67	45	38	2	8	5
Maumere	791	54	73	28	4	4	35	6	3	12	3	5
Palue	8	5	5	-	21	35	-	1	-	-	-	1
Kewapante	9	13	87	11	36	5	5	13	18	-	6	1
Bola	18	12	21	10	31	11	9	17	28	-	3	-
Talibura	82	27	30	25	39	10	-	-	-	14	8	4
Waigete	1	3	4	-	36	21	2	8	10	-	-	2
Sikka Total	1,191	393	1,596	168	318	126	226	149	155	43	43	23

Sub-Regency	Building Damage								
	Dewelling House			School			Toatal		
	Totaly Collapsed (house)	Heavy (house)	Light (house)	Totaly Collapsed (house)	Heavy (house)	Light (house)	Totaly Collapsed (house)	Heavy (house)	Light (house)
Paga	221	38	132	-	6	2	288	163	188
Lekebai	303	231	42	-	-	-	369	239	45
Lela	232	225	336	1	3	3	253	250	361
Nita	2,042	670	140	4	4	2	2,100	709	156
Alok	443	1,035	1,478	11	8	5	533	1,137	1,536
Maumere	3,413	325	174	3	1	1	3,491	339	187
Palue	48	105	89	-	-	-	48	127	125
Kewapante	228	279	255	3	7	1	247	341	280
Bola	117	104	79	-	3	2	136	158	120
Talibura	541	102	109	-	4	-	580	153	123
Waigete	31	401	119	-	4	2	33	449	154
Sikka Total	7,619	3,515	2,953	22	40	18	8,078	4,065	3,275

Source : The office of the Sikka Regency.

(4) The power generators for electric service suffered no damage. But the power line was cut somewhere. Because of that, electricity was not available for two (2) days. Water supply could not be used for a while, but it is available as usual, now.

(5) There lives about one thousand (1,000) persons on the Palu Island in northern Ende Regency. Tsunami attacked also this island from south-east direction. But people live in the opposite side, so that there was no damage due to tsunami. But it is said that some larger landslides killed eight (8) persons.

(6) The situation of damage is as shown in Table 2.3.

Table 2.3 Overall Damage in Ende Regency

22 Dec. 1992

Sub-Regency	Human Damage			Building Damage								Damage to Water Supply	
	Dead	Injured		Office	Church Mosk	People House	School	Student Inn	Shops	Inn	Total	Reservoir	Installation
		Heavy	Light										
	(Prs)	(Prs)	(Prs)	(house)	(house)	(house)	(house)	(house)	(house)	(house	(house)		
Ende	25	16	-	9	9	73	19	-	-	-	110	-	-
Ende Selatan	32	62	200	114	29	3,564	70	12	28	8	3,825	-	-
Ndona	30	32	62	35	23	813	42	1	-	2	916	27	12
Naga Panda	5	5	10	50	48	1,196	39	3	8	1	1,345	11	-
Detusoko	9	27	9	37	17	1,997	28	-	-	-	2,079	-	-
Wolo Waru	35	26	-	-	-	1,272	-	-	-	-	1,272	-	-
Maorole	21	4	50	43	22	2,250	31	2	2	-	2,350	2	-
Kotabaru	17	50	-	15	4	1,153	10	-	11	-	1,193	-	-
Watuneso	3	5	-	3	4	15	3	-	-	-	25	-	-
Wolojita	2	1	-	10	11	314	17	-	-	-	352	-	-
Weauvosa	14	-	-	8	3	540	2	-	-	-	553	-	-
Pukau Ende	-	-	2	9	3	155	5	-	-	-	172	-	-
Ende Total	193	228	333	333	173	13,342	266	18	49	11	14,192	40	12

Source : The office of the Ende Regency.

3. Tsunami Behavior and Damage

3.1 Introduction

Large tsunami was generated by an earthquake of Magnitude 7.5 occurred off the Flores island in Indonesia at 13:29 on December 12 in 1992. Extensive coastline near Maumere on Flores island was damaged by this tsunami. Particularly on Babi island located about 10 km east of Besar island, 750 people were killed out of total population (95) of the village and the village was totally destroyed by this tsunami. This report summarizes the results of the field observation of tsunami inundation height at several locations, tsunami damages in Babi island, Wuring area and Maumere Port, where severe damages were observed. Furthermore, future planning of the countermeasures against tsunami and useful recommendations are given.

3.2 Investigation of Tsunami Inundation Height

Field observation on tsunami inundation height was carried out between Dec. 23 and Dec. 25 along the coastline of Flores island as well as the Babi island. The inundation height was measured by a staff and a handlevel. Since the reference level of the ground was not known, vertical height of the inundation was measured with reference to the sea level at the measuring time. After the field investigation, the inundation height above the mean sea level at Maumere Port was calculated based on the astronomical tide at Maumere Port predicted by JODC of the Maritime Safety Agency, Ministry of Transport in Japan.

The mark of the tsunami inundation was clearly read on the outside wall of houses at many locations in Flores island. On the other hand, on Babi island the inundation height was measured based upon the height where floating debris attached to the trees, since all houses were destroyed by tsunami.

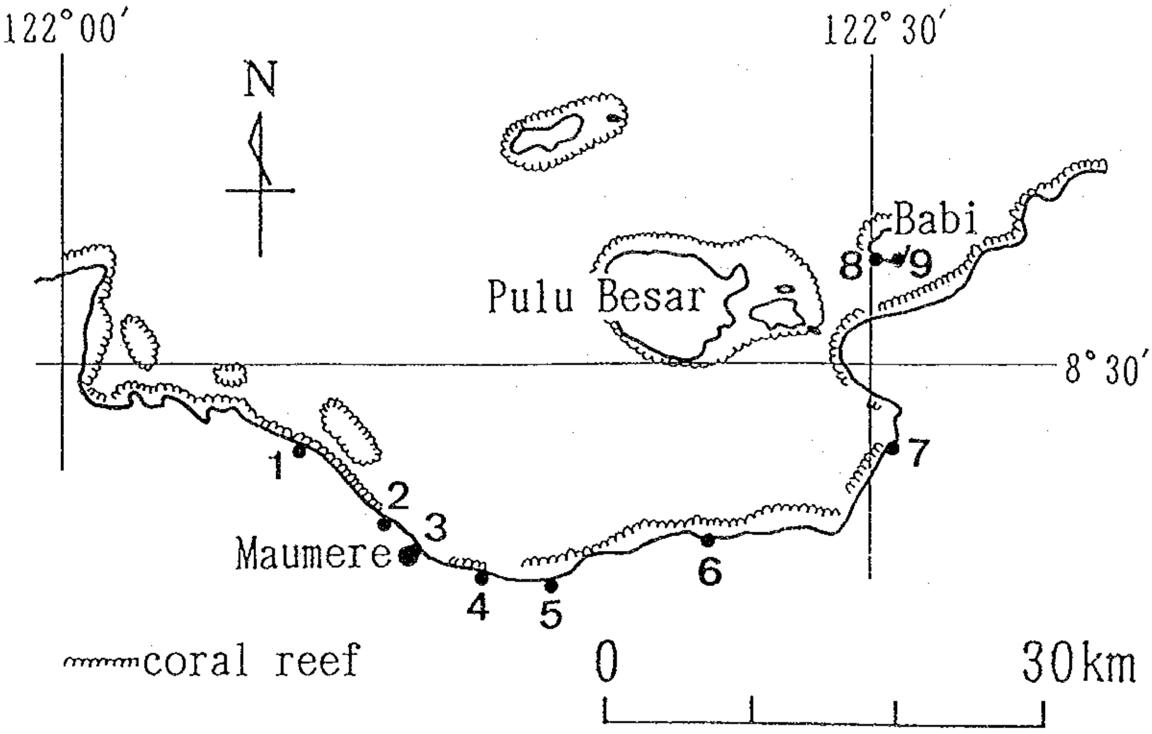
Figure 3.1 shows the location map of the observation sites and the measured inundation height in meter. Maximum inundation height of 2.45 m was measured at Wuring area in Flores island. Tsunami height decreases from this area to east because of the sheltering effect of Besar island, and to west due to the existence of the offshore coral reef as shown in Fig. 3.2. In Babi island maximum inundation height was about 3.7m, and it is about 1.2 m larger than that at Wuring area.

3.3 Tsunami Damages

Although tsunami brought many casualties in widespread area, most characteristic damages due to tsunami can be observed in Babi island and Wuring area. In Babi island 750 people died out of 950 living in this small island and only 200 were able to escape from tsunami. Similarly, death toll of 79 was confirmed at Wuring area. In the following tsunami damage at two locations are discussed as well as the case in Maumere Port.

(1) Maumere Port

Port facilities were severely destroyed not only by tsunami but also the liquefaction damage of the ground associated with the earthquake. Photo 3.1 shows a ship raised over the quay in Maumere Port. The height of the quay wall at this time was about 1.5 m above the sea level. Taking account of the draft of this boat, tsunami wave height at this location is considered to be about 1 m over the present ground level. At a location east of this point, the quay was destroyed by both the earthquake and tsunami as shown in Photo 3.2, and a truck was carried away toward the tip of the pier by the returning current of tsunami. Photo 3.3 shows the inundation height left at the outside wall of the house. The height pointed out by the right hand shows the inundation level and maximum depth at the side wall was about 50 cm.



Location	Inundation height(m)
① Nangahure	2.28
② Wuring	2.45
③ Maumere Port	2.25
④ Waloti	2.29
⑤(east of)Waipare	1.86
⑥ Waigate	2.22
⑦ Nangobrok	1.77
⑧ (west)Babi	3.68, 3.48, 3.28 3.28, 3.28
⑨ (east)Babi	3.67, 3.52, 3.70

Fig. 3.1 Location Map and Tunami Inundation Height

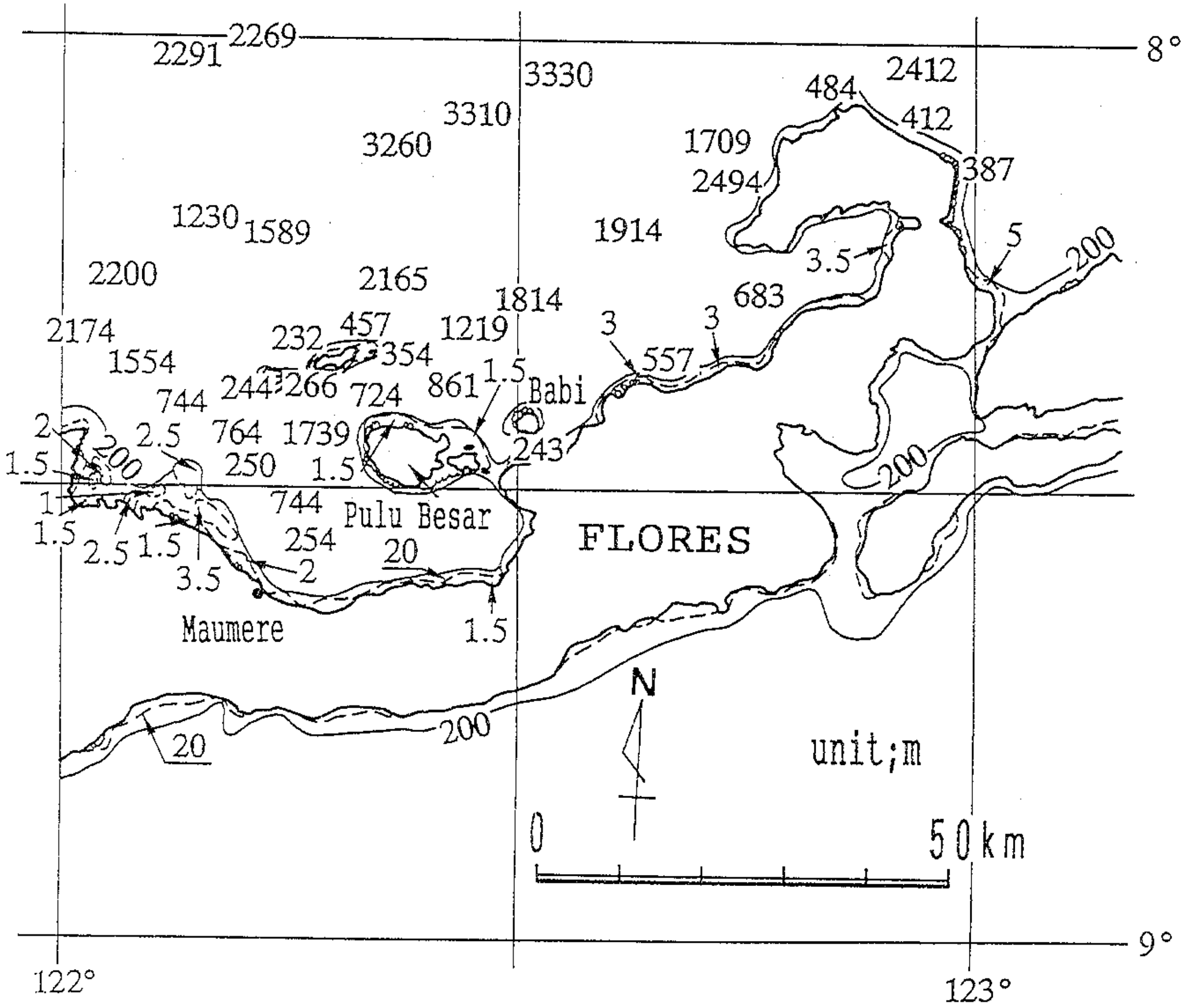


Fig. 3.2 Bottom Contours Around Flores Island

(2) Wuring Area

Wuring is located about 2 km northwest of Maumere Port. Tsunami can be characterized by the phenomena that vast amount of sea water invade land from the shoreline with keeping strong energy compared with the wave overtopping at a rough wave condition. This means that the damaged area due to tsunami is totally different from that by the flooding with gradual increase of water level. Everything including houses is destroyed and carried away in a mess. Furthermore near the fishery port fishing boats floating with tsunami often corride with the houses and thus enlarge the destruction of houses. Photo 3.4 shows the disastrous situation of Wuring area. It is seen from this picture that vast amount of debris were scattered and a fishing boat was also carried. Photo 3.5 shows the situation at a location further seaward from Photo 3.4. Here many houses of raised floor were destroyed and many boats were scattered on land. In Photo 3.4 some buildings were left since the position was located considerably landward from the shoreline, but the location shown in Photo 3.5 was destroyed to the further extent. At Wuring area many houses of raised floor had been built and almost all these houses were destroyed.

In Photo 3.6 the inundation height can be clearly read at the white wall of the building, of which ground level is about 1 m, and it is seen that the height between the mark and the present ground level is 1.6 m. This means that tsunami wave of the height of a man ran up in this area. In this area final death toll was 79. The causes of tsunami disaster at Wuring area can be summarized as follows:

1) This area is located outside of the shelter zone by Besar island.
2) It was not protected by shallow coral reef as the coastline west of this location.
3) This village is located at the western shore of U-shaped bay, where generally tsunami height increases by Green's effect.
4) Many houses of raised floor were built in the low land.

(3) Babi Island

Babi island is located about 38 km northeast of Maumere Port. This island is of circular shape and its diameter is about 2.5 km. Coral reef well develops around this small island as shown in Fig. 3.3. Off the north shore of this island wide reef develops due to the incidence of wind waves, whereas it is narrow off the south shore. In addition, two large cuspate forelands develop on the south side of the island. These geomorphological features imply that the location receiving the most severe action by wind waves are north and northwest shores, and two cuspate forelands were formed by the depositional effect of the coral debris produced near the reef edge by the action of breaking wave and carried by the longshore currents around the island.

Accordingly, the foreshore and backshore height of the sandy beach in two cuspate forelands are of the order (1 – 1.5 m) of the run-up height of diffracted waves in the leeside of the island.

Tsunami front invaded these sandy beaches from south, where water depth is very deep since the coral reef does not exist. The direction of the tsunami movement can be confirmed to be from south to north by the following observations:

1) Debris of the houses were scattered in the palm trees north of the original positions as shown in Fig. 3.3.
2) Palm trees were fallen down by tsunami with their roots heading south.
3) An eyewitness from this disaster pointed out that the tsunami came form south.

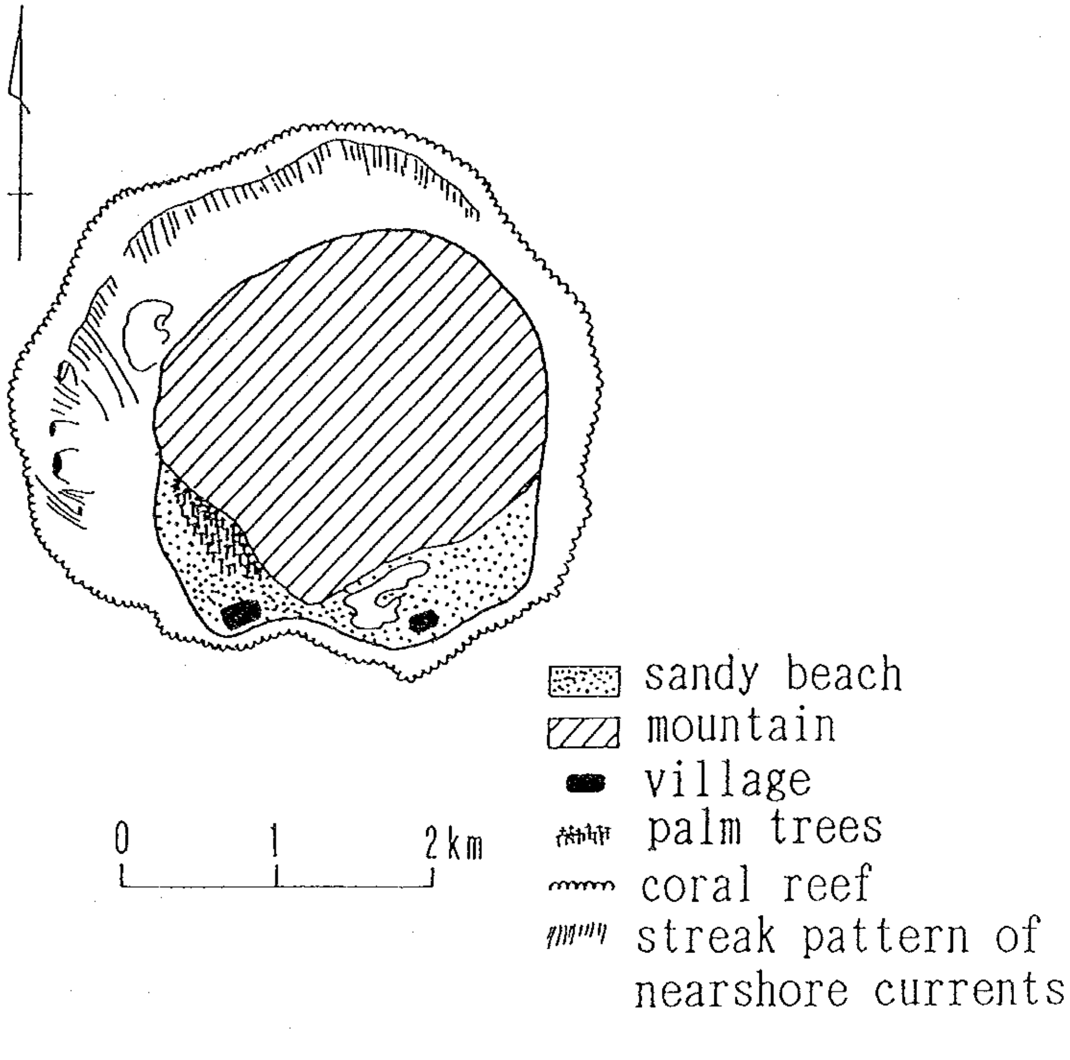


Fig. 3.3 Topographic Map of Bai Island Read from Aerial Photograph

By this tsunami attack all buildings of this village were destroyed. Photo 3.7 shows the oblique picture of the village devastated by the tsunami taken in the southwest direction from the middle of the mountain. Since tsunami attacked the village from south, debris of houses were carried northward and scattered inside the palm trees. For instance, from Photo 3.8 showing the situation inside the palm trees, it is observed that vast amount of debris were scattered. The village located on the sandy beach was totally demolished. Photo 3.9 shows the concrete basement of the destroyed school building.

In the observation of the inundation height of tsunami on Babi island, the height was read from the mark where some debris were attached on the trees (Photo 3.10). It was difficult to read the inundation mark from the side wall of the houses because every house had been totally destroyed. Since the pole is fixed 1 m above the ground level, the upper level of the attached debris becomes about 2.5 m. The ground level of this sandy beach is approximately equal to about 1 m, and this means that the inundation height with reference to the sea level attains to about 3.5 m.

As mentioned above, wide reef develops on the north shore of Babi island with poor development of coral reef on the south shore. In addition to this the bottom slope of the south shore is very steep. Since the cuspate foreland protrudes and wind waves incident from north are well protected by the island itself, the leeside of the island has been used for the anchoring harbor. However, since the wave length of tsunami is much longer than that of wind waves and therefore tsunami energy can reach the lee side of the relatively small scale island, the safety zone against wind waves does not necessarily mean the same zone against tsunami. If shore protection facilities had been built around the vilalge on the sandy shore, it is considered that tsunami disaster did not take place. In fact, the village was totally devastated because of the lack of the shore protection facilities. This is the same condition of the complete destruction of Taro village in Iwate Prefecture in Japan due to the Sanriku Tsunami occurred in 1933.

Above mentioned three examples can be summarized as follows. Generally speaking, tsunami damages are not large in the coastal zone of relatively high ground elevation. In the case of the Babi island, the ground elevation was low as 1 – 1.5 m, originally formed by the depositional effect of wind waves on the foreshore, so that large damages were observed. Similarly, at Wuring many houses were built on the ground elevation lower than 1 m. This again caused severe damages.

3.4 Measures Against Tsunami

In this section countermeasures against tsunami are discussed taking Babi island for an example. After the tsunami all inhabitants in Babi island evacuated to Flores island, and no one lives in this island at present. However the number of the people returning to the island will increase with time, since many people in this island have been living by fishery. And in the long-term a village will be formed again. Thus the generation of tsunami causes the same disaster in this island. In order to solve this problem without the abandonment of this island, it is necessary to build coastal dike along the shoreline. The coastal dike connecting the both ends of the hill side should be built along the shoreline on the sandy beach. Some important points regarding this project are as follows:

1) The front slope, crown and back slope of the coastal dike should be made of concrete. The necessary thickness of the concrete is over 30 cm.
2) The crown height of the coastal dike should be about 3.5 m above the mean sea level, by considering the measured maximum tsunami run-up height (3.7 m). This means that the designed crown height is a little lower than measured tsunami height. Since the construction of the coastal dike of high crown height is expensive, the structure which is not destroyed by tsunami overtopping or overflow is needed for the coastal dike.

3.5 Recommendations

(1) Must evacuate from potentially dangerous area for tsunami as rapidly as possible after the earthquake. It must be strictly prohibited to approach to the shoreline to see the tsunami or the movement of boats.

(2) The village in Babi island was protected against the wind waves because of its location in the sheltered area of the island itself. However, it does not necessarily mean for the safety against tsunami. In Indonesia there are many islands having the same natural conditions as Babi island. It is advisable to check the safety of these islands against tsunami.

(3) The forests formed by palm trees or other trees must be protected because they are useful for reducing tsunami energy.

(4) In the locations where high tsunami run-up was observed such as in Maumere Port, some signs showing the inundation height (usually recorded on the outside wall of the houses) should be noticed to open public in order to inform people of the danger of the tsunami and not to forget the tsunami disaster.

(5) When people must live in the potentially dangerous area for tsunami as in the case of Babi island, it is recommended to build shore protection facilities such as the coastal dike along the shoreline.

3.6 Concluding Remarks

Since the duration of the field observation was limited to be only three days in this urgent investigation of tsunami disaster, the measurement of tsunami height at sufficiently many points was impossible, and therefore, tsunami inundation height in rather narrow coastal zone was reported in this paper. Fortunately a study team of Ministry of Education in Japan further investigated tsunami inundation height in the other regions, and thus detailed information can be obtained by the report to be published later.

We would like to thank JODC of the Maritime Safety Agency, Ministry of Transport in Japan for the permission of utilizing the predicted tide level in Maumere Port.

In addition, we would like to thank Associate Prof. Yoshinobu Tsuji of Earthquake Res. Inst. of Univ. of Tokyo for many discussions on the prediction of tide level and the cause of the tsunami.

Study Schedule:

Dec. 22 Arrived Maumere Airport from Jakarta by C-130. Visited Babi Island by helicopter for the initial inspection on tsunami disaster.

Dec. 23 Investigated tsunami disaster and measured tsunami inundation height along the coastline between Wuring and Nebe (East coast).

Dec. 24 Visited Babi Island again by boat. It took 2.5 hours to reach the island. Measured inundation height at 8 locations on the island.

Dec. 25 Investigated the tsunami disaster between Maumere and Nangahure (West coast).

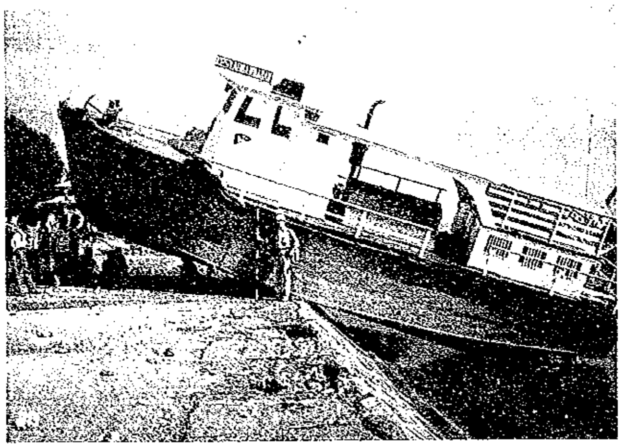


Photo 3.1 A Ship Raised Over the Quay in Maumere Port

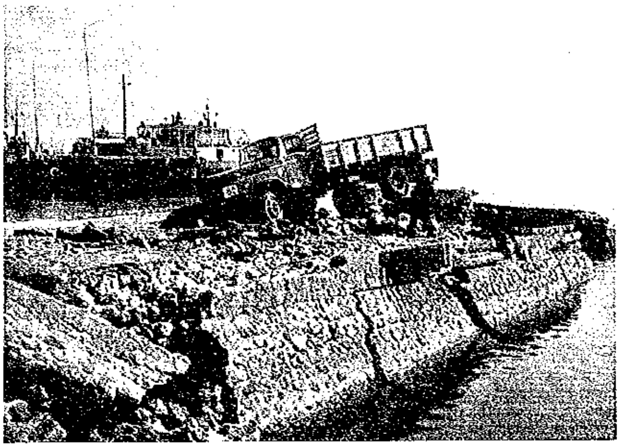


Photo 3.2 Damaged Pier of Maumere Port and a Truck Carried by Tsunami

Photo 3.3 Inundation Height in Maumere Port

Photo 3.4 Tsunami Disaster at Wuring Area (Landward side from the center of the village)

Photo 3.5 Tsunami Disaster at Wuring Area (Center of the village)

Photo 3.6 Inundation Height at Wuring Area

Photo 3.7 Ruin of the Village on South Cuspate Foreland of Babi Island

Photo 3.8 Debris Inside Palm Tree Forest in Babi Island

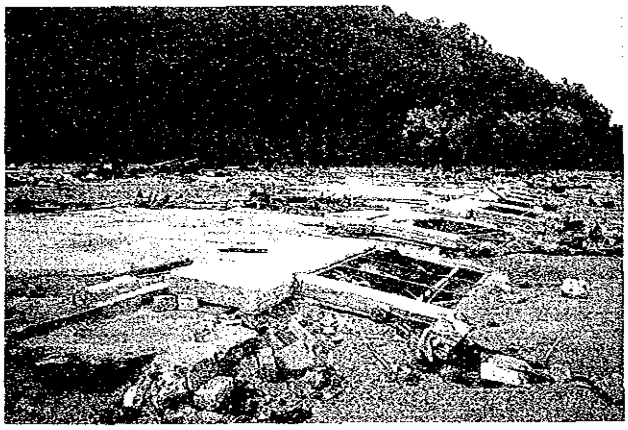


Photo 3.9 Damaged School Buildings

Photo 3.10 Inundation Height on Foreshore of Babi Island

4. Damage to Buildings

4.1 Damage in Ende City

Ende city locates in the central area of Flores Island and face to Savu Sea. Its population is about seventy thousand. Building team surveyed forty-four buildings in this city area for two hours guided by the staff of Ende prefecture office. Fig. 4.1 shows the outline of Ende city map. The numerals in this figure are the buildings which we reconnaisanced. Later part of this section, photographs of such buildings are shown.

Among forty-four buildings, twenty-five buildings were collapsed. It was very difficult to find out non-damaged buildings. Many of buildings are first storied brick masonry structures. Such structures have double stack of masonry brick as popular as in the world.

According to the interview of the engineer in Sikka prefecture, weight mixing ratio of portland cement, sand and lime is respectively 1.0:3.0:10.0 used in the mortal of masonry structure. Buildings of concrete block masonry were also observed, and many of them were severely damaged. Newly constructed buildings were used reinforced concrete frame. However their sizes of sections of columns and beams were much smaller than those as usual in Japan. Reinforced concrete columns are about 15 cm × 15 cm in sections and used longitudinal reinforcement was 13 millimeter diameter plain bars. Little of deformed bars were utilized in the reinforced concrete structures.

4.2 Damage in Maumere City

Maumere city's population is around fifty thousand, and it faces to Flores Sea. This city is beautiful city covered with green coloured trees. This city area is about three kilometer width in east and west direction and around two kilometers length in north-south direction. This city was also severely damaged. Figure 4.2 shows the sketch of this city. It's east part was not so severely damaged. However, first story reinforced concrete buildings of the airport facilities and army forces base camps were severely damaged. Almost of all buildings were brick masonry and first storied. Their roofing is timber structure covered with clay tiles or tin and so roofing is not heavy. Many of masonry building were much damaged in the central area. In this city around three hundred people were dead due to the collapse of such buildings by earthquakes.

As shown in Fig. 4.2, central area of this city was much damaged. Buildings along the coast area were tilted and settled due to liquefaction of foundation soil. In the central area, reinforced concrete water tank structure was found to be almost non-damaged. It's height is around fifteen meters. The section size of its four columns were 30 cm by 30 cm. Considering that this type of reinforced concrete water tank tower was not damaged so severely, input earthquake was estimated not to be so large; 0.1 g – 0.2 g. Typical masonry structural walls which are often observed in this city, were estimated the lateral load carring capacity of more than 0.2 g base shear coefficient from very lough assumptions and calculation. However, the lateral load carring capacity of masonry wall system in out-of-plane direction was much smaller than that of in-plane shear capacity of masonry wall as mentioned above.

Especially along the Radjacentis Street which is commercial main area in this city, more detailed damage survey was conducted. Such results are shown in Fig. 4.3. The classification of damage grade was defined by the outside observation of buildings.

Among thirty two brick masonry buildings (M), fifteen buildings were collapsed (47%). Two reinforced concrete framed masonry wall buildings (RC + M) were collapsed among twenty-two same types buildings (9%). Sixteen (RC + M) buildings were severely damaged (73%). Twenty-seven M structures were also severely damaged (84%).

Many of photographs as shown in later part, showed such traces of "out-of-plane" collapse of masonry buildings.

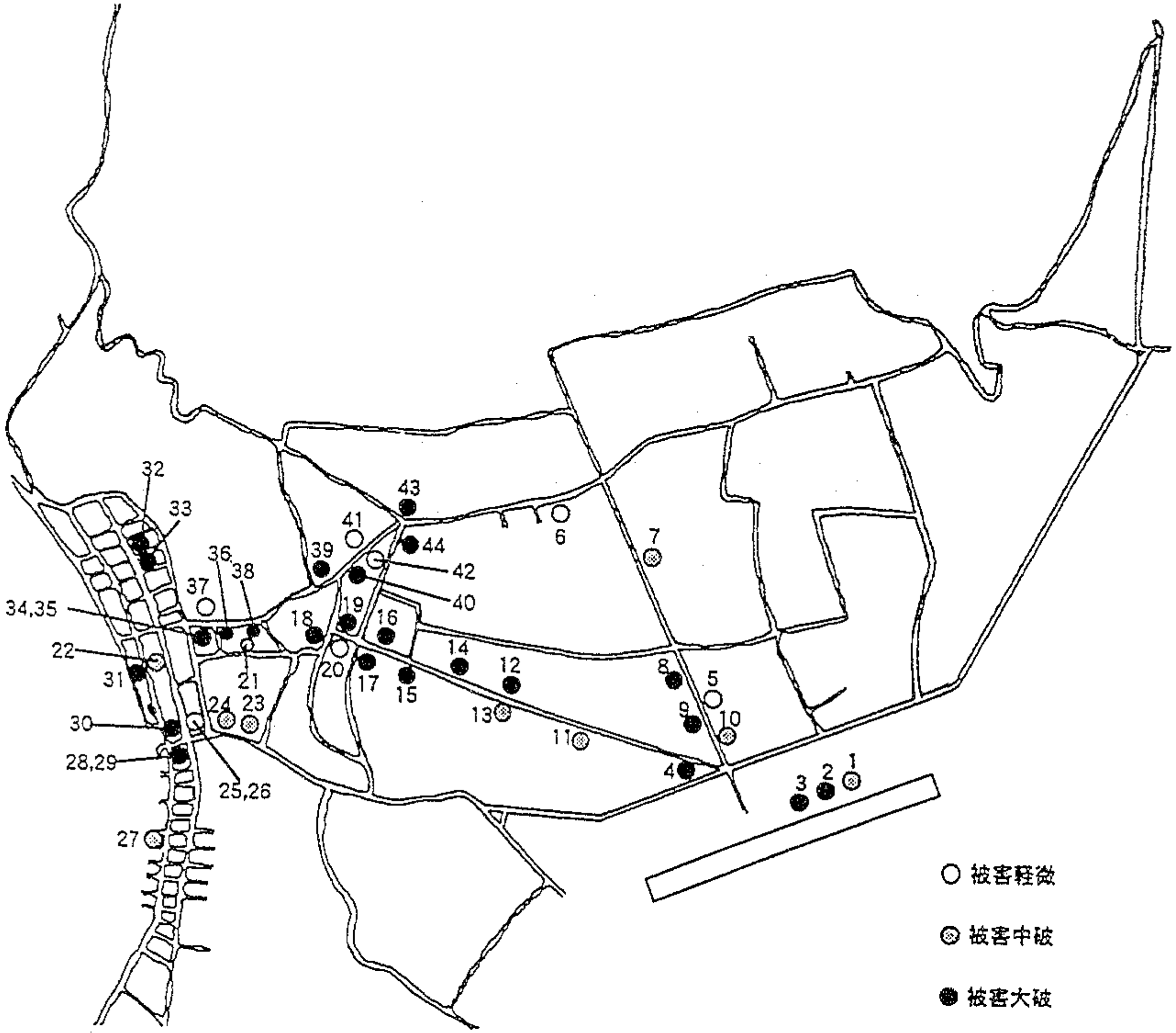


Fig. 4.1 Ende City Map

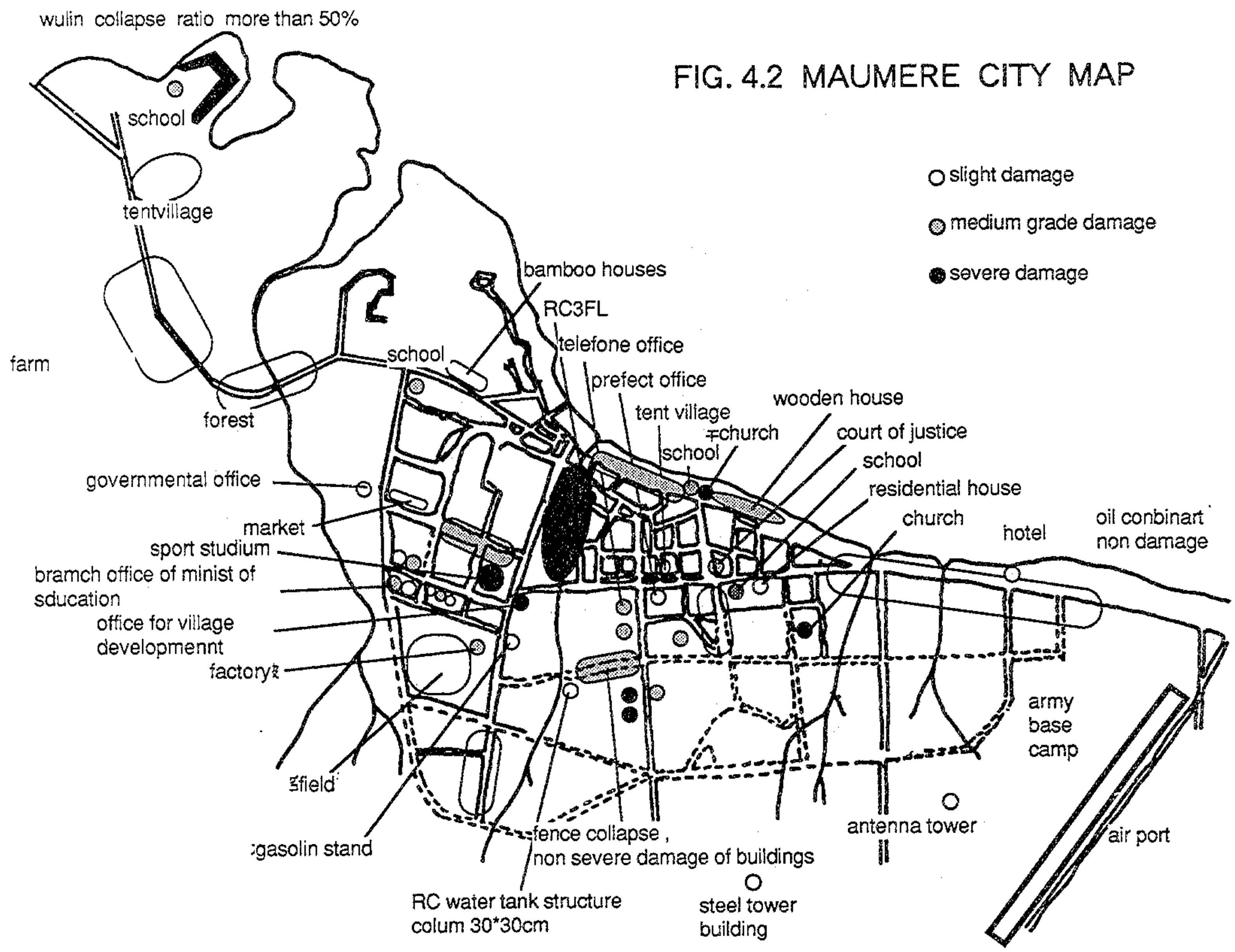


Fig. 4.2 Maumere City Map

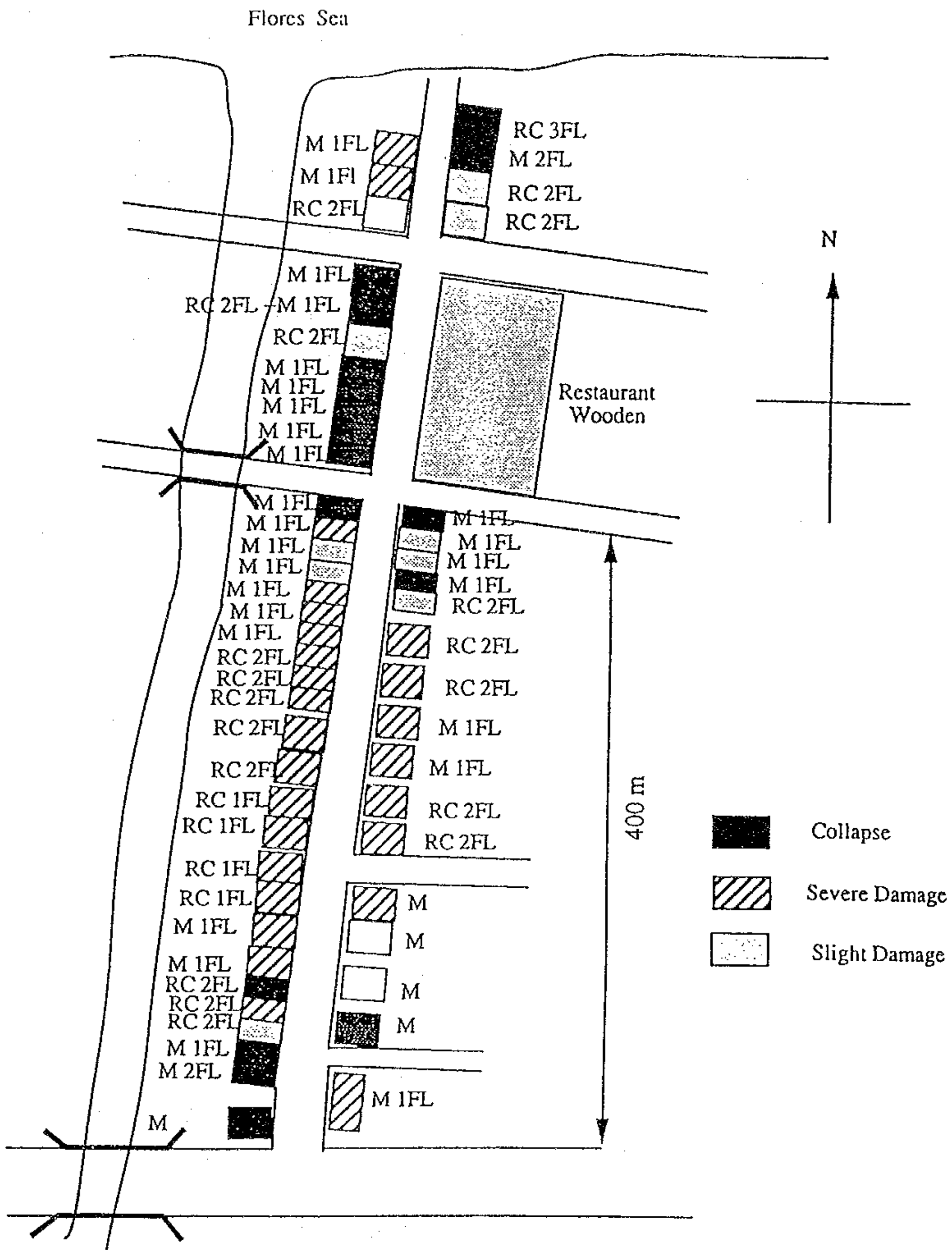


Fig. 4.3 Maumere City Commercial Area

4.3 Analysis of Damage

From only two days reconnaissance of damaged building, the followings are the summarized features of buildings damage which perhaps contain some inaccurate parts.

1) Many brick masonry buildings with wooden roofings were collapsed, which have non-seismic reinforcements. It was considered that the cause of such damage shall be based on the out-of-plane collapse of masonry wall segment.
2) In the down town area, some of buildings were more than two storeyed reinforced concrete frame structure with brick masonry walls. Their collapse ratio to total numbers of reinforced concrete buildings was smaller than that of masonry structures, and many of them remained in medium damage grade.
3) Damage of reinforced concrete buildings which were considered to be recently constructed was quite slight. The section sizes of their columns and beams were much smaller than those used in Japan.
4) Construction method of foundations and footings seemed to be poor for the out-of-plane resistance of masonry wall to earthquake force.

4.4 Seismic Regulations

According to the Indonesian Seismic Code by Ministry of Public Works, design seismic coefficient; Cd is defined as equation (4.1).

$$Cd = C.I.K \quad (4.1)$$

where C; base design shear coefficient, six categories are defined in all of Indonesia Republics. In each zone, two values are defined by the soil condition Flores Island is classified in Zone 2, as shown in Fig. 4.4.

I ; important factor
general building : 1.0
important facility : 1.5
important and dangerous facility: 2.0

K ; structural coefficient
reinforced concrete : 1.0
prestressed concrete : 1.4
steel : 1.0

According to this code, Fig. 4.4 becomes design base shear coefficient assuming I=1.0 and K=1.0. Cd's values are 0.09 in hard soil and 0.07 in soft soil in zone 2 for the short natural period of structures.

Calculated ultimate shear capacity coefficient of in-plane masonry wall system is larger than this design coefficient. However its out-of-plane capacity was evaluated as about 0.1 g. It is easily realized that the responsed earthquake force to the structure exceeds 0.1 g, then many masonry structure collapsed in out-of-plane. Considering these earthquake damage, design base shear coefficient Cd should be discussed again.

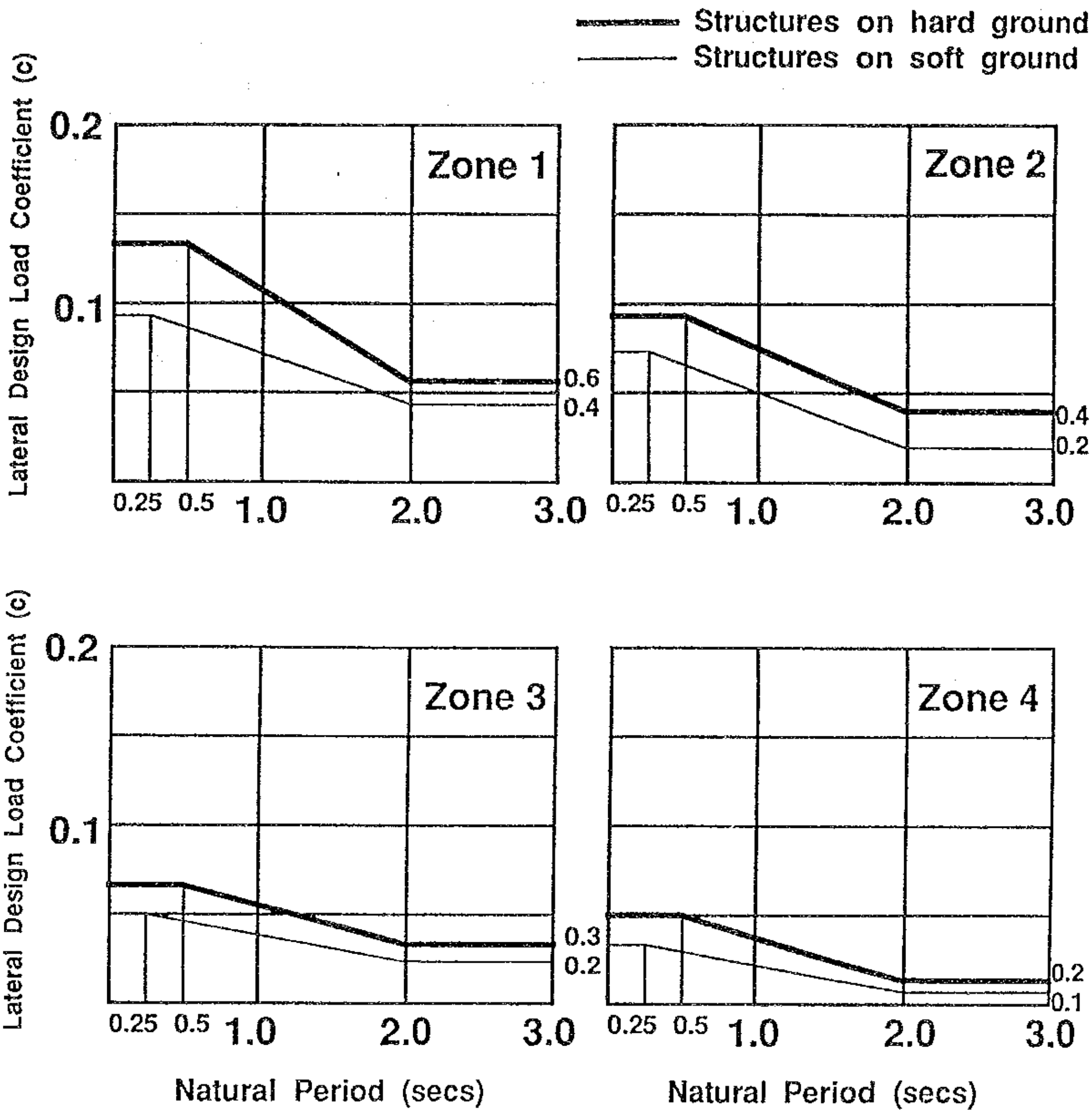


Fig. 4.4 Unmodified C Values