EARTHQUAKE DATABASE AND SEISMIC ZONING OF BANGLADESH

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ABSTRACT

Geographical location of Bangladesh makes it ideally suited to natural disasters. Bangladesh is one of the largest deltas of the world situated at the confluence with the Bay of Bengal of the Padma-Meghna-Jamuna river system. As a result occurrence of floods, cyclones and tornadoes are yearly phenomenon and considerable loss of lives and properties take place every year due to these disasters. From mid sixties to early nineties, the loss of lives amounted to millions and damage to properties amounted to billions of 2/3 of the land areas of the country and caused billions of dollars worth of property damage with some loss of lives.

Tectonic frame work of Bangladesh and adjoining areas indicate that Bangladesh is suited adjacent to the plate margins of India and Eurasia where devastating earthquakes have occurred in the past. Non-availability of earthquake, geological and tectonic data posed great problem in earthquake hazard mapping of Bangladesh in the past. The first Seismic zoning map of Bangladesh which was prepared in 1979 was developed considering only the epicentral location of past earthquakes and isoseismal map of very few of them. During preparation Natural Building Code of Bangladesh in 1994, substantial effort was given in revising the existing seismic zoning map using Geophysical and tectonic data, earthquake data, ground motion attenuation data and strong motion data available from within as well as outside of the country. Geophysical and tectonic data were available from Geological Survey of Bangladesh. Earthquake data were collected from NOAA data files of U.S. Coast and Geodetic Survey, U.S. dept. of Commerce.

It has been felt that the seismic zoning map prepared for Bangladesh National Building code is only the first step towards preparation of more refined and up-to-date zoning map in the near future. Much information on geophysical, geological, earthquake and strong motion data are needed for preparation of such a map. Earthquake occurrence data and ground motion data from instruments installed within the country is urgently needed for development of zoning map on a probabilistic basis. Co-operation of International Agencies, research institution etc. engaged in active research, is urgently needed to attain the goal of total earthquake hazard mitigation.

1. INTRODUCTION

Historical seismic catalogues (ISET, 1993) reveal that Bangladesh has been affected by earthquake disasters since ancient times. Earthquakes occurring in 1664, 1828, 1852 and 1885 are shown to have Dhaka as epicentral area. Similarly cities like Rangpur, Sylhet, Mymensingh, Chittagong, Saidpur, Sirajgonj, Pabna etc. have been shown to be epicentral area of some of the major earthquakes in the past. Although the ancient records do not specify the earthquake epicenter by giving coordinates in terns of latitudes and longitude, it is difficult to figure out whether these cities were directly hit by earthquakes. However occurrence of earthquakes both inside and outside of the country and around major cities indicate that earthquake hazard exists for the country in general and the cities in particular. Consideration of earthquake forces in structural design, city planning and infrastructure development is therefore a prerequisite for future disaster mitigation.

Unlike most natural disasters, earthquake affects millions of square kilometers in a very short time, which in most cases, is less than a minute. As it catches everybody in an unprepared state, earthquake tops the list of all natural disasters in producing damages and death. The 12th June 1897, Great Indian earthquake of magnitude 8.5 affected whole of Bangladesh and produced severe damage in northern, central and eastern parts of Bangladesh. The 15th January, 1934 Bihar Nepal earthquake affected only northern parts of Bangladesh where intensity of ground shaking was only VII on the MMI scale.

The historical seismicity data of Bangladesh and adjoining areas indicate that Bangladesh is vulnerable to earthquake hazards. As Bangladesh is the worlds most densely populated area, any future earthquake shall affect more people per unit area than any other seismically active regions of the world. Both of the above factors call for evaluation of seismic hazard of Bangladesh so that proper hazard mitigation measures may be undertaken before it is too late.

2. TECTONICS AND GEOLOGY

Tectonics and geology of Bangladesh and adjoining areas have been discussed in details by Guha, 1978; Matin et al., 1983; Sesoren, 1984; Bolt, 1985, 1987; and Khan, 1991; It is revealed in the above literatures that stratigraphy, structure and surface geology of Bangladesh are related to its tectonic evolution which started during late Cretaceous period when the northward moving Indian plate collided with the Eurasian plate. The collision caused the northern extremity of Bay of Bengal to separate into gulfs of Assam and Burma. During second collision at the end of Eocene time, the gulfs were shallowed. The third collision, which occurred in Middle Miocene, was intense due to which folding occurred in the sediments of Chittagong, Sylhet and Assam. The fourth and fifth collisions caused mainly vertical movements. The Shillong Plateau and Mikir Hills formed a horst and Dinajpur shield a graben during the fourth collision. The fifth collision uplifted the red clay tablelands.

Geologically, most of West Bengal of India and whole of Bangladesh are occupied by the Bengal Basin, where the Precambrian basement lies more than 3 km below mean sea level. The basin is bordered on the western side by the peninsula shield of India, and on the eastern side by the Shillong Massif.

The Precambrian rocks form the basement of all geological formations of Bengla Basin and shield areas. The surface geology of Bangladesh is essentially the geology of the sediments of only the Cenzoic Era. The geological succession of Bangladesh shows that the sub-surface stratigraphy includes, in addition to the continuation of the surface geological formations, the Precambrian, the Permain Gondwana sediments, the upper Jurassic Volcanic rocks, and a thin mantle of Cretaceous sedimentary rocks originating mainly from the deposition of the denuded volcanics. It also indicates that the Cenozoic sedimentary sequence is noncalcareous with sandstone, siltstone, sandy shale, shale and lignite comprising most of the depositis.

3. STRUCTURE AND SEISMICITY

Geological framework of Bangladesh and adjoining areas is shown in Figure 1 which shows that it is surrounded by a number of tectonics blocks which have produced damaging earthquakes in recent times. To the east, the Tripura-Naga Orogenic belt is a zone of highly faulted tertiary deposits. In it and along the borders of the Shilong massif occurs a number of faults of which the Sylhet fault, the Kopili fault, and the Dauki fault are worth mentioning. The 180km long Sylhet lineanent passing in a NE-SW direction across the Sylhet district forms the surface expression of a deep-seated, high angle reverse fault called the Sylhet fault. The fault has a dip of 70° towards South – East and is active seismically at present. The July 8, 1918 Srimangal earthquake located near the Sylhe fault originated due to subsidence along the southern side of a normal fault trending WNW – ESE through Balisera valley in Sylhet. The depth of hypocentre estimated for this earthquake was 15 km.

To the northwest part of Bangladesh a northeast –southwest tending fault called Bogra fault has recently been discovered. This fault is located to the west of the Jamuna river and south of Bogra town and is assumed to originate in the nasement complex and extend into the Pleistocene layers upto depths of almost 300m. The Bogra fault system may be associated with flezure of the basin along its north western margin.

Running in N–S direction through Longitude 90°E the Jamuna lineament cuts through all eastern Himalayan structures. It is the surface expression of a deep-seated subvertical fault called Jamuna fault. This fault might have played active role towards the evolution of the Meghalaya plateau during recent times (Gupta and Nandy, 1982).

To the north east of the country the Shilong plateau is separated from the Sylhet plain by E-W trending Dauki fault. Although a number of epicenters occur in the plateau proper, only a few epicenters appear on or close to he Dauki fault, including thereby that this fault is relatively inactive during the recent times. Maximum depth of hypocentre of earthquakes in the plateau is only 60 km. These earthquakes are caused by upward material transport from greater depth, which produces tensional stress in the crustal rocks.

Considering geology and tectonics of Bangladesh and neighborhood five tectonic blocks can be identified which have been active in producing damaging earthquakes. These are

(i) Bogra fault zone
(ii) Tripura fault zone
(iii) Sub-Dauki fault zone
(iv) Shillong plateau and
(v) Assam fault zone

The epicenters of earthquakes of NE Indian region bounded by Latitudes 20°N-28°and longitudes 87°E-94°E are presented in Figures 2 to 6 (ISET, 191993; NOAA, 1992). Considering fault length, fault characteristics, earthquake records etc., the maximum magnitude of earthquakes that can be produced in different tectonic blocks are given in Table 1 (Bolt, 1987).

TABLE. 1 MAXIMUM EARTHQUAKE MAGNITUDE IN DIFFERENT TECTONIC BLOCKS

SI. NO.	Tectonic block	Maximum Magnitude of Earthquake
1	Borga fault zone	7.0
2	Tripura fault zone	7.0
3	Sub Dauki fault zone	7.3
4	Shillong Plateau	7.0
5	Assam fault zone	8.5

4. MAJOR EARTHQUAKES AFFECTING BANGLADESH

During the last 150 years, seven major earthquakes (with M $\geq$7) have affected Bangladesh. Table 2 shows the date, magnitude for each earthquake. Out of the seven earthquakes, only two (viz. 1885 and 1918) had their epicenters within Bangladesh.

TABLE. 2 MAJOR EARTHQUAKES IN BANGLADESH DURING THE LAST 150 YEARS

Date	Name of Earthquake	Magnitude (Richter)
10 January, 1869	Cachar Earthquake	7.5
14 July, 1885	Bengal Earthquake	7.0
12 June, 1897	Great Indian Earthquake	8.7
8 July, 1918	Srimongal Earthquake	7.3
2 July, 1930	Dhubri Earthquake	7.1
15 January, 1934	Bihar-Nepal Earthquake	7.0
15 August, 1950	Assam Earthquake	8.5

5. VULNERABILITY OF CITIES

By close examination of the seismicity maps presented in Figures 2 to 6, it can be seen that. northeastern cities of Bangladesh are more vulnerable to earthquake hazards than the central, eastern, southern, south western and western cities. The most vulnerable cities in the northeast are Mymensingh, Kishorognj and Sylhet. The north western, central and southeastern cities which include Dinajpur, Rangpur Dhaka, Comilla, Chittagong and Cox's

Bazar are comparatively less vulnerable than the afore mentioned cities. The southwestern and western cities are the least vulnerable and include cities like Rajshahi, Faridpur, Khulna and Barishal etc.

6. SEISMIC ZONING AND ZONE COEFFICIENTS

The seismic zones and the zone coefficients may be determined from the earthquake magnitude for carious return periods and the acceleration attention relationship. It is required that for design or ordinary structures, seismic ground motion having 10% probability of being exceeded in design life of a structure (50 years) is considered critical. An earthquake having 200 year return period originating in Sub-Dauki zone have epicentral acceleration of more than 1.0g but at 50 kilometer the acceleration shall be reduced to as low as 0.3g.

In the Boar fault system, earthquakes having 200 year return period have a value of only 7.3 and at 50kilometer distance, the acceleration shall be reduced to a value of less than 0.1g.

The pattern of the ground surface acceleration contours having 200 year return period presented in Figure 7 (Hattori, 1979) forms the basis of seismic zoning of Bangladesh. IN the light of the outcome of the recent studies, Bangladesh may still be divided into three seismic zones, namely zone 3, zone 2 and zone 1 with zone 3 and zone 1 being the most and least severe respectively. For the present zoning north, northeastern part of greater Rangpur district has been included in zone 3 as this area is close to the Jamuna fault where the Dhubri earthquake of 1930 occurred causing great damage. Zone 2 and zone 1 boundary has been taken as the 1.0g contour with some modification of its location. In Tripura fault zone, magnitude (mb) 8.0 earthquake is possible in 200 year return period. Earthquake of such magnitude shall affect Chittagong and adjoining areas producing ground acceleration of 0.1g or more. Therefore 0 1g contour has been extended to include Chittagong and adjoining areas in southeast part of Bangladesh. In the northwest this contour has been extended to include parts of Rangpur and Bogra district not included in zone 3. The proposed zoning map is shown in Figure 8.

For determining zone coefficients, comparison of acceleration contour maps with earthquake risk maps of the USA indicate that Bangladesh is comparatively less seismic than California. This indicates that lower values of zone coefficients are appropriate in Bangladesh. The above comparison and also consideration of 1979 code, issoseismal maps of past earthquakes indicates that zone coefficient values of 0.25, 0.15 and 0.075 for zone 3, zone 2 and zone 1 respectively would be appropriate.

7. CONCLUDING REMARKS

In the light of the able discussions, following recommendation are made:

From the previous discussions it can be concluded that considerable seismic hazard exists for major parts of the country. Above 20 million people, representing one sixth of the current total population live in Zone 3, i.e. areas which may be classified as "liable to severe damage" and another 60 million (i.e. 50% of the population) live in Zone 2, i.e. areas "liable to moderate damage". Some of the major cities (including the capital Dhaka, with a population likely to reach 10 million by the end of the century, and the major port Chittagong) are in Zone 2. Measures for overall disaster mitigation must, therefore, include recognition of earthquakes as a major natural hazard.

8. RECOMMENDATIONS

The present study reveals that much information in the fields of tectonics, earthquake occurrence, ground motion attenuation etc are to be added continuously to the existing database for updating the seismic zoning map in the future. It is therefore recommended that:

- A more refined assessment of the seismic risk in various parts of the country should be undertaken. This should include, *inter alia*:

  (a) Review of the historical earthquake records and determine their source and mechanisms.

  (b) Future refinement of magnitude-frequency relationship and development of appropriate attenuation laws.

  (c) Microzonation in large urban centers in Zones 2 and 3 (starting with Dhaka, Chittagong, Sylhet, Mymensingh and Rangpur)

- Programs for educating engineers specialized in earthquakes; seismologists and geophysicists should be taken.

- Computer hardware and software should be acquired for carrying out the analytical modeling and simulation studies for various types of structures subjected to earthquake excitation.

REFERENCES

Bolt, B.A. (1985): "*Seismicity and Seismic Intensity for the Region North of the confluence of the Jamuna and Ganges Rivers*", Submitted to Jamuna Multipurpose Bridge Authority, Govt. of the people's Republic of Bangladesh, pp. 1-17.

Bolt, B. A. (1987): "*Site Specific Study of Seismic Intensity and Ground Motion Parameters for Proposed Jamuna River Bridge, Bangladesh,*" Jamuna Multipurpose Bridge Authority Govt. of the People's Republic of Bangladesh, pp. 1-36.

Guha, D.K. (1978): "*Tectonic Framework and Oil and Gas Prospect of Bangladesh,*" Proc. 4th Annual Conference of Bangladesh Geological Society, November, pp. 65-75.

Gupta, S. D. and D. R. Nandy (1982): "*Seismic and Tectonics of Meghalaya Plateau, Northeastern India*" VII Symposium on Earthquake Engineering, University of Roorkee, pp. 19-24.

Hattori, S. (1979): Bulletin of the International Institute of Seismology and Earthquake engineering, Building Research Institute, Ministry of Construction, Tokyo, Japan.

Indian Society of Earthquake Technology (ISET) (1993): "*Catalogue of Earthquakes in India and Neighborhood*", Roorkee, India.

Khan, F. H. (1991): "*Geology of Bangladesh*" University Press Limited, pp 1-207.

Matin, M. A., M. Khan, M. B. Fariduddin, M. A. Hossain, M. .M. Taslad and A. I. Kononov (1983): "*The Tectonic Map of Bangladesh –Past Present*", Vol.- 2, pp. 29-36.

National Oceanographic and Atmospheric Administration (NOAA) (1992): "*Earthquake Data Files*", Boulder, Colorado, U.S.A.

Sesoren, A. (1984): "*Geological Interpretation of Landsat Imagery of the Bangladesh Ganges Delta*", ITC Journal, pp. 229-232.

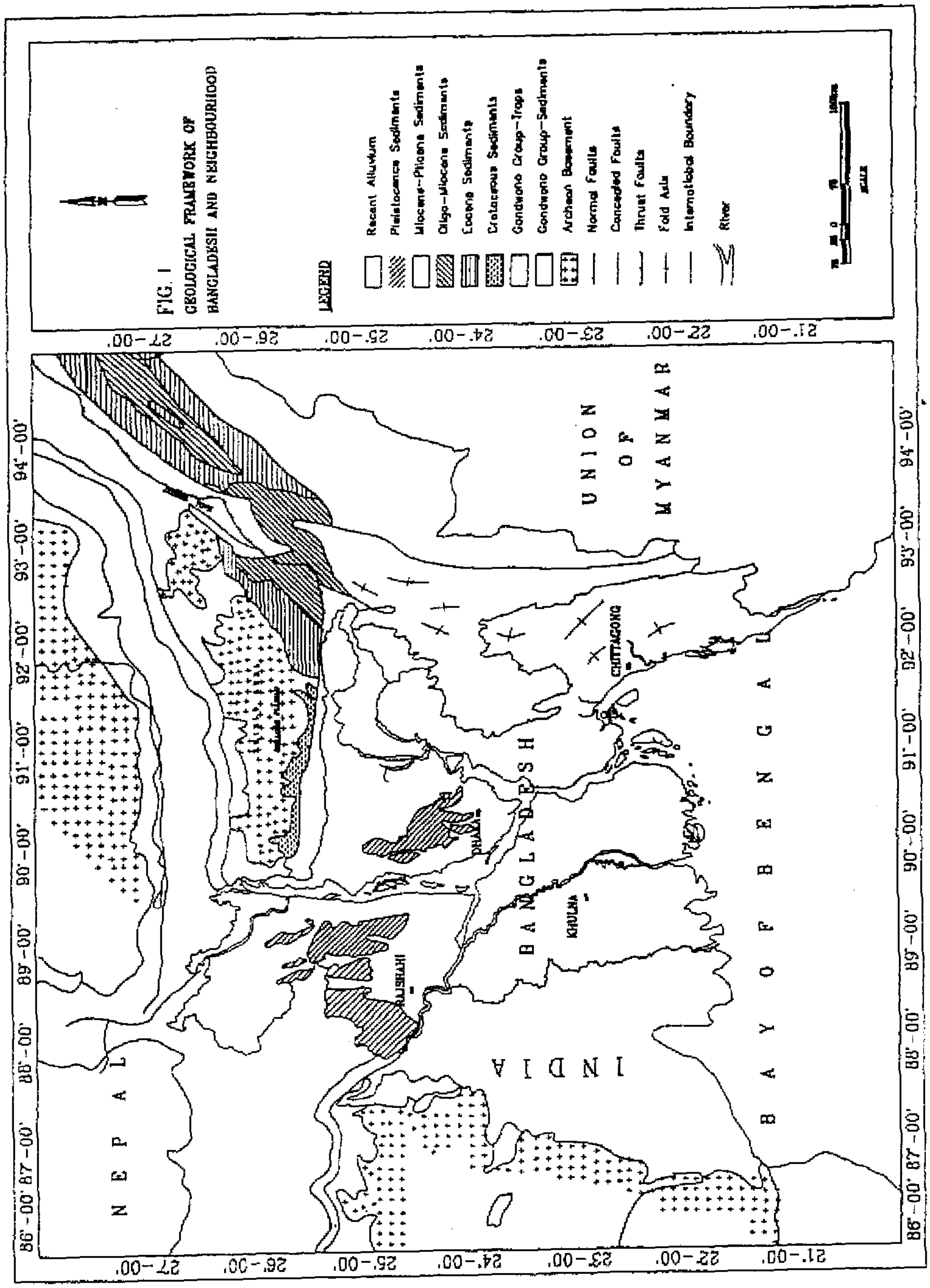


FIG. 1
GEOLOGICAL FRAMEWORK OF BANGLADESH AND NEIGHBOURHOOD
LEGEND
Recent Alluvium
Pleistocene Sediments
Miocene-Pliocene Sediments
Oligo-Miocene Sediments
Eocene Sediments
Cretaceous Sediments
Gondwana Group-Traps
Gondwana Group-Sediments
Archean Basement
Normal Faults
Concealed Faults
Thrust Faults
Fold Axis
International Boundary
River
SCALE
NEPAL
INDIA
BANGLADESH
UNION OF MYANMAR
BAY OF BENGAL
DHAKA
KHULNA
RAJSHAHI
CHITTAGONG
86'-00'
87'-00'
88'-00'
89'-00'
90'-00'
91'-00'
92'-00'
93'-00'
94'-00'
21'-00'
22'-00'
23'-00'
24'-00'
25'-00'
26'-00'
27'-00'

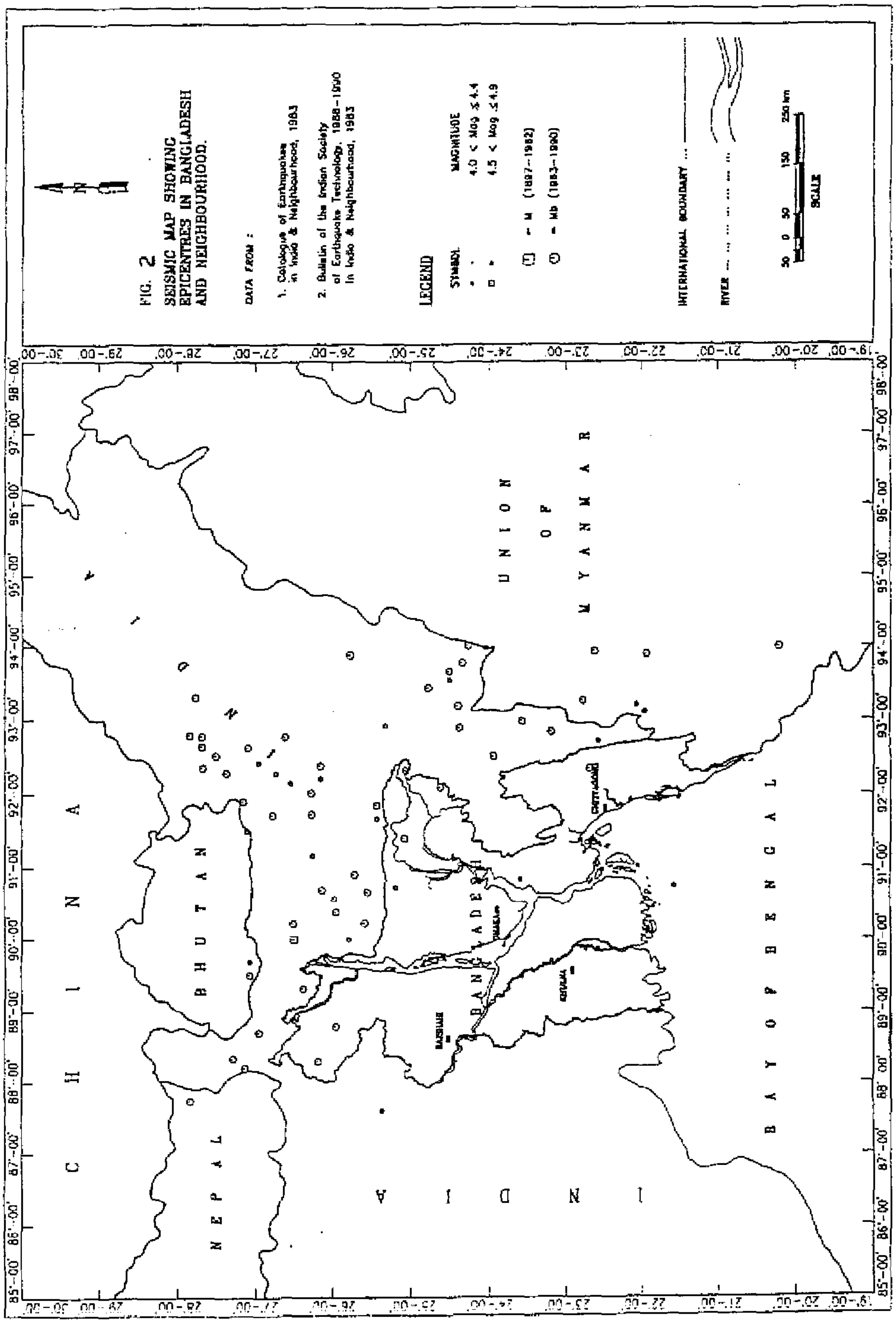


FIG. 2
SEISMIC MAP SHOWING
EPICENTRES IN BANGLADESH
AND NEIGHBOURHOOD.
DATA FROM :
LEGEND
SYMBOL
MAGNITUDE
INTERNATIONAL BOUNDARY
RIVER
SCALE
CHINA
BHUTAN
NEPAL
INDIA
UNION OF MYANMAR
BAY OF BENGAL
BANGLADESH

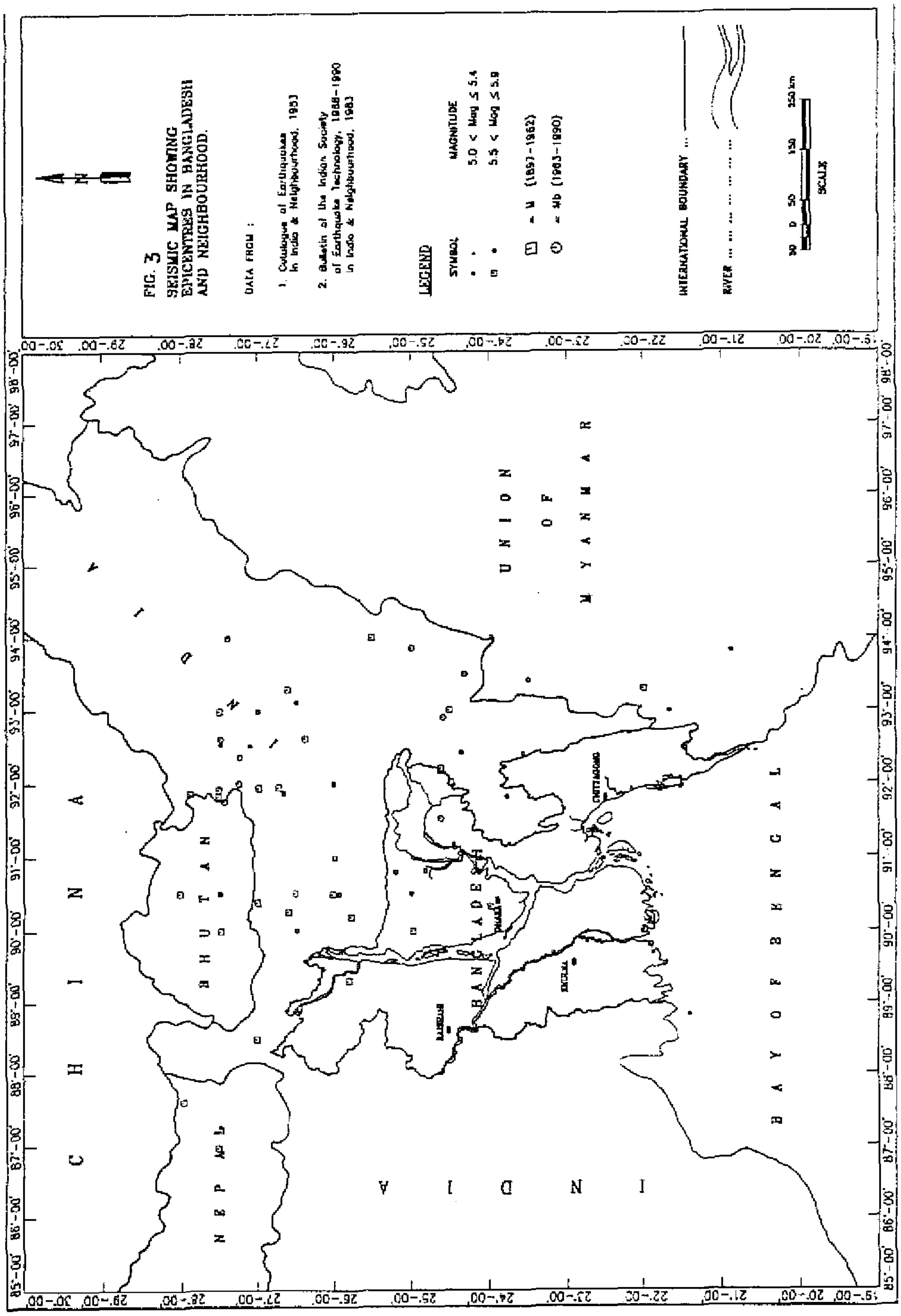


FIG. 3
SEISMIC MAP SHOWING EPICENTRES IN BANGLADESH AND NEIGHBOURHOOD.

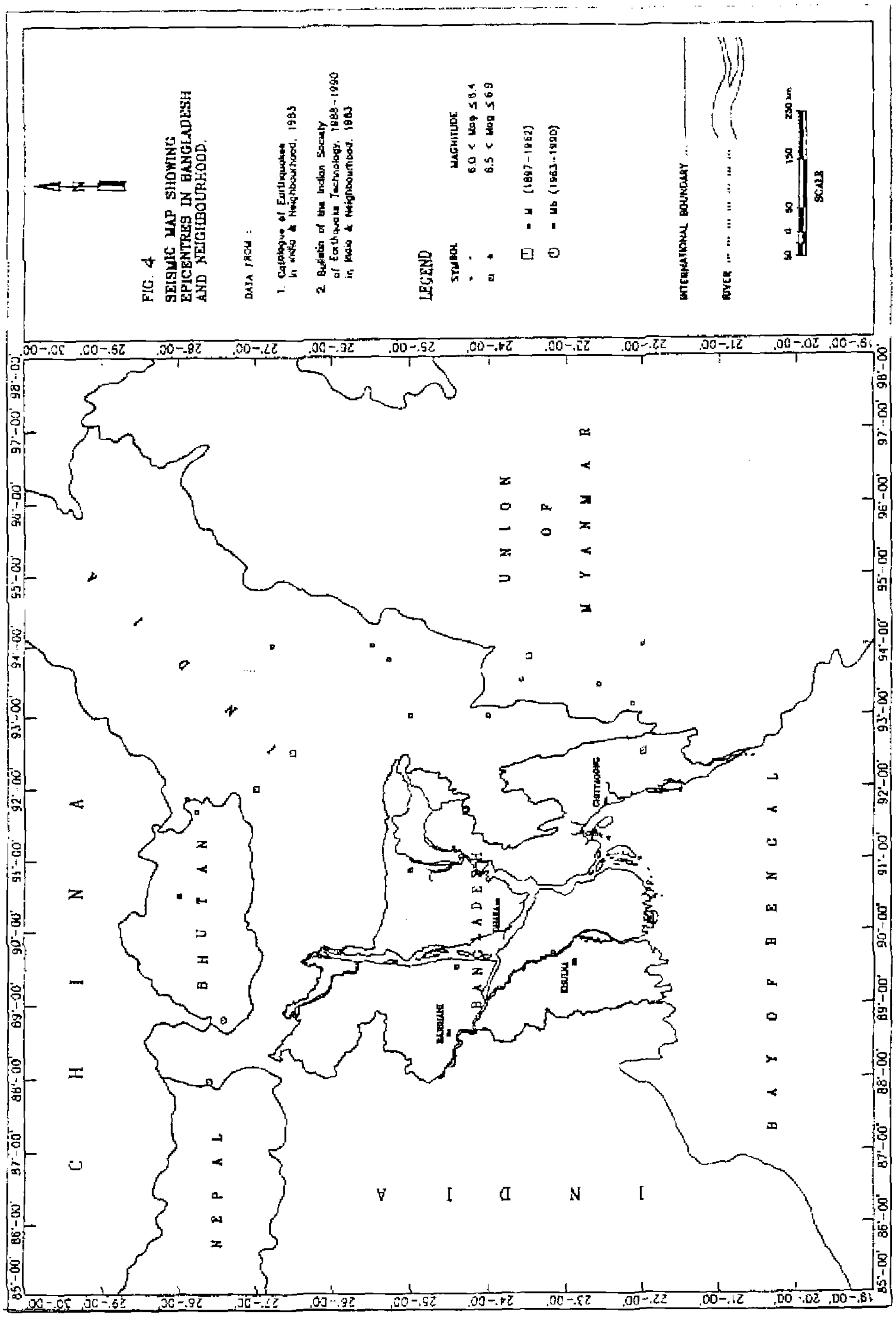


FIG. 4
SEISMIC MAP SHOWING EPICENTRES IN BANGLADESH AND NEIGHBOURHOOD.
DATA FROM :
LEGEND
CHINA
NEPAL
BHUTAN
INDIA
BANGLADESH
UNION OF MYANMAR
BAY OF BENGAL

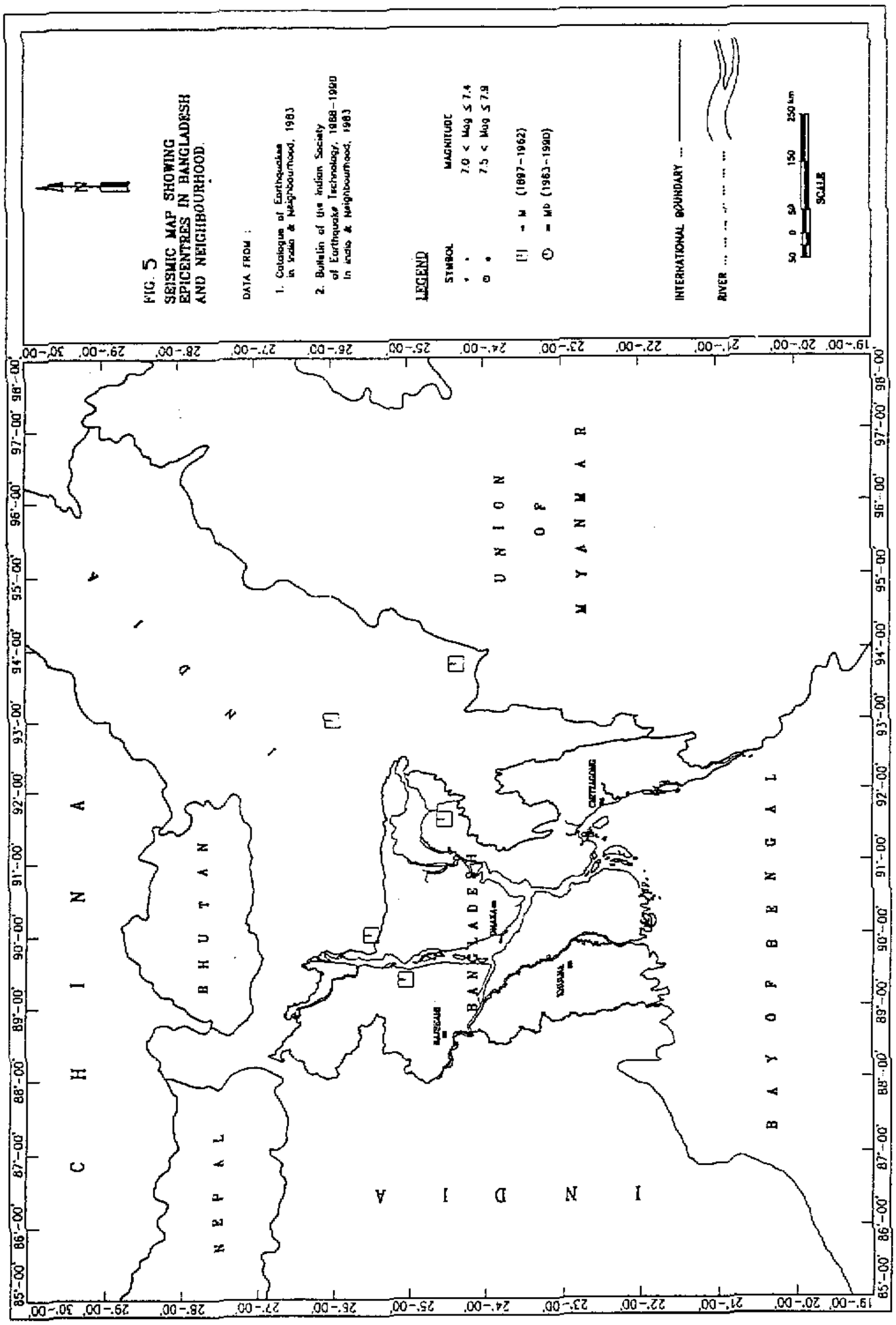


FIG. 5 SEISMIC MAP SHOWING EPICENTRES IN BANGLADESH AND NEIGHBOURHOOD.

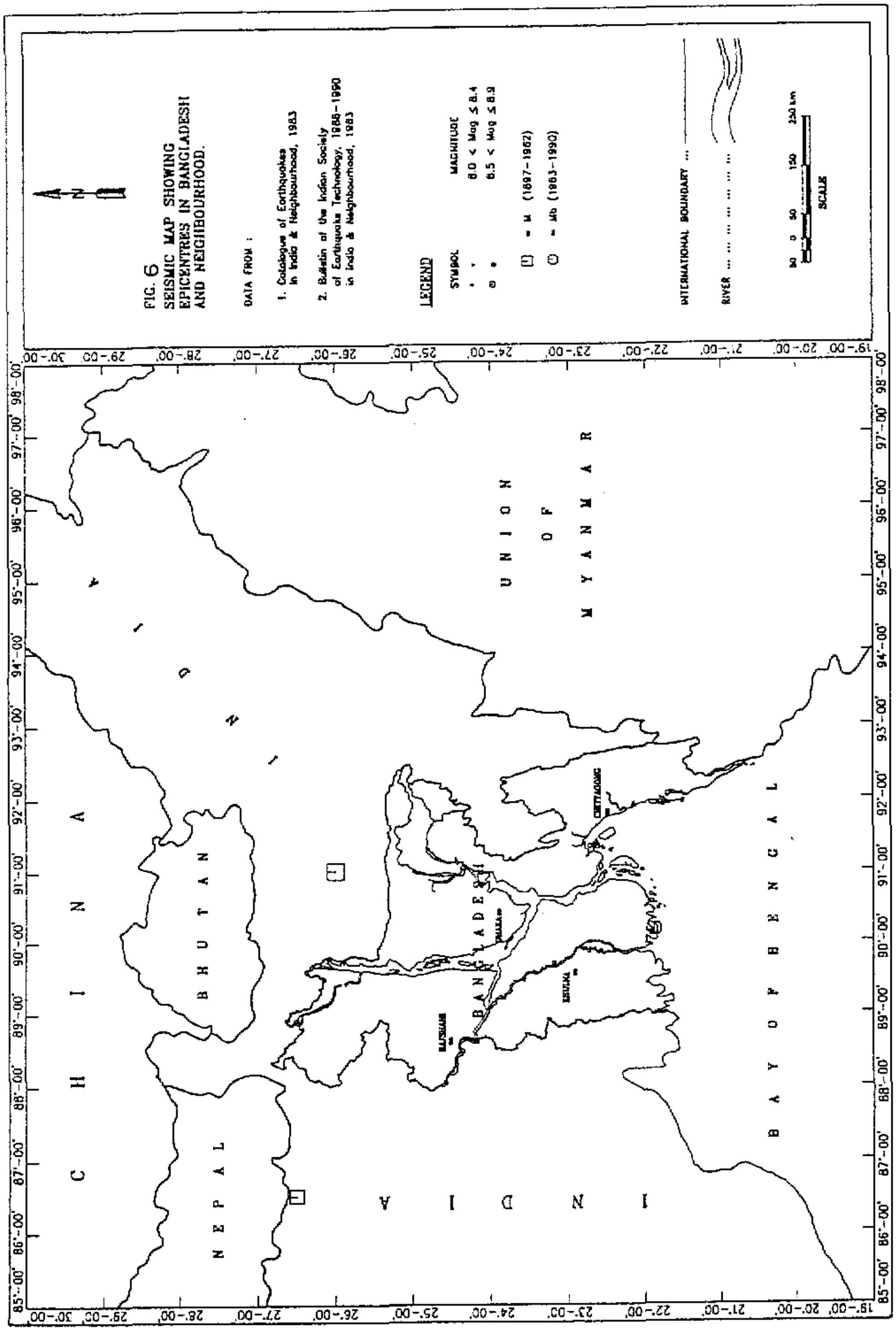


FIG. 6
SEISMIC MAP SHOWING
EPICENTRES IN BANGLADESH
AND NEIGHBOURHOOD.
DATA FROM :
1. Catalogue of Earthquakes in India & Neighbourhood, 1983
2. Bulletin of the Indian Society of Earthquake Technology, 1986-1990 in India & Neighbourhood, 1983
LEGEND
SYMBOL
MAGNITUDE
6.0 < Mag ≤ 8.4
6.5 < Mag ≤ 8.9
= M (1897-1962)
= Mb (1963-1990)
INTERNATIONAL BOUNDARY
RIVER
SCALE
C H I N A
B H U T A N
N E P A L
I N D I A
U N I O N O F M Y A N M A R
B A Y O F B E N G A L
B A N G L A D E S H
CHITTAGONG
DHAKA
KHULNA
RAJSHAHI

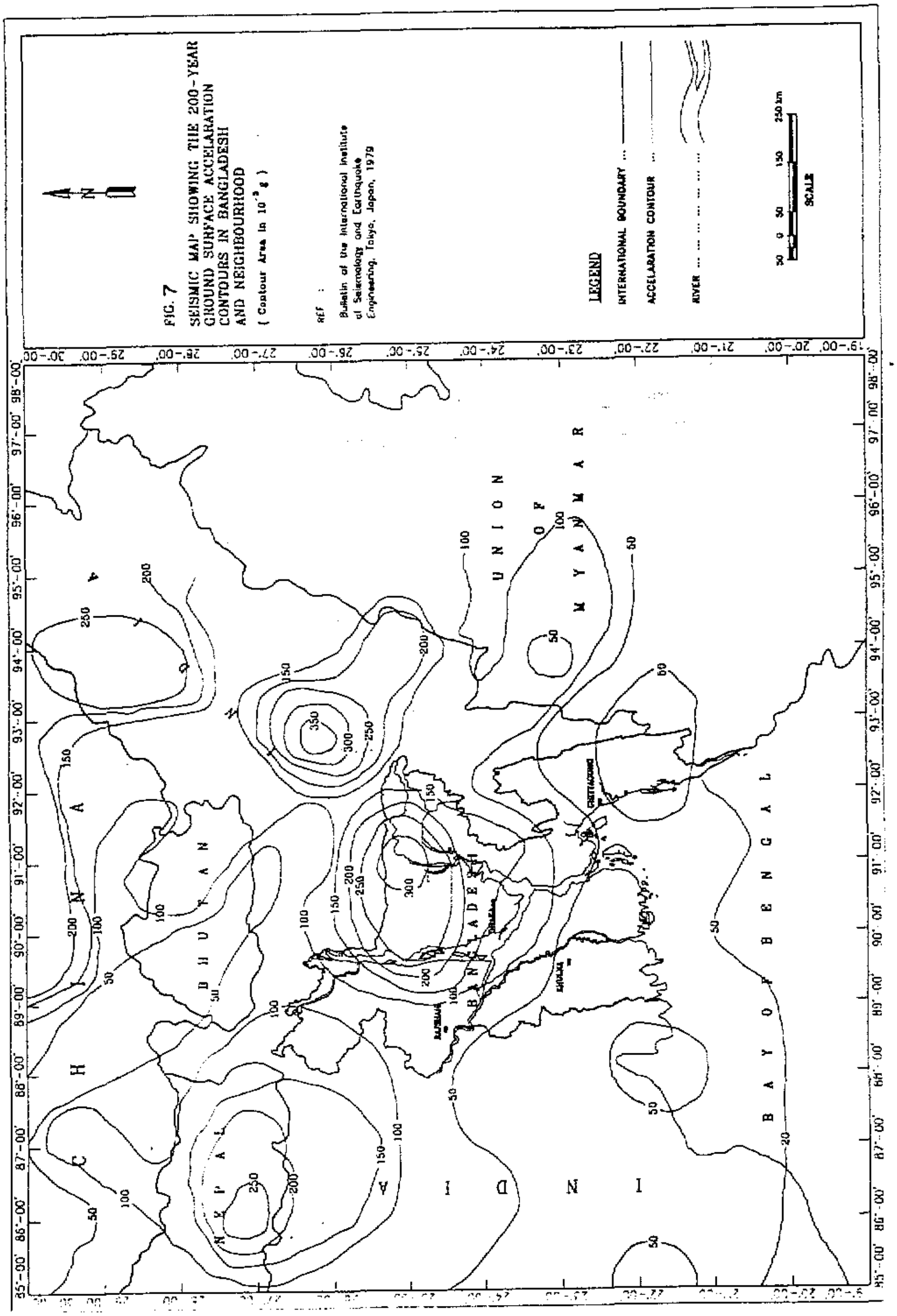
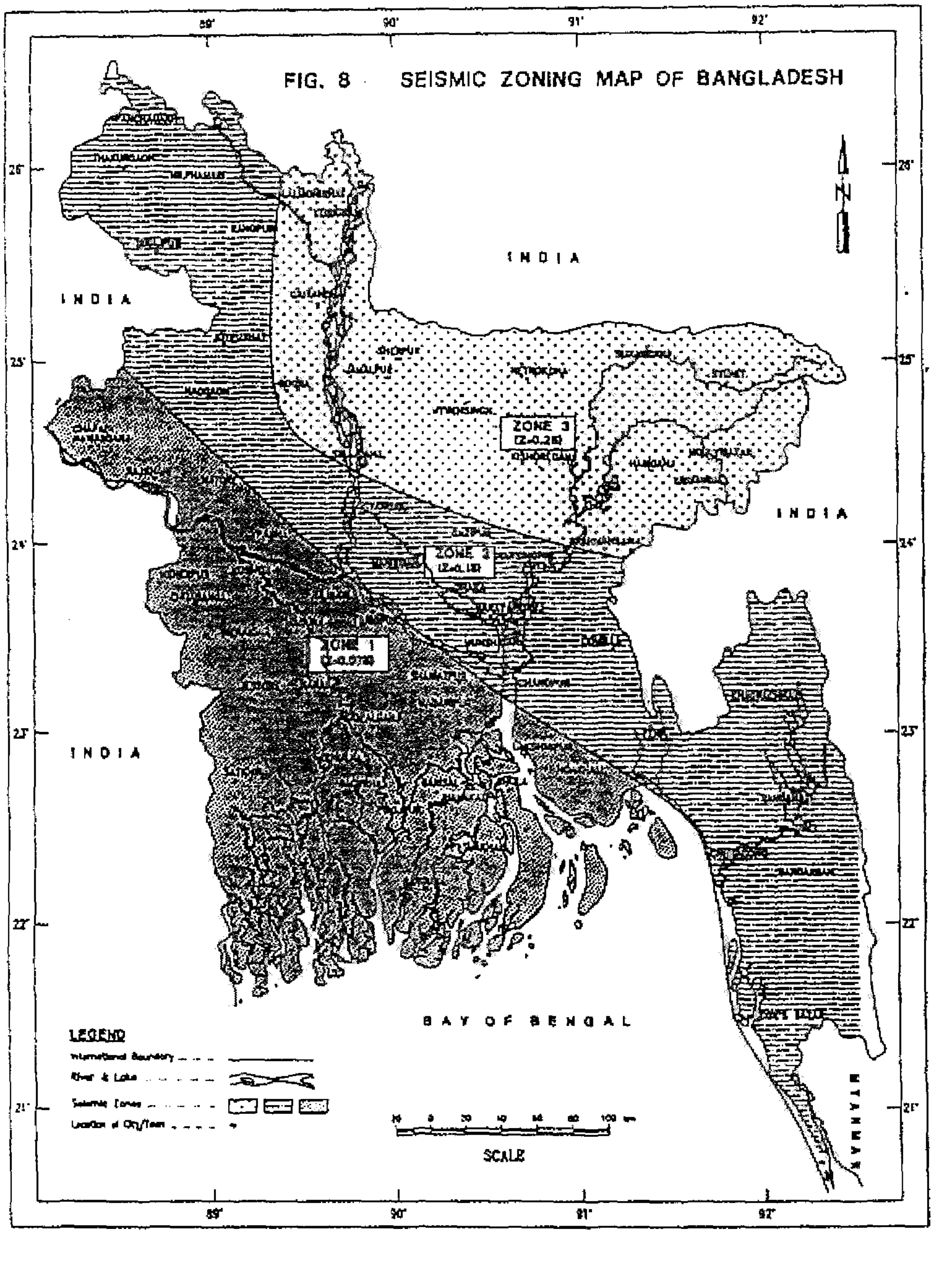
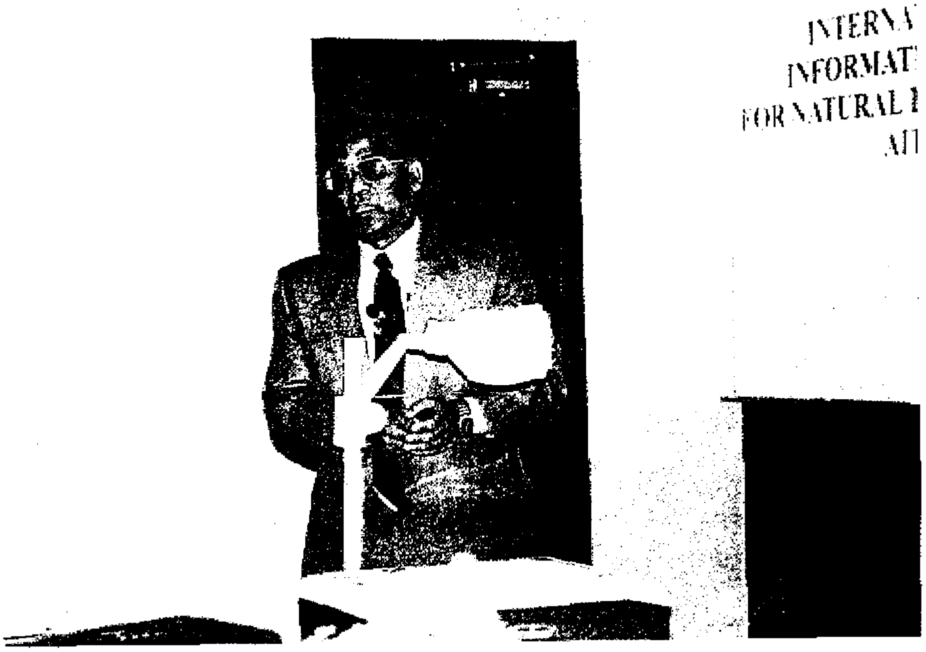


FIG. 7
SEISMIC MAP SHOWING THE 200-YEAR GROUND SURFACE ACCELARATION CONTOURS IN BANGLADESH AND NEIGHBOURHOOD
(Contour Area in 10^{-2} g)
REF :
Bulletin of the International Institute of Seismology and Earthquake Engineering, Tokyo, Japan, 1979
LEGEND
INTERNATIONAL BOUNDARY
ACCELARATION CONTOUR
RIVER
SCALE
N
CHINA
BHUTAN
NEPAL
INDIA
BANGLADESH
UNION OF MYANMAR
BAY OF BENGAL
CHITTAGONG

FIG. 8 SEISMIC ZONING MAP OF BANGLADESH





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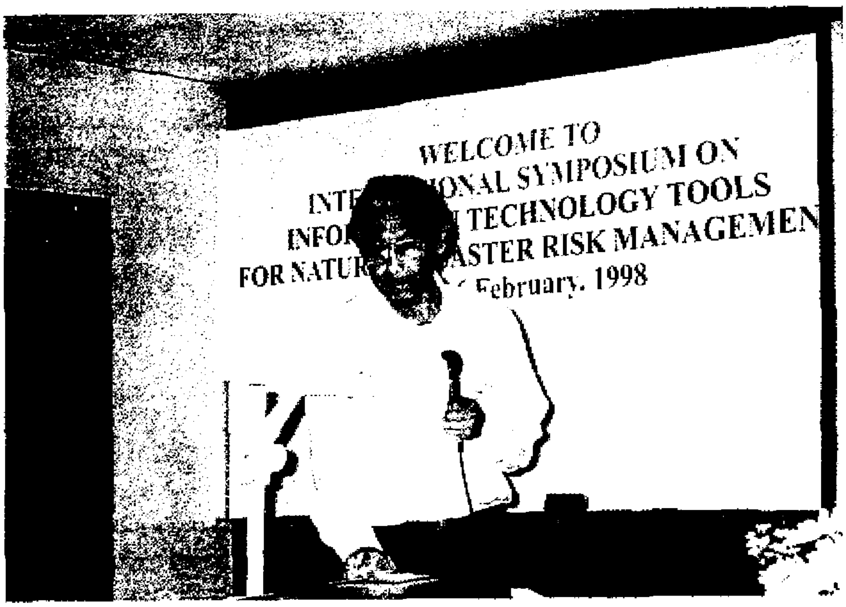

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