Seismic Zonation Map of Bangladesh

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Member Steering Committee

Bangladesh National Building Code

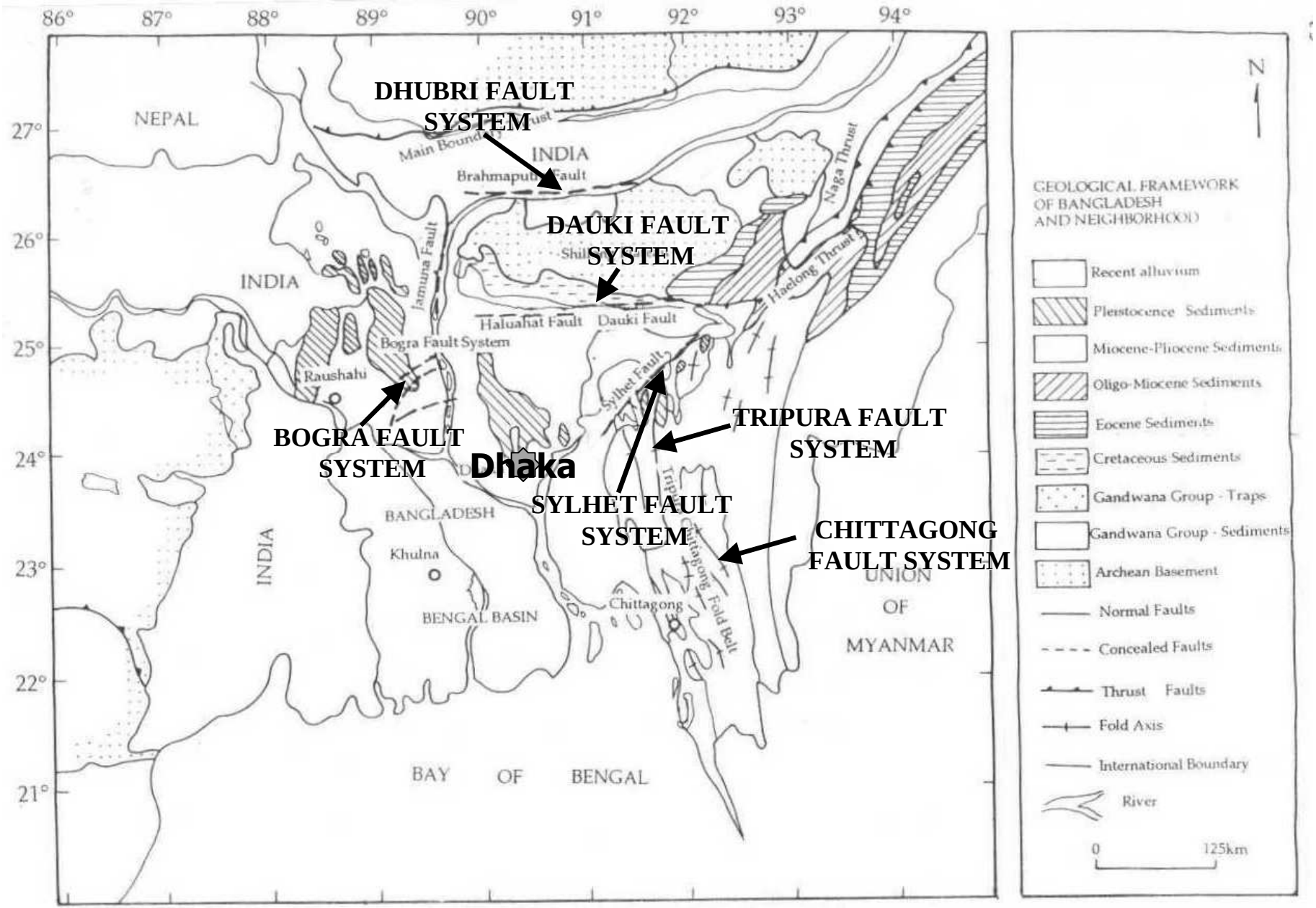
&

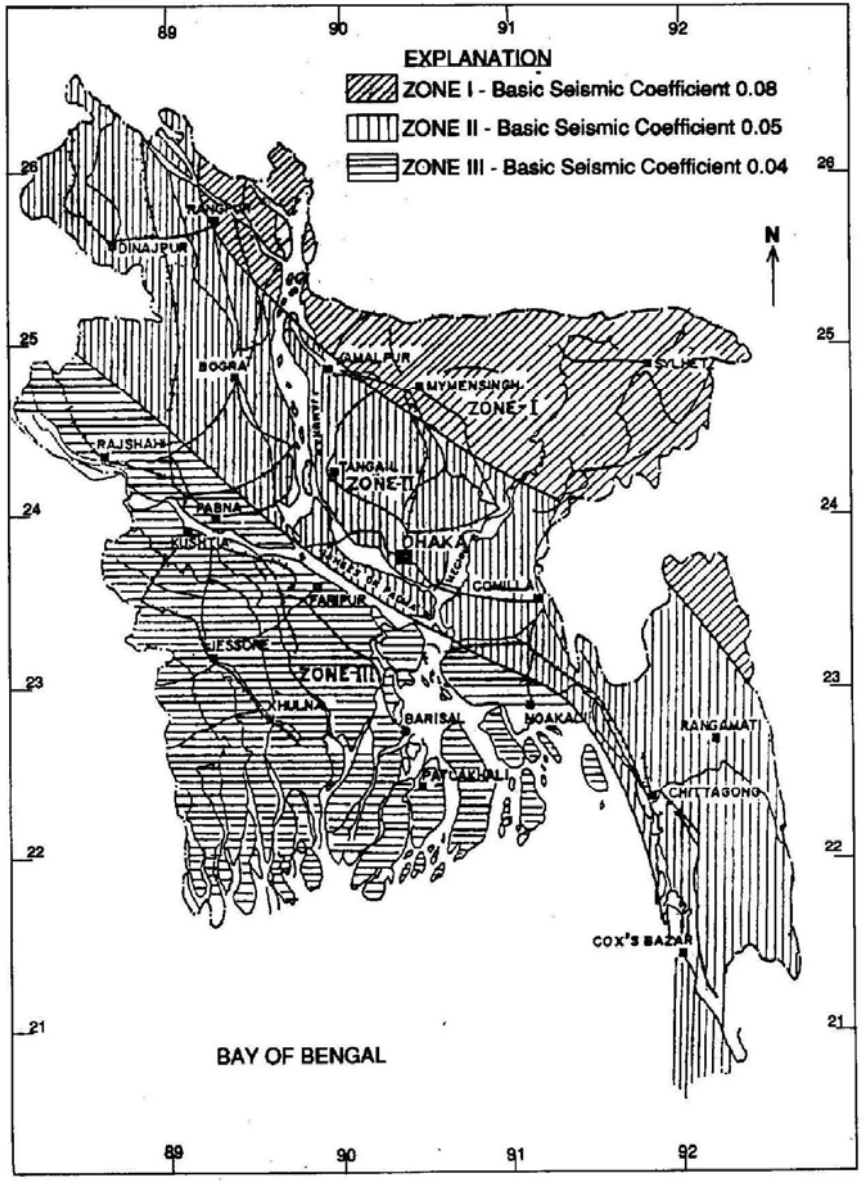
Bangladesh Earthquake Society

(BES)

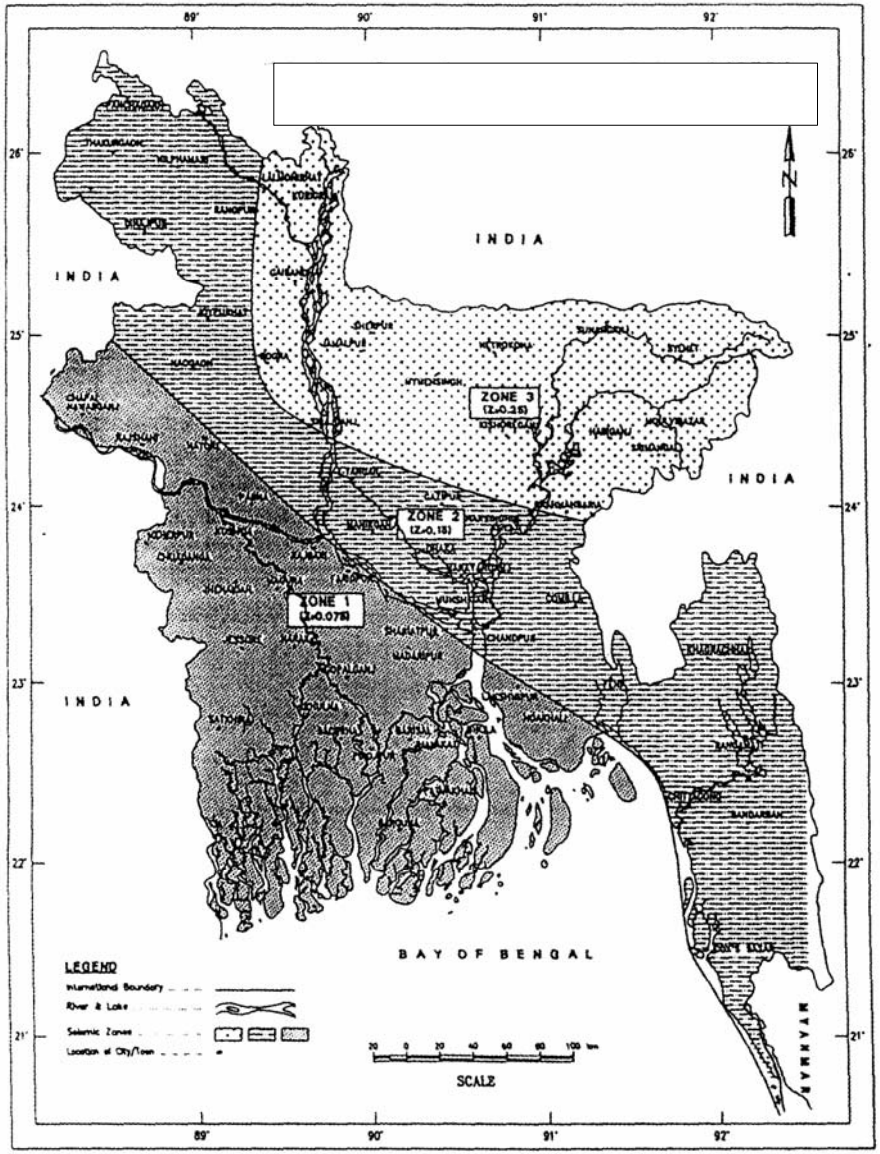
Department of Civil Engineering BUET

Active Faults Surrounding Bangladesh (Bolt, 1985)




EXPLANATION
ZONE I - Basic Seismic Coefficient 0.08
ZONE II - Basic Seismic Coefficient 0.05
ZONE III - Basic Seismic Coefficient 0.04
N
ZONE I
ZONE II
ZONE III
DINAJPUR
BOGRA
JAMALPUR
MYMENSINGH
SYLHET
RAJSHAHI
TANGAIL
PABNA
KUSHTIA
DHAKA
COMILLA
FARIDPUR
JESSORE
KHULNA
BARISAL
NOAKALI
RANGAMATI
CHITTAGONG
COX'S BAZAR
BAY OF BENGAL
89
90
91
92
21
22
23
24
25
26

1979


INDIA
INDIA
INDIA
INDIA
ZONE 3
(Z=0.25)
ZONE 2
(Z=0.15)
ZONE 1
(Z=0.075)
BAY OF BENGAL
LEGEND
International Boundary
River & Lake
Seismic Zones
Location of City/Town
SCALE
MYANMAR

1993

EARTHQUAKE HAZARD ANALYSIS

Earthquake Catalogue

- An earthquake catalogue forms a valuable input for seismic hazard assessment and microzonation studies.
- Critical structures such as nuclear power plants and dams, as well as siting of any new industry, require earthquake data that are accurate, homogeneous and as complete as possible.
- In this study an attempt is made to assess the seismicity of Bangladesh and adjoining region (**20-28^0** north latitude and **86-95^0** east longitude) during the period **1865-1995** by reviewing instrumental data as well as macroseismic information retrieved from various sources.

1865-2003

Existing Earthquake Catalogue

Date	Lat N°	Long E°	Magnitude M	Mb	Focal depth(km)
16-08-1950	27.5	91.9	5.5		
17-08-1950	27.9	91.9	6.0		
24-12-1950	24.4	91.7	6.3		
07-04-1951	25.9	90.5	5.0		
07-11-1952	25.5	94.0	6.0		
23-02-1954	27.8	91.7	6.0		
17-04-1955	26.5	90.0	4.5		
29-08-1955	26.0	90.5	4.2		
20-09-1955	27.5	90.0	5.7		
23-11-1955	26.5	90.0	5.0		
14-12-1955	22.0	92.5	6.5		
21-01-1956	23.6	93.5	6.1		
14-03-1956	25.2	90.8	5.0		
12-06-1956	24.8	90.9	5.3		
12-07-1956	22.0	94.0	6.3		
01-07-1957	24.4	93.8	7.2		
12-12-1957	24.5	93.0	5.5		
09-02-1958	25.0	90.5	5.0		
13-02-1958	27.5	92.0	5.5		
22-03-1958	23.5	93.8	6.5		
13-04-1959	22.0	93.3	5.9		
07-06-1959	24.0	94.0	5.4		
02-11-1959	21.5	92.4	5.0		30
26-05-1960	27.0	93.0	5.0		
29-07-1960	26.5	90.5	5.5		
21-08-1960	27.0	88.5	5.5		29
29-09-1961	28.0	87.6	5.5		100
06-11-1961	26.7	91.9	5.0		37
25-12-1961	27.0	90.4	5.5		33
23-10-1962	26.6	93.3	5.5		
17-08-1964	24.2	94.0		4.7	
30-08-1964	27.6	88.3		5.2	21
30-08-1964	27.1	88.4		5.0	
01-09-1964	27.2	92.3		5.7	33
12-01-1965	27.6	88.0		6.1	23
12-01-1965	27.3	87.7		5.3	33
11-04-1965	26.7	92.3		5.1	70

Revision of Magnitudes

- The idea of revising and unifying existing magnitudes is carried out. The main goal is to produce a file of reliable data that reflect, as homogeneously and completely as possible, the seismicity of the region.

Calculation of surface wave magnitude:

$$Ms = \log(A/T) + 1.66 \log\nabla + 3.3$$

Use of correlations:

- Surface-wave magnitudes are estimated where possible from semi-empirical relationships between M_s and M_b.

$$M_s = a + b*M_b.$$

$$Ms = 0.63 + 0.774*Mb \quad \text{- period 1978-1995}$$

$$Ms = 1.27 + 0.68*Mb \quad \text{- period 1964-1977}$$

- Surface-wave magnitudes are also assessed by using the number of stations (NS) that reported it to the ISS or ISC.

  Ms = a + b* Log (NS)

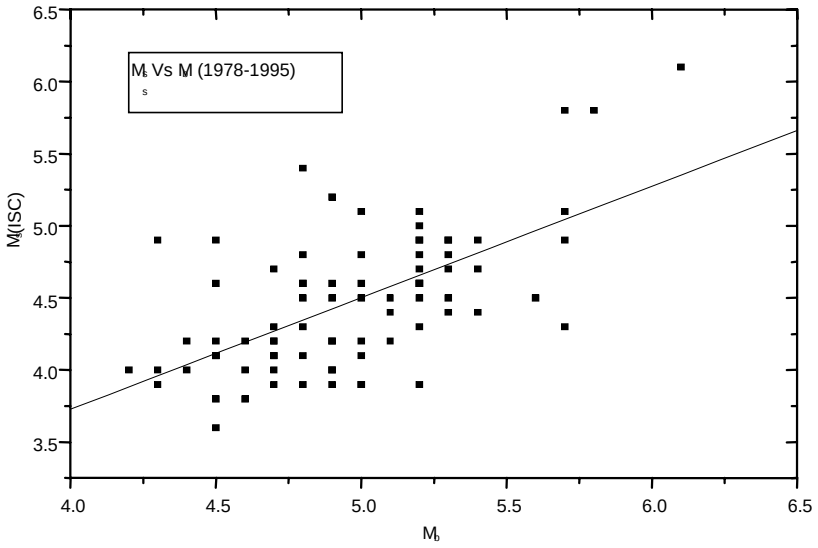
  a =4.21, b=1.12 - period 1900-1963

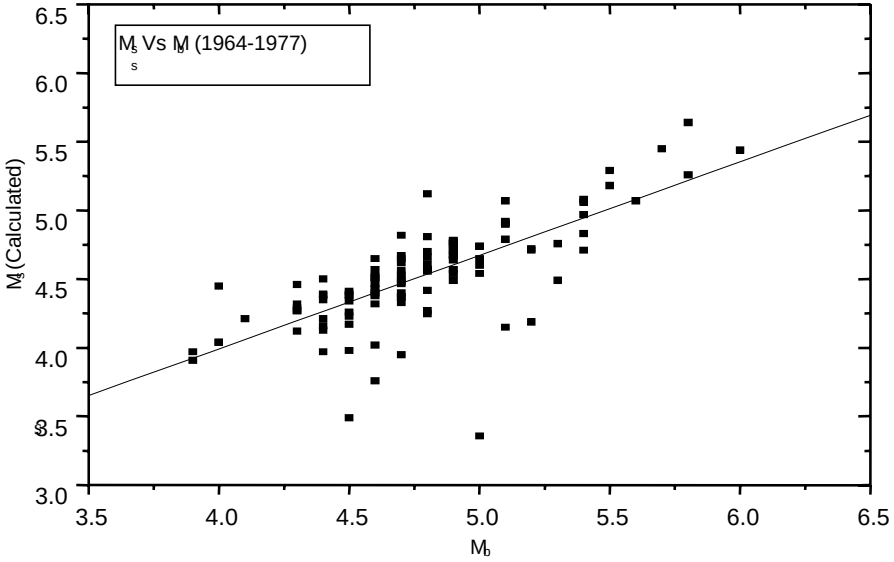
  a =3.21, b=0.72 - period 1964-1977

  a =2.77, b=0.81 - period 1978-1995

- Surface-wave magnitudes are also estimated where possible from semi-empirical relationships between M_s and Duration Magnitude M_d.

  $M_s = 0.57+1.057*M_d$ - period 1993-1995





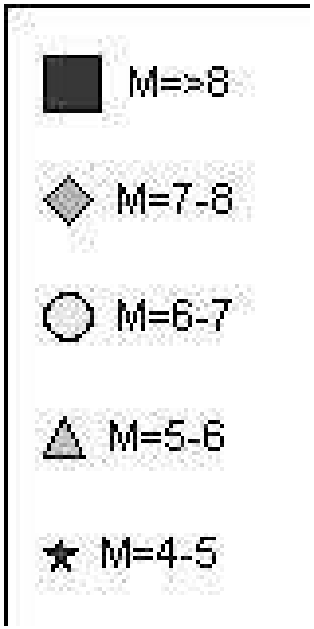
New Earthquake Catalogue

YR	MNH	DY	H	MIN	S	LON	LAT	DEP	Ms		Mb	Md	M	Ml	Mw	ITSC	NS	RMK	LOCATION	REFERENCES
1964	1	22	15	58	47	9360	2240	88	544	( )	610	-	600	-	-	-	153	-	MR-ID	ROT,ISC,MOS,SHL,USCGS,I
1964	2	1	11	28	19	8778	2730	33	442	( )	480	-	-	-	-	-	20	-	NP	ISC,USCGS,ISETR
1964	2	18	3	48	36	9110	2750	30*	449	( )	530	-	560	-	-	-	67	-	BU	ROT,ISC,MOS,USCGS,TS,IS
1964	2	18	4	26	34	9430	2500	-	-		-	-	540	-	-	-	-	-	-	TS
1964	2	27	15	10	48	9440	2170	102	545	( )	640	-	650	-	-	-	212	-	Mandalay.MR	ROT,ISC,MOS,SHL,USCGS,I
1964	3	20	19	0	53	9440	2360	86	465	( )	500	-	560	-	-	-	52	-	MR-ID	ROT,ISC,MOS,SHL,USCGS,I
1964	3	27	23	3	42	8930	2720	29	456	( )	500	-	-	-	-	-	46	-	BU	ROT,ISC,MOS,USCGS,GS,IS
1964	4	13	3	20	5	9020	2760	52*	473	( )	520	-	600	-	-	-	53	-	BU	ROT,ISC,MOS,USCGS,ISETR
1964	4	15	16	35	58	8800	2170	36*	468	( )	520	-	560	-	-	7	80	-	Calcutta.ID	ROT,ISC,QUE,MOS,USCGS,
1964	6	3				9500	2600					-							MR-ID	ISETR
1964	6	9	12	33	22	8790	2150	0	390	[1]	-	-	-	-	-	-	9	-	ID	ISC,SHL
1964	6	13	17	35	58	9400	2300	61	449	( )	520	-	600	-	-	-	108	-	MR-ID	ROT,ISC,MOS,USCGS,SHL,I
1964	7	12				9450	2700					-							Sagaing.MR	ISETR
1964	7	13	10	58	48	9470	2370	117	492	( )	540	-	600	-	-	-	138	-	MR-ID	ROT,ISC,USCGS,MOS,SHL,(
1964	8	17	14	42	54	9418	2432	158	438	( )	480	-	-	-	-	-	24	-	MR-ID	ISC,USCGS,ISETR
1964	8	30	2	35	8	8830	2760	21	456	( )	510	-	560	-	-	-	78	-	Sikkim.BU	ROT,ISC,SHL,MOS,USCGS,T
1964	8	30	5	12	32	8852	2790	33	377	[1]	-	-	-	-	-	-	6	A	Sikkim .BU	ISC,ISETR
1964	9	1	13	22	37	9230	2720	33	472	( )	550	-	600	630	-	-	148	-	ID-CH	ROT,ISC,SHL,USCGS,MOS,T
1964	10	4	20	55	38	9440	2600	-	372	[1]	-	-	-	-	-	-	5	-	MR-ID	NDI,ISETR
1964	10	6	2	55	0	9450	2790	413	422	( )	450*	-	-	-	-	-	11	-	E.ID	ISC,USCGS,ISETR
1964	10	13	10	36	56	9120	2400	-	399	[1]	-	-	-	-	-	-	12	-	ID-BD	ISC,NDI,ISETR
1964	10	21				9370	2800	37				-	590						ID-CH	ISETR
1964	10	25	15	40	7	8860	2790	0	434	( )	-	-	-	-	-	-	9	-	Sikkim	ISC,NDI,ISETR
1964	12	1	15	10	24	9446	2118	104	390	[1]	-	-	-	-	-	-	9	-	MR	ISC,ISETR
1965	1	12	13	32	24	8800	2760	23	529	( )	580	-	650	-	-	-	151	-	NP	ROT,ISC,PEK,QUE,USCGS,S
1965	1	12	13	55	20	8770	2730	33*	454	( )	520	-	560	-	-	-	52	-	NP	ROT,ISC,PEK,USCGS,ISETR
1965	1	18	8	17	38	9380	2500	-	-		-	-	590	-	-	-	-	-	-	PAPER
1965	1	22	2	41	35	9450	2010	76	454	[2]	480	-	560	-	-	-	37	-	MR-CH	ROT,ISC,ISETR
1965	2	18	4	26	34	9430	2500	36	479	( )	540	-	600	-	-	-	122	-	ID-CH	ROT,ISC,ISETR
1965	2	25	10	34	7	9464	2363	94	471	( )	520	-	-	-	-	-	98	-	MR-ID	ISC,PEK,USCGS,MOS,SHL
1965	3	27	20	45	51	8990	2730	33	360	[1]	-	-	-	-	-	-	7	-	BU	ISC
1965	4	11	22	33	7	9233	2682	70	465	( )	490	-	510	-	-	-	50	-	E.ID	ISC,USCGS,TS,ISETR
1965	6	1	4	32	45	9490	2020	57	477	( )	520	-	600	-	-	-	124	-	MR;MR-CH	ROT,ISC,GS
1965	6	18	8	17	38	9380	2500	46	464	( )	520	-	600	680	-	-	105	-	MR-ID;ID-CH (Arakan Y	ROT,ISC,GS,TS,ISETR
1965	7	5	23	41	39	9480	2120	65*	427	[2]	440	-	-	-	-	-	29	-	MR	ISC,USCGS,NDI,ISETR
1965	8	4	15	27	1	8830	2350	-	343	[2]	-	-	-	-	-	-	2	-	ID-BD	NDI
1965	9	30	8	48	27	9400	2500	-	356	[2]	-	-	-	-	-	-	3	-	MR-ID	NDI
1965	11	6	16	4	59	9170	2710	40	404	( )	430	-	-	-	-	-	9	-	BU	USCGS
1965	11	6				9160	2720	33				-	480						BU	ISETR
1965	12	5	22	1	28	9450	2330	13	467	( )	500	-	560	-	-	-	82	-	MR-ID	ROT,ISC,USCGS,ISETR
1965	12	9	20	26	4	9250	2750	22	478	( )	520	-	560	-	-	-	86	-	ID-CH	ROT,ISC,PEK,USCGS,TS,ISE

Earthquakes in and around Bangladesh (1664-2006)

Ms>7: 17 events

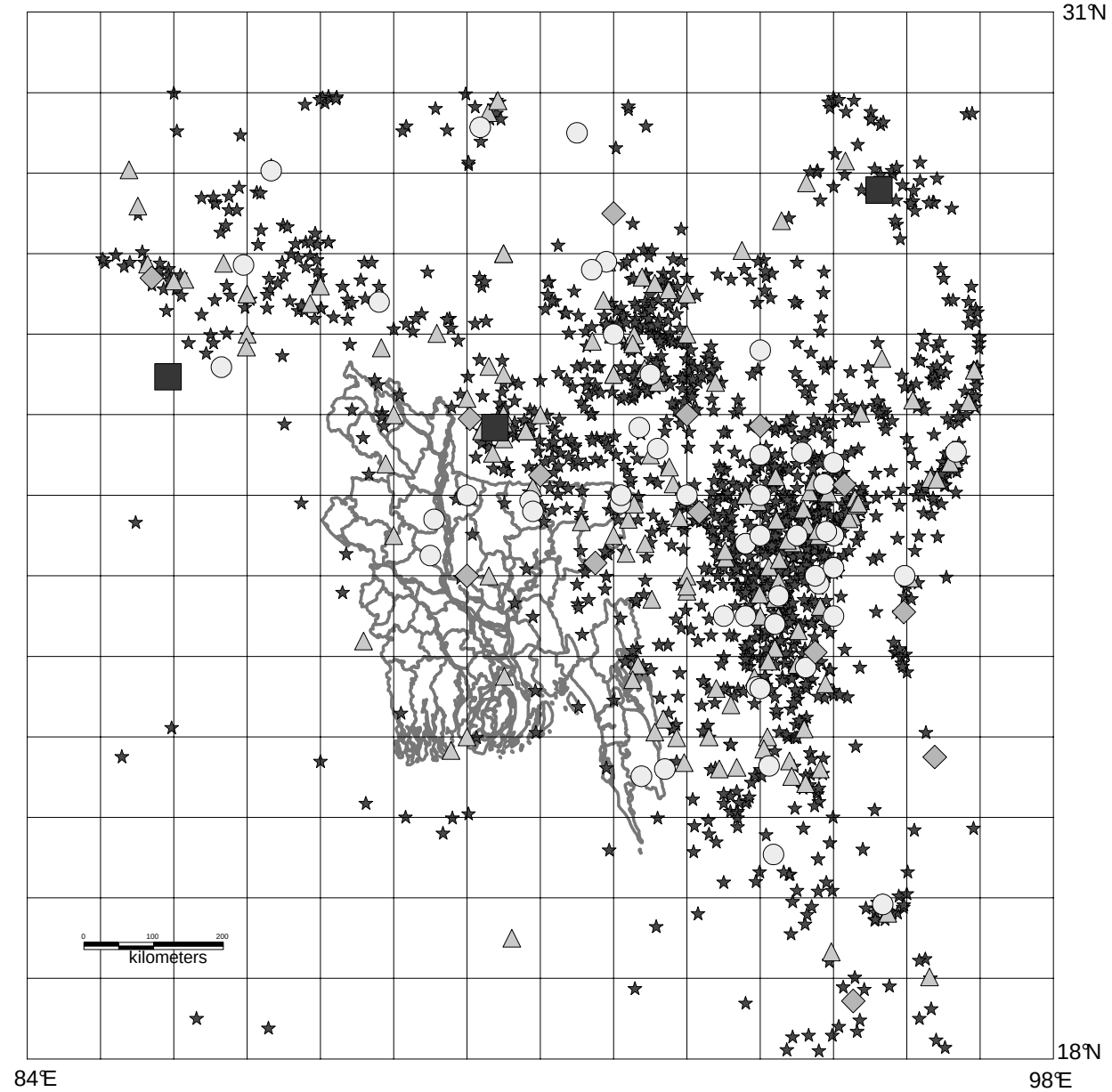
Ms>6: 69 events



Ms>4: 1647 events

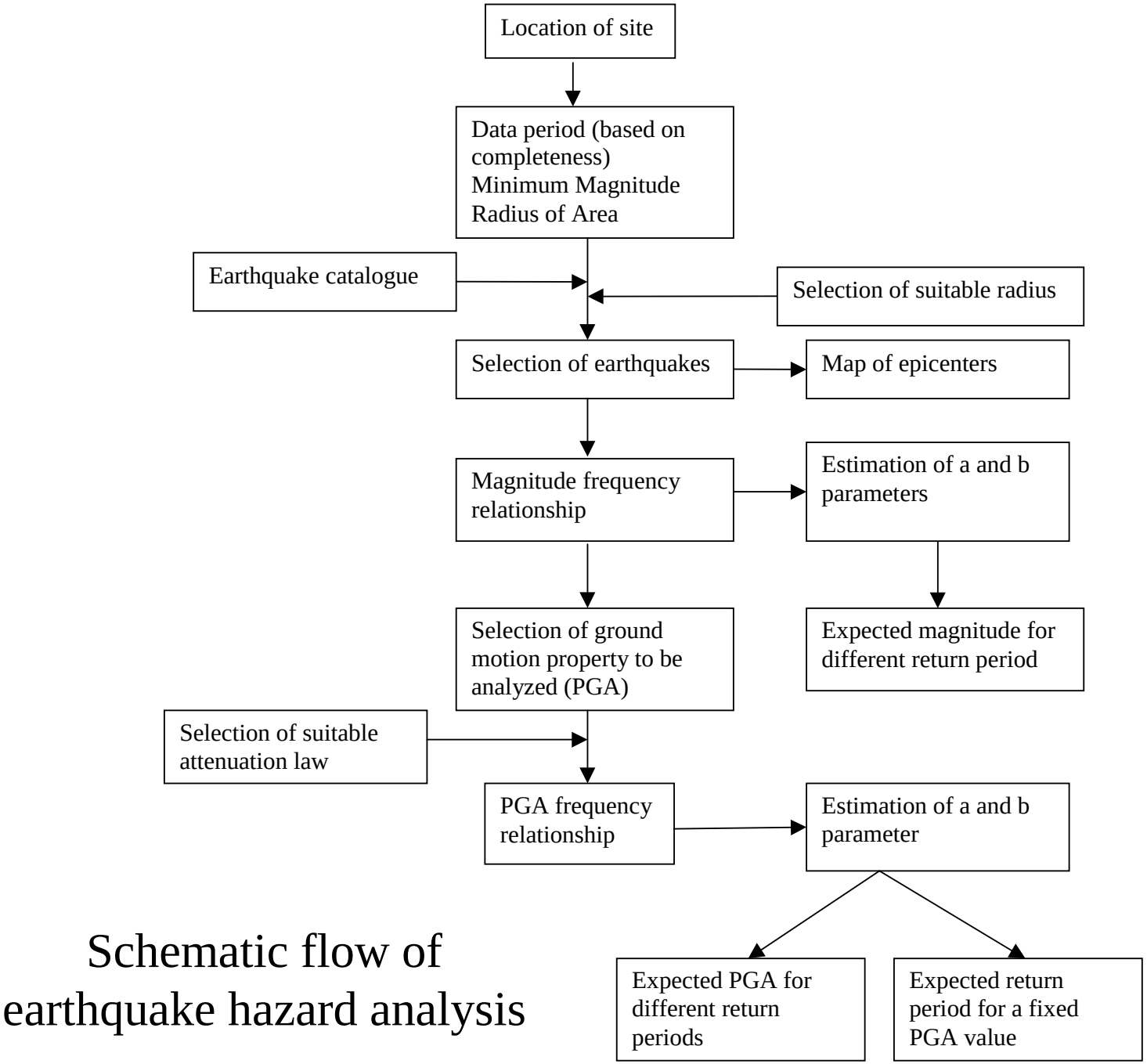
Ms>3.5: 3055 events

Ms>3: 4138 events



Results from Analysis of Completeness for the New Earthquake Catalogue

Magnitude Class	Period of Complete Reporting (year)
3≤M<4	1964-2006
4≤M<5	1964-2006
5≤M<6	1923-2006
6≤M<7	1927-2006
7≤M	1865-2006



Schematic flow of earthquake hazard analysis

Seismicity model:

- Available earthquake data
- Recurrence relationship

$$log\,(\nu) = a + b\,log(y)$$

$$log(y) = (-log(T) - a)/b \qquad [T=1/\nu]$$

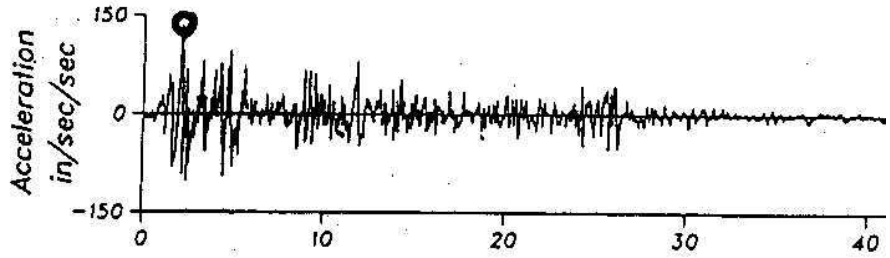
Attenuation models:

describes the transfer of ground motions from the source to a particular site in the form

$$log(PGA) = b_1 + b_2(M_s) - b_3\,log\,(r) - b_4(r)$$

Selected Attenuation Law

- Assessment of seismic hazard at any particular site requires an attenuation law for the Peak Ground Acceleration (PGA)

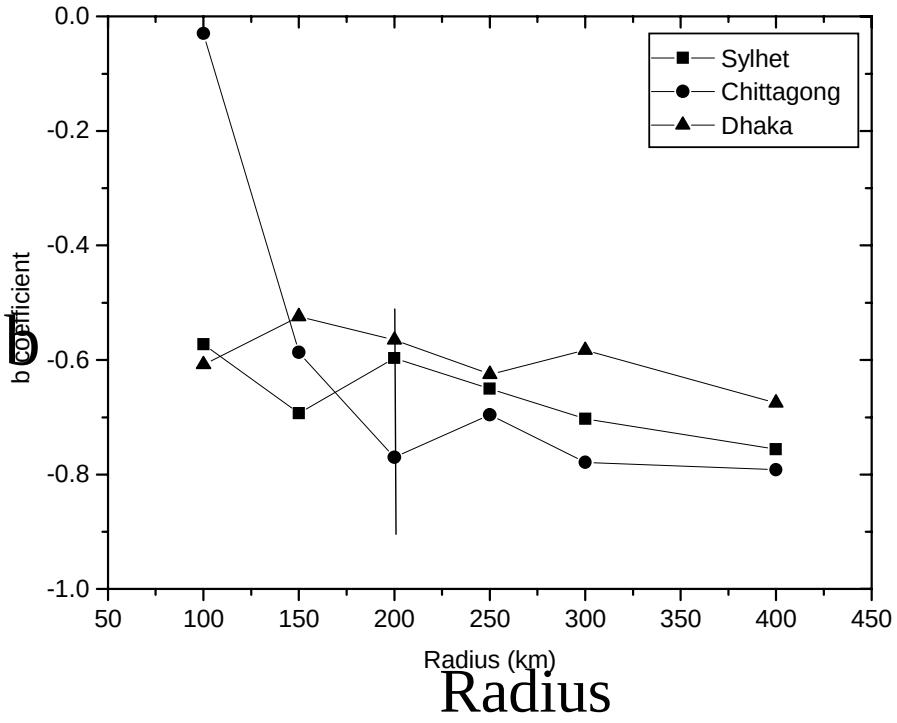


- For Bangladesh no PGA is available due to the lack of seismic devices
- Attenuation law for alluvial soils:

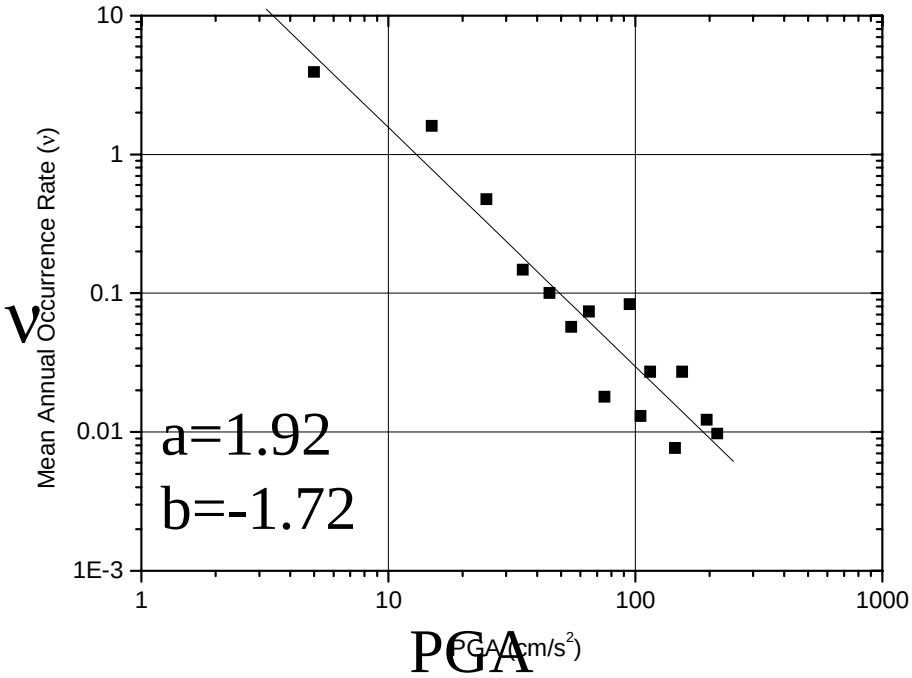
McGuire (1978) - $PGA=0.0306e^{0.89M}r^{-1.17}e^{-0.2}$ *(in g)*

Duggal (1989) - $PGA=227.3x10^{0.308M}(d+30)^{-1.201}$ (in cm/s^2)

SELECTION OF EARTHQUAKES AROUND A SITE

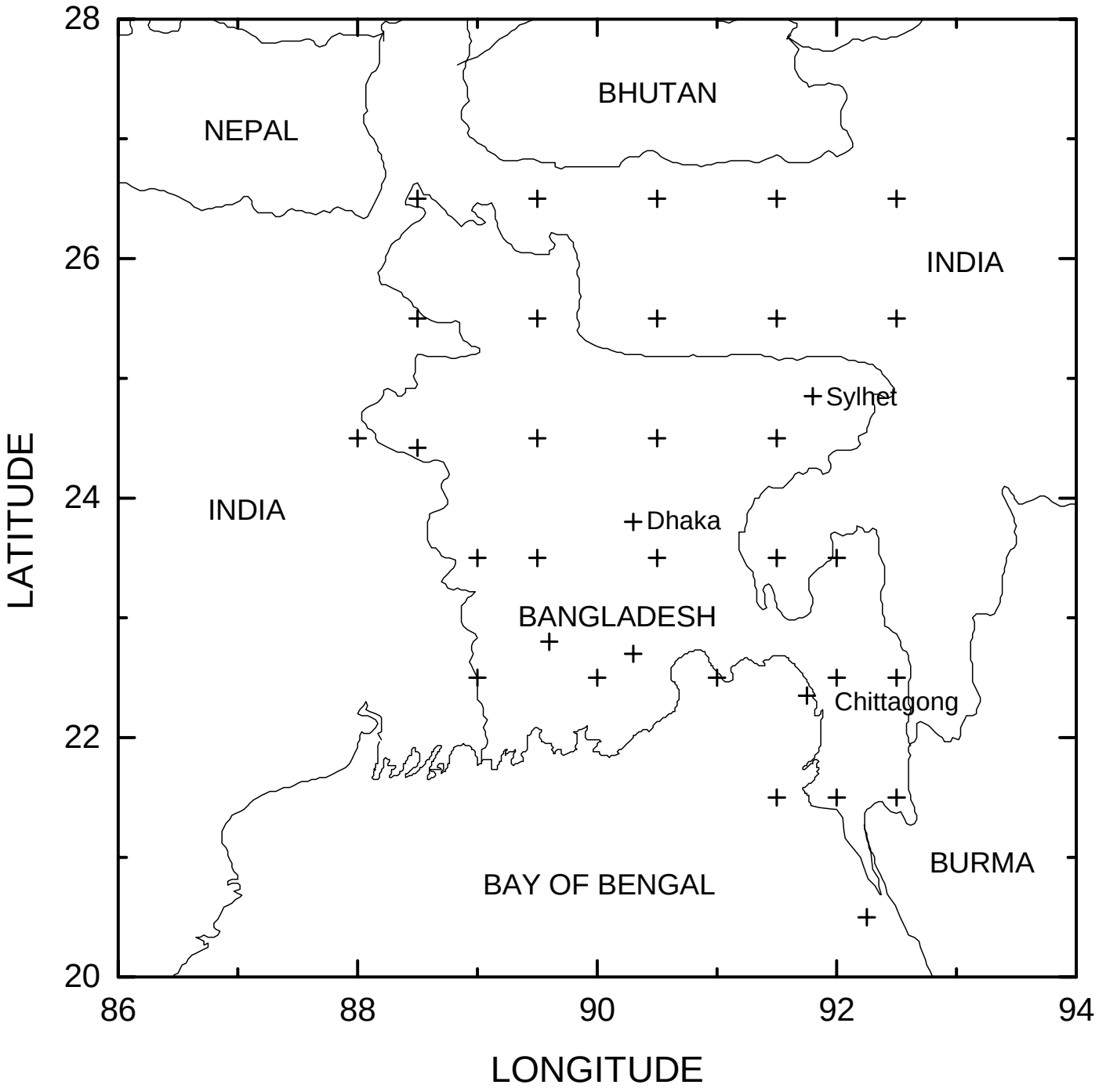


Sensitivity of b-coefficient

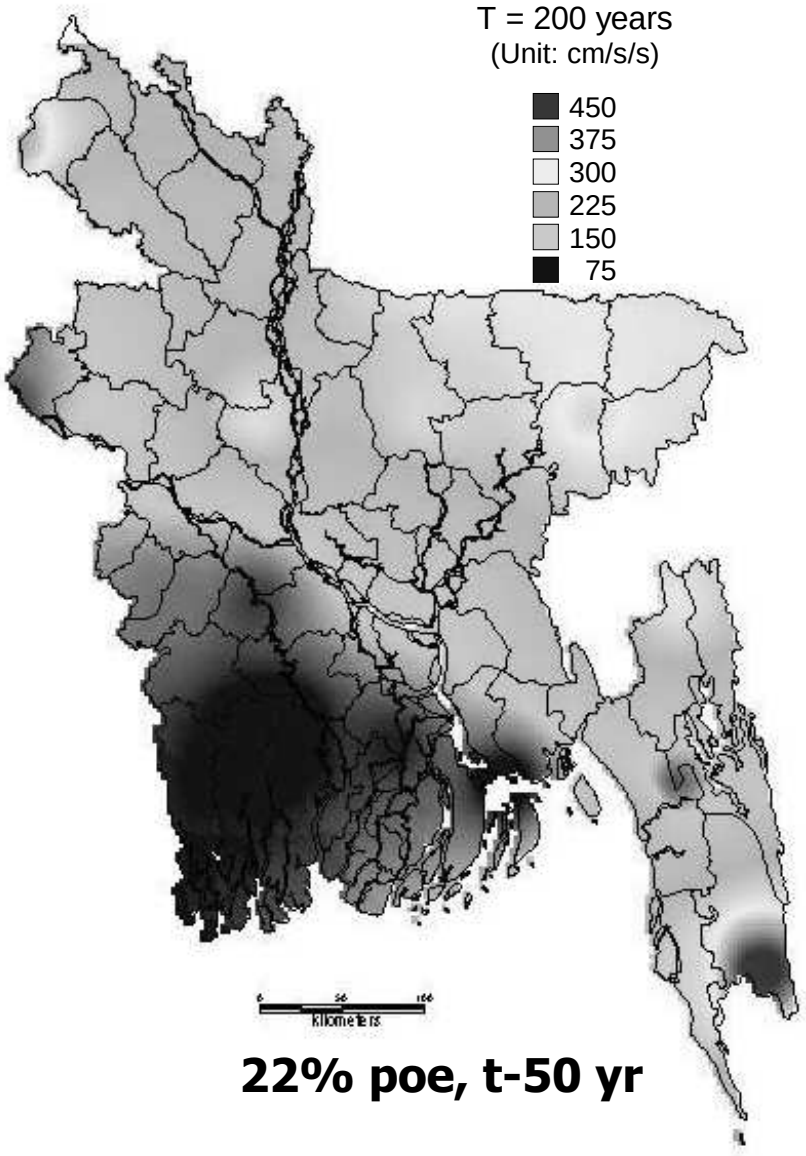


PGA versus ν for Sylhet

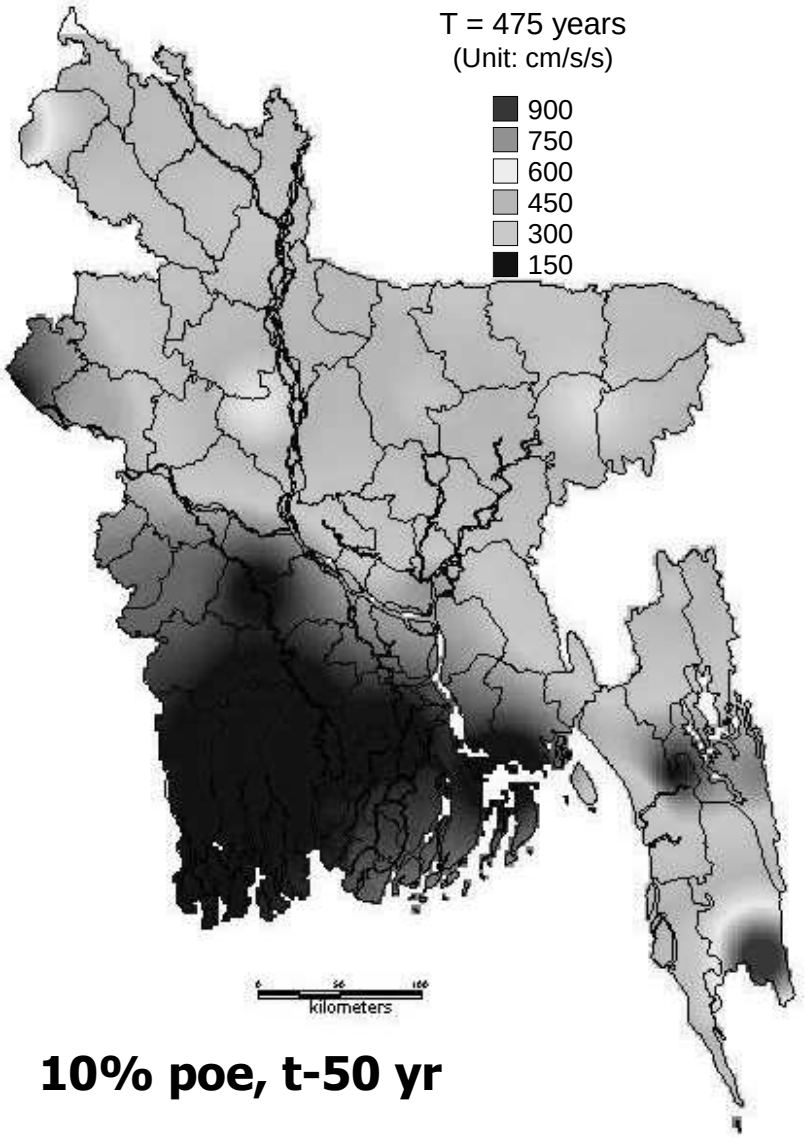
Study region showing the grid points



Seismic hazard of Bangladesh based on Duggal's (1989) attenuation law



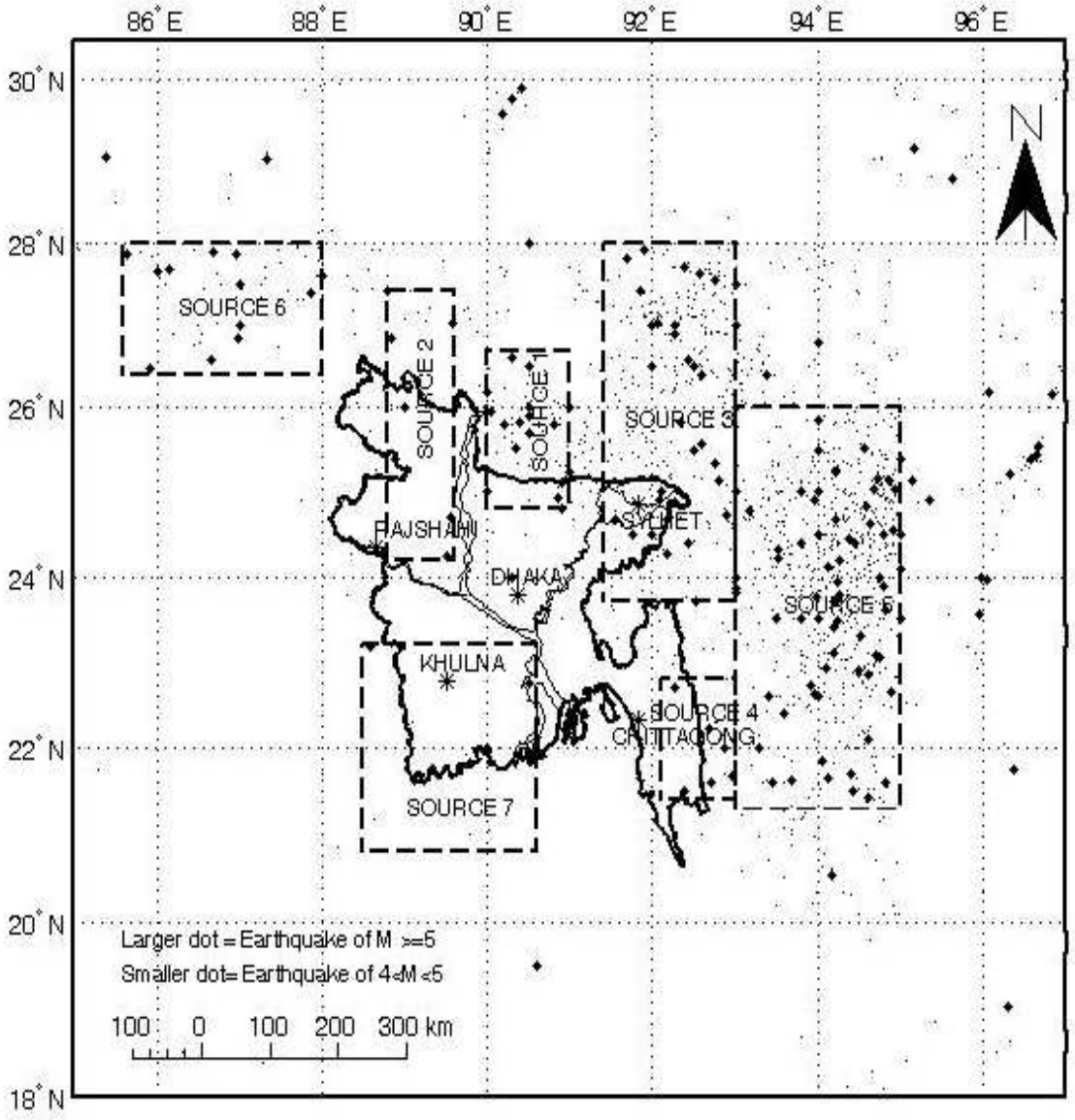
22% poe, t-50 yr



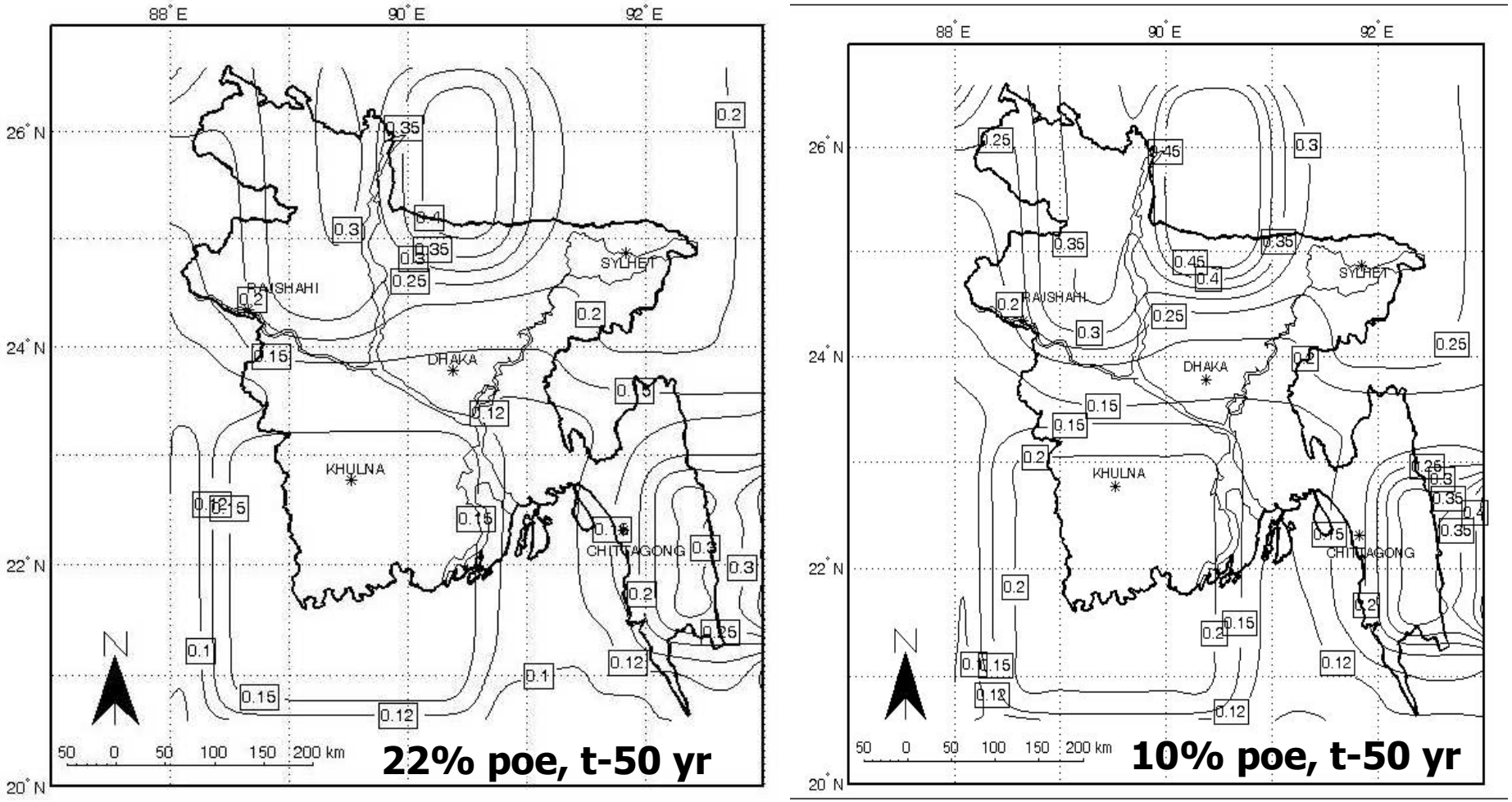
10% poe, t-50 yr

After Noor, Yasin & Ansary (2005)

- Grid interval of 0.3 degree are used
- Uniform probability distributions are assigned to each source zone implying that, earthquakes are equally likely to occur at any point within the source zone
- Seven area sources are assumed
- The sources are so divided that area of each division is limited to 1200 sq km

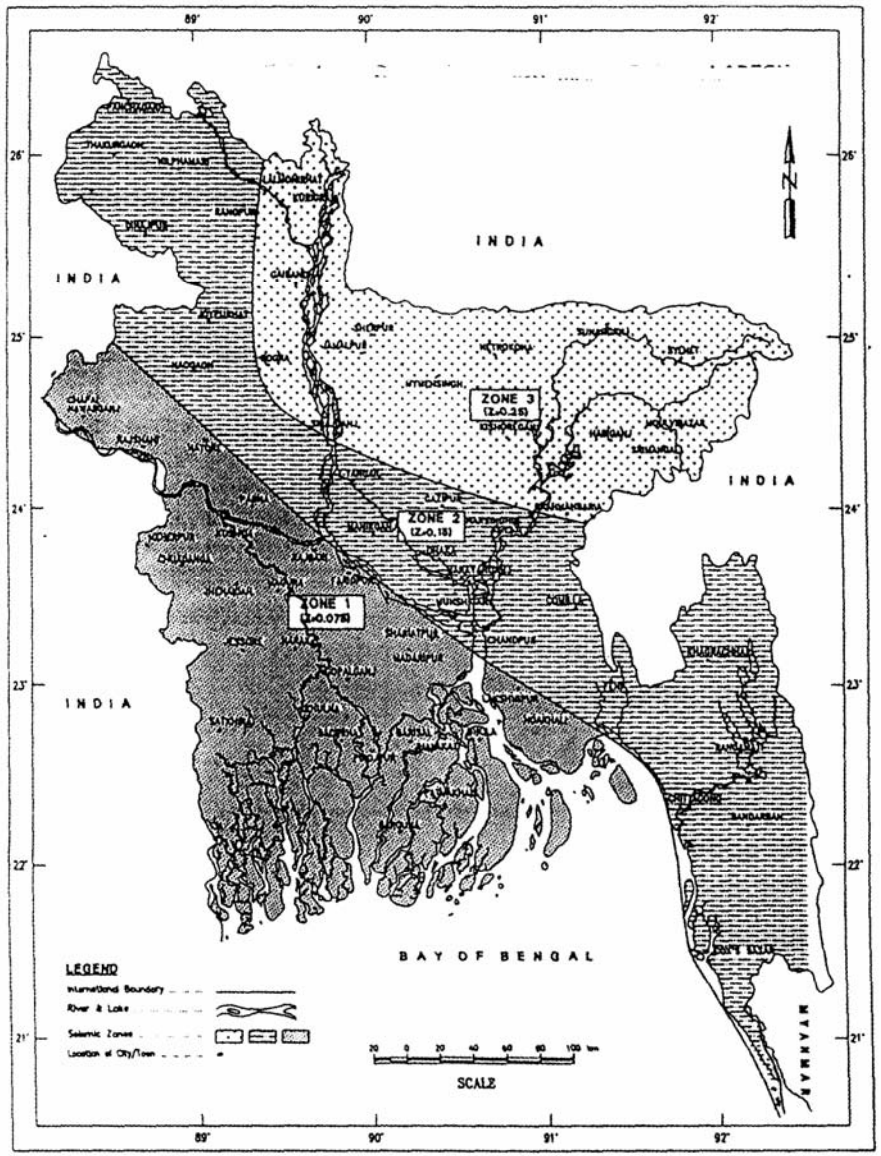


After Noor, Yasin & Ansary (2005)

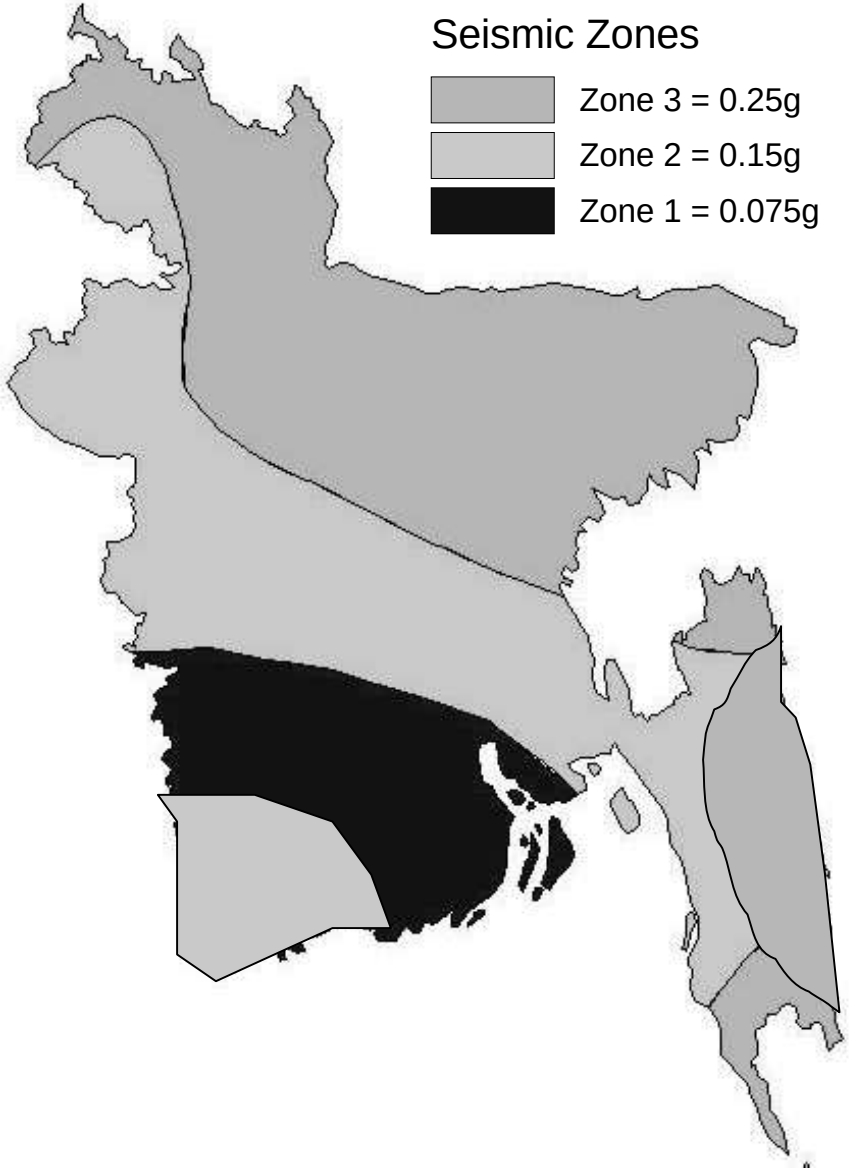


Seismic hazard of Bangladesh based on Duggal's (1989) attenuation law

Seismic Zoning Map of Bangladesh



BNBC (1993)



Proposed

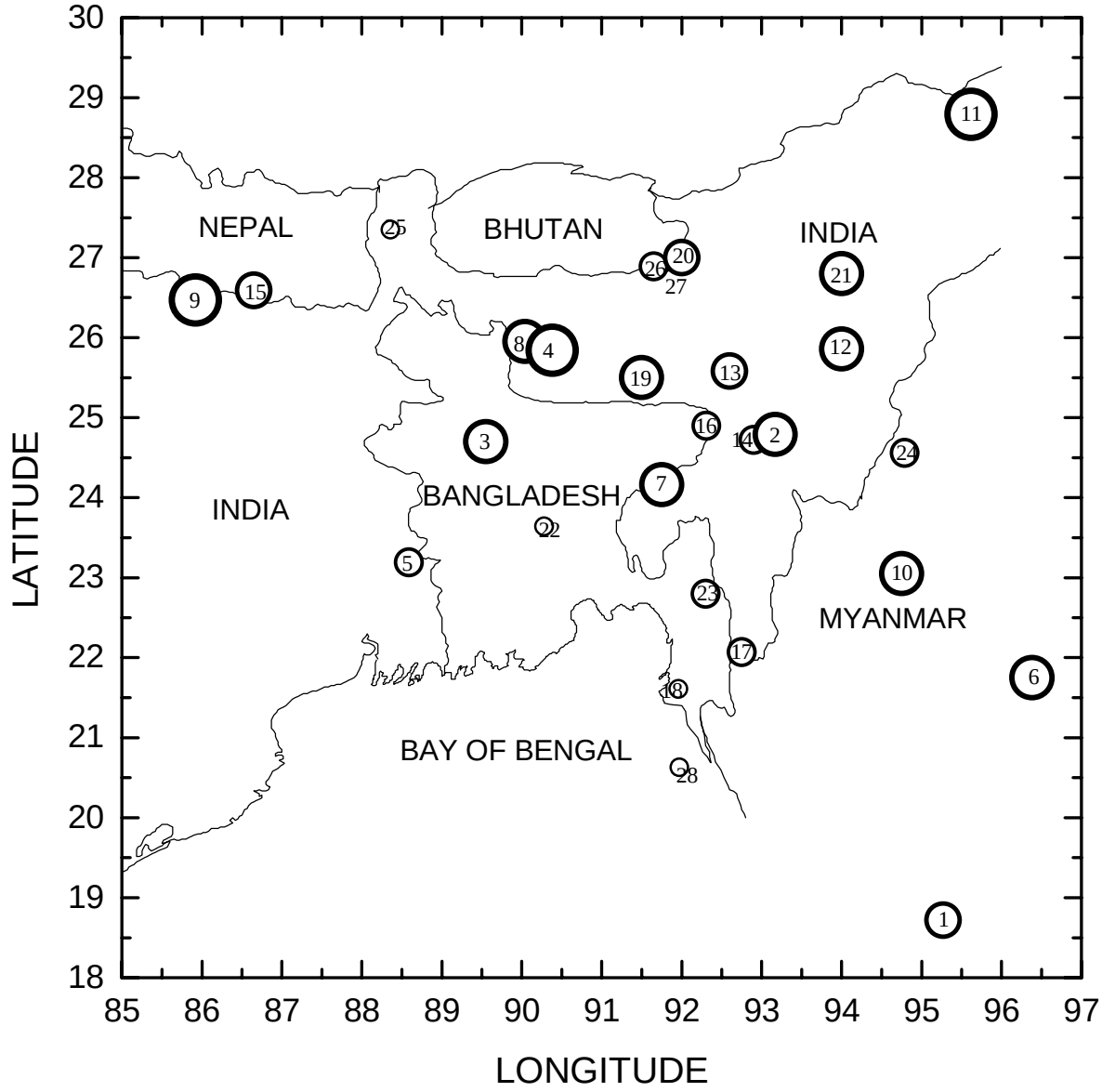
Development of Attenuation Law

Magnitude-Intensity & Intensity Attenuation

Data Preparation:

- The average radius of each isoseismal was determined from the radii measured in 16 directions at 22.5^0 intervals of the compass
- Isoseismals with no reliable data were disregarded from the regression analysis
- The description of the 18 earthquakes used in this study is presented in the following table

Area under study and locations of 28 events



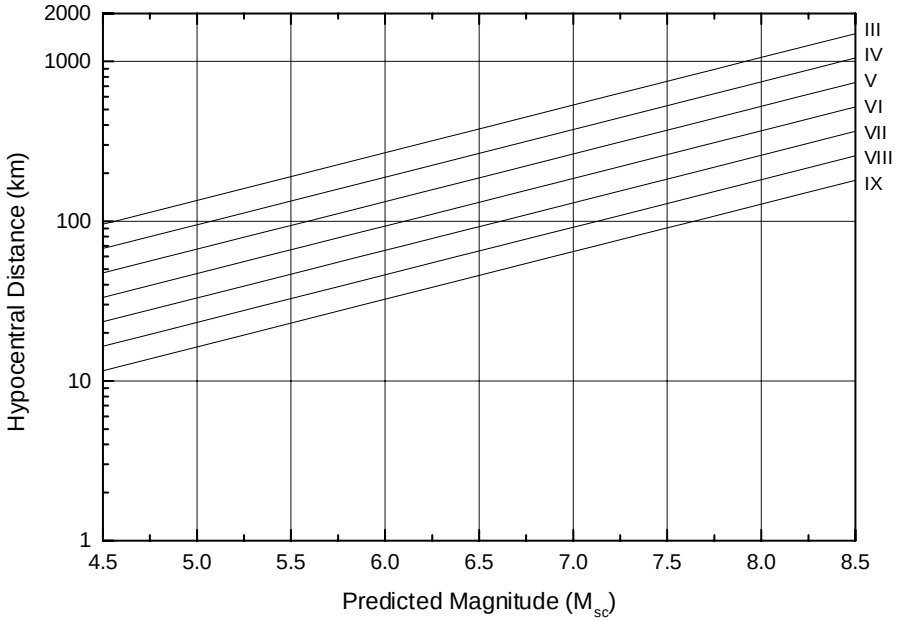
Magnitude-Intensity

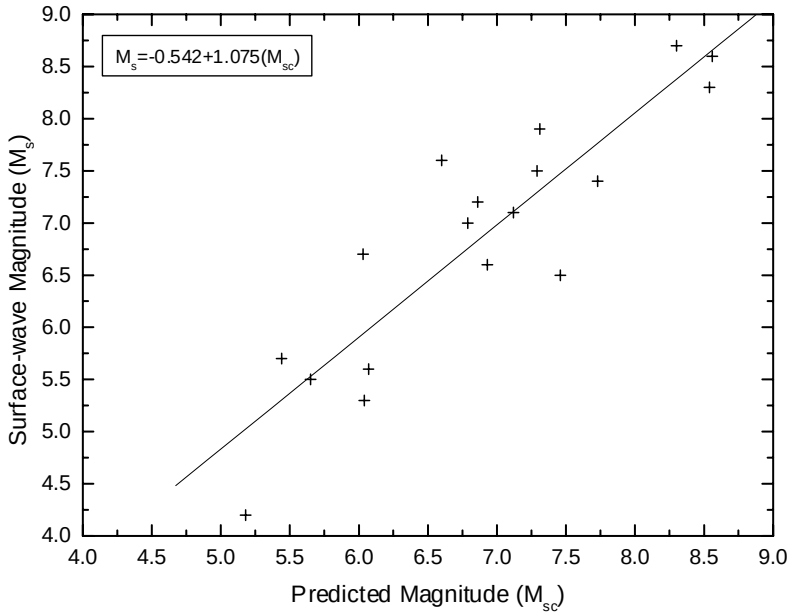
Magnitude Intensity Model:

$M_{sc} = A_1 + A_2(I_i) + A_3(R_i) + A_4 \log R_i + \sigma P$

Bangladesh and its surrounding region, which consists of 25 events and 93 pairs (I_i, D_i), is

$$M_{sc} = -3.336 + 0.549 j^{-1} \sum_{i}^{j} (I_i) + 0.000505 j^{-1} \sum_{i}^{j} (R_i) + 2.964 j^{-1} \sum_{i}^{j} (\log R_i) \pm 0.61P$$





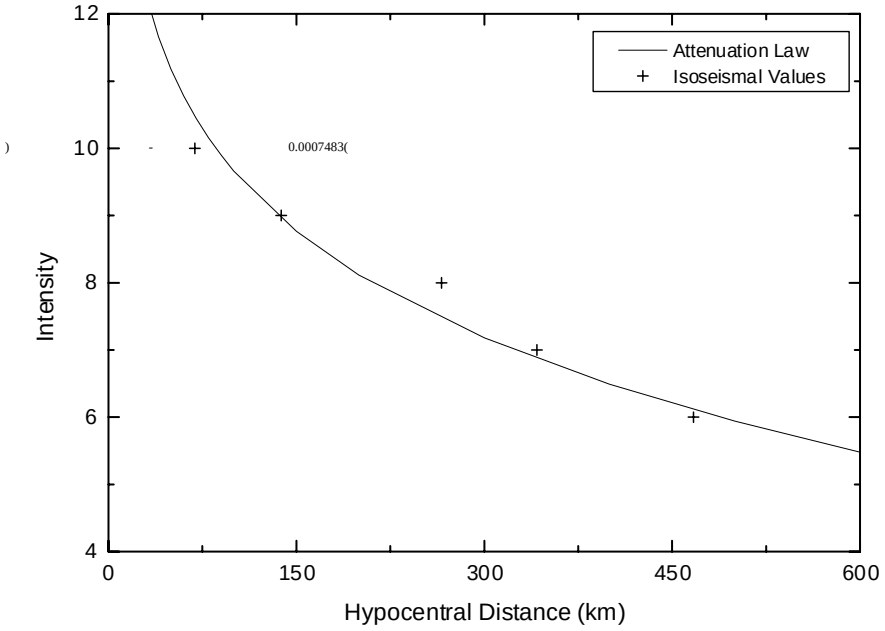
Intensity Attenuation

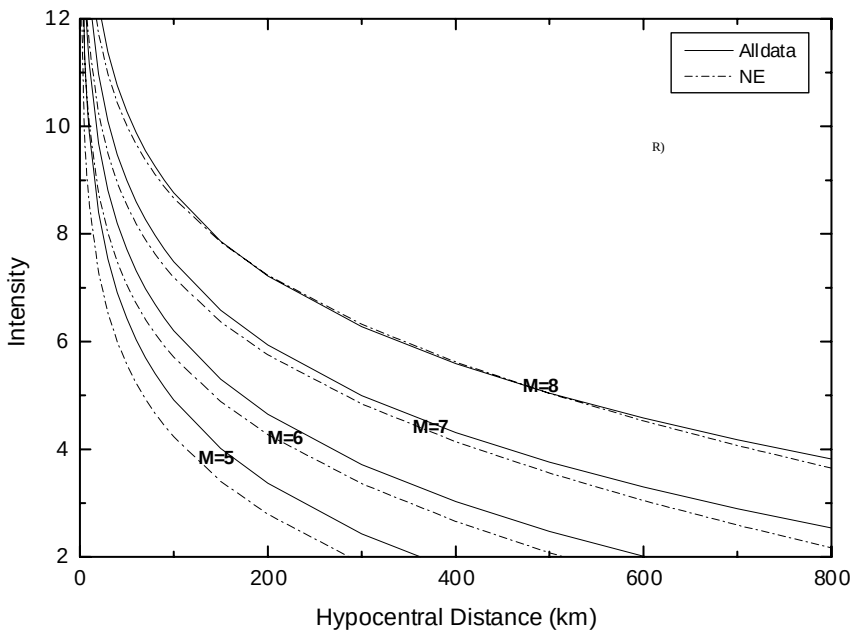
Intensity-Attenuation Model:

$I = B_1 + B_2(M_s) + B_3(R) + B_4 \log R + \sigma P$

The regression analysis for the whole data set, which consists of **93 (I_i, D_i)** pairs corresponding to 25 events, gives the following mean attenuation expression:

$$I = 6.702 + 1.254(M_s) - 0.0014(R) - 3.966(\log R) \pm 0.92P$$





STRONG MOTION INSTRUMENTATION

Why is Seismic Instrumentation Important ?

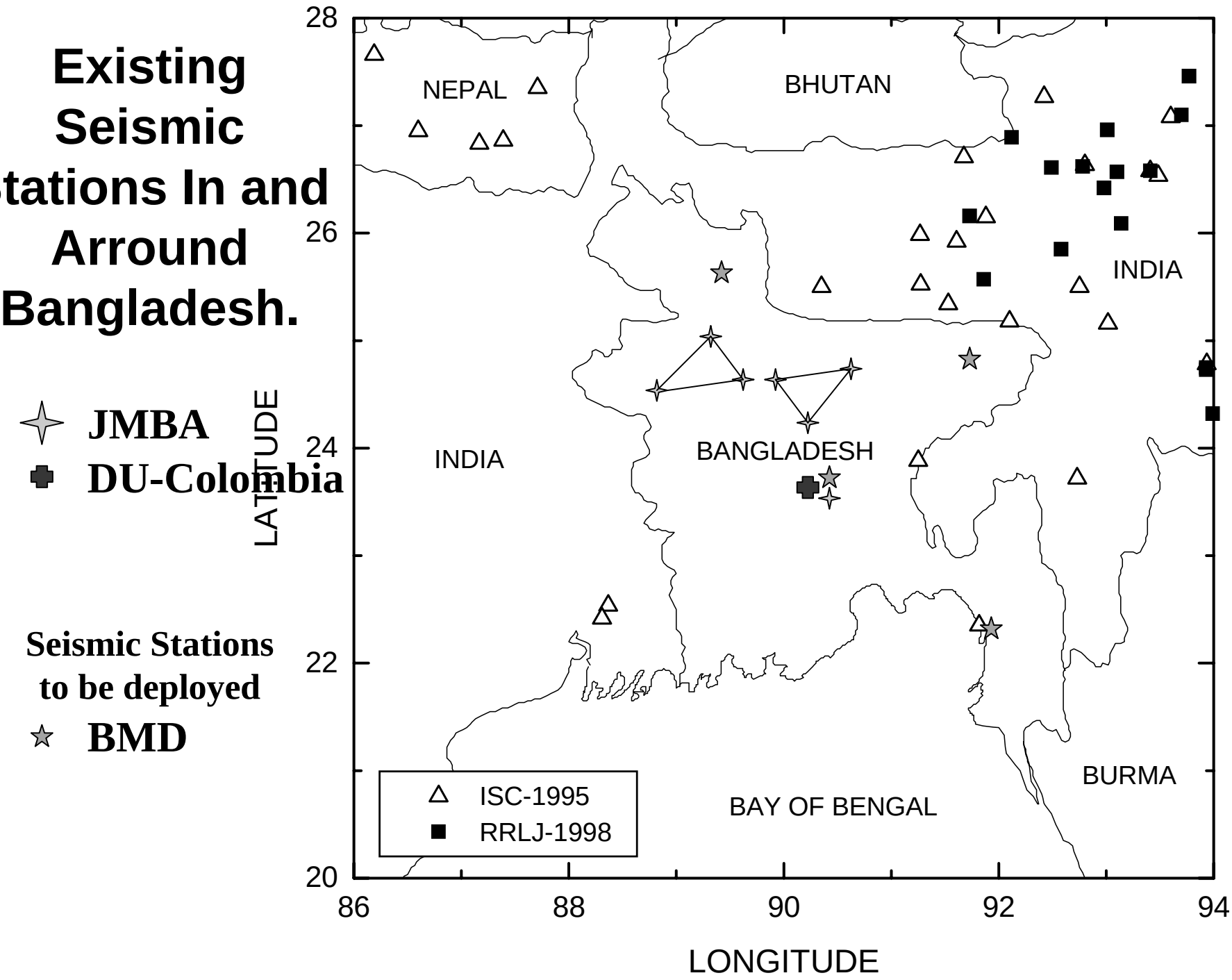
It helps us to:

- Estimate the probable ground motion.
- Locate earthquakes (epicentre, magnitude, depth)
- Tell how the structure behaves.
- Confirm how to strengthen the structure.
- Improve our design procedures and codes leading to **reduced costs but increased safety** for future structures.

Jamuna Bridge Seismic Instrumentation Project

- BUET is the Consultant to JMBA, Ministry of Communication, GOB
- Total Project Cost: Tk 4 crore
- Instrumentation has recently been installed (May-July 2003)
- BUET will monitor and analyze seismic data for the next 5 years

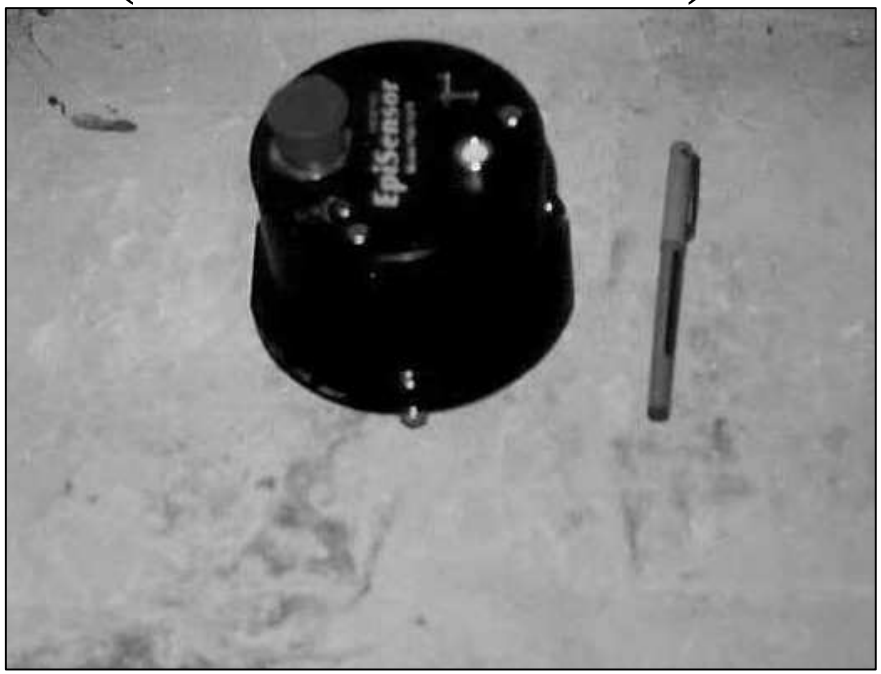
Existing Seismic Stations In and Arround Bangladesh.



Accelerometer Sensors on Bridge Deck

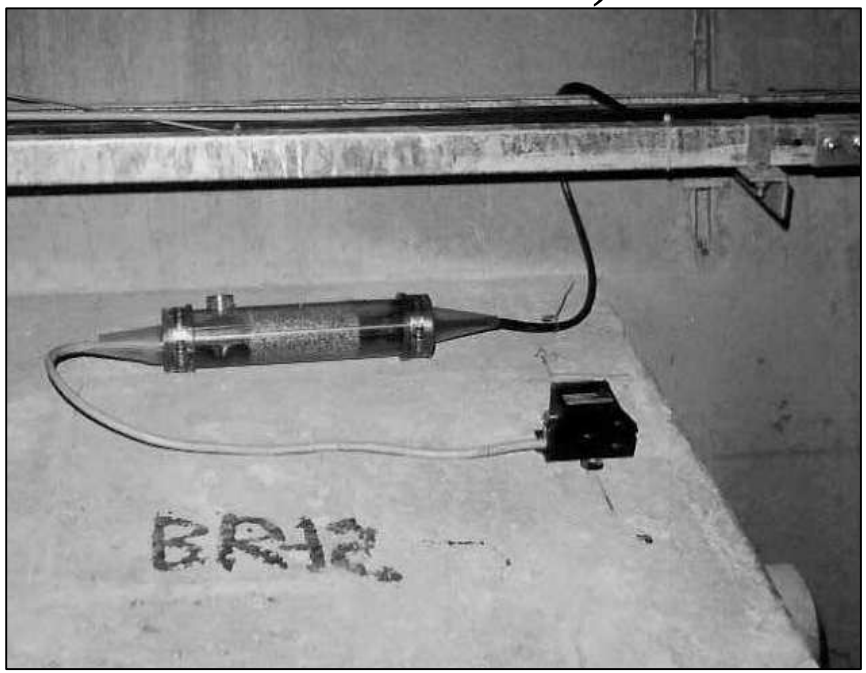
Triaxial Accelerometer

(Acceleration in 3 dirs.)



Uniaxial Accelerometer

(Horizontal Transverse Acceleration)



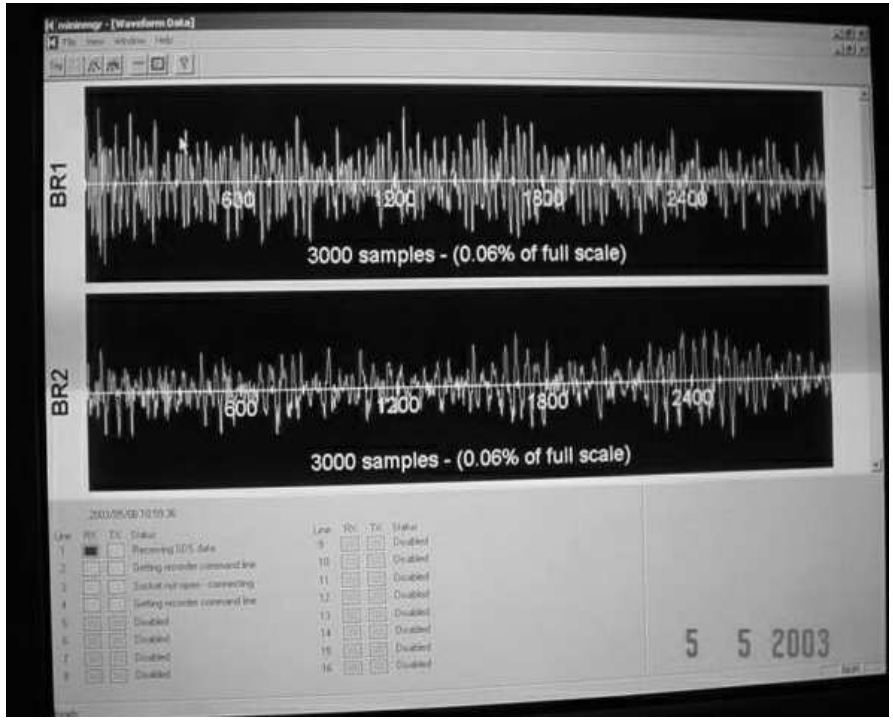
Seismic Data Transmission
Spread Spectrum / GPS

Transmitting from the Bridge

Receiving East End, Bhuapur

Data Control Centre

Communication Box / Computer Continuous Data Streaming



- Continuous digital data is transmitted to the **Data Acquisition Computer**
- Events exceeding threshold acceleration will be recorded on the computer

Free Field Stations (JMBA-BUET Project)

East Side: Bridge End, Mymensingh, Gazipur

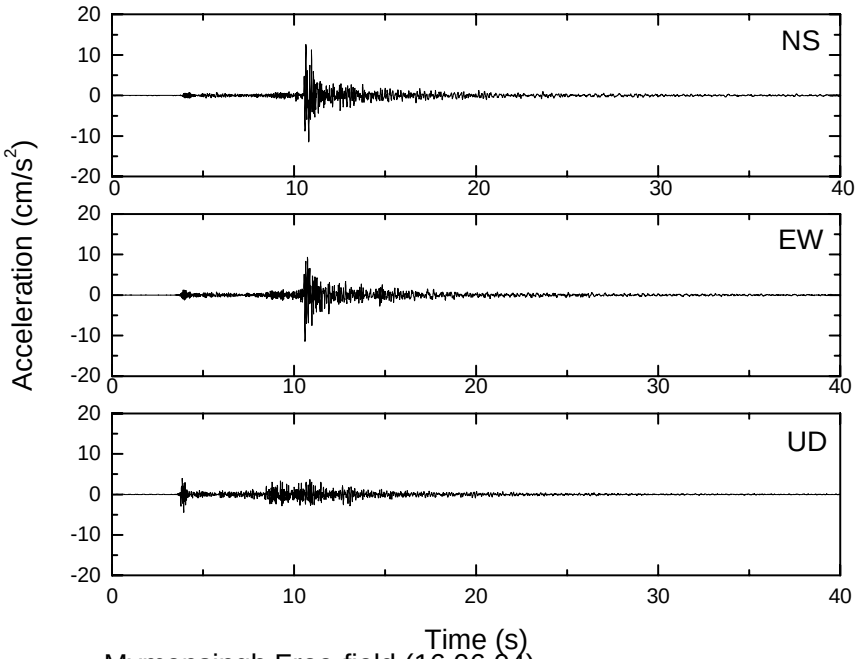
West Side: Bridge End, Bogra, Natore

- Triaxial Accelerometer
- Internal Recorder (PCMCIA Card)
- Solar Panel Charging

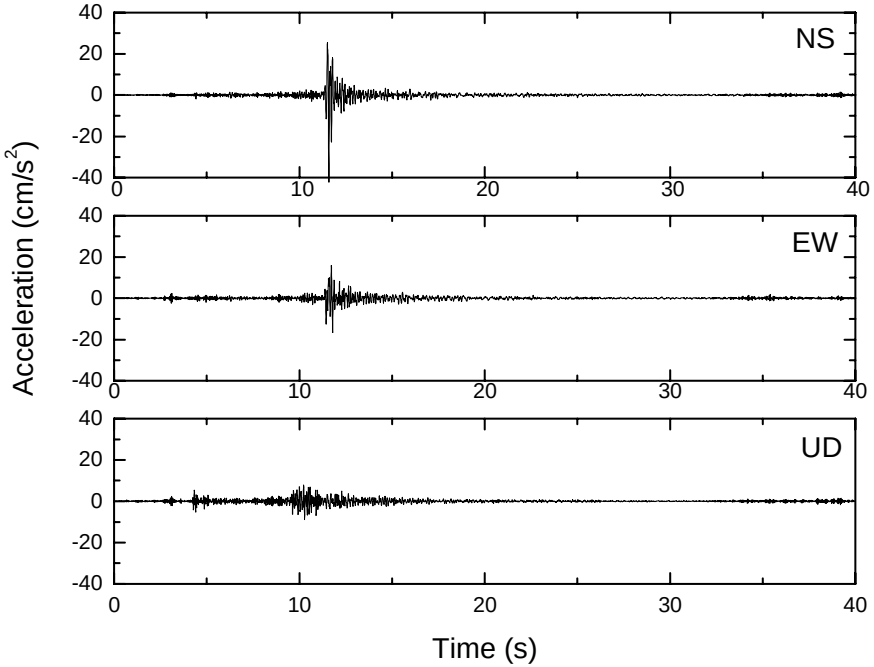
Installation Team

Strong Motion Recording During June 16, 2004 Earthquake

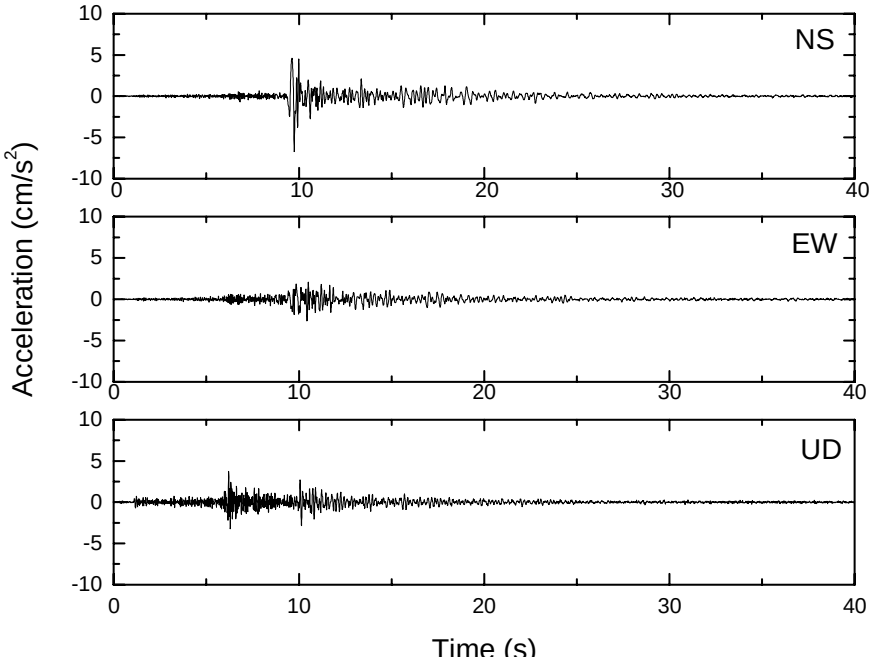
East Free-field (16.06.04)



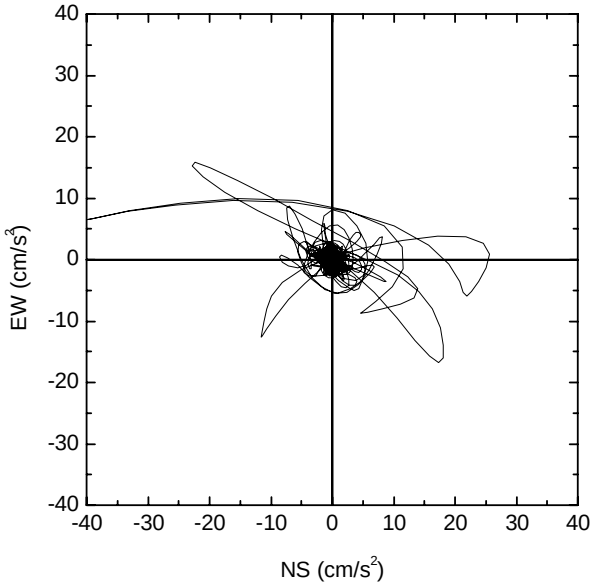
West Free-field (16.06.04)

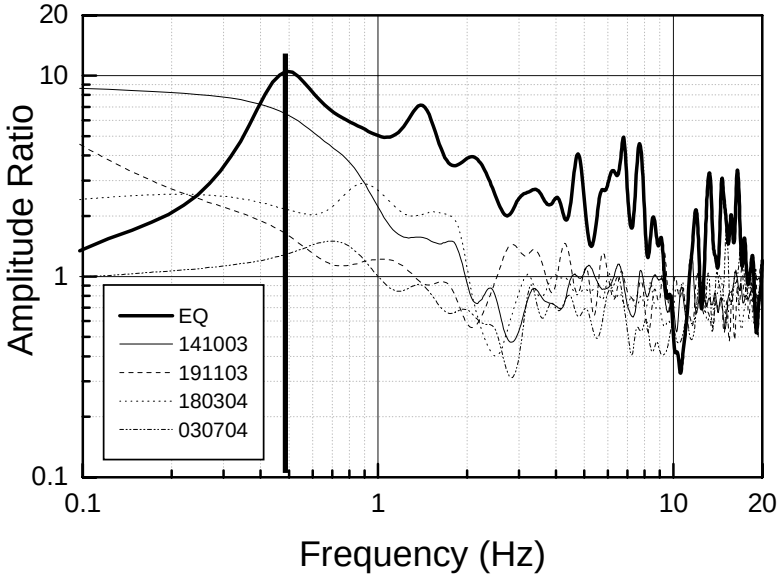


Mymensingh Free-field (16.06.04)

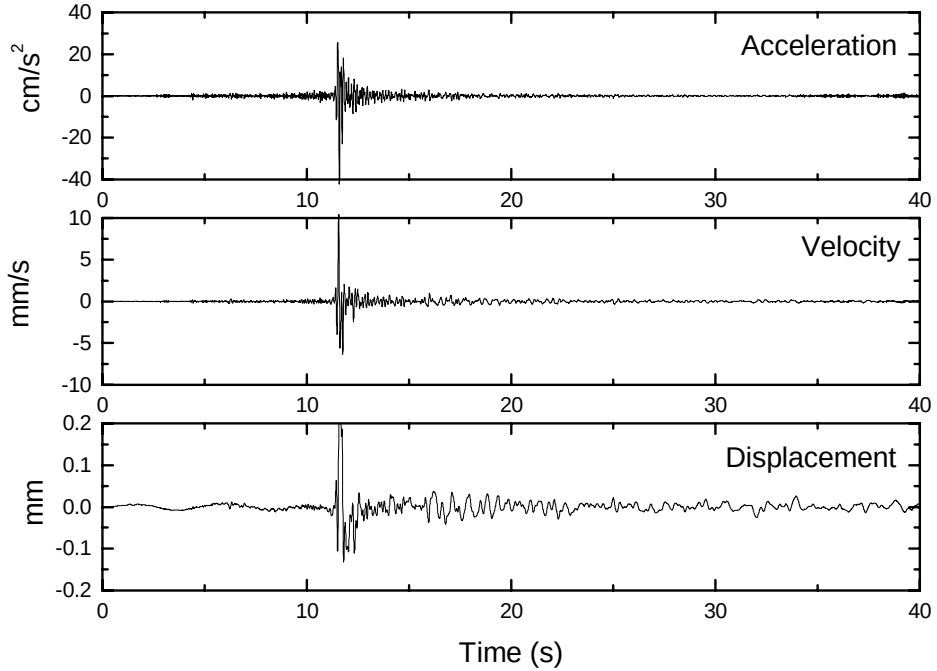


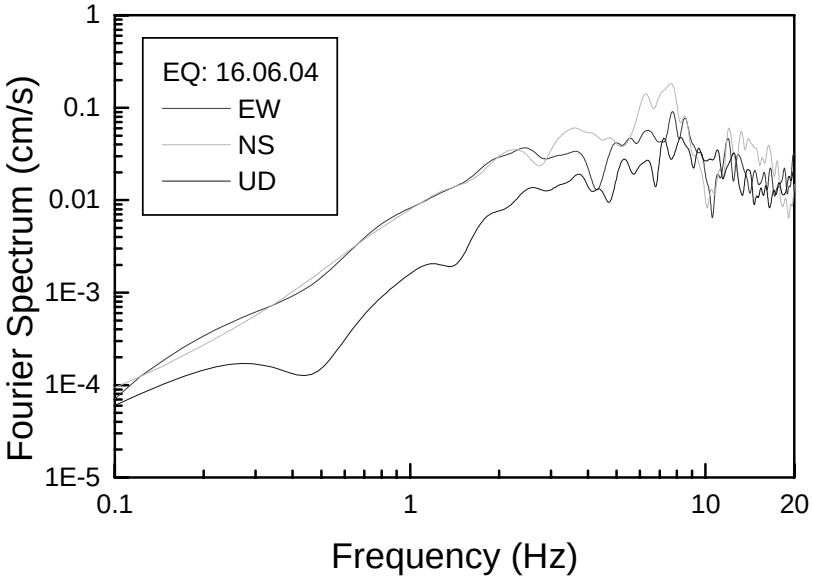
FF-WEST





West Free-field (NS-component; 16.06.04)

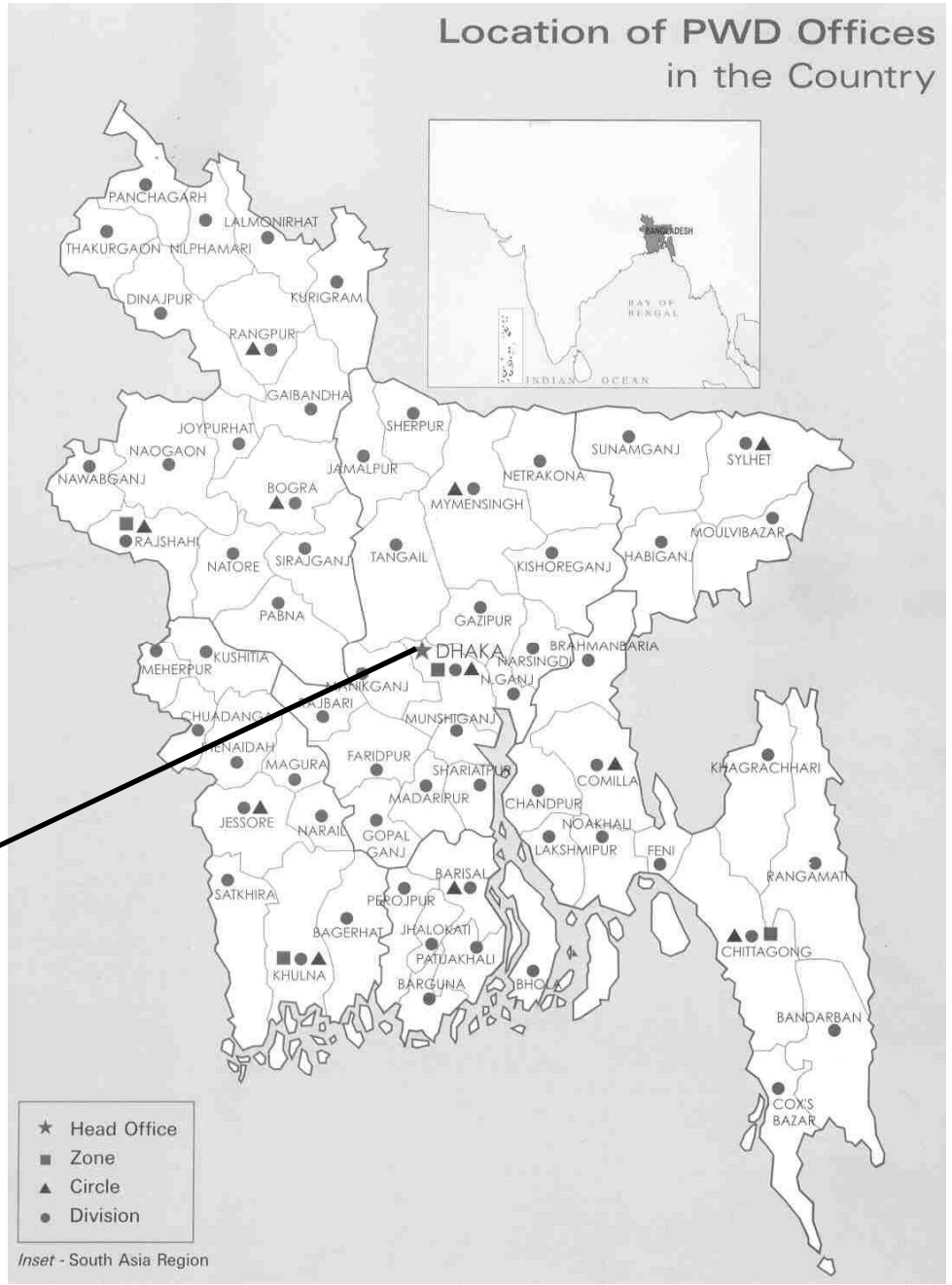




COSMOS-WSSI Project

(60 SMA-1 Type Accelerographs)

Equipment donated by USGS in 2005



Microzonation Maps based on SPT-N value and Microtremor Study

COMBINED HAZARD INTENSITY MAP FOR DHAKA, BANGLADESH

Thank You