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SEISMICITY AND TECTONICS OF BANGLADESH *

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ABSTRACT

Northern and eastern Bangladesh and surrounding areas belong to seismically active zone and associated with the subduction of the Indian plate. The seismicity and tectonics have been studied in detail and the observations have been correlated to understand the earthquake phenomenon in the region. The morphotectonic behaviour of the northern Bangladesh shows that it is deeply related to the movement of the Dauki fault system and relative upliftment of the Shillong plateau. Contemporary seismicity in the Dauki fault system is relatively quite comparing to that in the Naga-Disang-Haflong thrust belt giving rise to the probability of sudden release of energy being accumulated in the vicinity of the Dauki fault system. This observation corresponds with the predicted average return period of large earthquake (1897 type) and the possibility of $M > 8$ earthquake in the vicinity of the Dauki fault within this century should not be ruled out. The seismicity in the folded belt in the east follows the general trend of Arakan-Yoma anticlinorium and represents shallow and low-angled thrust movements in conformity with the field observation. Seismotectonic behavior in the deep basin part of Bangladesh demonstrates that an intraplate movement in the basement rock has been taking place along the deep-seated faults causing relative upliftment and subsidence in the basin. Bangladesh has been divided into three seismic zones on the basis of morphotectonic and seismic behaviour. Zone-I has been identified as the zone of high seismic risk.

1. INTRODUCTION

Bangladesh is surrounded by regions of high seismicity which include the Himalayan Arc and the Shillong plateau in the north, the Burmese Arc-Arakan Yoma anticlinorium in the east and the complex Naga-Disang-Haflong thrust zones in the northeast. It is also the site of the major Dauki fault system along with numerous subsurface active faults and a flexure zone to be called as Hinge zone. These weak zones are believed to provide with the necessary planes for movements within the basin area. Bangladesh experienced several historical great earthquakes during last the 100 years and has been affected by small earthquakes occasionally (Table 1 and Appendix A). The epincenters of large earthquakes lying beyond the border of Bangladesh equally effect the country for its morphotectonic continuity. The movement in the Dauki fault system influences the present configuration of the Surma basin and plays a vital role in the seismicity of the northern region of Bangladesh. The seismicity of Bangladesh is deeply related with tectonic behaviour in and around Bangladesh which is caused by the subduction of the Indian plate below the Tibet subplate in the north.

The present study attempts to relate the tectonics of the region with the seismicity in order to investigate earthquake phenomenon in Bangladesh. The primary objective of the study is to give seismotectonic definition of the region and to suggest a seismic zonation for minimizing earthquake damages. The secondary objective is to identify problems and to emphasize the importance of establishing appropriate seismic observatory for reduction of seismic risk in Bangladesh.

2. GEOLOGICAL SETTING

Bangladesh occupies a large part of the Bengal basin which is bounded by the peninsular shield area of Rajmahal Hills in the west, the Arakan-Yoma anticlinorium and the Naga-Lushai orogenic belts in the east, the Shillong plateau and the Himalayan foredeep in the north and the Bay of Bengal in the south (Fig.1). The pensinsular shield mainly consists of the Archean basement complex and the late Mesozoic volcanics of the Rajmahal Hills (Sengupta, 1966). The Archean basement exposed in the Shillong plateau on the north is virtually the northeasterly extension of the Indian shield through the Rangpur saddle. Upper Cretaceous and Tertiary sediments overlying basalt trap-flows occur in a narrow strip of the south Shillong plateau. The Arakan-Yoma folded belts extended towards north up to the Naga-Lushai thrust belts are composed of a zone of highly folded Tertiary sediments and bordered by complex thrusts systems. The Bay of Bengal on the south provides with an extended area of deposition of huge sediments, having an annual discharge of about 1 billion tons (Coleman, 1969) through the 'swatch

of no ground' to form the longest fan of the world - the Bengal Fan (300 km long) stretched up to latitude 7^{O}S (Curray and Moore, 1974).

Except for the eastern and northeastern regions (Chittagong, Chittagong Hill Tracts and part of Sylhet), Bangladesh is a flat basin deposited by huge alluvium carried by the Ganges, Brahmaputra and Meghna rivers which covers the area between the peninsular shield of India and Arakan-Yoma folded belts burying the older sediments of the basin. The delta thus formed in the subsided basin is attributed to be the largest delta of the world having an area of about 23,000 sq. miles which is about twice the size of the Mississippi delta (10,000 sq. miles) of the USA and the Niger delta (11,130 sq. miles) of Nigeria (Coleman, 1969).

The peninsular Indian shield is an old Craton where a Vindhyan series of lower Paleozoic age overlies Precambrian metamorphic and granitic rocks. The coal bearing Gondwana series (Carboniferous to Lower Triassic) are preserved in Synclines whereas the Cretaceous-Tertiary Deccan traps are generally eroded in the eastern part of the shield. The Shillong plateau and Mikir Hills are the two isolated blocks of exposed Indian shield associated with major fault systems and are the sites of frequent earthquakes (Gansser, 1964; Singh *et al.*, 1979; Verma *et al*, 1976; Gupta *et al.*, 1984 Richter, 1958). In between the Shilong plateau and main shield area in Rajmahal Hills, a depressed zone which was designated by Evans (1964) as 'Garo-Rajmahal Gap' and by Bakhtine (1966) as the 'Rangpur Saddle', has been interpreted as the edge of the subsurface Indian Craton. The basement contour and drilling data show that the depression represents a graben system and is not a 'gap' described by Evans (1964).

The Arakan-Yoma folded belt in the east is a mega-anticlinorium which is composed of north-south trending folds. The region has been designated by Raju (1968) as 'mobile belt' and is believed to have formed due to the subduction of the eastern boundary of the Indian plate below the Burmese subplate. The Arakan-Yoma folded belt has extended up to Bangladesh covering Chittagong Hill Tracts and part of Chittagong and Sylhet districts.

Subsurface drilling results and stratigraphy of the exposed rocks show that the sequence of rocks ranging from Upper Cretaceous to recent age have been deposited in Bangladesh. The Paleocene-Eocene rocks represented by the Chera, Sylthet and Kopili formations occurring in two distinct facies are deposited in shallow marine condition. Oliogocene rocks of Barail group found in Bangladesh have deposited in prograding deltaic environment. The Mio-Pliocene rocks (Surma, Tipam, Dupitila and Dihing groups) occurring in Bangladesh represent a deltaic deposits. Three relatively uplifted regions (Barind, Madhupur and Mainamati) known as Madhupur Clay of Pleistocene time lying over the flood plain are conspicuous (Morgan and McIntire, 1956) among the quartenary alluvium deposits occupying most part of Bangladesh. Apart from a small outcrop of the Sylhet Limestone of Eocene age (due to faulting in the Dauki fault system) in the Sylhet border area, the Miocene sequence of rocks are the oldest rock exposed in Bangladesh (restricted to eastern and northeastern zone).

3. TECTONIC SETTING

The tectonic and structural behaviour of Bangladesh and adjoining areas have been studied in connection with the geological survey and mineral exploration by different authors (Evans, 1959; Bakhtine, 1966; Raju, 1968; Alam, 1972; Desikachar, 1974; Mitra, 1971; Verma and Gupta, 1973; Guha, 1978; Brunnschweiller and Khan 1978; Hoque and Watney, 1982; Hossain and Akther, 1983; Leitz and Kabir, 1982; Hossain, 1986 and 1987; Khan *et al.*, 1988). The present study has summarized the knowledge of the tectonic set-up of Bangladesh (Fig.1) for comparison with the seismicity of the region. Bangladesh has been broadly divided into three major tectonic zones: (I) the shelf zone, (II) the hinge zone and (III) the Bengal foredeep zone.

I. THE SHELF ZONE

The shelf zone occupies the northwestern part of Bangladesh and is composed of the subsided pre-Cambrian Indian platform. Considering the depth of the basement rock and slope characteristics, the shelf has been subdivided into three parts: the Rangpur saddle, the Dinajpur slope and the Bogra slope (Bakhtine, 1968; Guha, 1978; Hossain, 1986). The thickness of the sedimentary cover on the central part of the saddle decreases and the shallowest part of the basement has been penetrated at about 150 meters in Madhyapara. According to Evans (1964), the Rangpur saddle area was considered as a 'gap' created by the strike-slip movement of the Dauki fault. Subsequent subsurface and geophysical studies gave no evidence of such a gap (Bakhtine, 1966; Sengupta, 1966; Murthy *et al.*, 1969, Brunnschweiller and Khan, 1978, Guha, 1978; Hoque and Watney, 1982). Murthy *et al.* (1969) indicated that the Dauki fault system demonstrates vertical movement.

Basement controlled lineaments obtained from aeromagnetic interpretation (Fig.2) show that the east-west, north-south and northeast-southwest trending lineaments occur in the shelf zone (Hunting Geology and Geophysics Ltd., 1980; Hoque and Watney, 1982). Basement contour and gravity contour maps also demonstrate as many as five basement depressions associated with faults in the region. Geological and geophysical investigation conducted in the western part of the Bengal basin (India) also identified subsurface faults: e.g. Malda fault and Bolepur fault (Sengupta, 1966; Chowdhury and Dulta, 1973). These subsurface and exposed faults are considered as responsible for the subsidence of the shelf region in the form of graben with respect to Rajmahal and Garo Hills (Horsts).

II. THE HINGE ZONE

The hinge zone is a narrow strip of about 25 Km wide complex flexure zone which separates the Bengal Foredeep from the shelf zone (Fig.1). It is characterized by the sharp change in dip of the basement rocks associated with deep-seated displacements in faults and is marked by the gravity and magnetic anomalies. The Eocene limestone dips at about 20^{0} in this zone compared to 2^{0}-3^{0} in the shelf zone. The seismic interpretation shows that the depth of the Sylhet limestone (seismic reflector) increases from 4000 to 9000 meter within a narrow zone of about 25 Km. The hinge zone trends approximately N30^{0}E along the Calcutta-Pabna Mymensingh gravity high and extends up to the western tip of the Dauki fault. During the subsurface interpretation of the southeastern part of the West Bengal in India, a zone of flexure in the top of the Sylhet limestone was recognized (Sengupta, 1966) which is the extension of the hinge zone in India.

III. THE BENGAL FOREDEEP

The Bengal foredeep occupies a vast area of Bangladesh between the shelf zone in the west and the Arakan-Yoma Hill Range in the east. It is characterized by the occurrence of deep subsided basement complex accomodating huge thickness of sediments which started to develop during the intense upliftment of the Arakan-Yoma anticlinorium in the Oligocene time. Based on the geotectonic behaviour, the Bengal foredep has been subdivided into two major parts: (a) a deep basin area and (b) a folded belt area.

(a) Deep basin area

The deep basin area of the foredeep is composed of huge thickness of sediments having two depressions (the Surma basin and the Patuakhali trough) separated by relatively uplifted Tangail-Comilla high (Fig.1)

The Surma basin lies in the north-eastern part of Bangladesh which was also known as Sylhet trough (Bakhtine, 1966; Guha, 1978) borders the most important Dauki fault system in the north. It is a fault bounded basin having history of subsidence from the Oligocene time reaching its peak in the Pliocene period (Holtrop and Keizer, 1970) and is the site of seven producing gas fields and an oil field. During the hydrocarbon exploration, eleven anticlines have been identified around the boundary of the basin. Most of the anticlines (eight) have been affected by NE-SW, N-S (longitudinal) and E-W (transverse) trending faults. The Dauki fault separating the Surma basin from the Shillong plateau has played an important role in the development of the basin. The deepest part of the basin lies in the Goyain trough adjacent to the Dauki fault system. The seismic reflection data in the basin show that the top of the Sylhet limestone is at a TWT about 7.5 seconds (on seismic line PK-SU6) which is equivalent to a depth of about 15,000 meters (Hiller and Elahi, 1984). The Sylhet limestone, on the other hand, outcrops on the surface just on the other side of the Dauki fault at Takerghat, Bagalibazar in Bangladesh and Meghalaya Hill slope in India. This enormous subsidence of the Surma basin and relative uplifment of the Shillong plateau along the Dauki fault system are responsible for the morphotectonic and seismic behaviour of the Surma basin.

A relatively uplifted zone separating the Surma basin from the Patuakhali trough is known as Tangail-Comilla high based on basement contour configuration (Fig.1). This narrow zone has subjected to recent movements evidenced by the upliftment of the Madhupur and Mainamati Pleistocene blocks and folding of Titas, Bakhrabad and Kamta anticlines.

The Patuakhali trough, previously known as Hatia trough (Bakhtine, 1966; Guha, 1978) is a large area embracing the Delta of Meghna and a vast area of the Bay of Bengal. It is the deepest trough in the Bengal foredeep formed by the relative subsidence of the basement complex along deep-seated faults.

(b) Folded belt

The folded belt area of the Bengal foredeep occupying the Chittagong Hill Tracts and Chittagong of Bangladesh is represented by the north-south stretching hills of sedimentary rocks. The belt is characterized by the gentle box-like north-south trending folds occasionally disrupted and complicated by numerous faults (Fig.1). It is believed to be the western extension of the Arakan-Yoma anticlinorium. Most of the folds have gentler dipping in the western flank compared to the eastern flank and the associated synclines are wider than anticlines. The intensity of folding increases towards east demonstrating the influence of the tectonics forces created by the overriding Burmese plate on the Tertiary sediments of the folded belt (Hossain, 1987). Numerous longitudinal faults and box-shaped plunging folds in the belt demonstrate the evidences for differential vertical movement of the basement blocks. Similar structures have been reported to be developed in the Tripura and Surma Valley of India by relative upliftment of the crystal blocks (Mitra, 1971) which has also been confirmed by the abnormal gravity anomaly and elevation relationship (Verma *et al.*, 1976). From the above observation, it can be inferred that the folded belt of the Bengal foredeep has developed due to both horizontal east-west compression and differential vertical crustal movements caused by the relative plate motion.

4. SEISMICITY

Northern and Eastern Bangladesh and the adjoining regions lie in the most seismically active zone in the world. Historical records (Table 1) show that at least seven large earthquakes (three of them having $M > 8$) in and around Bangladesh have occurred during the last one hundred years. Among these great earthquakes, Bengal earthquake of 1885 and Srimangal earthquake of 1918 having $M > 7$ had their epincenters located in Bangladesh. Although the region is within the seismic zone, no detailed work has been done in the field so far except for a preliminary unpublished report on the seismic zonation of Bangladesh by the Geological Survey of Bangladesh (1979).

The earthquake data used for the present study have been obtained from the NOAA catalogue covering 1900 - April 1988. In the catalogue, earthquake magnitudes were not identified as M_s or M_b prior to 1963 and hence, the magnitude appeared before 1963 was assumed as body wave magnitude for analysis and comparison. A subcatalogue of Bangladesh covering latitude 20°-27° N and longitude 88°-93° E has been prepared using the computer and the earthquake event having magnitude $M_p \geq 5$ (prior to 1963) and $M_b \geq 4$ (after 1963) have been listed in Appendix A. The events prior to the NOAA range have been collected from Goswami and Sarmah (1982) and also recorded in Appendix A. The epicenters of the listed earthquake events have also been plotted in Fig.5. Since the NOAA catalogue prior to 1963 is not complete, an anlysis of earthquake events in Bangladesh (including the Shillong plateau) from 1963 to April 1988 has been made and the magnitude-frequency distribution for every year has been evaluated which is shown in Table 2.

The northern and eastern regions adjoining Bangladesh are much related morphotectonically that the analysis of seismicity of Bangladesh without considering the adjoining areas will be incomplete and unrealistic. From the records of Indian great earthquakes it has been observed that all the great earthquakes located in India have caused damage in part and affected Bangladesh. The western Assam earthquake of 1897 is probably a well documented earthquake in India in this respect (Oldham, 1899; Ricther, 1958; Mathur and Evans, 1964; Seebers and Armbruster, 1981). Surface effects of the western Assam earthquake of 1897 has been mapped on the map of Bangladesh according to Oldham (1899) and Seeber and Armbruster (1981) which is shown in Fig.3. The intensity distribution in Bangladesh shows that the limit of damage represented by the Mercalli scale VII-VIII (ME) has been extended up to the southern districts of Bangladesh. The ME VIII-IX representing the limit of intense fissures and vents have spread up to Dhaka causing major damages in the northern district of Bangladesh.

The seismicity of the northeastern regions of India has been addressed by many authors (Chouhan *et al.*, 1966; Fitch, 1970; Kaila *et al.*, 1972; Rastogi *et al.*, 1973; Verma *et al.*, 1976). Inspection of the seismicity map of the region (Fig.4) shows that the Arakan-Yoma anticlinorium in the east, the Naga-Disang-Haflong thrust zones in the northeast, the Himalayan Arc, the Shillong plateau and the Dauki fault system in the north are seismically the most active zones. Having natural extension and morphotectonic similarity, the northern and eastern parts of Bangladesh belong to the same seismic zone (Fig.4). A remarkable linear distribution of earthquake epicenters along the Dauki fault indicates some activities (relatively quite) along the fault zone.

The Burmese Arc and the adjoining Arakan-Yoma anticlinorium are another potential seismic area to be accounted for the treatment of the eastern region of Bangladesh. The seismicity of the Burmese Arc and adjoining areas have been studied by several authors (Santo, 1969; Fitch, 1970; Chandra, 1975, 1978; Verma *et al.*, 1978; Khatri *et al*, 1984; Le-Dain *et al.*, 1984; Mukhapadhya and Dasgupta, 1988). Focal mechanism solutions in the region show mostly thrusting behaviour related to the Benioff zone seismicity. Relatively shallow depth earthquakes in the Arakan-Yoma region responsible for lateral faulting have also been indicated in the region which suggests E-W compression due to the subduction of Indian plate and overriding of the Burmese plate.

5. SEISMOTECTONICS

The epincenters of earthquake events obtained from the NOAA catalogue for the period of 1963-88 and prior large events recorded in the catalogue of Indian Meteorological Department (IMD) taken from Goswami and Sarmah (1982) have been plotted in the generalized tectonic map of Bangladesh (Fig.5). The distribution of epicenters are found to be linear along the Dauki fault system and random in other regions of Bangladesh. The investigation of the map (Fig.5) demonstrates that the epicenters are lying in the weak zones comprising surface or subsurface faults. It is observed from the magnitude of the events that most of the events are of moderate rank (M_b = 4-6) and lie at a shallow depth which indicates the recent movements in the sediments overlying the basement rocks. In the north-eastern region (Surma basin), major events are controlled by the Dauki fault system and hence the Dauky fault system should be carefully observed. The earthquake events in the folded belt demonstrate shallow and low-angled thrust behaviour which is conformable with the tectonic configuration of the region. The events located in and around Madhpur terrace block also indicate shallow displacements in the faults separating the block from the host alluvium. Two events located in Manikganj can be related with the sub-surface Jamuna fault and should be studied carefully before the construction of heavy engineering structure across the Jamuna river.

Bangladesh has been divided into three generalized seismic zones: zone-I, zone -II and zone-III on the basis of the distribution of earthquake epincenters and morphotectonic behaviour of the different tectonic blocks (Fig.6). Zone-I comprising the northern and eastern regions of Bangladesh is the most active zone with basic seismic coefficient of 0.08. Zone-II represents the regions of recent uplifted Pleistocene blocks of the Barind and Madhupur and the western extension of the folded belt. Zone-III is seismically inactive zone with estimated basic seismic coefficient of 0.04. The modified Mercalli scale of intensity (ME) has been assigned for each zone which is summarized in Table 3.

The present seismic zoning has been made on the basis of firm ground condition which is not true for Bangladesh. Within the same seismic zone, the ground condition ranges from soft and highly permeable soils to compacted and bedded rocks. The engineering structures built on soft and unstable soils (like in char or sand bars) with water content are likely to suffer more damage than those built on relatively stable and

bedded rocks. Hence, the intensity of earthquake may vary in the same seismic zone due to the variability of the ground condition.

6. DISCUSSION AND CONCLUSION

Historical records of two large earthquakes ($M > 7$) and occurrences of smaller events in Bangladesh (Appendix A) show that the northern and eastern regions of Bangladesh are seismically active. The epicenter of the 1885 Bengal earthquake has been located neat Manikganj. Although the recording of the location is not very accurate, it is seen that the event is generally associated with the deep-seated Jamuna fault. The epicenter of the 1918 Srimangal earthquake shows that the fault nearby Srimangal has been fractured by the 1918 earthquake. The epicenter of the 1897 west Assam earthquake was not known, but it is believed that it was located somewhere in the Shillong plateau and caused due to fracturing in the Dauki fault system. This earthquake damaged the northern part of Bangladesh and hence the large events occurring in the surrounding areas are also matter of concern for Bangladesh.

The average return period of earthquakes in the northeast region has been studied by Goswami and Sarmah (1982) and it was predicted that the largest annual earthquake expected to occur on the average in 50 years to be about M = 7.8-8.8 and in every 100 years to be about M = 8.3-9.3 (type-I distribution). 1897 type of earthquake ($M > 8$) in the vicinity of the Dauki fault has a return period of about 100 years and it is seen from the record that 1897 type earthquake has not occurred in the region since then. It is also observed from the seismicity that the Dauki fault region is relatively quite while the Naga-Disang-Haflong thrust zone in the northeast is seismically more active. Activities in the thrust zone may develop stress concentration in the vicinity of the Dauki fault system. Hence, it is suggested here that a careful study should be conducted to identify premonitory earthquake precursors in the region.

The seismitectonic map of Bangladesh shows that the epicenter locations have conformity with the present knowledge of faulting and other structural behaviours of the region. Earthquake events in the shelf zone are random and follow the occurrence of the subsurface faults. The Barind and Madhupur Pleistocene terraces have a recent history of upliftment evidenced by the changes of river courses (Hossain, 1986) and other geomorphological changes (Morgan and McIntire, 1956). The seismicity around the Madhupur terrace block suggests that the movements along the boundary faults responsible for the upliftment of the blocks are still active.

From the present investigation and discussion the following conclusions can be made:

a) The northern and eastern parts of Bangladesh lie in the seismically active zone. The region is also surrounded by most active seismic zones which influence the seismicity of Bangladesh.

b) The large earthquake events in India adjoining Bangladesh caused damage in the region and hence seismicity of Bangladesh should be considered regionally.

c) Historical record and predicted return period for large earthquake (M > 8) in the northeastern India shows that 1897 type of earthquake may occur in the vicinity of the Dauki fault system within the end of this century. It is suggested that an extensive investigation should be undertaken to identify earthquake precursors for reducing seismic risk in the region.

d) On the basis of morphotectonic behaviour and seismicity a seismic zoning map of Bangladesh has been prepared and Bangladesh has been divided into three generalized seismic zones.

e) The seismicity in the deep basin part of Bangladesh demonstrates deep-seated movements in the basement rocks causing upliftment and subsidence. The seismicity in the folded belt (eastern part of Bangladesh) suggests crustal shortening due to the subduction of the Indian plate and overriding of the Burmese plate from the east.

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APPENDIX A

List of major earthquakes in Bangladesh ($M_p > 5$; $M_b > 4$) from 1762 - April 1988
(source: NOAA catalogue and IMD data obtaine'd from Goswami and Sarmah, 1982)

PERIOD			LOCATION		MAGNITUDE (M_p/M_b)
Year	Month	Day	Latitude (° N)	Longitude (° E)	
1762	4	2	22.0	92.0	$M_p = 7.5$
1830	12	31	22.0	91.0	$M_p = 5.0$
1845	8	6	24.8	91.8	$M_p = 6.5$
1846	10	18	24.0	90.0	$M_p = 6.0$
1885	7	14	24.0	90.0	$M_p = 7.0$
1918	7	8	24.5	91.0	$M_p = 7.6$
1927	8	25	22.0	90.0	$M_p = 5.5$
1935	3	21	24.4	89.5	$M_p = 5.3$
1942	2	21	24.0	90.3	$M_p = 5.9$
1944	12	24	24.7	92.2	$M_p = 5.9$
1950	12	24	24.4	91.7	$M_p = 6.3$
1955	12	14	22.0	92.5	$M_p = 6.5$
1956	6	12	24.8	90.9	$M_p = 5.3$
1957	12	12	24.5	93.0	$M_p = 5.5$
1958	2	9	24.9	90.9	$M_p = 5.0$
1966	6	5	24.6	93.4	$M_b = 4.1$
1967	11	14	24.0	91.5	$M_b = 5.1$
1968	6	12	24.9	91.9	$M_b = 5.3$
1969	1	25	22.9	92.3	$M_b = 5.2$
1970	8	28	24.7	91.7	$M_b = 4.9$
1971	2	2	23.8	91.8	$M_b = 5.4$
1974	1	20	22.8	92.9	$M_b = 4.8$
1976	1	18	23.6	90.8	$M_b = 4.0$
1976	6	23	21.42	88.79	$M_b = 5.3$

APPENDIX A (cont.)

PERIOD			LOCATION		MAGNITUDE (M_p/M_b)
Year	Month	Day	Latitude (° N)	Longitude (° E)	
1977	12	23	23.6	92.4	$M_b = 5.1$
1978	3	28	23.2	92.9	$M_b = 4.8$
1978	4	7	22.6	92.4	$M_b = 4.6$
1979	1	28	24.61	91.17	$M_b = 4.7$
1979	4	11	25.98	88.82	$M_b = 4.8$
1979	5	2	23.97	92.45	$M_b = 4.7$
1980	10	30	23.93	91.29	$M_b = 5.0$
1980	12	22	26.34	89.31	$M_b = 4.5$
1981	11	20	21.69	90.77	$M_b = 4.2$
1982	1	11	24.7	92.07	$M_b = 4.7$
1982	1	28	25.17	90.66	$M_b = 4.2$
1982	8	21	25.05	92.34	$M_b = 4.7$
1982	8	31	25.38	91.47	$M_b = 5.0$
1982	9	21	25.15	91.40	$M_b = 4.6$
1984	5	21	23.72	91.59	$M_b = 5.3$
1985	11	3	23.58	91.50	$M_b = 4.9$
1986	2	19	25.13	91.18	$M_b = 5.3$
1986	9	10	25.38	92.07	$M_b = 5.2$
1986	10	14	25.03	91.97	$M_b = 4.7$
1987	4	29	22.46	92.41	$M_b = 5.3$
1987	7	16	23.70	91.41	$M_b = 4.4$
1987	9	3	21.27	92.17	$M_b = 4.8$
1987	9	5	23.85	92.18	$M_b = 4.8$
1988	2	6	24.65	90.48	$M_b = 5.8$

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TABLE 1

Great historical earthquakes in and around Bangladesh (M > 7)

DATE	NAME	EPICENTER	MAGNITUDE (M)
10th Jan. 1869	Cachar earthquake	Jantia Hill, Assam	-
14th July 1885	Bengal earthquake	Manikganj, Bangladesh	7.0
12th July 1897	West Assam earthquake	Shillong Plateau	8.7
18th July 1918	Srimangal earthquake	Srimangal, Sylhet	7.6
3rd July 1930	Dhubri earthquake	Dhubri, Assam	7.1
15th Jan. 1934	Bihar earthquake	Bihar, India	8.3
15th Aug. 1950	Assam earthquake	Assam, India	8.4

TABLE 2

Magnitude-Frequency Distribution of earthquake events in Bangladesh (including shillong plateau) from 1963 to April 1988.

	MAGNITUDE								
D-M-YEAR	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	Total events
10-1-1963	1	.	.	.	2	2	.	.	5
10-1-1964	.	.	.	.	2	1	.	.	1
10-1-1965	1	.	.	.	.	1	.	.	1
10-1-1966	.	.	.	.	3	1	.	.	4
10-1-1967	.	.	.	.	1	3	.	.	4
10-1-1968	.	.	.	.	2	3	.	.	5
10-1-1969	1	.	.	.	2	3	.	.	6
10-1-1970	.	.	.	.	1	1	.	.	2
10-1-1971	.	.	.	.	2	1	.	.	3
10-1-1972	.	.	.	.	1	.	.	.	1
10-1-1973	.	.	.	.	2	.	.	.	2
10-1-1974	.	.	.	.	3	.	.	.	3
10-1-1975	.	.	.	.	.	.	.	.	0
10-1-1976	1	.	.	.	.	1	.	.	2
10-1-1977	1	.	.	.	2	2	.	.	5
10-1-1978	.	.	.	.	5	.	.	.	5
10-1-1979	.	.	.	.	6	.	.	.	6
10-1-1980	.	.	.	.	2	1	.	.	3
10-1-1981	.	.	.	.	1	.	.	.	1
10-1-1982	1	.	.	.	9	3	.	.	14
10-1-1983	.	.	.	.	1	2	.	.	3
10-1-1984	.	.	.	.	1	4	.	.	5
10-1-1985	.	.	.	.	2	.	.	.	2
10-1-1986	1	.	.	.	3	4	.	.	8
10-1-1987	.	.	.	.	6	2	.	.	8
10-1-1988	.	.	.	.	1	.	.	.	1
Total events	6	0	0	0	57	36	0	0	99

TABLE 3

Characteristic features of the seismic zonation of Bangladesh

ZONING	AREA	MODIFIED MERCALLI'S SCALE (ME)	BASIC SEISMIC COEFFICIENT (Z)
ZONE-I	North and eastern regions of Bangladesh	IX	0.08
ZONE-II	Barind, Madhypur region, Dhaka, Comilla, Noakali belt	VIII	0.05
ZONE-III	Khulna Division (south-west Bangladesh)	VII	0.04

FIGURE CAPTIONS

Fig. 1 Tectonic setup of Bangladesh and adjoining areas (source of compilation: Alam, 1971; Bakhtine, 1966; Sengupta, 1966; Guha, 1978; Brunnsweiller and Khan, 1978; Hoque and Watney, 1982; Hossain and Akther, 1983; Hossain, 1987; Khan *et al.*, 1988).

Fig. 2 Basement controlled lineaments in Bangladesh (source: Hunting Geology and Geophysics Ltd., 1980; Hoque and Watney, 1982).

Fig. 3 Surface effects of 1897 western Assam earthquake in Bangladesh (compiled from Oldham, 1899; Seeber and Armbruster, 1981).

Fig. 4 Seismicity map of Bangladesh and the adjoining areas for the period 1890-1970 after Verma *et al.* (1976).

Fig. 5 Seismotectonic map of Bangladesh (epicenter locations are from Appendix A).

Fig. 6 Seismic zoning map of Bangladesh.

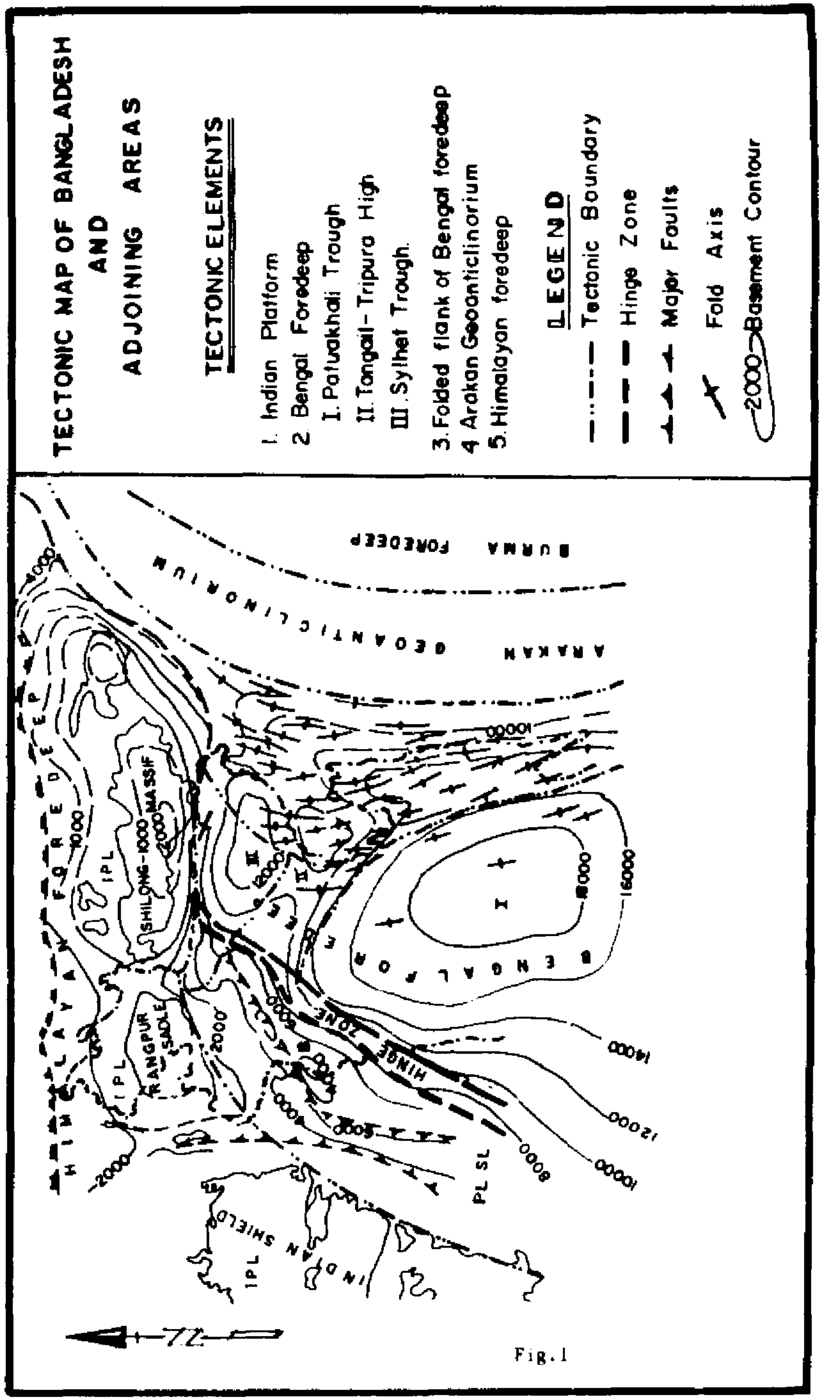

Fig. 1

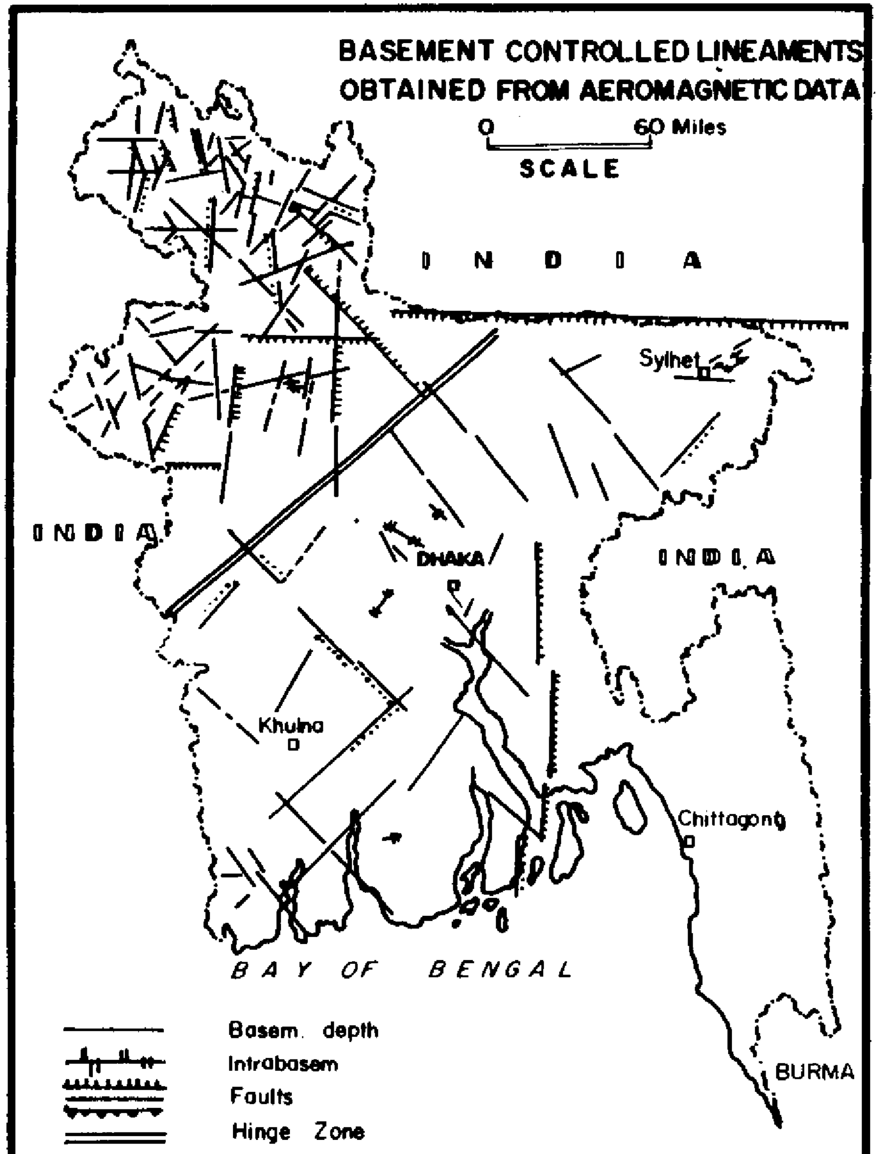
BASEMENT CONTROLLED LINEAMENTS
OBTAINED FROM AEROMAGNETIC DATA
0 60 Miles
SCALE
INDIA
Sylhet
INDIA
DHAKA
INDIA
Khulna
Chittagong
BAY OF BENGAL
BURMA
Basem. depth
Intrabasem
Faults
Hinge Zone

Fig.2

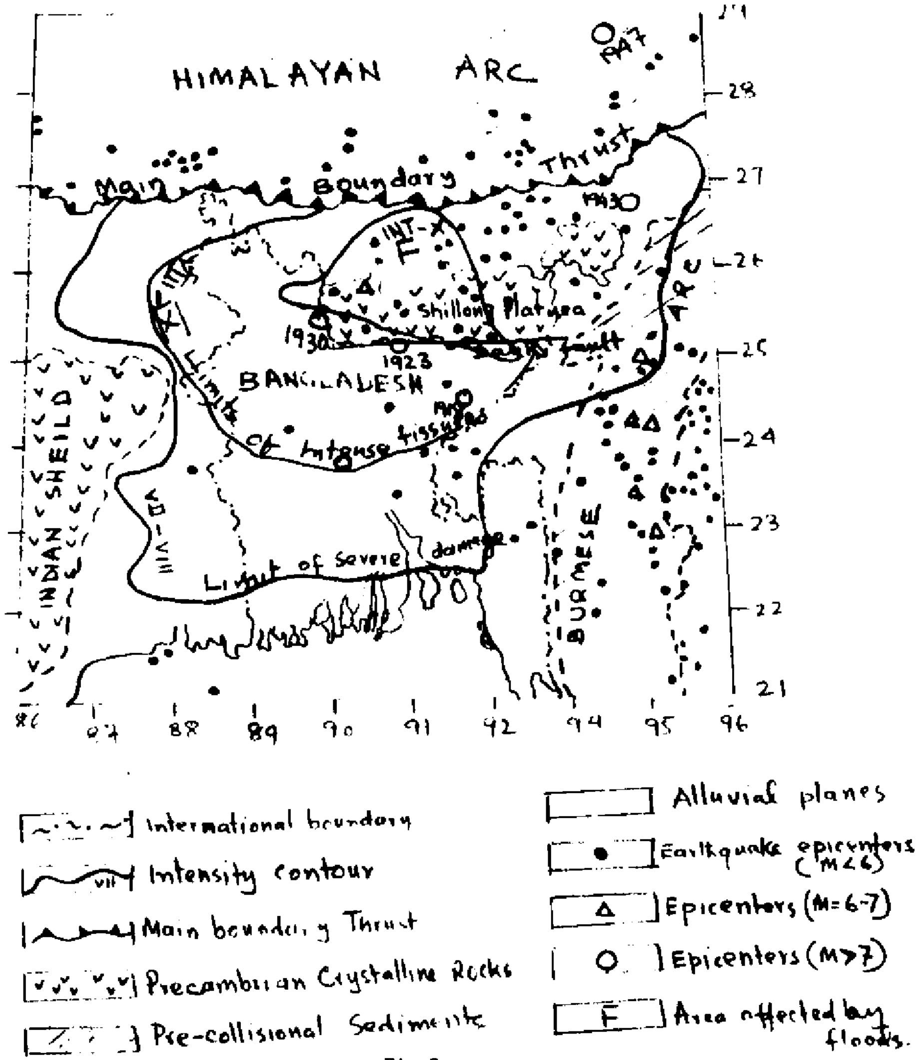
HIMALAYAN ARC
Main Boundary Thrust
Shillong Plateau
1930
1923
BANGLADESH
Limit of Intense fissures
Limit of Severe damage
INDIAN SHEILD
BURMESE
Alluvial planes
International boundary
Earthquake epicenters (M<6)
Intensity contour
Epicenters (M=6-7)
Main boundary Thrust
Epicenters (M>7)
Precambrian Crystalline Rocks
Pre-collisional Sediments
Area affected by floods.

Fig.3

SEISMICITY MAP OF BANGLADESH AND THE ADJOINIG AREAS

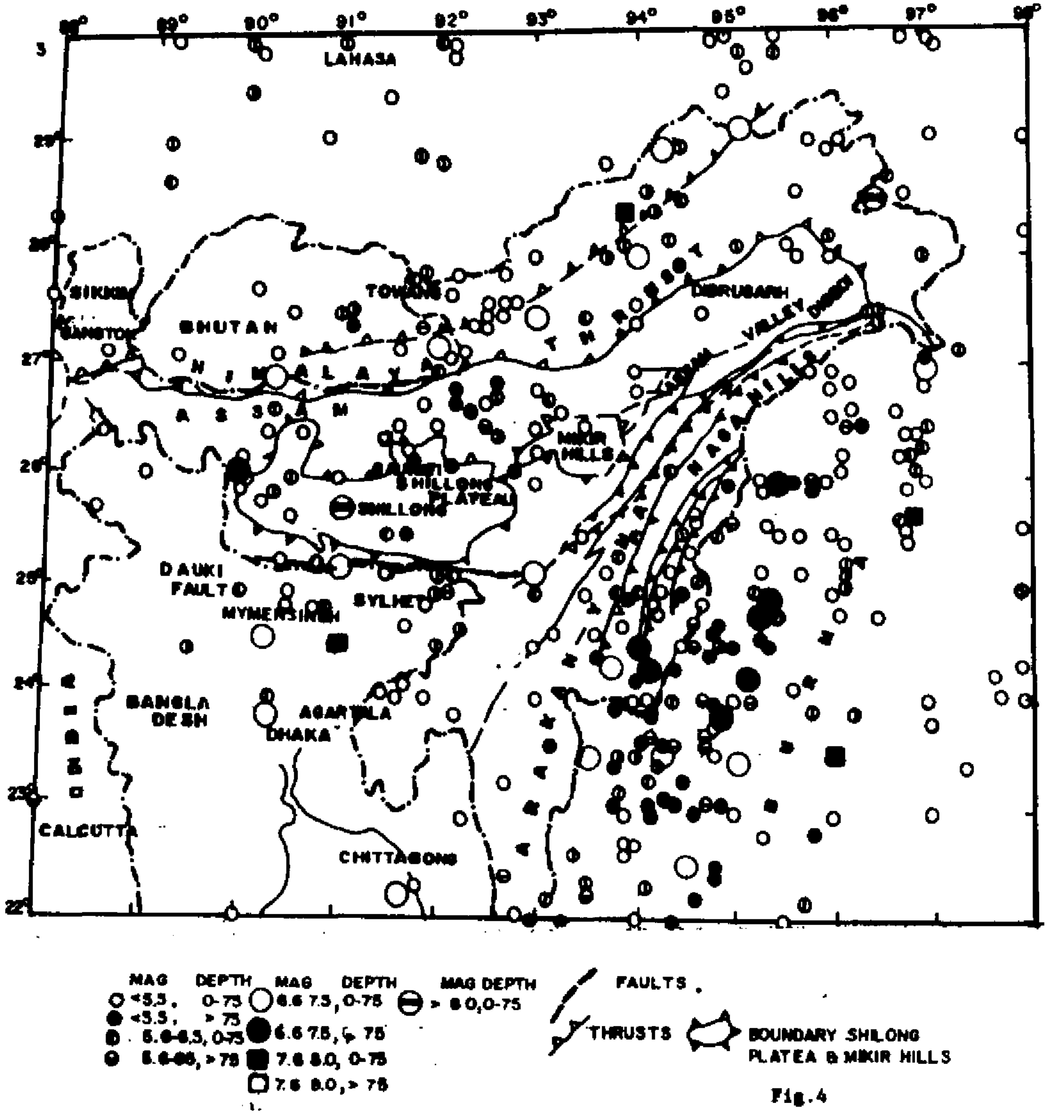

Fig.4

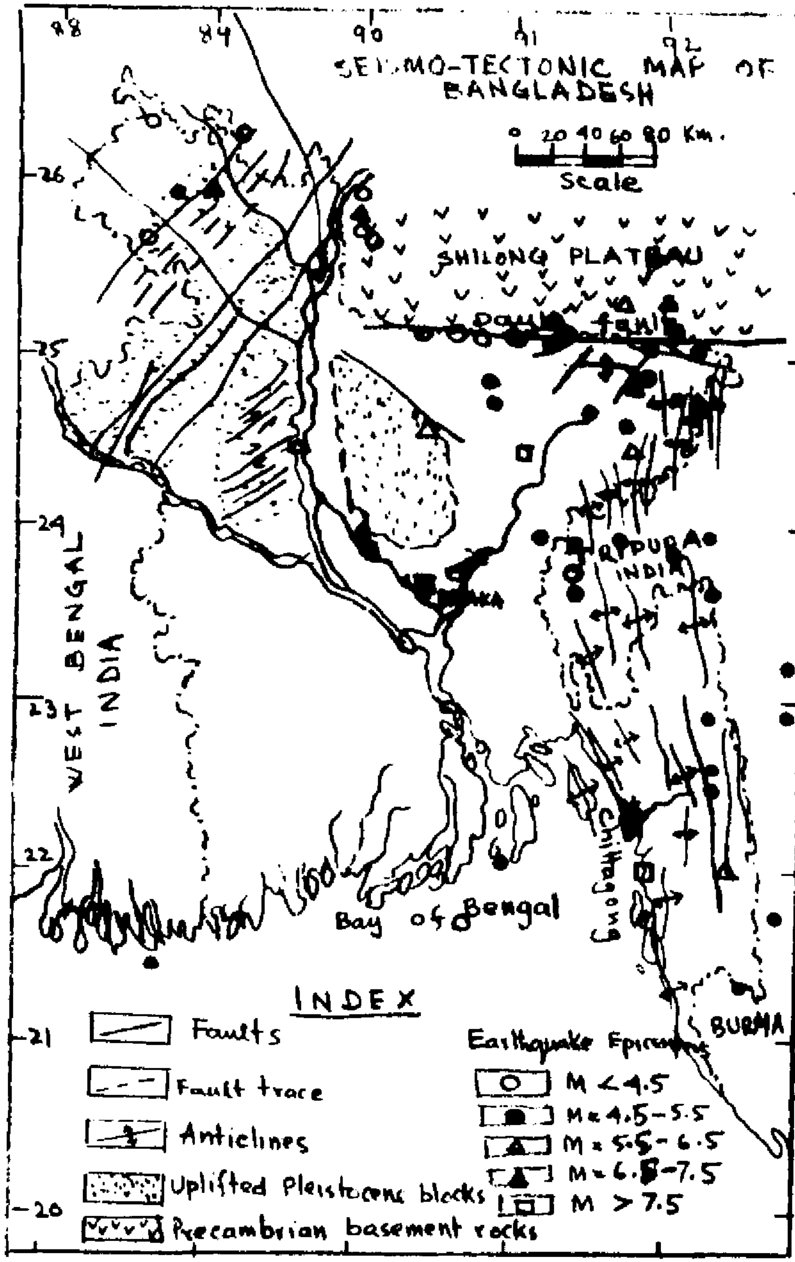

Fig.5