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SPATIO TEMPORAL SEISMICITY PATTERNS PRECEDING BIHAR - NEPAL AND MANIPUR BURMA BORDER EARTHQUAKE OF 1988

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ABSTRACT

The space and time variations of seismic activity preceding Bihar Nepal (M_B 6.5) and Manipur Burma (M_B 6.8) border earthquakes of 1988 have been examined and compared with those of 1968 and 1978 (Himachal Pradesh) and 1966 and 1980 (Nepal West Uttar Pradesh Hills). It was found that the seismicity pattern preceding Manipur Burma border earthquake was broadly similar to that of the earthquakes of 1968, 1978 and 1980 in western Himalayas namely increase in seismicity followed by seismic quescence. However, the logarithm of the quiescent area was not proportional to the magnitude of the impending earthquake. Such a pattern of seismicity did not develop in the case of Bihar Nepal Earthquake of 1988. However, increase in seismicity through the occurrence of earthquakes of magnitude 2 less than that of the mainshock was noted.

INTRODUCTION

Seismicity patterns preceding earthquakes help in understanding the earthquake preparatory process. A global survey of seismicity patterns before major subduction zone events has shown significant variations depending upon the heterogeneity and the complexity of the individual fault zones (Kanamori, 1981). In the Himalayan region, the continent - continent type of collision due to Indian and Eurasian plates gives rise to earthquakes of moderate to great intensity. Fault plane solutions of earthquakes bring out the complexity in the regional tectonics wherein the transverse faults are also occasionaly activated in addition to the northwesterly oriented Main Boundary or Main Central thrusts, (Srivastava and Chaudhary, 1979, Srivastava et.al. 1987 and others). Thus this region calls for greater efforts to identify the patterns of seismicity as a tool for earthquake prediction.

During August, 1988, two moderate earthquake occurred near Nepal-India (21 August) and Indian Burma border (6 August) regions which caused significant damage. The object of this paper is to study the seismicity patterns preceding these two earthquakes and compare them with the results of other Himalayan earthquakes.

GEOTECTONICS, FIELD AND STRONG MOTION OBSERVATIONS

The region where Nepal–India border earthquake occurred had its epicentral tract within Nepal as well as India. As is well known, Bihar-Nepal border region is close to the main boundary fault to the north and the Indo-Ganges plains in the South. The landsat imagery shows several lineaments transverse to the Himalayan front of which mention may be made of Patna fault and Tista lineament. Seismicity map of the region shows concentration of earthquakes epicentres near Dharachula region in the West and Sikkim India-Nepal border in the East (Srivastava, 1989).

However, the seismic activity near the August, 1988 earthquake has been less marked except for the great earthquake of 1934 (magnitude 8.4) causing a loss of about ten thousand lives and great destruction to buildings.

The N.E. Indian Region has been classified into five geotectonic units (Mazumdar and Nageswaram, 1988). The earthquake of August 6, 1988 occurred near Naga thrusts. Several earthquakes of intermediate depth in the range of 100 to 180 km occur rather frequently, the shock of 14th August, 1932 and the Manipur Burma earthquake of 22nd March, 1954 exceeded magnitude 7 in this region.

Field studies of the earthquakes of Bihar India and India-Burma border regions were undertaken by the Geological Survey of India, India Meteorological Department and several other geophysical institutions in the country. The maximum intensity within Nepal was VIII mm close to the epicentre of August 1988 earthquake with a small secondary maximum of intensity slightly to the west of Kathmandu and near Monger. It was interesting to note that the old buildings which were constructed 50 to 60 years ago were generally damaged by this earthquake. The pattern of damage was generally similar to that of the great Bihar-Nepal earthquake where the maximum intensity in mm scale in Bihar exceeded XI while near Kathmandu it had reached X mm. Sato and Kiyono (1989) have computed theoretical distribution of the maximum acceleration in the region near the earthquake source.

No significant damage was reported for Burma-India earthquake of August 1988. It showed a typical pattern of seismic intensity distribution as has been observed in the past during the earthquake of 1954 which had almost a similar magnitude but larger focal depth of 180 km, (Tandon, 1956). The earthquake was felt over a wider region whose vibrations continued for a few minutes.

4 strong motion seismic arrays have been installed in north East India through the University of Roorkee as a part of the project of the Department of Science and Technology, (Chandrasekaran and Das, 1988). While this array had also timing system, a network of indigenous strong motion instruments without time keeping had been in operation in Bihar in addition to several structural response recorders in both these regions. The structural response recorders indicated that the maximum displacement was almost oriented northsouth at Jangbani, Dharbanga, Biharganj, Mitia, Barauni, Madhubani, Marligang, Muzaffarpur, Nirmali and Samastipur.

The structural response recorders of Burma India earthquake showed an east west trend. Comparison of the acceleration recorded by the recent earthquake with that of 1954 earthquake showed that the duration of shaking and the acceleration was much larger in the case of earthquake of August, 1988 even though both had similar magnitude, (Tandon 1956, Roorkee University Report 1989). This is attributed to the relatively lesser focal depth of the recent earthquake.

DATA ANALYSIS

The epicentral parameters of earthquakes originating in Bihar-Nepal and Indo-Burma regions August, 1988 are given in Table 1. It is interesting to note that the Bihar-Nepal earthquake had a focal depth of about 70 km which is larger than that reported for most of the earthquakes since their focal depths are generally confined to the basement of granitic layer. Although exact crustal structure of this region is still not available but considering similar studies near Dharachula regions, (Srivastava, 1973) the estimates of the depth of Moho is not likely to exceed 45 to 50 km implying that the recent earthquake occurred in the upper mantle. The focal depth of the earthquake was recomputed by U.S.G.S. by inclusion of the data of all Indian stations in the vicinity, (Personal communication). It was found that the inclusion of this data increased the focal depth further. Accordingly,

the depth was restrained to 70 km on the basis of the phase identified in the seismograms at a few global seismological stations. Negative P-wave residuals of the order fo 2.5 to 6.5 sec. were found for the nearby stations which was attributed to the use of Jeffreys Bullen model which does not fit for continental areas in the epicentral range of 5 to 15Km or so.

The earthquake was accompanied by a few aftershocks which were reported by the US-Geological Survey. However, as there was no control from the northern side, the epicentral parameters of these aftershocks could also not be improved by the inclusion of the data of the Indian stations. The Burma Indian earthquake was also followed by a few aftershocks only. Compared to Nepal India earthquake, the aftershocks were however, localised over a much smaller area.

FOCAL MECHANISM AND REGIONAL TECTONICS

Based upon the P wave first motion data recorded at world wide stations, the focal mechanism was studied for these earthquakes. Figure 1 shows the focal mechanism of Bihar-India earthquake after including the data of Indian stations. One of the nodal planes was oriented in NE dipping towards NW direction while the other nodal plane showed orientation along NW direction with larger dip towards SW. The aftershock observations did not enable us to distinguish the fault plane from the auxiliary plane. Nevertheless, the orientation of the iso-seismals and the data from structural response recorded indicates that the north east oriented fault could be responsible for this earthquake. Shallow dipping pressures were acting from southerly direction. The nature of movement was thrust type on NE oriented fault with a strike slip component.

The UG Geological Survey reported the fault plane parameters of the Burma-India earthquake as follows :

Nodal plane 1 had a strike of 290 with a dip of 45 and slip as 65. The other nodal plane had a strike of 143 with dip angle of 50 with slip of 113. The pressures were very shallow (3) and acting from SSW direction. The focal mechanism showed thrust faulting with a moderate strike slip component but the preferred fault plane could not be determined. The number of aftershocks of this earthquake were also rather small to resolve the ambiguity in the nodal planes. The seismic moment using the broad band data was reported as 8.9×10^{19}.

SPATIO TEMPORAL VARIATION OF SEISMICITY PATTERN

Figure 2 shows the space time change in the seismic activity within 300 km from the epicentre of Bihar Nepal earthquake for the years 1964 and 1988. It may be noticed that with the exception of earthquake of 1967 within the epicentral distance of 50 km of August, 1988 earthquake, the seismic activity was generally confined at a distance of 100 to 300 km away from the epicentral area. However the seismic activity showed an increase with a large number of earthquakes of magnitude about 4.5 from 1986 onwards with one of the events at a distance of about 20 km during April 1988. It may be noticed that the occurrence of seismic activity in this region does not show a well-defined seismic gap or the doughnut shaped pattern (Mogi, 1979).

Figure 3 shows the seismic activity upto a distance of 200 km from ther epicentre of the Indo-Burma earthquake of August 1988. It is seen that there has been a well-defined clustering of seismic activity at an epicentral distance of 20 km during 1981-83 which started receding temporarily and extending upto a distance of about 200 km. While the seismic activity at a distance of about 25 km

showed earthquakes of magnitude of 4.5 to 4.9, a well defined seismic gap developed between 25 km to 75 km till the occurrence of earthquake of August, 1988. Thus the seismicity pattern was broadly similar to that of earthquakes of 1968, 1978 (H.P.) and 1980 (Indo-Nepal) except for the slight difference in the seismic gap which could apprently be associated with intermediate depth earthquakes.

DISCUSSIONS

The seismicity pattern of the August, 1988 earthquake in Bihar-Nepal border showed somewhat different pattern of seismicity than what had been reported so far. The case of the earthquake of 1968 and 1978 which occurred in Himachal Pradesh brought out a common pattern of seismicity pattern namely increase of seismicity followed by a period of relative quiescence before the occurrence of main earthquake (Srivastava et al. 1987). Study of the seismicity pattern of Indian Nepal earthquake of 1966 and 1980 has brought to light that the pattern of seismic activity preceding the earthquake of 1980 was also similar to that observed for two earthquakes in Himachal Pradesh where the logarithm of the area of the seismic gap was found to be proportional to the magnitude of the main shock. However, the pattern of seismicity preceding the earthquake of 1966 in India-Nepal border was different which was attributed to the occurrence of a doublet in close proximity and generated aftershock activity for a longer time than that of 1980 earthquake. The pattern of seismicity in the August, 1988 near Nepal-India border showed an increasing trend to earthquakes of magnitude about 2 less than that of the main shock without any well demarcated area of seismic quiescence.

It may be summarised that the pattern of seismicity observed for Burma-India border region of intermediate depth was broadly similar to the other three earthquakes in the Western Himalayan region. Thus while the clustering of seismicity followed by seismic quiescence was indicated, the seismic gap was relatively more complex. The logarithm of the area of seismic gap was also not proportional to the magnitude of the main shock. This may be due to deeper focal depth (100 km). The spread of seismic activity away from the epicentral zone to about 300 km suggested a doughnut pattern preceding the earthquake. Gupta and Singh (1987) studied the seismicity pattern of the Burma-India earthquake using a different approach similar to that by Evison (1977).

Kanamori (1981) proposed a simple asperity model to explain seismicity patterns. According to this model since the earthquakes of August 1988 were not preceded by foreshocks it implies that the asperity tended to fail in a single event.

Figures 4 and 5 show the strain energy release in Bihar Nepal and Indo-Burma regions for shallow, intermediate depths as well as by combining the data for both the depths. Comparison shows the difference in the mechanism of energy release for the two regions which has been reflected through the development of seismicity patterns and the duration of shaking.

CONCLUSIONS

The above study brings out the following conclusions :-

1. Bihar India earthquake of August, 1988 occurred in a region of low seismic activity and had its epicentre close to that of the great earthquake of 1934. The seismic activity preceding the event does not indicate any well marked pattern except for temporary increase in earthquakes of about magnitude 2 less than that of the impending earthquake.

2. The seismicity pattern preceding earthquake of 1988 near Indian Burma border showed an increase of seismic activity followed by an area of seismic quiescence within a zone of 25 to 75 km from the epicentre of the main earthquake. This pattern was broadly similar to that reported for three other earthquakes in the Western Himalayas during 1968, 1978 (in Himachal Pradesh) and 1980 (India-Nepal border). Slight complexity in the Seismic Gap preceding the earthquake is attributed to its intermediate depth.

3. Inspite of the similar magnitude of the Bihar-Nepal and Manipur-Burma border earthquake, the duration of shaking was much larger for the Burma-India event which is attributed to relatively deeper focal depth.

ACKNOWLEDGEMENT

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TABLE 1 - EPICENTRAL PARAMETERS OF BIHAR NEPAL AND BURMA INDIA EARTHQUAKE

Date	Original Time GMT	Epicentre N	E	Focal Depth km	Magnitude
6.8.80	00 36 24.6	25.15	95.13	91	6.8 MB
20.8.80	23 09 10.3	26.66	86.62	70	6.5 MB 6.5 MS

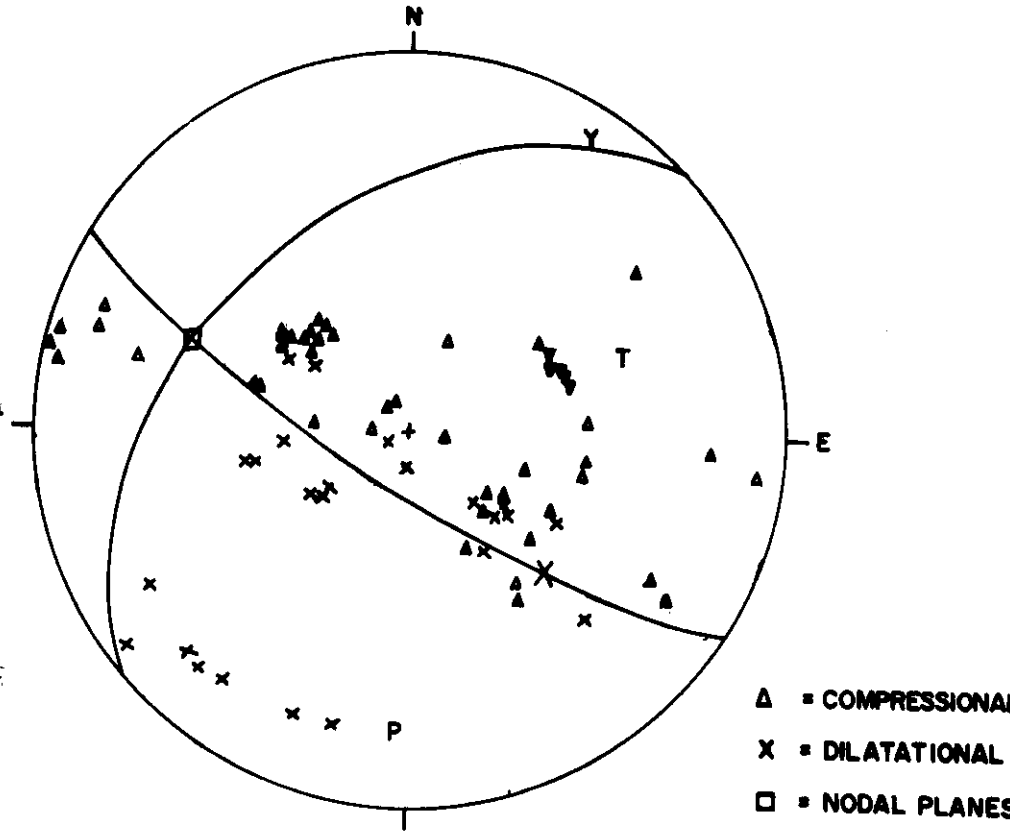

Fig. 1 : Focal mechanism of Bihar-India earthquake including the data of Indian stations.

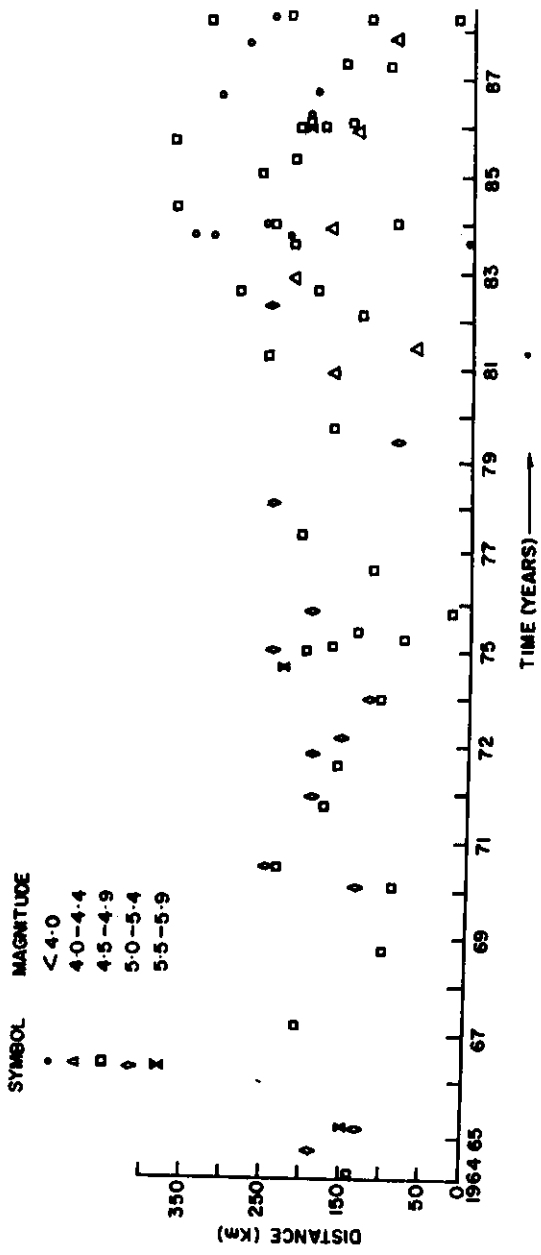

Fig. 2 : Space time change in the seismic activity within 300 km from the epicentre of Bihar-Nepal earthquake for the years 1964 to 1988.

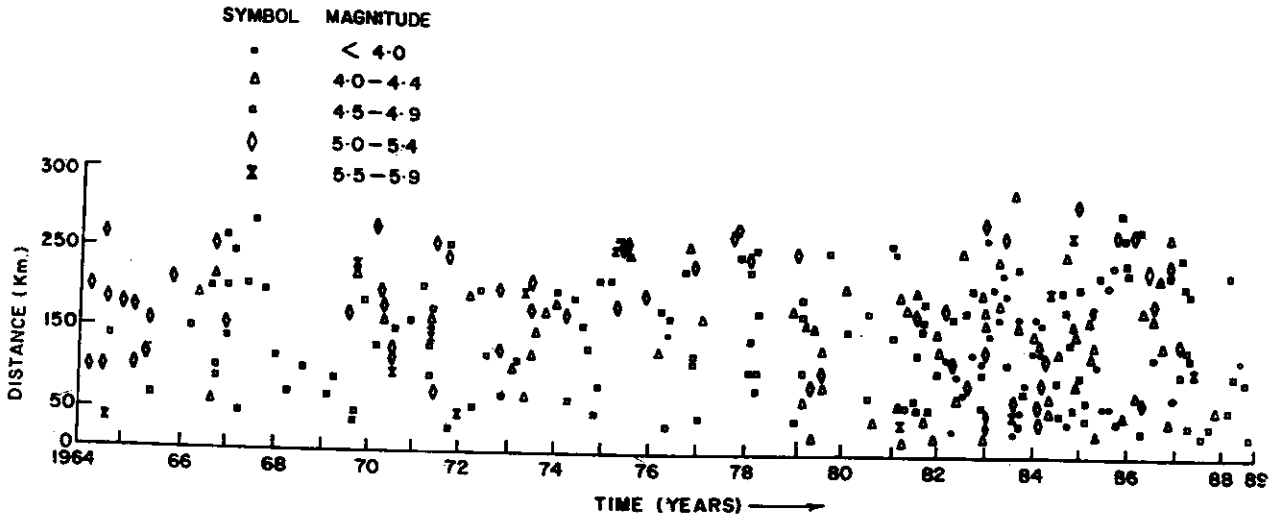

Fig. 3 : Seismic activity upto a distance of 200 km from the epicentre of the Indo-Burma earthquake of Augusst 1988

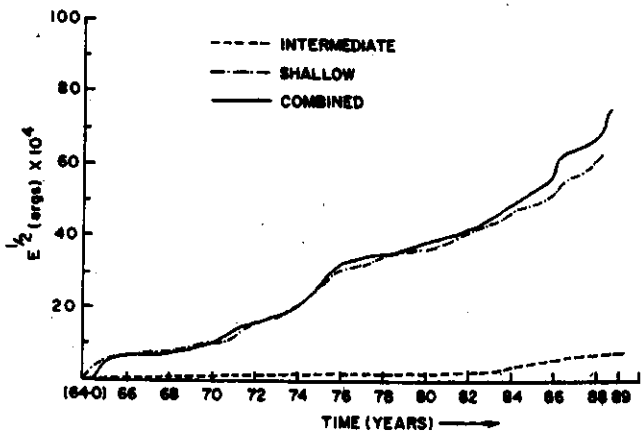

Fig. 4 : Strain energy release in Bihar-Nepal region.

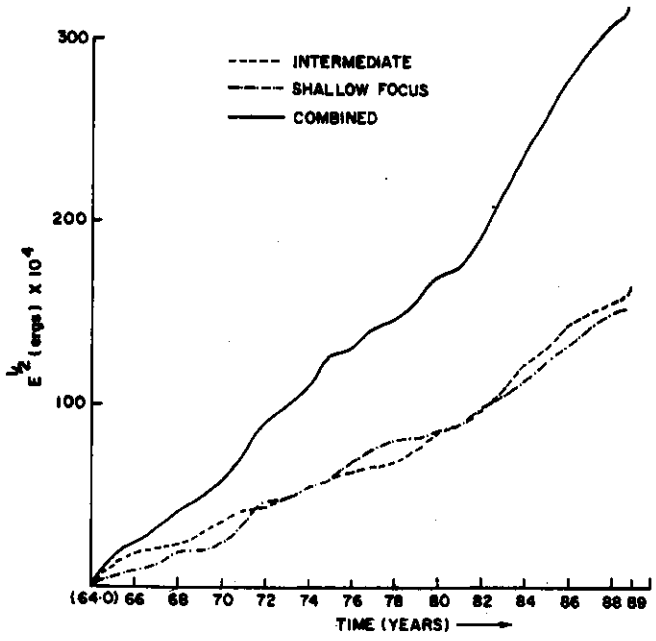

Fig. 5 : Strain energy release in Indo-Burma region.