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The b value before the 6th August, 1988 India–Myanmar Border Region Earthquake—a case study

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Abstract

Smith (1981, 1986) and Wyss et al. (1990) have observed that intermediate-term quiescence is often associated with an increasing b value. This study pertains to the temporal behaviour of the b value before the earthquake of 6th August, 1988, which occurred in the India–Myanmar border region. The b value in the preparation zone of the earthquake (21°–25.5°N, 93°–96°E), as identified by Gupta and Singh (1986, 1989), is found to have increased gradually from 1976 to a maximum value of 1.33 during July, 1987, followed by a short-term drop before the occurrence of the earthquake. The quiescence period observed by Gupta and Singh (1986, 1989) for this earthquake is better reflected by the intermediate-term increase in the b-value. A drop in the mean magnitude since 1978 is supported by a CUSUM plot.

1. Introduction

On the morning of 6th August, 1988, a moderate earthquake ($m_b = 6.8$, $M_s = 7.3$), in the India–Myanmar border region (epicentre 25.149°N, 95.127°E; depth = 91 km), shook the entire northeastern part of India. This earthquake was anticipated by Gupta and Singh (1986, 1989) in 1986. Their study shows that five out of the ten earthquakes of magnitude $M \geqslant 7.5$ that have occurred within the area bounded by Lat. 22°N–30°N, Long. 89°E–98°E were preceded by a period of swarm and quiescence. By considering $m_b \geqslant 5.5$ earthquakes they recognised a region in the vicinity of the Arakan–Yoma Fold Belt near the India–Myanmar border where a swarm occurred during 1963–1965 followed by a period of quiescence. On this basis it was pointed out that the area bounded by 21°N–25.5°N latitude and 93°E–96°E longitude could be the possible site for a future earthquake of magnitude $M = 8 \pm 0.5$, with a focal depth of 100 ± 40 km before 1990. Their intermediate-term forecast was partially fulfilled by the occurrence of the 6th August, 1988, India–Myanmar border region earthquake, although the magnitude of the event that occurred was 7.3.

The b value (b parameter of the Gutenberg–Richter relation $\log N = a - bM$) is an important seismic precursor and shows a good correlation with the other earthquake precursors. Imoto (1991) has classified the temporal variations of b value into three groups: increase, decrease and no change. The occurrence of high b values in the immediate vicinity of, and for a period of some years preceding, large earthquakes has been reported by Fiedler (1974) in Venezuala, Li et al. (1978) in China, Smith (1981, 1986) in New Zea-

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land and Kiek (1984) in Papua New Guinea. Both Smith (1981, 1986) and Wyss et al. (1990) report that intermediate-term quiescence is often associated with an increasing b value, while Main and Meredith (1989) report a short-term quiescence preceding the Western Nagano earthquake (M = 6.8) of September 14th, 1984, which was accompanied by a short-term drop in the b value. Smith (1981, 1986) reports several examples of intermediate-term increase in b value followed by a short-term drop before the occurrence of moderate-size earthquakes. The major temporal fluctuations in the b value are explained by Main et al. (1989) and Meredith et al. (1990) from the fracture mechanics approach, which includes the underlying physical process of time-varying applied stress and the growth of cracks under a constant strain rate. Their model predicts two minima in the b value, separated by a temporary maximum or inflection point; however, they also suggest that it may not be possible to observe the second short-term dip in the b value if there are few foreshocks. In this paper we try to investigate the behaviour of the b value before the occurrence of the 6th August, 1988, India–Myanmar border region earthquake.

2. The data and method of analysis

The area studied is part of the Arakan–Yoma fold belt, along the India–Myanmar (formerly known as Burma) border, characterised by the frequent occurrence of earthquakes of shallow and intermediate depth (Santo, 1969; Gupta and Bhatia, 1986; Saikia et al., 1987, 1990; Mukhopadhyay and Dasgupta, 1988; Gupta et al., 1990). The intermediate-depth earthquakes ($h > 70$ km, $m_b \geqslant 4.5$) occurring in this region for the period 1963–1990 obtained from the USGS earthquake catalogue are shown in Fig. 1. We studied the area within the latitude 21°N–25.5°N and longitude 93°E–96°E, which has been identified as the preparation zone of the 6th August, 1988, earthquake by Gupta and Singh (1986, 1989). The reason for considering the data since 1963 is that the body-wave magnitude (m_b) of earthquakes is

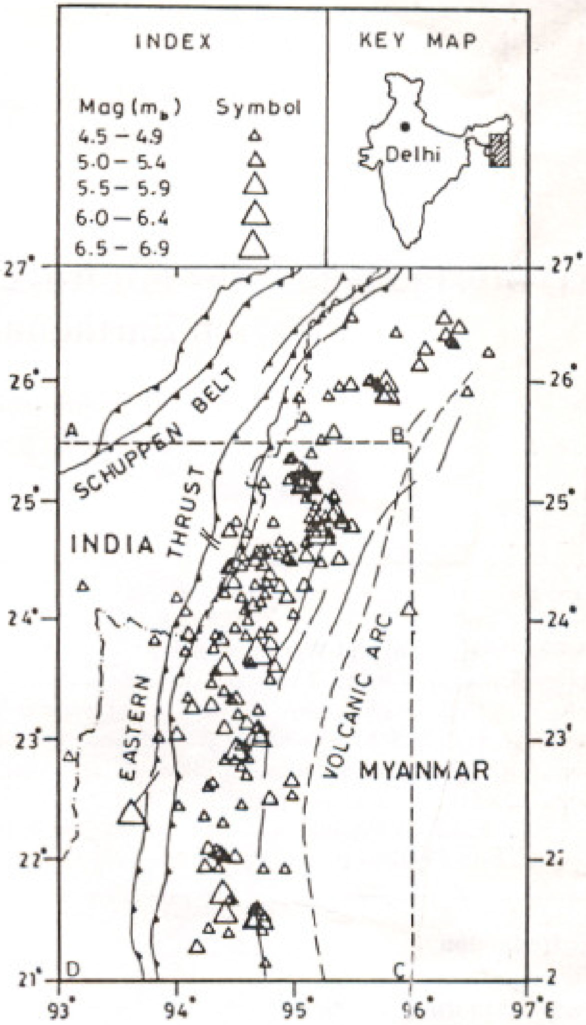

Fig. 1. Epicentral map of the intermediate depth earthqua[kes] along part of the Arakan Yoma Fold belt (Lat. 21°–2[7°] Long. 93°–97°E). $ABCD$ defines the area under investigat[ion] ☆ indicates the epicentre of the 6th August, 1988, earthqu[ake]

regularly reported, with only a few omissions the basis of the earthquake occurrence Gupta et al. (1986) have suggested 4.5 m_b a[s] detection threshold in the northeast India r[egion] for the USGS earthquake catalogue. No att[empt] has been made to remove swarms and aftersh[ocks] from the data.

The b value of a region may be estimat[ed by] linear regression, the maximum likelihood m[ethod] and visually. Aki (1965) gave the maximum likelihood estimate of the b value as:

$$b = \frac{\log_{10} e}{\overline{M} - Mo} \tag{1}$$

where, $\overline{M}$ is the mean magnitude above the detection threshold Mo. The standard error of the b value thus estimated is $\pm b/\sqrt{N}$, where N is the number of earthquakes in the sample. Zhang and Song (1981) have pointed out that Eq. (1) gives a biased estimate of the b value. An unbiased estimator from a sample of N events is:

$$b = \frac{(N-1)^{*} \log_{10} e}{N^{*}\overline{M}} \tag{2}$$

where:

$$\overline{M} = \frac{1}{N} \sum_{i=1}^{N} (M_i - M_o)$$

We used Eq. (2) to estimate the b value, when the threshold magnitude was taken as 4.5 m_b and, as the magnitudes were reported, it was lowered in steps of 0.05 over an interval of 0.1.

The temporal variation in the b value was evaluated using a constant length of event window. The number of earthquakes kept within the event window was 50, which was allowed to slide by 5 events. We arbitrarily chose a window length of 50 because the total number of earthquakes of $m_b \geqslant 4.5$ occurring in the preparation zone for the period 1963–1990 was only 153. This did lead to an increase in the standard error of the b value, however. The b values thus estimated are plotted where the last event entered the window. The first set of 50 earthquakes starts from 1963 and ends on the 25th May, 1976; the b value evaluated for this set is plotted on the time axis at the 25th May, 1976. The variation in the b value with time (Fig. 2) starts at May 1976, due to the procedure that we have followed.

3. Results and discussion

In the earlier period of observation, the b value of the preparation zone of the 6th August, 1988, earthquake is low compared to the average value (Fig. 2). For a sample of data the b value is directly related to the mean magnitude; a low value implies a high mean magnitude (Smith, 1981). The initial low b values might have been influenced by the higher-magnitude (5.5–6.7 m_b) events of the swarm period and the procedure adopted for plotting the b value on the time axis. It is clear from Fig. 2 that the b value increases gradually from 1976 and attains a maximum value

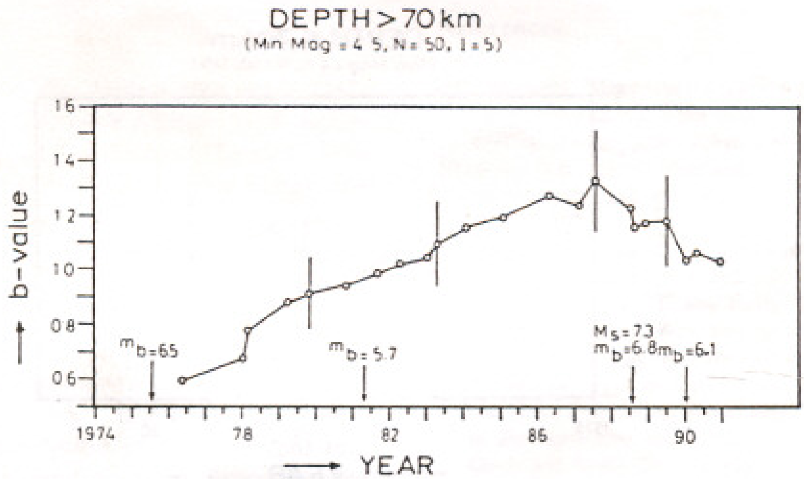

Fig. 2. Temporal variation in the b value for intermediate-depth earthquakes occurring in the preparation zone of the 6th August, 1988, earthquake. The b value is estimated using a window length of $N = 50$ events which slides by $I = 5$ events. The standard error in b value is indicated by the vertical bar at selected points. Arrows indicate the time of occurrence of earthquakes > 5.5 mb.

of 1.33 in July 1987, followed by a short-term drop before the occurrence of the 6th August, 1988, earthquake. Using an event window length of 20 and 30 events with a threshold magnitude of 4.5 m_b, Ghosh et al. (1986) also observed an increasing trend in the b value since 1974 for the entire northeastern region of India, which includes our study area. Fiedler (1974) also reported an increase in the b value to a maximum of 1.33 and a short-term drop before the occurrence of the Caracas earthquake ($M_s = 6.8$) of July 29th, 1967, in Venezuala. It is interesting to note that the RRL-J/NGRI seismic network in the northeastern region of India has recorded a probable foreshock (epicentre 25.114°N, 95.243°E; depth = 69 km) with a signal magnitude, $M_D = 4.5$ about 1 h 41 min before the occurrence of the main shock. Smith (1981, 1986) suggests that a period of high b value may be a more accurate description of the phenomenon than the commonly used term 'quiescence'. The quiescence period observed by Gupta and Singh (1986, 1989) before the occurrence of the 6th August, 1988, earthquake is better reflected by the intermediate-term increase in b value. The temporal variation in the b value for shallow earthquakes ($h \leqslant$ 70 km) occurring in the preparation zone of the 6th August, 1988, earthquake is represented in the Fig. 3. The mild fluctuation in the b value indicates that the seismicity of shallow earthquakes is normal before the earthquake.

Banghar (1992) reports that the mechanism solution of the 6th August, 1988, earthquake shows a large component of thrust faulting. An intermediate-term increase in the b value before the above-mentioned earthquake supports the idea of Smith (1986) that the b value is a medium-term precursor, at least for earthquakes with a significant dip-slip component.

It is clear from Eqs. (1) and (2) that an examination of the b value is essentially an examination of mean magnitude $\overline{M}$. To examine the fluctuation of earthquake magnitude from the mean magnitude we use the CUSUM (Page, 1954) technique, following Smith (1986). The method consists of determining:

$$Cn = \sum_{i=1}^{n} (M_i - \overline{M}),\ n = 1, N \qquad (3)$$

where $\overline{M}$ is the mean magnitude of the entire sample from a total of N earthquakes. Thus Cn is the cumulative sum (CUSUM) of the difference between the individual values and the mean. The effect is to expand the scale and allow a clear interpretation of the deviation from a uniform rate. A change in the gradient of the CUSUM indicates a change in the mean magnitude. We apply this CUSUM technique to our data set of

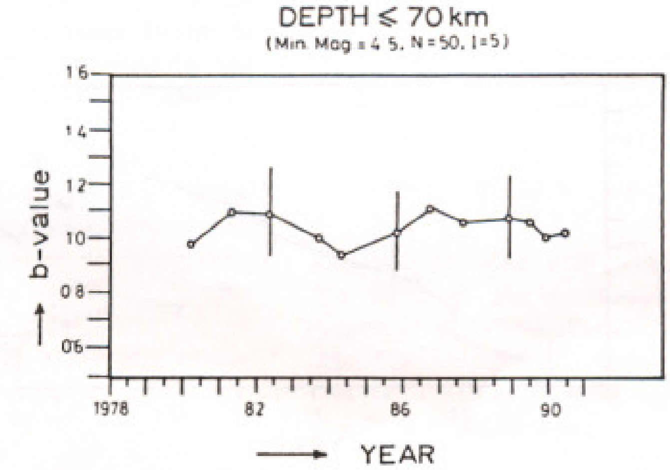

Fig. 3. Temporal variation in the b value for shallow earthquakes ($h \leqslant 70$ km) for the preparation zone of the 6th August, 1988, earthquake.

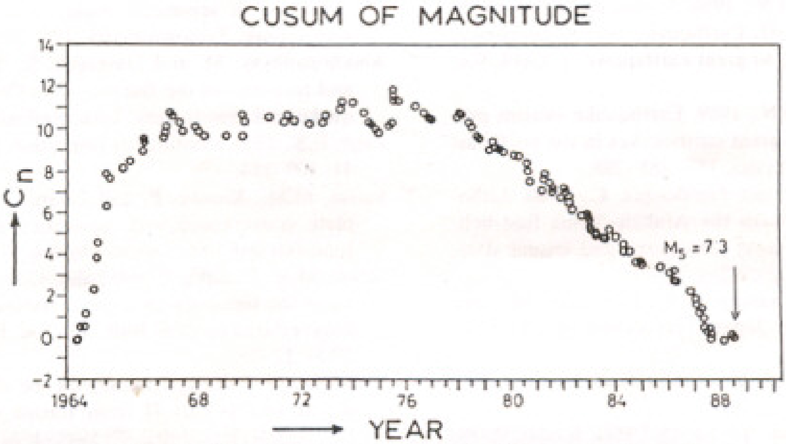

Fig. 4. CUSUM plot of magnitude for intermediate-depth earthquakes against occurrence time. The arrow indicates the occurrence of the 6th August, 1988, earthquake.

all earthquakes ($m_b \geq 4.5$) which occurred before the 6th August, 1988. The value of Cn is plotted against the occurrence time of each earthquake and is shown in Fig. 4. It is clear from Fig. 4 that the CUSUM gradient has been negative since 1978 and the trend reverses just before the occurrence of the 6th August, 1988, earthquake. This indicates that during 1978–1987 the mean magnitude was less than the mean magnitude ($m_b = 4.9$) of the entire period 1963–1988. A sharp decrease in Cn is observed during 1987–1988.

4. Conclusion

The *b* value for the preparation zone (21°–25.5°N, 93°–96°E) of the 6th August, 1988, earthquake increased gradually from 1976 until July, 1987, followed by a short-term drop before the occurrence of the earthquake. The intermediate-term increase in the *b* value more accurately reflects the quiescence period observed by Gupta and Singh (1986, 1989) for the 6th August, 1988, earthquake. Further, a CUSUM plot also indicates a drop in mean magnitude from 1978 onwards. Our results provide additional evidence in support of the observation of Smith (1986) that the *b* value is a medium-term precursor for earthquakes with a significant dip-slip mechanism. This study suggests that monitoring of the temporal variation in *b* values for various seismic sub-regions of northeast India may prove to be a useful method for earthquake prediction.

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