Mausam (1979), 30, 2 & 3, 297-300

550·341(541·1)

Existence of the dilatancy phenomena in the Assam region

V. P. SINGH and HARSH K. GUPTA

National Geophysical Research Institute, Hyderabad

ABSTRACT. In accordance with the dilatancy model for earthquakes, *P*-wave velocity decreases in the source region during the precursor time, and consequently the mean teleseismic *P*-wave travel-time residual at a station close to the source should increase. We have analysed teleseismic *P*-wave travel-time data at Shillong for the period from October 1964 through March 1974. The total number of events is 8021 including 1502 events with focal depths$\geqslant$100 km. Six monthly average residuals have been calculated for the considered period. For the averaging period, the standard deviations are found to be less than 0.15 sec. This indicates that the residuals of the order 0.3 sec could be detected In the average *P*-wave residual histograms, the 1 June 1969 earthquake of M_b=5.0, at a distance of 20 km is well reflected. The outstanding feature of the six monthly average residuals is that the *P*-wave velocities have decreased since 1969 and it appears that the Assam region is presently experiencing a precursory dilatancy stage.

1. Introduction

A few methods have been suggested in the past for prediction of earthquakes and are summarised by Rikitake (1976). In recent years, the *P*-wave residual method of Wyss and Holcomb (1973) and Wyss and Johnston (1974) has drawn the attention of many scientists such as Prozorov (1974), Sutton (1974), Wyss (1974-75) and others. They applied this method for different seismological stations situated in tectonically active regions and correlated the decrease in *P*-wave velocity with the occurrence of many large magnitude earthquakes which occurred in the neighbourhood of the station. However, in the central California region, Steppe *et al.* (1977) did not observe any change in the *P*-wave velocity residuals before the earthquakes of magnitude$\leqslant$5.

We have carried out *P*-wave residual analysis for Shillong Observatory data, in view of its location in a seismically very active region. Moreover, the Shillong station is equipped with WWSSN equipment and consequently the time keeping is very accurate. Therefore, a study of *P*-wave residuals for this station is expected to yield useful inferences on the possibility of occurrence of earthquakes in its neighbourhood.

2. Data analysis

The *P*-wave residual travel time data (observed —calculated), consist of a number of random and non-random errors. The errors associated with sources and paths are random and approximately Gaussian. If we take large sample population, the random errors are expected to cancel out. For this purpose six monthly interval provides sufficient data (Table 1). The followin procedure has been adopted to reduce the non-random errors, especially introduced by aftershock sequences as well as observational errors. Observations for which residuals are $\geqslant$5.0 sec and epicentral distances <10° and >100° have not been considered in order to eliminate gross observational errors and uncertainties associated with short epicentral distances as well as with the shadow zone. Data for earthquakes located on the bases of less than 25 *P*-wave arrival times have been discarded to exclude poor locations and large errors in origin time. For the remaining data set, averages have been calculated for six monthly intervals (Fig. 1). Most of the intervals contain 300 observations (Table 1). Average residuals have been also calculated for events with depth $\geqslant$100 km. In this set, each interval contains 45 to 105 events (Table 1). For this sample, the possible bias introduced by the lithospheric structure in the source region is eliminated. In addition, the *P*-wave velocity in the source region of deeper earthquakes, is unlikely to change with time because of the large lithostatic stresses at that depth. The long term averages for the set with all events (8021 observations) and for the set with focal depth $\geqslant$100 km (1502 observations are —0·55 sec and —0.01 sec, respectively. The standard deviations have been calculated for all intervals and are found to vary between 0.05 sec (567 observations) and 0.15 sec (45 observations) except for the two intervals (October '70 to March 71 and April 70 to September 71), where the values are 0.18 sec and 0.24 sec respectively. Wyss and Johnston (1974) reported standard deviations of about 0.06 sec for data sets with more than 300 observations. When the data

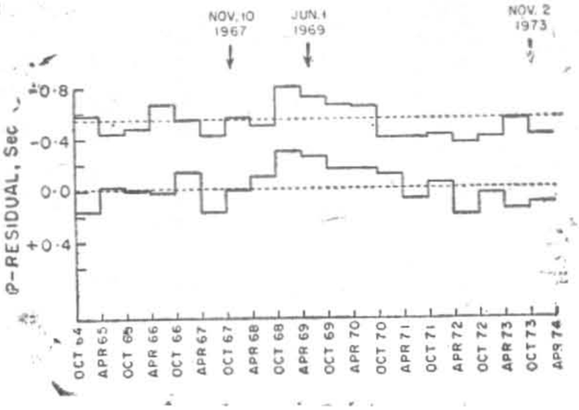

Fig. 1. Average P-wave travel-time residuals (six monthly) *versus* time at the Shillong station. The upper histogram includes all the events and the lower histogram includes earthquakes with depths $\geqslant$100 km only. Dotted lines represent long term mean.

sets had fewer observations, the standard deviations increased. For example, for a data set with 100 observations, Wyss and Johnston (1974) reported standard deviation of $\simeq 0.1$ sec.

To test the statistical significance of the data set, t-test has been applied. This test showed that the data are statistically significant and significant variations in the average residuals could be due to velocity changes in the neighbourhood of the station.

3. Discussion

On the bases of the standard deviations calculated for all intervals and the t-test performed on the data sets, it appears that the present approach is capable of revealing velocity variations of the order of a few tenths of a second in the neighbourhood of Shillong seismic station. The difference between the sample mean and the long term mean is considered to be an anomaly when its value is more than twice the standard deviation for that sample.

As seen from the Regional Catalogue of Earthquakes (Table 2), no strong earthquake (magnitude $m_b > 6.0$) has occurred within 2° epicentral distance from the Shillong station during the period investigated. A few earthquakes of smaller magnitudes have occurred within this distance. Three earthquakes with magnitudes 4.4, 5.0 and 4.8 occurred within 25 km from the station, remaining being greater that 70 km away. Of these, the 1 June 1969 earthquake of magnitude 5 seems to be associated with anomalous travel-time residual (Fig. 1). The moving time window analysis shows that the dilatancy period for this earthquake to be 16 months which is more than the time in accordance with the relation given by Whitcomb *et al.* (1973), *i.e.*, $\log t = 0.80\,M - 1.92$ (where t is the time in days and M is the magnitude). In an independent study presented at the

TABLE 1

Number of events considered

Period	No. of events for all focal depths	No. of events for focal depths $\geqslant$100 km
Oct 64-Mar 65	567	83
Apr 65-Sep 65	444	90
Oct 65-Mar 66	424	101
Apr 66-Sep 66	413	93
Oct 66-Mar 67	509	105
Apr 67-Sep 67	439	91
Oct 67-Mar 68	450	87
Apr 68-Sep 69	533	65
Oct 68-Mar 69	395	86
Apr 69-Sep 69	419	84
Oct 69-Mar 70	417	88
Apr 70-Sep 70	308	45
Oct 70-Mar 71	356	61
Apr 71-Sep 71	257	45
Oct 71-Mar 72	262	66
Apr 72-Sep 72	440	84
Oct 72-Mar 73	469	71
Apr 73-Sep 73	459	73
Oct 73-Mar 74	460	84
Total	8021	1502

Earthquake Prediction Symposium held at New Delhi, Srivastava and Chaudhury (1978) have also reported a decrease in velocity before the occurrence of this earthquake. The other two earthquakes of 10 November 1967 and 2 November 1973 do not appear to be associated with any anomaly (Fig.1). This may be due to the fact that earthquakes are of small magnitude and the corresponding dilatating earthquake volumes are

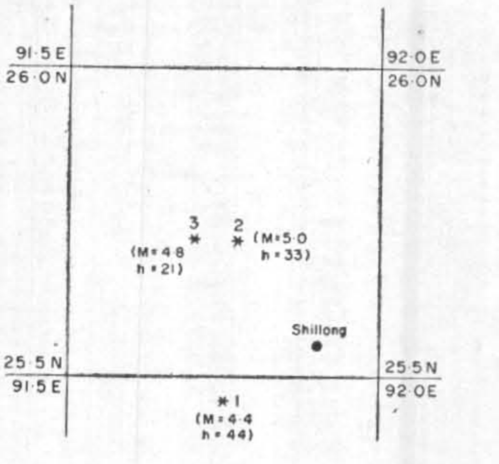

Fig. 2. The three nearby earthquakes which occurred close to the Shillong seismograph station during the period of analysis are shown by stars.

TABLE 2

Parameters of earthquakes within two degrees epicentral distances around the Shillong seismograph station for the period October 1964-March 1974

Date	Epicentral distance in degrees (ISC)	Magnitude USCGS (mb)	Depth (km) USCGS
11 Apr 1965	1·31	5·1	70
18 Jun 1965	1·74	5·8	66
6 Nov 1965	1·54	4·3	40
9 Dec 1965	1·94	4·8	70
24 Feb 1966	0·88	5·1	51
23 Mar 1966	1·70	4·4	20
23 Apr 1966	1·32	4·7	25
26 Jun 1966	1·04	4·8	49
30 Jan 1967	1·23	5·0	46
6 Sep 1967	1·55	5·0	18
15 Sep 1967	1·84	5·8	57
10 Nov 1967	0·16	4·4	44
14 Nov 1967	1·54	5·1	33
2 May 1968	0·75	4·8	53
12 Jun 1968	0·73	5·3	44
18 Aug· 1968	1·42	5·2	31
27 Dec 1968	1·47	5·2	26
22 Feb 1969	1·06	4·8	52
1, Jun 1969	0·19	5·0	20
30 Jun 1969	1·55	5·1	64
28 Aug. 1970	0·84	4·9	17
2 Feb 1971	1·86	5·4	37
21 Feb 1971	0·65	4·3	3.
17 Jul 1971	1·41	5·1	49
2 Nov 1973	0·23	4·8	20

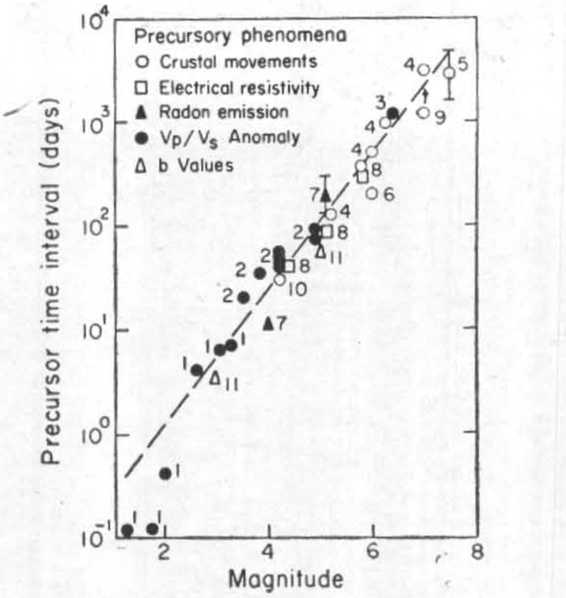

Fig. 3. Duration time of various precursory phenomena as a function of earthquake magnitude. Earthquake location and data sources are as follows : Point 1, Blue Mountain Lake, New York; Point 2, Garm, U.S.S.R.; Point 3, San Fernando, California; Point 4, Kitamino, Kita-Isu, and Omi, Japan; Point 5, Nitgata, Japan, Point 6, Odaigahara, Japan; Point 7, Tashkant, U.S.S.R.; Point 8, Garm, U.S.S.R.; Point 9. Alma Ata, U.S.S.R.; Point 10, Danville, California; and Point 11, Fairbanks, Alaska (adopted from Scholz *et al.* 1973).

small and do not affect the travel-times at Shillong, or the precursory time is less than the sample interval (six months). The important feature in Fig. 1 is that the *P*-wave velocity shows a decreasing trend from 1969 onwards. The maximum delay in average *P*-wave travel-time residuals from October 1969 onwards is observed to be 0.3 sec. This indicates that the region is experiencing a precursory dilatating stage. In case the velocity returns to the normal value and the presently observed delay of 0.3 sec disappears, in accordance with the dilatancy model, a large magnitude earthquake should be expected in this region. The large magnitude is inferred on the basis of long duration for which decreased velocities have been observed (Fig. 1). As shown in Fig. 3, with the increase of duration of various precursory phenomenon, the magnitude of the expected earthquake increases. The velocities have decreased in Shillong region since 1969, and if they now return to normal the magnitude of the expected earthquake would be $\simeq 7$.

Acknowledgements

The authors are thankful to the Director, National Geophysical Research Institute for his kind permission to publish this work and to Mr. K. Suryaprakasam for assisting in the preparation of the manuscript.

References

Prozorov, A.G., 1974, Dependence of seismic mean residuals on distance-azimuth and time, *Nature*, **252**, 558.

Rikitake, T., 1976, *Earthquake prediction*, Elsevier Scientific Publ. Co., Amsterdam.

Scholz. C.H., Sykes, L.R. and Aggarwal, Y.P., 1973, Earthquake prediction : A physical basis, *Science*, **181**, 803-810.

Srivastava, H.N. and Chaudhury H.M., 1978, Premonitory seismic observations in Himachal Pradesh and Shillong Plateau (Abstract). Symposium on Earthquake Prediction, New Delhi 8-10 March, *see* also *Mausam*, **30**, 289-296.

Steppe, J.A., Bakum W.H. and Bufe, C.G., 1977, Temporal stability of P-velocity anisotropy before earthquakes in central California, *Bull seismol. Soc. Am.* **67**, 1075.

Sutton, D.J., 1974, A fall in P-wave velocity before the Gisborne, New Zealand earthquake of 1966, *Bull. seismol. Soc. Am.*, **64** : 2508.

Whitcomb, J.H., Garmany, J.D. and Anderson, D.L. 1973, Earthquake prediction ; variation of seismic velocities before the San Fernando Earthquake, *Science*, **180**, 632.

Wyss, M. and Holcomb. D.J., 1973, Earthquake prediction based on station residual, *Nature*, **245** : 139.

Wyss, M. and A.C. Johnston, 1974, A search for teleseismic P-residual changes before large earthquakes in New Zealand, *J. Geophys. Res.*, **79**, 3283.

Wyss M., 1974, Will there be a large earthquake in central California during the next decade, *Nature* **251**, 126.

Wyss, M., 1975, Time dependence of P-residuals in Luzon *Bull. Sesmol. Soc. Am.*, **65**, 461.

DISCUSSION

(Paper presented by H. K. Gupta)

S.K. SARMAH (Gauhati University) : Is it possible to make some controlled experiment to find out if there is any dilatancy?

AUTHOR : This type of experiment will be very expensive.