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# Variation of $V_p/V_s$ ratios for granitic layers and weekly average number of earthquakes in NE India

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**सार** - इस शोध पत्र में भूकंपीय फ़ेज आँकड़ों के आधार पर तैयार किए गए वादाती चित्रों के द्वारा शिलांग के पठार में ग्रेनाइट परतों और आँशिक रूप से व्याप्त तेजपुर के भूकंपीय क्षेत्र के $V_p/V_s$ अनुपातों का परिकलन किया गया है।

शिलांग पठार से $V_p/V_s$ के लिए वर्ष 1979 के कुछ महीनों में लिए गए 23 अध्ययनों (रीडिंग्स) का औसत 1.71 पाया गया है।

तेजपुर क्षेत्र में वर्ष 1991-92 में $V_p/V_s$ के लिए गए 29 अध्ययनों का औसत 1.73 पाया गया है किन्तु वर्ष 1995-96 में लिए गए $V_p/V_s$ के लिए गए 49 अध्ययनों का औसत 1.68 पाया गया है। इस क्षेत्र में लिए गए 78 अध्ययनों का कुल औसत 1.70 है। वर्ष 1995-97 के कम $V_p/V_s$ अग्रगामी प्रतीत होते हैं।

ग्रेनाइट परत के लिए $V_p$=5.92 km/s और $V_p/V_s$ =1.70 लेने पर उत्तर पूर्वी भारत में $V_s$ =3.48 km/s प्राप्त होता है।

$V_p/V_s$ अनुपातों के मानों और प्रतिदिन आने वाले झटकों की संख्या को समयानुसार अंकित किया गया है और ये अनेक M≥4.2 भकंपों के समक्ष अचानक धीमे पड़ जाते हैं। ऐसे मामलों में $V_p/V_s$ सामान्यतः 1.60 से नीचे धीमा पड़ जाता है।

शिलांग पठार में वर्ष 1979 में प्रतिदिन आए झटकों की संख्या वर्ष 1991-97 में निकटवर्ती तेजपुर क्षेत्र में आए झटकों की कुल संख्या से तीन गुना पाई गई है।

**ABSTRACT.** $V_p/V_s$ ratios for the granitic layers in Shillong Plateau and the partially overlapping Tezpur seismic area, have been calculated from Wadati diagrams drawn on the basis of seismic phase data.

From Shillong plateau the average of 23 readings for some months of 1979 for $V_p/V_s$ is found to be 1.71.

For Tezpur area the average of 29 readings of $V_p/V_s$ for 1991-92 is found to be 1.73, but for 1995-96, the average $V_p/V_s$ from 49 readings is found to be 1.68. The overall average from 78 readings for this area is 1.70. The low $V_p/V_s$ for 1995-97 seems to be precursory.

For the granitic layer, taking $V_p$ = 5.92 kms/s and $V_p/V_s$ = 1.70. We get $V_s$=3.48 km/s for NE India.

Values of $V_p/V_s$ ratios and number of shocks per day are plotted against time and are shown to undergo sudden lowering before many M≥4.2 earthquakes. $V_p/V_s$ is generally lowered below 1.60 in such cases.

In Shillong plateau the number of shocks per day for 1979 is found to be three times the number in the adjoining Tezpur area, for 1991-97.

**Key words** – $V_p/V_s$ ratio. Wadati diagrams, Precursion time, Seismic quiescence, Hot springs.

## 1. Introduction

Collision of Continental plates is the cause of earthquakes in the Himalayas and North East India and Western Burma. The Indian plate underthrusting the Eurasian plate north wards and the Burmese plate eastwards swerving anticlockwise, has caused the north east part of India to be one of the most seismically active

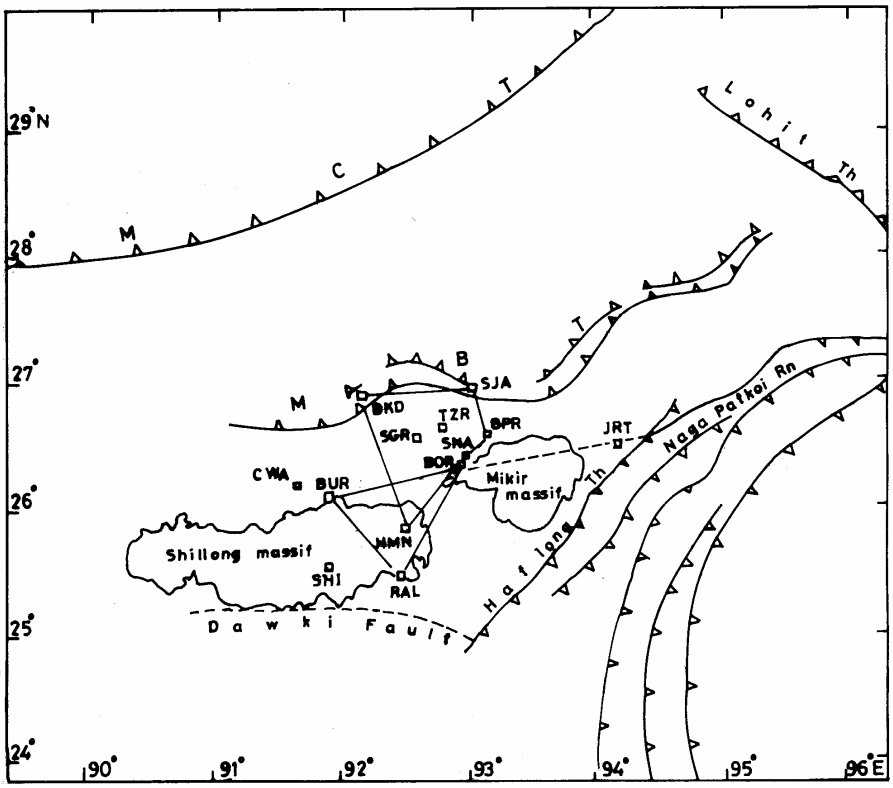



**Fig. 1.** Locations of stations providing preliminary seismic phase data and the tectonic background of the study area

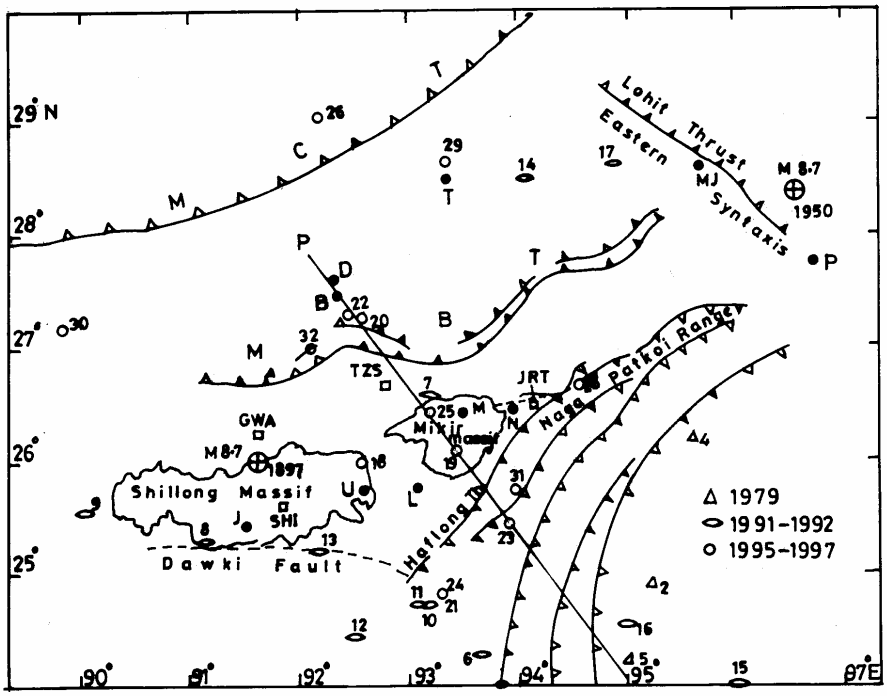
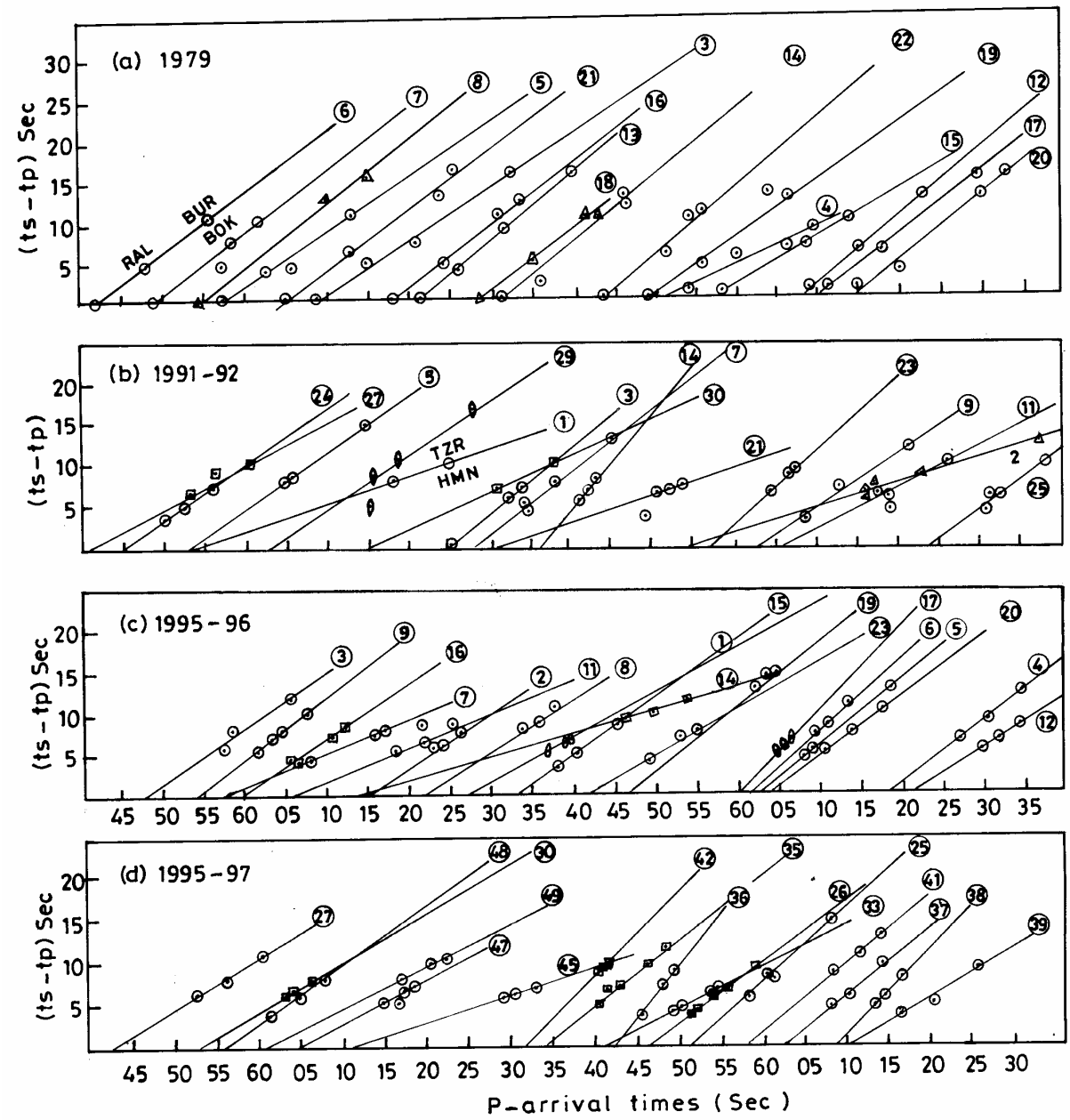



**Fig. 2.** Epicentral locations of M ≥ 4.2 earthquakes correlated with lowering of *Vp*/*Vs* ratio and number of shocks per day. Serial numbers are from Table 2. The hot springs Bishun (B), Dirang (D) Jakrem (J) Lumding (L) Mikir Hills (M), Maja (MJ) Nambar (N), Parsuram Kunda (P), Taksing (T) Umrangshu (U) are shown by solid circles




**Figs. 3(a-d).** Wadati diagrams drawn on the basis of seismic phase data from (a) G.S.I. for Burnihat, Raliang and Borjuri in Shillong Plateau. $V_p/V_s$ ratio in Table 1(a) are calculated from these diagrams. Serial numbers from Table 1(a) (June, July, August - 1979) are shown with diagrams, (b) N.G.R.I. Digital Telemetry Seismic Network around Tezpur for some periods of 1991-92. $V_p/V_s$ ratio in Table 1(b) are calculated from these diagrams. Serial numbers from Table 1(b). are shown with diagrams, (c) N.G.R.I. Digital Telemetry Seismic Network around Tezpur for some periods of 1995-97. $V_p/V_s$ ratio in Table 1(c) are calculated from these diagrams. Serial numbers from Table 1(c) are shown with diagrams and (d) N.G.R.I. stations around Tezpur for some periods of 1995-97. Serial numbers from Table 1(c) are shown with diagrams. $V_p/V_s$ in Table 1(c) are calculated from these diagrams

regions of the world. Two M 8.7 earthquakes have rocked the area in 1897 and 1950. A quiescence of large earthquakes is observed in the area for more than half a century (Satyabala and Gupta 1996) since 1952. According to Gupta *et al*. (1990) the continental collision is still taking place in the plate margin.

**TABLE 1(a)**

***$V_p/V_s$* ratio calculated from Wadati diagrams on the basis of MEQ phase data from GSI stations at Burnihat (BUR), Raliang (RAL), Borjuri (BOR) [Asterisks for points slightly off the curves, O=origin Time in phase data]**

| S. No. | Date and 0-time (GMT) | Station | Arrival time (UTC) P | | | S | $t_s$-$t_p$ | $V_p/V_s$ | Epicentre |
|---|---|---|---|---|---|---|---|---|---|
| | | | H | M | S | Sec | Sec | | |
| (1) | (2) | (3) | | | (4) | | (5) | (6) | (7) |
| 1. | 20 Jun 1979 | BUR | 14 | 22 | 7.00 | 21.0 | 14.0 | | 25°-4.48'N |
| | | RAL | | | 1.0 | 9.5 | 8.5 | 1.74 | 92°-58.80'E |
| | 14:21:48:24 | BOR | | | 0.0 | 9.0 | 9.0 | | |
| 2. | 23 Jun 1979 | BUR | 22 | 13 | 55.0 | 62.5 | 7.5 | | 25°-59.34'N |
| | | RAL | | | 54.0 | 61.0 | 7.0 | 1.67 | 92°-32.16'N |
| | 22:13:43.54 | BOR | | | 53.5 | 61.5 | 8.0 | | |
| 3. | 25 Jun 1979 | BUR | 15 | 59 | 15.0 | 20.0 | 5.0 | | 25°-43.65'N |
| | | RAL | | | 21.0 | 28.5 | 7.5 | 1.61 | 91°-49.34'E |
| | 15:59:9 | BOR | | | 32.5 | 48.0 | 15.5 | | |
| 4. | 27 Jun 1979 | BUR | 6 | 23 | 14.0 | 19.0 | 5.0 | | 25°-39.50'N |
| | | RAL | | | 6.0 | 10.0 | 4.0 | 1.74 | 92°-18.90'E |
| | 6:23:1.77 | BOR | | | 19.0 | 32.0 | 13.0 | | |
| 5. | 27 Jun 1979 | BUR | 22 | 16 | 10.0 | 17.5 | 7.5 | | 25°-42.64'N |
| | | RAL | | | 0.0 | 4.5 | 4.5 | 1.46 | 92°-36.49'E |
| | 22:15:54.44 | BOR | | | 10.0 | 17.5 | 7.5 | | |
| 6. | 29 Jun 1979 | BUR | 6 | 14 | 56.0 | 67.0 | 11.0 | | 25°-39.53'N |
| | | RAL | | | 48.0 | 53.0 | 5.0 | | |
| | 6:14:41 | BOR | | | 56.0 | 67.0 | 11.0 | | 92°-38.28'E |
| | | O | | | 41.0 | 41.0 | 0.0 | 1.73 | |
| 7. | 4 Jul 1979 | BUR | 16 | 9 | 57.5 | 62.5 | 5.0 | | 26°-11.16'N |
| | | RAL | | | 62.0 | 72.5 | 10.5 | 1.77 | 92°-21.99'E |
| | 16:9:48.25 | BOR | | | 58.5 | 66.5 | 8.0 | | |
| 8. | 6 Jul 1979 | BUR | 8 | 29 | 10.0 | 23.0 | 13.0 | | 26°-33.34'N |
| | | RAL | | | 15.5 | 31.0 | 15.5 | 1.77 | 92°-39.80'E |
| | 8:28:54.62 | BOR | | | 1.5 | 4.5 | 3.0 | | |
| 9. | 8 Jul 1979 | BUR | 0 | 38 | 30.0 | 38.5 | 8.5 | | 25°-57.5'N |
| | | RAL | | | 24.0 | 31.0 | 11.0 | | 92°-16.50'E |
| | 0:38:13 | BOR | | | 43.0 | 60.0 | 17.0 | 1.54 | |
| | | SHI | | | 21.4 | 26.8 | 5.4 | | |
| 10. | 20 Jul 1979 | BUR | 20 | 9 | 57.0 | 69.0 | 12.0 | | 26°-43.75'N |
| | | RAL | | | 63.0 | 80.5 | 17.5 | 1.68 | 92°-40.02'E |
| | 20:9:38.33 | BOR | | | 46.0 | 52.0 | 6.0 | | |
| 11. | 22 Jul 1979 | BUR | 16 | 6 | 6.0 | 10.5 | 4.5 | | 25°-45.86'N |
| | | RAL | | | 3.0 | 7.0 | 4.0 | | 92°-16.77'E |
| | 16:5:58.5 | BOR | | | 13.0 | 24.0 | 11.0 | 1.72 | |
| | | O | | | 56.27 | 56.27 | 0.0 | | |
| 12. | 27 Jul 1979 | BUR | 1 | 33 | 23.0 | 32.0 | 9.0 | | 25°-11.15'N |
| | | RAL | | | 23.0 | 34.0 | 11.0 | | 92°-40.11'E |
| | 1:33:8.95 | BOR | | | 15.1 | 20.1 | 5.0 | | |
| | | O | | | 8.95 | 8.95 | 0.0 | 1.77 | |
| 13. | 28 Jul 1979 | BUR | 22 | 33 | 37.0 | 46.0 | 9.0 | | 26°-32.37'N |
| | | RAL | | | 40.0 | 55.5 | 15.5 | 1.81 | 92°-29.21'E |
| | 22:33:21.02 | BOR | | | 32.0 | 41.0 | 9.0 | | |
| 14. | 9Aug 1979 | BUR | 14 | 38 | 46.5 | 59.0 | 12.5 | | 25°-13.28'N |
| | | RAL | | | 46.5 | 58.5 | 12.0 | | 92°-49.33'E |
| | 14:38:30.67 | BOR | | | 36.0 | 38.5 | 2.5 | 1.68 | |
| | | O | | | 30.67 | 30.67 | 0.0 | | |
| 15. | 9 Aug 1979 | BUR | 21 | 43 | 8.7 | 14.5 | 5.8 | | 25°-35.30'N |
| | | RAL | | | 14.0 | 22.5 | 8.5 | | 91°-32.75'E |
| | 21:42:57.85 | SHI | | | 6.4 | 11.9 | 5.5 | | |
| | | O | | | 57.85 | 57.85 | 0.0 | 1.54 | |

**TABLE 1(a)** (*Contd*.)

| (1) | (2) | (3) | (4) | | | | (5) | (6) | (7) |
|---|---|---|---|---|---|---|---|---|---|
| 16. | 10 Aug 1979 | BUR | 20 | 33 | 34.0 | 46.0 | 12.0 | | 25°-5.06'N |
| | | RAL | | | 31.5 | 42.0 | 10.5 | 1.74 | 92°-50.88'E |
| | 20:33:17.65 | BOR | | | 24.5 | 29.0 | 4.5 | | |
| 17. | 10 Aug 1979 | BUR | 23 | 49 | 29.8 | 43.0 | 13.2 | | 25°-16.25'N |
| | | RAL | | | 18.0 | 22.5 | 4.5 | 1.74 | 92°-32.99'E |
| | 23:49:11.24 | BOR | | | 32.5 | 48.7 | 16.2 | | |
| 18. | 11 Aug 1979 | BUR | 17 | 47 | 43.0 | 53.0 | 10.0 | | 25°-43.85'N |
| | | RAL | | | 35.0 | 40.0 | 5.0 | 1.72 | 92°-39.10'E |
| | 17:47:28.27 | BOR | | | 41.5 | 51.8 | 10.3 | | |
| 19. | 12 Aug 1979 | BUR | 8 | 25 | 64.0 | 76.0 | 12.0 | | 26°-19.38'N |
| | | RAL | | | 66.8 | 78.8 | 12.0 | | 92°-43.01'E |
| | 8:25:49.33 | BOR | | | 56.0 | 60.0 | 4.0 | 1.72 | |
| 20. | 12 Aug 1979 | BUR | 21 | 0 | 30.0 | 41.0 | 11.0 | | 25°-31.24'N |
| | | RAL | | | 19.9 | 22.0 | 2.1 | | 92°-31.24'E |
| | 21:0:15.11 | BOR | | | 33.0 | 46.5 | 13.5 | 1.80 | |
| 21. | 13 Aug 1979 | BUR | 13 | 59 | 26.0 | 42.0 | 16.0 | | 25°-10.89'N |
| | | RAL | | | 24.0 | 37.0 | 13.0 | 1.72 | 93°-10.37'E |
| | 13:59:4.85 | BOR | | | 12.8 | 19.0 | 6.2 | | |
| 22. | 14 Aug 1979 | BUR | 15 | 33 | 51.5 | 57.0 | 5.5 | | 26°-9.10'N |
| | | RAL | | | 56.0 | 66.5 | 10.5 | 1.75 | 92°-19.80'E |
| | 15:33:43.03 | BOR | | | 54.8 | 63.0 | 8.2 | | |
| 23. | 17 Aug 1979 | BUR | 17 | 03 | 14.0 | 29.0 | 15.0 | | 26°-16.69'N |
| | | RAL | | | 15.5 | 27.0 | 11.5 | 1.85 | |
| | 17:02:56.73 | BOR | | | 2.5 | 6.5 | 4.0 | | 92°-57.08'E |

Principal tectonic features of the present study areas consist mainly of (*i*) Main Central Thrust (M.C.T) (*ii*) Main Boundary Thrust (M.B.T), (*iii*) Naga Haflong Thrust (*iv*) Strike-Slip Dawki fault, (*v*) The fault system passing through Nagaland, Manipur and Western Burma almost concentric with Arakan Yoma arc, (*vi*) Hot springs parallel to the fault systems (*vii*) The Shillong Plateau separated by a basement fault into Meghalaya Massif and Mikir Hills Massif, (*viii*) A fault passing by Jorhat, Nambar Hot Spring and Mikir Hills hot springs (*ix*) Lohit Mishmi fault system (*x*) Eastern Syntaxis.

## 2. Study area

Two partially overlapping areas between the epicenters of 1897 and 1950 earthquakes of M 8.7, bounded on three sides by the Main Boundary Thrust (M.B.T), Naga Haflong Thrust and Dawki fault, encircled and crossed by lines of hot springs, is taken as the study area (Fig. 1). The first area is around the triangle formed by Burnihat (BUR), Railang (RAL) and Borjuri (BOR), M.E.Q. stations of G.S.I. The second is around NGRI Digital Telemetry Seismic Network with HQ at Tezpur. The seismic codes of the stations around Tezpur are Seijusa (SJA), Salonah (SNA), Bura Pahar (BPR), Bhairab Kunda (BKD), Tezpur (TZR), Hamren (HMN) and Singri (SGR).

Seismic phase data for the first and second areas from GSI and N.G.R.I. respectively have been used in the present work.

## 3. Methodology

(*i*) *Wadati diagrams with $S_g$ and $P_g$ arrival times for three or more stations were drawn*

If $t_p$ and $t_s$ be the times taken by the *P* and *S* waves to travel identical distances along identical propagation paths, then we get.

$$V_p t_p = V_s t_s \tag{1}$$

Giving $V_p/V_s = t_s/t_p = 1 + (t_s - t_p)/t_p$

or $$t_s - t_p = (V_p/V_s - 1)t_p \tag{2}$$

The $(t_s - t_p)$ values for 3 or more stations plotted against *P* arrival times and a best fit straight line through

**TABLE 1(b)**

**$V_p/V_s$ ratios calculated from Wadati diagrams on the basis of MEQ phase data for granite layer from NGRI, Digital Telemetry Seismic Stations HQ Tezpur (1991-92)**

| S. No. | Date and 0-time (GMT) | Station | Arrival time (UTC) P | | | S | $t_s$-$t_p$ Sec | $V_p/V_s$ | Epicentre |
|---|---|---|---|---|---|---|---|---|---|
| | | | H | M | S | Sec | | | |
| (1) | (2) | (3) | (4) | | | | (5) | (6) | (7) |
| 1. | 16 Apr 1991 | BKD | 1 | 51 | 18.0 | 26.0 | 8.0 | | 26°-16'N |
| | | TZR | | | 24.5 | 34.5 | 10.0 | 1.31 | |
| | 1:50:53 | HMN | | | 24.5 | 34.5 | 10.0 | | 91°-15'E |
| 2. | 19 Apr 1991 | TZR | 16 | 27 | 16.0 | 22.0 | 6.0 | | |
| | | BPR | | | 15.9 | 22.5 | 6.6 | | 27°-27.5'N |
| | 16:26:54 | HMN | | | 17.1 | 24.5 | 7.4 | 1.30 | 93°-15.5'E |
| | | BKD | | | 23.5 | 34.5 | 9.0 | | |
| | | SGR | | | 37.5 | 50.0 | 12.5 | | |
| 3. | 12 May 1991 | TZR | 9 | 50 | 34.0 | 41.0 | 7.0 | | 26°-2.5'N |
| | | HMN | | | 34.2 | 41.5 | 7.3 | 1.78 | 93°-3'E |
| | 9:50:25 | SNA | | | 32.0 | 37.5 | 5.5 | | |
| 4. | 17 May 1991 | TZR | 6 | 22 | 36.5 | 44.0 | 7.5 | | |
| | | SGR | | | 47.0 | 63.0 | 16.0 | 1.82 | 26°-15'N |
| | | BPR | | | 40.0 | 51.0 | 11.0 | | 92°-18.5'E |
| | 6:22:26.75 | SJA | | | 42.0 | N.A | | | |
| | | BKD | | | 37.5 | N.A | | | |
| | | HMN | | | 38.0 | N.A | | | |
| 5. | 26 May 1991 | TZR | 16 | 59 | 5.0 | 13.0 | 8.0 | | 26°-17.5'N |
| | | BKD | | | 14.5 | 29.0 | 14.5 | | 93°-25.5'E |
| | | SJA | | | 5.5 | 14.0 | 8.5 | 1.68 | |
| | 16:58:53 | SNA | | | 2.0 | N.A | | | |
| | | HMN | | | 9.0 | N.A | | | |
| | | BPR | | | 1.0 | N.A | | | |
| 6. | 5 Jul 1991 | TZR | 14 | 51 | 40.0 | 46.5 | 6.5 | | |
| | | BPR | | | 37.5 | 44.0 | 6.5 | 1.65 | 26°-40'N |
| | | SNA | | | 40.5 | 46.5 | 6.0 | | 93°-30'E |
| | 14:51:30.5 | HMN | | | 49.0 | 61.0 | 12.0 | | |
| 7. | 1 Aug 1991 | TZR | 6 | 34 | 38.0 | 45.5 | 7.5 | | |
| | | HMN | | | 44.0 | 56.0 | 12.0 | 1.80 | 26°-17'N |
| | | BPR | | | 34.5 | 38.5 | 4.0 | | 93°-21'E |
| | 6:34:28.5 | SNA | | | 34.5 | 39.5 | 5.0 | | |
| | | BKD | | | 49.0 | 65.5 | 16.5 | | |
| 8. | 17 Aug 1991 | TZR | 21 | 14 | 38.5 | 44.5 | 6.0 | | |
| | | HMN | | | 36.5 | 41.0 | 4.5 | | 26°-13.5'N |
| | | BPR | | | 41.0 | 50.0 | 9.0 | 2.0 | 92°-27'E |
| | 21:14:32 | BKD | | | 40.0 | 51.5 | 11.5 | | |
| 9. | 30 Aug 1991 | TZR | 23 | 3 | 13.0 | 20.0 | 7.0 | | 26°-25.5'N |
| | | HMN | | | 21.5 | 33.5 | 12.0 | 1.67 | 93°-26'E |
| | 23:3:3 | BPR | | | 9.0 | 12.5 | 3.5 | | |
| 10. | 31 Aug 1991 | TZR | 0 | 39 | 13.0 | 23.0 | 10.0 | | 27°-38.5'N |
| | | BKD | | | 3.0 | 10.5 | 7.5 | | 92°-11'E |
| | 0:39:2 | HMN | | | 22.5 | 41.5 | 19.0 | 1.56 | |
| | | BPR | | | 17.5 | 32.0 | 14.5 | | |
| 11. | 3 Nov 1991 | TZR | 7 | 33 | 19.0 | 23.5 | 4.5 | | 27°-5'N |
| | | BPR | | | 19.0 | 25.0 | 6.0 | 1.49 | 92°-43'E |
| | 7:33:6 | BKD | | | 18.0 | 24.5 | 6.5 | | |
| | | HMN | | | 26.0 | 36.0 | 10.0 | | |
| 12. | 13 Nov 1991 | TZR | 13 | 01 | 34.5 | 40.0 | 6.0 | 2.20 | 26°-6.5'N |
| | | BPR | | | 33.5 | 39.0 | 5.5 | | 93°-0'E |
| | 13:01:29.5 | BKD | | | 42.0 | 57.5 | 15.5 | | |
| 13. | 13 Dec 1991 | TZR | 16 | 39 | 48.5 | 61.5 | 12.5 | | 26°-5'N |
| | | BPR | | | 45.5 | 54.5 | 9.0 | 2.11 | 92°-40'E |
| | | HMN | | | 50.5 | 65.0 | 14.5 | | |
| | 16:39:33 | BKD | | | 60.5 | 80.0 | 20.5 | | |
| 14. | 17 Dec 1991 | TZR | 7 | 24 | 42.0 | 48.5 | 6.8 | | 26°-7'N |
| | | HMV | | | 43.0 | 51.0 | 8.0 | 2.13 | 93°-5'E |
| | | BPR | | | 41.0 | 46.5 | 5.5 | | |
| | 7:24:36 | BKD | | | 62.5 | | | | |

**TABLE 1(b)** (*Contd*.)

| (1) | (2) | (3) | (4) | | | | (5) | (6) | (7) |
|---|---|---|---|---|---|---|---|---|---|
| 15. | 23 Dec 1991 | TZR | 12 | 59 | 32.0 | 37.0 | 5.0 | | 27°-3'N |
| | | HMN | | | 41.5 | 59.0 | 17.5 | | |
| | | BKD | | | 35.0 | 44.0 | 9.0 | 2.20 | 92°-50'E |
| | 12:59:28 | BPR | | | 34.0 | 40.0 | 6.0 | | |
| 16. | 8 Jan 1992 | TZR | 3 | 17 | 42.0 | 50.0 | 8.0 | | 25°-53'N |
| | | HMN | | | 38.5 | 44.5 | 6.0 | 1.72 | |
| | | BKD | | | 45.0 | 58.5 | 13.5 | | 92°-32.5'E |
| | 3:17:30 | BPR | | | 43.5 | 53.0 | 9.5 | | |
| 17. | 8 Feb 1992 | TZR | 14 | 1 | 57.0 | 65.5 | 8.5 | | 26°-25'N |
| | | BPR | | | 53.0 | 58.5 | 5.5 | 1.80 | |
| | 14:1:46.25 | HMN | | | 63.0 | 76.5 | 13.5 | | 93°-28.5'E |
| 18. | 28 May 1992 | TZR | 1 | 38 | 65.0 | 74.5 | 9.5 | | 26°-0'N |
| | | BPR | | | 59.5 | 66.5 | 7.0 | | |
| | | HMN | | | 70.0 | 78.5 | 8.5* | 1.47 | 93°-38'E |
| | 1:38:45 | SNA | | | 61.5 | 69.5 | 8.0 | | |
| | | BKD | | | 74.5 | N.A | | | |
| 19. | 4 Jun 1992 | HMN | 14 | 52 | 33.5 | 44.5 | 11.0 | | 26°-11'N |
| | | BPR | | | 27.5 | 33.5 | 6.0 | 1.64 | 93°-19'E |
| | 14:52:17.5 | BK | | | 38.5 | 51.5 | 13.0 | | |
| 20. | 12 Jun 1992 | TZR | 8 | 48 | 57.5 | 66.0 | 8.5 | | 26°-21'N |
| | | HMN | | | 63.5 | 65.2 | 1.7 | 1.50 | |
| | | BPR | | | 49.0 | 53.0 | 4.0 | | 92°-35.5'E |
| | 8:48:42.5 | SNA | | | 54.5 | 60.0 | 5.5 | | |
| 21. | 14 Jun 1992 | TZR | 11 | 12 | 49.5 | 53.0 | 3.5* | | 27°-9.5′N |
| | | HMN | | | 57.5 | 71.5 | 14.0* | | |
| | | SNA | | | 52.5 | 59.5 | 7.0 | | 92°-50′E |
| | | BKD | | | 54.0 | 61.5 | 7.0 | | |
| | 11:12:33 | BPR | | | 51.0 | 57.5 | 6.5 | 1.36 | |
| 22. | 14 Jun 1992 | TZR | 12 | 39 | 56.5 | 60.5 | 4.0 | | |
| | | HMN | | | 59.5 | 65.5 | 6.0* | | |
| | 12:39:52.5 | SNA | | | 57.5 | 63.5 | 6.0 | ---- | ---- |
| | | BKD | | | 59.5 | 67.5 | 8.0 | | |
| 23. | 19 Jun 1992 | TZR | 3 | 31 | 1.5 | 9.0 | 7.5 | | 26°-55.5′N |
| | | SNA | | | 4.5 | 11.0 | 6.5 | | |
| | | HMN | | | 7.0 | 16.0 | 9.0 | 1.91 | 91°-44.5′E |
| | 3:30:57.5 | SJA | | | 6.5 | 15.0 | 8.5 | | |
| 24. | 28 Jun 1992 | TZR | 0 | 4 | 56.0 | 63.5 | 7.5 | | 26°-26′N |
| | | BPR | | | 50.0 | 53.5 | 3.5 | 1.65 | |
| | 0:4:45 | SNA | | | 52.5 | 57.5 | 5.0 | | 93°-25′E |
| 25. | 5 July 1992 | TZR | 20 | 2 | 31.0 | 35.5 | 4.5 | | 27°-1′N |
| | | BKD | | | 38.5 | 48.5 | 10.0 | 1.69 | 93°-0′E |
| | | BPR | | | 31.5 | 37.5 | 6.0 | | |
| | 20:2:24 | SNA | | | 32.5 | 38.5 | 6.0 | | |
| 26. | 22 July 1992 | TZR | 7 | 45 | 28.5 | 35.0 | 6.5 | | 26°-20′N |
| | | BPR | | | 27.0 | 31.5 | 4.5 | 2.03 | 93°-19′E |
| | 7:45:22.5 | SNA | | | 27.5 | 32.5 | 5.0 | | |
| 27. | 7 Aug 1992 | TZR | 9 | 56 | 56.5 | 65.5 | 9.0 | | 26°-8′N |
| | | SNA | | | 53.5 | 60.0 | 6.5 | | |
| | | HMN | | | 60.5 | 70.5 | 10.0 | | 93°-31′E |
| | | BKD | | | 71.0 | 83.5 | 12.5* | 1.52 | |
| | 9:56:40.5 | BPR | | | 45.0 | 51.5 | 6.5* | | |
| 28. | 11 Aug 1992 | TZR | 6 | 7 | 43.5 | 52.5 | 9.0 | | 26°-13.5′N |
| | | HMN | | | 41.5 | 48.5 | 7.0 | 2.00 | 92°-15′E |
| | 6:7:34.75 | SNA | | | 44.5 | 54.5 | 10.0 | | |
| 29. | 18 Aug 1992 | TZR | 14 | 28 | 18.5 | 28.5 | 10.0 | | 25°-47′N |
| | | SNA | | | 15.0 | 19.5 | 4.5 | 1.65 | 93°-9′E |
| | 14:28:2.75 | BKD | | | 27.5 | 43.5 | 16.0 | | |
| | | BPR | | | 15.5 | 24.0 | 8.5 | | |
| 30. | 27 Aug 1992 | TZR | 13 | 11 | 31.3 | 38.5 | 7.2 | | 27°-22′N |
| | | BPR | | | 31.5 | 38.5 | 7.0 | 1.43 | |
| | | BKD | | | 38.0 | 48.0 | 10.0 | | 93°-14′E |
| | 13:11:15 | SNA | | | 37.5 | 40.5 | 3.0 | | |

Mean $V_p/V_s$ from 29 readings = 1.73

**TABLE 1(c)**

**$V_p/V_s$ data for the seismic area near Tezpur Assam (1995 – 97) calculated from Wadati diagrams drawn on the basis of NGRI data**

| S. No. | Date and 0-time (GMT) | Station | Arrival time (UTC) P | | | S | $t_s$-$t_p$ | $V_p/V_s$ | Epicentre |
|---|---|---|---|---|---|---|---|---|---|
| | | | H | M | S | Sec | Sec | | |
| (1) | (2) | (3) | | | (4) | | (5) | (6) | (7) |
| 1. | 8 Jan 1995 | TZR | 13 | 34 | 40.5 | 45.5 | 5.0 | | 26°-17'N |
| | | SNA | | | 38.0 | 41.5 | 3.5 | 1.74 | 93°-9'E |
| | 13:34:33.5 | HMN | | | 45.5 | 54.5 | 9.0 | | |
| 2. | 9 Jan 1995 | TZR | 5 | 34 | 24.0 | 30.0 | 6.0 | | 26°-27'N |
| | | SNA | | | 23.5 | 29.5 | 6.0 | 1.67 | 92°-21'E |
| | 5:34:15 | HMN | | | 26.5 | 34.5 | 8.0 | | |
| 3. | 9 Jan 1995 | TZR | 12 | 53 | 58.5 | 66.5 | 8.0 | | 26°-17'N |
| | | SNA | | | 57.5 | 63.5 | 6.0 | | 92°-49.06'E |
| | 12:53:48 | HMN | | | 65.5 | 77.5 | 12.0 | 1.72 | |
| 4. | 12 Jan 1995 | TZR | 3 | 39 | 27.0 | 34.0 | 7.0 | | 26°-24.38'N |
| | | SNA | | | 25.5 | 34.0 | 8.5 | | 92°-40.38'E |
| | 3:39:18 | SGR | | | 30.5 | 39.5 | 9.0 | 1.75 | |
| | | HMN | | | 34.5 | 47.0 | 12.5 | | |
| 5. | 19 Jan 1995 | TZR | 16 | 12 | 8.5 | 13.5 | 5.0 | | 26°-56'N |
| | | HMN | | | 18.5 | 31.5 | 13.0 | | 92°-32.5'E |
| | 16:12:2.5 | SJA | | | 9.0 | 14.5 | 5.5 | 1.82 | |
| 6. | 28 Jan 1995 | TZR | 20 | 43 | 11.0 | 19.6 | 8.6 | | 27°-11'N |
| | | SJA | | | 9.5 | 17.0 | 7.5 | | 92°-29'E |
| | 20:43:01 | SNA | | | 13.5 | 24.5 | 11.0 | 1.85 | |
| 7. | 29 Jan 1995 | TZR | 20 | 29 | 17.0 | 25.0 | 8.0 | | 25°-53'N |
| | | SJA | | | 16.0 | 23.5 | 7.5 | 1.41 | 93°-10'E |
| | 20:28:57.5 | HMN | | | 8.0 | 12.5 | 4.5 | | |
| 8. | 29 Jan 1995 | TZR | 22 | 41 | 34.0 | 42.0 | 8.0 | | 26°-12'N |
| | | SJA | | | 35.5 | 44.0 | 8.5 | | 93°-31'E |
| | 22:41:21.5 | HMN | | | 37.5 | 48.0 | 10.5 | 1.64 | |
| 9. | 30 Jan 1995 | TZR | 20 | 13 | 2.5 | 8.5 | 6.0 | | 26°-31'N |
| | | HMN | | | 5.0 | 13.5 | 8.5 | | 92°-17'E |
| | | SJA | | | 7.5 | 17.5 | 10.0 | | |
| | 20.12.54 | SNA | | | 4.0 | 12.0 | 8.0 | 1.74 | |
| 10. | 1 Feb 1995 | TZR | 7 | 59 | 17.0 | 27.0 | 10.0 | | 27°-35.5'N |
| | | HMN | | | 27.5 | 46.5 | 19.0 | | 91°-57.5'E |
| | 7:58:55.5 | SJA | | | 17.0 | 30.0 | 13.0 | 1.55 | |
| | | SNA | | | 23.0 | 38.5 | 15.5 | | |
| 11. | 1 Feb 1995 | TZR | 10 | 26 | 22.0 | 28.5 | 6.5 | | 26°-5.5'N |
| | | HMN | | | 21.5 | 30.0 | 8.5 | | 93°-17.5'E |
| | | SJA | | | 25.5 | 34.0 | 8.5 | | |
| | 10:26:5.5 | SNA | | | 18.5 | 24.0 | 5.5 | 1.41 | |
| 12. | 1 Feb 1995 | TZR | 19 | 37 | 30.0 | 35.5 | 5.5 | | 26°-9'N |
| | | HMN | | | 31.5 | 38.5 | 7.0 | 1.63 | 93°-7'E |
| | 19:37:21 | SJA | | | 34.5 | 43.0 | 8.5 | | |
| 13. | 2 Feb 1995 | TZR | 0 | 47 | 8.5 | 17.0 | 8.5 | | 27°-21'N |
| | | HMN | | | 19.0 | 35.0 | 16.0 | | 91°-0'E |
| | | SJA | | | 10.0 | 21.5 | 11.5 | | |
| | 0:46:51 | SNA | | | 14.5 | 27.0 | 12.5 | 1.56 | |
| 14. | 2 Feb 1995 | TZR | 13 | 5 | 46.0 | 55.5 | 9.5 | | 27°-1'N |
| | | SJA | | | 49.5 | 59.5 | 10.0 | | 91°-51'E |
| | 13:5:14.5 | HMN | | | 53.5 | 65.0 | 11.5 | 1.29 | |
| 15. | 4 Feb 1995 | TZR | 4 | 21 | 37.0 | 42.5 | 5.5 | | 26°-35'N |
| | | SJA | | | 39.5 | 46.5 | 7.0 | | 93°-28'E |
| | | SNA | | | 39.0 | 45.5 | 6.5 | | |
| | 4:21:27 | | | | 12.91 | | | 1.55 | |
| 16. | 5 Feb 1995 | TZR | 14 | 59 | 6.0 | 10.0 | 4.0 | 1.67 | 26°-23'N |
| | | HMN | | | 12.0 | 20.5 | 8.5 | | 92°-44'E |
| | | SJA | | | 10.5 | 17.5 | 7.0 | | |
| | 14:59:59.5 | SNA | | | 5.5 | 10.0 | 4.5 | | |

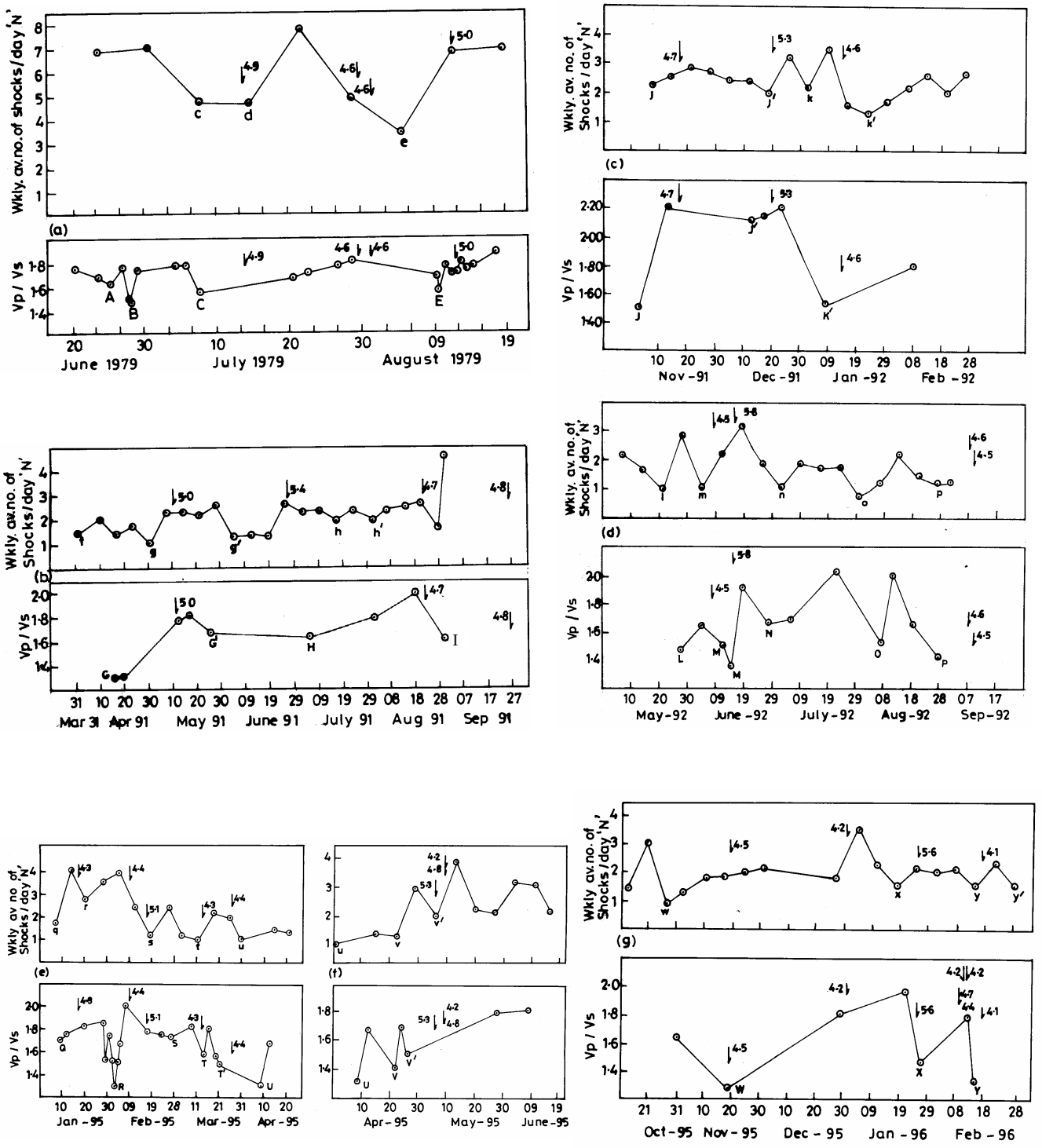
**TABLE 1(c)** (*Contd*.)

| (1) | (2) | (3) | | | (4) | | (5) | (6) | (7) |
|---|---|---|---|---|---|---|---|---|---|
| 17. | 7 Feb 1995 | TZR | 19 | 28 | 5.5 | 11.5 | 6.0 | | 26°-27'N |
| | | HMN | | | 15.5 | 26.5 | 11.0 | 2.00 | 93°-28'E |
| | | SNA | | | 6.5 | 13.5 | 7.0 | | |
| | 19:28:59.5 | SJA | | | 4.5 | 9.5 | 5.0 | | |
| 18. | 8 Feb 1995 | TZR | 1 | 48 | 26.5 | 33.0 | 6.5 | | 26°-48'N |
| | | HMN | | | 33.5 | 43.0 | 9.5 | 2.28 | 92°-2'E |
| | | SNA | | | 28.5 | 37.5 | 9.0 | | |
| | 1:48:10 | SJA | | | 29.5 | 40.0 | 10.5 | | |
| 19. | 17 Feb 1995 | TZR | 16 | 41 | 5.9 | 19.5 | 14.5 | | 27°-54'N |
| | | SGR | | | 4.5 | 19.0 | 14.5 | | 92°-13'E |
| | 16:40:46.5 | SJA | | | 2.5 | 15.5 | 13.0 | 1.78 | |
| 20. | 23 Feb 1995 | TZR | 23 | 21 | 14.0 | 21.5 | 7.5 | | 26°-19.18'N |
| | | SNA | | | 10.5 | 16.0 | 5.5 | 1.75 | 93°-1.53'E |
| | 23:21:35 | SJA | | | 17.5 | 28.0 | 10.5 | | |
| 21. | 27 Feb 1995 | TZR | 15 | 55 | 37.5 | 43.5 | 6.0 | | 26°-27.5'N |
| | | HMN | | | 45.0 | 56.5 | 11.5 | 1.73 | 93°-16'E |
| | 15:55:29.5 | SJA | | | 39.0 | 45.5 | 6.5 | | |
| 22. | 9 Mar 1995 | TZR | 12 | 44 | 43.0 | 51.0 | 8.0 | | 27°-13.5'N |
| | | HMN | | | 54.0 | 71.5 | 17.5 | | 92°-28'E |
| | | SGR | | | 41.0 | 49.0 | 8.0 | | |
| | 12:44:32.5 | SNA | | | 47.0 | 59.0 | 12.0 | 1.82 | |
| | | SJA | | | 42.0 | 49.5 | 7.5 | | |
| 23. | 14 Mar 1995 | TZR | 9 | 48 | 49.0 | 53.5 | 4.5 | | 26°-19'N |
| | | SJA | | | 53.0 | 60.0 | 7.0 | | 92°-42'E |
| | | HMN | | | 55.0 | 62.5 | 7.5 | 1.58 | |
| | 9:48:41.5 | SNA | | | 49.0 | 53.5 | 4.5 | | |
| 24. | 15 Mar 1995 | SJA | 9 | 7 | 15.5 | 21.5 | 6.0 | | 27°-3'N |
| | | SGR | | | 11.5 | 17.0 | 5.5 | | 92°-23.5'E |
| | | SNA | | | 18.0 | 26.5 | 8.5 | 1.57 | |
| | 9:7:3.5 | HMN | | | 24.5 | 37.5 | 13.0 | | |
| 25. | 16 Mar 1995 | TZR | 11 | 16 | 60.5 | 69.0 | 8.5 | | 26°-42'N |
| | | SJA | | | 58.5 | 64.5 | 6.0 | 1.88 | 93°-28.5'E |
| | 11:16:51 | SNA | | | 60.0 | 68.5 | 8.5 | | |
| | | HMN | | | 68.5 | 83.5 | 15.0 | | |
| 26. | 16 Mar 1995 | TZR | 18 | 35 | 51.5 | 55.5 | 4.0 | | 26°-22'N |
| | | SJA | | | 55.5 | 62.5 | 7.0 | | 93°-2'E |
| | 18:35:45.5 | SNA | | | 52.0 | 56.5 | 4.5 | 1.71 | |
| | | HMN | | | 57.5 | 67.0 | 9.5 | | |
| | | SGR | | | 53.5 | 59.5 | 6.0 | | |
| | | BKD | | | 59.0 | 68.5 | 9.5 | | |
| 27. | 19 Mar 1995 | TZR | 14 | 45 | 56.5 | 64.5 | 8.0 | | 26°-18'N |
| | | SJA | | | 58.5 | 65.5 | 7.0 | 1.58 | 93°-30'E |
| | 14:45:42.5 | HMN | | | 60.5 | 71.5 | 11.0 | | |
| | | SNA | | | 53.0 | 59.5 | 6.5 | | |
| 28. | 21 Mar 1995 | TZR | 3 | 11 | 60.5 | 69.0 | 8.5 | | 26°-40'N |
| | | HMN | | | 69.0 | 79.5 | 10.5 | 1.49 | 91°-55'E |
| | 3:11:45 | BKD | | | 51.5 | 53.5 | 2.0 | | |
| 29. | 9 Apr 1995 | TZR | 7 | 5 | 43.0 | 49.0 | 6.0 | | 25°-48'N |
| | | SJA | | | 46.0 | 54.5 | 8.5 | 1.31 | 93°-36'E |
| | 7:5:20.5 | SNA | | | 38.5 | 44.5 | 6.0 | | |
| 30. | 12 Apr 1995 | TZR | 18 | 3 | 3.5 | 9.5 | 6.0 | | 26°-13'N |
| | | SNA | | | 4.0 | 10.5 | 6.5 | 1.67 | 92°-24.5'E |
| | 18:2:54.5 | SJA | | | 0.5 | 10.0 | 9.5 | | |
| | | BKD | | | 6.5 | 14.5 | 8.0 | | |
| 31. | 22 Apr 1995 | TGR | 13 | 3 | 19.5 | 29.0 | 9.5 | | 25°-53'N |
| | | SGR | | | 18.0 | 27.5 | 9.5 | 1.42 | 91°-44'E |
| | 13:2:55.47 | BKD | | | 15.5 | 24.5 | 9.0 | | |
| 32. | 24 Apr 1995 | TZR | 5 | 38 | 31.5 | 36.5 | 5.0 | | 27°-3.5'N |
| | | SGR | | | 32.5 | 38.5 | 6.0 | | 92°-46'E |
| | 5:38:24.5 | BKD | | | 35.5 | 43.5 | 8.0 | 1.70 | |

**TABLE 1(c)** (*Contd*.)

| (1) | (2) | (3) | | | (4) | | (5) | (6) | (7) |
|---|---|---|---|---|---|---|---|---|---|
| 33. | 25 Apr 1995 | TZR | 20 | 39 | 49.5 | 54.0 | 4.5 | | 26°-17'N |
| | | SJA | | | 54.0 | 60.5 | 6.5 | 1.51 | 92°-26.5'E |
| | 20:39:40.5 | SNA | | | 50.5 | 55.5 | 5.0 | | |
| | | BKD | | | 53.5 | 60.0 | 6.5 | | |
| 34. | 27 May 1995 | TZR | 22 | 28 | 16.0 | 23.5 | 7.5 | | 26°-8.5'N |
| | | SNA | | | 12.5 | 17.5 | 5.0 | 1.80 | 93°-15'E |
| | 22:28:6 | HMN | | | 17.5 | 27.5 | 10.0 | | |
| 35. | 7 Jun 1995 | SJA | 18 | 47 | 48.5 | 60.5 | 12.0 | | 26°-5'N |
| | | SNA | | | 43.0 | 50.5 | 7.5 | | 92°-27'E |
| | | HMN | | | 41.5 | 48.5 | 7.0 | | |
| | 18:47:34 | SGR | | | 40.5 | 45.5 | 5.0 | 1.81 | |
| | | BKD | | | 46.5 | 56.5 | 10.0 | | |
| 36. | 3 Aug 1995 | TZR | 2 | 54 | 48.0 | 55.5 | 7.5 | | 26°-20'N |
| | | SNA | | | 45.5 | 49.5 | 4.0 | 2.20 | 93°-16'E |
| | | SJA | | | 49.5 | 58.5 | 9.0 | | |
| | 2:54:42 | SGR | | | 51.5 | 55.5 | 4.0 | | |
| 37 | 6 Aug 1995 | TZR | 11 | 52 | 10.5 | 16.5 | 6.0 | | 26°-11'N |
| | | SNA | | | 8.5 | 13.5 | 5.0 | 1.82 | 92°-38'E |
| | 11:52:2.5 | SJA | | | 14.5 | 24.5 | 10.0 | | |
| 38. | 18 Aug 1995 | TZR | 9 | 4 | 13.5 | 18.5 | 5.0 | | 26°-34.5'N |
| | | SNA | | | 14.5 | 20.5 | 6.0 | 1.97 | 92°-27.5'E |
| | 9:4:8.0 | SJA | | | 16.5 | 24.5 | 8.0 | | |
| 39. | 1 Nov 1995 | TZR | 1 | 29 | 20.5 | 26.0 | 5.5 | | 27°-12'N |
| | | BKD | | | 16.5 | 20.5 | 4.0 | 1.64 | 92°-25'E |
| | 1:29:11 | SNA | | | 26.0 | 35.5 | 9.5 | | |
| 40. | 19 Nov 1995 | TZR | 12 | 32 | 38.5 | 45.0 | 6.5 | | 26°-19.5'N |
| | | SNA | | | 39.5 | 47.0 | 7.5 | 1.28 | 92°-21.5'E |
| | 12:32:12.5 | BKD | | | 39.0 | 47.0 | 8.0 | | |
| | | O.T | | | 12.65 | 12.65 | 0.0 | | |
| 41. | 28 Dec 1995 | TZR | 20 | 37 | 11.5 | 22.5 | 11.0 | | 26°-12'N |
| | | SNA | | | 14.0 | 27.5 | 13.5 | 1.82 | 91°-57'E |
| | 2:36:57.5 | BKD | | | 8.5 | 17.5 | 9.0 | | |
| 42. | 21 Jan 1996 | TZR | 15 | 21 | 41.0 | 50.5 | 9.5 | | 26°-11'N |
| | | SNA | | | 41.5 | 51.5 | 10.0 | 1.98 | 92°-13.5'E |
| | 15:21:31.3 | BKD | | | 40.5 | 49.5 | 9.0 | | |
| 43. | 27 Jan 1996 | TZR | 7 | 30 | 49.0 | 62.0 | 13.0 | | 27°-57'N |
| | | BKD | | | 41.5 | 51.0 | 9.5 | | 92°-7'E |
| | 7:30:21.15 | SNA | | | 53.5 | 72.5 | 19.0 | 1.47 | |
| 44. | 12 Feb 1996 | SNA | 11 | 25 | 46.5 | 53.5 | 7.0 | | 26°-55'N |
| | | BKD | | | 46.5 | 54.0 | 7.5 | 1.80 | 92°-40'E |
| | 11:25:37.5 | SGR | | | 42.5 | 46.5 | 4.0 | | |
| 45. | 14 Feb 1996 | TZR | 16 | 18 | 33.0 | 40.0 | 7.0 | | 25°-47'N |
| | | SNA | | | 29.5 | 35.0 | 6.0 | 1.33 | 92°-30'E |
| | 16:18:14 | BPR | | | 30.5 | 37.0 | 6.5 | | |
| 46. | 16 Aug 1996 | TZR | 3 | 25 | 45.0 | 50.5 | 5.5 | | 26°-30'N |
| | | HMN | | | 52.0 | 64.0 | 12.0 | 1.82 | 93°-18'E |
| | 3:25:38 | SNA | | | 44.0 | 49.5 | 5.5 | | |
| 47. | 31 Jan 1997 | TZR | 3 | 13 | 17.0 | 22.5 | 5.5 | | 26°-31'N |
| | | SGR | | | 15.0 | 20.5 | 5.5 | 1.54 | 92°-12'E |
| | 3:13:4.5 | SNA | | | 17.5 | 24.5 | 7.0 | | |
| | | HMN | | | 18.5 | 26.0 | 7.5 | | |
| 48. | 15 Feb 1997 | TZR | 23 | 34 | 5.0 | 11.0 | 6.0 | | 26°-38'N |
| | | SNA | | | 8.0 | 16.5 | 8.5 | 1.71 | 92°-14.5'E |
| | 23:33:56 | SGR | | | 1.5 | 5.5 | 4.0 | | |
| 49. | 6 Apr 1997 | TZR | 1 | 2 | 20.5 | 30.5 | 10.0 | | 26°-1'N |
| | | SNA | | | 22.5 | 33.0 | 10.5 | 1.49 | 91°-49'E |
| | 1:1:60.5 | SGR | | | 17.0 | 25.0 | 8.0 | | |

Mean $V_p/V_s$ from 49 readings = 1.68




**Figs. 4(a-g).** (a)Dip in the number of shocks per day and in $V_p/V_s$ ratio prior to (a) M ≥ 4.6 earth quakes around Burnihat, Raliang & Borjuri in Meghalaya for the granitic layer (May - September 1995), (b) M ≥ 4.7 earth quakes around Digital Telemetry Seismic Network, Tezpur, Assam for the granitic layer (April - September 1991), (c) M ≥ 4.6 earth quakes around Digital Telemetry Seismic Network, Tezpur, Assam (November 1991- February 1992), (d) M≥4.5 earth quakes around Digital Telemetry Seismic Network, Tezpur, Assam, (e) M ≥ 4.3 earth quakes around Digital Telemetry Seismic Network, Tezpur, Assam, (f) M ≥ 4.2 earth quakes around Digital Telemetry Seismic Network, Tezpur, Assam (April - June 1995) and (g) M ≥ 4.3 earth quakes around Digital Telemetry Seismic Network, Tezpur, Assam

**TABLE 2**

**Magnitude of earthquakes correlated with lowering $V_p/V_s$ ratio and of number of shocks per day with corresponding precursion times. (N = wkly average number of shocks per day)**

| S. No. | Magnitude | Date | Origin time (UTC) | | | Epicentre | Dip in the curve for | | Precursion Time from | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | H | M | S | | $V_p/V_s$ | 'N' | $V_p/V_s$ days | 'N' days |
| (1) | (2) | (3) | | (4) | | (5) | (6) | | (7) | |
| 1. | 4.6 | 26 Jun 1979 | 6 | 11 | 42.6 | 30°-16.7'N 94°-6.5'E | A | - | 1 | - |
| 2. | 4.9 | 13 Jul 1979 | 23 | 2 | 9.9 | 24°-52.8'N 95°-13.2'E | C | c | 6 | 6 |
| 3. | 4.6 | 29 Jul 1979 | 14 | 16 | 21 | 26°-45.2'N 91°-44.3'E | | d | - | 15 |
| 4. | 4.6 | 1 Aug 1979 | 8 | 58 | 24.5 | 25°-10.8'N 95°-36'E | | d | - | 17 |
| 5. | 5.0 | 11 Aug 1979 | 20 | 32 | 8.3 | 24°-12'N 94°-55.8'E | E | e | 2 | 7 |
| 6. | 5.0 | 11 May 1991 | 2 | 15 | 22.2 | 24°-15.6'N 93°-40.8'E | G | g | 25 | 10 |
| 7. | 5.4 | 26 Jun 1991 | 16 | 4 | 1.7 | 26°-35.4'N 93°-11.4'E | G' | g' | 32 | 22 |
| 8. | 4.7 | 22 Aug 1991 | 3 | 53 | 44.3 | 25°-17.4'N 91°-10.8'E | H | h | 48 | 36 |
| 9. | 4.8 | 26 Sep 1991 | 5 | 4 | 48.7 | 25°-36'N 90°-18'E | I | i | 26 | 29 |
| 10. | 4.7 | 17 Nov 1991 | 5 | 17 | 5.2 | 24°-40.8'N 93°-0.8'E | J | j | 15 | 10 |
| 11. | 5.3 | 20 Dec 1991 | 2 | 6 | 5.2 | 24°-41.4'N 93°-7.2'E | - | j' | - | 1 |
| 12. | 4.6 | 13 Jan 1992 | 18 | 36 | 33 | 24°-25.2'N 92°-30'E | K' | k | 6 | 12 |
| 13. | 4.5 | 25 Feb 1992 | 1 | 57 | 26 | 25°-12'N 92°-12'E | k' | - | 33 | - |
| 14. | 4.5 | 8 Jun 1992 | 0 | 26 | 0 | 28°-30'N 94°-3.6'E | L | l | 11 | 18 |
| 15. | 5.8 | 15 Jun 1992 | 2 | 48 | 56.1 | 24°-0'N 95°-58.2'E | M | m | 3 | 11 |
| 16. | 4.6 | 6 Sep 1992 | 23 | 27 | 34.6 | 24°-31.8'N 95°-0.6'E | P | p | 10 | 11 |
| 17. | 4.5 | 8 Sep 1992 | 15 | 19 | 19 | 28°-36'N 94°-54'E | P | p | 12 | 13 |
| 18. | 4.3 | 17 Jan 1995 | 11 | 18 | 38.43 | 25°-57.59'N 92°-35.06'E | - | q | - | 11 |
| 19. | 4.4 | 8 Feb 1995 | 16 | 31 | 10.28 | 26°-4.87'N 93°-23.73'E | R | r | 5 | 19 |
| 20. | 5.1 | 17 Feb 1995 | 2 | 44 | 15.32 | 27°-14.20'N 92°-35.92'E | - | s | - | 2 □ |
| 21. | 4.3 | 13 Mar 1995 | 9 | 5 | 28.12 | 24°-46.67'N 93°-20.06'E | T | t | 1.5 O | 1 |
| 22. | 4.4 | 26 Mar 1995 | 18 | 22 | 17.97 | 27°-16.73'N 92°-29.12'E | T ' | - | 6 | - |
| 23. | 5.3 | 6 May 1995 | 1 | 59 | 10.22 | 25°-25.76'N 93°-53.47'E | U | u | 27 | 36 |
| 24. | 4.2 | 8 May 1995 | 23 | 25 | 57.36 | 26°-25.5'N 93°-14.9'E | U | u | 30 | 39 |
| 25. | 4.8 | 9 May 1995 | 7 | 54 | 36.18 | 26°-25.5'N 93°-14.4'E | U | u | 30 | 39 |

**TABLE 2 (*Contd.*)**

| (1) | (2) | (3) | | (4) | | (5) | (6) | | (7) | |
|---|---|---|---|---|---|---|---|---|---|---|
| 26. | 4.5 | 19 Nov 1995 | 5 | 14 | 43.86 | 29°-2.68'N 92°-7.01'E | W | w | M4.5 7 hours before dip | 22 |
| 27. | 5.6 | 25 Jan 1996 | 7 | 15 | 18.86 | 27°-1.28'N 87°-45.26'E | | x | | 7 |
| 28. | 4.7 | 8 Feb 1996 | 21 | 38 | 21.96 | 26°-39.31'N 94°-33.29'E | X | | 13 | - |
| 29. | 4.4 | 8 Feb 1996 | 23 | 41 | 1.13 | 28°-38.17'N 94°-13.82'E | X | | 13 | - |
| 30. | 4.2 | 10 Feb 1996 | 12 | 48 | 8.14 | 27°-8.39'N 89°-51.11'E | X | | 14.5 | - |
| 31. | 4.2 | 11 Feb 1996 | 11 | 56 | 48.75 | 25°-43.43'N 93°-59.66'E | X | | 15.5 | - |
| 32. | 4.1 | 17 Feb 1996 | 7 | 0 | 3.98 | 27°-0.39'N 92°-7.01'E | Y | y | 2 | 2 |

□ before dip. O before dip.

these points intersects the *P*- times axis at origin time 0, for which $t_s - t_p = 0$.

0-time mentioned with phase data is taken as an additional point in drawing these diagrams.

The slope of the line given by equation (2) is $(V_p/V_s - 1)$. Adding 1 to these values we get $V_p/V_s$.

Only $P_g$ and $S_g$ arrival times for which $t_s - t_p \leq 12$ secs are taken.

(*ii*) *Total number of shocks (excepting the teleseismic) for each week is divided by 7 to give the average number 'N' of shocs per day*

Values of $V_p/V_s$ and '*N*' are ploted side by side against time (days of the month) to study their variations.

## 4. Results and discussion

Wadati diagrams drawn on the basis of data in Tables 1 (a-c) are shown in Figs. 3(a-d).

Variations of $V_p/V_s$ and 'N' are shown in Figs. 4(a-g).

A few days before shocks of magnitude M ≥ 4.2, a sudden fall in $V_p/V_s$ ratio and a corresponding fall in '*N*' is observed. The points of dip in $V_p/V_s$ ratios are marked as A,B,C, etc and the corresponding points of dip in '*N*' values are marked as 'a', 'b', 'c' etc in these figures. The earthquakes mentioned in Table 2 are those that follow these lowerings. They are shown with arrow marks in these figures. The earthquakes mentioned in Table 2 have their epicenters within an area bounded by 24° N to 29° N Latitude and 90° E to 96° E Longitude. Their locations with Sr. Nos. from Table 2 are shown in Fig. 2. The cluster of shocks along the line PQ passing through the hot springs at Dirang (D) Bishun (B) and Mikir (M) Hot springs indicate high activity along and parallel to the basement fault separating Shillong massif and Mikir Hills massif.

For BUR-RAL-BOR region, the mean of 23 readings of $V_p/V_s$ for 1979 is found to be 1.71 as seen from Table 1(a).

For Digital Telemetry Seismic Network with HQ at Tezpur the mean value of $V_p/V_s$ out of 29 readings for 1991-92 is 1.73 as seen from Table 1(b) and mean $V_p/V_s$ for 1995-97 obtained from 49 readings is 1.68 for the same area. The mean of the 78 readings of $V_p/V_s$ for the area is 1.70.

It is seen from Table 2 and Figs. 4(a-g) that $V_p/V_s \leq 1.60$ are only followed by earthquakes of M ≥ 4.2.

The sudden lowerings of $V_p/V_s$ ratios and '*N*' values are comparable to the sudden lowering of resistivity or rocks in Shillong Plateau (Saha *et al*., 1982).

The lowering of average $V_p/V_s$ from 1.73 in 1991-92 to 1.68 in 1995-96 appears to be precursory and seems to confirm the conclusion from the quiescence of Major earthquakes (M ≥ 7.5) since 1952 in the Himalaya and North-east India [Satyabala and Gupta (1996), Khattri (1992), Gupta *et al*., (1995)].

Khattri and Wyss (1978) had identified a seismic gap between the 1897 and 1950 great earthquake (M.8.7) meizoseismal areas.

But according to Seeber and Ambruster (1981), the gap between the 1897 and 1950 ruptures was filled by the 1943 (M 7.25) and 1947 (M 7.75) earthquakes.

## 5. Conclusions

(*i*) $V_p/V_s$ = 1.71 for the granite layer in Shillong plateau and 1.70 around Tezpur Seismic station of N.E. India.

(*ii*) Taking $V_p$=5.92 km/s (Gupta *et al*., 1984), and $V_p/V_s$ =1.70 we get $V_s$=3.48 km/s for NE India, for the granitic layer.

(*iii*) Some of the shocks with M ≥ 4.2, appearing in the region seem to be preceded by precursory lowering of both $V_p/V_s$ ratio and weekly average number of shocks 'N' per day. $V_p/V_s$ is generally lowered below 1.60 before these earthquakes.

(*iv*) $V_p/V_s$ ratio has fallen from 1.73 in 1991-92 to 1.68 during 1995-97 in the Tezpur area. This seems to be precursory and in conformity with seismic quiescence reported for the region.

(*v*) $V_p/V_s$ analysis is not helpful in all geological or tectonic regions. The present work only suggests that it may work in N.E. India. Great care has to be taken to obtain 3 component seismic phase data from the region.

(*vi*) The present work is of limited accuracy and low confidence level due to uncertainties in S-arrival times.

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