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The role of seismic arrays in continuous monitoring of seismicity

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ABSTRACT. An array of sensitive short period seismometers established in 1965 near Gauribidanur has yielded valuable information regarding the seismicity of the Deccan Plateau. This array has the advantage of independent location of epicentres. It is the aim of this paper to present a summary of the findings of Gauribidanur array data regarding the distribution of epicentres upto a distance of about 400 km. In particular, we present also a summary of the observations of tremors coming from the Koyna region.

The observed distribution of epicentres around Gauribidanur shows broad correlation with Some known structural features. The present work has also brought out that the Deccan plateau is still seismically active. Continuous monitoring, as has been made at GBA, is likely to lead to correlation of seismlcity in relation to movement along faults and hopefully, the prediction o. major earthquakes.

1. Introduction

The seismicity of Deccan plateau has been studied, among others, by Oldham (1883), F.De Montessus De Ballore (1911), West (1937), Krishnan (1968), Tandon and Chatterjee (1968) and Gubin (1968). The Peninsula was believed to be aseismic and a region of high stability although feeble shocks were felt in some parts particularly around its margin (Krishnan 1968). It was, however, realised that although Peninsular India resisted folding of tertiary times, except along the northern border, it is greatly fractured by faulting which suggests that it is not so stable as is generally believed to be. There are north-south trending fault lines probably bordering Closepet granite as also the east coast and several parts of west India and Cambay (Radhakrishna 1969).

Despite the existence of some published studies of major earthquakes (F. De Montessus De Ballore 1911), there does not exist a comprehensive report of Peninsular seismicity including the information on minor earthquakes. This is due to the absence of sensitive seismographs in this region.

After the Gauribidanur seismic Array (GBA) with its highly sensitive seismometers became operational in its full capacity in the early part of 1968, it has been possible to monitor the local earth tremors down to their threshold of a few millimicrons of ground displacement which is set by the ambient ground noise. With its capability for independent determination of the epicentres, the seismic array has helped to locate the sources of seismic activity with a reasonable degree of accuracy.

It is the aim of this paper to report the results of a study of these events in the period 1968-1975, as observed at Gauribidanur. An attempt is also made to examine if the distribution of epicentres is related to known structural features of Deccan plateau, and the lineaments observed in LANDSAT imagery (Sreenivasan and Sreenivas 1977).

2. Salient features of Gauribidanur array

The seismic array is located near Gauribidanur (Lat. 13°36′ 15″ Long. 77°26′ 10″) and consists of 20 short period Willmore Mark II vertical seismometers spread over a L-shaped configuration whose two arms have a bearing of 212° (designated as arm 1) and 302° (designated as arm II) with a mean instrument spacing of 2·5 km. The operational magnification of each sensor is 180,000 at 1 Hz. The output of each seismograph is recorded on a 24 channel magnetic tape with accurate time code giving absolute GMT correct upto one second. This enables one to read time to an accuracy of 0.1 sec when the tape is replayed to produce visual analogue seismograms on a heat sensitive paper run at a speed of 10 mm/sec. The detailed information regarding the magnification curve, recording and replay systems is given in the proceedings of the Symposium on the use of Gauribidanur Data for Seismological Research (B.A.R.C. 1969).

3. Event selection for earth tremor study

For the purpose of this study, a total number of 259 events are selected first on the basis of the clear detection on the helicorder readings at three of the different points of the array to avoid spurious events like spikes and local sources of noise. A

* Deceased on 14 November 1977 in a fire accident at Manila, Philippines. The first version of this paper was seen by Shri Varghese in September 1977 and is now published with no substantial changes.

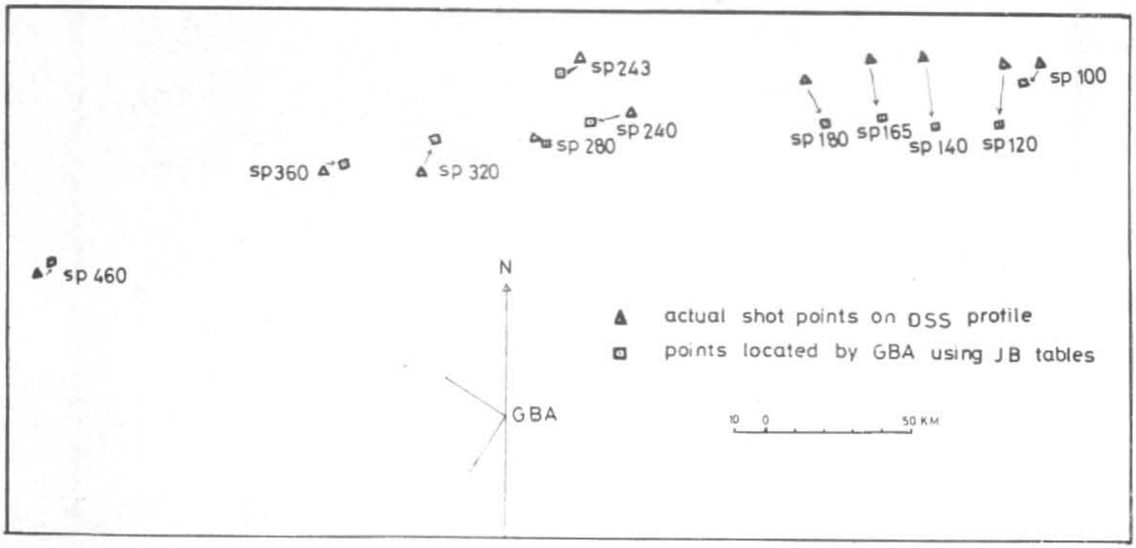

Fig. 1. Comparison of source location

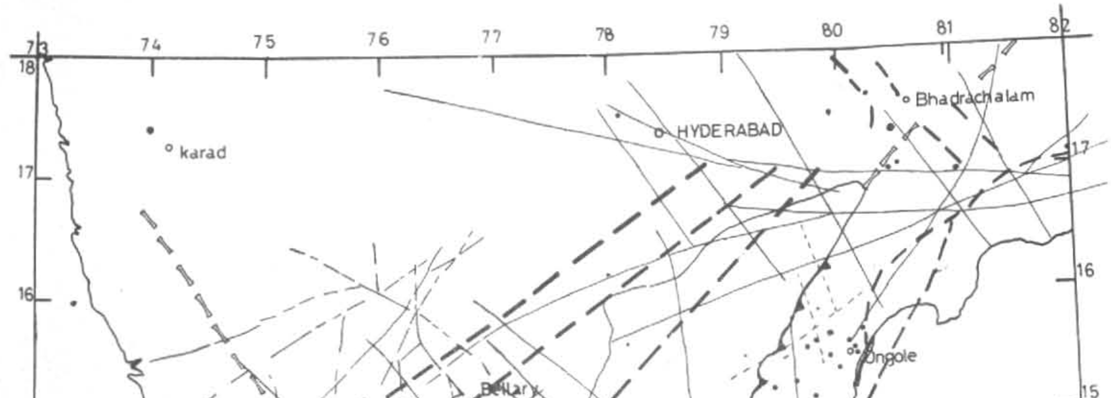

Fig. 2. Distribution of epicentres *vis-a-vis* tectonic features in the Deccan Plateau

complete list of these events is given in Appendix. For these events, an eight-channel replay is made from the magnetic tapes on a heat sensitive paper with accurate time marks at 1 second interval. There is provision to replay the tapes at different speeds ranging from 2.5 to 25 mm/sec with or without filters to remove high frequency noise to minimise errors in reading the onset of signal. There is also provision for three different sensitivities, namely 1V/cm, 2V/cm and 5V/cm, while replaying events from magnetic tapes. Usually the replay is done at a sensitivity of 2V/cm at a speed of 10 mm/sec.

The selected events are replayed on the 8-channel paper so as to get atleast two good seismograms from sufficiently widely spaced sensors on each arm of the array. Usually, we obtained 4 good seismograms from each arm for purpose of the present analysis.

The duration of replay of an event is decided on the basis of the presence or absence of later phases, namely, *S*-phase on the helicorder. A replay duration of one minute is adequate to cover all the later phases for all the events whose epicentral distance is about or less than four degrees with respect to GBA. Accordingly we have obtained the 8-channel playout for a maximum period of about one minute after the signal onset for the selected events.

All the events of interest have a frequency content in the range 5-16 Hz in *P*-phase, and hence the filters used were usually in the pass band 0-32 Hz for events whose distance is less than 2° and in the pass band 0-16 Hz for events beyond 2° distance.

4. Source location

For the selected events, the onset time of first *P*-phase at each sensor is read on the 8-channel playout. The apparent phase velocity V_a across the array is estimated on the basis of average time lag between pairs of sensors along each arm. The azimuth $\mathcal{Z}$ of the source is estimated from the formula :

$$\tan \mathcal{Z} = T_I/T_{II}$$

and V_a by the formula :

$$V_a = 2\cdot 5 / (T_I^2 + T_{II}^2)^{1/2}$$

where T_I and T_{II} are the average lags between successive sensors of each arm I and II respectively. The sign convention of these lags is so chosen that the azimuth can be expressed as angle beween 0°-360° due geographic north measured clock-wise.

The estimation of the epicentral distance is done using Jeffreys-Bullen Travel-Time Tables on the basis of "*P-S* lag" which is the interval between the arrival of first *P*-phase and that of first *S*-phase at the cross-over point of the array (that is the I-1 sensor). Whenever this channel is not available the sensor nearest to cross-over point is used for estimating this lag. In using this travel time tables, it is assumed that the depth of the source is shallow. We shall discuss in the next section the implication of this assumption on the source location. Thus, the *P-S* time lag and the estimation of T_I and T_{II} enable us to locate the epicentre of the event even without using the data of other stations.

5. Measurement errors

The source location is subject to following errors, some of which have been corrected for :

(*i*) The paper speed may not be exactly the same as 10 mm/sec, in which case a proper correction is made.

(*ii*) Due to emergent onset of the signal the reading of the lags can be inaccurate in the *P*-phase. This error is minimised by averaging the lag estimates from several combinations of the pairs of sensors.

(*iii*) The *S*-phase onset is embedded in the *P*-phase code and hence the reading of its onset is likely to be in error by about 0·2 sec.

(*iv*) Perhaps a major source of uncertainty in the eqicentral distance estimation is due to the possible difficulty in identifying the first arrivals of the body wave phase along the array in the transitional distance (P_g to P^* and P^* to P_n range of J-B Tables).

(*v*) All our epicentral estimates are done assuming a shallow source. In most of the cases studied, the apparent speed V_a along the array is found to be consistent with this assumption. Only in a few cases (three to be precise) we found that *P-S* difference is not consistent with the apparent phase velocity along the array. These events appear to have their foci deeper than 8 km as determined by separate analysis (unpublished).

6. Reliability of source location

To examine the reliability of source location we have compared locations estimated by us with the actual source location of DSS events. The two locations are shown in Fig. 1 where we see that the distance estimate is satisfactory, but the azimuth estimate is not. The azimuth can be different from actual one by an amount as much as 6° in some cases. For the purpose of this report, where we are interested in delineating regions of earth tremors, this inaccuracy is not serious.

7. Magnitude

To estimate roughly relative magnitude of the selected events we have used the simple formula :

$$m_b = \log (A/T) + Q$$

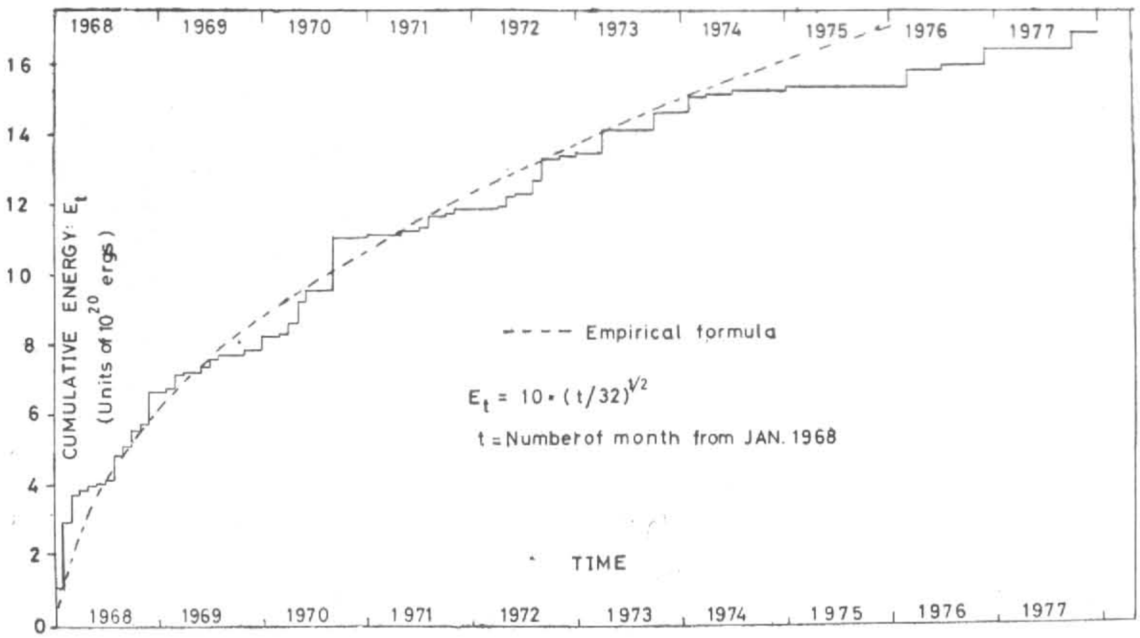

Fig. 3. Cumulative energy release of Koyna as observed at GBA

where A is the trace amplitude in microns and T is the period of the signal and Q is the Richter-Gutenberg depth distance correction (B.A.R.C. 1969).

Here it may be emphasised that the single station estimate of magnitude is not the best value for earthquakes due to uncertainty in the radiation pattern. Also the Q values are unknown for short distances of less than 2°. Since our purpose is only to broadly estimate the relative intensity of events as observed at GBA, we have used the Gutenberg's Q values extrapolated to shorter distances. The magnitude thus estimated is used to classify all the events into three categories shown by dots of different sizes as shown in Fig. 2 :

$$3 < m_b < 3.5$$
$$3{\cdot}5 \leqslant m_b \leqslant 5$$
$$m_b > 5$$

8. Seismicity of Koyna

The GBA is ideally suited to monitor events emanating from a given region. In view of its special place in the country, aftershocks of Koyna recorded at GBA were analysed before (Sharma and Murty 1975) upto end of 1973. Even after 1973 a number of minor tremors were recorded. The cumulative energy of these events was computed as before (Sharma and Murty 1975) and shown in Fig. 3. We see that the "energy release" is slower in the period 1971-1977 than what it was during 1969-1971. A physical interpretation of this result should await observations from other stations. It may tentatively be concluded, however, that either the rate of energy release is decreasing or the radiation pattern is changing as indicated by the observations at GBA.

9. Discussions

Fig. 2 shows the six important seismogenic regions as depicted by GBA together with some of the prominent lineaments in the Deccan.

(1) The most conspicuous seismogenic region lies between 12th and 14th parallels, from near Mysore upto near Kadiri in Andhra Pradesh through Mandya, Kanakapura, Krishnagiri, Vellore and Madanapalle, occupying the Cauvery-Palar river basins. The earthquakes from Mandaya region on 16 and 17 May 1972 were felt locally around Dodde Gowdana Koppal (Arora *et al.* 1973);

(2) A linear narrow belt along the east coast from near Nayudupeta north of Madras, upto Chirala through Kavali and Ongole;

(3) Across the southern part of Cuddapah basin along Penner and Papaghni river basins-from Jammalamadugu to Venkatagiri through Cuddapah;

(4) Along western Karnataka from near Mercara to Ramdurg through Hassan, Hosdurga and Pavagada. The earthquake of 12 May 1975 near Shimoga has been reported to have been felt over a wide area and has been recorded in the observatories of I.M.D. and NGRI;

(5) One small detached N-S extending patch near Palaghat, in the region described as Palaghat gap and

(6) A small cluster along the coast near Pondicherry.

Grady (1971), Borodin *et al.* (1971), Moralev *et al.* (1971), Radhakrishna (1952), Sreenivasan and Sreenivas (1977), and King (1872) have reported the existence of faults, fractures and shear zones in the regions mentioned above. The crustal siesmic activity along the above tracts suggests the existence of definite seismic sutures, which in turn are resultant of complex physico-geological conditions.

It would be interesting to examine the distribution of epicentres reported in this paper along with the lineaments seen in the imagery of LANDSAT together with any field evidence for seismogenic faults (Fig. 2). These integrated studies will be of great significance in deciphering the seismic behaviour of the region and knowing the belts of seismic risks.

Acknowledgements

One of the authors (H.S.S.Sharma) is thankful to Dr. M.V.N. Murthy, Geological Survey of India for his interest in this work and for providing us with a map of lineaments which supplemented the information (Sreenivasan and Sreenivas 1977). We thank our colleagues at Gauribidanur for acquiring the data analysed in this report. We are also thankful to Dr. G. S. Murty and Shri S. K. Arora for useful discussions.

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DISCUSSION

(Paper presented by H. S. S. Sharma)

S.N. Bhattacharya (I.M.D.): Can the error of determination be decreased by choosing right crustal model other than J-B ?

Author : These comments are self explanatory. The right crustal model, if it exists, will leave no error. But the 'best fit' model in the least square sense leaves some error. The actual errors are more due to the practical difficulty of lag determination by eye-ball search.

G.S. Murty (BARC) commented: Only some events of D.S.S. in some azimuths differ by 20 km. But majority are accurately located.

2. These seem to be essentially due to azimuthal errors.
3. Arora's tables are being used and compared.
4. Only eye ball search is used for this study. Computer is used mainly for teleseismic events analysis.

Author : The location error is mainly due to azimuthal error, which is essentially due to errors in lag estimates by eye-ball search. If the source is well within P_g range or beyond P_n range, the distance estimate by J-B table is satisfactory. It is only in the transmission range that errors are relatively large.

Appendix

List of events whose epicentres are shown in Fig. 2.

S. No.	Date	Onset time at GBA (GMT)	Azimuth (degree)	P (sec)	Distance (km)	Region	F.M.	M_b
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1	10-1-68	01:54:54 ·5	250	21 ·7	178	West of Hassan	C	4 ·2
2	16-1-68	17:31:45 ·5	126	18 ·6	155	Ambur	—	3 ·6
3	25-1-68	21:34:51	266	18 ·4	150	Birur	—	3 ·1
4	4-2-68	16:02:45 ·2	241	19 ·2	160	Hassan	D	—
5	4-2-68	16:04:05 ·2	241	19 ·2	160	Hassan	D	—
6	10-2-68	2:11:15 ·3	163	28	240	Salem	—	—
7	27-2-68	08:43:12	139	31	270	Tiruvannamalai	—	—
8	12-3-68	18:36:55	135	22 ·4	185	Dharampuri	—	—
9	13-3-68	09:06:14 ·4	122	37	330	Pondy Coast	—	—
10	15-3-68	01:05:25 ·9	212	56	517	Off the coast of Cochin	—	—
11	18-3-68	14:57:40 ·4	38	56 ·6	520	Bhadrachalam	—	—
12	18-3-68	17:23:30 ·5	245	23 ·7	198	Hassan	D	—
13	27-3-68	07:33:02 ·6	122	37 ·2	333	Pondy Coast	—	—
14	27-3-68	20:42:0 ·1	136	17 ·2	145	Vellore	D	—
15	28-3-68	07:03:06 ·4	122	39 ·4	355	Pondy Coast		
16	29-3-68	00:18:41 ·1	83	34 ·7	311	Off the coast of Madras		
17	13-4-68	15:27:52 ·8	73	20 ·5	166	Cuddapah Contact	—	4 ·0
18	14-4-68	12:08:35 ·7	42	31 ·5	277	Giddalur	C	3 ·3
19	16-4-68	06:32:22 ·9	206	41 ·1	370	Ponnani-Kerala	—	3 ·5
20	25-4-68	20:08:31	67	35 ·5	322	Coast of Nellore	—	—
21	25-4-68	20:10:02 ·5	67	35 ·5	322	Do	C	4 ·3
22	3-5-68	07:54:17 ·6	122	39 ·3	355	Off Pondy Coast	—	3 ·5
23	4-5-68	05:33:33 ·4	122	37 ·6	335	Do.	—	3 ·5
24	4-5-68	07:25:19 ·4	122	39 ·9	355	Do.	—	3 ·5
25	10-5-68	17:17:36 ·5	163	17 ·5	144	Krishnagiri region	D	3 ·3
26	12-5-68	18:19:49 ·6	52	26	222	East Cuddapah basin	C	3 ·9
27	15-5-68	02:12:01 ·6	138	25	211	Polur-vellore	—	3 ·0
28	21-5-68	06:28:18 ·8	122	34 ·8	310	Pondy coast	D	3 ·1
29	23-5-68	04:27:37	122	35 ·7	322	Off Pondy coast	—	3 ·5
30	25-5-68	05:22:01	120	35 ·6	320	Do.	—	3 ·5
31	27-5-68	06:52:39 ·8	296	37 ·2	330	Dandeli	—	3 ·8
32	28-5-68	06:18:23 ·1	124	37 ·2	333	Off Pondy Coast	—	3 ·8
33	28-5-68	06:59:40 ·6	329	13 ·0	110	Rayadurg	—	—
34	8-6-68	03:54:33 ·4	149	20 ·5	165	Dharmapuri	—	3 ·3
35	13-6-68	03:35:46 ·8	296	6 ·4	55	Madakasira	—	— Surface waves seen
36	20-6-68	09:28:32	41	53 ·4	500	Bhadrachalam	C	4 ·8
37	16-7-68	13:14:56 ·7	142	19	155	Krishnagiri	—	3 ·1
38	2-8-68	04:50:22 ·2	157	17 ·5	144	Do.	—	4 ·4
39	13-8-68	14:44:36 ·9	128	24	200	Polur-Vellore	D	4 ·4
40	26-8-68	19:54:18 ·6	163	19 ·6	160	Krishnagiri	D	3 ·7
41	3-9-68	08:02:52 ·6	250	29 ·6	255	Chickamagalur	—	4 ·5
42	7-9-68	23:31:43 ·3	256	29 ·5	255	Do.	C	4 ·4
43	28-9-68	14:50:37 ·7	251	27 ·5	235	Do.	D	3 ·8
44	4-11-68	08:19:21 ·5	299	48	433	Goa	D	5 ·0
45	28-11-68	11:49:20 ·5	200	15 ·0	125	Mandya	D	3 ·8
46	9-12-68	06:02:19 ·1	67	26 ·0	220	Eastern Cuddapah basin	—	3 ·9
47	28-12-68	05:30:54	224	17 ·8	150	Krishna Rajapet	C	4 ·1
48	3-1-69	13:31:28 ·5	184	38	333	Kodaikanal	—	4 ·0
49	16-1-69	20:56:20	77	18 ·2	150	Rayachoti	C	4 ·7
50	5-2-69	09:09:30 ·2	343	7 ·3	60	Pavagada	D	4 ·0
51	12-3-69	15:49:44 ·2	83	35	310	North of Madras	D	4 ·4
52	16-3-69	07:48:58 ·6	316	17 ·0	140	Chitldroog	D	3 ·7
53	31-3-69	01:06:43 ·1	100	17 ·5	144	Madanapalla	—	3 ·4
54	6-5-69	20:18:58 ·8	161	13 ·4	114	Krishnagiri	—	3 ·6
55	19-5-69	00:03:32	162	41 ·7	374	Dindigul	—	4 ·2
56	4-6-69	16:26:03 ·3	163	21 ·5	175	Dharmapuri	D	4 ·7
57	13-6-69	04:45:10	111	18 ·5	155	Chittor	—	3 ·4
58	13-6-69	05:17:59	111	18 ·5	155	Do.		3 ·4
59	24-6-69	13:40:52 ·9	220	23 ·8	200	Hunsur	D	4 ·1
60	1-7-69	13:23:32 ·8	68	18 ·2	150	Rayachoti	C	4 ·5
61	4-7-69	22:27:37 ·8	46	18 ·2	150	Cuddapah Basin	D	4 ·2
62	12-7-69	11:42:51	258	27	225	Chickamagalur	—	3 ·8

Appendix (*contd*)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
63	14-8-69	20:01:43·6	60	22·2	182	Cuddapah	C	4·0
64	15-8-69	06:50:45	182	17·4	144	Mandya	—	3·3
65	18-8-69	21:46:23·5	198	39·9	356	Yelandur	—	3·7
66	8-9-69	08:28:19	77	25·5	216	Eastern margin of Cuddapahs	—	3·8
67	21-9-69	22:04:32·8	163	14·7	122	Bangalore	—	4·0
68	27-9-69	17:54:43·1	194	41·0	367	Kodaikanal	D	4·8
69	29-9-69	18:47:02·5	162	14·8	122	Bangalore	—	3·8
70	5-10-69	05:46:45·8	192	15·3	126	Kanakapura	—	—
71	10-11-69	06:47:10	88	18·4	151	West of Thirupathi	—	4·0
72	12-11-69	05:30:59·8	241	22	181	Arakalgud	—	5·5
73	26-11-69	05:37:43·9	355	13·7	116	Ramgiri	D	3·7
74	3-1-70	17:48:56·4	72	7	61	Bagepalli	C	—
75	9-1-70	18:25:14·2	261	17·5	145	Hassan/Arsikere	C	3·7
76	12-1-70	15:33:03·3	50	31·8	277	Kavali/Ongole	C	4·4
77	16-1-70	03:06:20·8	56	33·8	300	Do.	—	5·0
78	19-1-70	02:23:46·2	195	13·9	117	Maddur/Mandya	D	5·3
79	12-2-70	17:10:21	237	20·5	166	Hassan region	C	5·2
80	12-2-70	17:58:18·4	148	13	110	Krishnagiri	—	3·4
81	20-2-70	03:39:39·6	342	13·1	110	Rayadurg	D	3·8
82	16-3-70	17:57:19·5	52	33·2	294	Kavali/Ongole	—	3·8
83	29-3-70	00:44:31·1	54	15·3	128	West of Cuddapah	—	3·8
84	3-4-70	02:27:11·1	32	17·0	144	SW of Cuddapah	D	4·3
85	8-5-70	02:33:30·9	95	6·9	60	Bagepalli	—	—
86	12-5-70	06:59:39·3	279	23·5	200	Shimoga	—	3·7
87	13-5-70	14:20:43·1	88	20·8	170	West of Thirupathi	—	4·2
88	2-6-70	18:26:13	77	25	211	Cuddapah basin	—	3·7
89	11-6-70	03:25:17·2	48	37·2	333	Ongole	—	4·1
90	6-7-70	16:11:31	67	7	61	Bagepalli	—	—
91	25-7-70	12:48:39·2	346	8·1	70	Rayadurg	D	4·1
92	28-7-70	04:00:14·6	164	14·5	122	South of Bangalore	—	3·9
93	11-8-70	01:13:57·2	254	19·5	161	Hassan	C	3·6
94	11-8-70	09:22:23·3	140	19·5	161	Vellore	—	3·5
95	2-9-70	22:12:01	189	14·8	120	Mandya/Malavalli	—	3·7
96	10-9-70	15:33:18·7	12	32·5	290	Kurnool	—	3·4
97	30-9-70	05:43:38·7	71	7·6	60	Bagepalli	C	—
98	19-11-70	03:04:22·9	63	33·4	300	Kavali/Ongole	—	3·7
99	28-11-70	13:27:22	163	13·8	110	Bangalore	—	—
100	2-12-70	16:26:57·7	52	37·4	333	Ongole	D	4·2
101	6-12-70	17:18:31·5	76	16·2	133	Kadiri/Thirupathi	—	4·5
102	29-12-70	11:08:28·5	118	42·0	377	Off Pondi Coast	—	3·9
103	17-1-71	14:00:14·4	192	15·3	125	Mandya/Malavalli	D	4·0
104	27-1-71	04:00:30	107	28	244	Arkonam	—	3·5
105	17-2-71	06:14:48·8	122	44	400	Off Cuddalore	D	3·5
106	24-2-71	21:22:38·3	303	15	122	Chitldroog	—	—
107	6-3-71	16:24:51·3	197	16·6	135	Mandya/Malavalli	D	4·0
108	15-3-71	20:30:15·6	176	11·2	100	Kanakapura	—	—
109	19-3-71	07:09:32·7	342	12·9	110	Kalyandurg	D	—
110	19-3-71	07:28:53·3	342	12·9	110	Do.	D	—
111	26-3-71	16:32:47·8	343	13·4	110	Do.	—	—
112	27-3-71	14:48:45·4	196	16·5	135	Mandya/Malavalli	D	4·1
113	16-4-71	06:37:38	136	22	182	Thiruvannamalai	—	3·6
114	16-4-71	06:51:54	134	22	182	Do.	—	3·6
115	19-4-71	06:11:58	324	12·6	105	Rayadurg	—	—
116	30-4-71	09:05:19·2	342	13·1	110	Kalyanadurg	C	—
117	13-5-71	17:17:48·8	45	39·3	355	Ongole	—	3·4
118	15-5-71	01:51:18·8	108	42	377	Off the coast of Madras	—	—
119	22-5-71	14:23:28·2	66	13·3	110	Kadiri	C	4·1
120	23-5-71	15:51:23·2	174	15	123	Kanakapura	D	4·1
121	27-5-71	21:41:02·4	3	46	422	Sangareddipet	—	—
122	30-5-71	02:50:10·9	159	8·5	77	Bangalore	D	3·8
123	31-5-71	04:48:19·3	113	37	333	Off Madras Coast	—	4·1
124	3-6-71	08:29:13·5	41	49·8	490	Khammam	D	4·2
125	5-6-71	03:55:17·6	85	21·7	177	West of Thirupathi	—	—
126	9-7-71	18:40:46·7	52	39·3	355	Ongole	D	4·4
127	10-7-71	21:38:47·2	181	15·6	128	Kanakapura	—	—
128	28-7-71	00:07:49·7	54	39·3	355	Ongole	D	4·9
129	3-8-71	11:12:45·9	69	26	220	NW of Vellore	—	3·0
130	4-8-71	10:23:07	122	39·2	355	Off Pondichery	D	4·0
131	5-9-71	18:34:57	179	23	188	Mettur Dam	—	3·5
132	14-9-71	21:43:38·7	78	5·6	35	Local	—	—
133	2-10-71	12:41:33·4	249	24·9	210	Hassan	—	3·6
134	14-10-71	18:43:16·5	73	13	110	Kadiri	—	—

Appendix *(contd)*

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
135	11-11-71	19:16:37·6	98	2.7	25	Gudibanda (Local)	—	—
136	12-11-71	20:31:12·5	134	20·2	165	Krishnagiri	—	4·0
137	16-12-71	12:33:29·3	185	23·1	188	Yelandur	—	3·2
138	31-12-71	01:23:36·5	48	36·5	322	Ongole	D	4·3
139	1-1-72	11:26:25	302	55	510	Malvan/West Coast	—	3·8
140	5-1-72	19:46:33	19	29·5	233	South of Kurnool	—	3·5
141	13-1-72	21:00:24	194	43	388	West of Ernakulam	—	3·6
142	7-2-72	19:29:46	138	14	118	South KGF	—	3·6
143	15-2-72	13:34:34	181	14	120	Kanakapura	—	3·3
144	11-3-72	16:02:26	54	37·5	333	Ongole	—	3·8
145	12-3-72	05:25:40	236	37·5	333	Off Cannanore	—	3·8
146	16-3-72	22:35:58	112	17	144	Vellore	—	3·7
147	23-3-72	13:16:36	84	33	290	North of Madras	—	4·0
148	23-3-72	14:15:23	180	14	115	Mandya/Malavalli	—	3·4
149	16-5-72	16:37:06·6	197	16.9	140	Mandya/Malavalli	D	4·1
150	17-5-72	10:00:17·8	196	16.9	140	Do.	D	4·5
151	10-7-72	12:33:29·5	104	32·5	288	West of Madras	—	3·9
152	30-7-72	20:08:21·8	34	57	533	Bhadrachalam	—	3·8
153	11-8-72	15:56:20·5	341	13	111	Rayadurg	D	—
154	11-8-72	18:47:50	342	13	111	Rayadurg	D	—
155	25-8-72	20:29:21·7	248	20·5	172	Hassan	C	3·9
156	3-9-72	13:04:54	51	65	620	Kakinada Coast	—	4·5
157	6-9-72	11:12:59·8	144	16·4	133	Krishnagiri	D	3·6
158	10-9-72	16:59:52	235	23·5	200	Arakalgd/Hassan	—	4·9
159	14-9-72	06:45:07·4	49	38·4	345	Ongole	—	4·1
160	19-9-72	06:52:32·2	200	15·4	130	Mandya	D	4·8
161	19-9-72	13:12:28	9	47·2	433	Sangareddipet/Hyderabad	—	4·4
162	30-9-72	08:02:35·7	53	39·3	355	Ongole	—	3·7
163	4-10-72	12:58:55·6	228	16·3	133	Channarayapatna/Hassan	C	3·6
164	22-10-72	21:44:24·9	52	42	382	Ongole	—	4·7
165	10-11-72	06:21:44·4	89	20·5	166	West of Thirupathi	—	3·3
166	11-11-72	21:53:18	172	23	200	Mettur dam	—	3·5
167	13-11-72	06:36:28	172	23	200	Do.	D	4·0
168	13-11-72	09:55:31·8	169	23	120	Do.	D	3·6
169	14-11-72	20:41:05·6	172	17·5	145	Kanakapura	—	3·6
170	16-11-72	03:12:36	172	17·5	145	Do.	—	3·1
171	20-11-72	03:18:21·8	169	14·9	125	Do.	D	3·7
172	20-11-72	03:20:04·3	144	14·0	119	Krishnagiri	—	3·6
173	27:11:72	03:38:22	172	15·5	130	Kanakapura	—	3·7
174	13-12-72	08:34:01·8	73	7·2	61	Bagepalli	—	—
175	16-12-72	01:23:27·5	70	7·8	66	Do.	—	—
176	17-12-72	12:19:21·5	157	14·8	125	Anekal/Bangalore	C	3·7
177	19-12-72	02:37:04·7	164	14·5	122	Do.	C	3·6
178	19-12-72	14:38:51·2	158	12·4	115	Do.	—	3·1
179	19-12-72	16:36:01·6	159	12·2	109	Do.	—	3·1
180	20-12-72	04:39:28·8	158	12·5	104	Do.	—	3·4
181	27-12-72	03:20:28·2	144	17·4	144	Krishnagiri	—	3·6
182	1-1-73	15:03:38·3	168	23	190	Dharmapuri	D	3·4
183	2-1-73	20:29:13·3	82	30·8	266	Kalahasti	—	3·5
184	10-1-73	19:11:39·7	239	29·3	255	Mercara	C	4·4
185	25-1-73	18:56:9·4	32	15·1	122	E of Dharmavaram/ Cuddapah margin	—	3·7
186	31-1-73	20:25:47·2	182	15	122	Kanakapura	—	3·4
187	25-2-73	04:34:26	181	13·2	110	Kanakapura	—	3·1
188	28-2-73	10:18:32·1	61	25·5	211	Cuddapah Basin	—	3·3
189	28-2-73	13:33:19	61	25·5	211	Do.	—	3·5
190	16-3-73	05:05:14·6	32	19·8	161	Jammalamadugu	D	3·6
191	24-3-73	09:51:48·2	58	28·8	244	Udaigiri	—	3·9
192	21-4-73	06:02-26·5	128	19·5	160	Vaniambadi	—	3·2
193	21-4-73	16:43:05·3	119	19	155	Vellore	—	—
194	24-4-73	23:57:45·0	32	53·8	500	Bhadrachalam	C	4·4
195	27-4-73	02:52:26·3	119	19	155	Vellore	D	3·7
196	1-5-73	04:40:54·9	182	15·5	130	Kanakapura	D	4·7
197	4-5-73	16:56:55·6	91	23·7	200	Thirupathi	C	3·8
198	29-8-73	09:12:46·5	200	17	144	Mandya/Malavalli	D	4·1
199	22-9-73	20:00:33·6	267	28	244	Chickamagalur	—	4·4
200	22-9-73	23:28:09·1	133	20·3	166	Vaniambadi	—	3·4
201	20-10-73	00:42:05·8	190	10·2	88	Bangalore	C	3·9
202	21-12-73	10:48:10	148	17·5	144	Krishnagiri	D	4·0
203	31-12-73	03:52:27	94	15·7	129	Madanapalli	—	3·1
204	15-1-74	01:06:20·7	156	15·4	128	Krishnagiri	—	3·1
205	15-1-74	02:01:40	151	15·4	128	Do.	C	3·4
206	23-1-74	15:43:22	53	22	183	Cuddapah basin	—	3·2

Appendix (*contd*)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
207	24-1-74	06:41:59 ·3	98	17 ·9	145	Madanapalli	—	3 ·3
208	24-1-74	16:05:18	99	19 ·3	158	Madanapalli	—	3 ·4
209	24-1-74	16:44:17 ·2	50	21	170	Cuddapah basin	—	3 ·2
210	25-1-74	05:43:16 ·4	197	21 ·6	178	Yelandur	C	4 ·2
211	25-1-74	15:42:49	56	21 ·3	175	Cuddapah basin	—	3 ·2
212	25-1-74	16:37:33 ·8	95	18 ·7	155	Madanapalli/Chittoor	—	3 ·2
213	27-1-74	10:03:39 ·2	59	21 ·3	175	Cuddapah basin	—	3 ·2
214	28-1-74	15:59:14	57	20 ·5	170	Do.	—	—
215	3-2-74	13:46:40	51	22	179	Do.	—	—
216	7-3-74	14:40:56	138	16 ·3	133	Krishnagiri	—	4 ·2
217	11-3-74	03:06:41 ·8	170	9	75	Bangalore	—	—
218	13-5-74	16:08:10	190	16 ·9	138	Madanapalli	C	3 ·5
219	3-10-74	03:55:38 ·6	180	10 ·2	89	Bangalore	—	—
220	3-10-74	11:54:53	81	22 ·3	182	Thirupathi	—	3 ·5
221	24-10-74	23:26:20	234	17 ·8	145	Hassan	C	4 ·1
222	7-11-74	03:16:32 ·3	348	10 ·6	90	Rayadurg	—	—
223	9-11-74	13:47:23 ·5	345	10 ·2	86	Rayadurg	—	—
224	9-12-74	18:17:39 ·3	341	12 ·2	102 ·5	Kalyandurg	C	3 ·5
225	11-12-74	16:36:03 ·5	337	12 ·2	102 ·5	Do.	C	3 ·5
226	17-12-74	18:47:26 ·5	341	12 ·4	105	Do.	C	—
227	17-12-74	19:35:05	287	19 ·2	157	Holalkere	D	—
228	19-12-74	10:07:41	183	18 ·2	149	Kollegal	—	3 ·5
229	20-12-74	03:39:07 ·7	154	13 ·8	116	Krishnagiri	D	3 ·7
230	22-12-74	17:22:18	341	13 ·2	111	Rayadurg	C	—
231	7-1-75	18:25:07 ·8	187	13 ·7	115	Malavalli	—	3 ·1
232	26-1-75	08:29:02	237	25	211	Chickamagalur	D	3 ·3
233	27-1-75	20:12:08 ·8	317	12	102	Chitldroog	—	4 ·0
234	29-1-75	09:23:06 ·4	274	23 ·6	197	Chickamagalur	—	3 ·7
235	30-1-75	20:58:32 ·7	274	23 ·8	200	Do.	—	3 ·8
236	30-1-75	23:33:35 ·2	47	57	530	Bhadrachalam	C	4 ·0
237	28-2-75	17:22:20 ·8	252	27 ·2	253	Mercara	—	3 ·8
238	28-2-75	17:27:47 ·5	268	23 ·5	198	Chickamagalur	—	3 ·2
239	1-3-75	17:55:14	283	23 ·9	200	Shimoga-Chickamagalur	—	3 ·9
240	4-3-75	15:59:31	147	16 ·3	134	Krishnagiri	—	3 ·6
241	23-3-75	23:27:02	133	16 ·5	135	Do.	D	3 ·7
242	28-3-75	14:28:05 ·5	72	29	250	Nellore	—	3 ·5
243	12-5-75	15:10:07 ·7	298	29 ·4	255	Shimoga	D	4 ·7
244	23-11-75	02:03:21 ·5	32	21	172	Cuddapah basin	—	3 ·4
245	03-12-75	06:07:53 ·5	250	35	210	Chickamagalur	—	3 ·5
246	06-12-75	00:14:40 ·6	147	14 ·8	121	Krishnagiri	—	3 ·4
247	6-12-75	02:46:43 ·8	175	13 ·5	116	Kanakapura/Bangalore	C	3 ·9
248	11-12-75	16:06:06	73	5 ·6	45	Bagepalli	—	—
249	15-12-75	11:48:36	99	20	166	Chittoor	—	3 ·8
250	15-12-75	05:48:19 ·4	122	22	178	Vellore	—	Weak
251	17-12-75	02:41:54	254	28 ·1	237	Chickamagalur	—	3 ·6
252	21-12-75	19:52:46	144	17	135	Kirshnagiri	D	3 ·6
253	23-12-75	17:01:26 ·8	68	6 ·4	50	Bagepalli	C	—
254	23-12-75	18:41:14 ·8	60	20 ·5	161	Cuddapah Contact	C	4 ·0
255	23-12-75	18:45:10 ·3	66	20 ·8	160	Do.	—	3 ·5
256	23-12-75	22:40:40 ·8	355	8 ·6	72	Pavagada	—	—
257	25-12-75	21:06:10 ·5	64	8	68	Bagepalli	—	—
258	25-12-75	21:06:40 ·6	64	8	68	Do.	—	—
259	28-12-75	15:06:58	161	10 ·5	90	Bangalore	—	—