Deep Electromagnetic Exploration
K.K. Roy et al (eds)

9. Telluric Field Observations During the Earth Tremor Activity Near Gandipet (Hyderabad, India)

S.V.S. Sarma, T. Harinarayana and C.V.G. Krishna*

National Geophysical Research Institute, Hyderabad-500 007, India
*Oil India Limited, Duliajan, Assam, India

Introduction

Amongst several geophysical parameters identified as useful precursors in earthquake prediction research, the 'electrical and electromagnetic precursors' are known to play a significant role. It is often reported that the earth's electrical resistivity in and around focal region undergoes systematic changes. Investigation of precursory changes in subsurface resistivity is generally realized by carrying out conventional resistivity measurements [1–6] and also by electromagnetic techniques such as magnetotelluric (MT) methods [7–10]. A review of these studies can be seen in the literature [11–13].

There were some attempts to use telluric currents in earthquake studies, but most of the attempts laid emphasis on the search for characteristic precursory changes of internal origin in the earth current signals itself. Reviewing these studies Yamazaki [14] pointed out that no convincing evidence could be found on this aspect. But recent studies report that anomalous changes in the telluric field are indeed detected as precursory phenomena in the case of a few earthquakes [15, 16]. Notwithstanding the results of attempts in search of an evidence for such precursory changes of internal origin, it may be pointed out that, since the telluric field at a place, when normalised with respect to a base station, is a function of subsurface resistivity, the telluric method, in principle, can be used to detect time dependent subsurface resistivity changes which may occur in the epicentral zone. On this basis an attempt is made here to examine the possibility of utilising the telluric currents in monitoring time-dependent subsurface resistivity changes, if any, related to earth tremor phenomena, using the data obtained during an earth tremor activity reported from an area near Gandipet, Hyderabad during January 14 to February 23, 1982.

Data and Analysis

The telluric field experimental study [17] included simultaneous and continuous recording of telluric pulsations in the 0.02–0.05 Hz frequency range at two stations, the field and the reference stations. The field station located at Wattinagulapalli (near Gandipet) is inside the epicentral region of the earth tremor activity (Fig. 1) and the other at the Geoelectric observatory (Choutuppal) of the National Geophysical Research Institute (NGRI) located about 70 km east of the focal zone and is free from earth tremor activity. Both the stations are located in the granitic region of the Indian peninsular shield.

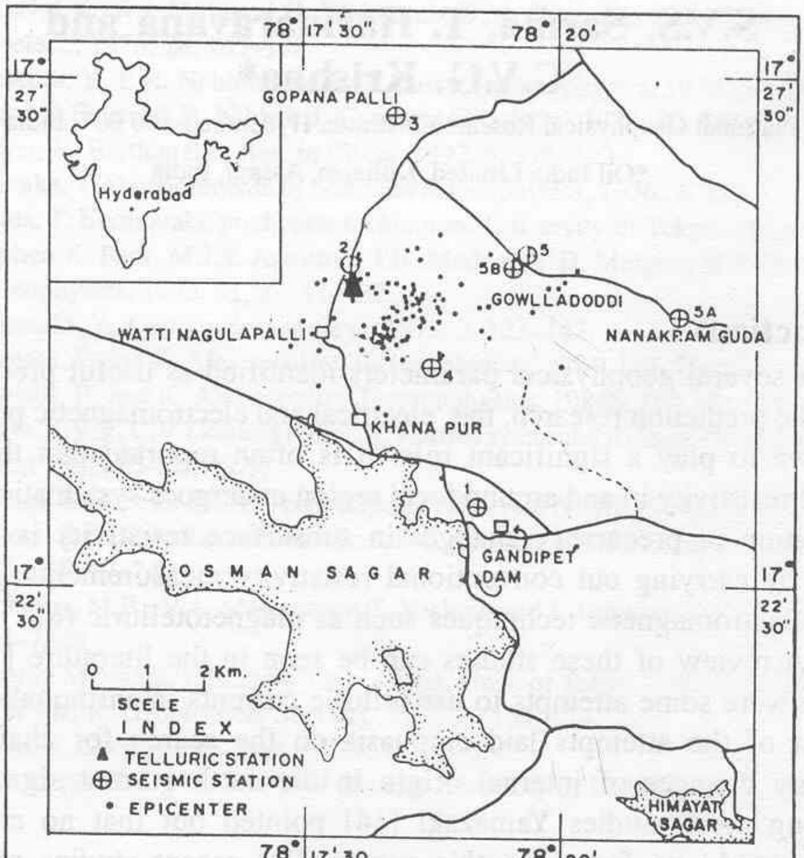


Fig. 1 Location map of telluric and seismic stations near Osman Sagar water reservoir, Gandipet village, Hyderabad. Five seismic station network operated from January 27 to February 22, 1982.

Telluric field observations at Gandipet were started on 6th February while the second telluric field station located at the Geoelectric Observatory, Choutuppal could be operated only from 12th February 1982 and served as a reference station for normalization of the telluric field amplitudes.

The telluric signals are recorded on analog chart recorders with a chart speed of 20 mm/min. At each station, although both NS and EW components of telluric field were recorded, the NS component recording at Choutuppal (reference station) was interrupted more often and as a result, continuous data for a meaningful comparison between the two stations are available on the EW component only. Accordingly, the data on the EW telluric field records of both the stations were time synchronised, corresponding signals identified and their amplitudes measured. For each half an hour portion of the tellurograms 5–10 amplitude measurements were carried out and the values of a simple ratio Rx = EW Gandipet/EW Choutuppal, were computed. Although attempts were made to record the data for about a month the analysis could be carried out only on the available simultaneous recordings (~150 hours) covering an eight day period between 12 and 21 February 1982.

Time Dependent Changes in Telluric Field

The normalized telluric field ratio, Rx values, are plotted against local time separately for each of the eight days. The times of occurrences of the earth tremor events reported during this period of telluric field experiment as shown in Table-1 [18] are also marked on the time axis of these plots. Typical examples of these plots corresponding to the two days (17th to 18th and 20th to 21st February) for which reasonably continuous data at both the stations were available are presented in Fig. 2. A careful examination of this plot (as also other plots corresponding to other days not shown here) points out at the first instance that the Rx parameter shows a broad local time dependent change. This is characterised by a fairly long wavelength variation which tends to repeat on almost all the days indicating the presence of a regular local time dependent diurnal component in Rx variation and hence can not be ascribed to any time dependent subsurface resistivity changes.

Table 1 Details of earth tremor activity discussed in the present study (from Rastogi et al, 1985)

Sl. No.	Date	Local time H	M	S	Lat. N	Long. E	Depth (km)
1.	07-02-82	16	59	56.59	17-25.23	78-18.49	0.08
2.	16-02-82	19	44	21.99	17-25.35	78-18.41	1.25
3.	17-02-82	15	33	36.01	17-25.04	78-18.15	1.00
4.	20-02-82	17	45	18.63	17-25.50	78-17.89	1.03
5.	20-02-82	18	25	47.44	17-25.47	78-18.38	0.62
6.	20-02-82	05	10	54.33	17-25.12	78-18.66	0.62
7.	21-02-82	19	30	07.76	17-25-40	78-18.19	1.32

Superimposed over these long period variations, are the short spells of disturbance in Rx values, limited to a short time interval, say half to one hour. Interestingly, some of these apparently sporadic changes of short duration in Rx coincide very closely with the "time of occurrence' of the reported earth tremor activity. For example, the tremors occurring at 1745 hrs and those at 1825 hrs on 20-2-1982 find associated disturbance in Rx values and similar feature can be noticed for the event at 0510 hrs on 21st

February 1982 (Fig. 2). A closer examination of such events with more detailed Rx plots covering a time interval of about 1 to $1^{1/2}$ hour on either side of the earth tremor event, has brought out, in some cases, certain characteristic changes in Rx, with reference to the time of occurrence of seismic event. For example, the two events occurring at 0510 and 1930 hours on 21st February 1982 (Fig. 3), the Rx value decreases before the occurrence of the earth tremor event and then rises immediately after the event after which it tends to regain its original pre-event level.

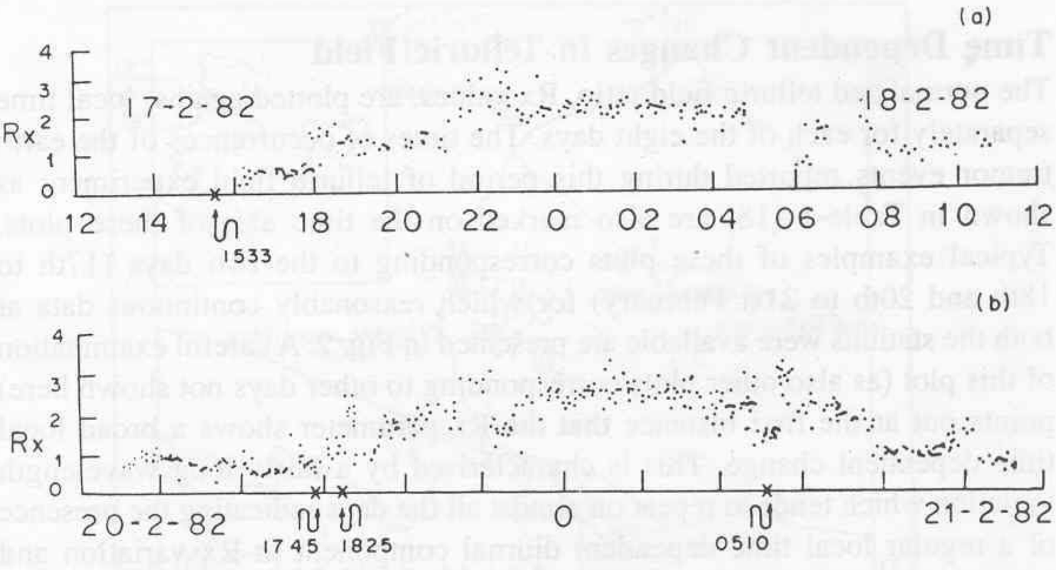


Fig. 2 Telluric field amplitude ration (Rx) at Gandipet (normalized with respect to Choutuppal) for two days 17-18, and 20th-21st February 1982 indicates occurrence time of earth tremor near Gandipet.

These short period changes (1 to $1^1/_2$ hour) may be considered as manifestations of temporal changes in subsurface resistivity expected to be associated with the build-up of an earth tremor. Such precursory changes in subsurface resistivity are reported in the case of a few earthquakes. It may be also recalled that dilatancy models [2] postulate a gradual decrease in the electrical resistivity prior to the onset of a seismic event and this decrease is generally attributed to availability of more microfractures filled with water resulting in the lowering of overall resistivity in the focal zone. It may be conjectured that in the present case since the focal depths are very shallow [19], changes in the subsurface resistivity could be expected to be significant because most of the microfractures that develop during dilatancy are located at shallow depths into which groundwater can have easy access to percolate through and reduce the subsurface resistivity.

Observation of High Frequency Telluric Signals

A feature of significant interest observed in the present study is the occasional appearance of minute spike like features, on the telluric field records obtained at the station in the epicentral zone. After a close examination of these signals it is inferred that these should represent a regime of high frequency

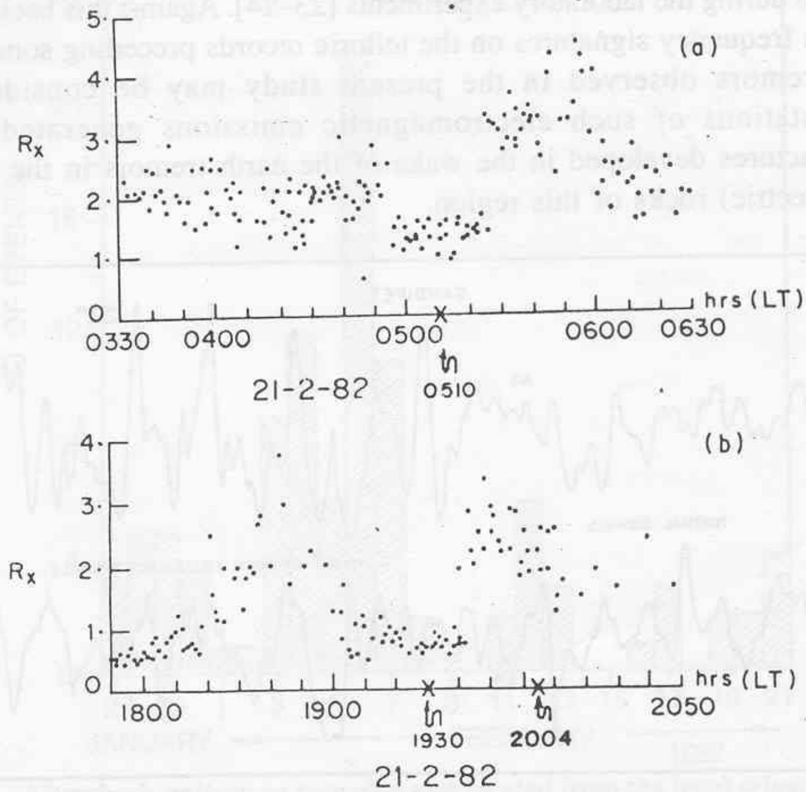
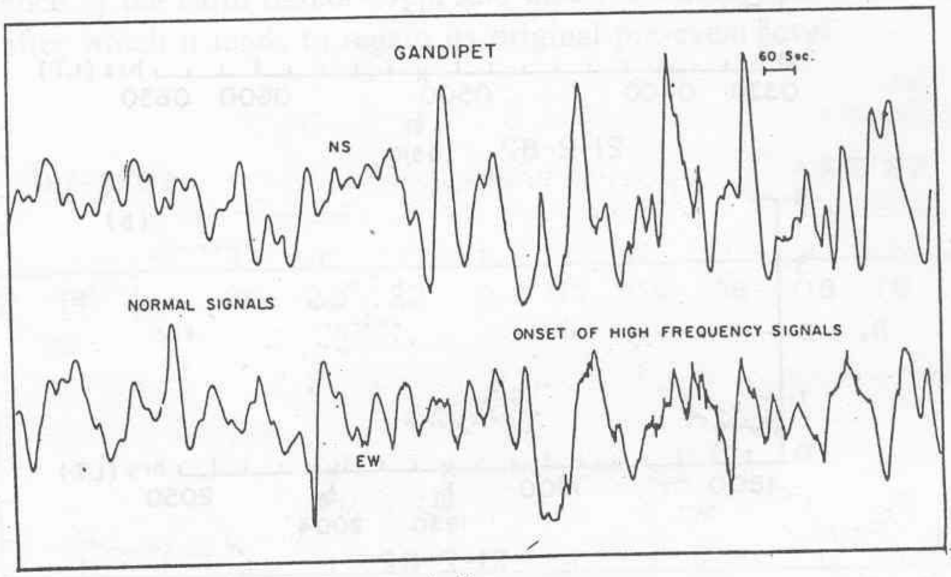


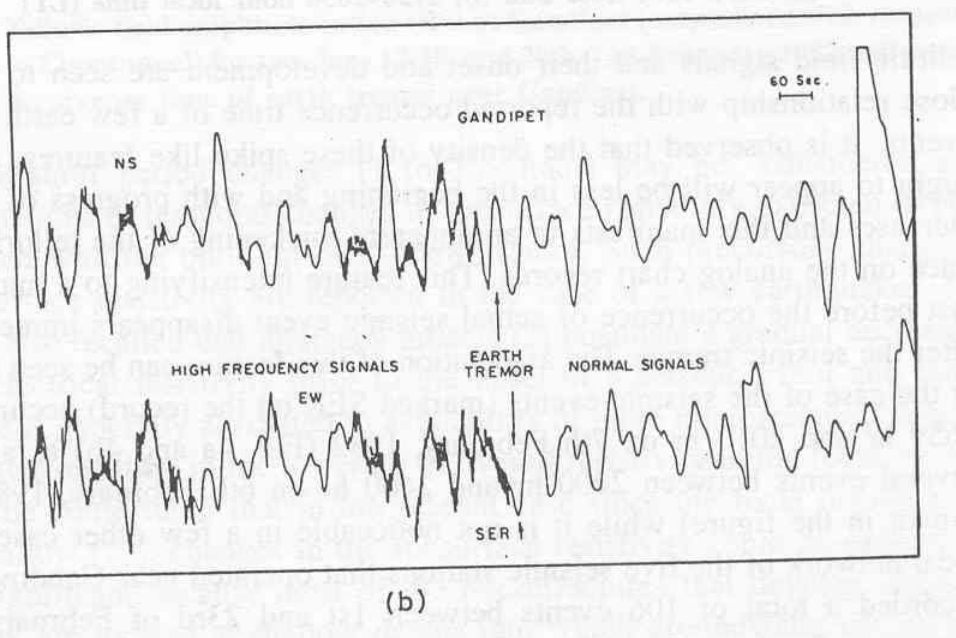
Fig. 3 Telluric Field amplitude ratio (Rx) on February 21, 1982 during: (a) 0330–0670 hour and (b) 1750–2050 hour local time (LT)

telluric field signals and their onset and development are seen to have a close relationship with the reported occurrence time of a few earth tremor events. It is observed that the density of these spike like features, as they begin to appear will be less in the beginning and with progress of time it increases and this manifests in an apparent thickening of the telluric field trace on the analog chart records. This feature intensifying to a maximum just before the occurrence of actual seismic event disappears immediately after the seismic tremor. The association of this feature can be seen clearly in the case of the seismic events (marked SER on the record) occurring at 1659 hr and 2017 hr on 7th February, 1982 (Fig. 4a and 4b) as also for several events between 2200 hr and 2400 hr on 6th February, 1982 (not shown in the figure) while it is not noticeable in a few other cases. The local network of the five seismic stations that operated near Gandipet [18] recorded a total of 106 events between 1st and 23rd of February. The histogram for these events is shown in Fig. 5. It is of interest to note that the seismic events preceded by high frequency telluric signals mentioned above (6th and 7th February) correspond to the events occurred during the maximum of the seismic tremor activity.

It may be pointed out in this context that there exists the possibility for emanation of electromagnetic emissions preceding some of the earthquakes occurring in the regions of piezoelectric rocks [20–22]. This has also been observed during the laboratory experiments [23–24]. Against this background, the high frequency signatures on the telluric records preceding some of the earth tremors observed in the present study may be considered as manifestations of such electromagnetic emissions generated whilst microfractures developed in the wake of the earth tremors in the granitic (Piezoelectric) rocks of this region.



(a)



(b)

Fig. 4 Telluric field signals recorded as both NS and EW components near Gandipet on 7th February 1982 showing the onset of high frequency signals. The high frequency signals (spike like features) can be seen more prominently during the intervals (a) 16 : 50 : 00 and 16 : 59 : 50 hr. LT and (b) 20 : 11 : 00–20 : 17 : 00 and 20 : 19 : 30–20 : 26 : 40 hr LT. Record speed is 10 mm/60 sec.

observed during the laboratory experiments [23–24]. Against this background, the high frequency signatures on the telluric records preceding some of the earth tremors observed in the present study may be considered as manifestations of such electromagnetic emissions generated whilst microfractures developed in the wake of the earth tremors in the granitic (Piezoelectric) rocks of this region.

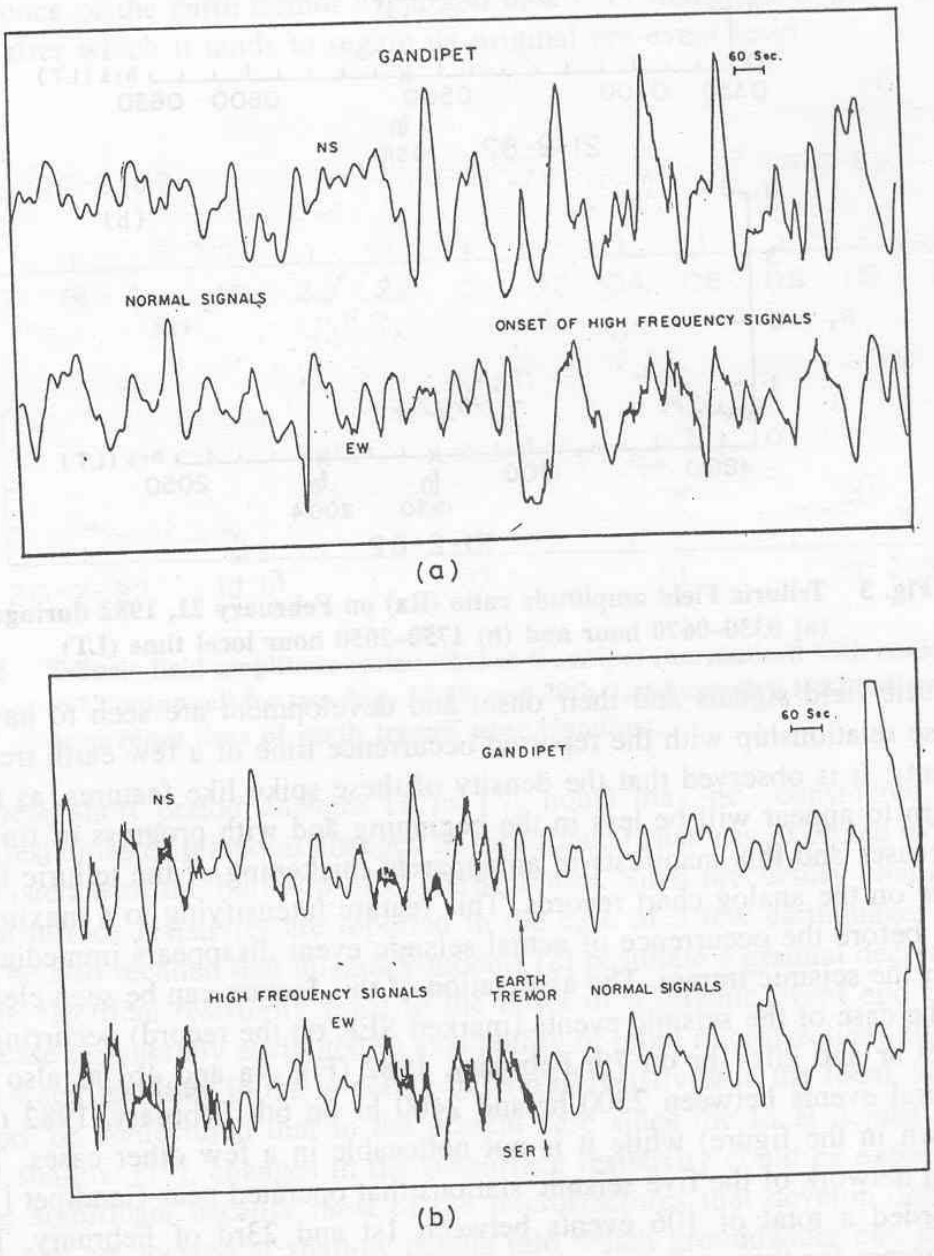


Fig. 4 Telluric field signals recorded as both NS and EW components near Gandipet on 7th February 1982 showing the onset of high frequency signals. The high frequency signals (spike like features) can be seen more prominently during the intervals (a) 16 : 50 : 00 and 16 : 59 : 50 hr. LT and (b) 20 : 11 : 00–20 : 17 : 00 and 20 : 19 : 30–20 : 26 : 40 hr LT. Record speed is 10 mm/60 sec.

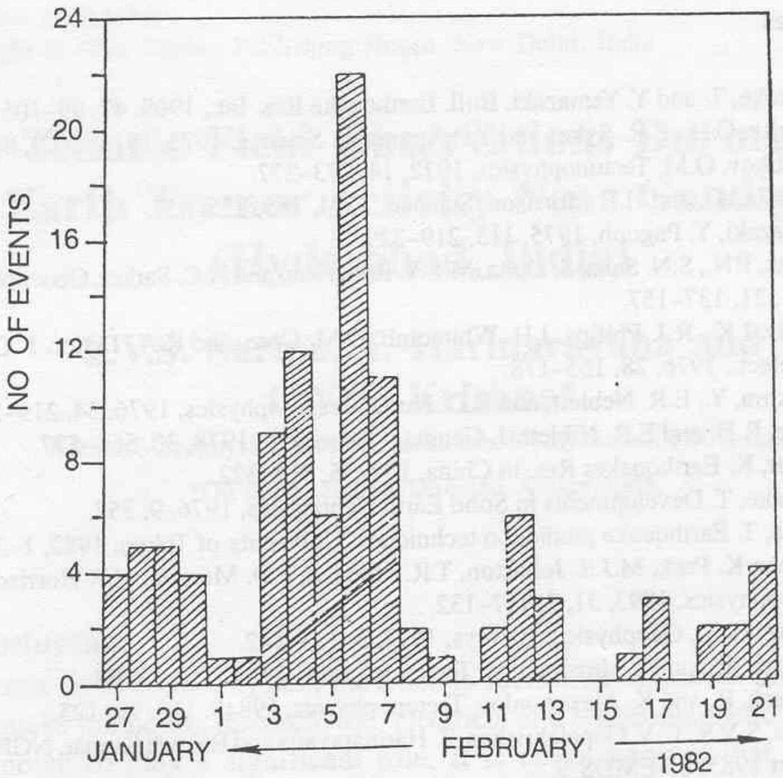


Fig. 5 Aftershock pattern as recorded and located from the local seismic network stations in Gandipet area.

Conclusions

Results of telluric field observations made at Gandipet, near Hyderabad, during an earth tremor activity are presented. The study indicates that tellurics could be used to carry out effective and continuous monitoring of resistivity changes related to earth tremor activity. The observations also brought out a significant features of interest, namely the onset of high frequency telluric field signals in the case of events which occurred during the peak phase of seismic tremor activity. These high frequency telluric signatures are interpreted to be the manifestation of electromagnetic emissions that might be generated during seismic activity occurring in the granitic terrain of the shield area. The results of the study, thus point out to the possibility for deployment of "Tellurics"—a simple geophysical tool, for detection and monitoring of subsurface resistivity changes on a continuous basis as also for detection of possible electromagnetic emissions associated with seismic phenomena including earth tremors and other shallow events like rock bursts occurring particularly in granitic (Piezoelectric) rocks.

Acknowledgements

We are grateful to Dr. H.K. Gupta, Director, NGRI for according permission to publish the results of these studies. We express our grateful thanks to Dr. V.K. Gaur, Ex-Director, NGRI and Dr. P.V. Sankernarayan, Ex-Dy Director, NGRI for their keen interest in these studies. We are also thankful to Sri M.V.C. Sarma for his help in operation of the station at Geoelectric Observatory, Choutuppal.

References

1. Rikitake, T. and Y. Yamazaki. Bull. Earthquake Res. Int., 1969. 47, 99–105
2. Schultz, C.H., L.R. Sykes and Y.P. Aggrawal. Science, 1973, 181 (4102), 803–810.
3. Barsukov, O.M. Tectonophysics, 1972, 14, 273–277.
4. Mazella, A., and H.F. Morrison. Science, 1974, 185, 855–857.
5. Yamazaki, Y. Pagoph, 1975, 113, 219–229.
6. Nayak, P.N., S.N. Saha, S. Dutta, M.S.V. Rama Rao and N.C. Sarker, Geoexploration, 1983, 21, 137–157.
7. Reddy, I.K., R.J. Philips, J.H. Whitcomb, D.M. Core, and R.A. Taylor. J. Geomag. Geoelect., 1976, 28, 165–178.
8. Honkura, Y., E.R. Neblett, and R.D. Kurtz. Tectonophysics, 1976, 34, 219–230.
9. Kurtz, R.D. and E.R. Niblett. J. Geomag. Geoelectr., 1978, 30, 561–577.
10. Meyer, K. Earthquakes Res. in China, 1992, 6, 315–322.
11. Rikitake, T. Developments in Solid Earth Geophysics, 1976, 9, 357.
12. Asada, T. Earthquake prediction techniques: University of Tokyo, 1982, 1–317.
13. Stephen K. Park, M.J.S. Johnston, T.R. Madden, F.D. Morgon, H.F. Horrison, Rev. in Geophysics, 1993, 31, 2, 117–132.
14. Yamazaki, Y., Geophysical surveys, 1977, 3, 123–142.
15. Varotsos, P. and K. Alexopoulos. Tectonophysics, 1984, 110, 73–98.
16. Varotsos, P., and K. Alexoponlov. Tectonophysics, 1984b, 110, 99–125.
17. Sarma, S.V.S., C.V. Gopalakrishna, T. Harinarayana and Rakesh Kumar, NGRI Tech. Report 1985, 85-EMDS-9.
18. Rastogi, B.K. et al, NGRI Tech. Report, 1985, No. NGRI-85-SEISM-240.
19. Rastogi, B.K., C.V. Ramakrishna Rao, R.K. Chadha, and H.K. Gupta. Tectonophysics, 1987, 138, 17–24.
20. Gokhberg, M.B., V.A. Morgounov, T. Yoshino and I. Tomizawa, JGR, 1982, 87, 89, 7824–7828.
21. Hitoship Mizutani. Edited by Toshi Asada, Univ. of Tokyo, 1982, 217–246.
22. Dmowska, R. Geophysical Surveys., 1977, 3, 157–174.
23. Nitsan, V. Geophy. Res. Lett., 1977, 4, 333–336.
24. Oike, K. and T. Ogwa. The 23rd General Assembly of IASPEI. Abstracts, 1985, 2.