Precursory response of low frequency signals for detection of seismic rapture in Indian region

Vijay Subhash Katta, Vinod Kushwah, Priti Dimri, Rudraksh Tiwari

Abstract: ***Recognition of seismic precursors is exigent task. Its study depends upon the environmental parameters, ground motion emissions (Low frequency signals), geological and tectonic structure. The theory of signal conductivity of two crust model between the epicenter region and above the ground surface calculated the amplitude enhancement of electromagnetic emissions. Extremely low frequency signals generate due to seismic emissions and penetrate the crystal layer to change the earth's surrounding and upper atmosphere conditions. These outputs are used to correlate the seismogenic VLF signals (f=3 KHz), which are recorded by borehole antenna system. It is observed that the low frequency signals goes to vertically and accumulated as low conductivity medium in the outer most layer through which transmitted to the atmosphere. The seismogenic ULF emissions, DEMETER satellite data, TEC anomalies, ionospheric disturbances and bio-electric amplitude was recorded at places nearby active fault line in Indian region and it is used to recognized the pre- seismic behaviour. We have also observed the stimulus data (solar flux, audio frequency signals, or electric charge emissions) as abnormal signals. These relations are verified and correlated by statistical analysis with null hypothesis testing and power spectrum magnitude which is helping us to understand the precursory signature of earthquakes.***

Index Terms: ***Bio-potential, DEMETER satellite, Very Low Frequency(VLF), Total Electron Content (TEC).***

I. INTRODUCTION

A couple of cases in an immense combination of fields including earth science, material science and various branches of sciences have exhibited that novel dynamical features squatted behind the time series model in the complex structure can ascend subsequent to separating them in a period space [9].

This examination which has been seemed to isolate the best information from a given time course of action enables the examination of the dynamical advancement of an acoustic sounding system and recognizes when the structure enters the fundamental phase of characteristic calamities. The continuous real time signal analysis has characterized before electromagnetic emissions, charge disturbance artificial sources and environmental parameters.

Revised Manuscript Received on July 05, 2019.

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Seismic tremor is one of the most exceedingly awful catastrophic events. In the past couple of decades, about 300,000 lives were claimed by the Tsunami generated on 26th December, 2004, in Sumatra`s region. The Muzzafarabad quake of 8th October, 2005 claimed an estimated, 80,000 human lives. Various studies have revealed seismic tremor precursors from ground based observations of Ultra Low Frequency (ULF), electro-magnetic outflows (f=0.01-10Hz) in the ongoing path [1][2][7][14]. Estimations of electromagnetic seismic emissions can be arranged into three parameters (Depth, location and magnitude) which are the detached by ground based observations [10][13]. The ground based emissions have been received from transmitter signals [3][11][21][36] and satellite observations [25][38]. The ultra low frequency band is considered as more convincing precursory signature of seismic event due to less attenuation, large hypocenter to epicenter distance and very less segregate conductivity in under the earth surface [7,14]. Further, the ULF precursors of earthquake have been also investigated in the upper atmosphere & magnetic disturbance above the earth surface through satellite observations [21].

With reference to the earlier studies of ground based observation [3][11][21][36] and satellite observations [25][12][39]-[41] which reveals that the correlation between the different precursory phenomenon are not permanent due to several reasons like sometimes it takes many years for a substantial seismic activities to occur with similar parameters in approx. same location and a second reason is that zones of high seismic movement usually differ widely in geological and seismic characteristics. In addition to such areas generally have a high level of geological in homogeneity. Both of these elements make the arranging of field tests and translation and correlation of results troublesome and third reason to catch seismic events, one must recognize it from the foundation which comprises of the both common and man-made electromagnetic emissions spreading over a large frequency band.

The objective of this work is to analyzing and identifying the correlation between the precursory parameters which are observed from earth environment and atmosphere either prior or after the earthquake.

We have verified the precursory seismogenic emissions by following parameters

(i) Very Low Frequency (VLF) (Bore-hole)/Ultra Low frequency (ULF) for seismo- ionospheric perturbations.

(ii) Seismogenic ULF emissions.
(iii) DEMETER satellite monitoring of plasma anomalies.
(iv) Total Electron Contents (TEC) monitoring of ionosphere perturbations.
(v) Bio-potential monitoring of Seismic Electric Signals (SES).

II. DATA ANALYSIS

In this study, we have analyzed the data of different parameters with different experiment setup i.e., borehole antenna system for VLF (Very Low Frequency), Amplitude and Phase Logger by Abs PAL receiver for low frequency signals, a three segment search coil magnetometer sensors framework for (ULF) Ultra Low Frequency, seismogenic emissions are observed by high frequency DEMETER (satellite data), Total Electron Contents(TEC) by dual frequency receiver system and transition change in concentration of xylem and phloem in the internal part of Banyan tree due to generate seismo-electromagnetic emissions recorded by bio-potential live sensor. We found the results of different seismic activity received by various equipments which give explanation one by one in this section.

A. Earthquake and magnetic storm data

In considering the seismic events for our investigation, consideration has been given to the impactful earthquakes (M>4), low depth and area along the VLF abnormal emissions between NWC transmitting station in Australia and Agra station in India and around our nearby locations. Seismic event related data (latitude, Longitude, depth, magnitude, date and time of occurrence) has been collected from earthquake information catalog provided by United State of Geological Survey (USGS) and Indian Meteorological department (IMD).

The impact of magnetic tempest has been inspected as far as $\sum K_p$ where K_p is three hour planetary index. It is eminent that the estimations of K_p in the extent of 0-4, 5-6, and 6-9 demonstrate moderate and genuine alluring conditions, individually. As far as $\sum K_p$, esteem more noteworthy than demonstrates extreme magnetic storm [39].

Various techniques have been studied for the identification of precursory signature and segregation the frequency ranges which confine the correlations with their outcomes. Several researchers has explore the various techniques for identification of hazards but seismo-electromagnetic technique is one of them which gives the information of precursory nature of seismic activities.

B. Borehole Data Analysis

We have analyzed the borehole data collected at Bichpuri, Agra for Chamoli earthquake (epicenter 30.408 ^{0}N, 79.416 ^{0}E, Magnitude 6.8, Depth 21Km) on dated 29 March 1999 and 18April 1999. Borehole antenna system had recorded the seismic signal with 3KHz frequency. Antenna is drilled around 120 meters under the ground. These data has been satisfied by null hypothesis test technique which have given a good correlation of seismic precursory signature [12].

It has been observed that ground and geo-potential of natural and artificial frequency have been increased from 10mV to 25mV before Chamoli earthquake.

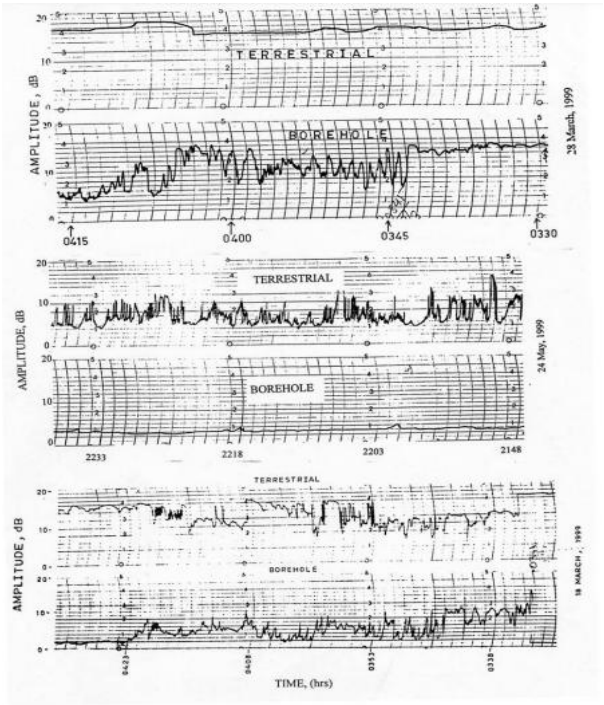

Fig 1. The abnormal disturbance pulse recorded by earth receiving sensor and atmospheric recording sensor system simultaneously in three windows on different dates

We observed the abnormal signal in borehole graph recorded at Agra station. This graph shows the abnormal amplitude change in both of the receiving antenna(borehole and terrestrial) shown in fig.1.

Since, the observations are taken in regional zone and the receiving wire is introduced in borehole, the density of information from different open sources, for example, spherics, power line radiations, building communication and radio transmission are pointed significantly. We have analyzed the six months (Mar 1999 - Sept., 1999) of borehole data recorded at Agra receiving center. First two months (March-April 1999) of recorded data has shown the impact of seismic activity in Chamoli region within 400km from receiving center. In next two months data (May-June1999), no variation has been observed in borehole system. While in next three months (July- Sept., 1999) the impact of lightning and thunderstorm activities has been recorded in Agra region. Hence, it shows that the signal recorded during March- April 1999 is due to only ground motion. This is verified by null hypothesis test and statistical T- test (Table- I).

We have recorded the disturbances in borehole data on 28 March 1999(first graph of fig 1). This abnormality has been received before 21 hours of main shock. The signal recorded on 24 May 1999 is due to signal noise burst (middle graph of fig.1) and simultaneous change has been recorded in terrestrial as well as borehole antenna on 18 March 1999(lower graph of fig.1). In the data analysis we separate out the data of March to September 1999 from few minute to few hours for restriction of recorded amplitude enhancement >1dB.

The enhancement in amplitude of borehole data (E_b) and terrestrial data (E_t) has been calculated by E_b/E_t ratio. From seven months of recorded data, we have noted the number of events where ratio of E_b/E_t >1 or E_b/E_t <1.

Published By:
Blue Eyes Intelligence Engineering
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It is depicted in middle graph of Fig. 2 by black and white coloured histogram. Monthly occurrence of seismic events has been shown in bottom graph of fig.2.

Table I: Statistical results for testing Null hypothesis

Noise bursts activity	Correlation coefficient, R	Test T Statistic analysis for Null hypothesis	Probability for R=0
Borehole	0.620	1.760	0.137
Terrestrial	-0.556	1.490	0.194
E_b/E_t >1	0.344	0.816	0.449
E_b/E_t <1	0.553	1.400	0.218

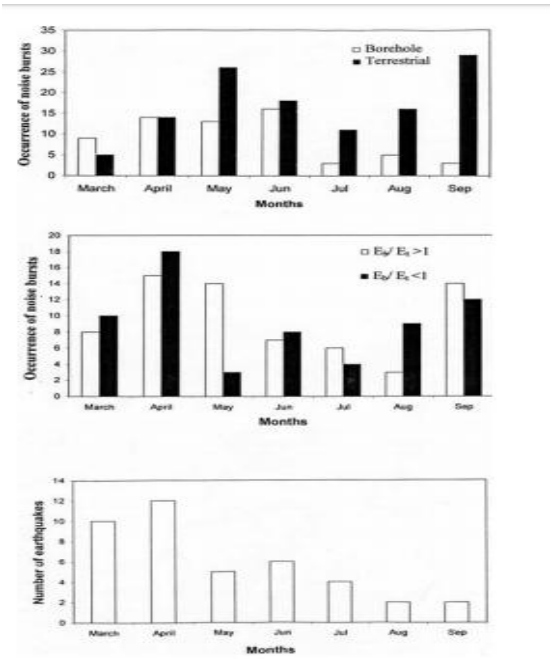

Fig 2:- Total monthly noise burst recorded by borehole and terrestrial antenna(top), the ratio of E_b/E_t>1 and E_b/E_t<1(middle), and monthly earthquake observations(bottom)

We have observed amplitude enhancement in both borehole and terrestrial antenna. The amplitude enhancement in borehole data has been observed in comparison to terrestrial data which directly correlated with seismic activities in the months of march 1999 which is represented in Fig 2.

C. VLF Data Analysis

In another, we had reviewed the absolute frequency data of evening time (2200h-0400h LT, LT=UT+5.5h) for VLF transmitter recorded at receiving station Agra at 19.8KHz for duration of Aug2002-Apr2003. The amplitude enhancement of VLF signals propagated through earth-ionosphere waveguide. The abnormality occurred in lithosphere is due to energy released during ground motion. A remarkable impact of quake is to lower ionosphere by E * B drift which may influence for the period of VLF signals.

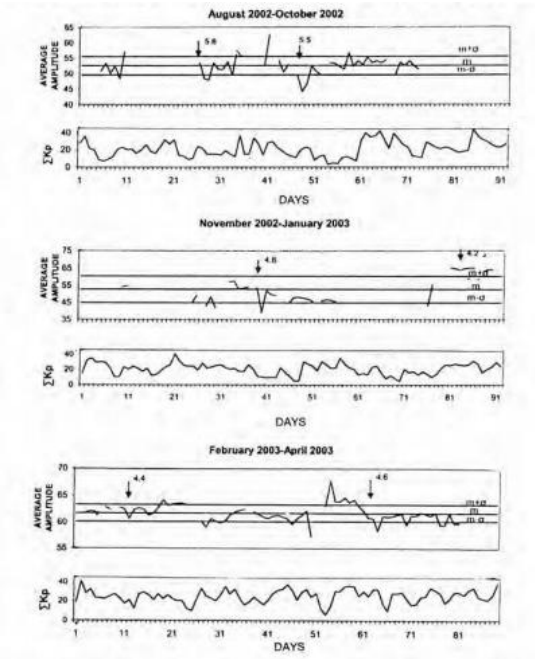

Fig 3:- Statistical analysis of VLF and magnetic storm data for Aug,2002- Apr,2003 in three panels(Top Pannel for Aug 2002-Oct2002,Middle for Nov,2002 -Jan.2003 and bottom for Feb,2003 to Apr,2003)

We have analyzed the data of VLF emissions with degree of confidence ($m \pm \sigma$) with August 2002-April 2003. During the period of Nov 2002 to Dec2002, the amplitudes have been recorded between 40-55dB which were at lowest during observation period and the enhancement (64-65 dB) has been observed during Jan2003 to April2003 which is highest among nine months of observation period. On 16 February 2003, the amplitude decrease by 1 dB and hence it lies within the standard deviation. The two cases of 41th day in the upper graph of Fig.3 and 54th day of the lower graph of same figure, the enhanced amplitude are higher than $m+\sigma$ due to enhancement of magnetic storm(ΣK_p lies between 35 to 40). Hence, we found that the decrement of amplitude is due to moderate seismic activities. The distance between receiver to transmitter by great circle path was 6735km. The amplitude and phase of the propagating VLF signals has been affected due to structural changes in lower ionosphere may be due to seismic activities.

During the observation period of nine months, six times (27 Aug.2002, 17,Sep 2002, 10 Dec.2002 and 22 Jan 2003, 16 Feb 2003 and 5 Apr.2003) VLF amplitude emissions have been decreased by 1-10dB with respect to mean value. We have shown all earthquake locations in the figure nearby great circle path which is plotted between transmitter and receiver stations.

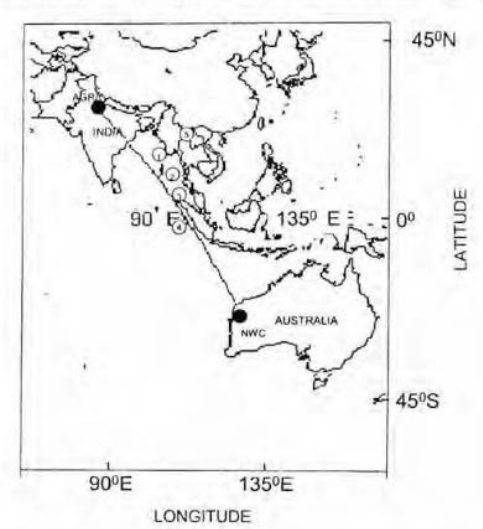

Fig 4: The map of VLF transmitter and receiving station. The white numbered circle represents the epicenter of earthquake nearby propagation path

D. ULF analysis data:

We have analyzed the ULF magnetic field sensor data for the period of August 2002-April 2003 for confirmation of any seismic anomaly observed with VLF amplitude anomalies recorded for same period. The abnormality in recorded data is due to the various generation mechanism processes which is discussed in VLF data analysis. The disturbances have been observed in magnetic ULF sensors in orthogonal directions. The amplitude enhanced during night time data in ULF magnetic sensor recorded on the date of 17Sept. 2002, 18 Sept 2002, and 20 Sept 2002. The fig. 5 clearly shown that the data pattern on 17Sept 2002 was normal for all the three recording sensors and on date 18 Sept. 2002 the noisy data signal have been recorded, spicks with real amplitude data in all three sensor. But unfortunately, we could not get recorded data on 19 Sept 2002 data due to power failure at recording center and this date was the occurrence day of seismic activity and next day on 20 Sept.2002 the amplitude is found enhanced due to after effect of earthquake.

The enhancement in amplitude has been observed on 18 Sept 2002, 10 Dec 2002, 24 Jan 2003, 18 Feb 2003and 02 Apr., 2003 by ULF sensor.

We have taken the data for the period between 12 Sept 2002 and 30 April 2003. We found enhancement in amplitude from 0.26nT to 0.96nT either on the day of earthquake occurred or ± 2days those on before VLF amplitude decreased. The similar amplitude enhancement was observed on respective date (18 Sept, 2002, 10 Dec., 2002 and 24 Jan, 2003, 18 Feb., 2003 and 02 Apr., 2003), which were due to modulation of unknown signal and sub harmonic i.e. Schumann resonance of power line. The simultaneous observation of VLF and ULF amplitude anomalies within ± 2days which were indicate towards the possibility of common causative sources generated by solar flares, magnetic storms or seismic activities.

Consequently, we found that the infrequent reductions in the sufficiency of signs are because of direct quake is bolstered by the outcomes in these figures in commanders.

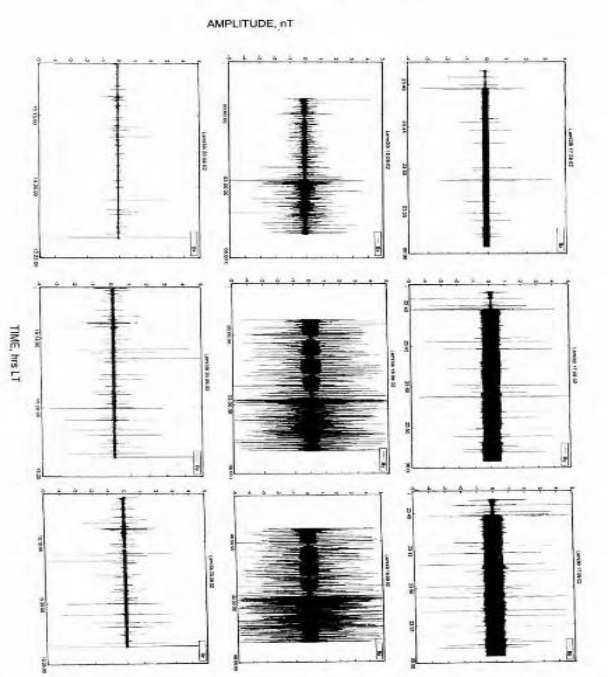

Fig 5: Ultra low frequency orthogonal(Bx, By, and Bz component) emissions on 17,18 and 20 Sept, 2002

In another analysis (Power spectrum magnitude analysis) have been completed in this case and found the intensity of lower frequency signal is much higher (i.e. -21dB) than other higher frequency signals which intensity has lower around -25dB are shown in fig 6. When we checked the enhancement possibility of data of other sources (i.e. magnetic disturbance, lighten activities) that found no correlation between them so there is a positive indication that the system response in the respect of amplitude enhancement is due to seismic activities.

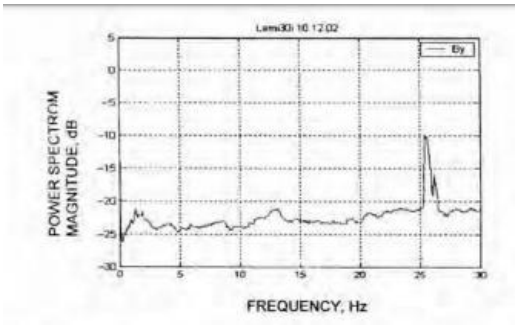

Fig 6: The dynamic power spectrum magnitude versus frequency of Y component on 10 Dec., 2002.

Table II: The list of earthquake which analyzed in observations

SN	Date	Time(UT)	Location	Magnitude	Depth	Distance form receiving station
1	18.09.02	120136.31	Lat.13.11N,Long.93.17E	5.5	33	2253
2	10.12. 02	024446.68	Lat.05.25N, Long.94.46	4.6	67	3039
3	23.01. 03	105840.23	Lat.7.59 N, Long.93.72	4.2	19	2777
4	16.02. 03	222749.86	Lat.5.73 N,Long.102.02E	4.4	17	4519
5	03.04. 03	234824.43	Lat.20.67N,Long.103.22	4.6	10	2652

The five earthquake data index (Table II) are taken from USGS website: https://earthquake.usgs.gov/earthquakes/

E. DEMETER Data Analysis

CNES, France has launched the DEMETER satellite (Detection of Electro-Magnetic Emissions Transmitted from Earthquake Regions) on 29 June 2004 at orbital distance 730km. The three months data from Jan, 2005 to March, 2005 has been analyzed and correlated with ground and satellite based electromagnetic emissions.

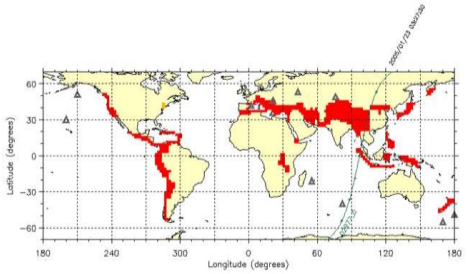

Fig 7: Orbital DEMETER satellite on 23 January, 2005 near to epicenter

We have observed the burst of ELF emissions prior to Indonesian earthquake (Lat 2.6^0N Long. 94.4^0E) at the depth of 28 km which occurred on 23 Jan., 2005 with Magnitude of 5.0. The satellite data has been given in fig 6.

For the confirmation of satellite data we have been taken the ULF magnetic field emissions since Jan,2005. We considered the data in mid night value of amplitude for analysis and found that Y component of search coil magnetometer in east-west direction is enhanced for the observing station.

The continuous enhancement in the ULF sensor from 02 January to 23 January, 2005 and then reduced abruptly afterward. We found that the ULF anomaly was due to direct propagation of ULF emissions to observing station through middle layer crust of low conductivity working as waveguide.

It has been observed a huge variation one day prior and one day after the event of seismic tremor individually. These irregularities are deciphered as far as electric field of seismic cause entering the lower ionosphere however no such abnormalities motion in borehole information on 23 Jan. 2005 due to very long distance and high attenuation from the epicenter region.

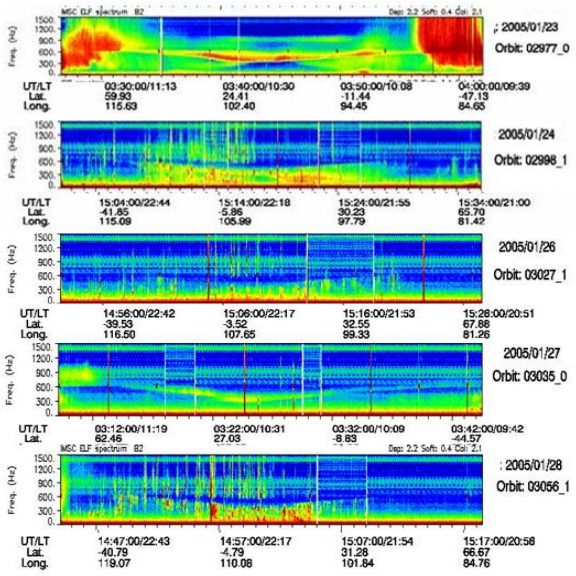

Fig 8: ELF noise burst at different frequency between 18-22 January, 2005.

We have categorized the change of sunlight based solar flux 10.7 cm for the entire time frame between 1 Jan., 2005-15 Feb., 2005. We have contemplated $\sum K_p$ varieties amid previously mentioned period and discovered extreme attractive tempest ($\sum K_p = 47$) happened on 18 Jan. 2005 five days prior the event of seismic tremor where as ULF amplitude enhancement observed on 11 days prior (from 12 January 2005) shown in fig 8.

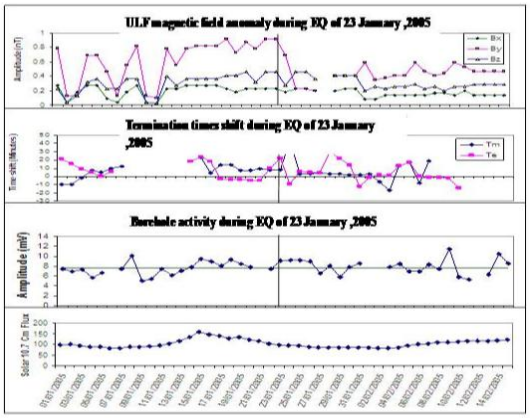

Fig 9:(Top) Amplitude variation for the three components(Bx, By and Bz) from 1 January to 15 February, 2005 (second) Variation of monitoring termination times (solid square) and evening termination time (solid rectangle). (Third) variation of borehole amplitude data and (bottom panel) the variation of solar 10.7cm flux during the whole period of correlation.

We have taken the termination time data receiving by Abs PAL receiver system which gives the time shifting information of sunrise and sunset time at receiving center due to any seismic activity. The amplitude and phase change in fixed frequency data before any seismic activity occurred near the GCP. This is mentioned in second graph of fig. 9 which indicate termination time during 23 Jan. 2005.

F. TEC analysis data

We analyzed the dual frequency receiver TEC data recorded at Bichpuri, Agra center. These are changed over into vertical TEC (VTEC) utilizing factual mapping capacity at various ionospheric piece point (IPP) areas [26][29]-[31]. The powerful ionospheric tallness of 350 km is utilized for assurance of IPP area which observed to be legitimate for deviation points 7500 in low scope part, we have information from just a single GPS beneficiary, we have applied the technique for examination of TEC information i.e. relationships system and inconstancy list, however for this reason there is require of no less than two GPS collectors. In our future examinations when more GPS collectors are accessible.

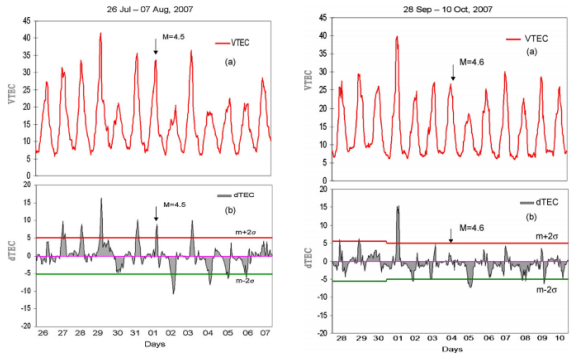

Fig 10: (Top left-a) Variation of VTEC for 13 days between 26-07 August 2007. Day of earthquake represented by arrow (Bottom Left-b) the same as previous (Top right-a) figure but for the earthquake of 04 Oct., 2007 anomalies in dTEC for the same period as above.

Differential TEC (dTEC) has been recorded for two earthquakes occurred during 26-07 Aug.,2007 and 26 Sept., 10Oct,2007. To verify a data with the degree of confidentiality [22, 26, 30], we have calculated ($m \pm 2\ \sigma$). To remove normal changes in TEC, dTEC is calculated as

dTEC= 15 days mean of VTEC- hourly observed VTEC (1)

Normal dTEC value lies between $m + 2\sigma$ or $m - 2\sigma$. The abnormal changes in dTEC data are recorded outside the range of $m \pm 2\sigma$. The enhancement and decreasement of TEC values are due to seismic activity. The analysis shows that the TEC values fluctuate in the form of enhancements and depletion. These anomalies cannot be attributed to magnetic storms because, as seen from fig. 10 effect of magnetic storm ($K_p > 30$) has not been observed during July and August 2007. So abnormality observed in TEC may be due to impact of seismic activity M=4.5. The reason of increase and decrease of TEC is pull down of E*B drift, which is one of the critical commitments to seismo-ionospheric impacts where electric field activated by a quake readiness process, either because of arbitrary outflows [15][23] or two different reasons including gravity waves infiltrates the ionosphere [26][27]. This might have the ability to be preliminary TEC peculiarities. Consumptions and improvements in thickness profile might be after effects of tremor related E*B float when the electron thickness may streams into or out of receiving station contingent on the area of epicenter of quakes [28][25]. The epicenter for the seismic tremors consider for the TEC investigate are under 610 Km from Agra, when all is said in done the impact of quake in ionosphere are accounted for to be over an extensive scope [23][30]. The TEC peculiarities are caused by an electric field created over epicenter and proliferated to ionospheric statures in way proposed by[23].

G. Bio-potential data Analysis

We demonstrate the wave type of normal information which were recorded by bio-potential emissions all these previously mentioned events in upper board in fig. 11. This information are taken the periods between around 20 hours and found square wave of fluctuating amplitudes and terms of throbbing influxes of rising amplitudes around 40 mV in all cases. The seismic activity occurred in Rohtak-Sonipat fault seismic movement, we have observed abnormal changes in bio-potential sensor however not in terrestrial system, the terrestrial incorporate with the impact of lithosphere and ionosphere coupling enhancement of the seismic activities.

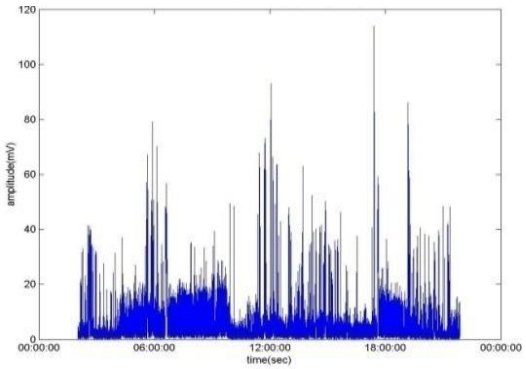

Fig:11: Biopotential amplitude recording system with time

The subsurface electric fields induced at the bio-potential antenna are installed to pre and main amplifiers. The pre-amplifier is a transistorized audio frequency amplifier used to convert high input impedance signals to that of low impedance. The gain of this amplifier is 40dB. The main amplifier is also a transistorized audio frequency amplifier having emitter followers of the input stage with a fixed voltage gain of 40dB. Both the pre and main amplifiers are adjusted in such a way that a flat response in the frequency range from 500 Hz to 15 kHz is obtained.

The pre and main amplifier circuit acts as a notch filter. The centre frequency or notch frequency of the band pass filter and bandwidth are set at 3 kHz and 250 Hz respectively. It gain is found to be 10.

In previous research [41], the subsurface electric fields induced at the bio-potential live antenna systems are pass through pre and main amplifiers and the amplified signal is send to band pass filter (f= 3kHz and bandwidth 250 Hz). The filtered signal is then peak detected and recorded on a DC chart recorder (Model: EPR3531 Electronic Poly Recorder, Hioki, Japan).The chart speed is maintained at 0.5cm per minute. The chart recorder measures the current (0 – 5 mA) and its internal resistance is 65 ohms. However, we have modified it to measure the current in the range 0-10mA. The enhancement in amplitude of the noise bursts above the background level may also be measured in terms of dB on the same scale of 0 – 10mA by calibrating it to read 0 – 20 dB as per the relation

dB=20log(amplitude enhancement) (2)

Table III: Earthquake with location and precursory time received in Bio-potential sensor at HCST Farah, Mathura.

S. No.	Date of Occurrence	Latitude (N)	Longitude(E)	Magnitude	Epicenter	Depth (Km)	Time of Occurrence	Distance of monitoring station from Epicenter	Bio-potential signal (received)
1	23-Dec-2011	28.85	68.80	5.1	Rajasthan-Pakistan border	12	12:02:02	320Km	1. 5h hours before
3	28-Jan-2012	28.8	76.7	3.5	Rohtak-Sonipat border	10	23:24:52	187Km	3 hours before
2	05-Mar-2012	28.7	76.6	5.0	Haryana-Delhi region	16	07:41:05	180Km	2 hours before

Now we have replaced analog recording of subsurface vertical electric field by digital recording with the help of MATLAB software. It has been simultaneously observed that the amplitude of bio-potential signal was not enhanced but the amplitude was enhanced in terrestrials antenna. We can say the signal was interrupted in environment and local changes in nearby recording station. The ΣK_p data is based on the variation of upper atmosphere and not due to bio-potential emissions. We recorded bio-potential signal for three seismic events shown in table III. We analyzed the wave type of the emissions recorded on 23th Dec, 2011 of Magnitude = 5.1, 20hours before the event of the main burst in Rajasthan-Pakistan fault. It tends to be seen effortlessly in the assume that there was no emissions found in the earthbound bio potential sensor.

In fig 12, we demonstrate the statistical analysis of time series data. Infect we have decide the primary mean (m) and standard deviation (σ) utilizing the adequacy records of bio-potential acquired from 4 months of observation. So as to recognize the substantial improvements in amplitudes from normal adequacy variance. We have expanded the area of standard deviation to positive to negative σ .The mean and standard deviation for plentifulness are appeared in upper pannel of the figure by solid line. The abundance varieties of the transient difference in potential distinction (bio-potential) are appeared by solid line in upper panel. Here, we discover the amplitude enhancements are within the standard deviation amid the entire time of examination aside from on the three days 22 Dec, 2011, 27 Jan, 2012 and 05 Mar 2012 when the sufficiency is unusually improved.

The signal enhancements have two conceivable outcomes. One possibility is that the amplitudes are upgraded because of a few changes in air. (i.e., seasonal variation and magnetic storm data(ΣK_p) and real time information which is plotted in the time series with amplitude and the second probability is because of that the enhancements are upgraded because of progress in potential contrast between two anodes created preceding or emissions of seismic events.

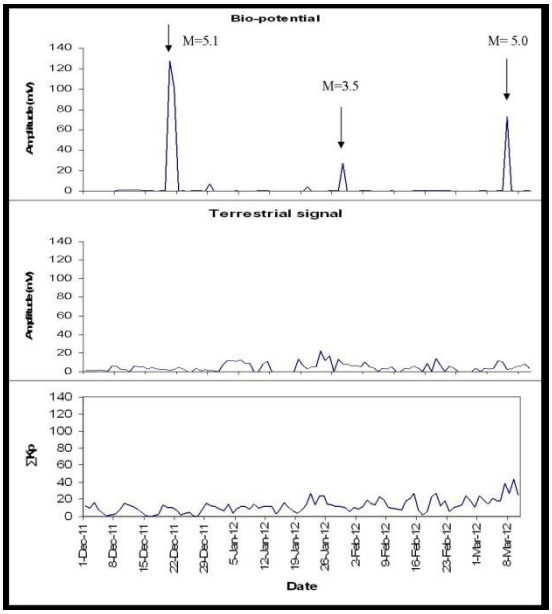

Fig 12: Upper Panel showing the variation of bio-potential signal, Middle panel showing the variation of terrestrial signal and lower panel showing the variation of magnetic storm data.

The possible outcomes of the abnormal changes in bio-potentials are because of minute change in structural plates and make the possibility of micro fracturing process and electro-kinetic effects. So when any seismic action happened adjacent around 100Km in shallow depth the weight has been delivered and discharged as vitality. So this signals enhancement in bio-potential live sensor gives the information of environmental change and seismic activity.

There are two possibilities to receive the seismic signal far away from epicenter at Farah, Mathura station. First, the active Mathura ridge connected transverse channel of Delhi-Haridwar ridge (DHR) across the main boundary fault [35] and second possibility is the emissions has been produced in low depth may be conduit to long distances through middle layer crust of low charge transfer possibility [19][42]. However, without attenuation the SES(Seismic Electric Signal) propagated through crustal region without less attenuation[19][42][41]. The enhancement of SES signal has been recorded at bio-potential sensor which shown in fig. 12. For the analysis of signal enhancement, we applied the statistical technique for verifying the signal generated before the seismic activity or any other artificial and environmental sources. We have received the precursory signature of amplitude enhancement in the case of Rajasthan earthquake, Sonipath earthquake and Haryana Delhi earthquake which is verified with the USGS and IMD earthquake catalog.

To verify the relation of bio-potential and earthquake occurred within 400km away from receiving station. We correlate atmospheric signal received by terrestrial signal at HCST Farah with bio-potential sensor data and found the signal enhancement recorded by bio-potential sensor are due to seismic activity not due to magnetic storm. An electromagnetic signal propagates to thousands of kilometer from epicenter. The propagation distance is depending upon the characteristics of the rocks and conductivity [47].

III. CONCLUSION

The field of seismo-electromagnetic is characterized by investigations of electromagnetic signals and influence related with tremors for purpose of brief time quake forecast. We have identified the abnormality in ionospheric, environmental, and ground motion data associated before and after seismic rapture. We have analyzed the low frequency parameters i.e. VLF, ULF, DEMETER Satellite, TEC and bio-potential which have given the preliminary signature.

In borehole, the precursory time of abnormal signals (VLF) is one day before Chamoli earthquake occurred on 28 March, 1999.

The Abs Pal receiver has received abnormal signal one day before the rapture and termination time of morning and evening have been sifted in 30 minute before the regular time. We identified the association of ULF abnormality with VLF fixed frequency signals mention in table II. ULF abnormalities (2-3nT) have been observed one and half day prior to earthquake.

In DEMETER satellite data, the low frequency emissions intensity above the earth surface has been increased one day before (on 22 Jan 2005) the Nicobar Island earthquake.

TEC measurement has been respond of less than one day before change in total electron contents in 1x1cm^2 and Bio-potential(around 30mV-40mV) receiver is respond to collect the abnormal signal around 3 to 4 day before seismic events. It might be certain that the accompanying system of antecedents of seismic tremor happens 30minutes to 4 days before the shallow depth, higher magnitude (≥4.0), and nearby by active fault line.

Further research on the above precursors can help us to predict the seismic activities near to active fault in Indian region.

REFERENCES

1. Fraser-Smith, C.Antony, A. Bernardi, P. R. McGill, M_E Ladd, R. A. Helliwell, and O. G. Villard. "Low-frequency magnetic field measurements near the epicenter of the Ms 7.1 Loma Prieta earthquake." *Geophysical Research Letters* 17, no. 9, 1990: pp. 1465-1468.
2. Fraser-Smith, C.Antony, P. R. McGill, R. A. Helliwell, and O. G. Villard. "Ultra-low frequency magnetic field measurements in Southern California during the Northridge earthquake of 17 January 1994." *Geophysical Research Letters* 21, no. 20 (1994): pp. 2195-2198.
3. M.B. Gokhberg, I.L. Gufeld, A.A. Rozhnoy, V.F. Marenko, V.S. Yampolsky, E.A. Ponomarev,"Study of seismic influence on the ionosphere by super long-wave probing of the Earth-ionosphere waveguide",Physics of the Earth and Planetary Interiors,Volume 57, Issues 1–2,1989,pp. 64-67.
4. M.Hayakawa, R. Kawate, O.A. Molchanov, K. Yumoto "Results of ultra-low-frequency magnetic field measurements during the Guam earthquake of 8 August 1993." *Geophysical Research Letters* 23, no. 3 (1996): pp.241-244.
5. O.A. Molchanov and M.Hayakawa, "On the generation mechanism of ULF seismogenic electromagnetic emissions". *Physics of the earth and planetary interiors*, *105*(3-4), pp.201-210.
6. S.K. Park, M.J.S. Johnson, T.R. Madden, F.D. Morgan, H.F. Morison, "Electromagnetic precursors toearthquakes in ULF band: A review of observations and mechanism". Rev. Geophys,1993, 31, pp.117-132.
7. Y. Kopytenko,V. Ismagilov,M. Hayakawa,N. Smirnova, V. Troyan, T. Peterson," Investigation of the ULF electromagnetic phenomena relates to earthquake: contemporary achievements and the perspective." Annali di Geophysica, 44, 2001, pp.325-334.
8. O.A. Molchanov and M. Hayakawa," Generation of ULF electromagnetic emissions by microfracturing".Geophys. Res. Lettr., 22,1995, pp.3091-3094.
9. P.A. Varotsos ,N.V. Sarlis and E.S. Skordas," Long range correlations in the signals that precede rupture", Physical Review E66, 011902, DOI:10.1103/PhysRevE.66.011902, 2002.
10. A.Benardi, Fraser Smith, A.C., P.R.McGill, and O.G. Villiard,(1991) "Phys.Earth Planet.Inter. edited by Galprin , Y.I., and Hayakawa, M., J.Geo. mag. Geo. electr., 48,1996,pp.1241-1263.
11. I. L.Gufeld, G. Gusev, and O. Pokhhotelov, "Electromagnetic Phenomena Related to Earthquake" Prediction", TERRAPUB, Tokyo.1994, pp. 381-390.
12. B. Singh, M. Hayakawa, P.K. Mishra, R.P. Singh, D.R. Lakshmi," VLF electromagnetic noise bursts observed in a borehole and their relation with low latitude" hiss. Journal of Atmospheric and Solar Terrestrial Physics.65,2003, pp.69-276.
13. P. Varotsos and P. Alexopoulos, "Physical properties of variations of the electric field of the earth preceding earthquakes", 1, Tectonophysics, **110**, 1984,pp.73–98.
14. M. Hayakawa,T. Itoh, K. Hattori and K. Yumoto, "ULF electromagnetic precursors for an earthquake at Biak, Indonesia in 17 February, 1996" , Geo. phys, Res. Lettr., **27**(10), 2000. pp.1531–1534.
15. S.Pullinets, K. Boyarchuk," Ionospheric precursors of earthquakes", Springer, Berlin,2004, pp.315.
16. M.A. Clivered, C.J. Rodger and N.R. Thomson, "Modeling of sub-ionospheric effects on a sub-ionospheric path", J Geophys Res (USA), 104, 28171, 1999.
17. R.L. Dowden and C.D.D. Adams," Phase and Amplitude perturbations on sub-ionospheric signals explained in terms of echoes from lightening-induced electron precipitation ionization patches", J Geo. phys Res (USA) , 93, 11543, 1988.
18. H. Toriyama, "Possibility of earthquake by measurement of tree potential electromagnetic phenomena related to earthquake prediction", Terra Sci. Publ. (TERRAPUB) , Tokyo,1994, pp.103-104.
19. V.A. Tsarev and V. Sasaki,"Low frequency seismic electromagnetic radiation: How does it propagate in the earth's crust and when it can be detected, Atmospheric and Ionsopheric electromagnetic phenomena associated with earthquakes", Terrapub, Co. Tokyo,1999,pp.383–393.
20. S.K. Park, D.J. Srauss and R.L. Acceves, " in the critical review of VAN : Earthquake prediction from seismic Electric Signals", edited by Sir J Lighthill , World Scientific (Singapore),1996, pp.267.
21. O.A. Molchanov, M. Hayakawa," Generation of ULF electromagnetic emission by microfracturing", geo.Phys.Res.Lett. 22,1995,pp.3091-3094.
22. P.Blikoh, "Atmospheric-ionospheric electromagnetic phenomena Associated with earthquakes ", Terra Sci, Tokyo, Japan.,1999, pp. 829.
23. S.A. Pulinets, A. D. Legen'ka, and V. A. Alekseev. "Pre-earthquake ionospheric effects and their possible mechanisms." In *Dusty and Dirty Plasmas, Noise, and Chaos in Space and in the Laboratory*, Springer, Boston, MA, 1994, pp. 545-557.
24. M. B Gokhberg, V. A. Morgounov, T. Yoshino, and I. Tomizawa.", Experimental measurement of electromagnetic emissions possibly related to earthquakes in Japan." *Journal of Geophysical Research: Solid Earth* 87, no. B9 (1982): pp.7824-7828.
25. M. Parrot and M. M. Mogilevsky. "VLF emissions associated with earthquakes and observed in the ionosphere and the magnetosphere." *Physics of the Earth and Planetary Interiors*57, no. 1-2 (1989): pp.86-99.
26. M. Devi, M. K. Barman, and A. K. Barbara. "Identification of quiet and disturbed days through IEC profile features over anomaly crest region." *Journal of atmospheric and solar-terrestrial physics* 64, no. 12-14 (2002): pp.1413-1423.
27. A.H. Depueva and Y.Y. Ruzhin,"The equatorial earthquake preparatory stage as a reason of fountain effect in the ionosphere", preprint IZMIRAN, N82, 1029, 10, 1993.
28. V. I. Larkina, A. V.. Nalivaiko, N. I. Gershenzon, M. B. Gokhberg, V. A. Liperovskii, and S. L. Shalimov. "Intercosmos-19 observations of VLF emissions associated with seismic activity." *Geomagnetism and Aeronomy* 23 (1983): pp.842-846.
29. P. R. Rao, K. Niranjan, , D.S.V.V.D. Prasad., S.G. Krishna and G. Uma, 2006, September." On the validity of the ionospheric pierce point (IPP) altitude of 350 km in the Indian equatorial and low-latitude sector". In *Annales Geophysicae* ,Vol. 24, No. 8, pp. 2159-2168.

30. O.P. Singh, V. Chauhan, V. Singh, B. Singh," Anomalous variation in total electron content (TEC) associated with earthquakes in India during September 2006–November 2007", *Physics and Chemistry of the Earth, Parts A/B/C*, *34*(6-7), 2009,pp.479-484.
31. A.P. Nickolaenko and M. Hayakawa "*Resonances in the Earth-ionosphere cavity"* (Vol. 19). Springer Science & Business Media,2002.
32. Yu.A. Kopytenko, T.G. Matishvili, P.M. Voronov, E.A. Kopytenko, "in Electromagnetic phenomena related to earthquake prediction", eds. By M. Hayakawa and Y. Fujinawa, TERRPUB, TOKYO, 175, 1994.
33. N.Sumimoto, "Electromagnetic phenomena related to earthquake prediction" , Terra Sci. Tokyo, Japan, 511, 1994.
34. M. Hata, I. Takumi, K. Ohta, J.Izutsu,T. Fujii, T. Sato, S. Yahasi and N. Watanabe, 2010. Development of ELF band receiver of detecting extreme low frequency magnetic flux variation due to earthquakes. *Journal of Atmospheric Electricity*, *30*(1), pp.37-52.
35. B.R. Arora and B.P. Singh, Geomagnetic and geo. electric investigations for seismicity and seismo-tectonics of the Himalayan region., Geol. Soc. India, Bangalore, 223-263, 1992.
36. M. Hayakawa, "Atmopsheric and Ionospheric electromagnetic phenomena with earthquake", Terra Sci. Pub. Co., Tokyo, 1996.
37. S. P. Kingsley, "Radio astronomical method of measuring the MST Radar Antenna technical report to MST Radar" Nuovo cimento , (Italy),12,117, 1989.
38. B.B. Balsley and K. S. Gage. "The MST radar technique: Potential for middle atmospheric studies." *Pure and Applied Geophysics* 118, no. 1 (1980): pp.452-493.
39. Y.I. Galperin and M. Hayakawa,"On the magnetospheric effects of experimental ground explosions observed from AUREOL-3". *Journal of geomagnetism and geoelectricity*, *48*(10), 1996,pp.1241-1263.
40. V. Kushwah, V.Singh and B. Singh," Ultra low frequency (ULF) amplitude anomalies associated with the recent Pakistan earthquake of 8 October 2005". *J. Ind. Geophys. Union*, *11*(4), 2007,pp.197-207.
41. V. Kushwah, R. Tiwari, M.S. Gaur and R.K. Tiwari, "Initial results of bio-potential signal (seismic electric signal) related to seismic activities". *Acta Geophysica*, *61*(4), 2013, pp.935-949.
42. R. Tiwari, V.S.Katta, V. K. Kushwah. M.S.Gaur and P.Dimri, "Study the Biopotential Parameter For Detection Of Seismic And Enviornmental Changes In Indian Region." *Journal of Geography and Cartography* 1, no. 3 (2018).
43. G.V. Keller, "ractical Handbook of Physical Properties of Rocks and Minerals", 361 pp., John Wiley, Hoboken, N. J., 1989.
44. N. Sumitomo, "What kind of electromagnetic phenomena originating in the earth's crust are observable at the earth's surface?, Electromagnetic Phenomenon Related to Earthquake Prediction", Terra Sci., Tokyo, 1994, pp. 511 – 521.
45. K.Oike and T. Ogawa, "Electromagnetic radiations from shallow earthquakes observed in the LF range". *Journal of geomagnetism and geoelectricity*, *38*(10), 1986. pp.1031-1040.
46. J.W. Warwick, C. Stoker and T.R. Meyer, "Radio emission associated with rock fracture: possible application to the great Chilean earthquake of May 22, 1960", *Journal of Geophysical Research: Solid Earth*, *87*(B4), 1982, pp.2851-2859.
47. T. Yoshino, I. Tomizawa, and T. Sugimoto, "Result of statistical analysis of LF seismogenic emissions as precursors to the earthquake and volcanic eruptions", Res. Lett. Atmos. Electr., 12, 1992,pp.203 – 210.
48. T. Rikitake and Y. Yamazaki, "earth strains as detected by electric resistivity measurements.", *Proceedings of the Japan Academy*, *43*(6), 1982, pp.477-482.

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