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The usefulness of geomagnetic observations for predicting the earthquakes

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सार — भूकम्पनों से प्रभावित क्षेत्र में और भूमध्यरेखीय विद्युत प्रधार के प्रभाव से काफी दूर के एक स्टेशन शिलांग (भौगोलिक अक्षांश 25° 34′ उ० एवं देशान्तर 91° 53′ पू०) में भूचुम्बकीय क्षेत्र के परिवर्तनों के नजदीकी क्षेत्र में झटके वाले भूकम्पों के साथ संभावित संबंध के लिए जांच की गई है। इन परिणामों की जयपुर के परिणामों के साथ तुलना की गई है। जयपुर और शिलांग एक ही अक्षांशों पर स्थित हैं, पर उनके स्थानीय समय में 1 घंटे का अन्तर है। केन्द्रीय भूकम्प विज्ञान वेधशाला, शिलांग में दिसम्बर 1979 से अप्रैल 1981 के अन्तराल में 29 हल्के या सामान्य झटके अंकित किए गए। उपरोक्त विशेष घटनाओं के बाद सुग्राही प्रोटोन प्रीसेशन चुम्बकत्वमापी से चम्बकीय क्षेत्र, '*F*' में हुए परिवर्तनों की प्रारम्भिक परीक्षा से पता चलता है कि जब भूकम्प का अभिकेन्द्र स्टेशन से ज्यादा दूर नहीं होता तब झटके से पूर्व आसपास का क्षेत्र अवनमित हो जाता है। बहुधा क्षेत्र के चुम्बकीय क्षेत्र में परिवर्तन पर्पटी प्रतिबल के परिवर्तनों की वजह से होता है। क्षेत्र में अधिकतम परिवर्तन और झटके लगने के बीच समय-अन्तराल का अभिकेन्द्रीय दूरी से समाश्रयण विश्लेषण किया गया है। इससे पता चलता है कि बहुत पास के झटके के लिए समय-अन्तराल लगभग 30 घंटे का था।

ABSTRACT. Geomagnetic field variations at Shillong (Geog. Lat. 25 deg. 34′ N and Geog. Long. 91 **deg. 53** ′ E), a station in the seismic prone region and far away from the influence of equatorial electrojet, is examined for the possible association with the felt shock earthquakes in the vicinity. The results were compared with Jaipur, a station in the same latitude as Shillong but differing in local time by 1 hr. During the interval of December 1979 to April 1981 about 29 shocks were reported to be felt moderately or slightly by the Central Seismological Observatory, Shillong and a preliminary examination of variations of the total geomagnetic field, *F*, taken by sensitive proton precession magnetometer on the above individual events reveals that there is a depression of the field prior to the shock, when the epicentre of earthquake is not far away from the station. The field change is most likely due to changes in the crustal stress in this region. A regression analysis performed on the time interval between the extreme field changes and occurrence of shock in relation to the epicentral distances has given a time interval of $\simeq$ 30 hours for the very close shock.

1. Introduction

In the literature extensive evidence have been reported on geophysical signatures of an impending earthquake. Amongst these are : ground deformation and tilt, geoelectric field, radon emission, ground water level and change of geomagnetic field etc. Such anomalies in areas near the epicentre, along geological faults and other weak zones have been reported from Japan, China, USSR and USA prior to an earthquake.

In the present communication, an investigation on the epicentral distance and the localised geomagnetic fields changes in the NE part of India, which is one of the sixth highly earthquake prone areas of the world, have most probably been studied for the first time. One of the main characteristics of the local geomagnetic field variations is the possible association with the changes of tectonic stress. The physical properties of the earth's crust change under stress and strain, introducing a change in the pattern of geophysical parameters — a potential tool for monitoring earthquakes. The variation of the anomalous part of the internal magnetic field is related to geology and seismicity of an area. The possibility of forecasting an earthquake in the seismic prone region may, therefore, be attempted from the geomagnetic characterstics of the area.

An appreciable association between local geomagnetic secular variation and earthquake has been reported by geophysicists from China, Japan, USSR and USA. In USSR at Tbilisi a correlation of secular variation of the geomagnetic field variation and earthquake was observed (Nodia *et al.* 1968). Tazima *et al.* (1976) in Japan have shown a significant change of secular variation of *Z* component in Morioka (near an active volcano) but no such change was observed in the neighbouring stations. The residual geomagnetic field in *H, Z* & *F* obtained by differencing the monthly mean values at Dairen and Peking in China, revealed

TABLE 1

Seismic data of Shillong station from 1 Dec 1979 to 30 April 1981 (data collected from C.S.O., Shillong which covers felt shocks and whose epicentres are available)

S. No.	Date			G.M.T.			Direction
	Date	Month	Year	Hr.	Min.	Sec.	
01	08	12	79	17	41	21	1.50 CNE
02	22	12	79	03	50	23	0.12 CSE, M=3.2
03	02	01	80	14	11	40	0.20 DSE
	30	01	80	02	36	11	0.12 CNW
04	30	01	80	02	37	48	0.10 DNW
05	17	01	80	00	16	33	0.62 DSW
06	27	02	80	16	57	19	0.42
07	09	03	80	19	47	10	0.49 DSW, M=3.7
08	28	03	80	16	15	49	2.53 DNW
09	16	04	80	21	21	38	0.12 DSE
10	20	05	80	13	19	46	2.53
11	11	06	80	05	25	38	1.34 CSE, M=5.0
12	06	08	80	14	31	25	1.04 DNE
13	14	09	80	18	59	16	0.06 CNE, M=2.5
14	30	10	80	05	30	07	1.53 DSW, M=5.2
15	01	11	80	04	20	20	0.39 CNE
16	03	11	80	17	29	05	0.96 DNE, M=3.7
17	10	11	80	16	38	05	1.13 CSW, M=4.7
18	19	11	80	19	01	41	3.90 NNW, M=6.5
19	23	11	80	12	14	49	0.37 CSE, M=3.9
20	02	12	80	00	54	39	0.65 DNW, M=3.7
21	07	12	80	21	53	20	1.83 CNW, M=4.6
22	11	12	80	01	28	40	2.43 DNW, M=5.0
23	06	01	81	18	44	02	2.6 CNW, M=4.7
24	14	01	81	07	24	03	0.95 DSW, M=4.1
25	29	01	81	11	23	49	0.32 DNE, M=3.4
26	28	02	81	01	58	50	1.00 Reported from Sprengnther
27	19	03	81	13	53	13	0.12 CSE, M=2.6
28	22	03	81	03	48	44	0.92 DNE
29	25	04	81	11	33	10	2.63 DNE, M=5.9

PPM data are insufficient in connection wih the following dates of earthquake : 08 Dec 79, 27 Feb 80, 09 Mar 80, 11 Jun 80, 10 Nov 80, 14 Jan 81.

a 15-20 nT change between October 1973 and May 1974. H and Z were of opposite sign. Based on this 20 nT change in the geomagnetic field components, it was predicted at the State Seismological Bureau conference held in June 1974 that an earthquake of magnitude 5-6 might occur in Pohai region within next 1-2 years. The Haicheng earthquake of magnitude 7.3 occurred on 4 February 1975, about 8 months after the prediction. The behaviour of geomagnetic field variations at Alibag and Hyderabad in relation to earthquake from Koyna region was examined by Arora and Singh (1979). Their analysis revealed that H difference between Alibag and Hyderabad were continuously decreasing and started increasing 3-4 months before the earthquake of 11 December 1967 in Koyna region. The Z showed reverse trend, and the tendency correlated with that reported for Chinese earthquake.

A tectonomagnetic effect before an earthquake of magnitude 5.2 near Hollister, California was reported by Smith and Johnston (1976). Simultaneous measurement of geomagnetic field with an array of seven proton precession magnetometers along the San Andreas fault showed that the most significant local magnetic field changes during 1974 were recorded at a site 11 km from the epicentre of an earthquake of 5.2 magnitude which occurred on 28 November 1974. The change of the geomagnetic field was observed at this site and recovered to its original value 4 weeks prior to the earthquake. Skovorodkin *et al.* (1978) in USSR made a resurvey of magnetic measurement with high precession magnetometer in seismically active areas in Tadjikistan which revealed that the local geomagnetic field variation was associated in all probability with the change of tectonic stress. The variation might be in different types (a) oscillation with a

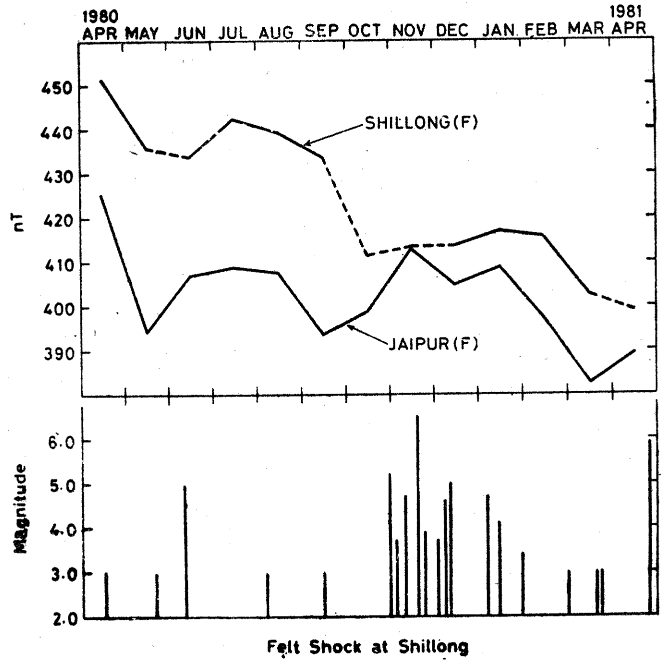

Fig. 1. Change of geomagnetic total field (F) at Shillong and Jaipur

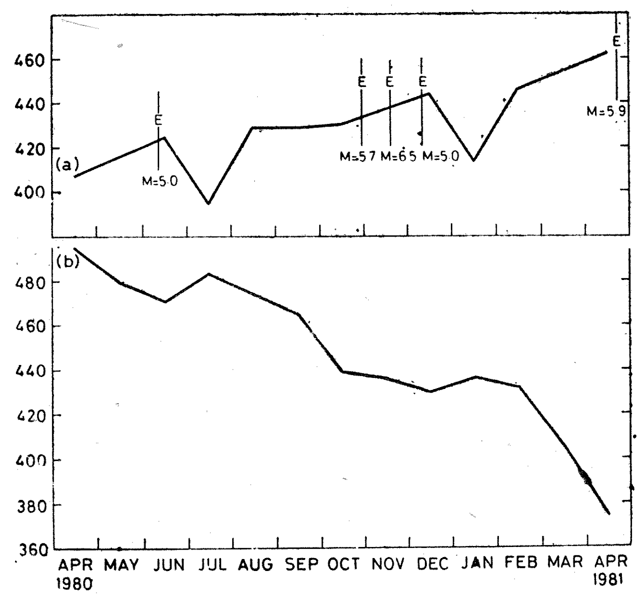

Fig. 2. Vertical (a) and horizontal components of the geomagnetic field at Shillong. Magnitude of the earthquakes at the corresponding timings are shown as vertical bars on curve (a)

period of week or more unconnected with the occurrence time of earthquake, (b) Monotonic change of level during a considerable time with subsequent change of sign shortly before earthquake and (c) Monotonic change of field (for months at a time).

The anomalous behaviour of local secular geomagnetic field variation is a long term process for predicting earthquakes. For this, monthly mean values of F at Shillong station derived by the standard nuclear magnetometer (Proton Precession Magnetometer, PPM) are taken and similar data of Jaipur station which is in the same geographical latitude are examined and compared with those of Shillong for finding out the possibility of earthquake associations in the NE region. A finer study in the response of F (total field) values derived by standard proton precession magnetometer of a particular place and at a fixed time has also been made in order to find out the possible association with the tectonic stress.

2. Results and discussion

The "tectonomagnetic" effect of Shillong station is compared with Jaipur, a station in the same latitude, but far away from the seismic belt. If one compares the feature of transient variation at the two places it is possible to isolate anomalies associated with the internal structure of one station over the other. The external component is almost comparable at the two places for night time events. During the day time magnetospheric component is still the same whereas the ionospheric component will have some difference. But in assuming the external field to be identical at both the stations one would not be introducing serious error.

With the introduction of the proton precession magnetometer at Shillong, since December 1979, and at Jaipur since April 1980 the stability of geomagnetic field measurements has been fairly improved. A comparison of the field values at the two stations reveals a systematic decrease in local magnetic field that occurs at Shillong prior to earthquake. The most probable source of this change seems to be tectonomagnetic effect around the earthquake epicentre.

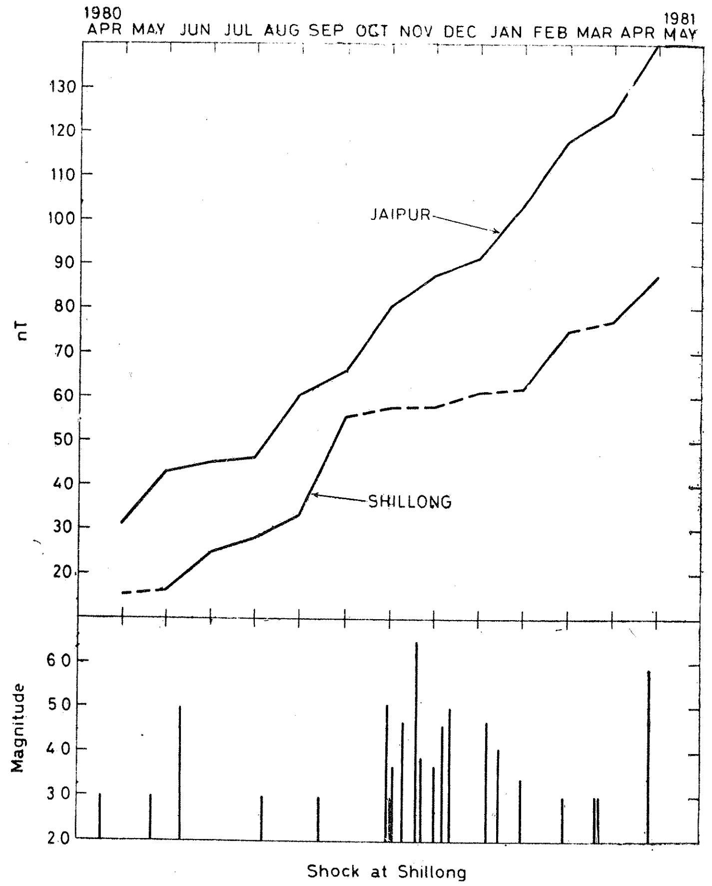

Fig. 3. Cumulative sum of month to month differences in total field (F) against the dates at Shillong and Jaipur

Table 1 gives the seismic data from C.S.O., Shillong consisting of moderate earthquakes, strongest being of mag. 6.5. From Table 1, it is noticed that the frequency of shocks is maximum during November and December 1980. Particular interest is the relation of magnetic field changes to the earthquakes and comparison of this anomalous behaviour with other station's observation in the nearby latitude. Monthly F (total geomagnetic field intensity) of Shillong and Jaipur for the period April 1980 to April 1981 are shown in the Fig. 1. The frequency of felt shocks during this interval are also shown at the bottom of the Fg. 1. The two curves have the same signature but the most significant change of geomagnetic field value F were observed at Shillong during September to October 1980. During this period Shillong shows —22nT change of field variation and Jaipur shows + 5 nT change (*plus* and *minus* signs show upward or downward changes of field value). The feature of this disturbance at Shillong is directly attributable to the phenomenon of the earthquakes, because it has been observed prior to the period of maximum frequency of earthquakes during this interval and includes the highest magnitude 6.5 earthquake. Similar type of monotonic change of field variation with subsequent change in signs were observed during May to June 1980, October to November 1980, and April to May 1981. The change is observed about one month before the earthquake. The monthly variation of vertical component taken by vector precession magnetometer shows an enhancement of magnetic field associated with earthquakes. At the same time H trends are reversed in Fig. 2(b). The response in magnetic field is not seen is association with earthquakes of magnitude less than 5.0.

From the above observations, the plausible inference is that a change of regional geomagnetic field values can be observed prior to the earthquake. This possibility of a change in the geomagnetic field may be due to internal relative changes in the subcrustal rocks. In Fig. 3 monthly mean values of cumulative sum of month-to-month differences in total geomagnetic field at Shillong and Jaipur are shown. In comparison to Jaipur, the increasing trend is less pronounced or nearly absent during the intervals April-May 1980, September 1980, January 1981 and March-April 1981 at Shillong synchronous with periods of relatively high seismic activity. It is interesting to note that this state of stress in the geomagnetic field (after comparing with Jaipur) occurs about one month before earthquake and hence the measurement of the same could be a powerful tool for monitoring premonitory phenomena, specially in major seismic events whose magnitude M is *4* and above.

It is apparent that an additional observation of magnetic signal near the time of earthquake is needed in

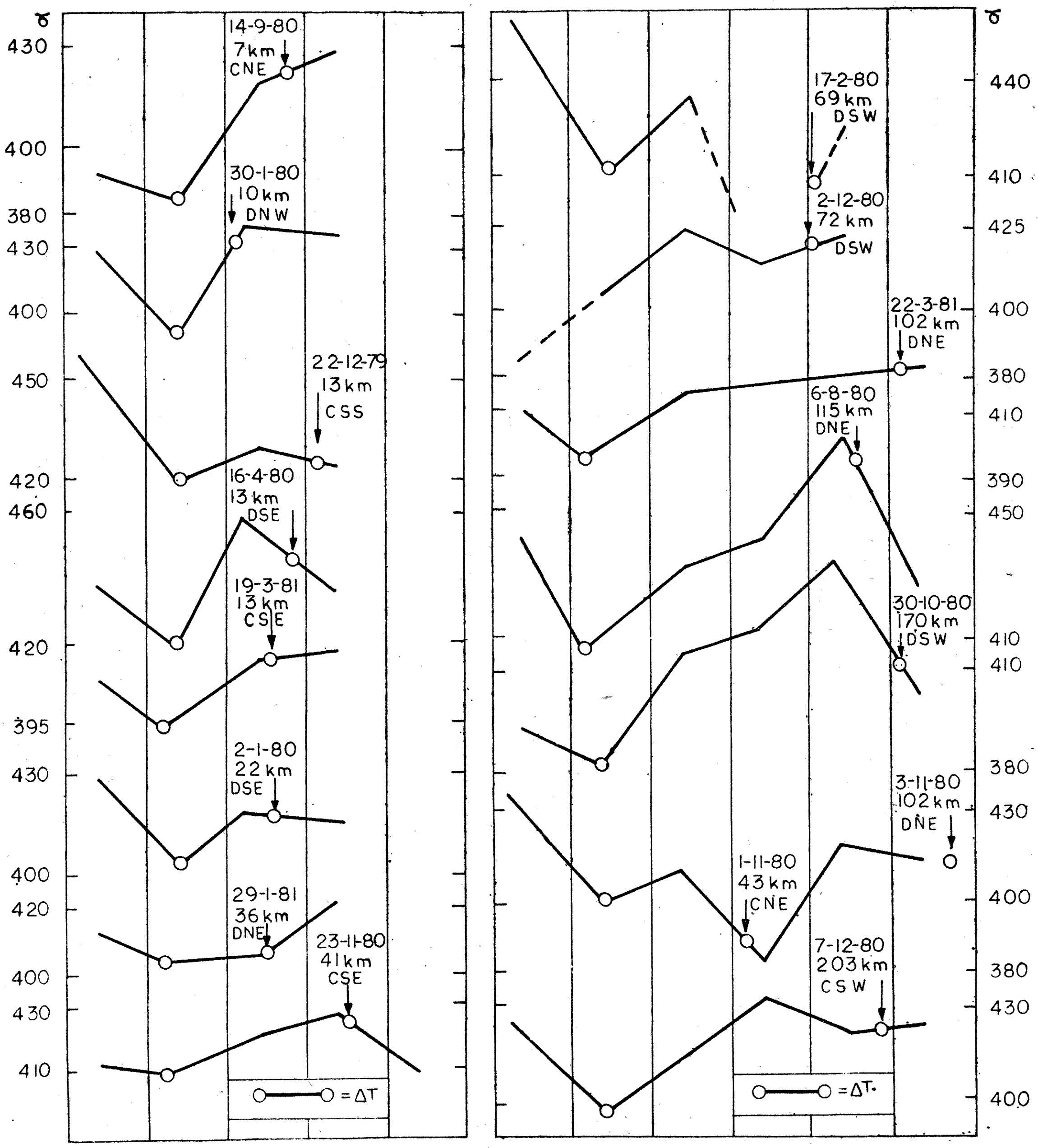

Fig. 4. Total geomagnetic field (*F*) variations at Shillong in the vicinity of few days prior to the felt shocks (Dotted line shows the days of geomagnetic disturbances)

order to establish the usefulness of magnetic observations for predicting the earthquakes. The proton precession magnetometer shows some encouraging results. Certain systematic or reproductive precursor to magnetic events have been observed for an individual earthquake. Total geomagnetic field values on each of the days prior to certain shocks along with the radial epicentral distances (vertical arrows marks) are shown in Fig. 4. The magnetic observations are taken at about the same time everyday at the same location. It can be noticed from Fig. 4 that the geomagnetic field had a bay-type of depression systematically prior to the earthquake in all the cases presented. The field is noticed to recover to the pre-depression value shortly before the day of the earthquake. The time interval in hours at which the minimum value of the field observed during the depression, to the time of shock is taken as the time interval ($\triangle T$) from Fig. 4. This $\triangle T$ along with the radial epicentral distance listed by C.S.O., Shillong for the respective shocks are collected with a view to examine further for a possible relationship. These data are given in Table 2.

From Table 2, there is a suggestion of an association between the epicentral distance $\triangle$ and the $\triangle T$. A relationship between the time interval of geomagnetic field precursor and the epicentral distance has been shown in Fig. 5 where a linear relationship is well

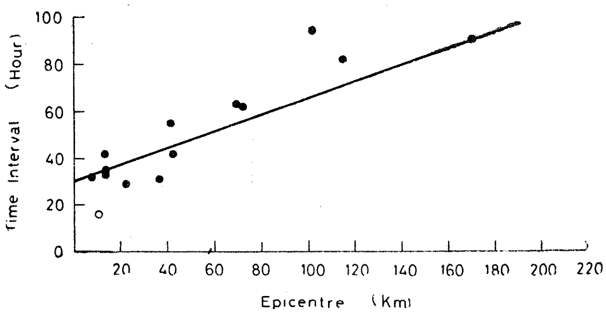

Fig. 5. Relation between epicentral distance and time interval of depression in F at Shillong

TABLE 2

The time interval ($\triangle T$) and the epicentral distance of the earthquake. There is a suggestion of an association between the epicentral distance and the $\triangle T$

S. No.	Date of eathquake			Epicentral distance (km)	Hours (Approx.) prior to eathquake ($\triangle T$)
	Day	Month	Year		
1	14	09	80	07	32
2	30	01	80	10	16
3	22	12	79	13	42
4	16	04	80	13	35
5	19	03	81	13	33
6	02	01	80	22	29
7	29	01	81	36	31
8	23	11	80	41	55
9	01	11	80	43	42
10	17	02	80	69	63
11	02	12	80	72	62
12	22	03	81	102	94
13	06	08	80	115	82
14	30	10	80	170	91
15	07	12	80	203	83

marked. A straight line fit *via* regression analysis has been made to find out the slope and intercept. The correlation coefficient is found to be + 0.88 and the slope is 0.3625. From the fitted line there is a suggestion that the minimum in the geomagnetic field at the epicentre would be registered about 30.2 hours before the occurrence of the shocks. Further study with more sensitive proton pression magnetometer observations in the seismic zone, and increasing the number of observations (at least 3 hourly) may enable one to study the incoming signal of the earthquake (specially in the NE part of India).

In conclusion, it is proposed that measurements of total geomagnetic field by proton precession magnetometer at Shillong is very useful for monitoring the crustal stress changes in this area which is seismically very active. Few cases of geomagnetic field changes are shown about one month before the major earthquakes in this area. In addition, an anomalous field changes which resembles the 'bay' like disturbance is also noticed few days prior to the shocks. The time interval between the minimum of the field in this bay and the time of the subsequent earthquake appears to be related to the radial epicentral distance of the nearby shocks. However, these preliminary inferences are to be further examined with more sensitive magnetometer measurements and with wider data base.

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