550·38 (548·4)

Some features of magnetic elements at Trivandrum and Annamalainagar, situated near the geomagnetic equator in the Indian Peninsula

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ABSTRACT. The *Sq* diurnal variation in *H* at Trivandrum and Annamalainagar are found to be large compared with those at Alibag. The quiet day range in *H* at Trivandrum in the month of March is abnormally large. Though the *Sq* variations in *V* at Trivandrum are not abnormal they are larger than those at Annamalainagar and Alibag.

The response of the *H* elements to disturbance at Trivandrum, Annamalainagar as well as Alibag are similar in sense. But the *V* element at Annamalainagar shows a difference in its response to disturbance. When the *V* elements at both Alibag and Trivandrum show an increase in numerical magnitude the *V* element at Annamalainagar shows a decrease and *vice versa*.

When the magnitudes of disturbance are examined they are found to be almost the same in the *H* element at all the observatories (including Alibag) during night hours. But during the day the magnitudes of disturbance in *H* element at Trivandrum and Annamalainagar are always greater than that at Alibag, a station away from the geomagnetic equator. Effects of disturbance in the *V* element are greatest at Trivandrum both during the day as well as the night.

The lines of force of an average disturbance field in a longitudinal plane over the region of the Indian Peninsula appear to be smooth curves with their concave side turned upwards, their turning points occurring between Annamalainagar and Alibag during the day and close to Alibag in the night.

1. Introduction

The large diurnal range in *H* around the region of the geomagnetic equator as shown by the records of the Huancayo Observatory has necessitated more magnetic observations in the region. The Colaba Observatory, as part of its IGY programme, set up two magnetic observatories, one slightly north and the other slightly south of the geomagnetic equator. The observatories have now been functioning for several months. It is the purpose of this paper to examine the records so far obtained, with respect to the *Sq* diurnal variation in *H* and *V* and the field intensities at the observatories due to disturbance field fluctuations caused by particle radiation.

2. Location of the observatories

One of the observatories is located at Trivandrum and the other at Annamalainagar (Chidambaram). Their geographic and geomagnetic coordinates are given in Table 1 along with those of Alibag and Huancayo observatories for comparison.

In its location, Trivandrum observatory has a similarity to that of Huancayo observatory. Though Huancayo has a southern geomagnetic latitude as shown in Table 1, absolute values at the place give it a north magnetic latitude, the vertical component of the permanent magnetic field being positive. The following facts are of interest —

(*i*) Trivandrum is located north of the geographic equator and south of the magnetic equator, just as Huancayo is south of the geographic equator and north of the magnetic equator.

(*ii*) Trivandrum is as close to the magnetic equator as Huancayo is. They are both almost on the magnetic equator, the former being very slightly south and the latter very slightly north of it.

3. Instruments at the observatories

The instruments used for recording the variations of the magnetic elements at Trivandrum and Annamalainagar are

TABLE 1

Observatory	Geographic		Geomagnetic	
	Lat.	Long.	Lat.	Long.
Trivandrum	8°29′N	76°50′E	0°53′S	145°50′
Annamalainagar	11°22′N	79°42′E	1°26′N	149°42′
Alibag	18°38′N	72°52′E	9°30′N	143°36′
Huancayo	12°03′S	75°20′W	0°36′S	353°48′

TABLE 2

Mean absolute values (from absolute observations) at Trivandrum, Annamalainagar and Alibag for the period October 1957 to January 1958

Magnetic element	Trivandrum	Annamalai-nagar	Alibag
Horizontal Force (γ)	40092	40615	38695
Vertical Force (γ)	—413	3841	17716
Declination	2° 51′ 27″ W	2° 46′ 52″ W	0° 47′ 57″ W

the Askania Geomagnetic Variometer Stations. They consist of *H*, *V* and *D* variometers, all the three recording on the same photographic paper. The scale values of the variometers are determined with the help of Helmholtz coils fixed to each variometer and these are determined at intervals of a fortnight.

A set of QHM and BMZ is used for determining absolute values. Absolute measurements are made daily.

Table 2 gives the mean absolute values of *H*, *V* and *D*. For comparison, those at Alibag are also given. The values are characteristic of the region. *H* is very high and *V* is very low. *V* at Trivandrum especially is very small being only about —400γ. This gives an idea of the closeness of the observatory to the magnetic equator. The vertical force at Trivandrum considered with respect to the north-seeking end of a magnet is directed towards the zenith (appropriate to its southern magnetic latitude) and that at Annamalainagar is directed towards the nadir. Therefore, having regard to the usual convention of signs, *V* at Trivandrum is negative and that at Annamalainagar is positive.

The declination at both the observatories are westerly and of magnitude of about 3°.

4. Diurnal variation of *Sq* field

The large diurnal variation in *H* near the region of the geomagnetic equator in India has been indicated by Pramanik and Hariharan (1953), but exact magnitudes involved have come to light only with the examination of continuous records obtained at Trivandrum and Annamalainagar. The *Sq* field variation was computed from the hourly values of *H* and *V* for the months of December 1957, March and June 1958 using the values of five quiet days. For the months of December and March, the International Quiet Days are used. The I.Q. Days for June 1958 had not been made available at the time of this computation and therefore five selected quiet days were used. In working out the *Sq* diurnal variation the non-cyclic variation was allowed for by applying the appropriate corrections. The diurnal variations may be seen in Tables 3(a) and 3(b). The variations for Alibag have also been given. Their graphical representations are given in Figs. 1(a) to 1(c) and 2(a) to 2(c). The following features may be noticed.

(*i*) The *Sq* diurnal variation of *H* is largest at Trivandrum for all the months considered. It is least at Alibag. This is true for the solstice months (December and June) as well as for the equinox month (March). The quiet day range in *H* for March at Trivandrum is extremely large, being of the order of 180γ. That for Annamalainagar is also large though not so large as at Trivandrum. The range at Annamalainagar for March is 130γ, and at Alibag it is 75γ. It is seen that the quiet day range in *H* at Trivandrum is more than double that at

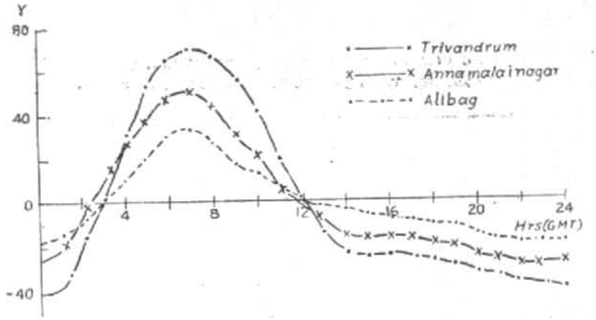

Fig. 1(a). Sq diurnal variation (5 I. Q. Days) for December 1957 (Horizontal Force)

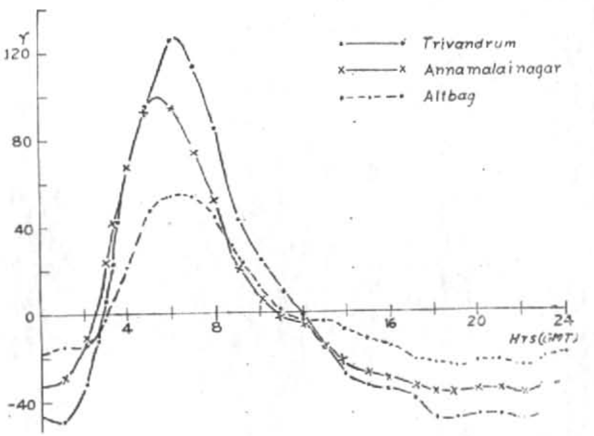

Fig. 1(b). Sq diurnal variation (5 I. Q. Days) for March 1958 (Horizontal Force)

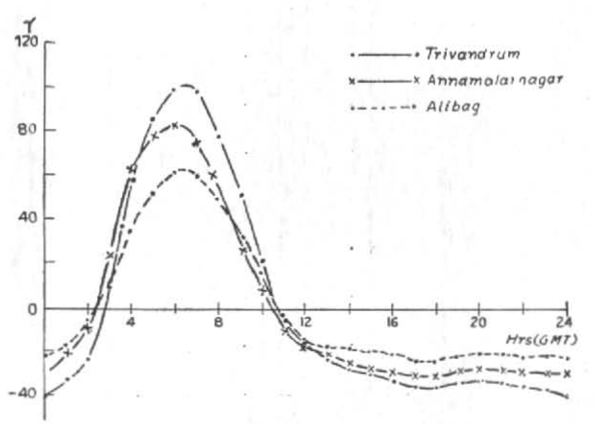

Fig. 1(c). Sq diurnal variation (5 selected Q days) for June 1958 (Horizontal Force)

TABLE 3(a)

Hourly variations (γ) in H of the Sq field at Trivandrum, Annamalainagar and Alibag for December 1957, March 1958 and June 1958, representing the solstice months and the equinox month

Hours (GMT)	December 1957			March 1958			June 1958		
	Trivandrum	Annamalainagar	Alibag	Trivandrum	Annamalainagar	Alibag	Trivandrum	Annamalainagar	Alibag
0	—40·3	—27·5	—18·3	— 46·2	—33·0	—18·4	— 40·5	—30·5	—23·4
1	—38·4	—21·1	—15·1	— 48·9	—29·2	—15·3	— 34·8	—22·9	—18·6
2	—17·6	— 5·8	— 8·8	— 32·9	—14·2	—15·4	— 24·7	— 9·3	— 7·4
3	+ 1·1	+ 8·7	+ 0·5	+ 8·2	+16·4	— 0·5	+ 8·1	+23·1	+11·4
4	+30·7	+27·2	+10·4	+ 67·2	+69·1	+20·5	+ 55·6	+62·4	+35·6
5	+54·7	+39·1	+20·4	+ 96·4	+97·7	+47·4	+ 87·1	+77·4	+55·5
6	+65·8	+48·8	+31·4	+125·9	+93·8	+54·4	+100·3	+82·2	+60·3
7	+69·7	+50·4	+34·1	+112·2	+76·4	+53·7	+ 97·3	+73·4	+59·3
8	+66·0	+43·7	+26·9	+ 82·9	+51·5	+42·4	+ 75·9	+51·9	+48·0
9	+56·3	+30·1	+16·6	+ 44·0	+20·4	+25·5	+ 50·3	+29·9	+32·8
10	+40·5	+20·4	+13·2	+ 25·1	+ 6·4	+11·3	+ 17·8	+ 8·5	+14·4
11	+19·0	+ 7·4	+ 5·9	+ 10·8	— 1·8	— 0·1	— 5·4	—10·9	— 4·8
12	+ 0·4	— 2·0	— 0·7	— 0·8	— 4·9	— 4·0	— 17·7	—19·7	—17·6
13	—14·3	— 8·5	— 1·3	— 15·7	—14·4	— 3·7	— 22·5	—21·7	—18·9
14	—22·9	—15·4	— 3·6	— 29·9	—24·9	— 8·1	— 29·1	—26·7	—19·6
15	—24·3	—16·0	— 4·9	— 33·8	—28·0	—12·6	— 31·2	—28·2	—20·4
16	—24·0	—15·9	— 6·2	— 36·0	—29·3	—15·0	— 33·5	—29·7	—21·7
17	—24·8	—16·3	— 8·2	— 39·5	—34·1	—21·2	— 36·6	—31·5	—25·0
18	—27·8	—19·7	—11·3	— 48·3	—37·0	—23·7	— 36·9	—31·6	—24·5
19	—28·6	—20·0	—11·5	— 48·8	—37·1	—24·9	— 35·3	—29·5	—22·9
20	—32·0	—24·6	—15·1	— 47·9	—36·0	—23·7	— 34·4	—28·2	—21·7
21	—34·4	—25·9	—17·8	— 47·5	—35·9	—22·8	— 34·5	—28·3	—21·6
22	—36·9	—28·5	—18·6	— 49·8	—37·6	—25·2	— 36·5	—29·9	—23·1
23	—38·3	—28·6	—19·2	— 47·3	—35·0	—21·4	— 38·1	—30·4	—22·7

TABLE 3(b)

Hourly variations (γ) in V of the Sq field at Trivandrum, Annamalainagar and Alibag for December 1957, March 1958 and June 1958

Hours (GMT)	December 1957			March 1958			June 1958		
	Trivandrum	Annamalainagar	Alibag	Trivandrum	Annamalainagar	Alibag	Trivandrum	Annamalainagar	Alibag
0	+ 7·6	+12·6	− 2·7	+ 8·0	+16·2	+ 4·5	+ 4·3	+12·8	+ 8·4
1	+ 8·0	+12·6	− 1·1	+ 7·5	+22·9	+ 7·5	− 4·8	+16·8	+18·1
2	+ 0·3	+ 8·9	− 1·3	+ 0·3	+21·2	+13·7	− 9·0	+19·6	+15·7
3	− 9·9	+ 3·4	+ 9·6	−16·9	+14·0	+10·0	−22·6	+18·1	+ 7·8
4	−22·2	− 4·3	+14·9	−39·5	+ 2·3	− 1·5	−33·8	+ 0·4	− 4·3
5	−30·3	− 7·2	+10·1	−50·3	−17·3	− 9·6	−30·5	−14·5	−17·2
6	−29·3	− 7·6	+ 4·2	−34·7	−27·2	−16·3	−22·7	−20·3	−25·5
7	−22·6	−16·7	+ 4·5	−20·6	−32·7	−16·6	−15·9	−24·8	−24·7
8	− 7·7	−28·9	+ 3·0	− 6·6	−35·1	− 8·9	− 3·3	−23·4	−13·8
9	− 0·6	−30·8	− 0·2	+ 8·3	−30·0	− 0·7	+ 3·7	−19·4	− 4·1
10	+ 0·1	−22·8	+ 2·1	+ 6·8	−21·3	+ 4·2	+13·6	−15·4	+ 4·7
11	+ 8·3	−11·8	+ 1·4	+10·2	−13·0	− 0·3	+19·0	−11·4	+ 5·8
12	+16·6	− 4·5	− 2·9	+10·3	− 4·7	− 5·5	+17·1	− 5·7	+ 2·4
13	+15·4	+ 4·3	− 4·2	+12·9	+ 0·9	− 6·3	+13·0	+ 0·3	− 1·1
14	+11·9	+ 5·9	+ 0·1	+15·0	+ 3·2	− 0·5	+15·2	+ 1·5	− 2·6
15	+ 8·4	+ 8·2	− 1·9	+12·6	+ 7·1	+ 1·6	+13·3	+ 4·4	− 1·8
16	+ 6·1	+ 9·0	− 4·5	+10·7	+ 9·4	+ 0·7	+ 9·3	+ 5·3	+ 0·8
17	+ 6·2	+ 9·2	− 6·2	+12·3	+ 8·9	+ 2·7	+ 9·2	+ 5·5	+ 3·6
18	+ 5·2	+ 9·3	− 6·9	+11·1	+10·7	+ 3·1	+ 6·4	+ 6·3	+ 3·9
19	+ 3·8	+10·4	− 5·1	+ 9·3	+10·7	+ 4·2	+ 3·0	+ 8·5	+ 4·0
20	+ 5·5	+ 9·4	− 4·4	+ 8·0	+12·5	+ 3·7	+ 2·1	+ 8·6	+ 4·7
21	+ 6·0	+ 9·4	− 3·9	+ 7·6	+13·0	+ 4·3	+ 2·9	+ 8·9	+ 4·7
22	+ 6·7	+ 9·8	− 2·1	+10·0	+12·8	+ 3·1	+ 5·1	+ 8·9	+ 4·7
23	+ 7·6	+11·0	− 1·7	+ 7·3	+15·6	+ 3·4	+ 5·4	+ 9·2	+ 5·1

NOTE—Figures for Trivandrum (where V is negative) are variations from the numerical mean value (M) of the vertical force. Thus, if at 1 hr GMT the variation is $+8\gamma$, the value of V at this hour is $-(M+8)\gamma$

Alibag. The diurnal range in H increasing abnormally as the magnetic equator is approached, is thus corroborated by the observations at Trivandrum and Annamalainagar.

(*ii*) At Trivandrum and Annamalainagar, for the three months considered, the variations are largest in the month of March and least in December. At Alibag while the variations remain least in December the maximum variations occur in June. In December, the sun being in the region of the Tropic of Capricorn zenith angle of the sun at noon is large for all the three observatories. The noon zenith angle of the sun is least (for the three months considered) in March at Trivandrum and Annamalainagar and in June it is least at Alibag. The dependence of the *Sq* diurnal variation in H on the noon zenith angle of the sun is thus clearly brought out by the graphs in Figs. 1(a) to 1(c).

(*iii*) The local time effect has also been shown up by the variation graphs. The peak variations and the change from negative to positive variation in the morning hours as well as the change from positive to negative variation in the evening all occur at about the same time at the three observatories. Since the local times of the observatories do not differ by more than 30 minutes the *Sq* variations of H may be considered to vary according to local time.

(*iv*) The *Sq* diurnal variation in V at the three observatories (Figs. 2a to 2c) as in the case of the H element, is the least in the month of December and largest in the month of March for Trivandrum and Annamalainagar and in June for Alibag. Here again the dependence of the variations on the noon zenith angle of the sun is shown clearly. The *Sq* variations are large for the month of low zenith angle of the sun at noon and *vice versa*.

(*v*) As in the case of the H element the range in V is largest at Trivandrum for all the months considered. It is especially striking for the month of March, when the range is 65γ. Corresponding range in V at Annamalainagar is 58γ. The maximum range for Alibag (in June) is 44γ. Ranges in V for Alibag are the least for all the three months.

(*vi*) An important feature seen in Figs. 2(a) to 2(c) is that the maximum variation in V, unlike the variations in H, do not occur at the same time at the three observatories.

5. Effects of disturbance on the magnetic elements, H and V

When the magnetic elements at the observatories (Trivandrum, Annamalainagar and also Alibag) are examined for their response to disturbance caused by particle radiation a difference is met with. At Alibag a rise in the magnitude of H is generally associated with a decrease in the magnitude of V and *vice versa*, during quiet as well as disturbed periods. The same feature is observed at Trivandrum as far as the numerical magnitudes of the elements are concerned. The H and V elements at Annamalainagar follow this rule only during quiet periods. During disturbance the H and V elements are observed to respond in unison, *i.e.*, an increase in H is associated with a similar increase in V. The magnetic elements at Annamalainagar appear to show a difference in field variations due to wave radiation and those due to particle radiation.

In Figs. 3(a) to 3(c) are reproduced the magnetograms of Alibag, Trivandrum and Annamalainagar for 5-6 February 1958. It may be clearly seen that the quiet period field changes are similar for all the observatories. During periods of disturbance (the bays for example), at Alibag and Trivandrum a depression in H is associated with an enhancement in V (numerically for Trivandrum) and *vice versa*. At Annamalainagar, on the other hand, during disturbance a depression in H is associated with a similar depression in V and an enhancement in H is associated with an enhancement in

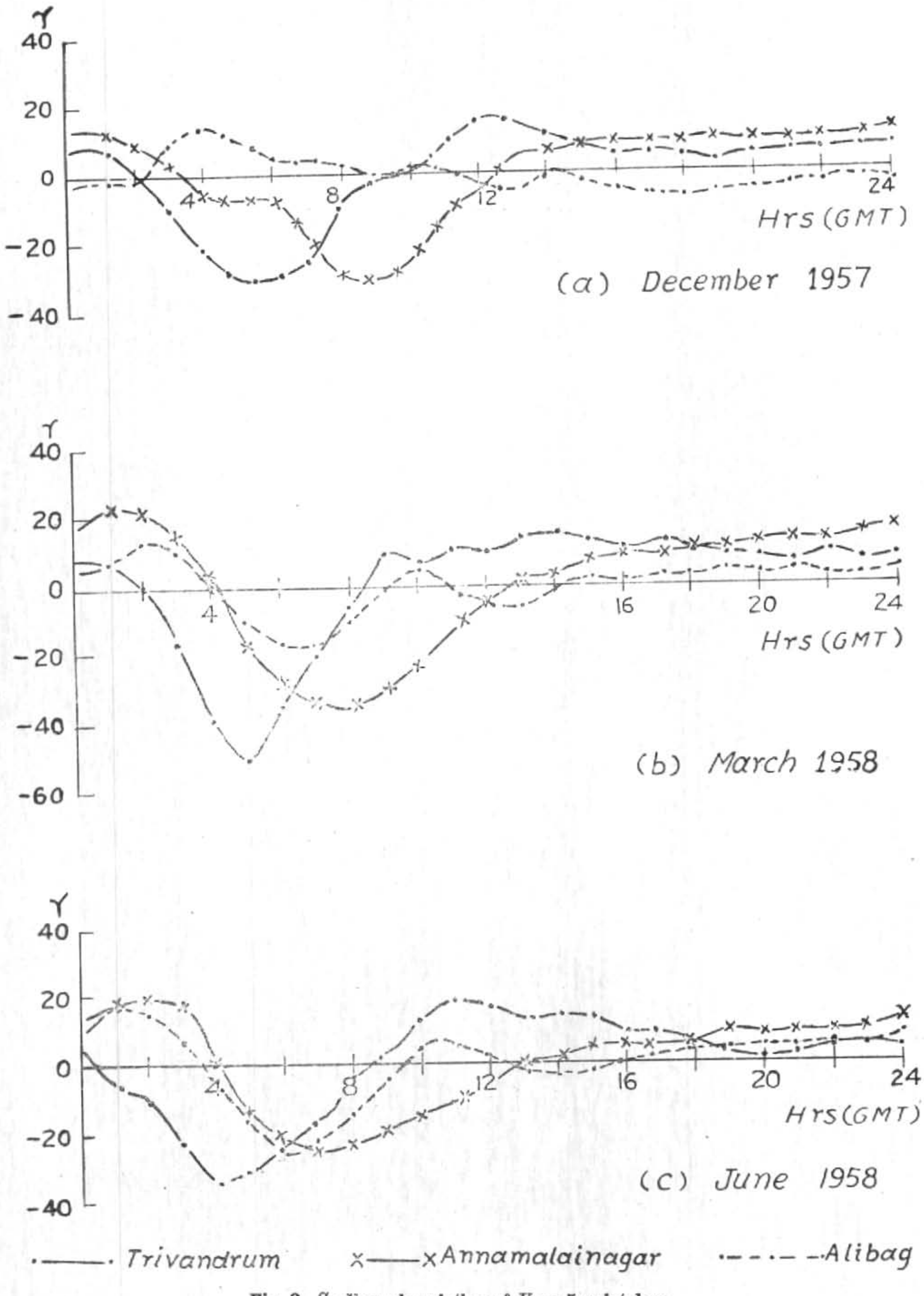

Fig. 2. *Sq* **diurnal variation of** *V* **on 5 quiet days**

Variations for Trivandrum are from the numerical mean value of *V*

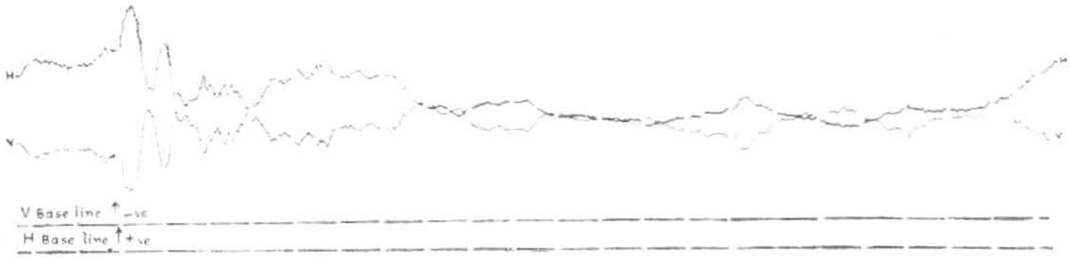

Fig. 3(a). Trivandrum H and V traces on 5-6 February 1958 (from 0837 to 0832 IST)

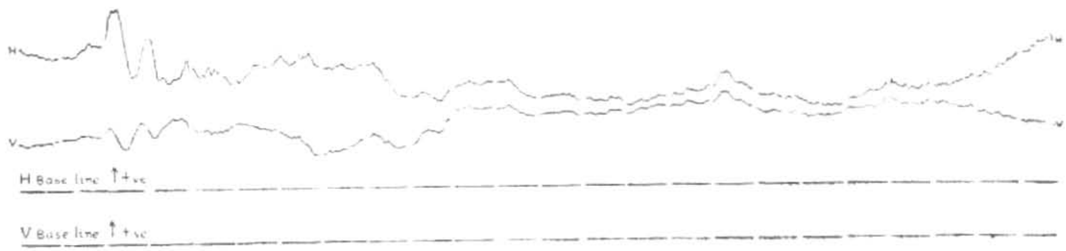

Fig. 3(b). Annamalainagar H and V traces on 5-6 February 1958 (from 0856 to 0855 IST)

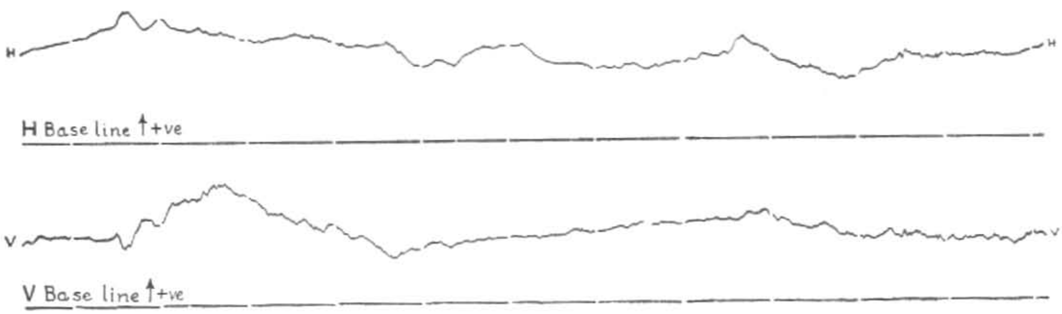

Fig. 3(c). Alibag H and V traces on 5-6 February 1958 (from 0852 to 0819 IST)

V also. This feature is very striking when individual disturbance field fluctuations like sudden commencements, bays, sudden impulses etc are examined.

If the magnitudes of H and V elements at the instant of commencement of a simultaneous disturbance fluctuation are H_1, H_2 and H_3 and V_1, V_2 and V_3 at Trivandrum, Annamalainagar and Alibag respectively (V_1 directed upwards and V_2 and V_3 directed downwards) and if the simultaneous fluctuation enhances the magnitudes of the H elements to $H_1 + \triangle H_1$, $H_2 + \triangle H_2$ and $H_3 + \triangle H_3$, the magnitudes of the V elements are then observed to be $V_1 - \triangle V_1$, directed upwards at Trivandrum, $V_2 + \triangle V_2$ directed downwards at Annamalainagar and $V_3 - \triangle V_3$ directed downwards at Alibag. The magnitudes of the disturbance field, thus turn out to be $+\triangle H_1$, $+\triangle H_2$ and $+\triangle H_3$ for the horizontal components and $+\triangle V_1$,

$+\triangle V_2$ and $-\triangle V_3$ for vertical components at the three observatories respectively. If the effect of the disturbance is to reduce the magnitudes of H at the observatories then the magnitudes of the disturbance field are observed to be $-\triangle H_1$, $-\triangle H_2$, $-\triangle H_3$ for its horizontal components and $-\triangle V_1$, $-\triangle V_2$ and $+\triangle V_3$ for its vertical components at the three observatories respectively. In other words a simultaneous disturbance field fluctuation having its horizontal components directed northwards at the three observatories has its vertical component directed upwards at Alibag and downwards at both Annamalainagar and Trivandrum. Similarly a fluctuation having its horizontal components directed *southwards* at the three observatories, has its vertical components directed downwards at Alibag and upwards at Annamalainagar and Trivandrum.

The behaviour of the magnetic elements H and V at Annamalainagar during disturbance has been observed to occur at Kodaikanal (Lat. 10°.14 N, Long. 77°.28 E) also by Sivaramakrishnan (1956) while examining sudden commencements.

In order to examine the feature in detail and to ascertain the field magnitudes at the observatories due to disturbance, some disturbance fluctuations like sudden commencements, bays, sudden impulses, that are known to be caused by particle radiation were investigated and their horizontal and vertical component field magnitudes were computed. Each disturbance fluctuation was checked for its simultaneous occurrence at the three observatories. The amounts of increase or decrease in H as well as in V for different disturbance fluctuations were computed using the scale values of the different elements. Tables 4 and 5 give the values of the horizontal component ($\triangle H$) and vertical component ($\triangle V$) of the disturbance fluctuations considered. $\triangle H$ is positive when there is an increase in H ordinate and negative when there is a decrease in the ordinate. Similarly $\triangle V$ is positive when there is an increase in V ordinate and *vice versa*. This holds good for Annamalainagar and Alibag. For Trivandrum, where V is negative and where an increase of V ordinate means an increase in the negative value of V, $\triangle V$ is positive when the effect of the disturbance fluctuation produces a decrease in V ordinate and *vice versa*.

All the disturbance field fluctuations occurring during the night hours are grouped together in Table 4. This is the period when the magnetic elements are not affected by wave radiation and, therefore, whatever disturbance occurs can be taken to be entirely due to effects of particle radiation. The disturbance fluctuations grouped in Table 4 are mostly bay disturbances with some sudden commencements and sudden impulses. While examining these disturbances it was noticed that the shapes of the disturbance traces of H were identical for all the observatories (Figs. 3a to 3c). The disturbance traces of V at Annamalainagar were identical with those of H and at Trivandrum the V traces were exact mirror-images of the traces of H. But at Alibag the disturbance traces of V very seldom showed any resemblance to those of H. The effects of disturbance in V during the night hours were so small that their measurement proved very difficult.

To bring out the difference, if any, in the effect of disturbance on the magnetic elements during the night hours and the day hours of the three observatories some disturbance fluctuations occurring during the day time were also examined. They are grouped together in Table 5. The response to disturbance of the V elements at Alibag was more marked during the day time.

In addition to giving the magnitudes, with signs, of the horizontal and vertical components of the simultaneous disturbance field, that causes the magnetic elements to be depressed or enhanced for a short duration of time, the dip [$\tan^{-1}(\triangle V/\triangle H)$] of the disturbance field as well as its total field $\triangle F$ calculated from the magnitudes of the

TABLE 4

Disturbed-field fluctuations occurring during the night hours

Date	Time (IST)	TRIVANDRUM				ANNAMALAINAGAR				ALIBAG			
		(*a*) ($\triangle H_1\gamma$)	(*b*) ($\triangle V_1\gamma$)	(*c*)	(*d*) ($\triangle F_1\gamma$)	(*a*) ($\triangle H_2\gamma$)	(*b*) ($\triangle V_2\gamma$)	(*c*)	(*d*) ($\triangle F_2\gamma$)	(*a*) ($\triangle H_3\gamma$)	(*b*) ($\triangle V_3\gamma$)	(*c*)	(*d*) ($\triangle F_3\gamma$)
						NOVEMBER 1957							
6	2350	+43·6	+55·4	52	70·5	+60·1	+31·4	28	67·8	+47·2	—11·5	—14	48·6
16	2331	+22·4	+25·4	49	33·9	+26·5	+13·2	26	29·6	+25·1	—2·5	—6	25·2
19	0330	—10·2	—14·3	54	17·6	—16·1	—9·4	30	18·7	—12·6	+4·7	—20	13·4
26	2022	—25·7	—41·3	58	48·6	—51·4	—18·8	20	54·7	—33·3	+3·4	—6	33·5
26	2223	+33·7	+53·2	57	63·0	+51·0	+27·6	28	58·0	+35·1	+4·9	8	35·4
29	0229	+29·0	+31·9	48	43·5	+34·9	+13·8	22	37·5	+34·2	—2·7	—5	34·3
30	2041	—10·5	—12·4	50	16·3	—12·9	—6·0	25	14·2	—11·7	+1·7	—8	11·8
30	2223	—9·2	—9·7	47	13·4	—10·6	—5·7	28	12·0	—8·2	+2·0	—13	8·4
						DECEMBER 1957							
10	0238	+26·0	+37·4	55	45·5	+31·2	+13·7	24	34·1	+29·5	—2·0	—4	29·6
11	0350	+13·2	+15·1	49	20·1	+16·5	+ 9·3	29	18·9	+16·9	nil	0	16·9
11	1930	—37·2	—39·4	47	54·2	—43·9	—20·0	24	48·2	—43·8	—5·6	6	44.1
13	2040	+20·1	+21·0	46	29·1	+24·8	+12·7	27	27·9	+21·7	—7·2	—18	22·9
15	1923	—45·4	—46·5	46	65·0	—53·4	—21·0	21	57·3	—48·2	nil	0	48·2
19	2358	—16·5	—20·7	52	26·5	—20·0	— 9·0	24	21·9	—17·4	,,	0	17·4
31	2144	+48·7	+74·8	57	89·3	+57·5	+27·3	25	63·7	+57·3	,,	0	57·3
						JANUARY 1958							
1	0048	+48·6	+63·3	52	79·8	+56·0	+26·9	26	62·1	+58·4	—7·0	—7	58·8
1	0409	+43·3	+61·5	55	75·2	+53·4	+24·2	24	58·6	+52·3	—9·0	—10	53·1
11	2151	+ 9·7	+10·5	48	14·3	+12·7	+ 6·6	27	14·3	+ 9·6	—1·0	—6	9·7
14	0136	+20·0	+25·4	52	32·3	+25·1	+15·2	31	29·3	+22·2	—5·0	—13	22·8
16	2235	—12·7	—15·5	51	20·0	—15·6	—7·1	24	17·1	—12·7	+0·5	—2	12·7
18	0038	+10·3	+13·2	52	16·7	+13·4	+ 8·1	31	15·7	+11·8	—1·7	—8	11·9
19	0011	+21·6	+20·0	42	29·4	+25·7	+15·7	31	30·1	+21·8	—5·0	—13	22·4
19	1905	+13·7	+17·2	51	22·0	+18·8	+14·7	38	23·9	+20·9	—6·0	—16	21·7

(*a*) *H*-component of *D*-field; (*b*) *V*-component of *D*-field; (*c*) Dip of *D*-field [$\tan^{-1}(\triangle V/\triangle H)$] in degrees; (*d*) Total *D*-field

TABLE 4 *(contd)*

Date	Time (IST)	TRIVANDRUM (a) ($\triangle H_1\gamma$)	(b) ($\triangle V_1\gamma$)	(c)	(d) ($\triangle F_1\gamma$)	ANNAMALAINAGAR (a) ($\triangle H_2\gamma$)	(b) ($\triangle V_2\gamma$)	(c)	(d) ($\triangle F_2\gamma$)	ALIBAG (a) ($\triangle H_3\gamma$)	(b) ($\triangle V_3\gamma$)	(c)	(d) ($\triangle F_3\gamma$)
						FEBRUARY 1958							
4	2220	—17·2	—21·5	51	27·5	—23·9	—11·3	25	26·4	—17·8	+6·7	—21	19·0
4	2308	+14·2	+17·1	50	22·2	+21·4	+13·7	33	25·4	+17·4	—2·2	— 7	17·5
10	0016	+26·1	+23·7	42	35·3	+30·9	+15·5	27	34·6	+29·5	—6·9	—13	30·3
11	0312	+20·2	+30·3	56	36·4	+27·7	+15·5	29	31·7	+13·5	nil	0	13·5
12	2318	+43·0	+39·2	42	58·2	+46·3	+32·4	35	56·5	+47·7	—9·9	—12	48·7
13	0246	+16·9	+21·8	52	27·6	+21·7	+13·3	32	25·4	+18·7	—2·7	— 8	18·9
13	2330	+26·1	+30·6	50	40·2	+30·8	+17·7	30	35·5	+29·1	—4·2	— 8	29·4
14	2121	+33·4	+43·1	52	54·5	+40·9	+24·5	31	47·7	+35·6	—4·7	— 8	35·9
15	2127	+30·5	+35·9	50	47·1	+36·9	+19·4	28	41·7	+32·1	—2·5	— 4	32·2
16	2211	+24·2	+27·1	48	36·4	+31·5	+19·1	31	36·8	+26·5	—4·5	—10	26·9
18	2356	+13·9	+16·6	50	21·7	+15·7	+8·8	29	18·0	+16·5	—4·7	—16	17·2
22	0138	+32·4	+32·6	45	46·0	+40·0	+22·0	29	45·7	+35·6	—8·9	—14	36·7
22	0256	+34·7	+35·6	46	49·7	+41·6	+22·0	28	47·1	+42·1	—4·0	— 5	42·3
						MARCH 1958							
3	2102	+15·9	+12·9	39	20·5	+21·4	+13·4	32	25·2	+16·9	—5·2	—17	17·7
4	0044	—33·4	—28·1	40	43·7	—37·2	—17·7	25	41·2	—36·0	nil	0	36·0
4	0200	+33·1	+38·9	50	51·1	+40·6	+23·6	30	47·0	+37·8	—5·0	— 8	38·1
10	2315	+19·6	+24·7	52	31·5	+25·2	+15·0	31	29·3	+20·0	nil	0	20·0
19	0008	+24·9	+33·6	53	41·8	+30·9	+16·1	28	34·8	+25·6	—4·2	— 9	25·9
19	0442	+29·4	+39·7	53	49·4	+36·7	+20·8	30	42·2	+34·3	+2·7	5	34·4
24	2158	+24·9	+32·4	52	40·9	+33·4	+20·8	32	39·3	+29·5	—7·2	—14	30·4
25	2109	+49·5	+63·1	52	80·2	+65·3	+40·4	32	76·8	+56·4	—14·2	—14	58·2
25	2320	—36·8	—45·2	51	58·3	—47·2	—25·5	28	53·6	—38·6	+10·7	—15	40·1
26	0422	—8·2	—12·0	56	14·5	—12·0	—8·5	35	14·7	—13·0	+4·7	—20	13·8
30	2049	—16·8	—22·0	54	27·7	—24·7	—16·1	33	29·5	—21·7	+8·7	—22	23·4
						APRIL 1958							
2	1956	—20·5	—26·9	53	33·8	—27·5	—13·9	27	30·8	—18·2	+5·0	—15	18·9
5	0209	+24·7	+31·3	52	39·9	+29·3	+14·7	27	32·8	+29·0	—4·8	— 9	29·4
14	2233	—11·5	—15·5	53	19·3	—14·9	—8·7	30	17·3	—10·0	+4·5	—24	11·0
17	0025	+33·3	+38·7	49	51·0	+39·5	+21·7	29	45·1	+36·8	—6·5	—10	37·4

(*a*) *H*-component of *D*-field; (*b*) *V*-component of *D*-field; (*c*) Dip of *D*-field [$\tan^{-1}(\triangle V/\triangle H)$] in degrees; (*d*) Total *D*-field

TABLE 5

Disturbed-field fluctuations occurring during the day hours

Date	Time (IST)	TRIVANDRUM (a) ($\triangle H_1 \gamma$)	(b) ($\triangle V_1 \gamma$)	(c)	(d) ($\triangle F_1 \gamma$)	ANNAMALAINAGAR (a) ($\triangle H_2 \gamma$)	(b) ($\triangle V_2 \gamma$)	(c)	(d) ($\triangle F_2 \gamma$)	ALIBAG (a) ($\triangle H_3 \gamma$)	(b) ($\triangle V_3 \gamma$)	(c)	(d) ($\triangle F_3 \gamma$)
						NOVEMBER 1957							
6	1400	—19·8	—16·2	39	25·6	—16·5	—0·9	3	16·5	— 6·0	+ 2·7	—24	6·6
8	1008	—38·9	—43·3	48	58·2	—35·9	—6·6	10	36·5	— 7·7	+ 2·7	—19	8·2
8	1236	—25·4	—30·3	50	39·5	—25·2	—5·7	13	25·8	— 8·2	+ 6·7	—39	10·6
10	1224	+26·4	+31·4	50	41·0	+26·5	+4·1	9	26·8	+12·5	— 4·7	—21	13·4
19	1020	+54·5	+47·3	41	72·2	+45·5	+3·1	4	45·6	+15·1	—13·7	—42	20·4
26	1430	+42·9	+52·8	51	68·0	+38·8	+6·9	10	39·4	+15·5	— 6·1	—21	16·7
27	0650	—27·7	—29·0	46	40·1	—31·7	—10·0	18	33·2	—12·5	+ 6·7	—28	14·2
27	0934	—81·8	—87·5	47	119·8	—65·6	—9·1	8	66·2	—18·5	+16·4	—42	24·7
27	1023	—60·1	—68·3	49	91·0	—52·0	—12·2	13	53·4	—18·9	+ 9·2	—26	21·0
						DECEMBER 1957							
1	1213	+61·2	+57·6	43	84·0	+60·4	+20·0	18	63·6	+43·5	—6·8	— 9	44·0
5	1240	+26·3	+33·1	52	42·3	+22·3	+ 3·3	8	22·5	+ 3·9	—6·0	—57	7·2
6	1018	+43·4	+44·1	45	61·9	+32·8	+ 7·0	12	33·5	+ 8·7	—6·8	—38	11·0
19	1506	+36·8	+46·8	52	59·5	+37·5	+ 0·6	1	37·5	+26·1	—4·1	— 9	26·4
						JANUARY 1958							
5	1116	+56·3	+45·9	39	72·6	+47·7	+ 9·6	11	48·7	+17·9	—9·4	—28	20·2
5	1209	+26·8	+24·9	43	36·6	+25·4	+ 8·6	19	26·8	+ 8·7	—4·4	—27	9·7
30	1309	—89·4	—78·3	41	118·9	—83·6	—14·7	10	84·9	—34·4	+14·3	—23	37·3
30	1521	—27·1	—15·1	29	31·0	—24·8	— 6·6	15	25·9	—14·0	+4·8	—19	14·8
						FEBRUARY 1958							
5	1100	+50·3	+42·9	40	66·1	+44·1	+ 8·2	11	44·9	+17·0	—8·7	—27	19·1
12	1429	+69·8	+83·0	50	108·5	+66·1	+30·1	24	72·6	+38·4	—8·7	—13	39·4
						MARCH 1958							
3	1500	+25·3	+20·7	39	32·7	+22·7	+8·5	21	24·2	+8·6	—6·4	—37	10·7
15	1213	—118·6	—116·6	45	166·3	—113·6	—34·0	17	118·6	—50·4	+15·8	—17	52·8
15	1527	+49·5	+48·2	44	69·1	+43·6	+15·3	19	46·2	+21·5	—8·7	—22	23·2
21	1345	—63·8	—65·2	46	91·2	—55·2	—15·7	16	57·4	—25·9	+9·2	—19	27·5

(*a*) *H*-component of *D*-field; (*b*) *V*-component of *D*-field; (*c*) Dip of *D*-field [$\tan^{-1}(\triangle V/\triangle H)$] in degrees; (*d*) Total *D*-field

horizontal and vertical components $\triangle H$ and $\triangle V$, are also given in Tables 4 and 5. By "dip" of the disturbance field is meant the angle subtended by the direction of the total disturbance field, $\triangle F$, from the horizontal assuming a separate existence for the disturbance field.

The following features of the magnetic elements during disturbance may be gleaned from Tables 4 and 5.

(a) Features during the night hours

(*i*) For any disturbance fluctuation the magnitudes of the horizontal components of the disturbance field are not much different from observatory to observatory. But a persistence of greater values for Annamalainagar is noticeable. On a few occasions $\triangle H$ values at Alibag are greater than those at Annamalainagar. For all the instances examined $\triangle H$ values at Trivandrum are the least, though comparable with the values at the other two observatories.

The signs of $\triangle H$ for any disturbance are the same at all the observatories.

(*ii*) The values of $\triangle V$ for any disturbance fluctuation is seen to fall sharply from Trivandrum to Alibag. For almost all the cases examined the $\triangle V$ values at Trivandrum are the highest. The difference in the values of $\triangle V$ at Trivandum and Annamalainagar is appreciable, while those at Alibag stand no comparison with the corresponding values at the other two observatories.

The signs of $\triangle V$ for any disturbance fluctuation are the same at Trivandrum and Annamalainagar. The sign of $\triangle V$ at Alibag on most of the occasions is the reverse of those at the other two observatories.

(*iii*) The average dip angle [$\tan^{-1}(\triangle V/\triangle H)$] of disturbance field at Trivandrum is 50°, that at Annamalainagar is 28° and the value at Alibag is —9°. These values for the dip of the disturbance field are only to be expected from the magnitudes of V at the different observatories.

(*iv*) Magnitudes of the total disturbance field $\triangle F$ at Trivandrum and Annamalainagar are comparable. Generally the values are always a little higher at Trivandrum than at Annamalainagar. Though $\triangle F$ is always the least at Alibag, it is not much different from those at the other two observatories.

(b) Features during the day hours

(*i*) For any disturbance fluctuation the magnitudes of the horizontal component ($\triangle H$) of the disturbance field at Trivandrum and at Annamalainagar are comparable. But the magnitude at Trivandrum is consistently a little higher. This is the reverse of what is seen during the night hours. The magnitudes of $\triangle H$ at Alibag are appreciably lower than those occurring at the other two observatories.

As in the case of the night hours, the signs of $\triangle H$ for any disturbance fluctuation remain the same at all the observatories.

(*ii*) The magnitudes of the vertical component of the disturbance field ($\triangle V$) are consistently higher at Trivandrum than those at the other two observatories. The values of $\triangle V$ are the least at Alibag. The differences in the magnitudes from Trivandrum to Alibag are very striking.

The signs of $\triangle V$ are the same at Trivandrum and Annamalainagar but opposite at Alibag. This feature is exactly the same as has been seen during the night hours.

(*iii*) The average dip angle [$\tan^{-1}(\triangle V/\triangle H)$] of disturbance field at Trivandrum is about 45°, at Annamalainagar it is 13° and at Alibag it is —26°. The dip angle at Trivandrum does not show a marked change from that occurring during the night hours, but the dip angle at Annamalainagar shows a sharp decrease from its night value. The dip angle at Alibag shows an increase in magnitude (numerically) from its night value.

(*iv*) The magnitudes of the total disturbance field $\triangle F$ are consistently higher at Trivandrum and they are least at Alibag.

The differences from observatory to observatory are more marked than those occurring during the night hours.

From the above facts it may be seen that though magnetic activity is of the same order at the three observatories during the night hours, a tendency for greater activity during the day hours at Trivandrum and Annamalainagar than at Alibag exists. The horizontal element, especially at Trivandrum, shows greater activity during the day hours. This finding assumes great significance when considered in the light of the note of Ferraro (1954) regarding the assymetry in the normality of geomagnetic disturbance during daylight and night hours near the geomagnetic equator.

An important feature established from the foregoing investigation is the difference in behaviour of the V element at Annamalainagar during disturbance from those at Trivandrum and Alibag. V at Annamalainagar increases when the same element at Alibag and Trivandrum (numerically at Trivandrum) decreases and *vice versa*.

From the magnitudes of the dip angles of the disturbance field at the three observatories an interesting feature emerges. The dip angles of the disturbance field decrease from Trivandrum to Annamalainagar and in the process of further decreasing towards Alibag actually get reversed there. The dip angles indicate the directions of the total disturbance field ($\triangle F$) at the different observatories and these directions are the tangents to the lines of force of the disturbance field in a longitudinal plane.

The negative sign for dip of the disturbance field ($\triangle F$) at Alibag indicates that the direction of the disturbance field is opposite to those at Trivandrum and Annamalainagar. If the direction of the total disturbance field at Trivandrum and Annamalainagar have a downward slope the direction of the field at Alibag has an upward slope and *vice versa*. A reference to Tables 4 and 5 will show that for disturbances producing enhancements in the magnitudes of the H elements (*i.e.*, horizontal components of the disturbance field directed northwards), the directions of the total disturbance field ($\triangle F$) at Trivandrum and Annamalainagar have a downward slope and that at Alibag an upward slope. Similarly a disturbance producing diminutions in the magnitudes of the H elements (*i.e.*, horizontal component of the disturbance field directed southwards) the directions of the total disturbance field have an upward slope at Trivandrum and Annamalainagar and a downward slope at Alibag. This is the significance of the dip angles being of opposite sign at Trivandrum and Annamalainagar on one hand and Alibag on the other.

The main dip angles of the disturbance field at the different observatories are the angles measured from the horizontal at the respective observatories. If the same horizontal (say that at Trivandrum) is taken for all the observatories then the dip angles will have to be corrected by amounts equal to difference in the latitudes of the observatories and then an idea of the lines of force due to disturbance field, in space, can be formed.

In the night hours the mean dip angles are 50°, 28° and —9° at Trivandrum, Annamalainagar and Alibag respectively. If the angles are measured from the horizontal for Trivandrum then the dip angle at Annamalainagar becomes 31° and that at Alibag becomes 1°, the difference in the latitudes of Trivandrum and Annamalainagar being about 3° and that between Trivandrum gnd Alibag being about 10°. If a smooth curve is drawn in a longitudinal plane across the latitudes so that the tangents to the curve make an angle 50° with the horizontal at Trivandrum and angles 31° and 1° with the horizontal (same as for Trivandrum) at Annamalainagar and Alibag respectively, then this curve will represent a line of force of the disturbance field in the longitudinal plane and in space, since the tangents to the curve are the directions of the disturbance field at the respective observatories. Thus

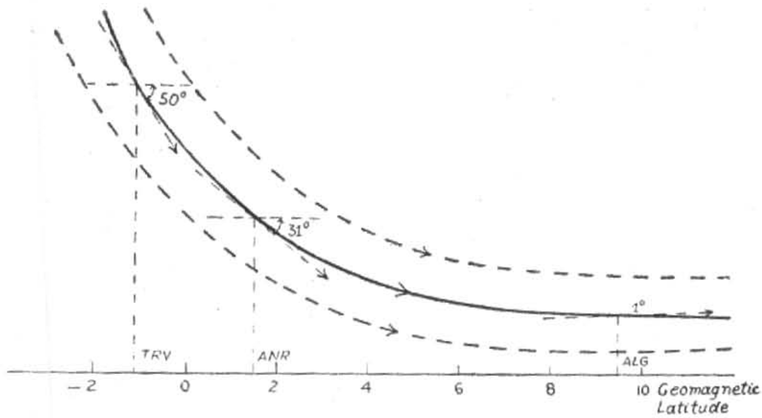

Fig. 4

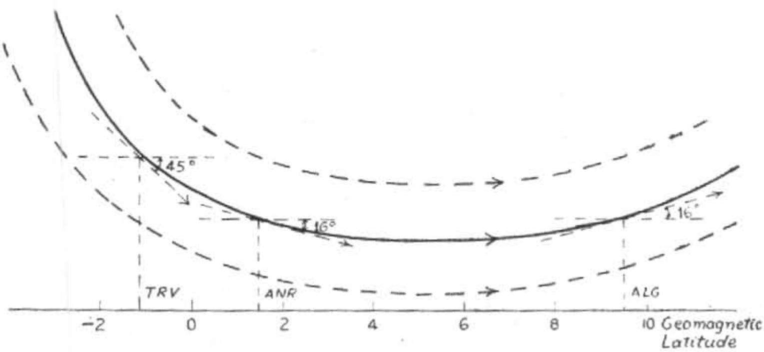

Fig. 5

Figs. 4 and 5. Lines of force in longitudinal plane over the Indian Peninsula, for an average disturbance fluctuation occurring during night (Fig. 4) and day (Fig. 5) hours

Arrows indicate direction of field for fluctuations producing enhancements in magnitudes of the *H* elements of the observatories

TRV–Trivandrum, ANR–Annamalainagar, ALG–Alibag

we find that the lines of force of the disturbance field in the longitudinal plane are smooth curves. The nature of change of dip angles of the disturbance field from Trivandrum to Alibag make the concave side of the curves turn upwards. Such lines of force in space and over the region under consideration are shown in Fig. 4. The portion of the curve above Alibag is almost horizontal.

In the same way the lines of force due to disturbance field may be pictured for the day hours and this has been shown in Fig. 5. During the day the mean dip angles are 45°, 13° and —26° at Trivandrum, Annamalainagar and Alibag respectively and if they are measured from the same horizontal as for Trivandrum then the angles are 45°, 16° and —16°. The curve is no longer horizontal at Alibag. It takes a turn between Annamalainagar and Alibag and curves upwards at Alibag.

In drawing the lines of force of the disturbance field in space it is assumed that the total disturbance fields are approximately the same at all the observatories, the difference being attributed to differences in the induced parts of the field. The small differences in longitude of the observatories are ignored and the same longitudinal plane is supposed to pass through all the three observatories.

The contours of the lines of force of the disturbance field both for the night hours as well as the day hours indicate that the disturbance fields considered are caused by currents flowing over head from east to west or west to east. These current-flows appear to occur almost above the region of Alibag in the night hours and in between Annamalainagar and Alibag in the day hours. If this is really the case then the behaviour of the V element at Annamalainagar during disturbance (increasing in magnitude when the V elements at Trivandrum and Alibag show a decrease in numerical magnitude and *vice versa*) is not an anomaly but as it should be.

6. Conclusion

The following conclusions can be derived from the above investigation—

(1) The Sq diurnal variation in H is abnormally large near the region of the geomagnetic equator.

(2) Though the Sq diurnal variatons in V do not show any abnormality in the region of the geomagnetic equator they are consistently greater at Trivandrum than at Alibag.

(3) The magnetic activity during night hours appear to be of the same order for Trivandrum, Annamalainagar and Alibag. But during the day hours a comparatively greater activity near the region of the geomagnetic equator is noticeable.

(4) For any disturbance the H elements at all the three observatories respond in a similar manner, *i.e.*, the H elements at all the observatories either increase or decrease in magnitude.

But the magnitude of V at Annamalainagar increases when the V elements at both Trivandrum and Alibag decrease in magnitude during disturbance and *vice versa*.

(5) The lines of force of the disturbance field in a longitudinal plane over the region of the Indian Peninsula appear to be smooth curves with their concave side turned upwards, their turning points occurring between Annamalainagar and Alibag during the day and close to Alibag during the night.

These findings give great importance geomagnetically to the region of the Indian Peninsula. Its importance has been stressed by Malurkar (1954) in a consideration of the magnetic field distribution around the region of the Andamans.

Considering the short period of data examined it has to be said that whatever inferences have been made can only be of a tentative nature. More conclusive inferences can only follow after a longer period of observations and with more rigorous methods of analysis of the data.

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