with sufficient separation to allow a fractionation method to be based on the reaction. My results, not being sufficiently definite, were never published; but as the organic acids were in my laboratory when the Scandium research was commenced, I preferred to use these acids, of which the purity and the history were known, rather than start afresh with acids of unknown history.

On the Rotatory Character of some Terrestrial Magnetic Disturbances at Greenwich and on their Diurnal Distribution.

By Robert B. Sangster.

(Communicated by Dr. C. Chree, F.R.S. Received March 8,—Read April 28, 1910.)

On the occasion of a brilliant display of aurora some apparently rotatory movements in the position of the corona suggested to the author the possible existence of similar changes of direction in the total magnetic force during disturbance. For investigating these changes the most convenient available data were the plates published with the "Greenwich Magnetical and Meteorological Observations" (hereafter referred to as the "Report"), showing on a reduced scale the diurnal registers of the three components of magnetic force for several disturbed days in each year. The eight years 1900–7 were dealt with, and a preliminary inspection of all the registers figured for these years was made to select an example for special consideration. The published registers are reduced in scale from the originals in the ratio 11 : 20, and to lessen the chance of error on this account, it was decided to select a disturbance showing comparatively slow, but steady and decided, changes. The registers selected in the first instance were those for October 12, 1903, and it was decided to determine the variation in direction of the total force from 18 hours onwards, at intervals of about 5 minutes, leaving out of account the effect of the small temperature variations recorded, for reasons presently to be stated. This variation in direction was found in terms of transverse deflecting force, the unit employed being 1×10^{-5} C.G.S. (1γ).

In the following remarks the letters D, H, and Z denote the declination, the horizontal force, and the vertical force, respectively; F and I, respectively, denote the total force and the dip; while the prefix Δ signifies inequality increments. Ordinates of the components D, H, and Z were measured on the plate at time intervals of 1/40 inch, corresponding to a measure once every 5 minutes, approximately. The zero of a scale divided to 1/40 inch was applied to the immediately preceding hour line, and points on the respective traces were thus set off at equal increments of time, and, from these, the force ordinates were measured to the adopted base lines. A division of the hour intervals into 12 equal parts was not so important as having the ordinates measured at exact time equivalents in all three registers. Regarding the accuracy with which the three registers were placed in time juxtaposition for the purpose of photo-lithographic reduction there is the assurance given in the "Report" (p. 37 for 1903) that great attention has been paid to this detail.

Values of ΔD were measured and tabulated directly in units of γ. This really represents the component (HΔD) causing variation in the direction of the total force transverse to the magnetic meridian. The component perpendicular to HΔD and to the axis of the dipping needle is FΔI, causing variation in the angle of I in the magnetic meridian. Therefore, diurnal variation of the direction of the total force can be represented by rectangular co-ordinates corresponding to HΔD and FΔI. For the determination of FΔI base lines were drawn on the plate (III, 1903, October 12 and 13) at the scale marks representing 27×10^{-3} H for the H trace and at 14×10^{-3} Z for Z. The absolute values of the adopted base lines are, approximately, 18,500 γ and 43,610 γ, respectively, and ordinates at the stated time intervals were measured $\pm$ from these, using the C.G.S. scales at the foot of the plate, in which one division $= 10\,\gamma$. Values of $Z/H = \tan I$ were thus obtained, and thence ΔI and FΔI. In finding FΔI, F was taken as constant at 47,392 γ, and so $1'$ deflection in dip $= 13{\cdot}8\,\gamma$, nearly. Thus, values for describing Diagrams (1) and (2) were furnished, the former showing the variation in direction of the total force as viewed towards the N-seeking end of a freely suspended dipping needle for the hours 18 to 23, October 12, 1903, and the latter for the following five hours. Cross marks on the trace indicate the points of measured ordinates at simultaneous intervals of about five minutes, while the trace between is drawn with chief regard to the connecting up of the points in proper succession. By following the trace in Diagram (1) from 18 h. onwards, it will be seen that the movement is almost wholly rotatory in character and anti-clockwise in direction. The convolutions vary greatly in size and in time rate, but the long-continued lævorotatory progression of the disturbance is very evident.

Doubt might naturally arise as to whether long stretches of trace joining up measured points in the diagram give a fair representation of the actual variation, *e.g.*, from 22 h. 15 m. to 22 h. 20 m., and one might reasonably question whether there were not, in this case, an intermediate convolution,

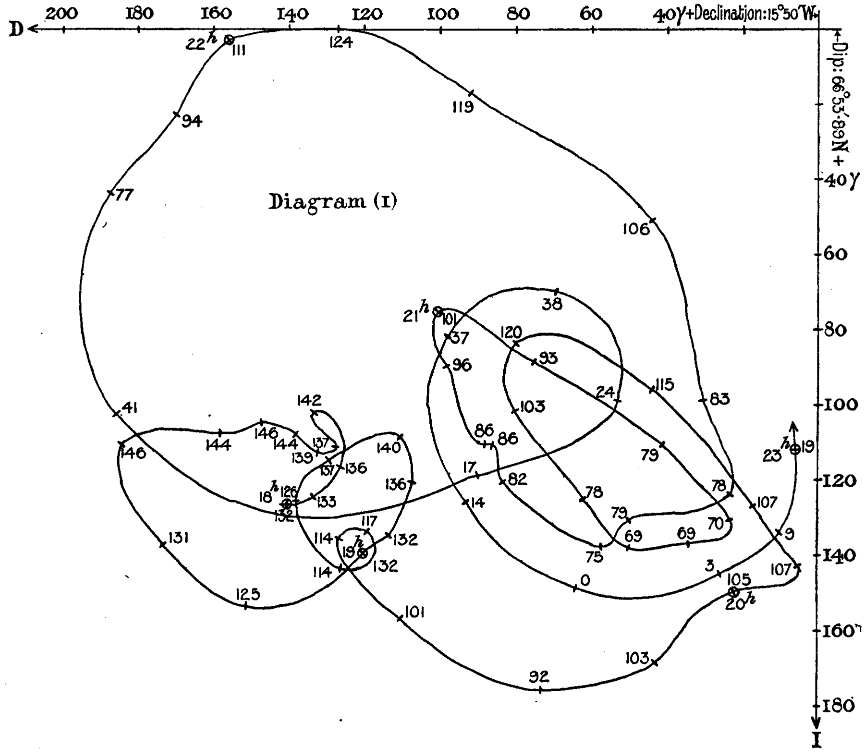


Diagram (1)

perhaps of opposite rotatory character. Assurance on this point, however, is easily obtained from a consideration of the intermediate trend of the three traces in the Greenwich plate.

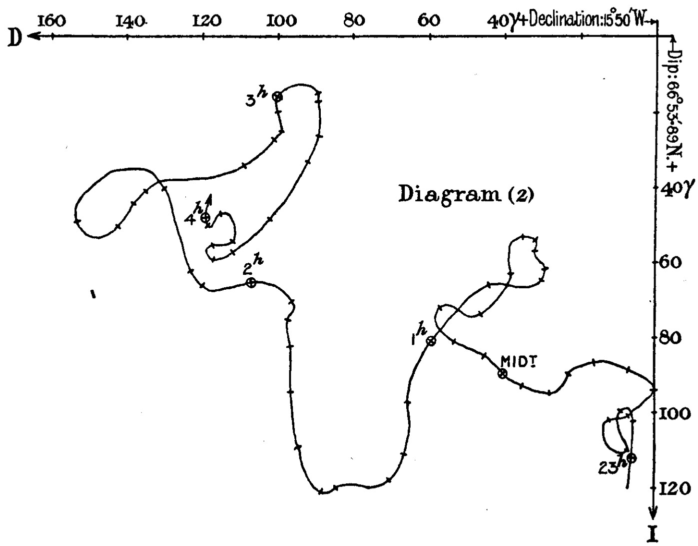


Diagram (2)

The author also assured himself that the effect on the diagram of applying the small and regular temperature corrections required to H and Z would be insignificant, and it was thus decided to neglect them.

Diagram (2) shows the disturbance to have continued in a changed character; there is a want of definiteness in the movements at times, but some of the changes after midnight are distinctly rotatory in a clockwise direction.

The total force ($Z/\sin I = F$) was also determined for each of the points in Diagram (1), and the values in γ's of ΔF, taken all positive, are shown beside the corresponding points. An examination of these ΔF values indicated that the variations of the disturbance vector were, roughly, approximately in the horizontal plane, and a diagram showing the changes of force $H\Delta D$ and ΔH was constructed and was found to be very similar in character to Diagram (1), the direction of all rotatory movements being the same in both.

This result obviously holds good so long as ΔH and ΔI are of opposite sign. But

$$\tan I = Z/H,$$

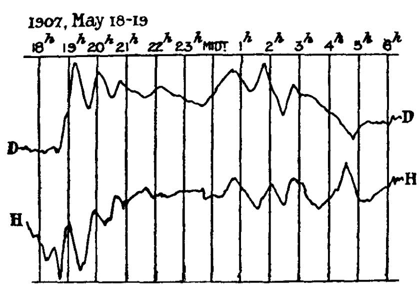
and so

$$\Delta I = \tfrac{1}{2} \sin 2I (\Delta Z/Z - \Delta H/H).$$

As $\sin 2I$ is positive, ΔI and ΔH are necessarily opposite in sign, unless $\Delta Z/Z$ has the same sign as and is numerically larger than $\Delta H/H$.

This did not occur in any of the seventy Greenwich disturbances dealt with here, and the nearest approach to it was found at 21 h. on November 15th, 1905, when the simultaneous changes were, approximately, $+80\,\gamma$ in H and $+140\,\gamma$ in Z. Therefore, subject to the above limitation, a rotatory effect in the horizontal plane implies a rotation in the same sense of the N-seeking end of a freely suspended magnet.

In order to determine the existence of rotatory movement in the disturbance vector it is usually unnecessary to measure force ordinates, for it is the time sequence of the changes of phase of the orthogonal components of the force in a plane which determines this feature. A good example of right and left rotations is furnished by a disturbance at Greenwich in 1907, May 18 d. 19 h. to 19 d. 5 h., the registers of which are reproduced on Plate IV. of the "Report" for that year, a copy of the reproduction being shown in the accompanying figure. Downward motion indicates increase of D and of H; increase of D means a movement of the disturbance vector to the west, or left, the observer being supposed to view the vector diagram from the south; increase



of H means a movement of the vector to the north, or away from the observer. Referring then to the figure, just previous to 19 h. the vector is moving towards the south and to the right. A minute or two after 19 h., ΔH changes sign from − to + and the vector moves north, but still continues its motion to the right. The next change of sign occurs in D about 19 h. 15 m., when the vector changes from easterly to westerly movement, while still continuing its northerly course. Then H begins to decrease about 19 h. 25 m., and so the alternate changes of D and H continue in regular sequence to about 22 h., when the oscillation of H ceases. The motion of the disturbance vector here is clearly rotatory in character and anti-clockwise in direction. In the tabular statement of rotatory disturbances found later in this paper the disturbance figured is described as rotatory and negative from 19 h. to 21 h., and again in the half-hour preceding 22 h. But, next day, from before 1 h., continuously on to between 2 h. and 3 h., and again before 5 h., the rotatory movement is clockwise, or positive. At 1 h. the vector is moving to the left and north, it then changes to right hand and northerly motion at 1 h. 20 m., and to right-southerly motion at 1 h. 35 m., the same sequence continuing to 2 h. 30 m. Between 4 h. and 5 h. the same reasoning shows there was a large semi-circular movement of the vector in a clockwise direction.

It was apparent, therefore, that some magnetic disturbances resulted from more or less conical motion of the line of total force, some movements showing clockwise (positive) and others anti-clockwise (negative) change, and a consideration of cases already described shows the remarkable feature of the negative rotatory movements occurring before midnight and those with a positive or right-handed rotation after that hour. An orderly feature of the kind in the complex subject of magnetic disturbances would be a useful stepping stone for any general theory of the subject, and the cases quoted could not but rouse curiosity as to the existence of some regular diurnal distribution. A close scrutiny was therefore made of all the disturbed magnetic registers published with the "Reports" for the eight years 1900–7 to pick out all clear cases of rotatory change after the manner already described. Some cases of magnetic storms having very rapid changes of phase had to be omitted from consideration, owing to the uncertainty as to the relative epoch of these changes in the several components. Seventy-two sets of traces in all were dealt with, and the practice was to set down a + or − before or after the hour line according as positive or negative rotation was in evidence in the 30 minutes preceding or following the exact hour. One sign, counting as one, was tabulated whether there occurred but one half circle of rotation, or one complete circle, or more, as sometimes happened. In a few cases + and − rotations were found in the same half hour, and these are tabulated ± or ∓, the upper sign indicating the first to occur, and in making up the totals each component is counted one of its kind. The signs, therefore, refer to diurnal distribution of + and − rotatory disturbance, and the tables are qualitative only in regard to rotation The meaning to be attached to the blanks is that no rotatory movement could be detected in the curves at these times. In the following tables the presence of two dates means that the register runs from noon of the first day to noon of the second, as is usually done at Greenwich. When one date only is mentioned the afternoon hours are put first, being *followed* by the forenoon hours of the *same* day.

The results are shown in Tables I to III grouped under three seasons of the year, with March, April, September, and October taken as one season. In Table IV the results of all three seasons are grouped in half-hour intervals, and in Table V in whole hours. The most remarkable feature in these tables is the entire absence of positive rotations during the hours 16 to 21, while the negative rotations rise to a notable maximum at 20 hours. Again the number of cases of positive rotation reaches a maximum at hour 2, while, meantime, the negatives rapidly decrease. It has to be pointed out, however, that the numbers in the tables are not exact measures of the diurnal distribution of rotatory effect, because the maximum incidence of disturbance occurred about hours 22 to 24, the Greenwich registers thus providing more night than daylight cases.

The afternoon interval, during which no positive rotations appear, is extended in the individual seasons, in winter and equinox up to noon, in summer up to midnight.

Table I.—Winter.

	Noon–13	13–14	14–15	15–16	16–17	17–18	18–19	19–20	20–21	21–22	22–23	23–Midt	Midt–1	1–2	2–3	3–4	4–5	5–6	6–7	7–8	8–9	9–10	10–11	11–Noon
1900 Jan. 14-15								−	−	+	+	− −			+	−						− −		
„ „ 19-20									−															
„ „ 20-21							−	−		+	+	−		+										
„ Feb. 4-5				−	−		−	−		−	−	−												
1901 Jan. 5-6					−	−			− −	+ +														
„ „ 22-23								−					− −										−	−
„ Feb. 22-23						−					− −	−												
1902 Jan. 15-16									−	−	+ +	+	+	−		−								
1903 Dec. 13-14					− −	−	−	−	− −			−	−											
„ „ 30-31											−	−		+	+		+ −	+ +						
1904 Jan. 28-29								− −	−			−	−											
1905 „ 5-6						− −	− −	−					− −											
„ Feb. 3						−		−		− −								+						
„ Nov. 12						− −	− −	−																
„ „ 15							−			−					−	+ +								
„ „ 16								− −				−		−										
1906 Jan. 31						−	− −			−	− −	∓												
„ Feb. 24									− −	− −	−													
„ „ 26													+ −	− −			+	+						
„ Nov. 21-22							− −				− −			+										
„ Dec. 22-23					−	− −	−	−	−	− −	− −	−	− −	+										
1907 Jan. 14-15						−			− −	− −											+	+ −		
„ Feb. 10						−	−				−	− −												
„ „ 11-12								− −	− −	−	− −	−			−									
„ Nov. 21			−	−			−		− −															
POSITIVES										1-3	2-2	1-1	1-1	1-3	1-1	1-1	1-1	2-2			1	1		
NEGATIVES			1	1-1	2-3	5-8	9-6	5-10	9-8	6-7	7-7	9-5	5-4	3-1	2	2	1					1-2	1	1

Table II.—Equinoxes.

	NOON	13	14	15	16	17	18	19	20	21	22	23	MIDT	1	2	3	4	5	6	7	8	9	10	11
1900 Mar. 8-9										−	−		++	++				−						
" " 9-10				−−	−		−−	−	−	−−					++									
" " 13		−	−	−				−−	−	−−	−−							++						
1901 " 24-25						−	−−	−			−	−−	+											
" Sept. 10-11						−								++	++									
" Oct. 8-9												++	++											
1902 Apr. 10-11		−										−				+	++	+		+		−	−−	
1903 Sept. 19-20						−	−	−		−	−−													
" " 20-21					−	−		−	−−															
" Oct. 12-13							−−	−−	−−	−−	−−	−		+		+						−		
" " 13-14								−−			−+	−		++	++	+								
" " 30-31										−							−							
1904 Apr. 1					−	−	−	−−	−			−		+		−	+		−					
" " 19	−	−−												+	+	+	+							
" Sept. 25				−−		−	−−	−−			−	+		+		++								
" Oct. 21-22					−	−		−−	−−				++											
1905 Mar. 2							−	−							++	++	++	+			+	+		
" " 7									−							+	++							
" Apr. 1												−−			−									
" " 2								−	−−	−−	−	−−		±										
1906 Sept. 22-23									−	−	−	+−	−−											
1907 Mar. 10-11					−	−		−−	−		−	−∓		−−										
" " 11-12						−		−	−−							+	−			++	+			
" " 21-22									−−	−−	−−	−−	−											
" Sept. 10-11					−		−−			−−	−+			+										
" Oct. 13						−			−	−														
" " 14					−−	−−	−		−			−+												
POSITIVES											2	3-3	4-3	6-6	5-4	5-5	5-3	3-1		1-2	1-1	1		
NEGATIVES	1	2-2	1	3-2	2-6	6-6	6-8	10-11	11-9	9-8	9-7	10-6	2-1	1-2	1	1	2	1	1			2	1-1	

Table III.—Summer.

	NOON	13	14	15	16	17	18	19	20	21	22	23	MIDT	1	2	3	4	5	6	7	8	9	10	11
1900 May 5		−		−−			−										+	+						
1901 " 10								−	−−	−														
" July 12														−		+								
1902 Aug. 21								−		−−	−−	−												
1903 June 29-30			++			−			−				+	+	++									
" Aug. 21-22											−	−		±	−+	+		−						
" " 22					−		−	−		−														
1904 June 15-16											−	−+	++	+					+	++				
" July 6					−	−				−−														
" Aug. 3-4						−−				−	−		+											
1905 July 6			+											+	+	++								
" Aug 2								−	−			−									+			
1906 " 7-8											−−			−		+	++	+						
1907 May 18-19								−−	−−	−			+	++	+		+							
" " 29	−−					−−													+		+			−
" June 19-20										−							+	+						
" July 10-11				+			−			−−				++	++									
" " 27-28										−		−−	−		∓	++		+						
POSITIVES			1-2	1								1	2-3	4-4	4-4	3-4	1-4	3-1	2	1-1	2			
NEGATIVES	1-1	1		1-1	2	4-2	3	3-3	4-2	5-7	3-4	5-1	1	1-2	1-1			1						1

Table IV.—All Seasons.

POSITIVES			1-2	1						1-3	2-4	4-5	7-7	11-13	10-9	9-10	7-8	8-4	2	2-3	1-4	2		
NEGATIVES	1-2	2-3	2	5-4	4-11	15-16	15-17	18-24	24-19	20-22	19-18	24-12	8-5	5-5	2-3	3	2-1	1-1	1			1-4	1-2	1-1

Table V.—All Seasons, in 1-hour intervals.

POSITIVES			3	1						4	6	9	14	24	19	19	15	12	2	5	5	2		
NEGATIVES	3	5	2	9	15	31	32	42	43	42	37	36	13	10	5	3	3	2	1			5	3	2

With regard to the interval from hour 6 to noon, Table IV shows a nearly clear separation of positives and negatives into equal periods; but the cases of rotation are too few here to do more than suggest that this distribution may be general. It should be noted, however, that 6 h. 30 m. to 9 h. is the only period of the day showing an entire absence of negative rotations, while 12 hours later we find the greatest incidence of these, along with an entire absence of positive rotations.

On the Direction of Motion of an Electron ejected from an Atom by Ultra-Violet Light.

By R. D. Kleeman, D.Sc., B.A., Mackinnon Student of the Royal Society; Emmanuel College, Cambridge.

(Communicated by Prof. Sir J. J. Thomson, F.R.S. Received March 25,—Read June 2, 1910.)

When light is absorbed by matter it exerts, according to the electromagnetic theory of light, a pressure upon the matter, or gives a momentum to it, in the direction of propagation of the light. The existence of this pressure has been proved by a number of observers. When ultra-violet light is absorbed by matter we know that a part at least of the absorbed energy is expended in liberating cathode rays of small velocity. The momentum corresponding to the absorption of energy in this case thus probably appears in part in the form of moving electrons. We would, therefore, expect these cathode rays to have a component of velocity in the direction of propagation of the light.

The results that have been obtained in experiments on the secondary cathode radiation from substances exposed to γ- and X-rays also suggest that possibly such an effect exists. Thus the larger amount of secondary β radiation given off from the side of a radiating plate where the stream of exciting γ-rays emerges than where it enters has been explained by Prof. Bragg by supposing that the secondary β-rays are projected in the direction of propagation of the γ-rays. Cooksey showed that a similar effect exists with X-rays. It appeared a promising experiment therefore to look for such an effect in the case of ultra-violet light, and the writer accordingly carried out a set of measurements to test this point.

The apparatus by means of which the experiment was carried out is shown in fig. 1. The source of ultra-violet light was a vacuum tube A in which the discharge took place between an aluminium ring and an aluminium rod contained in a glass tube. It contained hydrogen at a pressure of a few millimetres. The electrodes were connected with the secondary circuit of an