XXIV. *On the Diurnal Deviations of the Horizontal Needle when under the influence of Magnets.* *By* SAMUEL HUNTER CHRISTIE, *Esq. M. A. Fellow of the Cambridge Philosophical Society: of the Royal Military Academy. Communicated by Sir* HUMPHRY DAVY, *Bart. Pres. R. S.*

Read June 19, 1823.

HAVING been for a considerable time engaged in investigating different magnetical phænomena, a suggestion of Mr. BARLOW's, that the daily variation of the needle might be rendered more sensible by diminishing the directive force by means of a magnet, was received by me with much interest. He stated to me, that he proposed so to reduce the terrestrial force, that instead of the daily variation being only ten or twelve minutes, it should amount to three or four degrees, or more if necessary. In consequence of this I offered to make simultaneous observations, simply for the purpose of comparison; but having been led to prosecute the inquiry farther than I at first intended, I think that the observations which I have made, with much care, may not be deemed unworthy the attention of the Royal Society.

In making these observations, I adopted an arrangement different from that which Mr. BARLOW informed me he proposed making use of. Instead of one magnet applied towards the end of the needle, and in the same horizontal plane with it, it appeared to me that a more equable distribution of the forces acting on the needle would be obtained, if I substituted

two, and still more so if these were placed in the line of the dip. According to the manner in which I have for a long time viewed the nature of the forces which give direction to the horizontal needle, and their disturbance by other forces, it appeared to me that, by applying two magnets to the needle in the line which it would take if freely suspended by its centre of gravity, but having their poles in the reverse position to those of the needle, one above and the other below its centre, a portion of the forces acting upon the horizontal needle in the line of these magnets, or of the dip, would be destroyed; and it would therefore still be acted upon by forces in the same direction as before, but of less intensity: whereas by even applying the poles of two magnets to the corresponding poles of the needle, and in the same plane with them, the horizontal directive force of the needle would be diminished, by increasing the angle which the resultant of the terrestrial forces, and those of the magnet made with the horizon; and which would be nearly equivalent to increasing the angle of the dip. This, however, will not be quite correct when the length of the needle bears a sensible ratio to the distances of the magnets; but, when this adjustment occurred to me, I was not aware that the magnets must be brought so near to the needle as I afterwards found necessary. Notwithstanding this, as I considered the arrangement to be a good one when the observations were to be made with the needle in the meridian, I adjusted, in the line of the dip, two powerful bar magnets, each twelve inches long, .95 inch wide, and .375 inch thick, to an instrument with which I had made a variety of magnetical experiments; one above the needle with its north pole towards the centre, to destroy a portion of the

force acting upon the needle from the centre upwards towards the south; the other below the needle with its south pole towards the centre, to destroy a corresponding portion of the force from the centre downwards towards the north: that is, both the magnets having their north poles downwards. To prevent any ambiguity, I must here state, that, by the *south pole* of a magnet, I understand always the end which, when the magnet is freely suspended, points towards the north pole of the earth; so that the *north end* is the *south pole*, and the *south end* the *north pole* of a magnetic needle. By diminishing the distances of the magnets from the centre, I diminished the directive force of the needle until I destroyed it, after which, by diminishing the distances, I increased the force by which the north end was directed towards the south.

Previously to giving any of the observations, to avoid unnecessary repetition, I will here state that, whenever the direction of the needle, or its deviation, or the direction of the forces urging it, is mentioned, reference is always made to the end of the needle which, when undisturbed, points towards the north, that is its south pole, unless the contrary is expressed. To compare more readily with each other, the directions of the deviations when the needle is held in different positions by means of the magnets, whenever the direction itself of the north end of the needle is not given, I consider the deviations which take place in the direction of the westerly, or principal daily variation to be plus, and those in a contrary direction minus: that is, in stating the deviations from any point, considered as zero, those which take place, from that point, in the direction of the sun's apparent

daily motion are considered minus, and those in a contrary direction plus, whatever may be the position of the needle.

The first observations which I made, being principally with a view of ascertaining how my apparatus would answer, and likewise the general characters of the deviations, were necessarily somewhat imperfect; but as they show the great extent to which the deviation may be rendered sensible, and first indicated to me distinctly, what I afterwards found so decidedly marked, the morning easterly deviation, I will not omit them. The needle which I made use of is a very light one, about $\frac{1}{10}$ of an inch broad close to where the agate is centered, and diminishing from there to very fine points at the ends: its length is six inches. The rim within the compass-box is very accurately divided into degrees, and thirds of a degree; so that, from practice, I can easily read off the directions of the needle to every two minutes. It may at first sight appear superfluous to mention any particulars respecting the room in which the observations were made, but as both Mr. BARLOW and myself found some anomalies in the directions of the needle, when corresponding observations were made in different situations, and as these anomalies may perhaps be attributable to such local circumstances, I shall always state them as nearly as possible. The observations contained in the following table, were made in a room with a single window, facing E 40° S, magnetic, and having an iron grate in it, the situation of which was S 15° E, distant six feet from the needle; but care was taken that no iron should be moved in the room, nor any small articles of iron brought into the immediate neighbourhood of the needle.

In the first column of the table, the hours are marked at

which the several deviations from the magnetic meridian, in the second and following columns, were observed, and the day on which the observations were made is indicated above.

Observations of the Deviations of a Magnetic Needle having its directive power diminished by the action of two bar Magnets placed in the line of the Dip.

March	26	27	28	29	30	31
h. m.	° ′	° ′	° ′		° ′	° ′
7 00	——	−2 10	——		——	−0 40
8 00	——	——	−4 04		−1 06	——
9 00	——	−4 40	−2 30		−0 10	——
11 00	——	——	+2 12		+1 50	——
Noon.	——	+6 16	+8 20		+2 32	——
1 00	+ 9 20	——	+9 10		+3 10	+4 30
1 30	+10 40	+9 20	+8 10		——	——
2 00	+ 7 40	——	+7 26		+2 30	——
4 00	+ 4 34	——	+4 40		+1 06	——
6 00	+ 2 32	0 00	+3 30		+0 10	——
10 00	+ 0 04	——	——		+0 10	——

The magnets were removed farther from the centre, to render the directive force greater.

The deviation towards the east before 8 o'clock in the morning, and the greatest westerly deviation about 1 o'clock afternoon, are here very manifest.

As it was by the diminution of the directive force that the daily variation was rendered thus sensible, the needle possessed so little in the first three days observations, that there was a considerable degree of indecision about the point at which it settled; and although on the 29th of March I increased the directive power by placing the magnets at a greater distance, at the same time rendering that part of the apparatus which supported them more secure, I was by no means satisfied with the manner in which the needle came home. In consequence of this I made a new needle from part of a clock spring, which I considered to be excellent

steel. The form of the needle was that of two segments of circles joined by their chords, the sum of the versed sines, or the greatest breadth, namely, where the agate was centered, being .425 inch, and the chord 6 inches: the extremities were hardened and very accurately terminated in very sharp points. This I found to have much greater directive force than the other; making, when not under the influence of the magnets, twenty-three vibrations in 60 seconds, whereas the other made only eighteen vibrations in the same time; so that the directive force of the new needle was to that of the other as 1.63 to 1. I had also made other needles, of the same steel, of greater breadth in the middle, but found that this had considerably the greatest directive power. With this needle I made most of the subsequent observations.

Having placed the apparatus in a room having two windows facing W 40° N, and an iron stove at the distance of nine feet from the needle in the direction W 20° S, it was fixed so that zero of the arc in the compass-box corresponded with the magnetic north. On the 4th of April, at $10^h\ 35^m$ P. M. I adjusted the magnets, which I had before used, in the line of the dip, as I have already described, so that the needle, when under their influence, pointed to zero, and made five vibrations in forty seconds. As previously to applying the magnets the needle had made thirty vibrations in seventy-eight seconds, the directive force was diminished by them nearly in the ratio of 1 to .106. I here assume that the forces will be as the squares of the number of vibrations in the same time, which is not very accurate, since, when the directive force was much diminished, I was under the necessity of commencing the vibrations at 60° from zero, in order to obtain a sufficient number to estimate, at all correctly, their duration.

At $11^h\ 45^m$ P. M. the north end of the needle had settled at N 0° 04′ E; and on the following day I observed as follows, noting the direction which the needle had assumed between the observations, and likewise the point where it settled, after it had been agitated by gently tapping the compass-box.

5th April.	Direction of the N. end.	
	When first Observed.	After agitating the Needle.
Morning. h. m.	° ′	° ′
7 00	−0 04	−0 12
7 35	−0 46	−0 54
8 10	−0 30	−0 56
8 35	−0 50	−1 00
9 15	−1 16	−0 46
10 00	−0 20	−0 20
10 35	−0 10	0 00
11 05	−0 06	+0 06
0 05	+0 32	+0 42
0 30	+1 00	+0 58
1 00	+1 00	+0 58
1 30	+1 00	+0 56
2 00	+1 02	+0 58
4 15	+0 26	0 00
8 45	0 00	0 00

Here the times of the greatest easterly deviation in the morning, and of the westerly in the afternoon, correspond with the preceding observations, but the easterly appears much greater, compared with the westerly, than I had before observed. I had intended to continue observing for several days with the present adjustment of the needle, but being still not quite satisfied that the needle moved freely on the point of suspension, I carefully polished the inside of the agate cap, and also the point on which it rested, preparatory to the observations of the next day. As I found, after I had done this, that the needle settled with great precision, in order to obtain rather larger arcs of deviation, I adjusted the magnets

so that the needle made ten vibrations in one-hundred seconds, and consequently the directive force was still farther reduced; its ratio to the whole undiminished force being now .068 to 1. With this adjustment I observed very carefully the direction of the needle, nearly every hour, except during the night, from the evening of the 5th of April, till that of the 12th of April. On the 5th of April, $9^h\ 50^m$ P. M. the needle pointed N 0° 04′ W, and at $11^h\ 45^m$ it pointed N 0° 10′ E, but as it appeared afterwards to be most stationary in the evening at about N 0° 20′ E, that point is assumed as zero in the following table.

Table of the Diurnal Deviations of a Magnetic Needle whose directive force was diminished in the ratio of 1 *to* .068, *by the action of two bar Magnets placed in the line of the Dip, the N. end of the Needle pointing North.*

April	6	7	8	9	10	11	12	Means.
h. m.	° ′	° ′	($4^h\ 15^m$)	° ′	($5^h\ 15^m$)	° ′	° ′	° ′
6 00	——	−0 24	0 00	——	−0 22	——	——	——
6 30	−1 00	−0 48	——	——	——	——	+0 04	−0 35
7 00	−1 00	——	——	−0 06	——	−0 24	−0 20	−0 28
7 30	−1 20	−1 16	——	−0 14	——	−0 08	−0 38	−0 43
8 00	−1 38	−1 00	−0 36	0 00	−1 02	——	−0 10	−0 44
8 30	−1 24	——	——	——	−1 16	——	−0 12	−0 57
9 00	−1 16	−0 44	−0 24	−0 10	−1 06	+1 04	+0 28	−0 18
10 00	−0 28	−0 04	+0 32	+0 16	——	+1 06	+0 46	+0 21
11 00	+0 28	+1 00	+1 40	+1 54	——	+1 40	——	+1 20
Noon.	+1 26	+2 00	+2 50	+2 30	+1 06	+2 40	+2 48	+2 26
0 30	——	+2 00	+2 50	——	+2 04	——	——	+2 18
1 00	+1 46	+2 12	+2 50	+2 32	——	+4 00	+3 36	+2 49
1 30	+1 40	+2 12	+2 44	——	+2 10	——	+3 56	+2 32
2 00	+1 40	+2 00	+2 18	+2 24	——	+4 20	+3 28	+2 41
2 30	+1 26	——	+2 10	——	+1 48	+4 14	——	+2 24
3 00	——	+1 16	+1 36	——	——	——	——	+1 26
4 00	+1 08	+0 52	+1 14	+1 06	+0 56	+3 08	+2 04	+1 13
5 00	+0 18	+0 28	+0 44	−0 04	+0 42	+2 04	——	+0 42
6 00	+0 02	+0 14	+0 34	−0 04	+0 28	+1 30	+0 16	+0 26
7 00	−0 04	0 00	+0 16	+0 12	+0 34	+0 54	+0 24	+0 20
8 00	——	−0 06	0 00	−0 06	+0 40	+0 20	+0 26	+0 12
9 00	0 00	+0 08	——	——	——	+0 38	+0 14	+0 15
10 00	——	+0 12	+0 04	−0 58	+0 28	(−1 40)!	——	−0 03
11 00	0 00	+0 08	−0 10	−0 16	0 00	−0 06	——	−0 04

As the corresponding observations could not always be taken at precisely the same hour, they are put down to the nearest half hour: they however were generally taken within five or ten minutes of the times specified. In estimating the times of the maxima deviations, I take those at which the observations were actually made: and for the time of zero, I take a proportional time between the nearest observations. This notice will apply to the other tables of the deviations.

From these observations I deduce the following table.

Table of the greatest Easterly and Westerly Deviations, their times, the times of Zero, or no deviation, and the total daily changes in the direction of a Needle, whose directive force was diminished in the ratio of 1 *to* .068, *by the action of two bar Magnets placed in the line of the Dip: the N. end of the Needle pointing North.*

April.	Max. E. or minus.		Time of Zero.	Max. W. or plus.		Time of Zero.	Total change.
	Value.	Time.	Morning.	Value.	Time.	Afternoon.	
	° ′	h. m.	h. m.	° ′	h. m.	h. m.	° ′
6	— 1 38	8 00	10 30	+ 1 46	1 45	6 30	3 24
7	— 1 16	7 30	10 04	+ 2 12	1 15	7 00	3 28
8	— 0 36	8 00	9 15	+ 2 50	0 45	8 00	3 26
9	— 0 14	7 35	9 20	+ 2 32	0 50	5 15	2 46
10	— 1 16	8 30	10 22	+ 2 10	1 30	———	3 26
11	— 0 24	7 10	7 50	+ 4 20	2 00	6 25	4 44
12	— 0 38	7 30	8 42	+ 3 56	1 40	7 00	4 34
Mean	— 0 52	7 45	9 26	2 49	1 24	6 40	3 41

During the time that I was making these observations, and likewise all the subsequent ones, I noted the general characters of the weather, but as I neglected to observe the states of the thermometer and barometer, such loose observations would, to others, be of little use, and I therefore omit them, although at the time they served to convince me that the

state of the weather had considerable influence on the nature and extent of the changes. On several occasions I certainly noticed that a cold cloudy morning, with the wind easterly, appeared to be very unfavourable to the increase of the easterly deviation, but I would not venture to draw any general conclusions from such observations. After having made these observations, I still farther diminished the directive power of the needle, by bringing the magnets nearer to the centre. The needle now made five vibrations in seventy seconds, so that the directive force was diminished in the ratio of 1 to .034, or was half what it was in the preceding case.

Table of the Diurnal Deviations of a Magnetic Needle, whose directive force was diminished in the ratio of 1 *to* .034, *by the action of two bar Magnets placed in the line of the Dip: the N. end of the Needle pointing North.*

April	15	16	17	18	19	Mean.
h. m.	° ′	° ′	° ′	° ′	° ′	° ′
7 0	——	— 0 40	——	— 5 00	— 3 40	— 3 07
7 30	— 2 20	— 0 20	— 3 10	— 5 40	——	— 2 53
8 0	——	——	— 2 40	——	— 3 02	— 2 51
9 0	— 3 00	+ 1 44	— 1 10	— 3 00	+ 1 40	— 0 45
10 0	+ 0 58	+ 5 30	——	+ 2 10	+ 1 20	+ 2 30
11 0	+ 3 22	+ 5 58	——	+ 4 56	——	+ 4 45
Noon.	——	+ 7 00	+ 4 34	+ 6 20	——	+ 5 58
1 0	+ 6 40	——	——	——	+ 8 16	+ 7 28
1 30	——	+ 8 14	+ 4 20	+ 4 56	——	+ 5 50
2 0	+ 5 44	+ 7 00	——	——	+ 5 50	+ 6 11
4 0	——	+ 4 40	+ 2 50	+ 1 20	+ 1 54	+ 2 41
6 0	+ 0 28	——	— 2 12	+ 0 50	— 0 18	— 0 18
8 0	——	——	— 2 34	+ 1 44	+ 2 10	+ 0 27
10 0	——	——	——	+ 3 00	——	——
11 0	+ 2 06	+ 1 10	— 5 30	——	——	— 0 45

From these I derive the following

Table of the greatest Easterly and Westerly Deviations, their times, the times of Zero, and the total daily changes in the direction of a Magnetic Needle, whose directive force was diminished in the ratio of 1 *to* .034, *by the action of two bar Magnets placed in the line of the Dip: the N. end of the Needle pointing North.*

April.	Max. E. or minus.		Time of Zero.	Max. W. or plus.		Time of Zero.	Total change.
	Value.	Time.	Morning.	Value.	Time.	Afternoon.	
	° ′	h. m.	h. m.	° ′	h. m.	h. m.	° ′
15	— 3 00	9 00	9 44	+ 6 40	0 55	6 10	9 40
16	— 0 40	7 00	7 50	+ 8 14	1 30	——	8 54
17	— 3 10	7 40	10 30	+ 4 34	0 05	4 40	7 44
18	— 5 40	7 30	9 36	+ 6 30	0 15	——	12 10
19	— 3 40	7 10	9 00	+ 9 24	0 50	6 15	13 04
Mean	— 3 14	7 36	9 20	+ 7 04	0 43	5 02	10 18

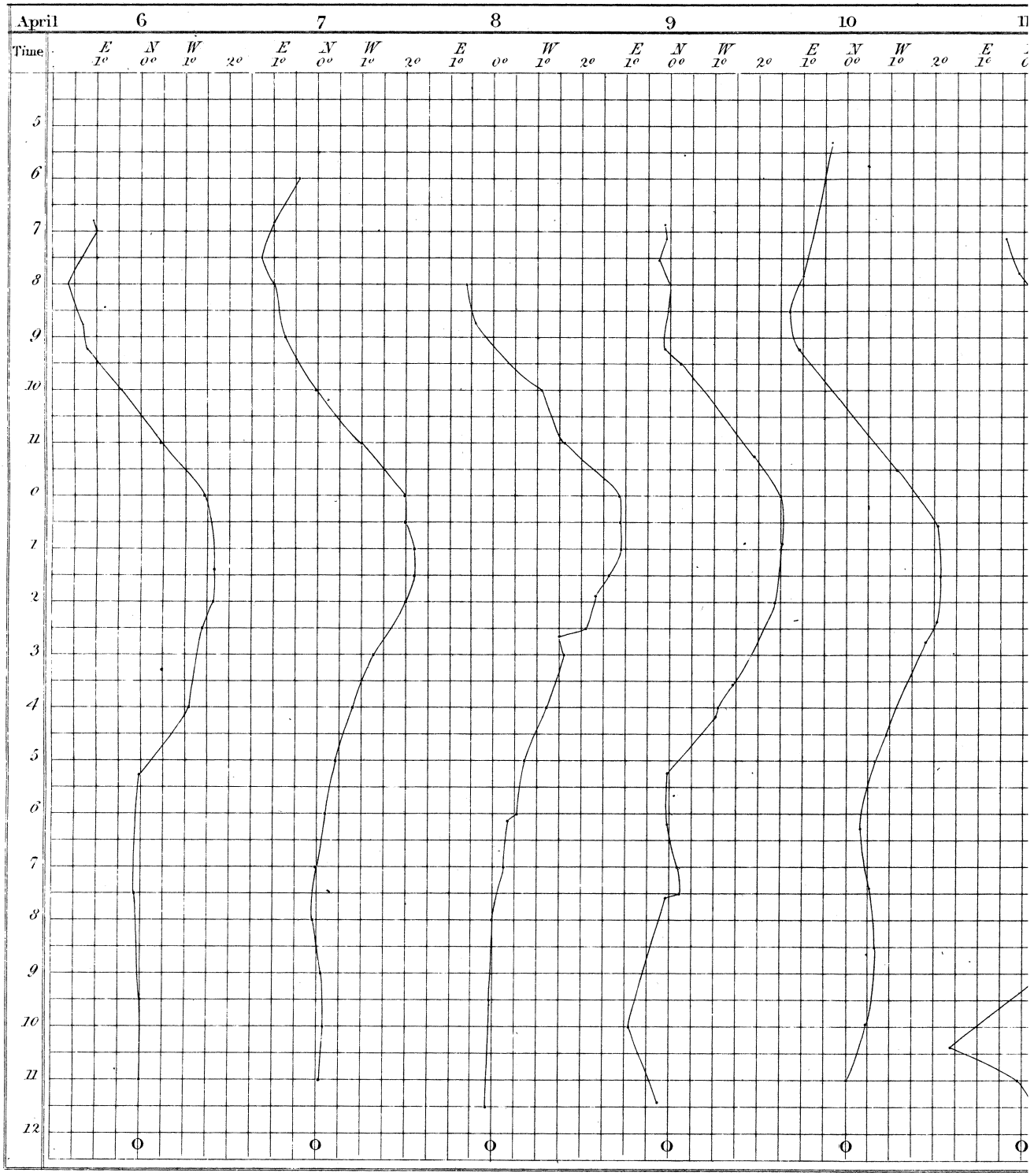
Comparing these mean results with those in the preceding table of maxima, we find the times in general earlier: the observations are however much too limited to point out a very correct mean in either case.

After having made these observations I entirely removed the magnets, and found that the needle made thirty-eight vibrations in one hundred seconds, so that its directive power continued nearly the same as at the commencement.

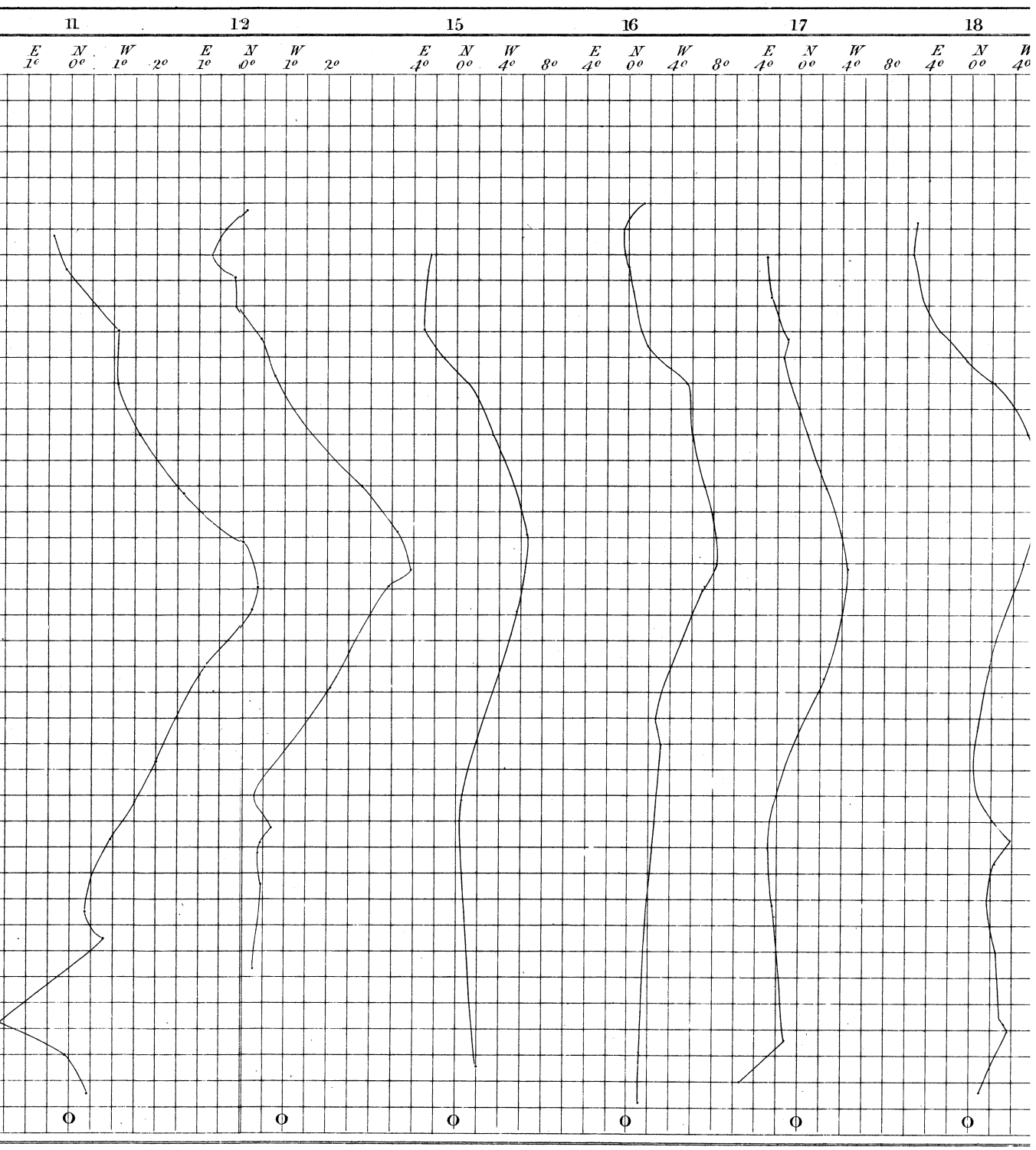
For the purpose of exhibiting at one view the facts pointed out by these observations, I have, in the following diagram, [Pl. XXIV.] placed the deviations as ordinates to a curve, the distances between them representing the intervals of time. The axis of the curve corresponding to zero, the westerly, or plus deviations, are measured to the right, and the easterly, or minus deviations, to the left. The days on which the observations were made are placed over the respective curves, and

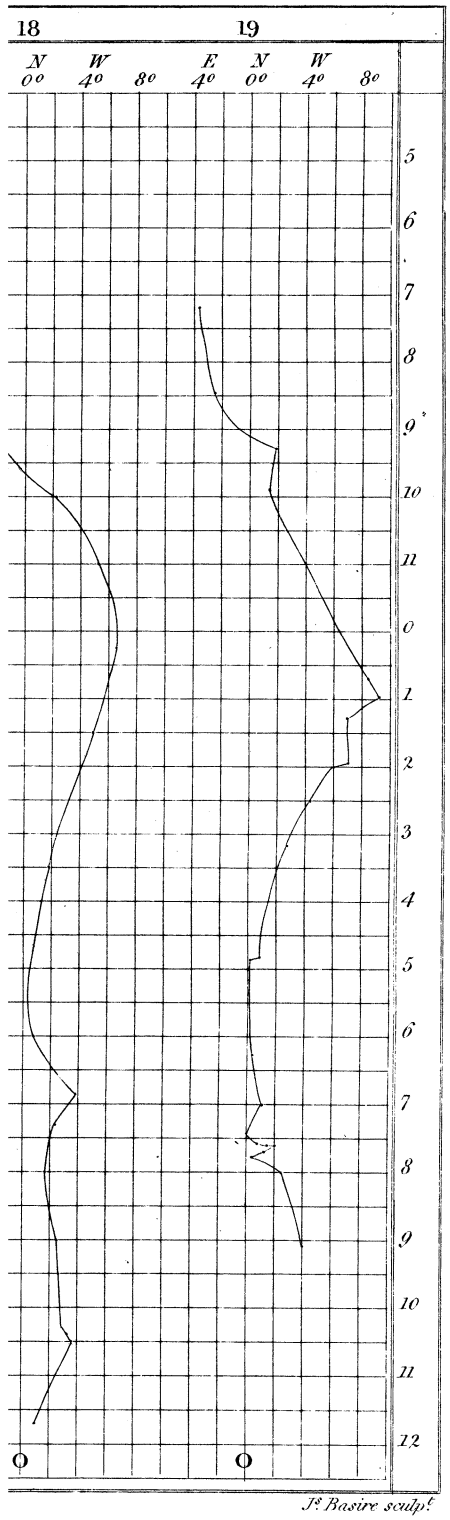
Curves of the diurnal deviations of a n

the action of two bar magnets placed in



of a magnetic needle whose directive power was diminished by
uced in the line of the dip: the N. end of the needle pointing north.





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the hours of the day are marked in the lines of the several ordinates. The points determined by actual observation are marked with a dot, and are connected by a line, as nearly as I could judge, in the direction which the curve would have taken had more points been so fixed. When the observations were made, it had not occurred to me to represent them in this manner, or they would have been more multiplied for the purpose: this defect I remedied when I observed the deviations with the north end of the needle to the south.

Many anomalies are here apparent, but I cannot attribute any of them to particular local causes, such as the moving of iron in or near the room. The door of the room was locked, so that nothing could be moved in it without my being aware of it; and whenever I found any peculiarity in the deviation, I minutely examined the adjacent rooms to ascertain whether it could have been produced by any article of iron having been introduced or moved in them. This caution was perhaps unnecessary, since I had found that transferring the fire irons from one part of the room to another, at nearly the same distance from the needle, did not produce any very sensible effect. I have before omitted to state that there was no fire in the room: had there been one, the difference in the temperature of the iron might have produced a slight effect.

That several of these irregularities were caused by the electric state of the clouds I have no doubt; and for the purpose of showing how distinctly the effects are marked by a needle under such circumstances, I subjoin the observations made on the 19th, at times when, although there was no thunder, there were unequivocal signs of the electric state of the atmosphere.

16th April. Morning cold and cloudy; wind N.W. strong.

Time. h. m.	Direction of Needle. ° ′	
0 40	8 16 W	
0 50	9 24 W	Showers of hail and heavy rain.
1 15	7 08 W	A heavy cloud and hail shower in W: cloud apparently highly electric.
1 50	7 00 W	Cloud passed to S; sun bright.
2 00	5 40 to 5 50 W	At several observations.
4 45	1 00 W	Gradually decreased to 0° 10′ W. A heavy shower of hail: the cloud from W, though S to E and in zenith.
6 15	0 18 E	
7 00	0 56 W	A heavy cloud from N to NW; greatest height that of the equator of the dipping needle.
7 05	0 16 W	
7 25	0 10 W	Cloud passed to S.
7 32		Changed to 0° 50′ W, 1° 40′ W, 2° 00′ W, then gradually went back to 1° 10′ W, 0° 50′ W, 0° 40′ W, settling at 0° 30′ W.
7 43	0 30 W	

In some of my first observations, I had noticed that the directions of the needle were different, according as I stood to the east or to the west of the needle; and although I did not then attribute this effect to the right cause, namely, a very minute change in the level of the instrument, I always took particular care, by placing myself directly in front of the instrument when I observed, that this should not affect the observations: in those which I am about to describe, the possibility of any effect of this kind was avoided by the instrument standing on a stone floor, which was laid on the ground itself.

Having ascertained the general character of the deviations when the north end of the needle pointed towards the north, my next observations were with a view of comparing with it, that of the deviations when the north end pointed towards the south. For this purpose the magnets were brought

nearer to the needle, their nearest ends being at the distance of 9.6 inches from the centre; and they were carefully adjusted in the magnetic axis, or line of the dip, so that the north end of the needle pointed very accurately to the south, or 180° of the instrument. In this position I vibrated the needle, as before, and found that it made ten vibrations in one hundred and five seconds. From this it appears that the force by which the needle was now directed towards the south, was to the undiminished terrestrial force towards the north, as .0625 to 1; and was therefore rather less than the force towards the north in the observations from the 6th to the 12th of April. The instrument was placed near the outer wall in a room having a single window facing N 40° E; the only iron in the room being a large lock to the door and the weights to the windows, which were always in the same position when the observations were made.

The observations were begun on the 21st of April, and continued to the 27th, when they were unavoidably interrupted. Whilst making them, after the first two days, I perceived a gradual increase in the deviation easterly, but as I could only attribute this to a small change taking place by degrees in some part of the instrument, any correction of it must have been in a great measure arbitrary. Had I reduced the observations each day, by considering the morning and evening nearly stationary points as zero, it would have had the effect of separating the evening observations of one day from the morning ones of the next: I therefore preferred giving the observations as they were made, although on the last day the accumulated increase amounted to 2°.

Table of the Diurnal Deviations of a Magnetic Needle having the North end held in equilibrio, at South by two bar Magnets placed in the line of the Dip.

April	20	21	22	23	24	25	26	27	Mean
h. m.	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
5 00	—	—	—	—	+ 2 26	—	+ 2 38	+ 2 48	—
5 30	—	—	—	—	+ 2 26	—	+ 2 50	+ 3 02	—
6 00	—	—	+ 1 20	—	+ 2 42	—	+ 2 58	+ 3 06	—
7 00	+ 1 22	+ 2 12	+ 1 44	+ 1 46	+ 2 50	+ 2 48	+ 3 30	+ 3 30	+ 2 19
7 30	—	+ 2 30	+ 1 56	+ 1 52	+ 3 02	+ 2 48	+ 3 34	+ 3 48	+ 2 37
8 00	+ 1 28	—	+ 2 02	+ 2 08	+ 3 02	+ 2 44	+ 3 36	+ 3 56	+ 2 30
8 30	—	—	+ 2 04	+ 1 56	—	—	+ 3 36	+ 4 00	—
9 00	+ 1 08	+ 2 18	+ 1 24	+ 1 40	+ 2 38	+ 2 36	+ 3 18	+ 3 54	+ 2 09
10 00	+ 0 08	+ 1 24	+ 0 56	+ 1 20	+ 1 34	+ 1 42	+ 2 36	+ 2 58	+ 1 23
11 00	— 0 22	+ 0 02	— 0 02	+ 0 44	—	+ 0 36	+ 1 28	+ 1 42	+ 0 24
Noon	— 0 56	— 1 06	— 0 40	+ 0 26	+ 0 26	+ 0 22	+ 0 44	+ 0 48	— 0 06
0 30	— 1 12	— 1 10	—	—	—	+ 0 16	+ 0 34	+ 0 48	—
1 00	— 1 24	—	— 0 40	+ 0 12	+ 0 06	+ 0 10	+ 0 22	+ 0 44	— 0 12
1 30	— 1 20	— 1 40	—	—	— 0 06	—	+ 0 26	—	—
2 00	— 1 00	—	— 1 00	+ 0 10	— 0 02	— 0 14	+ 0 52	+ 1 00	— 0 12
3 00	— 0 34	— 0 34	— 0 44	+ 0 28	+ 0 06	+ 0 44	+ 1 12		+ 0 05
4 00	—	— 0 20	+ 0 20	+ 0 06	+ 0 22	+ 1 20	+ 2 40		+ 0 45
5 00	— 0 12	+ 0 08	— 0 14	+ 1 00	+ 0 42	+ 1 52	+ 2 28		+ 0 49
6 00	— 0 14	— 0 28	+ 0 24	+ 0 40	+ 1 20	+ 2 06	+ 3 02		+ 0 59
7 00	0 00	+ 0 22	+ 0 02	+ 1 36	+ 1 18	+ 2 06	+ 3 10		+ 1 13
8 00	—	+ 0 14	+ 0 18	+ 1 42	+ 1 12	+ 2 00	+ 2 50		+ 1 23
9 00	0 00	0 00	+ 0 16	+ 1 40	+ 1 46	+ 1 54	+ 2 52		+ 1 13
10 00	+ 0 04	— 0 06	+ 0 26	+ 1 40	+ 1 56	+ 2 02	+ 2 40		+ 1 15
11 00	—	0 00	+ 0 32	+ 1 38	+ 1 54	+ 2 00	+ 2 40		+ 1 27

Observations discontinued.

As there are not corresponding observations on all the days, and there appears to be a considerable change in the point which should be considered as zero, a very correct mean of all the observations cannot be taken; but I have adopted that which embraces the greatest number. I exclude the observations of the 27th, as not carried through the whole day, and of the others, I take the means of those at the several hours on which there were observations for at least six days.

I have stated that the deviations are those actually observed from 180° or the south point, and the mean deviations will be from the same point; but to have the mean deviations from the most stationary point, or that which should be considered as zero, it is necessary to ascertain, as correctly as possible, the mean time of the needle being stationary, and its mean direction at that time. Now we have the observations at every hour from three till eleven on every day but the 20th and 27th, and taking the means of these six days, we shall have the deviations as under.

at $3^h\ 0^m$ P.M.	$+\ 0^\circ\ 12'$
4 0 - -	$+\ 0\ 45$
5 0 - -	$+\ 0\ 59$
6 0 - -	$+\ 1\ 11$
7 0 - -	$+\ 1\ 25$
8 0 - -	$+\ 1\ 23$
9 0 - -	$+\ 1\ 25$
10 0 - -	$+\ 1\ 26$
11 0 - -	$+\ 1\ 27$

So that from seven o'clock the mean change in direction is extremely small, and the mean situation of the stationary point is $+\ 1^\circ\ 25'$. Considering this point as zero, we shall have the mean deviations at the different hours as follow:

Time.	Deviation.
h. m.	° ′
7 0	+ 0 54
7 30	+ 1 12
8 0	+ 1 05
9 0	+ 0 44
10 0	— 0 02
11 0	— 1 01
Noon.	— 1 31
1 0	— 1 37
2 0	— 1 37
3 0	— 1 13
4 0	— 0 40
5 0	— 0 26
6 0	— 0 13
7 0	0 00

Taking the whole of the observations, the direction at nine o'clock appears to be that from which the evening observations vary least: considering then the direction at nine o'clock as the zero of each day, we obtain the following

Table of the greatest Easterly and Westerly Deviations, their times, the times of Zero, and the total daily changes in the direction of a Magnetic Needle having its North end held in equilibrio, at South by two bar Magnets placed in the line of the Dip.

April	Max. E. or Plus.		Zero.		Max. W. or Minus.		Total change.
	Value.	Time.	Value.	Time.	Value.	Time.	
	° ′	h. m.	° ′	h. m.	° ′	h. m.	° ′
20	+1 28	7 55	0 00	10 18	−1 24	0 48	2 52
21	+2 30	7 40	0 00	11 00	−1 40	1 35	4 10
22	+1 48	8 30	0 16	10 40	−1 16	2 05	3 04
23	+0 34	8 08	1 40	9 00	−1 30	1 30	2 04
24	+1 16	7 40	1 46	9 57	−1 52	1 45	3 08
25	+0 54	7 15	1 54	9 47	−2 08	2 00	3 02
26	+0 44	8 15	2 52	9 30	−2 32	1 15	3 16
27	+1 08	8 30	2 52	10 06	−2 08	1 00	3 16
Mean	+1 18	7 59	1 25	10 2	−1 49	1 30	3 6

The times of the corresponding maxima in the several days agree with each other, and likewise with the observations at north, as nearly as we could expect, but those of zero are more at variance. This however is accounted for by considering that this point has been, in some measure, assumed arbitrarily, in consequence of the gradual change in the direction. The mean total changes here and at north, likewise agree very nearly with each other, taking into the account the difference of the intensities in the two cases; and particularly if we take the means of those observations which

agree most nearly with one-another at the same point: they are,

At South.	At North.
2 52	—
3 4	—
3 8	3 24
3 2	3 28
3 16	3 26
3 16	3 26
Means 3 6	3 26

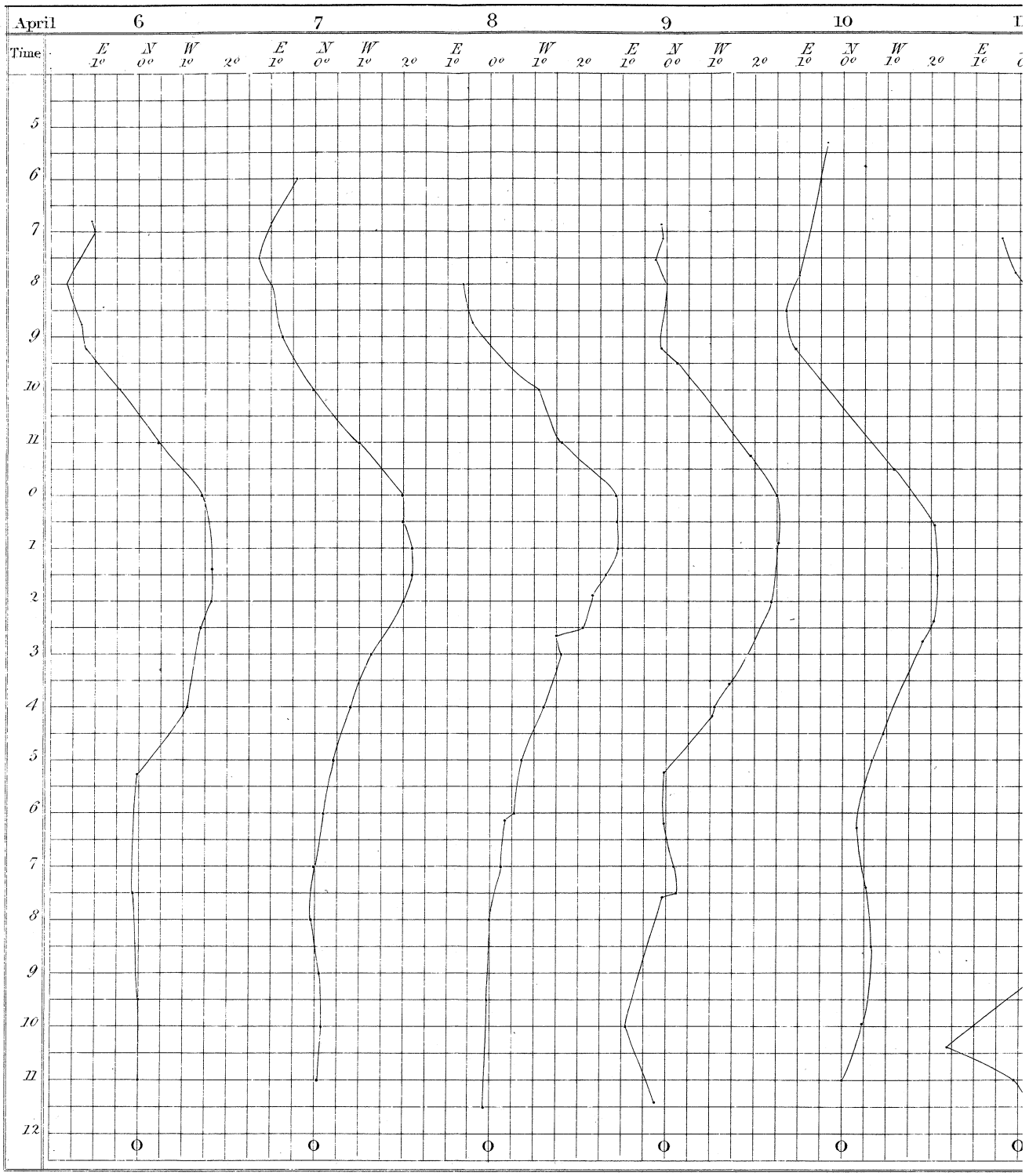
and the proportion of the intensities 100^2 to 105^2, would give $3^\circ\ 6'$ and $3^\circ\ 25'$.

Being desirous of observing the changes from the earliest time in the morning, I commenced the observations on the 26th, at $2^h\ 15^m$ A. M. and continued them throughout the day at intervals of half an hour, and sometimes less, until 11^h P. M. As they exhibit very minutely all these changes, and point out clearly the early period at which they commence, I here subjoin them at length. In the second columns are the directions which the needle had when undisturbed at the times specified in the first columns, and in the third are the points at which it settled, at the times marked in the fourth columns, after being very gently vibrated. Where there are two directions corresponding to any time, it indicates that, when observed, the needle kept vibrating between them. I have added the morning observations of the 27th till past the easterly maximum, that the evening deviations might again be connected with those of the following morning in one view. At $11^h\ 15^m$ P. M. April 25th, the needle pointed + 2 00.

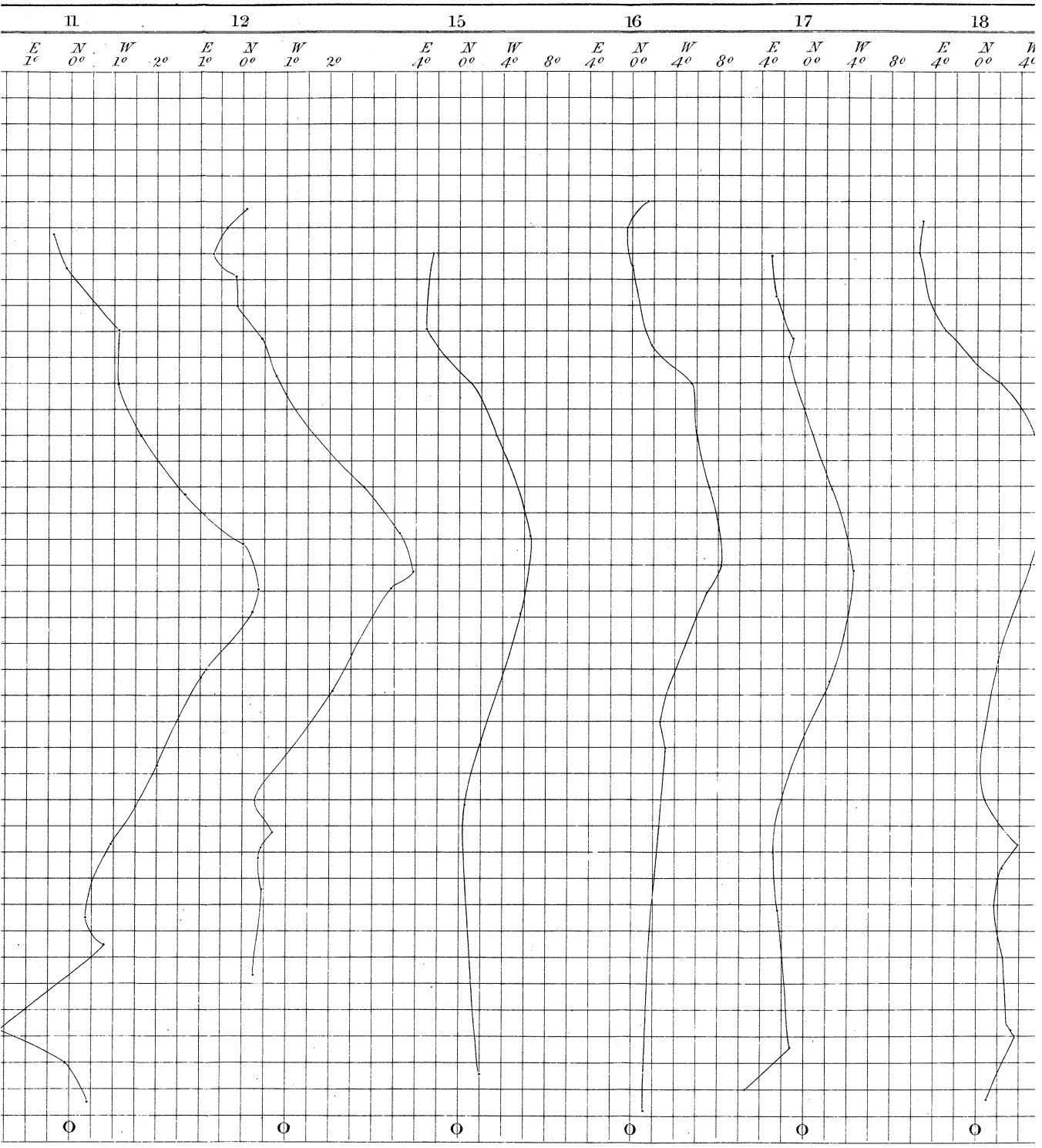
Table of the Deviations of a Magnetic Needle having the North end held in equilibrio, at South by two bar Magnets placed in the line of the Dip, on the 26th April, 1823.

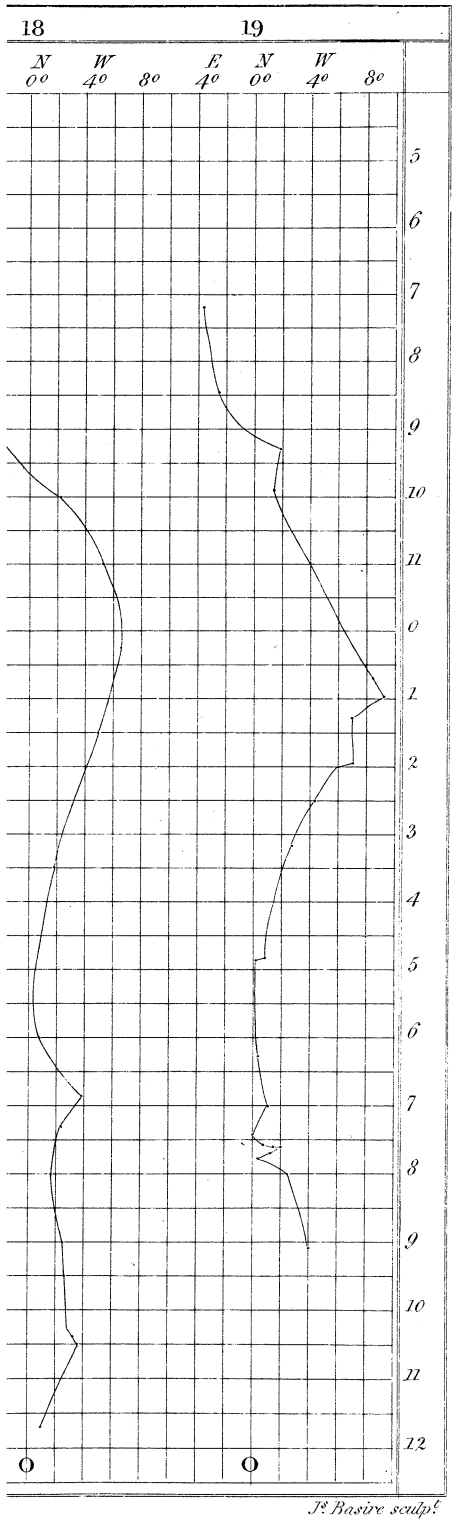
Before Noon.				After Noon.							
Observations Commenced, undisturbed.		Concluded, after vibration.		Observations Commenced, undisturbed.		Concluded, after vibration.		Observations Commenced, undisturbed.		Concluded, after vibration.	
Time.	Direction.	Direction.	Time.	Time.	Direction.	Direction.	Time.	Time.	Direction.	Direction.	Time.
h. m.	° ′	° ′	h. m.	h. m.	° ′	° ′	h. m.	h. m.	° ′	° ′	h. m.
2 15	+2 00	+2 00	2 17	0 12	+0 40	+0 38	0 15	6 30	+3 04	+3 06	6 31
2 32	2 00	2 04	2 35	0 28	0 34	0 32	0 30	6 44	3 10	3 12	6 45
2 57	2 03	2 08	3 00	0 43	0 28	0 20	0 45	6 59	3 10	3 10	7 00
3 28	2 08	2 10	3 30	0 58	0 22	0 22	1 00	7 14	3 08	2 58	7 15
3 57	2 10	2 18	4 00	1 14	0 22	0 20	1 15	7 29	2 54	2 50	7 30
4 28	2 20	2 22	4 31	1 27	0 22	0 26	1 30	7 44	{ 2 26 / 2 22 }	2 46	7 45
4 56	2 24	2 38	5 01	1 44	0 32	0 38	1 45	7 59	2 52	2 50	8 00
5 27	2 40	2 50	5 30	1 58	0 40	0 52	2 00	8 14	2 52	2 52	8 15
5 57	2 52	2 58	6 00	2 14	0 54	1 08	2 15	8 30	2 46	2 34	8 31
6 28	3 02	3 14	6 30	2 31	1 12	1 20	2 33	8 44	2 42	2 46	8 45
6 57	3 20	3 30	7 00	2 43	1 08	0 58	2 45	8 59	2 46	2 52	9 00
7 27	3 28	3 34	7 30	2 51	1 12	{ 1 16 / 1 10 }	2 52	9 14	2 48	2 44	9 15
7 57	3 34	3 36	8 01	2 58	1 10	1 12	3 00	9 30	2 46	2 42	9 31
8 27	3 36	3 36	8 30	3 13	1 27	1 44	3 15	9 44	2 42	2 40	9 45
8 56	3 30	3 18	9 00	3 28	1 46	2 12	3 30	9 58	2 38	2 40	10 00
9 27	3 10	{ 2 56 / 2 50 }	9 30	3 43	2 20	{ 2 24 / 2 34 }	3 45	10 29	2 42	2 44	10 30
9 57	2 44	2 36	10 00	3 58	2 36	2 40	4 00	10 58	2 44	2 40	11 00
10 29	2 10	2 06	10 30	4 13	2 20	{ 2 18 / 2 14 }	4 15	16 57	2 44	2 48	17 00
10 42	2 00	1 47	10 45	4 26	2 16	{ 2 06 / 2 20 }	4 30	17 29	2 56	3 02	17 30
10 57	1 30	{ 1 28 / 1 24 }	11 00	4 42	2 20	2 24	4 45	17 57	3 04	3 06	18 00
11 07	1 25	1 20	11 10	4 58	2 26	2 28	5 00	18 29	3 09	3 10	18 30
11 13	1 22	{ 1 18 / 1 14 }	{ 11 14 / 11 15 }	5 14	2 42	3 00	5 15	18 59	3 18	3 30	19 00
11 23	1 10	{ 1 10 / 1 08 }	11 25	5 29	3 00	3 04	5 30	19 29	3 40	3 48	19 30
11 28	1 08	1 04	11 30	5 44	3 06	3 04	5 45	19 59	3 48	3 56	20 00
11 43	1 00	0 56	11 45	5 59	3 04	3 02	6 00	20 28	3 56	4 00	20 30
11 57	0 52	0 44	0 00	6 14	3 02	3 04	6 15	20 59	3 58	3 54	21 00

Curves of the diurnal deviations of a n
the action of two bar magnets placed in



of a magnetic needle whose directive power was diminished by
ced in the line of the dip: the N. end of the needle pointing north.





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During this day and the following, until the observations were discontinued, I observed the barometer every hour, but as it was remarkably steady, (varying during the 26th only from 29.77 at 3^h A. M. gradually to 29.75 at 3^h P. M., and from that to 29.82 at 11^h P. M., and on the 27th from 29.92 at 5^h A. M., to 30.075 at 1^h P. M.,) change of atmospheric pressure could have little influence in the deviations which took place. I regret much that I did not observe, what I now consider of more importance, the temperature both of the instrument and of the atmosphere. There was continued rain nearly through the whole day, no sensible change taking place in the temperature of the air; and I am persuaded, from this circumstance and the situation of the place in which the observations were made, that no material change took place in that of the instrument.

The observations from the 20th to the 27th of April, are exhibited [Pl. XXV.] in the same manner as were those at north. In the present instance, the easterly deviations were in a contrary direction to what they were in the former case, but I have still placed them towards the left, that the similarity of the curves in the two cases may be the more evident.

The principal irregularities to be observed here take place in general from about three o'clock in the afternoon to seven o'clock; and we might almost be led to infer from this circumstance that there are two causes, in opposition to each other, producing the deviation, and that these being nearly equal at this time, alternately preponderate: but the observations are too limited to allow of our drawing such general inferences from them. We shall see, from observations in other positions of the needle, that irregularities very frequently take place during the afternoon.

In this position of the needle, the morning deviation is at first towards the east, and afterwards towards the west, the same as when the north end of the needle pointed north, the needle tending towards the same point in the two cases, but in contrary directions. This is what we might expect from a simple change in the direction of the terrestrial force, but the observations which I shall presently describe, clearly point out both a change of direction and of intensity.

Having ascertained the nature of the changes which take place with the north end of the needle towards the north, and also towards the south, I proceeded to make observations with the north end in other directions. For this purpose I had prepared another compass, in order that I might observe at different points at the same time. This compass was placed in my garden, that it might be completely out of the influence of the magnets adjusted to the other needle, and likewise that I might be able to notice, whether, as Mr. BARLOW had found, the deviations were in contrary directions in the two cases, when the north end had the same, or nearly the same, direction in both. The observations were not, in this point of view, very conclusive, because although the deviations differed in many respects, in some they agreed, and likewise because the magnets were not adjusted in the same manner in the two cases; those within doors being in the line of the dip, and those to the other needle being in the meridian, on the same horizontal table as the compass. The points at which the observations were made within doors were the north end at N 28° W and N 49° W; and with the other needle at N 55° W. After continuing to make these observations carefully for some days, it occurred to me that I

might so adjust the magnets, that I could make simultaneous observations on the same needle in three different positions, without altering the situations of the magnets, or of the centre of the needle. As I consider that these observations point to conclusions which cannot fairly be drawn from those made at several points, under different adjustments of the magnets, I shall omit giving those mentioned above.

Previously to giving the observations themselves, I shall describe the principle on which I adjusted the magnets, and state what I considered would be the effects of certain changes in their distances from the centre of the needle, and in the angle which their axes made with the meridian, describing likewise the experiments, which proved the correctness of these conclusions: this will enable me the better to draw inferences from the observations. It is very evident that if the magnets are exactly in the meridian, at the same distances from the centre of the needle, and in the same horizontal plane with it, whatever may be the directions of the resultants of all the forces acting on the needle in any particular position of its ends, if that be changed for one diametrically opposite, the directions of the resultants will also be changed into others directly opposite; so that for every position of *stable equilibrium*, where the resultants are in the directions from the centre towards the extremities of the needle, there will be a corresponding position of *instable equilibrium*, where the directions of the resultants are from the extremities of the needle towards its centre. Calling zero, the point of *stable equilibrium* for the north end, when the needle is free from every other action but terrestrial magnetism, 180° will be the point of *instable equilibrium*. If

the magnets are in the meridian, and their poles are placed towards those of the needle of the same name, zero will still continue the point of *stable equilibrium*, and 180° of *instable equilibrium*, while the terrestrial forces are greater than those of the magnets; but when the forces of the magnets are equal to the terrestrial forces, both these points become what may be termed points of indifferent equilibrium, since the needle is not retained in the one by forces acting from the centre towards the extremities, nor do any forces act from the extremities towards the centre in the other: the equilibrium, however, at zero still possesses one character of stability, a tendency to return to it when disturbed, whilst that at 180° has the character of instability, a tendency to recede from it, under the same circumstances. If the magnets be brought somewhat nearer, the forces which they exert on the ends of the needle will be greater than the terrestrial forces, and zero will therefore become a point of *instable*, and 180° of *stable equilibrium*. It is besides evident, that the excess of the forces of the magnets above the terrestrial forces may be such, that they will be in equilibrio between zero and 180°; so that there will be a point of *stable equilibrium* between zero and the west, and zero and the east. Corresponding and opposite to these there will be two points of *instable equilibrium*; one between 180° and the east; the other between 180° and the west. There would therefore now be six points of equilibrium, alternately *stable* and *instable*. As the magnets are made to approach the needle, the two easterly points of equilibrium will approach each other, and also the two westerly; and when they coincide at east and west, the four will become two points of indifferent equilibrium, the resultants of all the

forces being here nothing. The magnets having approached beyond this, there will be only two points of equilibrium, a point of *stability* at 180°, and of *instability* at zero. The same effects would manifestly be produced, if instead of the force of the magnets being increased by their approach towards the centre, the terrestrial forces were to decrease, whilst the magnets remained at the same distances: so that the receding of the easterly and westerly points of stable equilibrium from the north, would indicate a diminution, and their approach to it, an increase of the terrestrial magnetic intensity.

Let us now consider what would be the effect if the line in which the magnets are placed described a small angle from the meridian, the magnets remaining at the same distances from the centre; or, which is the same thing, if the direction of the terrestrial forces were changed without any change in their intensities. We will suppose that the line in which the magnets are placed moves through a small angle in the direction of the sun's motion, which is equivalent to supposing that the magnetic meridian describes a small angle in the contrary direction.

Taking first the case of there being only one point of *stable equilibrium*, it is evident that when it is at zero, it will move in a direction contrary to that of the sun's motion, and that it will move in the same direction as the sun, when it is at 180°.

When there are three points of *stable equilibrium*, that which is at 180° will still move in the direction of the sun's motion, and the opposite point of *instable equilibrium* will move in the same direction, that is, from its position at zero, towards the *east*. In consequence of the decreasing angle

which the repulsive force, acting on the needle at the *easterly* point of *stable equilibrium*, makes with the needle, its stability will be diminished, and this point will approach the northern point of instability, until the two coincide: and beyond this the one will be transferred to the *westerly* point of *stability*, and the other to the *easterly* point of *instability*. In the mean time the *westerly* point of *stable equilibrium*, in consequence of the repulsive force of the magnet acting at a greater angle, will move farther towards the *west*: the three points ultimately forming but one.

If the line of the axes of the magnets revolve in a direction contrary to that of the sun's motion, or which is the same thing, if the magnetic meridian describe an angle in the direction of the sun's motion, effects the reverse of these will evidently take place.

I had drawn these conclusions, and proposed applying them to the observations on the daily changes in different directions of the needle, when it occurred to me that it would, after all, be more satisfactory, to apply to these observations, the facts that might be actually observed, by making the distances of the magnets and the line of their axes undergo the changes I have specified. In consequence of this I made the following experiments. A strong table being prepared, with the legs firmly driven into the ground, at a distance from any building, the compass with which I had made the preceding observations, and which, for the sake of distinction, I shall call No. 1, was placed on a meridian line very carefully drawn. The magnets which I had always used with this needle, were then placed on this line, at equal distances from the centre of the

needle, having their poles directed towards those of the same name of the needle, and their axes coinciding with the meridian, so that the north end of the needle still pointed to zero. The magnets were then brought in towards the centre, their axes still coinciding with the magnetic meridian, until the distances of their nearest ends were each 16.95 inches, when the north end was in equilibrio at each of the three points,

N 25° 26′ W, N 20° 10′ E, S 2° 20′ W.

that is, the needle being led near each of these points by means of a small piece of iron wire, settled steadily at each, after agitation.

I now drew lines perpendicular to the meridian, from the ends of the magnets, and measured off distances of .05, .10, .15, .20, .25 of an inch on each side of the magnets at the ends nearest to the centre, and distances at the farther ends corresponding to them; so that the sides of the magnets coinciding with the respctive points, the north magnet towards the east and the south magnet towards the west, or vice versa, the line of their axes had described angles from the meridian, about the centre, the tangents of which were $\frac{5}{1695}$, $\frac{10}{1695}$, $\frac{15}{1695}$, &c. respectively, or very nearly angles of 10′, 20′, 30′, &c.

In the following table, the angles which the north end of the line of the axes of the magnets made with the meridian are placed in the first column, and the points of equilibrium corresponding to these situations of that line are placed opposite to them in the following columns. When *not stable* is placed in the column, it is to be understood that the needle rests near the point above, but, on being in the least agitated, moves to the point which is found to continue stable through out. When *no point* is placed, it is to be understood that the

needle does not rest at any point corresponding to those which had before been observed.

Table of the Points of Equilibrium corresponding to the several angles between the meridian and the axis of the Magnets, the distances of the Magnets from the centre of the Needle remaining the same. 11*th May, from* 6^h *A. M. to* 9^h *A. M. compass No.* 1.

North end of the axis towards East.				North end of the axis towards West.			
Angle.	Points of Equilibrium.			Angle	Points of Equilibrium.		
N. 0° 0′ E.	N. 25° 26′ W.	N. 20° 10′ E.	S. 2° 20′ W.	N. 0° 0′ W.	N. 25° 26′ W.	N. 20° 10′ E.	S. 2° 20′ W.
0 10	27 58	not stable	10 6	0 10	21 16	21 0	S. 4 12 E.
0 20	29 28	not stable	17 48	0 20	15 10	25 32	16 0*
0 30	30 2	no point	no point.	0 30	no point	27 36	no point
0 40	31 40	no point	no point.	0 40	no point	29 56	no point
				0 50	no point	31 34	no point

From the first part of this table it appears, that, if the north end of the axis of the magnets described an angle from the meridian towards the east, without any change in the intensities of the forces which the magnets exerted on the needle, or, which amounts to the same thing, if the direction of the force urging the north end of the needle deviated towards the *west*, without any change in its intensity, the *westerly* point of equilibrium would move towards the *west*: and also the *easterly* and *southerly* points of equilibrium would move towards the *west*, until they were lost in the *westerly* point: so that, the directions of the deviations of the *easterly* and *westerly* points of equilibrium would be *both plus*, and that of the *southerly* point *minus*, if, without any change of intensity, the direction of the terrestrial force deviated towards the *west*. From the second part it appears, that if the direction of the terrestrial

* At this point, if the needle was much agitated, it moved towards east.

force urging the north end of the needle deviated towards the *east*, without changing its intensity, the deviations of the *westerly* and *easterly* points of equilibrium would be *both minus*, and that of the southerly point *plus*. These agree precisely with the conclusions I had previously drawn.

In order to point out the effects of increasing or diminishing the forces which the magnets exerted on the needle, compared with the terrestrial forces, or the effects that would take place if, without changing their direction at any particular time, the terrestrial forces decreased or increased in intensity, from both the last positions of the axis of the magnets, namely, N 0° 40′ E and N 0° 50′ W, I brought the magnets nearer to the centre, keeping their axes still in the same line, and observed the corresponding changes in the points of equilibrium at every $\frac{1}{10}$ inch by which they approached the centre of the needle.

Table of the Points of Equilibrium corresponding to several distances of the Magnets from the centre of the Needle, the angle between the axis of the Magnets and the meridian remaining the same.
11 *May*, 9^{h} *A. M. to Noon; compass No. I.*

Angle between the axis of the magnets and the meridian.							
N. 0° 40′ E.				N. 0° 50′ W.			
Distances.	Points of Equilibrium.			Distances.	Points of Equilibrium.		
16.95	N. 33 36 W.	no point	no point	16.95	no point	N. 31 34 E.	no point
16.85	37 16	no point	no point	16.85	no point	36 20	no point
16.75	41 22	N. 17*20 E.	S. 17 10 W.	16.75	N. 27 40 W.	39 0	S. 16 20 E.
16.65	46 24	30 26	13 16	16.65	34 32	45 38	10 18
16.55	50 08	40 32	10 38	16.55	42 18	49 22	8 40
16.45	54 52	46 16	8 50	16.45	50 04	55 38	7 16
16.35	58 46	52 30	8 12	16.35	54 38	59 0	6 28
16.25	63 18	57 16	7 18	16.25	59 50	64 14	5 16
16.15	70 06	65 34	6 34	16.15	66 14	72 26	5 10
16.05	78 48	74 06	6 12	16.05	74 00	83 00	5 06
15.95	no point.	no point	5 50	15.95	no point	no point.	4 18

* The equilibrium at this point was not stable; at the opposite point S 17° 10′ W the needle was very steady.

From this it appears, that, as the magnets approached the centre of the needle, or as the intensity of their action *increased*, the *westerly* point of equilibrium proceeded towards the *west*, and the *easterly* towards the *east;* that is, both *receded* from the *north;* or the direction of the deviation of the first was *plus* and of the second *minus*. The *southerly* point of equilibrium, as the intensity *increased*, proceeded towards the *south;* so that when the northern extremity of the axis of the magnets made an angle with the meridian towards the *east*, or in the direction *minus*, the *southerly* point of equilibrium deviated in the direction *plus;* and when the angle was in the direction *plus*, the deviation of the *southerly* point, arising from the *increased* action of the magnets, was in the direction *minus:* that is, as the intensity of the action of the magnets *increased*, the *southerly* point of equilibrium deviated in a direction contrary to that of the angle which the axis of the magnets made with the meridian.

Applying this to the variation of the terrestrial magnetic intensity, supposing that of the magnets constant, as this intensity *decreased*, the *easterly* and *westerly* points of equilibrium would *both recede* from the *north*, and the *southerly* would proceed towards the *south;* as it *increased*, the *easterly* and *westerly* points would *approach* the *north*, and the *southerly* point *recede* from the *south*. Hence the deviation of the *westerly* point of equilibrium being *minus*, and, at the same time, that of the *easterly* point *plus*, would indicate an *increase* in the intensity of the terrestrial force; and the same would be indicated by the *receding* of the *southerly* point from the *south*. If at the same time that the intensity of the terrestrial force *increased*, the direction of that urging the north end of

the needle deviated towards the *west*, the deviation of the *westerly* point of equilibrium from the *increase* of intensity would be *minus*, and from the *change of direction*, *plus*; so that its character, whether *plus* or *minus*, depending upon the one cause or the other producing the greater effect, would in some cases be somewhat ambiguous. With regard to the *easterly* point of equilibrium, under the same changes of intensity and direction, its deviation from both causes would be *plus*; and if the intensity and westerly deviation of the force increased during the same period, we should expect little or no ambiguity in the character of the deviation of the easterly point of equilibrium. With regard to the *southerly* point of equilibrium, when that point is towards the *east*, the *increase* of intensity would cause its deviation to be *plus*, and the *change of direction*, *minus*; so that here again we might expect some ambiguity; but when the *southerly* point is towards the *west*, these two causes acting at the same time, would both tend to make its deviation *minus*. From this it would appear, that at particular points of equilibrium, to the west of north and to the east of south, if the intensity of the terrestrial force *increased* with the deviation of its direction *westward*, the two causes might so counteract each other's effects that little or no deviation of the needle at these points would be apparent; but the precise situation of such points would depend in a great measure on the nature of the arrangement of the magnets by which the needle was held in equilibrio at them.

To proceed with the observations on the daily changes in the several points of equilibrium, I have stated that, during the time in which I made observations, in-doors, on the needle No. 1, I had likewise observed, in the open air, the deviations

of another needle, which I call No. 2. This needle is 4.3 inches long, nearly of a similar form to No. 1, and, like it, balanced by an agate cap on a fine point. The rim of the compass-box is accurately divided into degrees, so that I can read to the nearest 5′. The observations with this needle were commenced on the 4th of May, and continued without much interruption until the 18th: these I shall first describe.

Two bar magnets, each ten inches long, .95 inch wide, and .4 inch thick, but not by any means powerful, were placed on the same horizontal table as the compass, with their poles towards those of the needle of the same name. As my object at first was, to observe the changes at points differing considerably in their positions with regard to the north and the south, I did not adjust the magnets in the meridian, but each somewhat inclined to it, the nearest end of each being 11.575 inches from the centre of the needle. I had taken the time of vibration of the needle previously to applying the magnets, but lost the memorandum of it; however, when they were removed, at the conclusion of the observations, it made ten vibrations in nineteen seconds.

My first object was, to determine the three points at which the needle would remain stationary, after being agitated; that is, the three points of *stable equilibrium*, and likewise the three points of *instable equilibrium*: I determined them as under:

4th of May, $5^h\ 20^m$ A. M.

At	S 55° 30′ W	The north end of the needle was stationary, but being agitated, it moved towards	South.
	S 55 40 W		West.
	S 59 0 E		South.
	S 59 45 E		East.
	N 20 50 E		East.
	N 20 10 E		North.

So that the three points of *instable equilibrium* were nearly

S 55° 35′ W, S 59° 20′ E, N 20° 30′ E.

At the three points N 56°40′ W, S 15°55′ W, N 40°55′ E, the north end of the needle, after being agitated, settled steadily. Hence the six points of equilibrium, in their order round the compass, were,

Stable.	Instable.	Stable.	Instable.	Stable.	Instable.
N 56° 40′ W,	S 55° 35′ W,	S 15° 55′ W,	S 59° 20′ E,	N 40° 55′ E,	N 20° 30′ E.

Vibrating the needle from S 60° W, it made six vibrations in thirty seconds about the point N 56° 40′ W; vibrating it from S 54° W it made four vibrations in twenty seconds about the point S 15° 55′ W: I could not obtain the vibrations about the point N 40° 55′ E, on account of its proximity to the instable point N 20° 30′ E.

I have been thus particular in describing the steps which I took previous to the first set of observations, in order that the nature and situation of the three points of *stable equilibrium* may be clearly understood, and to render unnecessary any previous explanation for the other sets of observations.

Tables of the daily changes observed to take place in the points at which a Needle was retained in equilibrio by two bar Magnets.

I.

The Points of Equilibrium nearly N. 57° W., N. 40° E., S. 16° W.; the axes of the Magnets slightly inclined to the meridian; the distances from the nearest ends of the Magnets to the centre of the Needle, 11,575 inches. Compass No. II.

May 4.			
Time.	Points of Equilibrium.		
h. m.	° ′	° ′	° ′
6 00	N. 56 40 W.	N. 40 55 E.	S. 15 55 W.
6 30	56 20	40 10	16 15
7 00	56 05	39 30	15 50
7 30	55 40	39 20	15 50
8 00	56 20	39 35	15 45
9 00	56 00	39 20	16 0
10 00	54 10	35 15	16 40
11 00	52 55	27 20	17 40
Noon	53 10	no point	17 40
0 30	52 30	no point	18 10
1 00	53 30	no point	17 55
2 00	55 35	29 15	16 45
3 00	56 45	37 20	16 15
4 00	56 30	36 45	15 55
5 00	57 05	38 30	15 50
6 00	56 40	38 10	15 40
7 00	57 20	40 20	15 20

Here we see that the *westerly* and *easterly* points *approach* and *recede* from the *north together*, or that when the deviation of the *one* is *minus*, that of the *other* is *plus*; that they *approach*, with a slight interruption, betwen seven and eight o'clock, until between twelve and one o'clock, after which they recede, with a slight interruption, about four o'clock, during the rest of the day: and that the *southerly* point *recedes* from the *south* until between twelve and one o'clock, and *approaches* it during the rest of the day, with similar interruptions.

II.

The Points of Equilibrium nearly N.36° W., N.57° E., S.5° E.; the axes of the Magnets slightly inclined to the meridian; distances 11,575 inches. Compass No. II.

Time.	May 5. Points of Equilibrium.			May 6. Points of Equilibrium.			May 7. Points of Equilibrium.		
	N. W.	N. E.	S. E.	N. W.	N. E.	S. E.	N. W.	N. E.	S. E.
h m.	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
5 30	37 25	57 00	5 15	34 35	55 45	5 15	—	—	—
6 00	35 00	56 00	5 15	35 00	56 10	5 20	34 40	56 15	4 25
6 30	34 20	55 15	5 15	33 15	55 10	5 20	33 40	53 55	5 30
7 00	34 40	55 45	5 20	32 05	54 40	5 20	30 40	52 55	5 30
7 30	32 30	54 30	5 30	31 25	54 10	5 40	29 20	53 05	5 00
8 00	30 25	53 55	5 30	28 40	52 50	5 45	23 30	51 35	5 25
9 00	no point	49 06	6 36	23 30	50 55	5 35	no point	47 35	5 40
10 00	no point	47 34	5 44	no point	49 40	5 30	no point	45 30	5 40
110 0	no point	48 00	6 16	no point	48 20	5 15	no point	46 00	5 46
Noon	no point	47 30	5 00	no point	47 15	5 05	no point	45 20	6 00
0 30	no point	47 00	5 00	no point	47 30	5 05	—	—	—
1 0	no point	46 35	5 15	no point	48 10	5 05	no point	47 06	5 20
1 30	no point	46 10	5 00	—	—	—	—	—	—
2 00	—	—	—	—	—	—	no point	48 45	5 30
3 0	31 15	52 55	4 15	30 30	52 55	4 30	no point	50 30	5 00
4 0	32 00	54 05	4 40	31 36	52 10	4 40	23 30	51 20	5 30
5 0	31 30	52 34	5 50	30 40	52 30	5 15	29 40	52 40	5 15
6 0	32 00	54 00	4 05	30 00	54 00	4 30	32 15	54 00	5 00
7 0	32 30	54 25	4 45	29 40	53 30	5 00	29 00	53 55	5 35
8 0	34 30	54 55	5 05	32 30	54 34	5 05	32 15	55 40	5 30
9 0	35 40	55 00	5 20	36 30	56 30	5 00	33 25	55 00	5 40
10 0	—	—	—	34 30	55 16	5 30	34 45	55 15	5 20
11 0	36 30	55 20	5 30	35 20	55 55	5 05	—	—	—

Here it appears that the *easterly* and *westerly* points *approach* and *recede* from the *north together*, with only five exceptions, viz. May 6th, at 4^h 5^h and 6^h P. M.; 7th, at 7^h 30^m A. M. and 9^h P. M. The direction of the deviation of the *easterly* point is *minus* till the middle of the day nearly regularly, and is *plus*, during the remainder, with some irregularities in the afternoon. Though the character of the deviation of the *southerly* point is somewhat ambiguous, as we have seen would be the case in this situation, if the changes of direction and of intensity counteracted each other's effects, yet, with the exception of some irregularities, it agrees with that of the observations at the south, from the 20th to the 27th of April, the maxima being however rather later.

III.

The Points of Equilibrium nearly N. 19° W. N. 10° E. S. 3° W.; the line of the axes of the Magnets very nearly in the meridian; distances 11.725 inches. Compass No. II.

Time.	May 10.			May 11.			May 12.			May 13.			May 14.		
	Points of Equilibrium.			Points of Equilibrium.			Points of Equilibrium.			Points of Equilibrium.			Points of Equilibrium.		
	N. W.	N. E.	S. W.	N. W.	N. E.	S. W.	N. W.	N. E.	S. W.	N. W.	N. E.	S. W.	N. W.	N. E.	S. W.
h. m.	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
6 0	—	—	—	15 55	11 15	1 55	15 10	5 50	4 30	16 0	10 0	3 15	17 50	not stable	5 35
7 0	10 15	15 30	S. 4 40 E.	15 15	13 30	S. 0 40 E.	14 10	5 30	2 10	19 30	16 40	1 25	18 0	13 30	7 20
8 0	8 20	13 45	S. 2 45 E.	16 40	16 15	S. 0 25 E.	12 40	no point	2 40	17 20	12 0	1 25	13 45	14 30	S. 0 10 E.
9 0	4 5	2 45	S. 4 45 E.	16 0	13 45	S. 0 30 W.	10 0	no point	2 0	15 50	not stable	3 35	14 50	12 30	S. 0 45 W.
10 0	10 0	no point	no point	18 55	11 40	4 30	6 0	no point	S. 0 30 E.	11 0	no point	no point	11 50	no point	no point
11 0	13 50	no point	no point	19 50	not stable	9 50	15 20	no point	no point	8 40	no point	no point	15 5	no point	no point
Noon.	16 15	no point	no point	21 30	no point	no point	14 0	no point	no point	12 30	no point	no point	15 55	no point	no point
1 0	16 30	no point	no point	16 5	no point	no point	16 0	no point	no point	10 35	no point	no point	13 25	no point	no point
2 0	15 20	no point	no point	18 50	no point	no point	15 40	no point	no point	17 50	no point	no point	18 0	no point	no point
3 0	17 20	no point	no point	17 20	no point	no point	16 45	no point	no point	17 35	no point	no point	19 10	no point	no point
4 0	15 0	not stable	not stable	17 45	no point	9 30 scarcely stable.	17 10	no point	no point	18 0	no point	no point	19 20	no point	no point
5 0	—	—	—	16 30	9 15 Instable	9 15	18 15	no point	no point	18 0	no point	no point	19 25	no point	10 20
6 0	17 30	12 15	S. 2 30 W.	16 20	10 10	4 30	18 50	no point	no point	18 40	no point	no point	19 40	no point	6 20
7 0	18 40	10 15	3 40	17 25	11 30	2 30	18 40	9 10	S. 3 10 W.	19 30	no point	no point	21 5	8 40	5 15
8 0	18 40	9 30	3 25	18 40	12 40	2 0	20 0	13 20	3 0	21 0	11 0	4 40	22 25	15 50	4 55
9 0	—	—	—	16 0	15 20	3 30	19 30	15 0	2 0	21 30	14 30	4 0	22 5	13 50	4 40
10 0	—	—	—	17 40	14 35	8 40	17 0	18 35	S. 0 5 E.	—	—	—	22 55	10 0	6 0
11 0	18 40	11 15	2 25	—	—	—	19 50	16 20	S. 1 30 W.	—	—	—	—	—	—

In this position of the magnets, their forces so very nearly balance the terrestrial forces, that the *southerly* and *easterly* points of equilibrium are soon lost in the *westerly*, the character of which is in consequence, as we might expect, somewhat ambiguous. The *easterly* point, when it could be observed in the morning, *approached* the *north* from between seven and eight o'clock until it was lost in the *westerly* point; and, from its first appearance in the afternoon, it *receded* from the *north* till the evening, except on the tenth, when it again *approached* the *north* previous to its finally receding. With respect to the deviation of the *southerly* point, its direction appeared to be *plus* till about eight o'clock in the morning, after which it was *minus* as long as it could be observed; and when again observed it had become *plus*: which, as far as the observations go, agrees with those at the south, before mentioned.

After making the observations at 8^h P. M. on the 14th of May, pins being fixed by the sides of the magnets so that I could make them recede from the needle in the same line, I drew them back by very small distances, to see whether, from this point, an increase of the terrestrial force would give changes in the points of equilibrium of the same nature as those which had taken place in the preceding observations: I found them to be as under.

14th May, 8^h 15^m P. M.

Distances.	Points of Equilibrium.		
	° ′	° ′	° ′
11.725	N. 22 25 W.	N. 15 50 E.	S. 4 55 W.
11.742	21 00	10 30	6 40
11.760	19 35	7 40 not stable	6 55
11.775	18 30	no point	8 00

The agreement in the general character of these with that of the observations from five o'clock till eight, will clearly lead us to infer that the changes observed in the positions of the points of equilibrium during that time, arose from a *diminution* of the terrestrial forces, as well as a change in their directions: had the agreement in all the observations themselves been complete, we must have inferred that *diminution* of intensity was the sole cause of the changes. After these observations, the magnets were restored to their former distances for those at nine and ten o'clock.

IV.

The Points of Equilibrium nearly N. 25° W., N. 25° E., S. 3° E.; the line of the axes of the Magnets coinciding with the meridian; distances 11.655 inches. Compass No. II.

Time.	May 15. Points of Equilibrium.			May 16. Points of Equilibrium.			May 17. Points of Equilibrium.		
	N. W.	N. E.	S. E.	N. W.	N. E.	S. E.	N. W.	N. E.	S. E.
h. m.	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
6 00	13 10	19 30	4 40	——	——	——	21 45	24 35	3 00
7 00 *	12 35	17 45	6 45	23 00	26 40	4 05	20 05	23 40	4 20
8 00	no point	15 00	no point	21 50	25 40	5 20	18 35	24 00	5 05
9 00	13 10	17 10	5 05	23 00	26 45	5 40	18 55	22 35	3 55
10 00	11 00	15 00	6 50	23 00	25 35	4 00	19 05	22 15	3 20
11 00	——	——	——	20 30	21 30	3 10	18 00	19 40	3 00
Noon.	10 20	13 00	2 00	19 40	18 50	0 50	22 05	20 20	0 55
1 00	17 50	15 25	0 15	22 25	19 40	S. 1 10 W.	21 30	21 05	0 50
2 00	19 10	15 15	0 50	21 15	18 45	S. 0 15 W.	21 00	20 30	1 26
3 00	20 00	17 50	0 40	20 55	19 35	S. 0 20 E	20 00	21 25	3 20
4 00	20 20	20 40	2 30	21 00	21 00	1 20	19 50	20 00	2 55
5 00	21 00	22 20	3 10	21 20	22 30	2 15	21 10	21 50	2 00
6 00	22 00	24 00	3 00	22 30	24 00	2 25	21 30	22 40	2 20
7 00	23 50	24 40	2 00	——	——	——	22 54	24 30	2 40
8 00	25 15	26 20	2 25	——	——	——	24 00	26 40	3 20
9 00	25 15	26 20	2 00	23 10	26 55	4 35	26 20	27 00	2 00
10 00	25 00	26 05	2 05	24 50	25 06	2 26	26 36	28 05	3 00

* These observations were made with the distances 11.725 inches.

From these we see, as before, that the *westerly* and *easterly* points *approach* and *recede* from the *north together*, with a few exceptions, which happen about eight o'clock in the morning and three o'clock in the afternoon. The nearest *approach* of these points towards the *north*, or their *greatest* deviations in the directions *minus* and *plus*, appeared to take place about noon. The changes in the *southerly* point again agree very nearly with the observations at the south from the 20th to the 27th of April: the *maximum* in the direction *minus* appearing to happen about an hour after noon.

The following observations were made with the compass No. *I*, having the magnets adjusted on the same horizontal table, in the open air, as I have described previous to the observations with it on the 11th of May. During the same time that these were made, I likewise made those with the compass No. *II.*: the two sets were made in the following order; those with No. *II.* were begun a few minutes before the hour, so as to finish those with No. *I.* at nearly the same time after it, the whole time occupied being, in general, about ten minutes.

V.

The Points of Equilibrium nearly N. 80° W.; N. 80° E.; S.; the line of the axes of the Magnets coinciding with the meridian; distances 15.95 inches. Compass No. 1.

Time.	May 14.			May 15.			May 16.			May 17.		
	Points of Equilibrium.			Points of Equilibrium.			Points of Equilibrium.			Points of Equilibrium.		
	N. W.	N. E.	S. E.	N. W.	N. E.	S. E.	N. W.	N. E.	S. E.	N. W.	N. E.	S. E.
h. m.	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
6 00	83 20	83 14	1 06	not stable	not stable	0 52	——	——	——	75 36	75 28	0 56
7 00	80 08	79 36	1 22	83 18	83 26	0 42	77 50	77 34	0 46	74 28	74 22	0 54
8 00	80 14	79 26	1 16	78 46	78 36	0 44	76 00	76 16	0 52	73 48	73 24	0 58
9 00	83 12	84 58	1 06	77 54	77 24	0 34	77 42	77 52	1 22	73 52	73 28	0 46
10 00	81 46	80 18	0 52	77 20	77 52	0 40	77 12	77 20	1 04	73 32	73 24	0 46
11 00	79 02	77 24	0 36	——	——	——	73 36	73 18	0 54	73 06	72 52	0 40
Noon	78 44	77 28	0 14	70 40	69 18	0 18	73 06	72 48	0 30	74 48	73 44	0 18
1 00	78 52	78 32	0 18	71 40	70 34	0 18	73 32	72 50	0 22	74 10	73 08	0 24
2 00	78 38	77 20	0 34	69 48	68 50	0 18	72 18	71 52	0 24	72 06	71 36	0 14
3 00	77 32	78 00	0 36	70 54	70 00	0 32	72 52	72 28	0 24	71 40	71 08	0 40
4 00	79 00	78 24	0 42	72 10	71 44	0 42	73 04	72 54	0 34	71 46	71 02	0 34
5 00	81 18	81 04	0 56	73 40	72 52	0 50	74 16	74 04	0 34	73 06	72 38	0 34
6 00	83 12	82 22	0 52	74 52	74 20	0 42	75 10	75 04	0 30	73 08	73 06	0 40
7 00	87 08	88 34	0 52	76 18	75 08	0 40	——	——	——	75 20	74 46	0 38
8 00	89 40	89 40	0 36	78 38	77 08	0 32	——	——	——	77 12	76 30	0 54
9 00	not stable	not stable	0 34	78 00	77 44	0 20	76 56	77 26	0 56	79 00	78 50	0 44
10 00	no point	no point	0 34	77 50	77 32	0 22	77 28	77 10	0 50	79 44	79 30	0 42

In these the *westerly* and *easterly* points *approach* and *recede* from the *north together*, almost without exception. The *maximum* deviation of the *westerly* point in the direction *minus*, and of the *easterly* point in the direction *plus*, here take place between two and three o'clock in the afternoon. The changes in the *southerly* point again agree very nearly with the observations in April; the *maximum* in the direction *minus* still happening about an hour after noon.

I have shown, by the observations made on the 11th of May, that a change in the *directions* alone of the terrestrial

forces, would cause the deviations of the *easterly* and *westerly* points of equilibrium to be always *both plus* or *both minus*, that is, that the *one* would always *approach* the north whilst the *other receded* from it; that the effect of a change of *intensity* alone of these forces was, to make the deviation of the *one point plus*, whilst that of the *other was minus*, or to make them *approach* and *recede* from the north *together;* and that if a change took place at the same time both in the *intensity* and direction, the *westerly* and *easterly* points might *both approach* and *both recede* from the north, or the *one approach* and *the other recede*, according as the one cause or the other produced the greater effect; but that their *both approaching* or *both receding* from the *north*, at any time, must arise from a change of *intensity*. Comparing then the whole of the preceding observations with these effects, it is evident that the changes which take place cannot be explained by a change in the directions alone of the terrestrial forces, but that their characters agree, as nearly as we can possibly expect, with the effects that would take place from an *increase of intensity* at the time that the direction deviated towards the *west:* we are therefore led to infer, that such an *increase of intensity* must take place in the terrestrial force during the time of the *westerly deviation*. The change of intensity during the day, has been already ascertained by the observations of HANSTEEN on the vibrations of a needle very delicately suspended, but in the present state of our information respecting the magnetical phænomena of the earth, the series of observations which I now present will not, I trust, be considered without interest, although they should, at first sight, appear only to confirm results obtained from previous observations.

At different times on the 14th of May, after observing the directions of the needle No. *I*, I found its time of vibration at the south point of equilibrium. This was not done with the expectation of being able to draw any very decided conclusions from these observations, since the suspension of the needle was not sufficiently delicate to admit of its making many vibrations under a diminished force, nor had I then more accurate means of ascertaining the time than a good watch with a seconds' hand; but to see how far the change in the ratio of the intensities of the terrestrial forces and those of the magnet would be sensible. The times required for eight vibrations of the needle at different hours in the day were as follow:

	Vibrations.		
At 6h A. M.	8	in	50″
10	8		52
Noon	8		52
1 P. M.	8		52
4	8		50.4
9	8		50

The differences here are such, that, even with the means I possessed, they could not arise from errors in the observations, and they point distinctly to a diminution, during the middle of the day, of the forces tending towards the point about which the vibrations were made; that is, to an increase in the ratio of the terrestrial forces to those of the magnet. With a very delicate suspension, such as HANSTEEN made use of, and very accurate means of measuring the time, I consider that the times of vibration of a needle so adjusted would give a ready and accurate measure of the ratio of the terrestrial forces to those of the magnet, and, if taken under precisely

the same circumstances with respect to the magnets, of the intensity of the terrestrial forces.

Previous to giving the observations, I have considered what would be the case if, at the same time that the direction of the force deviated towards the west, its intensity increased; but from the observations of HANSTEEN this does not appear to be precisely the case. He found the minimum intensity to take place about ten o'clock in the morning, that is, about two hours and a half after the westerly deviation had commenced; and the maximum intensity about the same time after the return towards the east. This increase of the intensity during the latter part of the westerly deviation will account for the general character of the changes; and the difference in the times at which the changes of intensity and direction take place, may possibly be pointed out by some of the apparent anomalies in the various changes observed at different points.

Having arrived at these conclusions from my observations, I intended to close them for the present, with those I have last given, but as I had not removed the compasses, I again observed the directions on the following day, and I soon found that changes took place to an extent I had never before noticed. In consequence of this I continued to observe during the day, and felt much gratified that I still had the opportunity, as by this means I discovered that I had not noticed a circumstance, which must in all cases affect the extent of the deviations, and must be allowed for when the effects arising solely from the changes in the terrestrial forces are to be considered. In my first observations I had not noticed the temperature of the room in which they were made; and although I had noticed that the state of the weather appeared to have an

influence on the extent of the deviations, I did not consider that such changes of temperature as they were liable to would sensibly affect the energy of the magnets themselves.

In the experiments of CANTON, on the effects of temperature in increasing or diminishing the forces of magnets, the precise change of temperature in the magnets could not very well be ascertained from the manner in which it was produced, but it could not be less than 80° or 90° on FAHRENHEIT's scale, and yet this only caused the needle to move from N 45° E to N $44\frac{1}{4}$° E, when applied to a single magnet retaining the needle in this position; and when two magnets were applied on contrary sides of the needle, so that it pointed due north between them, an increase of temperature to this extent, in either of the magnets, only caused it to deviate $2\frac{3}{4}$° towards the other. From this we might be led to suppose that in such observations as I had been engaged in making, the effects of small changes of temperature might be neglected without sensible error, and that even in extreme cases the deviations would not be materially affected: the latter, however, I found was far from being the case.

I had continued to observe in the open air under the same impression which I had when the compasses were in a room, but, on the day in question, the effects of a hot sun upon the magnets were too unequivocal to be doubted. So early as seven o'clock in the morning I had found a deviation of 13° 20′ of the western point, and 11° 48′ of the eastern, towards the north, from their situations at $5^h\,15^m$ in the compass No. *I.*; and in No. *II*, 6° 55′ of the westerly and 4° 20′ of the easterly point: whereas on the preceding day, the corresponding changes from the night before had been, for No. *I*, 2° 54′ and

2° 58′; and for No. II, 5° 35′ and 1° 55′. The effects afterwards corresponded with these, but they will be best understood from the observations themselves.

Compass No. I. *May* 18.

Time.	Points of Equilibrium.			Remarks.
	N. W.	N. E.	S. E.	
h. m.	° ′	° ′	° ′	
5 15	80 40	79 38	0 52	
6 00	72 36	72 46	1 06	
7 00	67 20	67 50	1 16	Clear sun, striking hot upon the magnets.
8 00	62 38	63 04	1 08	
9 00	64 26	64 48	1 00	The magnets somewhat sheltered by trees.
10 00	65 36	65 42	0 52	
11 00	52 28	50 56	1 04	The magnets had become hot.
Noon.	45 22	44 16	0 42	
1 00	49 32	49 14	0 06 W.	Sun obscured.
2 00	50 26	50 24	0 18 E.	
3 00	51 26	51 34	0 32	
4 00	51 52	51 48	0 30	Sun faintly out.
5 00	53 20	53 24	0 30	
6 00	54 00	54 06	0 26	
7 00	54 20	54 30	0 32	
8 00	55 40	55 50	0 36	Cold evening.
9 00	56 20	56 28	0 38	

Comparing the changes here with those of the day before, we have:

	Changes of direction.					
	May 18.			May 17.		
	W. point.	E. point.	S. point.	W. point.	E. point.	S. point.
	° ′	° ′	° ′	° ′	° ′	° ′
From the morning till the middle of the day -	35 18	35 22	1 22	3 56	4 26	0 44
From the middle of the day till night - -	10 58	12 12	0 44	8 04	8 28	0 40

The effect produced on the magnets by the heat of the sun appears to have been of a permanent character, since, although

the evening was cold, the needle did not return to within 24° and 23° of its situations in the morning. When the sun was hottest, a thermometer exposed to its rays stood at 97° FAHRENHEIT, so that the change in the temperature of the magnets could not exceed 50°.

On the day following, a thermometer being placed on the table with the bulb exposed close to the side of one of the magnets, I observed as follows:

Time.	Ther.	Points of Equilibrium.	
		N. W.	N. E.
h.	°	° ′	° ′
3 P.M.	73	50 28	50 58
9 P.M.	51.5	54 52	55 08

Here, although the magnets experienced a change of temperature of 21°,5, yet the changes of direction were only 4° 30′ and 4° 10′.

The observations with the other compass were of the same character on the 18th of May as those with No. I.: they were as follow:

Compass No. II, *May* 18.

Time.	Points of Equilibrium.			Remarks.
	N. W.	N. E.	S. E.	
h. m.	° ′	° ′	° ′	
5 10	26 25	28 40	3 15	Clear sky.
6 00	19 40	23 15	4 55	
7 00	19 30	24 20	5 05	
8 00	17 45	22 55	6 00	Clear sun, striking hot upon the magnets. Therm. in shade 63°; exposed to the sun 97°.
9 00	no point	13 00	no point	
10 00	no point	5 15	no point	

Finding the deviations so much increased and the magnets hot, I covered them over with porous earthen pans, pouring

cold water on the pans to reduce the temperature; and had at

Time.	Points of Equilibrium.			Remarks.
		N. E.		
h. m.		° ′		
11 0	no point.	7 20	no point.	I now uncovered the magnets.
11 15	no point.	1 45	no point.	
11 30	no point.	0 40	no point.	

The needle now appeared to have scarcely any directive power, since, when agitated again, it moved to N 1° 15′ W, and at $11^h 45^m$, on being agitated, it settled at N 2° 15′ W.

At this time I covered the magnets with blotting paper, to retain the water, and poured on them, for some minutes, water at the temperature 55°, after which I had at

	N. W.	N. E.	S. W.	
h. m.	° ′	° ′	° ′	
11 52	18 00	14 40	0 20	I removed the paper from the magnets.
0 55	14 55	9 20	0 20	
1 12	10 20	When the needle was at this point I again		

covered the magnets with paper, and poured water nearly boiling on them; when the needle went rapidly to 0°, then returned and stood steadily at N 1° 20′ W. I again reduced the temperature by pouring water at 55° on the magnets, and had, at

h. m.	N. W.	W. E.	S. W.	
1 25	17 10	14 10	0 10	
The needle pointing		14 10	I again poured hot water on the	

magnets; when it went rapidly to 0°, N 3° W, and, when continually agitated, stood at N 0° 40′ W, but a few minutes

afterwards at N 1° 20′ W. On cold water being poured on the magnets, they now only recovered their power so far that their forces were very nearly equal to the terrestrial forces, since the needle appeared to have little or no directive power either at north or at south: it would bear almost any degree of agitation at several positions within 3° or 4° on either side of these points. On the following morning at seven o'clock the magnets had recovered rather more power, the needle then pointing N 9° 10′ E.

In these observations the effects of increase of temperature, in diminishing the power of the magnets, are most decided, and certainly much beyond what could have been anticipated from the experiments of CANTON. The greatest change of temperature which these magnets underwent, could not exceed that to which his were subjected, and the power exerted on the needle by his, must have been fully equal to that of the magnets here made use of. The angle at which the forces were exerted, in the one case or the other, would have an effect, but not, as appears to me, equal to the difference in the deviations in the two cases. On this, however, I cannot speak decidedly, as I can at present only refer to the abridged account of his experiments. Another difference in the effects which took place in the two cases is, that after some hours, the magnets, which CANTON made use of, recovered their power; whereas, in the present instance, a considerable portion appeared to be permanently destroyed, although in the case of those applied to the compass No. I, they were not subjected to a heat by any means so great as those were which he employed, since the temperature of these could never have exceeded 100° FAHRENHEIT. After sixteen days, they now

produce only the same effect at the distance 15.25 inches which they previously produced at the distance 15.95; but during the whole of this time they appear to have exerted the same, or very nearly the same energy at the same temperature. It would appear then, that the permanent destruction of their power must have arisen from their being heated beyond a certain degree, and it does not seem improbable, that solar heat may have a greater influence than any other in producing such an effect.

Seeing then that such is the effect of the temperature of the magnets on the changes which take place in the points of equilibrium, it might perhaps be supposed that variations in it, if not the only, were the principal causes of the peculiarities which I have pointed out. Although I felt persuaded that this was not the case, I delayed presenting these observations until I had seen such peculiar effects taking place independent of the temperature of the magnets. For this purpose, I have been observing the changes in the points of equilibrium, in a situation where the magnets were exposed to very small variations in temperature, the greatest during eleven days not having exceeded 8° FAHRENHEIT, and not 4° during the observations of any day. The changes in the temperature of the magnets I regularly noted, and expected to see, in perhaps some few instances, that the changes in the situations of the points of equilibrium would be in opposition to those which would arise from the change of temperature in the magnets alone. My expectations have been more than answered; since I have noticed this to take place, not in a few instances, which, being decided ones, would have been sufficient to have established the principle, but repeatedly in the observations of the same day.

It will be remembered that, the effect of an *increase of temperature* in the magnets, by *diminishing the intensity* of their forces, is to make *both* the *westerly* and *easterly* points of equilibrium *approach* the *north*, and that a *diminution of temperature* has the effect of making them *both recede* from it, independent of any other cause. Now, in these last observations, it has only happened on one day that I have not seen repeatedly *both* points *approach* the *north* when the *temperature* of the magnets has *decreased*, and *both recede* from the north with an *increase of temperature;* showing clearly that the tendencies in one case of *both* points to *approach* the *north*, and of *both* to *recede* from it in the other, were sufficient to counteract the contrary tendencies arising from the changes of temperature in the magnets; and proving that the peculiar changes which I have noticed, although modified by the temperature of the magnets, were not the effects of it.

I do not propose at present to give these observations, as it is my intention to make a series on the precise effects of changes of temperature in the magnets, so as to be able to free the observations entirely from such effects, by reducing them to the same standard. When this is done, I shall no doubt find, that the extent of the deviations which I have obtained require some correction, chiefly in the observations with the needle out of the meridian; and I likewise expect that here the times of the maxima deviations will be found nearer to the times of the maximum intensity and minimum intensity, as determined by HANSTEEN; but the leading fact, of the *westerly* and *easterly* points *approaching the north at the same time*, and *receding from it at the same time*, during certain periods, will remain unaltered. Thus the conclusions which I have before drawn respecting the increase and decrease of intensity in the

terrestrial forces will not be materially affected by the changes which may have taken place in the temperature of the magnets during the times of observation. With regard to the observations in the meridian, that is, with the needle pointing *north* or *south*, they could not be much affected by changes in the temperature of the magnets, especially by such small changes as I am persuaded alone took place: the extent of the deviations may, in some instances, have been slightly increased or diminished, but their directions could not be changed.

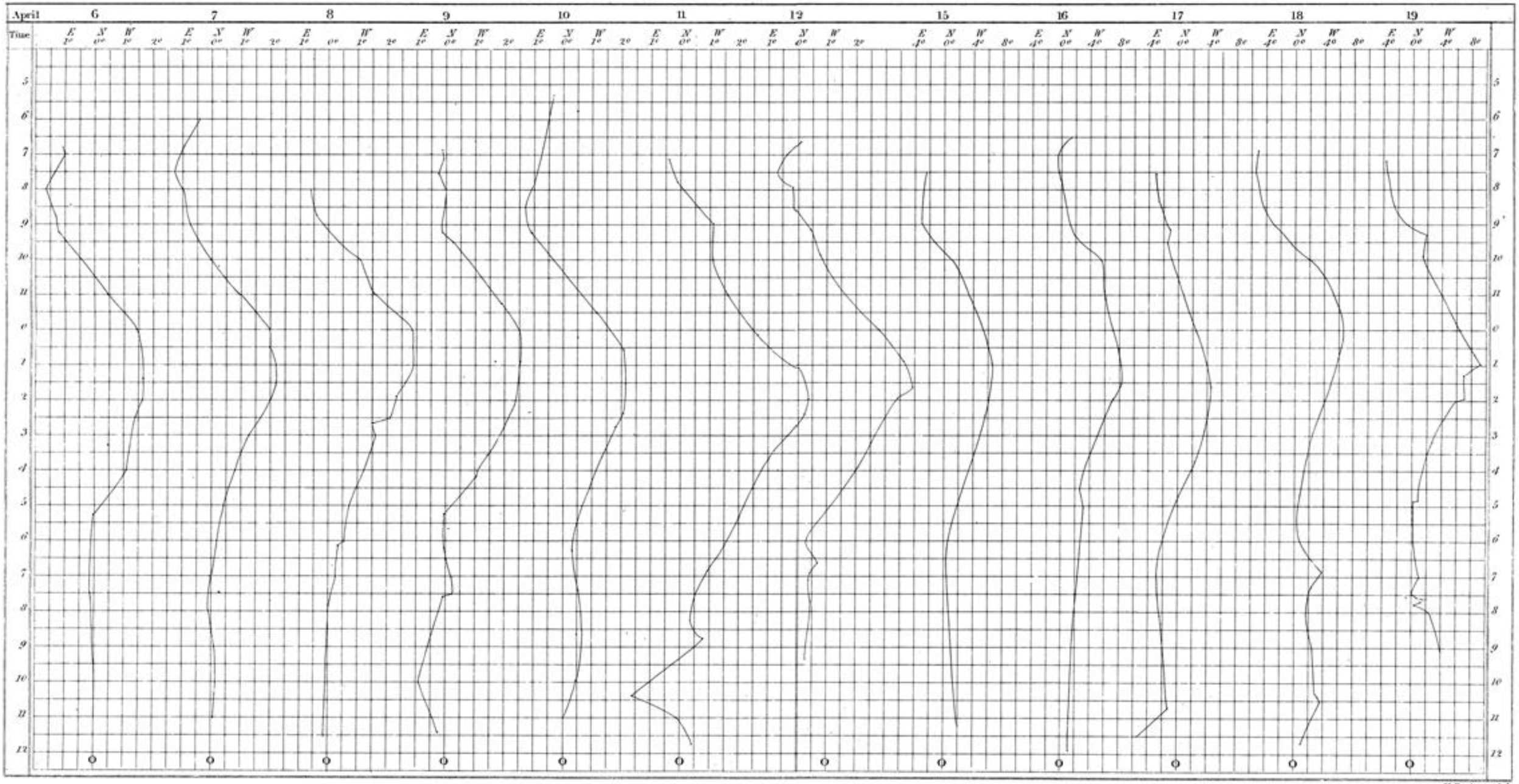
I have before mentioned that both Mr. BARLOW and myself found some anomalies between the observations in-doors and those at the same points in the open air. When the times of the maxima shall have been determined independent of the temperature of the magnets, I expect it will be found that these anomalies have arisen from the difference in the changes of temperature in the magnets when in-doors and when in the open air: of this I only feel that degree of doubt, which should always be entertained until a fact is established.

If such observations as I have given were continued for a length of time, particularly those near the east and west, I certainly expect that they would lead to important conclusions respecting the causes of the diurnal variation, and I regret that, as I have not the time to devote to them myself, I must leave them to be made by others possessed of more leisure. Should they be undertaken, the necessity of ascertaining in the first instance, the effects which changes of temperature have on the forces of the magnets employed, and of observing the temperature of the magnets themselves

when the directions of the needle are taken, is here clearly pointed out.

The striking effects which I have seen to arise from a change of temperature in the magnets have certainly led me to adopt the opinion, that temperature, if not the only cause of the daily variation, is the principal. This was the opinion of CANTON, but he could not, by it, account for the morning easterly variation. I might here offer some conjectures on this subject, but as it is not my intention at present to enter fully into the general question of the cause of the daily variation, I will defer them, at least until I shall have ascertained the precise effects of changes in the temperature of magnets.

Curves of the diurnal deviations of a magnetic needle whose directive power was diminished by the action of two bar magnets placed in the line of the dip: the N. end of the needle pointing north.



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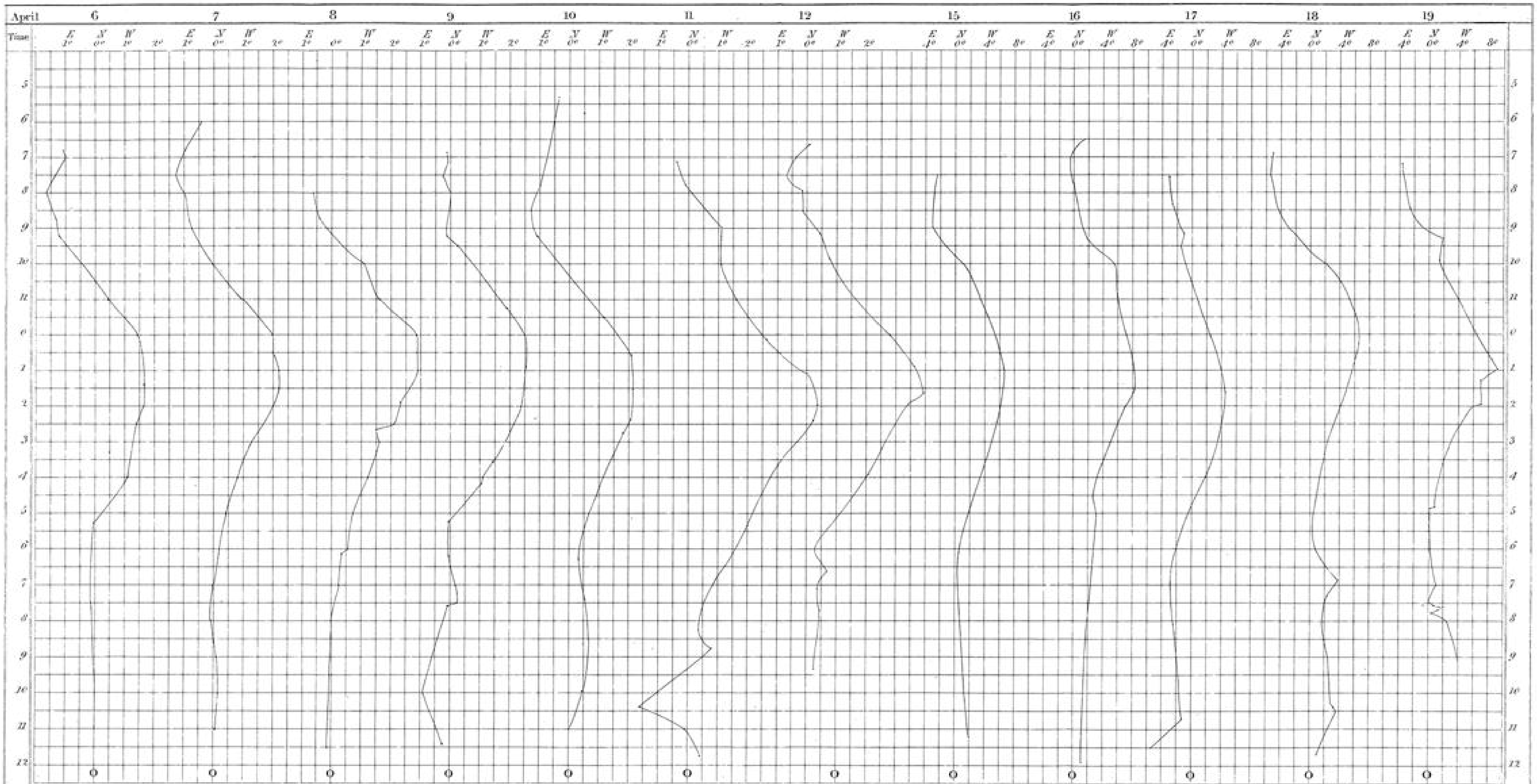

J. Basire sculp.