XXI. *Theory of the Diurnal Variation of the Magnetic Needle, illustrated by experiments.* *By* S. H. CHRISTIE, *Esq., M. A. F. R. S.*

Read June 14 and June 21, 1827.

IN a Paper published in the Transactions for 1823, I stated my opinion, that the diurnal variation of the needle was probably due to the influence of temperature, but that the principle adopted by CANTON would not account for the morning easterly variation. In a subsequent paper,* I pointed out that the changes in direction and intensity appeared always to have a reference to the position of the sun with regard to the magnetic meridian; the direction of the needle being undisturbed nearly at the time the sun passed that meridian; and the horizontal intensity being the least at the same time. Having taken this view of the subject previously to my being aware of Dr. SEEBECK's discovery, that magnetical phænomena will arise from a disturbance in the equilibrium of temperature, my knowledge of that discovery and of subsequent experiments, particularly those of Professor CUMMING, confirmed me in the opinion, that temperature must have a considerable effect in producing some of the phænomena of terrestrial magnetism, although I considered that this influence might be modified by the effects produced by rotation, or by peculiar influence in the sun's rays.

At the conclusion of the Paper† describing the experiments

* Philosophical Transactions, 1825.

† It appears that this Paper was read before the Cambridge Philosophical

to which I have referred, Professor CUMMING makes this remark: "Magnetism, and that to a considerable extent, it appears, is excited by the unequal distribution of heat amongst metallic, and possibly amongst other bodies. Is it improbable that the diurnal variation of the needle, which follows the course of the sun, and therefore seems to depend upon heat, may result from the metals and other substances which compose the surface of the earth, being *unequally* heated, and consequently suffering a change in their magnetic influence?" And in the second part of a paper detailing some thermo-magnetical experiments, read before the Royal Society of Edinburgh, Dr. TRAILL considers, "that the disturbance of the equilibrium of the temperature of our planet, by the continual action of the sun's rays on its intertropical regions, and of the polar ices, must convert the earth into a vast thermo-magnetic apparatus:" and "that the disturbance of the equilibrium of temperature, even in stony strata, may elicit some degree of magnetism."* I am not, however, aware that any thermo-magnetical experiments bearing directly on the subject of the phænomena of terrestrial magnetism, have yet been published.

By varying the original experiment, Professor CUMMING,

Society in April, 1823, but was not published for a considerable time afterwards; and I was not aware of its having been read when I sent my second Paper to the Royal Society in 1824.

* This interesting communication appears to have been read in February, 1824, but I believe it has not yet appeared in the Edinburgh Philosophical Transactions; and I only know it from a short abstract in the Edinburgh Philosophical Journal for October, 1824, with which, however, I was not acquainted, until I had made nearly the whole of the thermo-magnetic experiments described in the present Paper.

Dr. TRAILL, M. BEQUEREL, and others, obtained many highly interesting results; but in all these, the metals had been united only at *particular points*, and heat or cold applied at *the joints;* and I am not aware of any experiments having been made with different metals *symmetrically united throughout.* Perhaps however the following experiment, mentioned in the abstract of Dr. TRAILL'S Paper, may be considered an exception: "When a piece of metal has one of its surfaces applied *flatly* to another equal metallic plate, a thermo-magnetic combination is formed." It is an exception, and one bearing directly on the subject, if we are to look to "*the disturbance of the equilibrium of temperature in stony strata,*" as the cause of any of the phænomena of terrestrial magnetism. If however these phænomena are to be attributed to *electro-magnetism excited by heat*, it appears to me more probable, that *the disturbance of the equilibrium of temperature* arises from the *inequality of the conducting powers of the atmosphere, and of the land or water, with which it is every where in contact*, or *of those of the land and water*, than from the difference in the conducting powers of the various *strata* of the earth itself.

Thermo-magnetic phænomena have as yet only been exhibited by *metallic* combinations, but this may have arisen from the smallness of the masses on which we may have been enabled to experiment; and it is by no means improbable, that, were experiments made on a large scale, these phænomena might be exhibited in combinations of *any substances whose conducting powers differ greatly.*

Admitting then the possibility of electro-magnetism being excited in such combinations as the *earth and its atmosphere,*

their contact being supposed to take place as between *a bar and a wire connecting the two ends*, heat being applied at *a joint*, we must first enquire, whether substances which exhibit magnetic phænomena when *thus joined*, and heat is *so applied*, will *also* exhibit them when their contact is *symmetrical throughout*, and heat is applied to *any point;* and if so, whether the directions in which the forces elicited would act, according to the distribution of heat on the earth, will account for any of the phænomena of terrestrial magnetism.

In the first experiments which I made with these views, I employed a compound ring of bismuth and copper, the bismuth having been cast in a circular ring, the outer circumference of which was formed by a slip of thin copper having the two ends rivetted together, and holes punched through at regular distances: the metals were thus in contact throughout. With this ring I immediately found, that, to whatever point heat was applied, magnetic phænomena were exhibited, a needle being affected differently, according to the different positions in which the ring was placed with regard to it. It is not my intention to detail the results which I obtained, as, although they were as uniform as I could expect, the experiments were made only for a first trial, to ascertain whether any sensible effect would be produced on a needle, by copper and bismuth so united, to whatever point in the combination heat was applied. They removed all doubt on this part of the subject; but after making them, I was so much otherwise engaged, that more than two years elapsed before I had sufficient leisure to repeat and extend them with a more efficient apparatus.

In the experiments which I have more recently made, and

which I shall now describe, I made use of a flat ring of cast copper, the outer diameter of which is 11·9 inches, the inner diameter 10·05 inches, ·24 inch in thickness, and weighing 31 oz. Tr. In the interior side of this ring, three grooves were turned, and this side was covered with solder, consisting of 2 parts bismuth and 1 part lead, which, being fusible at a very low temperature, ensured a perfect contact between the copper ring and the bismuth which was cast in the interior of it. This formed a circular plate nearly 12 inches in diameter, and weighing 119 oz. Tr. A wooden axis passed through a hole, ·3 inch in diameter, in the centre of the plate, so that it could be made to revolve in its own plane.

This plate being placed vertically or horizontally, a small compass, with a needle two inches in length, very delicately supported, and having the rim within the box, which is of silver, accurately divided to degrees, was placed in different positions with regard to it; the directive force of the needle being always diminished in the ratio of 9 to 1, by means of a bar magnet placed at an invariable distance to the south of the needle. Heat was then applied to a point in the periphery of the plate for a certain time, by means of a lamp with a small wick, giving a small and well defined flame. The lamp being removed, and the deviation of the needle observed, different points of the plate were successively brought under, or opposite to, the needle, according as it happened to be placed over, or by the side of, the plate, by turning it, in its own plane, about the axis at right angles to it, and the deviation of the needle corresponding to each position of the plate, noted. When the plate had been brought into its original position, and the deviation corresponding to this position

again noted, the lamp was again applied to the same point, for the same time as before, and a second set of observations made, by bringing the several points of the plate to the compass in the order contrary to that which had been previously used. By this means, the deviation of the needle corresponding to each position of the plate, and to a temperature of the heated point nearly a mean between its temperature at commencing and that at concluding the observations, was obtained.

The experiments which I proposed to myself were these: to place the plane of the plate vertical, and likewise horizontal; in the former case both in the plane of the meridian, and at right angles to it: to adjust the compass to certain positions with regard to its centre and surface, and to observe the effects produced on the needle when the heated point on the plate had various positions. By this means, I expected to be able to determine the nature of the laws which these deviations observed in all cases, or the species of polarity in the plate which would account for them. Having made these observations, I found that, if through the place of heat a diameter were drawn, which, for distinction, I call *the axis of heat*, and another at right angles to it, then looking on to either side of the plate, with the place of heat downwards, if I supposed a *south pole* in the lower quadrant on the *right hand*, and a *north pole* in that on the *left*, the character of the deviations would agree with such polarity of the plate.

It is not my intention to enter upon any theoretical views with regard to the nature of the forces which are the cause of thermo-magnetical phænomena: whether they arise from electric currents being excited in particular directions, and

acting in a peculiar manner on a magnetised needle, or not, is not the object of my present enquiry, although the experiments which I shall detail may be of a nature to throw some light on this part of the subject. I therefore adopt the term *pole*, as a convenient one, to indicate in a general manner, the points towards which the attractive and repulsive forces, apparently acting upon the needle, seem to tend; and the term *axis of polarity*, to indicate the line joining two poles, the forces towards one of which are attractive, and towards the other repulsive, for the same end of the needle.

My first object was to ascertain that, whatever might be the action of the plate, it was tolerably uniform throughout. This was done in the first instance by placing the plate with its plane in that of the meridian, and the centre of the needle in the vertical diameter produced, at the distance ·55 inch from the upper edge, and then observing the deviations, in the manner I have described, when different points of the plate had been heated, by applying the lamp to them for two minutes, taking care, after a set of observations had been made for each heated point, to cool the whole previously to heating another. The circumference of the plate was on one face divided into eight equal parts, and the points of division numbered 0, 45, 90, 135, 180, 225, 270, 315, so that this face being towards the west and 0 downwards, 90 was south. The observations are contained in the following table. The centre of the plate being taken as the centre, the angular distances between the centre of the needle and the heated point are indicated in the first column: they are measured from the vertical towards south, and always in the same direction to 360°. The observed deviations of the needle,

corresponding to these different angular positions of the heated point, are inserted in the columns over which are indicated the points on the plate which were successively heated; the deviations in the first column of each set being due to the particular angular positions of the heated point when that point approached the compass through the north; those in the second, when it approached through the south; and those in the third, the means of these two, and which are considered as the deviations due to the several positions of the heated point, had that point preserved its mean temperature throughout the revolution of the plate.

Angular distance of the heated point from the centre of the compass.	0 the heated point.			18 ie heated point.			90 the heated point.			270 the heated point.			Means of the mean Deviations.
	Deviations.			Deviations.			Deviations.			Deviations.			
	When the points on the plate brought under the compass in the			When the points on the plate brought under the compass in the			When the points on the plate brought under the compass in the			When the points on the plate brought under the compass in the			
	Direct order.	Reverse order.	Mean.	Direct order.	Reverse order.	Mean.	Direct order.	Reverse order.	Mean.	Direct order.	Reverse order.	Mean.	
°	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
180	3 00 E	0 30 E	2 15 E	0 45 E	0 30 W	0 15 E	1 30 E	0 30 W	0 52 E	0 30 W	1 30 W	1 22 W	0 30 E
225	12 30 W	12 30 W	12 30 W	22 30 W	17 45 W	20 07 W	23 30 W	16 45 W	20 07 W	15 00 W	17 00 W	16 00 W	17 11 E
270	32 30 W	23 30 W	28 00 W	34 00 W	25 45 W	29 52 W	34 30 W	24 30 W	29 30 W	26 30 W	26 30 W	26 30 W	28 28 E
315	32 00 W	26 30 W	29 15 W	31 00 W	25 30 W	28 15 W	30 30 W	25 00 W	27 45 W	26 30 W	33 00 W	29 45 W	28 45 E
0	3 30 W	7 00 W	5 15 W	1 30 E	1 45 W	0 07 W	5 15 E	0 15 E	2 45 E	4 00 W	8 45 W	6 22 W	2 15 W
45	22 00 E	33 00 E	27 30 E	23 30 E	31 30 E	27 30 E	26 00 E	33 00 E	29 30 E	16 15 E	34 30 E	25 22 E	27 28 E
90	20 30 E	35 30 E	28 00 E	24 30 E	36 00 E	30 15 E	25 00 E	34 30 E	29 45 E	16 30 E	38 30 E	27 30 E	28 52 E
135	12 00 E	25 00 E	18 30 E	16 30 E	23 30 E	20 00 E	16 30 E	25 00 E	20 45 E	9 15 E	23 30 E	16 22 E	18 54 E
180	1 00 E	4 30 E		0 30 E	0 15 E		1 00 E	2 30 E		0 30 W	3 00 W		

In comparing the mean results when the different points of the plate were heated, it is to be considered that minute accuracy could not be attained, either in applying the lamp to the *precise* point indicated, or *exactly* to the middle point between the two surfaces of the plate; and that the angular distances

of the heated point were liable to errors arising from the first circumstance, as well as from adjustment; also, that the needle not always coming to rest in the same time, it was not possible to make the successive observations at precisely the same intervals throughout. Such care was however taken to guard against this last source of error, that each set was made in very nearly the same time: the whole set, when the point 0 was heated, occupied 18 minutes; that when 180 was heated, 18 minutes; that when 90 was heated, again 18 minutes; and that when 270 was heated, 19 minutes. The observations then clearly show that the deviations of the needle, corresponding to the several positions of the heated point, did not arise from a peculiarity in the arrangement of the particles, or in the contact of the two metals, in particular parts of the plate; but that to whatever polarity in the plate, or to whatever electric currents these deviations were due, these poles were symmetrically situated, or these currents were uniformly excited, to whatever point in its circumference heat was applied: and that, consequently, whatever might be the results obtained by applying heat in all cases to the same point in the circumference, they would not differ sensibly from the mean of the results obtained from corresponding observations, if heat were applied to several points successively, as in the foregoing instance, in each particular case. To have adopted the latter method in every particular position of the compass and the plate, in which I proposed to investigate the effects, would indeed have been almost an endless task: however, to leave no doubts respecting the results which I might obtain, whenever the deviations were of a nature that might possibly arise from a want of uni-

formity of action in the plate, I invariably observed the deviations corresponding to the heating of different points. In some positions of the compass, observations were made when 0, 45, 90, 135, 180, 225, 270, 315 had each been the heated point, and likewise when the plate had been reversed; but in no instance did the results differ in character, or even the corresponding deviations vary much in their extent, to whatever point heat had been applied.

To determine the laws which govern the magnetic phenomena resulting from the application of heat to a point in such a metallic combination as I made use of, I first adjusted the plane of the plate at right angles to the plane of the meridian, and placed the compass with its centre in the plane of the meridian passing through the centre of the plate, with its centre 6 inches above that centre, or opposite to the outer edge of the copper ring, and 1·3 inch to the north of the plane of the plate, that is, as near to it as the compass-box would, without touching, admit. The lamp having been applied for 5 minutes to the outside of the copper ring at the point 0, which was the lowest, the deviations of the needle corresponding to the different angular positions of the heated point were observed, as in the preceding instance. Corresponding observations were made when the compass was in the position diametrically opposite, or below the centre of the plate; and also when in the same horizontal plane with that centre, to the east or to the west of it, opposite the outer edge of the copper, at the same distance, 1·3 inch north from its surface: and similar observations to these were likewise made with the centre of the needle, in the corresponding positions, to the south of the plate. Observations also, of precisely the same nature as these, were made with the centre of the

compass opposite to the line of junction of the copper ring with the circular plate of bismuth. I thus obtained the deviations of the needle when the compass was opposite to the outer edge of the copper, and when it was opposite to the line of junction of the copper and bismuth, in eight different positions of the compass, in each case; the heated point being, in each position of the compass, in four different positions with respect to the centre of the needle.

The observed deviations, corresponding to the different angular positions of the place of heat from the needle, the centre of the plate being the angular point, are contained in the following table, where this angle is measured from the needle, in the direction of the sun's daily motion, round the whole circle.

Table of the deviations of the needle when the plane of the plate was at right angles to the plane of the meridian, and the centre of the needle opposite to the outer edge of the copper.

Angular distance of the place of heat from the centre of the compass.	The centre of the needle being in the plane of the meridian passing the plate's centre.				The centre of the needle being in the horizontal plane passing through the plate's centre.			
	Above the plate's centre, and		Below the plate's centre, and		To the east of the plate's centre, and		To the west of the plate's centre, and	
	1·3 inch north of its surface.	1·3 inch south of its surface.	1·3 inch north of its surface.	1·3 inch south of its surface.	1·3 inch north of its surface.	1·3 inch south of its surface.	1·3 inch north of its surface.	1·3 inch south of its surface.
°	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
0	29 30 W	26 45 E	29 00 E	28 15 W	6 15 W	10 00 E	7 15 E	11 30 W
90	24 30 E	24 45 W	6 00 W	5 00 E	35 30 E	32 30 W	30 00 W	33 00 E
180	5 00 E	9 15 W	7 45 W	7 00 E	0 05 E	0 30 W	2 30 W	5 00 E
270	3 00 E	5 00 W	11 30 W	11 00 E	34 30 W	34 00 E	25 30 E	26 30 W
Table of the corresponding deviations of the needle when its centre was opposite to the line of junction of the copper and bismuth.								
0	47 30 W	48 00 E	44 45 E	31 15 W	8 30 W	10 45 E	6 00 E	13 45 W
90	10 45 E	5 15 W	6 00 W	6 45 E	14 45 E	13 15 W	14 20 W	18 20 E
180	23 30 E	26 00 W	15 30 W	11 30 E	0 30 W	2 30 W	3 00 W	4 15 E
270	164 30 E	167 30 W	{ 135 00 W 61 15 W	165 00 E 43 30 E } *	51 30 W	44 45 E	45 30 E	52 00 W

* The upper numbers indicate the directions of the needle when first observed, the lower ones those which it assumed almost immediately afterwards. These directions correspond to different positions of equilibrium noticed in a former paper; Phil. Trans. 1823.

If these deviations are to be considered as due to polarity in the plate, the situations of the poles may be deduced from them, pretty nearly, without entering into any calculations; for which purpose indeed the observations could scarcely be made with sufficient precision. For example: the needle being below the centre, and the heated point opposite to it, it is evident, from the character of the deviations, that, looking from the compass on to the plate, either there must be a *south* pole to the *right* of the needle, *or* a *north* pole to its left; or a *south* pole to the *right and* a *north* pole to the *left*. As however the direction of the deviation is changed by making the heated point describe a quadrant, on *either* side of the compass, both these poles must exist, the *south* pole being within the lower quadrant on the right, and the *north* pole within that on the left. The positions of these poles are more precisely fixed by some of the other observations. When the compass was opposite to the line of junction of the copper and bismuth, above the centre of the plate, and to the *north* of its surface, the angular distance of the place of heat from the centre of the needle being 180°, the deviation was 23° 30′ east; when this distance became 270°, the place of heat being 90° to the *east*, or to the *left* of the compass, the deviation became 164° 30′ east; and as the place of heat approached the needle, the *north* end passed through *south*, the deviation becoming N 47° 30′ W, when the place of heat was opposite to the compass. This effect is precisely that which would have taken place had a strong *north* pole existed in the *north*, or marked surface of the plate, in the radius forming an angle of about 64° with the axis of heat, to the *left* or *east*, supposing the place of heat downwards; this *north* pole,

as the plate turned on its axis, passing to the south of the needle and repelling its *south end*, or *north pole*. When the needle was to the *south* of the plate, similar changes in its direction fix the position of a *south* pole in a point on its *south*, or unmarked surface opposite to the *north* pole on the *north* side. The observations below the centre indicate the same positions for the pole. I should mention that these observations were made when o was the heated point: but to leave no doubt with regard to these results being due to a uniform action in the plate, I made corresponding observations when 315, 270, 225, 180, 135, 90, 45 were successively the heated points, and in all cases obtained corresponding results. By reversing the sides of the plate, that is, making the marked face south, the observations showed that the positions of the poles were independent of this circumstance.

From the deviations being of the same character, but of greater extent, when the needle was opposite to the line of junction of the copper and bismuth than when opposite to the outer edge of the copper, it would follow, that the poles were nearer to the centre of the plate than this line of junction. I afterwards found, by placing the compass in the horizontal plane passing through the centre of the plate, and at different distances from it towards the east, that when the place of heat was the lowest point, the *north* pole on the *north* side of the plate was in the vertical 4 inches to the *east* of the centre, and *below* the compass; and when the centre of the needle was at this distance to the east, by making the place of heat describe 45° towards the compass, the *north* pole appeared to be a little to the east of the needle's centre, and *above* it. I thus determined, pretty accurately, that the lines drawn to the poles on the east side of the axis of heat, made an angle with that axis of

about 64°, and that the poles were at the distance 4·5 inches from the centre.

The same positions of the poles will account for the deviations when the compass was to the east, or to the west of the plate's centre. It however appears from these, that the plate did not act with *perfect* uniformity; that is, that the poles were not *quite* symmetrically situated with respect to the axis of heat. If the *axis of polarity* be supposed to cut the *axis of heat* about 1·9 inch from the centre towards the place of heat, and to be inclined to it so that, supposing the place of heat downwards, the angle below *the axis of polarity* on the western side is slightly obtuse, and on the eastern side, acute, it would perfectly account for the nature of the deviations when the angle between the place of heat and the compass was 0, or 180°.

It would appear then, that such deviations as those observed with the plane of the plate at right angles to the plane of the meridian would arise from four poles in the plate, two near each surface, in a line cutting the axis of heat nearly at right angles, between the centre and the place of heat, the *south* pole being on each surface of the plate on the *right* hand, looking on that surface from the place of heat.

The same polarity will also account for the deviations that I observed with the plane of the plate in the plane of the meridian, and likewise with its plane horizontal. The observations with the plane of the plate in the plane of the meridian were made in precisely the same manner as the preceding, with the addition, that the deviations were likewise observed when the heated point was 45° on each side of the needle. In these the marked face of the plate was west, and

the lamp was applied to the point marked o, as before. They are contained in the following Table.

Table of the Deviations of the Needle when the plane of the Plate was in the plane of the Meridian, and the centre of the Needle opposite to the outer edge of the Copper.

Angular distance of the place of Heat from the centre of the Compass.	The centre of the Needle being in the vertical plane at right angles to the plate and passing through its centre.				The centre of the Needle in the horizontal plane passing through the Plate's centre.			
	Above the Plate's centre, and		Below the Plate's centre, and		To the North of the Plate's centre, and		To the South of the Plate's centre, and	
	1·3 inch East of its surface.	1·3 inch West of its surface.	1·3 inch East of its surface.	1·3 inch West of its surface.	1·3 inch East of its surface.	1·3 inch West of its surface.	1·3 inch East of its surface.	1·3 inch West of its surface.
°	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
0	2 15 E	2 15 E	{ 11 00 E 1 00 E	2 52 E 0 15 E } *	4 45 E	3 15 E	2 45 E	1 30 E
45	13 00 W	14 00 W	14 15 W	17 00 W	37 15 W	13 30 W	16 30 W	30 00 W
90	10 00 W	9 00 W	8 45 W	11 30 W	36 30 W	10 30 W	11 07 W	24 15 W
180	0 15 W	0 15 W	0 00	0 15 W	0 30 E	1 15 E	0 30 W	0 52 W
270	9 15 E	7 00 E	9 15 E	10 45 E	15 37 E	16 00 E	17 45 E	12 15 E
315	12 45 E	12 15 E	10 45 E	13 00 E	20 30 E	22 00 E	21 45 E	14 30 E
Table of the corresponding Deviations of the Needle when its centre was opposite to the line of junction of the Copper and Bismuth.								
0	6 00 E	9 00 E	{ 10 00 E 0 37 W	7 45 E 0 15 W } *	12 00 E	15 15 E	3 15 E	5 30 E
45	34 30 W	45 00 W	34 00 W	40 00 W	77 00 W	38 45 W	36 30 W	61 00 W
90	39 00 W	29 45 W	25 45 W	36 00 W	74 00 W	29 00 W	27 45 W	59 15 W
180	0 22 E	1 15 W	1 07 E	0 15 E	0 00	0 37 W	2 00 W	2 00 W
270	40 00 E	29 00 E	25 15 E	36 30 E	30 15 E	65 30 E	51 00 E	28 30 E
315	36 30 E	44 00 E	30 00 E	31 00 E	38 30 E	72 00 E	58 30 E	34 30 E

* It will be remembered, that, in all cases, the first observation of the deviation was made, after removing the lamp, when the point to which the lamp had been applied was the lowest, and the deviation was again observed when this point was brought into the same situation, by the plate having been turned on its axis, in order to observe the deviations due to other positions of the heated point; and likewise, that similar observations were made when the plate was turned in the contrary direction. In each of these four positions, then, of the compass, there were four observations corresponding to the angular distance 0°: the upper numbers are the means of the deviations first observed on removing the lamp; and the lower, the means of those when the plate was again brought round into its original position. In the position of the needle opposite to the line of junction of the copper and bismuth, and to the east of the plate, during the time that the lamp

In this position of the plate, the deviations of the needle arising from the action of four poles in the plate, in the situations I have indicated, with the compass in corresponding positions on contrary sides of the plate, would, in each, be in the same direction, the preponderating force on the one side being attractive, on the other side repulsive. These deviations would not however be equal; the limit of the deviation due to the attractive force, however great, being the azimuth of the attracting pole from the centre of the compass; and the limit of that due to the repulsive, the supplement of this angle. So that when the force is considerable, and this angle much less than a right angle, the deviation arising from the repulsive force on one side, will greatly exceed that due to an equal attractive force on the other. On examining the deviations in these tables, it will be found, that, when the deviation on one side of the plate greatly exceeds the corresponding one on the other, as 77° W., 38° 45′ W.; 74° W., 29° W.; 65° 30′ E., 30° 15′ E.; 72° E., 38° 30′ E.; &c., the situations of the poles were such that the deviations in the former cases were due to repulsion, and in the latter to attraction.

The deviations corresponding to the angular distance 0, being in this position of the plate all easterly, is in accordance with what I have stated with regard to the inclination of *the axis of polarity* to *the axis of heat*. According to this,

was applied, the deviation was N. 140° E., and when it was removed, the needle stood for an instant at N. 117° E., and then moved gradually back till it came to N. 10° E., when the observation was made. This great deviation, probably, arose from some irregularity in the action of the flame during the time it was applied; or, possibly, of the plate itself, rendered, in this position of the compass, at that time particularly sensible.

likewise, if the sides of the plate were reversed, that is the marked face placed east instead of west, the corresponding deviations should be all westerly; and on examining the observations which I made with the marked face so placed, the compass being in the same horizontal plane as the centre of the plate, and opposite to the line of junction of the copper and bismuth, I find them to have been; with the needle to the north of the centre of the plate, 8° W., when it was 1·3 inch to the east of it, and 5° 45′ W., when 1·3 inch to the west; also 12° W., when it was 1·3 inch to the east, and 14° 45′ W., when 1·3 inch to the west, and on the south side of the centre. The other observations agreed with those in the preceding table.

In the observations which I made with the plane of the plate horizontal, and which in every other respect were similar to the preceding, the marked face, or that which in the other observations had been towards the west or the north, was upwards. The compass was placed north, south, east, and west of the centre of the plate, and, as before, its centre 1·3 inch from the surface, and vertically above and below the outer edge of the copper ring. It was likewise placed in corresponding positions vertically over the line of junction of the copper and bismuth; but the corresponding observations could not be made below the plate, as the extremity of the needle was in general hid by it. The plate was, as before, turned in its own plane, and the deviations of the needle noted when the place of heat had different positions with respect to the compass. The observations are contained in the following table, where the angular distance of the place of heat is measured from the needle in the direction of the sun's daily motion round the whole circle.

Table of the Deviations of the Needle when the plane of the Plate was horizontal, and the centre of the Needle vertically above or below the outer edge of the Copper.

Angular distance of the place of Heat from the centre of the Compass.	The centre of the Needle being in the plane of the meridian passing through the Plate's centre.				The centre of the Needle in the vertical plane at right angles to the meridian and passing through the Plate's centre.			
	To the North of the Plate's centre.		To the South of the Plate's centre.		To the East of the Plate's centre.		To the West of the Plate's centre.	
	1·3 inch above its surface.	1·3 inch below its surface.	1·3 inch above its surface.	1·3 inch below its surface.	1·3 inch above its surface.	1·3 inch below its surface.	1·3 inch above its surface.	1·3 inch below its surface.
°	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
0	5 45 E	11 30 W	9 00 W	8 45 E	5 45 W	2 22 E	1 00 E	2 15 W
45	0 38 E	5 00 W	3 45 W	1 30 E	18 15 E	25 45 W	16 15 E	24 30 E
90	2 30 W	5 00 E	3 00 E	2 15 W	14 00 E	23 15 W	15 30 W	22 15 E
180	3 00 W	3 15 E	2 00 E	3 30 W	4 22 W	1 15 W	0 38 E	0 08 E
270	4 00 W	2 30 E	2 30 E	5 30 W	22 30 W	21 45 E	15 30 E	21 00 W
315	0 52 E	3 15 W	1 20 W	3 08 E	25 30 W	22 00 E	17 00 E	27 00 W

Table of the corresponding Deviations of the Needle when its centre was vertically above or below the line of junction of the Copper and Bismuth.

0	11 00 E	18 00 W*	16 00 W	12 45 E*	0 30 E	Observations could not be made in this position of the compass.	1 30 E	Observations could not be made in this position of the compass.
45	1 15 E	8 00 W	6 00 W	2 45 E	20 15 E		11 30 W	
90	4 00 W	6 45 E	4 45 E	3 15 W	16 00 E		14 30 W	
180	5 00 W	6 30 E	4 00 E	6 00 W	0 00		1 00 W	
270	6 15 W	4 30 E	5 00 E	8 30 W	17 00 W		15 00 E	
315	1 30 E	5 00 W	3 30 W	3 30 E	18 45 W		14 00 E	

The character of these deviations perfectly accords with the position which I have assigned to the poles in the plate, but when the centre of the needle was in the plane of the meridian, and the heated point directly under or over it, the extent of the deviations, compared with others, was greater than would arise from this position of the poles, supposing

* These observations were made with the centre of the compass vertically below a point ·35 inch from the line of junction towards the outer edge, the extremity of the needle not being visible when nearer to the centre of the plate.

them to be the points of greatest intensity. Throughout the observations, however, a certain degree of irregularity was manifested when the heated point was that nearest to the compass. This, supposing the action to be produced by currents excited in the plate, would arise from the much greater energy of these currents in the immediate neighbourhood of the heated point, and likewise from their being more influenced by variations in the temperature of that point there, than elsewhere. And it is to be observed, that although I have in a general manner referred the action of the whole plate to four poles, in certain positions, yet I by no means suppose, that the forces acting upon the needle tend to points absolutely fixed, whatever may be the position of the compass: and, indeed, I have rather adopted the term, *pole*, to illustrate, in a general manner, the nature of the effects, than as supposing that the action which takes place between the plate and the needle can, in all cases, particularly in the immediate vicinity of the heated point, be *precisely* represented by that which would take place between the poles of two magnets.

It appears, then, from all these observations, that, when heat was applied to a point in the copper ring, the characters of the deviations of the needle, and generally also their extent nearly, were such as would arise from a polarising of the plate in lines nearly at right angles to *the axis of heat*, and cutting that axis between the centre and the place of heat, near each surface, *contrary* poles being *opposite* to each other in the two surfaces. We may therefore, I think, infer, that, if magnetic phænomena are manifested by heat being applied to the joint of two substances, united in any of the

usual ways, they will likewise be exhibited when the line of junction is symmetrical throughout, as with a ring of one substance surrounding a circular plate of another, heat being any where applied; and that these phenomena will nearly correspond to a polarising of the compound disc, similar to that which I have indicated for the plate of bismuth and copper; the precise positions of the points to be considered as poles depending upon the nature of the substances united.

Admitting, then, that the *earth and the atmosphere* are subtsances in which such action can, under any circumstances, take place, these experiments would indicate that *any portion of the earth, bounded by parallel planes, with the atmosphere surrounding it, would become similarly polarised, if one part were more heated than another.* Thus, considering alone *the equatorial regions of the earth,* we should have *two magnetic poles on the northern side, and on the southern side two poles similarly posited; the poles of different names being opposed to each other on the contrary sides of the equator.*

In order fully to investigate this subject, it would be necessary that we should know the times of maximum and minimum heat, at least in the equatorial regions, both on the continents and likewise over the surface of the sea; if however we assume, that, in general, the greatest heat occurs about 3 o'clock in the afternoon, and the least about 5 o'clock in the morning, when the sun is vertical to the equator, which is probably very near the truth, it will serve to give an outline of the effects that would be produced on the needle by the revolution of such poles, developed on each side of the equator. According to this view, the coldest point

on the equator will be 150° west, or 210° east from the hottest point. On the *northern* side of the equator, we should therefore have the *north* pole which is to the *west* of the place of heat, of *greater* intensity, and *nearer* to that place, than the *south* pole which is to the *east* of it; but, supposing the hypothesis to be correct, the precise situations of these poles could only be determined from accurate observations of the diurnal variation of the needle. Different points in the earth's equator becoming successively those of greatest heat, these poles would be carried round the axis of the earth, and would necessarily cause a deviation in the directions of the horizontal needle in different parts of its surface. We have then to consider, whether the deviations that would arise from magnetic poles, so circumstanced, correspond with the observed diurnal variations of the needle.

With this view, I had proposed to compare the deviations of the needle, caused by the compound plate of bismuth and copper, with the diurnal changes in the needle, observed at different places, by adjusting the plate so that its plane should make with the horizon an angle equal to the complement of the latitude of the place of observation, and the axis about which it revolved an angle with the magnetic meridian equal to the variation at that place: the centre of the needle being then placed vertically over the centre of the plate, the poles in the plate would represent those which I have supposed to be developed on each side of the equator. I however found that at such a distance as the compass would here be placed from the plate, the deviations caused by it would not be of a magnitude to be determined with sufficient accuracy, with the small compass which I had employed. A pretty close approx-

approximation, however, to the nature of these deviations, may be obtained by making two magnetic poles revolve, relatively to a needle, in the same manner as I have supposed those near the equator.

For this purpose I made use of an instrument somewhat resembling an altitude and azimuth circle. To the vertical graduated limb an axis, in the direction of a diameter, is firmly attached. Perpendicular to this axis is a graduated circle carrying two arms, to the ends of which slender bar magnets 6 inches in length are attached perpendicularly to the plane of the circle, and so that their upper poles, which are of contrary names, are in the plane of the circle. These arms are moveable, and may be fixed so that the poles shall subtend any required angle at the centre of the circle, which, with the magnets, may be made to revolve round the axis. It is evident, that if the axis be inclined to the horizon at an angle equal to the latitude of the place of observation, and so that the azimuth of its lower extremity from south of the magnetic meridian be the same as the variation of the north end of the needle at that place, then, a needle being placed vertically over the centre of the revolving circle, the magnets would revolve, relatively to the needle so placed, as the poles which I have supposed near the equator, with respect to a needle at the place of observation; and the deviations of this needle, corresponding to particular positions of the magnets, would indicate the nature of the changes due to the action of poles, similarly placed, near the equator of the earth.

For the purpose of comparison, I have selected the observations made by Lieut. Hood in 1821, at Fort Enterprise,

lat. 64° 28′ N. long. 113° 06′ W, where the variation was 36° 24′ E; those made by CANTON in London in 1759, when the variation was nearly 19° W; and the highly interesting observations made by Lieut. FOSTER in the early part of 1825, at Port Bowen, lat. 73° 14′ N, long. 88° 54′ W, and where the variation was 124° W.

As Colonel BEAUFOY had for so many years observed the course of the variation of the needle with the most zealous care, and having the advantage of the best instruments, I hoped to have been able to procure a set of his observations at every hour during the day, for a considerable period of time; and I have no doubt, had it not been for the recent loss which science has sustained by the death of that able and indefatigable observer, that whatever observations he had made, that could at all have been applicable to the purpose I had in view, would have been placed at my command, with that liberality for which he was so much distinguished. His published observations, which were commenced in the year 1813, were generally made between 8 and 9 o'clock in the morning, and 1 and 2 in the afternoon, with the view of determining the maximum easterly and the maximum westerly deviations. The last observations to which the times are given are for March 1822, and the mean of these gives $8^h\ 32^m$ A.M. as the time of the maximum east, and $1^h\ 29^m$ P.M. as the time of the maximum west; the mean daily variation being 8′ 58″, and the mean maximum westerly variation 24° 36′ 36″. An observation was likewise made between 6 and 7 P.M. but the maximum easterly deviation in the evening does not generally appear to have been determined: however, after the observations for July 1813,

Colonel BEAUFOY states, " from several observations it is after eleven at night."

The observations at Fort Enterprise were made every day from the 10th January to the 16th March, and from the 22d March to the 7th April; but as considerable disturbance took place in the direction of the needle, in taking the mean of the deviations at the several hours of observation, it is necessary to exclude those days on which observations were not made at each of these hours. The following table contains the mean, so taken, of the variations at different hours in the months of January, February, and March.

	10^h A. M.	1^h P. M.	5^h P. M.	9^h P. M.	12^h P. M.	No. of Day's Observations.
January - - -	35° 54′ E	35° 42′ E	35° 42′ E	35° 44′ E	35° 51′ E	18
February - - -	35 54	35 47½	35 40	35 41½	35 41⅓	19
Means for Jan. and Feb.	35 54	35 45	35 41	35 43	35 46	
March - - -	9 A. M. 35 57	35 39	35 30	35 30	35 33	13
Means for Jan. Feb. and March	....	35 43	35 37	35 38½	35 42	

Lieut. HOOD states, that the maximum variation east occurred at 9 A. M. and the minimum at 3 or 4 P. M.; but these means clearly indicate that the minimum happened after 5 P. M. Some latitude however must certainly be allowed in determining these points.

CANTON'S observations in 1759, which are published in the 51st vol. of the Philosophical Transactions, appear to have been made with great care, with the view of determining the amount of the variation at different seasons of the year. On a few days

in each month great irregularities, attributed by CANTON to the effect of the aurora borealis, are observable; and in deducing the mean times of maximum and minimum variation, I have excluded all the observations on the days on which these irregularities happened. These are however few, and I am not aware that including them would have much affected the results; but as my object is to determine the more regular effects, I consider that, in taking the mean, they are better excluded. CANTON'S observations were not always made at corresponding hours on different days; so that, to obtain the mean variation at or near to particular hours, I have taken the observations nearest to such hours, on the several days in each month; and taken a mean of the times, and of the observed variations. The following table contains the results thus deduced.

Abstract of the Means deduced from Canton's observations, in 1759, of the variation of the needle in London.

	First observation in the morning.		Morning, Minimum West.		Observation between 10^h and 11^h A. M.		Maximum West.		Evening Minimum West.		Observation nearest to 9^h P. M.		No. of Days Observations.
	Time A. M.	Variation West.	Time A. M.	Variation West.	Time A. M.	Variation West.	Time P. M.	Variation West.	Time P. M.	Variation West.	Time P. M.	Variation West.	
	h. m.	° ′ ″	h. m.	° ′ ″	h. m.	° ′ ″	h. m.	° ′ ″	h. m.	° ′ ″	h. m.	° ′ ″	
January	0 15	18 55 21	9 07	18 55 03	10 32	18 57 20	1 35	19 01 47	9 14	18 55 51	8 57	18 56 00	30
February	0 22	18 57 03	9 17	18 54 57	10 51	18 56 49	1 58	19 03 33	9 30	18 57 00	8 48	18 57 57	22
March	0 17	18 58 04	9 09	18 54 45	10 49	18 58 30	1 43	19 05 48	8 35	18 57 56	8 58	18 58 00	30
April	0 22	18 58 30	8 37	18 53 45	10 45	18 59 10	1 33	19 05 53	8 43	18 58 39	9 46	18 58 48	24
Means	0 20	18 57 52	9 01	18 54 29	10 48	18 58 10	1 45	19 05 05	8 56	18 57 52	9 10	18 58 15	
May	0 21	18 58 43	8 29	18 54 11	10 35	19 00 25	1 26	19 05 47	8 22	18 58 54	8 48	18 59 14	27
June	0 22	18 59 00	8 29	18 54 31	10 43	18 59 55	1 19	19 07 06	8 24	18 59 02	9 20	18 59 25	29
July	0 14	19 00 20	8 15	18 56 00	10 07	19 00 18	1 42	19 08 16	8 29	19 00 26	9 13	19 01 52	26
Means	0 19	18 59 21	8 24	18 54 54	10 28	19 00 13	1 29	19 07 03	8 25	18 59 27	9 07	19 00 10	
August	0 19	19 00 40	8 29	18 57 41	10 17	19 01 23	1 18	19 09 19	7 37	19 00 18	9 17	19 01 23	28
September	0 26	19 03 28	8 51	19 01 03	10 25	19 05 28	1 20	19 12 58	8 46	19 02 52	9 11	19 02 42	24
October	—0 05	19 05 27	8 55	19 01 03	10 54	19 07 26	1 17	19 11 46	8 58	19 04 27	9 03	19 04 39	22
Means	0 13	19 03 12	8 45	18 59 56	10 32	19 04 46	1 18	19 11 21	8 27	19 02 32	9 10	19 02 55	
November	0 15	19 07 48	9 04	19 07 15	10 46	19 08 43	1 37	19 14 30	9 20	19 07 00	9 05	19 06 51	24
December	0 19	19 06 07	9 06	19 06 21	10 48	19 08 48	1 45	19 12 39	9 15	19 05 50	9 12	19 06 03	28
Means with preceding Jan.	0 16	19 03 05	9 06	19 02 53	10 42	19 04 57	1 39	19 09 39	9 16	19 02 54	9 05	19 02 58	
Means for the whole year	0 17	19 00 53	8 49	18 58 03	10 38	19 02 01	1 33	19 08 17	8 46	19 00 41	9 08	19 01 05	314

From these it appears, that the maximum westerly variation occurred about 1^h 30^m P. M. from which time the needle deviated towards the east until nearly 9 P. M.; after which a small deviation to the west took place during the night, until an early hour the next morning; from which time the deviation was easterly until nearly 9 A. M. when the easterly deviation attained its maximum, this maximum being considerably to the east of the minimum westerly variation in the evening. This excess appears to be different for different seasons of the year. The mean of the winter months, November, December, January, gives it very nearly nothing, the whole amount of daily variation being 6′ 46″. For February, March, April, it is 3′ 23″, or not quite a third of the whole variation 10′ 36″. For May, June, July, it is 4′ 33″, or more than a third of the daily variation 12′ 09″. And for August, September, October, it is 2′ 26″, or not quite a fourth of 11′ 25″, the whole daily change. In this table, the mean daily variation for different months is rather less than that deduced by CANTON. This arises from the exclusion, in the mean, of those days on which the variation was irregular, and on which, in general, the maximum west was considerably greater, and the minimum less, than on those days on which it was regular.

The observations at Port Bowen have been so recently published, that it is unnecessary for me here to point out the nature of the results; and any remarks I may have to make on them, I shall reserve until I have given the experiments with which I propose to compare them.

In order to determine how nearly the changes in the direction at Fort Enterprise, in London, and at Port Bowen, might

be represented by the rotation of two poles, as I have described, I placed the small compass I had before made use of vertically over the centre of the circle in the plane of which the upper poles of the magnets were to revolve, and adjusted the arms carrying the magnets, so that the upper poles were at the distance 10·25 inches from that centre. In the first instance, the distance of the centre of the needle above that of the circle described by the poles was 12·25 inches; and after observations had been made with the compass at this distance, it was lowered until the distance was 10·25 inches, and again until the distance was 8·25: the first of these distances corresponds to the poles being developed interior to the surface of the earth; the second on the surface; and the third exterior to it. Observations were at first made with the arms carrying the magnets so adjusted, that the angle between the poles or their difference of longitude was 130°; and the observations were repeated when this angle had been altered to 170°.

For the observations corresponding to those at Fort Enterprise, latitude 64° 28′ N. variation 36° 24′ E, the axis about which the poles revolved was inclined to the horizon at an angle of 64° 28′, and the azimuth of its lower extremity from magnetic south was made 36° 24′ E: so that, the north end of the needle pointed N 36° 24′ E from the plane of the circle representing the true meridian. Adjustments similar to these, and corresponding to the latitudes of the places and the variation, were made for the observations to be compared with those at London, variation 19° W, and variation 24° 40′ W, and at Port Bowen, latitude 73° 14′ N, variation 124° W.

The observations which I made of the deviation of the needle, under these different circumstances, at every change

of 15° in the angular position of the poles relatively to the meridian, corresponding to their positions at intervals of an hour throughout the day, are contained in the opposite Table. The time indicated in the first column is that elapsed since the magnet having its *north* pole *upwards*, which represents the *north* pole near the *equator* on its *northern* side, was on the *northern* true meridian: and in the following columns are indicated the deviations of the north end of the needle, from the magnetic meridian, at the respective hours, and under the circumstances indicated above the several columns. The magnet having its *north* pole *upwards* was considerably *stronger* than the other. When this magnet was on the *southern* meridian, that which had its *south* pole *upwards* was to the *east* of it: the angular distance between the poles is indicated above the columns containing the deviations of the needle. It is scarcely necessary for me to mention, that had I adjusted the compass and the magnets so that the deviations should not have exceeded the observed diurnal variation, I should not have been able to observe the effects with any precision: the adjustments therefore were made so that the deviations should greatly exceed the diurnal changes. The deviations in each set are only comparable among themselves.

In order to compare the deviations corresponding to different hours, reckoned from the passage of the north pole over the true north meridian, with the observed changes in the direction of the needle at different times in the day, it is necessary to assign some particular time in the day for that which is taken as the zero in this table. Considering that the diurnal changes have been most accurately observed by

Angle described by the north magnetic pole from true north, reduced into time.	Latitude 64° 28′ N, variation 36° 24′ E, the same as at Fort Enterprise in 1821.						Latitude 51° 30′ N, variation 19° W, the same as in London in 1759.						L
	Angle between the magnetic poles.						Angle between the magnetic poles.						
	130°			170°			130°			170°			
	Height of the needle's centre above the centre of the circle described by the poles.			Height of the needle's centre above the centre of the circle described by the poles.			Height of the needle's centre above the centre of the circle described by the poles.			Height of the needle's centre above the centre of the circle described by the poles.			Hei ab de
	Inches 12·25	Inches 10·25	Inches 8·25	Inches 12·25	Inches 10·25	Inches 8·25	Inches 12·25	Inches 10·25	Inches 8·25	Inches 12·25	Inches 10·25	Inches 8·25	In 12
	Deviation.	Deviation.	Deviation.	Deviation.	Deviation.	Deviation.	Deviation.	Deviation.	Deviation.	Deviation.	Deviation.	Deviation.	Dev
h	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	°
0	0 15W	0 15W	0 35W	1 45W	1 55W	2 40W	2 30 E	3 40 E	4 20 E	2 35 E	3 50 E	4 50 E	2
1	0 15 E	0 30 E	0 20 E	0 45	0 40	1 00	2 20	3 15	3 50	3 15	4 40	5 40	2
2	0 35	1 05	1 00	0 15 E	0 35 E	0 25 E	2 10	2 45	3 35	3 20	4 35	5 40	2
3	1 00	1 20	1 40	0 50	1 20	1 30	2 10	2 45	3 30	3 15	4 15	5 35	2
4	1 20	2 00	2 25	1 30	2 15	2 35	2 10	2 55	3 50	3 10	4 10	5 20	2
5	2 00	2 40	3 20	2 15	3 05	3 40	2 25	3 30	4 30	3 10	4 15	5 40	2
6	2 35	3 45	4 40	2 45	4 00	5 00	3 05	4 20	5 35	3 30	4 45	6 25	3
7	3 25	4 55	6 20	3 40	5 15	6 40	3 40	5 20	6 50	4 10	5 40	7 35	3
8	4 30	6 20	8 15	4 45	6 40	8 35	4 30	6 20	8 20	4 45	6 40	8 50	4
9	5 30	7 45	10 15	5 45	8 05	10 35	4 45	6 45	9 10	5 05	7 20	9 50	4
10	6 10	8 40	11 30	6 25	9 15	12 00	3 50	5 35	7 10	4 10	6 00	7 55	2
11	5 55	8 25	11 20	6 15	9 00	12 00	0 00	0 30W	1 10W	0 15	0 00	0 40W	1
12	4 20	6 20	8 15	4 40	6 40	8 50	5 45W	9 30	13 35	5 25W	9 05W	13 15	7
13	1 40	2 15	2 50	2 10	2 50	3 40	9 35	14 20	18 45	9 15	13 50	18 45	10
14	1 05W	1 45W	2 45W	0 35W	1 05W	1 40W	9 35	13 35	17 30	9 20	13 05	17 20	9
15	3 10	4 30	6 40	2 25	3 40	5 15	7 55	11 00	14 10	7 30	10 30	13 40	7
16	4 15	6 05	8 20	3 25	4 50	6 50	6 15	8 20	10 50	5 40	7 40	10 15	5
17	4 40	6 40	9 10	3 45	5 25	7 30	4 40	6 15	8 15	4 10	5 30	7 40	4
18	4 40	6 40	9 10	3 45	5 30	7 35	3 30	4 35	6 10	3 15	4 20	5 50	3
19	4 35	6 05	8 20	3 45	5 30	7 35	2 10	2 45	3 40	2 40	3 25	4 45	1
20	3 50	5 15	6 55	3 45	5 25	7 25	0 25	0 30	0 50	2 15	2 50	3 50	0
21	2 55	3 50	5 15	3 40	5 00	6 50	1 20 E	2 05 E	2 15 E	1 40	1 50	2 30	1
22	1 50	2 25	3 20	3 25	4 25	5 55	2 30	3 35	4 15	0 35	0 00	0 20	2
23	0 55	1 05	1 45	2 40	3 20	4 25	2 40	3 55	4 40	1 05 E	2 15 E	2 30 E	3
24	0 15	0 15	0 40	1 45	1 50	2 40	2 35	3 35	4 20	2 35	3 50	4 45	2

: as	Latitude 51° 30′ N, variation 24° 40′ W, the same as near London in 1820.						Latitude 73° 14′ N, variation 124° W, the same as at Port Bowen in 1825.					
	Angle between the magnetic poles.						Angle between the magnetic poles.					
	130°			170°			130°			170°		
entre circle	Height of the needle's centre above the centre of the circle described by the poles.			Height of the needle's centre above the centre of the circle described by the poles.			Height of the needle's centre above the centre of the circle described by the poles.			Height of the needle's centre above the centre of the circle described by the poles.		
ches ·25	Inches 12·25	Inches 10·25	Inches 8·25	Inches 12·25	Inches 10·25	Inches 10·25	Inches 12·25	Inches 10·25	Inches 8·25	Inches 12·25	Inches 10·25	Inches 8·25
iation.	Deviation.	Deviation.	Deviation.	Deviation.	Deviation.	Deviation.	Deviation.	Deviation.	Deviation.	Deviation.	Deviation.	Deviation.
′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
50 E	2 45 E	3 40 E	4 35 E	2 50 E	4 25 E	5 15 E	1 40 E	2 20 E	3 00 E	2 55 E	3 50 E	5 05 E
40	2 25	3 25	4 05	3 30	5 00	6 10	1 05	1 20	1 35	2 15	2 40	3 40
40	2 10	2 55	3 40	3 30	4 40	6 00	0 20	0 20	0 20	1 20	1 25	1 50
35	2 10	2 55	3 40	3 15	4 20	5 40	0 15W	0 30W	1 00W	0 20	0 15	0 00
20	2 10	2 55	3 50	3 05	4 15	5 25	0 55	1 25	2 20	0 25W	1 00W	1 40W
40	2 25	3 25	4 30	3 05	4 15	5 35	1 40	2 20	3 30	1 30	2 20	3 26
25	3 05	4 15	5 25	3 25	4 40	6 15	2 25	3 25	4 50	2 25	3 30	5 00
35	3 40	5 10	6 35	3 55	5 35	7 20	3 20	4 30	6 25	3 20	4 45	6 35
50	4 15	5 55	7 40	4 25	6 20	8 20	4 05	5 35	7 40	4 15	5 50	8 00
50	4 20	6 05	8 00	4 30	6 20	8 35	4 40	6 30	8 35	4 55	6 45	9 10
55	2 50	3 50	5 15	3 15	4 15	5 40	4 55	6 45	8 55	5 20	7 10	9 25
40W	1 20W	2 50W	4 15W	1 00W	2 10W	3 50W	4 50	6 35	8 30	5 20	6 45	9 05
15	7 00	11 30	15 30	6 45	10 50	15 25	4 05	5 30	7 00	4 30	5 50	7 40
45	10 05	15 00	19 25	9 50	14 45	19 35	2 50	3 40	4 50	3 20	4 15	5 35
20	9 45	13 40	17 35	9 25	13 25	17 30	1 20	1 35	2 20	1 50	2 10	3 00
40	7 55	10 30	13 45	7 25	10 20	13 25	0 05 E	0 30 E	0 20 E	0 25	0 15	0 35
15	5 50	7 50	10 35	5 30	7 25	10 00	1 30	2 25	2 35	0 50 E	1 30 E	1 40 E
40	4 20	5 45	7 40	3 55	5 15	7 20	2 40	3 45	4 30	1 55	2 50	3 30
50	3 00	4 00	5 25	2 55	3 55	5 30	3 30	4 50	6 00	2 40	3 45	4 50
45	1 40	2 15	2 55	2 20	3 00	4 20	3 45	5 25	6 55	3 15	4 35	5 50
50	0 05 E	0 00	0 00	1 55	2 20	3 20	3 45	5 30	7 05	3 35	5 15	6 35
30	1 45	2 40 E	2 55 E	1 15	1 15	1 45	3 40	5 20	6 45	3 40	5 20	6 50
20	2 50	4 00	3 40	0 05	0 35 E	0 25 E	3 10	4 30	5 45	3 40	5 20	6 40
30 E	3 05	4 20	5 05	1 30 E	2 40	3 20	2 25	3 25	4 25	3 30	4 45	6 15
45	2 50	3 40	4 35	2 55	4 25	5 20	1 40	2 20	3 00	2 55	3 50	5 05

CANTON and Colonel BEAUFOY, in London and its vicinity, I shall determine this from their observations. It appears from these, that the maximum west variation happens about $1^h\ 30^m$ P. M. Now, in the table, when the variation is 19^o W., or $24^o\ 40'$ W., this maximum corresponds to about $13^h\ 30^m$, or $13^h\ 20^m$ after the north pole has passed the northern meridian. So that the hours in the first column of the table must, in all cases, nearly indicate the times since midnight. This being the case, it will be seen, that when the angle between the poles is 130°, the times of the maxima, and the characters of the deviations, in the respective cases, approximate to the observations at Fort Enterprise, in London, and at Port Bowen, and perhaps as nearly as we ought to expect, when we consider that, admitting the correctness of the hypothesis, many circumstances in the experiment must necessarily be different from those accompanying the phænomena in nature. But to form a more just estimate of the nature of the agreement, I shall point out the principal discordances and coincidences between these results and the observed diurnal changes. I may premise, that, whether the poles revolve in the interior of the sphere, on the surface of which the needle is supposed to be situate, on its surface, or exterior to it, the character of the changes which take place in the direction of the needle is nearly the same. I will, however, for the purpose of comparison, take the case where the poles and the needle are at the same distance from the centre.

Observations at Fort Enterprise. Lieutenant HOOD states that the maximum east variation occurred at 9^h A. M., but the first observations in the morning which are given for January and February, were at 10^h A. M., and none are

recorded after this hour until 1^h^ P. M.: for March, the first observation is at 9^h^ A. M. Even with instruments best adapted for the purpose, the time of maximum cannot be determined with great precision; and although Lieutenant HOOD possessed the requisites of zeal and ability, yet the instruments that were made use of were not such as would have been employed, had not the nature of the expedition in which Captain FRANKLIN was engaged, restricted him to carrying only those most essential. Much latitude, with respect to the time of maximum, must therefore, under these circumstances, be allowed; and I think the time by experiment, 10^h^ A. M., is probably not far from the truth. The time of minimum east or maximum west appears by the table to be between 5^h^ P. M. and 6^h^ P. M. Lieutenant HOOD states it at 3^h^ or 4^h^ P. M.; but the mean of his observations certainly indicates that the time was later than 5^h^ P. M.

Observations in London, variation 19° *W*. The mean of CANTON'S observations for the months nearest the equinoxes, February, March, April, August, September, October, gives 8^h^ 40^m^ P. M. as the time of minimum west in the evening: the experimental result is about 11^h^ P. M., making the difference in the times considerable. In both cases, however, the course of the deviation is the same; the needle deviating slightly towards the west during the night and early part of the morning; then proceeding towards the east, and attaining the maximum east, or minimum west, at almost precisely the same time in the two cases: namely, 9^h^ A. M. in the one, and 8^h^ 53^m^ A. M. in the other. CANTON'S observations give 11′ as the mean difference for these equinoctial months, between the maximum west and morning minimum west, and

8′ as the difference between the maximum and afternoon minimum: the corresponding differences in the table are, 21° 10′ and 18° 20′, which have the same character, but are not in the same ratio; so that the ratio of the intensities of the poles in these experiments, is not precisely that which the observed diurnal changes require.

Observations near London, variation 24° 36′ W. I have already mentioned the reason that I have not been able to refer more particularly to the extensive observations of Colonel BEAUFOY; however, the maximum east and the maximum west in those to which I have referred, appear to have happened earlier than those, at the same time of the year, when the variation was 19° W; and in this respect they agree with the results in these experiments. The time of the evening minimum west, 11^h P. M., also coincides with the time at which Colonel BEAUFOY states it to have occurred. The observations which I made in 1823,* on the deviation of the needle when under the influence of magnets, are of too limited a nature to draw any very decided conclusions from them; but the course of the daily variation, as exhibited in the diagrams, agrees remarkably with the results in the table.

There is one circumstance in which all the observations on the daily variation in this latitude most strikingly correspond with the results in the table: little change takes place in the direction of the needle during the latter part of the evening until about five o'clock in the morning; and, from the results in the table, it appears that this would arise from there being a small maximum easterly deviation about 11^h P. M., and an

* Philosophical Transactions, 1823.

intermediate minimum east about 4^h A. M., previous to the absolute maximum east about 9^h A. M. Another circumstance, common to all the observations in northern latitudes, namely, that the extent of the daily variation increases as the sun passes to the north of the equator, and decreases on its passage south, so clearly follows from the hypothesis that it is scarcely necessary to mention it.

Observations at Port Bowen. Mr. FOSTER states that the mean time of maximum west deviation, deduced from four month's observations, is $11^h\ 49^m$ A. M.; and that of the maximum east $10^h\ 01^m$ P. M. The corresponding times in the table are a little after 10 in the morning and 8 in the evening. So that the experiments differ considerably from the observations in the absolute times, but agree very closely in the interval of time between the two maxima. It is extremely probable that the forces brought into action by the heat of the sun are not directed, at the same instant of time, towards points absolutely fixed, whatever may be the situation of the needle on the surface of the earth; and it is easily seen that in such an extreme case as this, where the dip of the needle is 88°, this may have a considerable influence on the changes that take place in its direction: therefore, although the deviations in their general character may agree with the effects produced by the revolution of two poles, yet we ought not, perhaps, to expect that they should do so in every respect. Whether the times of the maxima arising from the rotation of these poles would precede those that would actually result from the hypothesis I have advanced, would be best determined by experiments on substances having different conducting powers, and whose contact, like that of the

earth and the atmosphere, should be symmetrical. Another circumstance in which the experiments differ from the hypothesis, is this: that in these the needle is not only of finite dimensions compared with the distance of the revolving poles from the centre, but its length is even considerable in this respect, being a fifth of that distance; and this will modify all the results.

I have before mentioned that the intensity of the magnet whose north pole was upwards in these experiments, and which, for the sake of distinction, I will now call N, was considerably greater than that of the magnet whose south pole was upwards, and which I call S. Their intensities were such, that when they were severally placed to the west of the needle, so that their axes were in a horizontal line drawn through its centre at right angles to the magnetic meridian, and their nearest ends 4·2 inches from that centre, the deviations of the north end of the needle were: for the magnet N, 60° 40′ W., and 59° 40′ E., according as its north, or its south pole was that nearest to the needle; and for the magnet S, 26° 00′ E, when the south pole was nearest to the centre, and 31° 00′ W., when its north pole was nearest. I afterwards increased the intensity of the weaker magnet by passing the poles of the other alternately over it from centre to ends. After this the deviations observed as before were: for the magnet N, 60° 20′ W., 58° 20′ E.; for the magnet S, 39° 40′ E., 41° 30′ W. In this state the magnets were again adjusted to the instrument as before, excepting that the distance of their poles from the centre was 10 inches instead of 10·25 inches, as, at the latter distance, the stem of the support to the compass was liable, in some cases, to interfere with their

revolution. The greatest east and west deviations, the times at which they occurred, and the times at which the needle passed zero, were alone in this instance determined in the several cases. The results are contained in the following table.

	Height of the needle's centre.	Angle between the poles.	Minimum East.		Maximum East.		Zero.	Maximum West.		Zero.	2d Maximum East.	
			Time.	Deviation.	Time.	Deviation.	Time.	Time.	Deviation.	Time.	Time.	Deviation.
Lat. 64° 28′ N; var. 36° 24′ E, as at Ft Enterprise, 1821.	Inches.	°				° ′	h. m.	h. m.	° ′	h. m.		
	12	130	The minimum does not occur here.		10 30 A.M.	6 00 E	1 35 P.M.	5 40 P.M	5 55 W	11 40 P.M	The minimum does not occur here.	
	12	170			10 20	6 15	1 55	8 15	5 00	1 34 A.M.		
	10	130			10 30	9 20	1 40	5 40	8 20	11 38 P.M.		
	10	170			10 30	9 25	1 56	8 20	6 40	1 34 A.M.		
	8	130			10 30	12 00	1 35	5 40	11 20	11 45 P.M.		
	8	170			10 30	12 45	1 55	8 00	9 15	1 34 A.M.		
Lat. 51° 30′ N; var. 29° W, as in London, 1759.			h. m.	° ′							h. m.	° ′
	12	130	3 20 A.M.	2 20 E	9 00 A.M.	4 30	11 05 A.M.	1 40 P.M.	10 20	8 05 P.M.	10 30 P.M.	4 10 E
	12	170	5 00	3 15	9 00	4 30	11 10	1 30	9 50	10 24	1 30 A.M.	4 15
	10	130	3 30	3 05	9 00	6 20	11 05	1 30	15 30	8 08	10 40 P.M.	5 50
	10	170	5 00	5 00	9 00	7 30	11 08	1 20	14 40	10 20	1 20 A.M.	6 50
	8	130	3 30	4 15	9 10	9 15	11 03	1 20	20 25	8 05	10 50 P.M.	7 40
	8	170	5 00	6 45	9 10	10 25	11 08	1 20	19 35	10 25	1 30 A.M.	8 40
Lat. 51° 30′ N; var. 24° 40′ W, as near London, 1820.	12	130	3 30	2 15	8 40	3 55	10 50	1 30	10 35	7 52	10 30 P.M.	4 20
	12	170	5 20	3 15	8 40	4 00	10 54	1 30	10 20	10 18	1 20 A.M.	4 40
	10	130	3 45	3 15	8 55	6 15	10 50	1 20	16 10	7 50	10 30 P.M.	6 10
	10	170	5 00	4 45	9 00	6 10	10 54	1 20	15 20	10 05	1 20 A.M.	6 40
	8	130	3 10	4 15	9 00	7 50	10 46	1 10	21 30	7 53	10 40 P.M.	7 50
	8	170	5 00	6 40	9 00	8 45	10 52	1 10	20 00	10 07	1 30 A.M.	8 35
Lat. 73° 14′ N; var. 124° W. as at Port Bowen, 1825.	12	130	The minimum does not occur here.		8 00 P.M.	4 30	1 53 A.M.	10 10 A.M.	5 05	2 46 P.M.	The maximum does not occur here.	
	12	170			10 00	4 30	3 12	10 20	5 40	3 20		
	10	130			8 00	6 50	1 54	10 10	7 10	2 44		
	10	170			10 20	6 25	3 00	10 10	7 45	3 20		
	8	130			8 10	8 55	1 54	10 00	9 30	2 50		
	8	170			10 00	8 40	3 15	10 20	10 20	3 25		

Here the times do not, in any instance, sensibly agree more nearly with the observed times at the respective places,

and in some they differ sensibly more widely, than when the intensity of the easterly pole was less. Likewise the variation from the morning maximum east to the maximum west, compared with the variation from the maximum west to the evening maximum east, does not so nearly agree with the ratio of the observed variations in London as in the former case. So that, an increase of intensity in the eastern magnet causes a greater discordance between the experimental results and the observations. By a small diminution in the intensity of this pole they might agree more nearly; but if it were removed altogether, that is, if we were to suppose only one pole to revolve in the equator, the evening maximum east would not obtain, with the latitude and variation corresponding to those of London, and the discordance in the results would be still greater.

I have not as yet noticed what may appear an incongruity in these experimental results, as compared with the observations in London and at Port Bowen, viz., that here the deviations corresponding to those in London are considerably greater than those corresponding to the observations at Port Bowen, whereas the diurnal changes at the latter place greatly exceed those at the former. This incongruity is however only apparent, and its cause is easily pointed out. The changes in the direction of the horizontal needle are dependant on those which would take place, under the same circumstances, in the direction of a needle freely suspended by its centre of gravity, in such a manner that, if we conceive their centres to coincide, and the disturbing force to act upon the dipping needle alone, the horizontal needle would always be found in the vertical plane passing through this imaginary

dipping needle.* According to this, if equal disturbing forces act at places where the dips are different, the sines of the

* I first stated this law of the dependance of the deviations of the horizontal needle on those of the dipping needle, in the form of an hypothesis, in the Cambridge Philosophical Transactions for 1820; but without adverting to that hypothesis, it may be considered as a most convenient method of embracing in one view, various phænomena observed with the horizontal needle. From whatever cause deviation in the direction of the horizontal needle may have arisen, except, possibly, in cases where the length of the needle bore a very sensible ratio to the distance of the disturbing body, I have met with no instance that was not quite consistent with this law; nor was I aware that any such was said to exist, until I heard the circumstance stated in a paper of Mr. BARLOW'S, recently read before the Royal Society. Not being in possession of Mr. BARLOW'S experimental results, however far I may be from being convinced by the arguments he has adduced against the law itself, independent of any hypothetical views, I will not venture to point out the nature of their fallacy: but as far as I could collect the facts during the reading of the paper, I am of opinion that they would result from my view of the subject. Thus supposing the centre of the shell, in his experiments, to be placed in the equator of the imaginary dipping needle passing through the centre of the horizontal needle, so that, if the branches of this needle were of equal intensity, no deviation would, according to my view, take place; then, if either branch be deteriorated, the centre or pivot of the needle will no longer be the centre of its magnetism, and a point in the horizontal needle, remote from its pivot, must now be considered as the centre of the dipping needle; and the centre of the shell being now above, or below the equator of this dipping needle, according to the circumstances of deterioration, unequal action will take place on the branches of the dipping needle, and consequently, according to the law in question, deviation of the horizontal needle will ensue. Although this law has been called in question, I will here mention an instance of its advantage in connecting different phænomena. By supposing the effect of a disturbing force to be produced on the dipping needle, and that in consequence the poles describe, in a certain time, a circle round their undisturbed places, connecting the observations on the dip, in this manner, with those on the horizontal needle, I found, as I have stated in my paper in the Cambridge Philosophical Transactions, 1820, that the resulting variations will agree, within less than half a degree, with the observed variations of the horizontal needle in London, during a period of 200 years. These results I never published; but I found very shortly afterwards, that, on this view, the same approximation might be made to the variations of the horizontal needle observed at Paris, during the same period.

greatest horizontal deviations will be to each other inversely as the cosines of the dips. In the experiments, although the variation and latitude were those at the different places of observation, the dip remained the same in all cases: so that in the deviations corresponding to those at Port Bowen, no increase, arising from an increase in dip, could here take place, but on the contrary, a decrease took place from the increased distance of the revolving poles.

This manner of viewing the effects on the horizontal needle, as depending on those produced on the dipping needle, will serve to explain the nature of the changes which take place in the intensity of the horizontal needle. The horizontal intensity varying as the cosine of the dip, when the dip is a *maximum* the horizontal intensity will be a *minimum*, and *vice versa*. Let us now consider what effects will be produced on a dipping needle with its centre in the same situation as that of the horizontal needle in the preceding experiments; the angle between the magnets being 130° and the instrument adjusted to correspond to the latitude and variation of London. It is manifest that the *maximum* dip will take place nearly when the *north* pole is on the *south* magnetic meridian; that is, nearly at the time when the needle passes zero from the easterly deviation in the morning towards the westerly, or a little before 11^h A. M.; and the *minimum* dip will happen nearly when the *south* pole is on the *south* mag-

On the same view of the subject, Lieutenant FOSTER has recently been enabled to connect the changes observed in the horizontal intensity with changes in the dip. I must however say, that, should the deviations which are observed when one branch of the needle is deteriorated, not be consistent with this law, no one will be more ready than myself, to expunge from the philosophical code, a law which is found to be inconsistent with observed phænomena.

netic meridian, or nearly when the needle passes zero from the westerly deviation in the evening towards the east, that is before 8^h P. M.: the dip of the needle will be nearly undisturbed about 3 P. M. It is evident also, that, the intensity of the north pole being greater than that of the south, the maximum dip will exceed the undisturbed dip by a greater quantity than this last does the minimum. It appears then, according to this theory, that the horizontal intensity ought to decrease here until a little before 11 o'clock in the morning, when it should be a minimum; that it should increase from this time till nearly 8 o'clock in the evening, when it reaches its maximum; and that taking the intensity at 3 o'clock in the afternoon as the undisturbed intensity, this should exceed the minimum by a greater quantity than it is itself exceeded by the maximum.

I am not aware of any extensive series of observations having been made near London, on the diurnal changes in the intensity of the horizontal needle. Those which I made in May and June, 1823,* having been undertaken for the particular purposes of pointing out the cause of what had been considered an anomalous change in the direction of the needle, and of exhibiting and illustrating the particular mode of observation, were consequently of a limited nature; but as they are the only ones I can refer to, I shall compare the preceding conclusions with the results obtained from them. From a mean of these observations it appears, that the horizontal intensity was the least about $10^h\ 30^m$ A. M., and that the maximum happened nearer to $7^h\ 30^m$ P. M. than to 9^h P. M.: also that, taking the minimum as unity, the excess

* Philosophical Transactions, 1825.

of that at 3^h P. M. above it was ·00177, and the excess of the maximum above this was ·00049. So that the theory agrees in all respects as nearly with these observations as can possibly be expected. I may also notice that the mean of seven months' observations by Professor HANSTEEN, at Christiania, where the variation was about 20° west, gives the minimum intensity at 10^h 30^m A. M., and the maximum of the recorded observations 7^h P. M.: the maximum appearing however to happen somewhat later. It may be proper to add, that the method I adopted for determining the diurnal changes in the intensity of the horizontal needle was totally dissimilar to that employed by Professor HANSTEEN.

Although I have hitherto but slightly noticed the observations made at Port Bowen, I nevertheless fully appreciate those observations, and the zeal and ability of the observers. As might have been anticipated from the law to which I have referred, as connecting the deviations of the horizontal needle with those of the dipping needle, the extent of the daily variation observed at Port Bowen was such, that had the changes taken place with any degree of regularity, the times at which the maximum east and maximum west deviation occurred, would have been determined with great precision. This however was by no means the case, and such irregularities take place, from day to day, in the extent of the variations, in the times of their maxima, and in the times of maximum and minimum intensity, that it appears to me, these irregularities must be the effects of local causes, equally irregular in their operation, unless we admit that from the peculiarity of the situation, the dip being above 88°, irregularities, which in other cases completely elude

observation, are here, not only sensible, but very commonly have a preponderating influence. Such irregularities have been occasionally noticed by CANTON and Colonel BEAUFOY, but they are comparatively of extremely rare occurrence; and, certainly, irregularities that were not detected by the accuracy of Colonel BEAUFOY's observations, with a dip of 70°, would not, simply from the increase of the dip to 88°, obliterate every trace of regularity, though they might undoubtedly become sensible. I have made several attempts to separate, in these observations, those which appeared to follow some general law, from those which appeared to be altogether irregular, but hitherto without success, possibly from my having been restrained from making any selection that might appear to favour the hypothesis I have advanced. Perhaps, if the deviations and intensities observed at Port Bowen at the several hours throughout the day, were exhibited as the ordinates of a curve, the times being the abscissæ, in the manner in which I have represented some observations in 1823, the variations and intensities having the true characters of maxima and minima might be separated from those accidentally the greatest or the least. I have not yet had sufficient leisure to accomplish this, but I think that when I have, I may be repaid for the time devoted to it, by the light that may be thus thrown upon these very interesting observations.

Admitting that the daily changes in the direction of the needle may be represented by the revolution of poles near the equator, it appears that the times at London, reckoning from the passage over the true meridian, of the *north* pole, that of greatest intensity, nearly agree with the times reckoned

from the sun's passage: so that the *north* pole, to the *north* of the equator, would always have the sun nearly on its meridian; the *south* pole to the *north* of the equator would probably be nearly in the longitude 130° east from this meridian: and corresponding to these, a *south* and a *north* pole would be developed to the *south* of the equator. Supposing then that the place of greatest heat on the equator is in general 45° to the east of the sun, the poles of *greasest* intensity would be developed in the longitude of about 45° *west*, and those of *least* intensity in the longitude of about 85° *east* from the place of heat. The situation however of the place of heat, and the distances of the poles from it, must be greatly influenced by the nature of that part of the earth to which the sun is vertical. For there can be no doubt, that if, during the passage of the sun over the scorched desarts of Africa, the place of greatest heat is in general 45° behind the sun, the border of that continent on the west will continue the place of greatest heat, for some time after the sun has advanced 45° over the Atlantic; and that on the other hand, the eastern shores of the continent of America will become more heated than the Atlantic, even when the sun has scarcely passed the aquatic meridians. Besides this, owing to the different conducting powers of land and water, the intensities of the poles, and likewise their distances from the place of heat, may vary according as that place is on the land or on the water. Since then, when the sun is in the *northern* tropic, it passes over the greatest extent of land without intervening sea, and afterwards of sea scarcely intersected by land; and that the case is the reverse when it is in the *southern* tropic; this would produce a considerable effect on

the diurnal variation at different times of the year. It is by no means improbable, that it is owing to circumstances of this kind that we have a maximum daily variation in April, and another in August. The situation of the poles will also be influenced by the elevation of the land to which the sun is vertical; and when it passes over the plains of Hindoostan, with the Himaleh mountains covered with perpetual snow, and the high and cold plains of Tartary to the north; and again, when it crosses the Andes; the situations of these poles, with respect to the place to which the sun is vertical, will, I consider, be different from their positions with regard to it, when the sun is vertical to the centre of Africa, or of the Pacific ocean. The great disturbances which take place in the atmosphere in the intertropical regions, and which when of considerable extent must influence the situation of the place of heat, will also become a source of anomalous action on the needle. All these circumstances, admitting the correctness of the hypothesis, must greatly modify the regular effects that would otherwise be produced, and must influence considerably the nature and extent of the daily variation when observed at different parts of the earth; and probably they are the causes of some apparent discrepancies in the preceding results.

On commencing the experiments with the compound plate of bismuth and copper, I had no expectation of reducing the deviations of the needle to so simple a law as that resulting from a polarising of the plate in a particular direction; but I considered that it would be essential to determine, whether the deviations near the outer edge of the copper were of the same character as those near the line of junction of the

copper and bismuth, since these situations of the needle would correspond to those of a needle placed successively in the higher regions of the atmosphere, and on the surface of the earth. As the character of the deviations is the same in the two cases, it would follow, that the course of the daily changes in the direction of the needle would be the same at the level of the sea, and at the summit of the highest mountain, although the extent of those changes might be slightly different. At the time of making these experiments, and when I had drawn this conclusion, I was not aware that Lieut. Foster had made any observations at Port Bowen, with the view of comparing the changes which take place in such cases; but, previously to his sailing for Spitzbergen, he informed me, that at Port Bowen he had found them to be simultaneous.

I am perfectly aware that it would have been more satisfactory, had I drawn my conclusions from experiments on substances in contact more precisely in the manner of the earth and the atmosphere; that is, for example, from experiments on a copper shell filled with bismuth. This I proposed doing, and for the purpose had a six-inch copper shell cast, into which, after having it cleaned and soldered on its inner surface, I cast bismuth to fill it. In consequence however of inequalities in the thickness of the copper, and possibly from imperfect contact in some parts, the results, when different points had been heated, were not, in all cases, of such an uniform character as to enable me to determine the general magnetical phenomena that would ensue from applying heat to any part of the sphere. This being the case, I shall detail none of these experiments. As however one effect, which was invariably produced to

whatever point of the equator heat was applied, bears immediately on the subject of the daily variation, and besides, coincides perfectly with the results obtained with the plate of copper and bismuth, I shall state it.

The sphere was adjusted on an axis, of which that part in contact with the copper was of wood, and this axis being adapted to the instrument to which I have already referred, could be inclined to the horizon at any angle, and could likewise be placed in any azimuth. When the axis was in the plane of the magnetic meridian, if the centre of the needle was placed vertically over the centre of the sphere, its position would correspond to that of a needle on the surface of the earth at a place having the latitude equal to the elevation of the pole of the sphere, and where the mean variation vanished. The angle of elevation of the pole of the sphere was 50°, as most convenient for making observations at a distance from the equator. A lamp being applied so that its flame was as nearly as possible on a point in the equator, the sphere was turned on its axis until the equatorial regions became nearly uniformly heated; and the lamp was allowed to remain for 5 minutes after the sphere was brought to rest; so that the point during this time over it became the place of greatest heat, and the poles of rotation the points of greatest cold. Now, whatever point in the equator was made the place of heat, I invariably found, that when the elevated pole was towards the *north*, the deviation of the *north* end of the needle was towards the *west*, when the place of heat was on the meridian *above* the horizon, that is to the south; and towards the *east*, when the place of heat was on the meridian *below* the horizon. This is precisely the character of the

daily variation at places in *north* latitude, to which the above positions of the compass and sphere correspond. If the instrument was turned 180° in azimuth, so that the elevated pole was now to the south of the needle, the effects were reversed: that is, when the place of heat was on the meridian *above* the horizon, the deviation of the north end of the needle was towards the *east*; and it was towards the *west*, when the place of heat was on the meridian *below* the horizon. So that, *the deviation of the end of the needle of the same name as the latitude* was always towards the *west*, when the place of heat was on the meridian *above* the horizon, and towards the *east*, when it was on the meridian *below* the horizon. I am not aware of any observations having been made on the variation of the needle in a high *southern* latitude, but consider that the agreement of the theoretical results with such observations would be almost decisive of the correctness of the theory.

Besides the method which I have described, I adopted others for heating the equatorial part of the sphere; one of these, by which the results were greatly increased, was this: having covered a copper wire with very loosely spun string, I wetted it throughout with spirits of wine, and placed it round the sphere, somewhat below the equator, so that, when the spirit was inflamed, the equatorial part of the sphere was the hottest. The string being in largest quantity where the two ends of the wire were joined, and this joint being downwards during the combustion, the corresponding part of the sphere became the place of greatest heat. To whatever part of the equator this joint was adapted, the effects perfectly corresponded with, though they greatly exceeded those which I have before stated.

I have mentioned that, owing to the want of uniformity in the thickness of the copper, and possibly likewise in the contact of the two metals, some other results which I obtained with this sphere were not of the same uniform character. I have however not yet been able to make such alterations in the apparatus as shall remedy this defect. If, with an apparatus similar to that which I employed, but of much larger dimensions, and in which the copper sphere should be of uniform thickness, and the contact of the two metals perfect throughout, means were adopted by which the distribution of heat should nearly resemble that on the earth, and that observations were made with such adjustments of the instrument, that the positions of the needle should correspond to those of a horizontal and of a dipping needle on different parts of the earth's surface, I consider that much light might probably be thrown on the various phenomena of terrestrial magnetism.

S. H. CHRISTIE.

Royal Military Academy,
26th May, 1827.

Angle described by the north magnetic pole from true north, reduced into time.	Latitude 64° 28′ N, variation 36° 24′ E, the same as at Fort Enterprise in 1821.					
	Angle between the magnetic poles.					
	130°			170°		
	Height of the needle's centre above the centre of the circle described by the poles.			Height of the needle's centre above the centre of the circle described by the poles.		
	Inches 12·25	Inches 10·25	Inches 8·25	Inches 12·25	Inches 10·25	Inches 8·25
	Deviation.	Deviation.	Deviation.	Deviation.	Deviation.	Deviation.
h	° ′	° ′	° ′	° ′	° ′	° ′
0	0 15W	0 15W	0 35W	1 45W	1 55W	2 40W
1	0 15 E	0 30 E	0 20 E	0 45	0 40	1 00
2	0 35	1 05	1 00	0 15 E	0 35 E	0 25 E
3	1 00	1 20	1 40	0 50	1 20	1 30
4	1 20	2 00	2 25	1 30	2 15	2 35
5	2 00	2 40	3 20	2 15	3 05	3 40
6	2 35	3 45	4 40	2 45	4 00	5 00
7	3 25	4 55	6 20	3 40	5 15	6 40
8	4 30	6 20	8 15	4 45	6 40	8 35
9	5 30	7 45	10 15	5 45	8 05	10 35
10	6 10	8 40	11 30	6 25	9 15	12 00
11	5 55	8 25	11 20	6 15	9 00	12 00
12	4 20	6 20	8 15	4 40	6 40	8 50
13	1 40	2 15	2 50	2 10	2 50	3 40
14	1 05W	1 45W	2 45W	0 35W	1 05W	1 40W
15	3 10	4 30	6 40	2 25	3 40	5 15
16	4 15	6 05	8 20	3 25	4 50	6 50
17	4 40	6 40	9 10	3 45	5 25	7 30
18	4 40	6 40	9 10	3 45	5 30	7 35
19	4 35	6 05	8 20	3 45	5 30	7 35
20	3 50	5 15	6 55	3 45	5 25	7 25
21	2 55	3 50	5 15	3 40	5 00	6 50
22	1 50	2 25	3 20	3 25	4 25	5 55
23	0 55	1 05	1 45	2 40	3 20	4 25
24	0 15	0 15	0 40	1 45	1 50	2 40

Angle described by the north magnetic pole from true north, reduced into time.	Latitude 51° 30′ N, variation 19° W, the same as in London in 1759.					
	Angle between the magnetic poles.					
	130°			170°		
	Height of the needle's centre above the centre of the circle described by the poles.			Height of the needle's centre above the centre of the circle described by the poles.		
	Inches 12·25	Inches 10·25	Inches 8·25	Inches 12·25	Inches 10·25	Inches 8·25
	Deviation.	Deviation.	Deviation.	Deviation.	Deviation.	Deviation.
h	° ′	° ′	° ′	° ′	° ′	° ′
0	2 30 E	3 40 E	4 20 E	2 35 E	3 50 E	4 50 E
1	2 20	3 15	3 50	3 15	4 40	5 40
2	2 10	2 45	3 35	3 20	4 35	5 40
3	2 10	2 45	3 30	3 15	4 15	5 35
4	2 10	2 55	3 50	3 10	4 10	5 20
5	2 25	3 30	4 30	3 10	4 15	5 40
6	3 05	4 20	5 35	3 30	4 45	6 25
7	3 40	5 20	6 50	4 10	5 40	7 35
8	4 30	6 20	8 20	4 45	6 40	8 50
9	4 45	6 45	9 10	5 05	7 20	9 50
10	3 50	5 35	7 10	4 10	6 00	7 55
11	0 00	0 30W	1 10W	0 15	0 00	0 40W
12	5 45W	9 30	13 35	5 25W	9 05W	13 15
13	9 35	14 20	18 45	9 15	13 50	18 45
14	9 35	13 35	17 30	9 20	13 05	17 20
15	7 55	11 00	14 10	7 30	10 30	13 40
16	6 15	8 20	10 50	5 40	7 40	10 15
17	4 40	6 15	8 15	4 10	5 30	7 40
18	3 30	4 35	6 10	3 15	4 20	5 50
19	2 10	2 45	3 40	2 40	3 25	4 45
20	0 25	0 30	0 50	2 15	2 50	3 50
21	1 20 E	2 05 E	2 15 E	1 40	1 50	2 30
22	2 30	3 35	4 15	0 35	0 00	0 20
23	2 40	3 55	4 40	1 05 E	2 15 E	2 30 E
24	2 35	3 35	4 20	2 35	3 50	4 45

Angle described by the north magnetic pole from true north, reduced into time.	Latitude 51° 30′ N, variation 24° 40′ W, the same as near London in 1820.					
	Angle between the magnetic poles.					
	130°			170°		
	Height of the needle's centre above the centre of the circle described by the poles.			Height of the needle's centre above the centre of the circle described by the poles.		
	Inches 12·25	Inches 10·25	Inches 8·25	Inches 12·25	Inches 10·25	Inches 10·25
	Deviation.	Deviation.	Deviation.	Deviation.	Deviation.	Deviation.
h	° ′	° ′	° ′	° ′	° ′	° ′
0	2 45 E	3 40 E	4 35 E	2 50 E	4 25 E	5 15 E
1	2 25	3 25	4 05	3 30	5 00	6 10
2	2 10	2 55	3 40	3 30	4 40	6 00
3	2 10	2 55	3 40	3 15	4 20	5 40
4	2 10	2 55	3 50	3 05	4 15	5 25
5	2 25	3 25	4 30	3 05	4 15	5 35
6	3 05	4 15	5 25	3 25	4 40	6 15
7	3 40	5 10	6 35	3 55	5 35	7 20
8	4 15	5 55	7 40	4 25	6 20	8 20
9	4 20	6 05	8 00	4 30	6 20	8 35
10	2 50	3 50	5 15	3 15	4 15	5 40
11	1 20W	2 50W	4 15W	1 00W	2 10W	3 50W
12	7 00	11 30	15 30	6 45	10 50	15 25
13	10 05	15 00	19 25	9 50	14 45	19 35
14	9 45	13 40	17 35	9 25	13 25	17 30
15	7 55	10 30	13 45	7 25	10 20	13 25
16	5 50	7 50	10 35	5 30	7 25	10 00
17	4 20	5 45	7 40	3 55	5 15	7 20
18	3 00	4 00	5 25	2 55	3 55	5 30
19	1 40	2 15	2 55	2 20	3 00	4 20
20	0 05 E	0 00	0 00	1 55	2 20	3 20
21	1 45	2 40 E	2 55 E	1 15	1 15	1 45
22	2 50	4 00	3 40	0 05	0 35 E	0 25 E
23	3 05	4 20	5 05	1 30 E	2 40	3 20
24	2 50	3 40	4 35	2 55	4 25	5 20

Angle described by the north magnetic pole from true north, reduced into time.	Latitude 73° 14′ N, variation 124° W, the same as at Port Bowen in 1825.					
	Angle between the magnetic poles.					
	130°			170°		
	Height of the needle's centre above the centre of the circle described by the poles.			Height of the needle's centre above the centre of the circle described by the poles.		
	Inches 12·25	Inches 10·25	Inches 8·25	Inches 12·25	Inches 10·25	Inches 8·25
	Deviation.	Deviation.	Deviation.	Deviation.	Deviation.	Deviation.
h	° ′	° ′	° ′	° ′	° ′	° ′
0	1 40 E	2 20 E	3 00 E	2 55 E	3 50 E	5 05 E
1	1 05	1 20	1 35	2 15	2 40	3 40
2	0 20	0 20	0 20	1 20	1 25	1 50
3	0 15W	0 30W	1 00W	0 20	0 15	0 00
4	0 55	1 25	2 20	0 25W	1 00W	1 40W
5	1 40	2 20	3 30	1 30	2 20	3 26
6	2 25	3 25	4 50	2 25	3 30	5 00
7	3 20	4 30	6 25	3 20	4 45	6 35
8	4 05	5 35	7 40	4 15	5 50	8 00
9	4 40	6 30	8 35	4 55	6 45	9 10
10	4 55	6 45	8 55	5 20	7 10	9 25
11	4 50	6 35	8 30	5 20	6 45	9 05
12	4 05	5 30	7 00	4 30	5 50	7 40
13	2 50	3 40	4 50	3 20	4 15	5 35
14	1 20	1 35	2 20	1 50	2 10	3 00
15	0 05 E	0 30 E	0 20 E	0 25	0 15	0 35
16	1 30	2 25	2 35	0 50 E	1 30 E	1 40 E
17	2 40	3 45	4 30	1 55	2 50	3 30
18	3 30	4 50	6 00	2 40	3 45	4 50
19	3 45	5 25	6 55	3 15	4 35	5 50
20	3 45	5 50	7 05	3 35	5 15	6 35
21	3 40	5 20	6 45	3 40	5 20	6 50
22	3 10	4 30	5 45	3 40	5 20	6 40
23	2 25	3 25	4 25	3 30	4 45	6 15
24	1 40	2 20	3 00	2 55	3 50	5 05