XIX. *Discussion of the Magnetical Observations made by Captain* Back, *R.N. during his late Arctic Expedition. By* S. Hunter Christie, *Esq. M.A. F.R.S. &c.*

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PREVIOUS to Captain Back's departure in 1833 with the expedition for the relief of Captain Ross, he consulted me respecting the nature of the magnetical observations which I considered it desirable should be made in the regions he was likely to visit. I was fully sensible that, however available the expedition on which he had so nobly volunteered might be made to the cause of science, its primary object, and that to which all others must give place, was the relief of our gallant countrymen, at that time considered to be in imminent danger of perishing in the inhospitable regions which their enterprising spirit had led them to explore. I therefore considered it an object of the first importance, that whatever observations were to be made during the movements of the expedition should be so conducted as to cause as little delay as possible consistently with obtaining data for correct results, and also, that they should be made in the order of their importance. Compared with observations of the direction of the magnetic needle, both with reference to the meridian and to the vertical, other observations are of minor importance towards establishing anything like a theory of terrestrial magnetism. Considering that observations of the direction of the needle with reference to the meridian, though quite as important in a theoretical point of view as those with regard to the vertical, were necessarily called for in the conducting of the expedition, I, in the first instance, pointed out the observations which I considered necessary for determining the dip of the needle at the various stations where it might be practicable to make such observations; and I left the less important ones for the determination of the relative intensities of the absolute force acting upon the needle, which required more care, attention and assistance, to be made or not, according to the circumstances under which the expedition might be placed. Immediately on his return, Captain Back did me the favour to place all his magnetical observations at my disposal, and I feel that I should not do justice to the zeal and ability which that enterprising officer has displayed in the cause of science, if I did not, now that I have had leisure to reduce the observations, lay an account of them before the Royal Society.

I. *Observations of the Dip of the Magnetic Needle.*

The instrument employed for determining the dip was a small but very accurate one, by Dollond, furnished with two rectangular needles, each three inches in length.

This instrument is more fully described in the Appendix to Captain Back's Narrative. I have already stated that, in the mode of observing which I recommended to Captain Back, I had particular regard to the economy of time. Considering, therefore, that the operation of inverting the poles of the needle more than doubles the time required for observing without performing it, and, indeed, that it is one which can only be tolerated because generally necessary to counteract imperfections in the instrument employed, I proposed that, in general, this operation should be dispensed with. In order that the dip may be determined independently of this operation, it is necessary that the position of the centre of gravity of the needle employed, with reference to the axis of vibration, should be permanent, and that that position should be ascertained. Owing to the very short interval between the completion of the instruments and the departure of Captain Back, the observations made in London, from which, in conjunction with those to be made at the winter quarters of the expedition, I proposed determining this point, were not so satisfactory as might be desired; and I have consequently been under the necessity of having recourse to the latter alone. It is therefore necessary that in giving an account of the observations for the dip of the needle I should commence with those at Fort Reliance, the winter station.

Dip at Fort Reliance.—Of the two needles No. I. and No. II. belonging to the instrument, No. II. was reserved for determining the dip and intensity at the various stations, and was carefully preserved from all interference with its magnetic state; but with No. I. the dip at Fort Reliance was determined by observations made with its poles direct and likewise inverted. In the following Table are given the means of five observations made with this needle in each position of the instrument, and the mean results of two sets of observations.

Observations of the Dip at Fort Reliance with the Needle No. I.

Date.	Time.	Therm.	Poles of the needle direct.				Poles of the needle reversed.				Means.
			Face of the needle to the face of instrument.		Face of the needle reversed.		Face of the needle to the face of instrument.		Face of the needle reversed.		
			Face of instrument East.	Face of instrument West.	Face of instrument East.	Face of instrument West.	Face of instrument East.	Face of instrument West.	Face of instrument East.	Face of instrument West.	
	h m	°	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′ ″
1833. Oct. 10.	11 15 A.M. / 2 15 P.M.	41·25	84 19·5	84 17·5	84 54	84 25	82 34·5	86 9·5	85 47·5	82 12	84 19 56
1834. May 22.	3 10 P.M. / 8 20 P.M.	47·0	85 27	83 27	83 21	85 00	81 1·5	83 44·5	85 38·5	82 0·5	83 42 30
			Mean dip at Fort Reliance...................								84 1 13

In a paper "On Improvements in the Instruments and Methods employed in determining the Direction and Intensity of the Terrestrial Magnetic Force," published in the Philosophical Transactions for 1833, I have given the equations

$$\left.\begin{aligned} w\,g\cos({}_{,}\theta+\gamma) - l\,m\sin({}_{,}\theta-\delta) &= 0 \\ w\,g\cos({}'\theta-\gamma) - l\,m\sin({}'\theta-\delta) &= 0 \end{aligned}\right\}*$$

for the determination of the dip, without inverting the poles of the needle, when the position of the centre of gravity of the needle is known. These equations, when the dip is known, determine the position of the centre of gravity. The form, however, in which I have given the expression for the determination of the dip,

$$\tan\delta = \frac{2 - (\cot{}'\theta - \cot{}_{,}\theta)\cot\gamma}{\cot{}'\theta + \cot{}_{,}\theta},$$

is not so convenient for computation as another which it may be made to assume. The above equations may be put in the form,

$$\text{M}\sin({}'\theta-\delta) - \cos({}'\theta-\gamma) = 0 \quad \ldots\ldots\ldots \quad (1.),$$

$$\text{M}\sin({}_{,}\theta-\delta) - \cos({}_{,}\theta+\gamma) = 0 \quad \ldots\ldots\ldots \quad (2.);$$

where M will represent the ratio of the static momentum of the magnetic force acting upon the needle, to the static momentum of its weight, about the axis of motion; δ representing the inclination of the direction of the terrestrial magnetic force to the horizon, or the dip; γ the angle which the line joining the centres of gravity and motion makes with the magnetic axis of the needle; ${}'\theta$ and ${}_{,}\theta$ the angles which that axis makes with the horizon, when the centre of gravity is above the axis of motion, and when it is below that axis. From these equations we obtain

$$\text{M}\{\sin({}'\theta-\delta) + \sin({}_{,}\theta-\delta)\} - \{\cos({}'\theta-\gamma) + \cos({}_{,}\theta+\gamma)\} = 0,$$

$$\text{M}\{\sin({}'\theta-\delta) - \sin({}_{,}\theta-\delta)\} - \{\cos({}'\theta-\gamma) - \cos({}_{,}\theta+\gamma)\} = 0.$$

Consequently,

$$\text{M}\,.\cos\frac{{}'\theta-{}_{,}\theta}{2}\,.\sin\left\{\frac{{}'\theta+{}_{,}\theta}{2}-\delta\right\} - \cos\frac{{}'\theta+{}_{,}\theta}{2}\cos\left\{\gamma-\frac{{}'\theta-{}_{,}\theta}{2}\right\} = 0,$$

$$\text{M}\,.\sin\frac{{}'\theta-{}_{,}\theta}{2}\,.\cos\left\{\frac{{}'\theta+{}_{,}\theta}{2}-\delta\right\} - \sin\frac{{}'\theta+{}_{,}\theta}{2}\sin\left\{\gamma-\frac{{}'\theta-{}_{,}\theta}{2}\right\} = 0;$$

or, putting $\text{S} = \frac{{}'\theta+{}_{,}\theta}{2}$ and $\text{D} = \frac{{}'\theta-{}_{,}\theta}{2}$,

$$\text{M}\cos\text{D}\sin(\text{S}-\delta) - \cos\text{S}\cos(\gamma-\text{D}) = 0 \quad \ldots\ldots\ldots \quad (3.),$$

$$\text{M}\sin\text{D}\cos(\text{S}-\delta) - \sin\text{S}\sin(\gamma-\text{D}) = 0. \quad \ldots\ldots\ldots \quad (4.).$$

Hence we have

$$\tan\text{S}\,.\tan(\text{S}-\delta) = \tan\text{D}\,.\cot(\gamma-\text{D}) \quad \ldots\ldots\ldots\ldots \quad (5.);$$

a most convenient equation for computing the value of δ, that of γ being known; or, *vice versâ*, for determining the value of γ from that of δ, to which purpose I shall now apply it, with reference to the observation made at Fort Reliance with the needle No. II.

In the following Table are given the means of five observations made with the

* Philosophical Transactions, 1833, p. 345.

needle No. II. in each position of the instrument, and the resulting mean values of the angles $'\theta$ and $_{\prime}\theta$.

Observations for the Dip at Fort Reliance with the Needle No. II.

Date.	Time.	Therm.	Face of the needle to the face of instrument. Face of instrument East. $_{\prime}\theta$.	Face of the needle to the face of instrument. Face of instrument West. $'\theta$.	Face of the needle reversed. Face of instrument East. $'\theta$.	Face of the needle reversed. Face of instrument West. $_{\prime}\theta$.	Mean values. $'\theta$.	Mean values. $_{\prime}\theta$.
1833. Oct. 9.	h m 2 15 P.M. – 5 40 P.M.	39°	84° 17′	86° 42′	86° 35·5′	81° 21·5′	86° 38′ 45″	82° 49′ 15″
1834. May 21.	3 30 P.M. – 6 45 P.M.	49·6	83 55·5	86 10	86 8	81 59	86 9 0	82 57 15
			Means of the two sets of observations ……				86 23 53	82 53 15

Taking 84° 1′ as the dip at Fort Reliance, substituting this for δ, and the values in the preceding Table for $'\theta$ and $_{\prime}\theta$, in the equation (5.), we obtain $\gamma = 16° 29' 19''$. By means of this value of γ and the observed values of $'\theta$ and $_{\prime}\theta$, the value of δ, or the dip, is determined at the several stations at which observations were made with the needle No. II., assuming that the position of the axis of the needle was permanent in all these observations. The following Table contains: the means of Captain Back's observations of the direction of the needle, five being made in each position of the instrument, and both the lower and upper reading of the needle being registered; the deduced mean values of $'\theta$ and $_{\prime}\theta$; and the value of δ, or the dip, determined by substituting these mean values of $'\theta$ and $_{\prime}\theta$, and the above value of γ in the equation (5.).

Place of observation.	Latitude North.	Longitude West.	Date.	Observed dip of the needle. Face of the needle to face of instrument. Face of instrument East. $_{\prime}\theta$.	Observed dip of the needle. Face of the needle to face of instrument. Face of instrument West. $'\theta$.	Observed dip of the needle. Face of the needle reversed. Face of instrument East. $'\theta$.	Observed dip of the needle. Face of the needle reversed. Face of instrument West. $_{\prime}\theta$.	Mean values. $'\theta$.	Mean values. $_{\prime}\theta$.	Deduced value of δ or dip.
New York …………	40° 42′ 7″	74° 1′ 15″	1833. April 1.	72° 24·7′	73° 28·7′	73° 47′	73° 16′	73° 37′ 51″	72° 50′ 21″	72° 49′ 18″
Montreal …………	45 29 34	73 42 27	April 19.	77 12	78 28	78 58	76 36·4	78 43 00	76 54 12	77 6 27
Fort Alexander……	50 36 49	96 21 25	June 10.	78 56·25	79 46·25	80 12·9	78 24·4	79 59 35	78 40 19	78 53 37
Cumberland House	53 57 33	102 21 46	July 6.	79 00	82 21	83 26·25	78 27·5	82 53 37	78 43 45	79 29 59
Isle à la Crosse…..	55 25 25	107 54 36	July 17.	79 45	82 2·9	82 40	77 53·5	82 21 28	78 49 15	79 28 24
Fort Chipewyan …	58 42 32	111 19 00	July 31.	80 27	82 38·5	84 14·5	80 6·5	83 26 30	80 16 45	81 00 39
Fort Resolution …	61 10 26	113 45 00	Aug. 9.	81 38·5	85 11·5	85 29·5	80 7·5	85 20 30	80 53 00	82 3 9
Fort Reliance ……	62 46 29	109 0 39	Oct. 9.	84 17	86 42	86 35·5	81 21·5	86 38 45	82 49 15	84 3 19
			1834. May 21.	83 55·5	86 10	86 8	81 59	86 9 00	82 57 15	83 58 44
Musk-Ox Rapid …	64 40 51	108 8 10	July 2.	85 10	87 36·25	87 35·6	84 28·75	87 35 56	84 49 23	85 53 32
Rock Rapid ………	65 54 18	98 10 7	July 23.	85 27	89 41	89 40·5	86 49	89 40 45	86 8 00	87 39 34
Point Beaufort……	67 41 24	95 2 16	July 31.	86 2	89 24·5	89 45·5	87 39	89 35 00	86 50 30	88 3 15
Montreal Island …	67 47 27	95 18 15	Aug. 2.	86 0	89 19	88 14	87 25·5	88 46 30	86 42 45	87 35 49
Point Ogle ………	68 13 57	94 58 1	Aug. 12.	89 28·5	91 45·5	88 56·5	87 34	90 21 00	88 31 15	89 24 12
Fort Reliance ……	…………	……………	Oct. 9.	84 2	86 30·5	86 27	83 1·5	86 28 45	83 31 45	84 31 24

In this and subsequent Tables I have given the results to the nearest second; not that I, by any means, consider that the dip has been in this, or that it is in any case determined to anything like such a degree of accuracy; but because such results rendered testing the accuracy of calculation more convenient; and that having, in subsequent calculations, employed the actual results obtained, I have thought it right to give them in all cases.

In order to show the care which Captain Back took, in making the observations, to be as free as possible from the effects of any particular local influence, it is necessary that I should give his notes on the situations, with reference to surrounding objects, of the spots on which the observations were made; and it will be proper that I should do so previous to making any remarks on the results contained in the foregoing Table.

New York. "The observations were made in the garden of the British consul under a temporary shed, erected for the purpose, and distant from the house eighty paces."

Montreal. "The observations were made under a tent on the island of St. Helen's, in the St. Lawrence, one thousand yards from the city of Montreal. There was no iron near; the roofs of the houses in the city are most of them covered with tin."

Fort Alexander. There is no note appended to the observations, on the position of the instrument here; but, in his Narrative, Captain Back makes a remark on some discrepancies in the dip of the needle, which he attributes to the influence of a distant thunder storm*.

Cumberland House. "The observations were made in a tent about two hundred yards from the house."

Isle à la Crosse. "The observations were made in a tent forty paces from the stockades of the fort."

Fort Chipewyan. "The observations were made in a tent to the westward of the fort."

Fort Resolution. "This set was made in a tent placed inside of the stockades of the fort, but quite free from the influence of any iron."

It is necessary I should remark, that in this set of observations the differences in the observed angles were considerable, with the face of the needle reversed and the face of the instrument west. Six observations were made in this position; they were as follow: 79° 00′; 79° 17′·5; 79° 55′; 80° 5′; 80° 12′·5; 80° 17′·5. The result given in the eighth column of the Table is the mean of the last four: I rejected the first two, because the others are very accordant and indicate no disposition in the needle to return to its first position. On the subject of these observations Captain Back has made this remark: "At the time the needle changed from 79° 15′ to 80° (lower readings) the weather was more than commonly gloomy, and some few drops of rain fell." During the time of making this whole set of observations "the weather was gloomy, dark, and overcast, with light rain at intervals:" so that the discrepancy here noticed was most probably owing to some change in the electric state of the atmosphere.

* Narrative of the Arctic Land Expedition, p. 41.

Fort Reliance. "These observations were made in my tent, which had a leather circular lodge or wigwam attached to it, in which was a small fire. The ground on which the stand was placed was gravel, about one hundred yards from the lake."

Rock Rapid. "These observations were made as before in the tent, the theodolite stand being placed on shingle, at the foot of a high gneiss rock."

Point Beaufort. "The observations made as usual; the stand on shingle at the base of a gneiss rock three to four hundred feet high."

Montreal Island. "The stand was placed on firm sand about sixty yards from some low rocks, and a sail was put over the tent to afford more shade."

Point Ogle. "The stand was firmly fixed in sand and shells, of which the beach was composed, thirty paces from the beach, which was packed with ice."

Independently of the accuracy with which the observations were made, and of the precautions taken to exclude the effects of any particular local influence upon the needle, it is evident that the correctness of the results deduced from them in the foregoing Table must depend upon the permanence of the angle γ, and upon a correct value having been assigned to that angle. It is therefore necessary to inquire whether any tests can be applied to these observations which may indicate the extent of the errors by which these results may be affected.

Values being assigned to γ and δ in the equations (1.) and (2.) or (3.) and (4.), these equations furnish measures of the terrestrial magnetic intensity, viz.

$$M = \frac{\cos ({}'\theta - \gamma)}{\sin ({}'\theta - \delta)}, \qquad \text{or } M = \frac{\cos ({}_{,}\theta + \gamma)}{\sin ({}_{,}\theta - \delta)} \quad . \; . \; . \; . \; . \; . \; . \quad (6.);$$

$$M = \frac{\cos S}{\cos D} \cdot \frac{\cos (\gamma - D)}{\sin (S - \delta)}, \text{ or } M = \frac{\sin S}{\sin D} \cdot \frac{\sin (\gamma - D)}{\cos (S - \delta)} \quad . \; . \; . \; . \; . \quad (7.)$$

In order, however, that the values of M, thus determined, should be as little as possible affected by errors of adjustment of the instrument or needle, it is necessary that the centre of gravity of the needle should be distant from the axis of motion, and that the angle γ should be large*. The needle with which these observations were made not having been constructed for this purpose, but with the view of determining the variations in the terrestrial intensity by means of its times of vibration, its centre of gravity was made to coincide as nearly as possible with its axis of vibration. In determining therefore the values of M from the equations (6.) by means of it, we are not to expect very close approximations to the values derived from other principles. Admitting this, however, the results ought not in any case to be quite discordant. In the following Table I have given the values of M deduced from the equations (6.), assuming the value of γ to be 16° 29′ 19″; and in the following column, for the purpose of comparison, the relative values of M deduced from the times of vibration of the needle No. II. in the plane of the meridian†.

* Philosophical Transactions, 1833, p. 348.

† The observations from which these are deduced are given in a subsequent part of this paper.

Place of observation.	Relative intensity $M = \frac{\cos ('\theta - \gamma)}{\sin ('\theta - \delta)}$, or $M = \frac{\sin S . \sin (\gamma - D)}{\sin D \cos (S - \delta)}$.	Relative intensity, or value of M deduced from the time of vibration of the needle No. II.
New York	38·41	8·140936
Montreal	16·60	8·3 ?
Fort Alexander	23·25	8·569610
Cumberland House	6·76	8·409142
Isle à la Crosse	8·12	8·278406
Fort Chipewyan	9·23	8·324042
Fort Resolution	6·29	8·612853
Fort Reliance	8·26702	8·26702
Musk-Ox Rapid	10·73	8·169870
Rock Rapid	8·20	8·327742
Point Beaufort	10·90	8·041422
Montreal Island	14·80	8·154152
Point Ogle	16·82	8·277498
Fort Reliance, Oct. 9, 1834.	10·03	8·269714

Making every allowance for the want of adaptation of the needle to this method of determining the relative intensities, for errors of observation in determining the times of vibration of the needle, and for any disturbing causes affecting these observations, such differences are here exhibited in the results obtained by the two methods, at New York, Montreal, Fort Alexander, Montreal Island, and Point Ogle, as can only be accounted for by errors in the assumed value of the angle γ, and clearly indicate a want of permanence in that angle. It therefore becomes necessary to inquire what changes in the angle γ will account for these discrepancies, and how far the dip may be affected. For this purpose either γ or δ must be eliminated from the equations (3.) and (4.), and the value of the other determined in terms of M.

Putting these equations in the form

$$\left.\begin{aligned} M^2 \cos^2 D . \sin^2 (S - \delta) &= \cos^2 S . \cos^2 (\gamma - D) \\ M^2 \sin^2 D . \cos^2 (S - \delta) &= \sin^2 S . \sin^2 (\gamma - D) \end{aligned}\right\},$$

we obtain immediately

$$M^2 \{\sin^2 S . \cos^2 D - \cos^2 S . \sin^2 D\} . \sin^2 (S - \delta) = \sin^2 S . \cos^2 S - M^2 \cos^2 S . \sin^2 D,$$

$$M^2 \{\sin^2 S . \cos^2 D - \cos^2 S . \sin^2 D\} . \cos^2 (S - \delta) = M^2 \sin^2 S . \cos^2 D - \sin^2 S . \cos^2 S.$$

Putting $P = M . \frac{\sin D}{\sin S}$, and $Q = M . \frac{\cos D}{\cos S}$, these equations become

$$M^2 \sin '\theta \sin {}_{,}\theta \sin^2 (S - \delta) = \frac{1}{4} \sin^2 2 S (1 - P^2) \quad . \; . \; . \; . \; . \; . \; . \quad (8.),$$

$$M^2 \sin '\theta \sin {}_{,}\theta \cos^2 (S - \delta) = \frac{1}{4} \sin^2 2 S (Q^2 - 1) \quad . \; . \; . \; . \; . \; . \; . \quad (9.);$$

whence,

$$\tan (S - \delta) = \sqrt{\left\{\frac{1 - P^2}{Q^2 - 1}\right\}} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (10.)^*$$

The equation (5.) gives

$$\cot (\gamma - D) = \frac{Q}{P}\sqrt{\left\{\frac{1 - P^2}{Q^2 - 1}\right\}} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (11.);$$

or, putting $P_{,} = \frac{1}{P}$ and $Q_{,} = \frac{1}{Q}$,

$$\cot (\gamma - D) = \sqrt{\left\{\frac{P_{,}^2 - 1}{1 - Q_{,}^2}\right\}} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (11_{,}.)$$

Assuming that the values of M deduced from the time of vibration of the needle at the several stations are the correct values, and substituting them in the equation (10.), I have computed the values of $S - \delta$, $\gamma - D$, and thence determined the dip and the angle γ at these stations. The results are arranged in the following Table.

Place of observation.	Value of M deduced from the time of vibration of the needle No. II.	Value of $\gamma - D$ deduced from the foregoing value of M.	Value of $S - \delta$ deduced from the foregoing value of M.	Resulting value of γ.	Resulting value of δ.	Value of δ deduced from the constant value $\gamma = 16°\ 29' 19''$.	Difference between the two values of δ.
		° ′ ″	° ′ ″	° ′ ″	° ′ ″	° ′ ″	° ′ ″
New York	8·140936	3 21 55	2 1 37	3 45 40	71 12 29	72 49 18	+1 36 49
Montreal	8·3 ?	7 43 10	1 26 41	8 37 34	76 21 55	77 6 27	+0 44 32
Fort Alexander	8·569610	5 46 7	1 13 54	6 25 45	78 6 3	78 53 37	+0 47 34
Cumberland House	8·409142	18 1 36	1 2 7	20 6 31	79 46 34	79 29 59	−0 16 35
Isle à la Crosse	8·278406	15 0 21	1 5 37	16 46 28	79 29 45	79 28 24	−0 1 21
Fort Chipewyan	8·324042	13 24 54	0 56 54	14 59 47	80 54 44	81 00 39	+0 5 55
Fort Resolution	8·612853	19 43 10	0 45 6	21 56 55	82 21 39	82 3 9	−0 18 30
Fort Reliance, October 9, 1833, and May 21, 1834	8·267020	14 44 0	0 37 34	16 29 19	84 1 0	84 1 0	0 0 0
Musk-Ox Rapid	8·169870	11 26 22	0 27 16	12 49 39	85 45 24	85 53 32	+0 8 8
Rock Rapid	8·327742	14 56 30	0 14 35	16 42 53	87 39 48	87 39 34	−0 0 14
Point Beaufort	8·041422	11 5 49	0 13 5	12 28 4	87 59 40	88 3 15	+0 3 35
Montreal Island	8·154152	8 26 47	0 16 25	9 55 17	87 27 13	87 35 49	+0 8 36
Point Ogle	8·277498	7 35 38	0 4 3	8 30 31	89 22 5	89 24 12	+0 2 7
Fort Reliance, Oct. 9, 1834	8·269714	12 20 15	0 35 23	13 48 45	84 24 52	84 31 24	+0 6 32

The differences between the values of γ in the above Table, deduced from the equation (11.), and its assumed value, are certainly in many cases considerable; and the dip also, in some, differs considerably from that previously deduced. It is, however, to be remarked with regard to these differences, that the above values of γ are deduced from the assumption that no other sources of error existed in the instrument than the want of permanence in the axis of the needle itself. Those who have been most in the habit of making observations for determining the dip, will be best able

* Either of the equations (8.) or (9.) gives a convenient expression for the calculation of $S - \delta$, viz. $\sin (S - \delta) = \frac{\sin 2 S}{2 M}\sqrt{\frac{1 - P^2}{\sin {}'\theta \sin_{,}\theta}}$, or $\cos (S - \delta) = \frac{\sin 2 S}{2 M}\sqrt{\frac{Q^2 - 1}{\sin {}'\theta \sin_{,}\theta}}$; but the equation (10.) is even more so. It might appear that the equation (10.) would be better adapted for logarithmic computation, if put in the form $\tan (S - \delta) = \sqrt{\frac{(1 + P) \cdot (1 - P)}{(Q + 1) \cdot (Q - 1)}}$; but this is not the case, since the computation which would determine P determines P^2 by simply doubling the logarithm; and besides this, the same opening of the table by which Q^2 would be found, gives the logarithm of $Q^2 - 1$.

to judge how far this is likely to be the case in any dipping instrument; I can only say that in the observations which I have myself made, and in those of others which I have examined, I have rarely considered that the observed angles could be relied upon, as being absolutely those which the axis of the needle would make with the horizon, if perfectly free, in any assumed position; and even when a mean of several observations has been taken, I have in general felt that it might differ from the truth by several minutes. I do not therefore consider that all the discrepancies in the relative terrestrial intensities can properly be attributed to the want of permanence in the axis of the needle, though no doubt some, those which are the greatest, are principally attributable to this cause. It may, however, be proper to inquire what errors in the observed values of $'\theta$ and $_{,}\theta$ will account for these discrepancies, as we shall thus be enabled to judge whether they may not in some cases be ascribed to this cause. It however unfortunately happens that in this inquiry a knowledge of the dip itself is absolutely necessary; and it is only by assuming that which has been determined by means of the values $'\theta$ and $_{,}\theta$, now supposed to be erroneous, that we can determine the changes requisite in the values to account for the discrepancies in the relative intensities.

The equations (1.) and (2.) give immediately,

$$\cot {'\theta} = \frac{\mathrm{M} \cos \delta - \sin \gamma}{\mathrm{M} \sin \delta + \cos \gamma} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (12.)$$

$$\cot {_{,}\theta} = \frac{\mathrm{M} \cos \delta + \sin \gamma}{\mathrm{M} \sin \delta + \cos \gamma}. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (13.)$$

Assuming then the values of M already given as deduced from the times of vibration of the needle, the dips as first deduced from the observations, and the constant value $\gamma = 16° \ 29' \ 19''$, the values of $'\theta$ and $_{,}\theta$ in the following Table are deduced from these equations.

Place of observation.	Value of M deduced from the time of vibration of the needle No. II.	Dip first deduced or value of δ.	Value of $'\theta$ computed from the equation (12.).	Observed value of $'\theta$.	Resulting error in the observed value of $'\theta$.	Value of $_{,}\theta$ computed from the equation (13.).	Observed value of $_{,}\theta$.	Resulting error in the observed value of $_{,}\theta$.
New York........	8·140936	72° 49′ 18″	76° 21′ 23″	73° 37′ 51″	+2° 43′ 32″	72° 53′ 48″	72° 50′ 21″	+0° 3′ 27″
Montreal	8·3 ?	77 6 27	80 10 10	78 43 00	+1 27 10	76 43 16	76 54 12	−0 10 56
Fort Alexander	8·569610	78 53 37	81 41 53	79 59 35	+1 42 18	78 19 54	78 40 19	−0 20 25
Cumberland House...	8·409142	79 29 59	82 17 38	82 53 37	−0 35 59	78 51 53	78 43 45	+0 8 8
Isle à la Crosse.........	8·278406	79 28 24	82 18 34	82 21 28	−0 2 54	78 49 54	78 49 15	+0 0 39
Fort Chipewyan	8·324042	81 00 39	83 40 48	83 26 30	+0 14 18	80 12 29	80 16 45	−0 4 16
Fort Resolution	8·612853	82 3 9	84 32 23	85 20 30	−0 48 7	81 9 59	80 53 00	+0 16 59
Musk-Ox Rapid	8·169870	85 53 32	88 6 16	87 35 56	+0 30 20	84 32 58	84 49 23	−0 16 25
Rock Rapid	8·327742	87 39 34	89 39 9	89 40 45	−0 1 36	86 9 13	86 8 00	+0 1 13
Point Beaufort.........	8·041422	88 3 15	90 4 7	89 35 00	+0 29 7	86 27 28	86 50 30	−0 23 2
Montreal Island	8·154152	87 35 49	89 38 5	88 46 30	+0 51 35	86 4 9	86 42 45	−0 38 36
Point Ogle	8·277498	89 24 12	91 13 34	90 21 00	+0 52 34	87 42 22	88 31 15	−0 48 53

The differences here shown between the observed and computed values of the angle $_{,}\theta$ are, with a few exceptions, within the limits of the errors of dip observations; but those of the angle $'\theta$ are by no means so, excepting in a few instances. Upon the whole we must therefore conclude, that the discrepancies which appear between the values of the terrestrial intensity, as deduced from the times of vibration of the needle, and from the observed angles of inclination to the horizon, are principally attributable to a want of absolute permanence in its axis of motion. With respect to the amount of the change in this axis, it is to be observed, that in this needle the centre of gravity was nearly coincident with the axis; and, consequently, that a very minute derangement of the axis would cause a considerable change in the value of the angle γ. We must not therefore infer, in consequence of the differences in the values of this angle exhibited in the preceding Table, that the needle itself received any serious injury during the expedition. To such it could not be liable, being, during the whole expedition, under the personal charge of Captain BACK, who, aware of the importance of preserving this and other needles as nearly as possible in the same state, carried them himself with the same care as he bestowed on the chronometers.

Having now fully discussed the observations which Captain BACK made with the dipping needle, it is proper that I should state how far I consider that the dip is determined by them at the several stations. If we refer to the Table at p. 384, it will be seen that, excepting the New York, Montreal, and Fort Alexander observations, the differences between the dips as determined by means of the constant value assumed for the angle γ, and as determined from the relative terrestrial intensities, deduced from the times of vibration of the same needle, are generally much within the limits of the errors to which observations of the dip, with our present instruments, are generally found liable. I think therefore that we are to consider the results not only as entitled to the confidence which is generally given to those deduced from observations carefully made with good instruments, but that the differences in the last column of the table, in general, fairly exhibit the amount of the error in each case, by which the result may be affected. In the cases of New York, Montreal, and Fort Alexander this is so considerable that much uncertainty must attach to the results determined by means of the constant value assumed for the angle γ. With respect to the dip at these places as determined by means of the intensity, it may be considered that the same degree of uncertainty may not attach. It is, however, singular that the results at New York and Fort Alexander in this case differ more widely from preceding determinations than in the other. Sir JOHN FRANKLIN* determined the dip at New York in 1825 to be 73° 27′ 3″, which differs only 37′ 45″ from the dip determined from Captain BACK's observations by means of the constant value of γ, but differs 2° 14′ 34″ from the result obtained by means of the intensity. At Fort Alexander Sir JOHN FRANKLIN's determination of the dip in 1825 was 78° 47′ 8″, differing only − 5′ 29″ from the result from Captain BACK's observations in the first case, but + 41′ 5″ from the result in the second. In December 1822 Captain SABINE determined the dip at New York to be† 73° 5′ by means of a MEYER's needle, and

* Narrative of a Second Expedition to the Shores of the Polar Sea, Appendix, p. cxxxvi.

† An Account of Experiments to determine the Figure of the Earth, &c., p. 474.

72° 55′* by the times of vibration in the meridian and at right angles to it, which differ but little from the first determination from Captain BACK's observations.

Looking to the geographical positions of some of the stations, Rock Rapid, Point Beaufort, Montreal Island, and Point Ogle, we should be led to infer that the small difference in the dip at Rock Rapid, Point Beaufort, and Montreal Island, and the considerable difference between the dip at the two latter stations and that at Point Ogle, must be due to errors of observation, or to some local cause influencing the direction of the needle. The results at all the other stations would lead us to expect, at Point Beaufort and Montreal Island, a dip but little under 89°; and it will be seen that the observations for determining the intensity by the times of vibration of horizontal needles, indicate that such should be nearly its amount.

Independently of the reduction of Captain BACK's observations, and ascertaining the degree of reliance which might be placed on the results I have deduced, I had another and more general object in the long discussion into which I have entered, that of pointing out the kind of tests which may be applied to dip observations, in order to ascertain whether the observations are consistent with themselves, and by this means whether the results deduced from them are worthy of confidence. I have not yet had leisure to enter upon such an inquiry with many observations; but in some which I have examined I find far greater discrepancies in values of the angle γ than the greatest which I have noticed in the present instance. On some future occasion I may perhaps enter more fully upon such an inquiry, but for the present I shall leave it, and proceed with Captain BACK's observations.

II. *Observations of the Variation of the Magnetic Needle.*

As these observations are published in Captain BACK's Narrative, it would be superfluous to introduce them here in the form of a table, particularly as they are given in a subsequent table, in which I have instituted a comparison between results deduced from them, in conjunction with the dip observations which I have detailed, and certain theoretical results, with the view of ascertaining how far these observations tend to support the theory. I shall therefore here simply refer to the table at p. 390 for the variation at the different stations of observation.

III. *Comparison of the Observations of the Dip and Variation of the Needle with theoretical results.*

On the hypothesis of two magnetic poles symmetrically situated in a diameter of the earth and near to its centre, the poles of verticity and of convergence will coincide, and the tangent of the dip will be equal to twice the tangent of the magnetic latitude. Although, viewing all the phenomena on the whole surface of the earth, such an hypothesis is clearly inadequate to their explanation, it is interesting to inquire how far it may be consistent with those observed on a limited portion. For such an inquiry,

* An Account of Experiments to determine the Figure of the Earth, &c., p. 476.

the observations made by Captain BACK are peculiarly well adapted, since in no case has so direct a progress been made, to such an extent, towards the magnetic pole, whether we consider that point as the point of convergence of magnetic meridians, or that at which the direction of the force is vertical. Assuming then the coincidence of these points, I had proposed inquiring whether the differential of the dip and the differential of the magnetic latitude, taking the increments in observations not very distant from each other to express these differentials, had the ratio which the theory gave, and had indeed made the requisite computations and comparisons; but on further consideration it appeared to me that this comparison was not so good a test of the theory as the more direct one of the dip itself with the magnetic latitude, since small errors in the dip would become very sensible in the value of the differential, and if these errors happened to conspire at two stations, this value might be doubled or reduced one half. I do not propose in the first instance giving the detail of that comparison, but it may be proper to mention the general nature of the results.

If λ represents the magnetic latitude, and δ the dip, then the equation

$$\tan \delta = 2 \tan \lambda$$

gives

$$\frac{d\,\delta}{d\,\lambda} = \frac{3 \cos 2\,\delta + 5}{4}.$$

In comparing the observations with this formula, I took the sum of the dips at two stations as the value of $2\,\delta$. The first observations which I employed in this comparison were those at Musk-Ox Rapid and Rock Rapid; and here the agreement was so marked that I certainly anticipated a general close agreement of the observations with the theory. This, however, was the only instance of that agreement which we ought to expect in such cases, if a theory be correct.

As the magnetic polar distances of two stations are determined from their geographical position and the observed variations of the needle by the solution of two spherical triangles, it would be superfluous to point out the course of calculation which I adopted; but it is necessary that I should state the nature of the comparison which I propose instituting between the results of theory and observation.

If φ is the magnetic polar distance of one station, and $\varphi_{\prime}$ that of another, the dip at the two stations being δ and $\delta_{\prime}$, then if the theory and the observations be both correct we shall have

$$\tan \delta \,.\, \tan \varphi = 2 \text{ and } \tan \delta_{\prime} \tan \varphi_{\prime} = 2 \quad . \quad . \quad . \quad . \quad . \quad . \quad (15.)\,;$$

and we may judge, by the approximation of these products in all cases to the number 2, of the degree of coincidence between the theory and the observations.

In the third column of the following Table are given the distances of the several stations from the magnetic pole of convergence, whose position is determined from the variations in the second column at the respective stations, combined as indicated in the first column; in the fourth column, the dip of the needle at these stations, as already determined from the constant value of the angle γ; in the fifth column, the numerical value of the product $\tan \delta . \tan \phi$; and in the sixth column, the differences between this product and the number 2, that is, the error of the theoretical result. In the three following columns are given, first, the value of $\frac{d . \delta}{d . \lambda}$, deduced from the observations; secondly, the value of $\frac{3 \cos 2 \delta + 5}{4}$, to which the former should, according to the theory, be equal; and thirdly, the difference between the values of these fractions, or the error of the theoretical result. In this Table I have not included the observations at Point Ogle, because, from the greatly diminished horizontal force acting upon the needle, I do not consider that the variation could have been determined with any precision; indeed, the amount of the daily variation, in such a position, would, supposing that the variation could be accurately determined at any instant, render the hour at which the observation was made a matter of the first importance, the position of the magnetic pole resulting from an observation made at one period of the day being necessarily very different from that deduced from observations made at others *. This remark would in a great degree apply to the observations at Point Beaufort and Montreal Island, but these places are more conveniently situated with respect to Rock Rapid, for a comparison of the observations, than Point Ogle: indeed, the variation at Rock Rapid would assign a position to the south of Point Ogle for that of the magnetic pole, which position is quite at variance with the observations at the latter station.

* This is a consideration which does not appear to have occurred either to Sir John Ross or Captain James Ross in assigning a position to the magnetic pole. Taking a mean of Sir John Ross's daily variations at Victory Harbour for the month of April 1830, we have the variation at noon 100° 53′ W., and at midnight 85° 22′ W.; giving a diurnal variation of more than 15°. Assuming the dip here 88° 55′, as determined by Captain James Ross, the distance of the pole of verticity from Victory Harbour would be 2° 9′ 57″ nearly: consequently the situation of the pole at midnight would be 35′ 5″, or rather more than 40 miles distant from its position at noon. It appears to have been considered that the *true* position of the magnetic pole has been determined within much narrower limits than such an interval. Taking this view of the subject, it may be an inquiry worth entering upon, to ascertain whether the extent of the diurnal variations observed by Captain Foster at Port Bowen corresponds to the same orbit, if I may use the expression, of the magnetic pole on the earth's surface as that observed by Captain Back at Fort Reliance; whether these correspond with the orbit which would result from the diurnal variation given by Sir John Ross; and also whether the several times of the maxima and minima are in accordance with the same motion, whether uniform or not, of the pole in one orbit. This is an inquiry upon which my present engagements do not admit of my now entering, but I propose doing so as soon as I have the requisite leisure.

Places from the observations at which the position of the pole of convergence is determined*.	Observed variation of the needle.	Magnetic polar distance.	Dip.	Value of $\tan\delta . \tan\varphi$.	Error, or value of $\tan\delta . \tan\varphi - 2$.	Value of $\frac{d.\delta}{d.\lambda}$.	Value of $\frac{3\cos 2\delta + 5}{4}$.	Error, or value of $\frac{d.\delta}{d.\lambda} - \frac{3\cos 2\delta+5}{4}$.
	° ′	° ′ ″	° ′ ″					
Fort Alexander	15 16 E.†	28 22 43	78 53 37	2·7519	+ 0·7519	·2874	·5527	− ·2653
and Cumberland House	19 14 E.†	26 16 11	79 29 59	2·6630	+ 0·6630			
Cumberland House ...	19 14 E.†	22 20 28	79 29 59	2·2173	+ 0·2173	−·1316	·5499	− ·4183
and Isle à la Crosse ...	23 19 E.†	22 8 26	79 28 24	2·1897	+ 0·1897			
Isle à la Crosse ...	23 19 E.†	32 13 34	79 28 24	3·3931	+ 1·3931	·6921	·5431	+ ·1490
and Fort Chipewyan ...	25 30 E.†	30 0 16	81 0 39	3·6504	+ 1·6504			
Fort Chipewyan ...	25 30 E.†	21 19 2	81 0 39	2·4668	+ 0·4668	·6244	·5325	+ ·0919
and Fort Resolution ...	29 15 E.†	19 38 56	82 3 9	2·5575	+ 0·5575			
Fort Chipewyan ..	25 30 E.†	10 6 50	81 0 39	1·1276	− 0·8724	·7044	·5325	+ ·1719
and Fort Resolution ...	37 20 E.	8 38 6	82 3 9	1·0878	− 0·9122			
Fort Resolution ...	37 20 E.	9 4 53	82 3 9	1·1449	− 0·8551	·7521	·5220	+ ·2301
and Fort Reliance ...	35 19 E.	6 28 11	84 1 0	1·0770	− 0·9230			
Fort Reliance ..	35 19 E.	7 13 11	84 1 0	1·2087	− 0·7913	·9148	·5116	+ ·4032
and Musk-Ox Rapid ..	44 24 E.	5 30 14	85 53 32	1·3417	− 0·6583			
Musk-Ox Rapid ...	44 24 E.	7 52 46	85 53 32	1·9271	− 0·0729	·5205	·5047	+ ·0158
and Rock Rapid ...	29 16 E.	4 29 4	87 39 34	1·9188	− 0·0812			
Rock Rapid ...	29 16 E.	2 21 16	87 39 34	1·0059	− 0·9941	·1868	·5021	− ·3153
and Point Beaufort ..	6 00 W.‡	0 14 28	88 3 15	0·1239	− 1·8761			
Rock Rapid ...	29 16 E.	2 29 56	87 39 34	1·0677	− 0·9323	−·0288	·5025	− ·5313
and Montreal Island ...	2 00 W.	0 19 30	87 35 49	0·1352	− 1·8748			
Fort Alexander ...	15 16 E.†	27 55 38	78 53 37	2·7003	+ 0·7003	·5096	·5411	− ·0315
and Fort Resolution ...	29 15 E.†	21 43 42	82 3 9	2·8546	+ 0·8546			
Fort Alexander ...	15 16 E.†	23 9 47	78 53 37	2·1794	+ 0·1794	·5909	·5411	+ ·0498
and Fort Resolution ...	37 20 E.	17 49 1	82 3 9	2·3021	+ 0·3021			
Fort Reliance ...	35 19 E.	10 53 26	84 1 0	1·8357	− 0·1643	·7017	·5079	+ ·1938
and Rock Rapid ...	29 16 E.	5 41 56	87 39 34	2·4415	+ 0·4415			

By an inspection of the numbers in the sixth column of this Table, which indicate the errors of the theoretical result, it will be seen that, with very few exceptions, there is not that accordance between the observations and the theory which, for the establishment of the theory, we ought to look for; and that they rather indicate that although the theory may be true as a first approximation, yet it requires considerable modification to render it accordant with the observations. The numbers in the ninth

* I have not included the observations at New York and Montreal in this table, on account of the uncertainty which appears to attend the determination of the variation at those cities. The variation at New York, according to the Admiralty Chart, is 2° 30′ W. Captain Bayfield found the variation at Vercheres, about twenty miles below Montreal, to be 10° 30′ W.; and we may from this assume 10° W. as the variation nearly at Montreal. These variations would give the place of the pole of convergence 7° 56′ from New York, and 3° 11′ from Montreal. Such a result is so totally at variance with all others, that it would be absurd to institute any comparison between conclusions drawn from it and any theoretical results. There can, I think, be no doubt that either the variation at New York is more than 2° 30′ W., or that at Montreal less than 10° W., or that each of these is erroneous, the one in defect, the other in excess. This is one among many instances of the very vague determination of an important element in terrestrial magnetism at places where we might expect that it would have been determined with considerable precision; and very forcibly points out the necessity of more accurate observations of the variation than we at present possess.

† Variations observed in 1825 by Sir John Franklin. Captain Back did not observe the variation at those stations in the present expedition. The other variations are those observed by Captain Back in this expedition.

‡ In the variations which Captain Back sent me, he has marked uncertain against this. The same uncertainty must apply to the variation at Montreal Island and Point Ogle. At Montreal Island the morning observation gave the variation 2° 43′ E., and the afternoon one 6° 42′ W.; the mean 2° W. At Point Ogle the variation by the morning observation was 1° 52′ E., and by the afternoon one 1° 46′ W.; "the sun's bearing at noon was first 180°, and after tapping the compass 183° 30′."

column point to the same conclusions. It must however be borne in mind that the variations at Fort Alexander, Cumberland House, Isle à la Crosse, and Fort Chipewyan, which determine the positions of the pole of convergence in these cases, are those observed by Sir JOHN FRANKLIN in 1825, and that the dips at these places, which determine the situation of the pole of verticity, are those resulting from the observations of Captain BACK in 1834: so that these observations cannot be considered as strictly comparative. This objection cannot, however, be urged against the observations from Fort Resolution to the sea, which give results equally discordant with the theory.

We have already seen that the dip at the several stations, as determined from the constant value of the angle γ, differs, and in some cases considerably, from that deduced from the value of that angle determined by means of the relative intensities. It may therefore be satisfactory to inquire whether, by employing the dips obtained from these values of the angle γ, we shall obtain results more accordant with theory. In the following Table I have arranged the results in the same form as in the preceding, the variations and magnetic polar distances employed being those there given.

Places from the observations at which the position of the pole of convergence is determined.	Observed variation of the needle.	Magnetic polar distance.	Dip.	Value of $\tan\delta . \tan\varphi$.	Error, or value of $\tan\delta . \tan\varphi - 2$.	Value of $\frac{d.\delta}{d.\lambda}$.	Value of $\frac{3\cos 2\delta+5}{4}$.	Error, or value of $\frac{d.\delta}{d.\lambda} - \frac{3\cos 2\delta+5}{4}$.
Fort Alexander	15° 16′ E.	28° 22′ 43″	78° 6′ 3″	2·5815	+ 0·5815	·7944	·5552	+ ·2392
and Cumberland House	19 14 E.	26 16 11	79 46 34	2·7366	+ 0·7366			
Cumberland House ...	19 14 E.	22 20 28	79 46 34	2·2786	+ 0·2786	−1·3975	·5485	− 1·9460
and Isle à la Crosse ...	23 19 E.	22 8 26	79 29 45	2·1944	+ 0·1944			
Isle à la Crosse ...	23 19 E.	32 13 34	79 29 45	3·4005	+ 1·4005	·6375	·5309	+ ·1066
and Fort Chipewyan ..	25 30 E.	30 0 16	80 54 44	3·6101	+ 1·6101			
Fort Chipewyan ...	25 30 E.	21 19 2	80 54 44	2·4396	+ 0·4396	·8683	·5317	+ ·3366
and Fort Resolution ...	29 15 E.	19 38 56	82 21 39	2·6621	+ 0·6621			
Fort Chipewyan ...	25 30 E.	10 6 50	80 54 44	1·1152	− 0·8848	·9795	·5317	+ ·4478
and Fort Resolution ..	37 20 E.	8 38 6	82 21 39	1·1322	− 0·8678			
Fort Resolution ...	37 20 E.	9 4 53	82 21 39	1·1917	− 0·8083	·7863	·5198	+ ·2665
and Fort Reliance ...	35 19 E.	6 28 11	84 24 52	1·1596	− 0·8404			
Fort Reliance ...	35 19 E.	7 13 11	84 24 52	1·2953	− 0·7047	·7823	·5110	+ ·2713
and Musk-Ox Rapid ...	44 24 E.	5 30 14	85 45 24	1·2987	− 0·7013			
Musk-Ox Rapid ...	44 24 E.	7 52 46	85 45 24	1·8653	− 0·1347	·5616	·5047	+ ·0569
and Rock Rapid ...	29 16 E.	4 29 4	87 39 48	1·9220	− 0·0780			
Rock Rapid ...	29 16 E.	2 21 16	87 39 48	1·0076	− 0·9924	·1567	·5022	− ·3455
and Point Beaufort ...	6 00 W.	0 14 28	87 59 40	0·1201	− 1·8799			
Rock Rapid ...	29 16 E.	2 29 56	87 39 48	1·0695	− 0·9305	− ·0965	·5027	− ·5992
and Montreal Island ...	2 00 W.	0 19 30	87 27 13	0·1275	− 1·8725			
Fort Alexander ...	15 16 E.	27 55 38	78 6 3	2·5156	+ 0·4844	·6872	·5432	+ ·1440
and Fort Resolution ...	29 15 E.	21 43 42	82 21 39	2·9713	+ 0·9712			
Fort Alexander ...	15 16 E.	23 9 47	78 6 3	2·0304	+ 0·0304	·7968	·5432	+ ·2536
and Fort Resolution ...	37 20 E.	17 49 1	82 21 39	2·3962	+ 0·3962			
Fort Reliance ...	35 19 E.	10 53 26	84 24 52	1·9673	− 0·0327	·6258	·5072	+ ·1186
and Rock Rapid ...	29 16 E.	5 41 56	87 39 48	2·4456	+ 0·4456			

Although the differences here shown between the results of theory and those deduced from the observations are in some cases less than in the preceding Table, yet in others they are greater; and the comparison does not upon the whole show a nearer coincidence. If this want of coincidence is to be attributed to errors in the observations, I think that the two comparisons which I have instituted indicate errors in the observed variations rather than in the dips of the needle, which have been deduced from the observations. The character of the differences between the theory and the observations, independently of their magnitude, strongly corroborates this conclusion. In all the results deduced from the observations at stations from Fort Alexander to Fort Resolution, in deducing which the variations observed by Sir JOHN FRANKLIN in 1825 have necessarily been employed, these differences indicate that the pole of convergence is more remote from the place of observation than the pole of verticity; whereas, in those deduced from observations at stations from Fort Resolution to Point Beaufort, in deducing which both the dip and variation are derived from Captain BACK's observations, these differences indicate precisely the reverse. If, however, we are not to suppose considerable errors in the observations of either the dip or variation of the needle, this comparison clearly indicates that the theoretical magnetic pole of verticity does not coincide with the pole of convergence, even when the positions of these points are deduced from observations made at very limited distances from them.

Having compared the results deduced from Captain BACK's very interesting observations with some of those derived from theory, I might now proceed to point out the actual positions which these observations, variously combined, would assign to the northern magnetic pole of convergence, and also those which, according to this theory, they would give to the pole of verticity. As, however, I propose investigating this subject with reference not only to Captain BACK's but also to other observations made in the same regions, I will reserve this branch of the inquiry for another communication.

IV. *Intensity of the Terrestrial Magnetic Force.*

The observations which were made by Captain BACK for the determination of the magnetic intensity were of two kinds, viz. by the time of vibration of a needle in the plane of the magnetic meridian, and by the times of vibration of three needles suspended horizontally, according to HANSTEEN's method.

I shall first discuss the observations which were made with the needle vibrated in the plane of the magnetic meridian. This needle is that with which the observations for the determination of the dip without the reversion of the poles was made, No. II. belonging to the dipping instrument, in which instrument its times of vibration were determined. The times of vibration were determined with the face of the instrument east and with its face west, the face of the needle being towards the face of the instrument; and also, where time admitted, similar observations were made with the needle reversed on its axis. In some cases two sets of observations were made in each position of the needle. The following Table contains the results of the observations which were made at various stations, and, in all cases, on the same spot as the corresponding observations for the dip, the two sets of observations having been made consecutively.

Place at which the observations were made.	Date.	Time of day nearly.	Face of the needle to the face of the instrument. Face of the instrument East. Semi-arc of vibration. Begin^g.	Ending.	No. of vibrations.	Time of vibrating.	West. Semi-arc of vibration. Begin^g.	Ending.	No. of vibrations.	Time of vibrating.	Mean time of one vibration.	Therm., mean of, at beginning and ending.	Face of the needle reversed. Face of the instrument East. Semi-arc of vibration. Begin^g.	Ending.	No. of vibrations.	Time of vibrating.	West. Semi-arc of vibration. Begin^g.	Ending.	No. of vibrations.	Time of vibrating.	Mean time of one vibration.	Therm., mean of, at beginning and ending.	Mean time of one vibration in the meridian.	Therm. Mean.
London	1833. Feb. 9.	h m 1 30 P.M. – 3 00	° 43	° ′ 1 20	80	s 109·5	° 30	° ′ 2 15	80	s 108·5	s 1·3625	......	° ′ 40 0	° ′ 7 30	80	s 112·5	° ′ 34 30	° ′ 5 0	80	s 112·0	s 1·4031	......	s 1·3828	° 50
New York	April 1.	3 30 P.M. – 4 00	30	3 0	70	91·0	30	3 0	70	89·0	1·2857	69°	Observations were not made in this position of the needle.											
Fort Alexander ...	June 10.	1 13 P.M. – 2 8	30	2 0	110	136·0	30	2 0	108	135·0	1·2432	70·5	32 0	2 0	90	112·0	30 0	2 0	110	141·0	1·2631	°72·25	1·25315	71·4
Cumberland House	July 6.	2 42 P.M. – 4 15	30	2 0	106	135·0	30	2 0	102	128·0	1·2643	59·5	(30 0	2 0	112	189·0)*	30 0	2 0	120	152·0	1·2667	66	1·26505	62·75
Isle à la Crosse ...	July 17.	1 28 P.M. – 2 30	30	2 0	64	83·0	(30	2 0	72	150·0?)*	1·2969	73·5	(30 0	2 0	74	475·0!)*	30 0	2 0	79	99·0	1·2532	75·0	1·2750	74·25
Fort Chipewyan...	July 31.	2 45 P.M. – 4 00	30	2 0	90	117·0	30	2 0	100	130·0	1·3000	95·0	30 0	2 0	89	110·0	30 0	2 0	84	105·0	1·2430	95·0	1·2715	95·0
Fort Resolution...	Aug. 9.	3 48 P.M. – 4 42	30	2 0	110	135·0	30	2 0	96?	120·0	1·2387	65·6	30 0	2 0	100	125·0	30 0	2 0	110	140·0	1·2613	64·0	1·2500	64·8
Fort Reliance	Oct. 9.	2 9 P.M. – 5 00	30	4 0	80	103·0	30	5 0	80	101·0	1·2750	44·0	30 0	3 0	80	101·0	30 0	5 0	70	90·0	1·2741	39·8	1·27455	41·9
	1834. May 21.	3 17 P.M – 6 30	40	4 0	80	102·6	30	2 0	80	102·9	1·2844	49·13	40 0	3 30	80	101·2	40 0	5 0	80	102·0	1·2700	50·12	1·2772	49·625
	Oct. 9.	11 52 A.M. – 2 00 P.M.	40	3 30	80	101·5	40	4 0	80	103·0	1·27813	27·62	40 0	3 0	70	89·0	40 0	4 0	60	76·5	1·27321	32·0	1·27567	29·81
Musk-Ox Rapid	July 2.	3 33 P.M. – 3 50	40	3 0	70	89·8	40	1 15	60	77·5	1·28726	64·0	Observations were not made in this position of the needle.											
Rock Rapid	July 23.	2 46 P.M. – 3 00	40	3 0	40	51·2	40	2 0	50	64·0	1·2800	86·75	Observations were not made in this position of the needle.											
Point Beaufort ..	July 31.	3 5 P.M. – 3 30	40	2 30	100	129·5	40	4 0	100	130·0	1·2975	72·5	Observations were not made in this position of the needle.											
Montreal Island...	Aug. 2.	1 59 P.M. – 2 21	40	3 20	100	128·7	40	4 30	100	129·0	1·2885	74·12	Observations were not made in this position of the needle.											
Point Ogle	Aug. 12.	1 43 P.M. – 3 39	42	5 0	80	101·5	40	3 40	80	101·0	1·26563	53·0	40 0	2 10	70	90·0	40 0	4 30	60	77·0	1·28451	55·12	1·27507	54·06
London	1836. Feb. 12.	0 49 P.M. – 1 8	36	2 0	90	127·0	35	7 0	80	117·0	1·4368	44·0	Observations were not made in this position of the needle.											

* These observations, for reasons which I shall assign, have not been included in the means.

To this Table of the direct results of the observations, it is necessary that I should add a few remarks of Captain BACK's, on circumstances connected with the observations, and of my own, on the observations themselves.

At Montreal, Captain BACK remarks, that "from some mistake of the assistant the observations were so confusedly set down as to be useless:" and afterwards, that "not having an assistant to take time, &c. I adopted this plan;" that is, the time at which the needle commenced vibrating being noted, the vibrations were counted until the semi-arc of vibration was reduced to 2° or 3°, and the time again noted; so that, in each case, the time could not well be determined more accurately than to the nearest second. He subsequently instructed his servant WILLIAM MALLY in the manner of noting the time by chronometer; and although, as I am sorry to have to notice, there are, in the early observations, manifest errors in the time, yet this person appears, from the greater detail in the observations at Fort Reliance and subsequently (the arc and time being each noted at every tenth vibration), to have given very efficient assistance in this operation. In the foregoing Table I have marked with an asterisk those observations in which I consider that an error must have been made, either in the time or the number of vibrations, and which I have consequently omitted in taking the mean; and it will be proper that I should point out more particularly the results which these observations give.

At Cumberland House, with the face of the instrument east and the needle reversed on its axis, 112 vibrations appear to have been made in $3^{m}\ 9^{s}$, giving $1^{s}{\cdot}6875$ as the time of one vibration, which is so greatly at variance with the other results, that no conclusions could possibly be drawn from a mean in which it should enter. We may conceive that an error of ten vibrations in counting, or of one minute in the time, may easily have been made, but neither supposition would give a result at all in accordance with the others. It is scarcely conceivable that any change in the terrestrial intensity, whether arising from atmospheric or any other influence, could have caused so great an increase in the time of vibration; it is, however, proper to give Captain BACK's remarks on the weather, which I shall do after noticing other observations which have been omitted in taking the means.

At Isle à la Crosse, with the face of the instrument west and the face of the needle to the face of the instrument, it appears that 72 vibrations were made in $2^{m}\ 30^{s}$, the times at beginning and ending being $8^{h}\ 56^{m}\ 30^{s}$ and $8^{h}\ 59^{m}\ 00^{s}$, by chronometer $13^{m}\ 20^{s}$ slow of Greenwich time. This interval would give $2^{s}{\cdot}083$ for the time of vibration. If we suppose an error of one minute to have been made in the time, then $1^{s}{\cdot}25$ would be the time of vibration, a result by no means improbable; but I consider that the safest course is to reject the observation. With the face of the needle reversed and the face of the instrument east, the times at beginning and ending were $9^{h}\ 50^{m}\ 30^{s}$ and $9^{h}\ 58^{m}\ 25^{s}$. We may conceive that here in transcribing 56^{m} may easily have been mistaken for 50^{m}; and this would reduce the interval in which seventy-four vibrations were made to $1^{m}\ 55^{s}$, and the time of one vibration to $1^s{\cdot}554$; but even this is a most improbable result. In the subjoined Table I give the times of beginning and ending the vibrations, with Captain BACK's remarks on the weather, &c. at the times of observing.

Place of observation.	Face of the needle to the face of the instrument. Face of the instrument East.	Face of the needle to the face of the instrument. Face of the instrument West.	Face of the needle reversed. Face of the instrument East.	Face of the needle reversed. Face of the instrument West.
Cumberland House.	Time commencing $10^h 22^m 25^s$. Time concluding 10 24 40. Wind S.W. by compass. Weather squally, with rain; cloudy.	Time commencing $10^h 50^m 22^s$. Time concluding 10 52 30. Wind S.W. by compass. Weather squally, with light rain; overcast.	Time commencing $9^h 47^m 32^s$. Time concluding 9 50 41. Wind S.W. by compass. Weather squally, with rain; dark clouds, but no thunder.	Time commencing $9^h 18^m 59^s$. Time concluding 9 21 31. Wind S.W. by compass. Weather calm and sultry, with distant thunder.
Isle à la Crosse.	Time commencing $8^h 37^m 00^s$. Time concluding 8 38 23. Weather overcast, calm. Needle sluggish.	Time commencing $8^h 56^m 30^s$. Time concluding 8 59 00. Weather clearer; the sun seen at intervals.	Time commencing $9^h 50^m 30^s$. Time concluding 9 58 25. Weather clearer; sun out.	Time commencing $9^h 28^m 00^s$. Time concluding 9 29 39. Weather clearer.
	The needle was decidedly sluggish though carefully wiped.			

At Rock Rapid it appears that there was considerable difficulty in counting more than forty or fifty vibrations of the needle, its motion being extremely unsteady, and occasionally it came to a dead stop. I have selected the two sets of vibrations in which it continued vibrating for the longest time. In two other sets, in similar positions, it made only thirty-two vibrations in the one case, and thirty-eight in the other: Captain BACK has a remark on these observations in his Narrative*. It is difficult to conceive any local cause for this tendency of the needle to come so much quicker to rest than in other cases, and I cannot but attribute it to the influence of the sun†. The observations were made as usual in a tent, but the height of the thermometer clearly indicates that the sun must have had considerable influence even under this screen. This view of the cause of the needle so soon coming to rest at Rock Rapid, is corroborated by the fact that, at Montreal Island "a sail was put over the tent to afford more shade," and there "the needle was particularly lively, and vibrated smoothly until it finally rested," the number of vibrations being one hundred. Whatever may have been the cause which thus affected the vibration of the needle, the circumstance must throw some uncertainty on the measure of the intensity deduced from its time of vibration.

Although I have found it necessary to make these remarks on Captain BACK's observations, it cannot, I trust, be supposed that I attribute the errors which I have pointed out to want of care or attention on the part of that most enterprising officer, for no one can appreciate more highly than I do the zeal which he manifested for the promotion of scientific research, by undertaking to make these observations on such an expedition as that on which he so nobly volunteered. I attribute these errors solely to Captain BACK's destitution of assistance; and I cannot but regret that it

* Narrative of the Arctic Land Expedition, p. 360.

† Philosophical Transactions, 1826, p. 219; 1828, p. 379.

should not have been afforded him from that service, the Royal Navy, which has furnished, and still continues to furnish, abundant instances of zeal and intelligence in the prosecution of scientific inquiry.

In order to deduce the relative magnetic intensities at the several stations from the results in the foregoing Table, it will first be necessary that a correction should be applied for the difference of temperature at which the observations were made. Immediately that I received the needles belonging to Captain Back's instruments, I instituted experiments for the determination of the correction to be applied, for this purpose, to the observations with each needle. As the method I adopted was the same with all the needles, I consider that it will be better to give all the experiments with their results in one view, and shall therefore defer giving these experiments and deducing the intensities at the different stations from the preceding observations until I have given an account of the observations which were made by Captain Back with horizontal needles, for the same purpose.

A small apparatus, on the plan first suggested by Hansteen, was employed for determining the horizontal intensity. It was furnished with two cylindrical magnetical needles, and a brass one of the same form and weight to divest the suspending silk fibres of torsion. As I had always found that pointed needles, whether of the form of a double segment of a circle or of that of a lozenge, vibrated more quickly than rectangular needles of the same weight, I suggested the advantage of having such a needle. A needle of a lozenge form was in consequence added to the apparatus. The horizontal intensity was therefore, where time admitted of it, determined by the vibrations of these three needles, distinguished as No. 1, No. 3, and Lozenge Needle. The observations appear to have been made in the usual manner, by noting the arc and time at the commencement; the time at every ten vibrations; generally the time and vibration at which the arc was diminished one half, and the terminal arc of vibration. The vibrations were, in general, continued until the arc was reduced to two or three degrees; but it appears that only with one of the needles, No. 3, could the vibrations be counted, even in London, as far as three hundred. As the dip increased, the number of vibrations, within the same limits of arc, decreased, and was ultimately reduced, at Point Ogle, to forty or fifty. I do not consider that, in these observations, the time could have been determined with sufficient accuracy to admit of the application of the method adopted by Hansteen, of taking a mean of several intervals, or that much advantage would arise from the application of a correction for the arc, to the time of vibration. I have not therefore thought it necessary to give the observations at length, but still I have, in the following Table, given the times in all cases where the arc was noted, in order that such a correction might be applied, if thought necessary. This Table will, I consider, require little explanation. In each case, the number of vibrations, the corresponding arcs, where observed, and the times, are given in three consecutive columns; and where the vibrations are continued beyond one hundred, the arcs and corresponding times are given in two subsequent columns, in which those corresponding to 100, 150, &c. vibrations are opposite to 0 50, &c. in the first column.

Table of the Times of Vibration of Horizontal Needles at different Stations.

Needle No. 1.

Place at which the observations were made.	Date.	Time of day nearly.	No. of vibrations.	Arc.	Time.	Arc.	Time.	Time of one vibration.	Therm.
London, the Admiralty Garden.	1833. Feb. 7. Nos. 1&3. Feb. 9. Lozenge.	h m 1 30 P.M.	0 50 80 90 100	° 20 15 ... 10 ...	m s 0 5 3 48 6 1·5 6 46 7 31	° ... 6·5 5 ... 4·5	m s 7 31 11 12 13 26 14 10 14 54	s 4·445	° 56·0
Montreal, Island of St. Helen's.	April 19.	No observations were made.							
Fort Reliance.	Oct. 11.	2 57 P.M.	0 50 80	20 11 7·5	0 46 7 12 11 3	6 3·75 2·75	13 36·5 29 1 23 52	7·7000	45·5
Fort Reliance.	1834. Feb. 8.	No observations were made.							
Fort Reliance.	May 21.	2 22 P.M.	0 40 90	20 ... 5	0 47 5 55 12 18·5	... 3	13 36 18 43·5	7·6893	51·0
Fort Reliance.	Oct. 9.	No observations were made.							
Musk-Ox Rapid.	July 2.	No observations were made.							
Rock Rapid.	July 23.	No observations were made.							
Point Beaufort.	July 31.	No observations were made.							
Montreal Island.	Aug. 2.	No observations were made.							
Point Ogle.	Aug. 12.	No observations were made.							
London, the Admiralty Garden.	1836. Feb. 12.	3 48 P.M.	0 90	20 ...	0 14 7 15	... 4	8 0 15 0	4·6632	45·0

Needle No. 3.

Place at which the observations were made.	Date.	Time of day nearly.	No. of vibrations.	Arc.	Time.	Arc.	Time.	Arc.	Time.	Time of one vibration.	Therm.
London, the Admiralty Garden.	1833. Feb. 7. Nos. 1&3. Feb. 9. Lozenge.	h m 2 0 P.M.	0 30 50 80 100	° 30 ... 20 16·5 15	m s 0 51 3 3 4 31 6 42 8 9	° 15 ... ... 6·5	m s 8 9 10 19·5 11 47 13 57 15 24·5	° 6·5 5 ... ... 2·75	m s 15 24·5 17 35 19 1·5 21 12 22 39·5	s 4·3167	° 56·0
Montreal, Island of St. Helen's.	April 19.	4 00 P.M.	0 10 50 70 90	20 ... ... 10 ..	0 41 1 26·5 4 40·5 6 16·5 7 53·5	... ... 5	8 42 9 29·5 12 43 14 19 15 56·5	... ...	16 44·5 17 32·5 20 45·5 22 22 23 58·5	4·82857 *	56·5
Fort Reliance.	Oct. 11.	2 13 P.M.	0 60 90	20 10 7	0 4 7 35 11 20	6·25 3·25 2·75	12 35 21 16·5 23 45			7·4790	46·0
Fort Reliance.	1834. Feb. 8.	2 5 P.M.	0 50 70	20 10 ...	0 35·5 6 51 9 21	 2	13 5·5 19 9·8 21 49·5			7·4941	45·25
Fort Reliance.	May 21.	1 40 P.M.	0 30 50	20 ... 10	0 9 3 53 6 22	... 3	12 32·5 16 14·5			7·42692	50·5
Fort Reliance.	Oct. 9.	3 12 P.M.	0 50 60	20 10 ...	0 13 6 36 7 52	5 ... 2	12 56·3 19 17 20 33·5			7·6281	30·0
Musk-Ox Rapid.	July 2.	4 57 P.M.	0 10 40	20 ... 9	0 32·5 2 1·5 6 28·5	3 2	15 21 16 50·5			8·8909	71·0
Rock Rapid.	July 23.	0 20 P.M.	0 70	20 2·5	0 35·5 15 47·5					13·0286	82·0
Point Beaufort.	July 31.	5 14 P.M.	0 70	20 2	0 15 21 50					18·500	74·0
Montreal Island.	Aug. 2.	5 15 P.M.	0 20 60	20 10 2·25	0 9·5 5 45 16 56					16·775	67·5
Point Ogle.	Aug. 12.	4 50 P.M.	0 40 50	20 ... 2·5	0 11·5 15 28 19 19	20 2·5	0 24 15 23			mean s 22·7125	62·125
London, the Admiralty Garden.	1836. Feb. 12.	4 8 P.M.	0 70	20 ...	0 34 5 53	... 5	8 11 13 29			4·5588	45·25

Lozenge Needle.

Place at which the observations were made.	Date.	Time of day nearly.	No. of vibrations.	Arc.	Time.	Arc.	Time.	Time of one vibration.	Therm.
London, the Admiralty Garden.	1833. Feb. 7. Nos. 1&3. Feb. 9. Lozenge.	h m 3 56 P.M.	0 30 70 90 100	° 30 20 ... 10 ...	m s 0 12 1 8·5 2 22·5 2 59·5 3 18·5	° ... ... 5 ... 3	m s 3 18·5 4 13·5 4 27·5 6 4·5 6 22·5	s 1·8525	° 50·0
Montreal, Island of St. Helen's.	April 19.	No observations were made.							
Fort Reliance.	Oct. 11.	3 45 P.M.	0 40 50	20 10·75 9	0 59·5 3 6 3 37·5	4 2	6 15 8 21	3·15357	46·0
Fort Reliance.	1834. Feb. 8.	2 50 P.M.	0 28 40	20 ... 10	0 42 ...... 2 48	... 2	5 57 7 25	3·14844	35·0
Fort Reliance.	May 21.	2 50 P.M.	0 60 100	20 5·5 1·75	0 15 3 25 5 31·5		·	3·1650	51·0
Fort Reliance.	Oct. 9.	3 25 P.M.	0 30 90	20	0 30 2 4·3 5 12·8	... 2	5 44 7 18·5	3·1423	30
Musk-Ox Rapid.	July 2.	No observations were made.							
Rock Rapid.	July 23.	No observations were made.							
Point Beaufort.	July 31.	No observations were made.							
Montreal Island.	Aug. 2.	5 47 P.M.	0 30 50	20 5·5 2·25	0 33 3 59·5 6 17			6·880	63·5
Point Ogle.	Aug. 12.	5 48 P.M.	0 20 40	20 ... 1·5	0 4·5 3 0 5 56·5	20 ... 1·5	0 1 2 58·5 5 55	mean s 8·8250	63·5
London, the Admiralty Garden.	1836. Feb. 12.	4 24 P.M.	0 80	20 ...	0 47 3 20	... 3·5	3 57 6 28	1·8944	44·75

* Time of 280 vibrations, from 10th to 290th vibration = 1352 seconds.

I shall not now make any remarks on the results contained in the foregoing Table, but proceed to describe the method I adopted for determining the correction necessary to be applied, in order to reduce the measures of intensity at different temperatures, to be derived from the times of vibration in this and the preceding Table, to measures of intensity at the same temperature.

Determination of the Correction for the Difference of Temperature.

Since I first pointed out the necessity of applying a correction for the difference in the temperature at which observations for determining the magnetic intensity may have been made *, such a correction has, in many instances, been applied; but its amount has seldom been determined from direct experiments on the individual needle employed in the observations from which the intensities were to be deduced. This I consider to be essential; for in the numerous experiments which I have made on the subject, I have found that, in different needles, there is a very considerable difference in the amount of this correction; and M. KUPFFER's experiments † show that this amount depends upon the nature and the temper of the steel employed. I therefore proposed to determine this correction for each of the needles which had been employed by Captain BACK. For this purpose I employed an earthenware vessel having a wooden bottom firmly fixed in it, to which the needle under trial could be securely attached by means of ivory pegs. Above this vessel was placed a stage, supporting a compass having a small trial-needle, 1·36 inch long, delicately suspended by a single *fibre* of silk. The time in which this needle performed 100 vibrations having been carefully determined by two trials, the needle under examination was fixed to the wooden bottom of the vessel below, but separated from the wood by narrow slips of glass. This needle was placed with its centre exactly below the centre of the trial-needle, its axis in the magnetic meridian and its marked end towards north; and the distance of the upper or vibrating needle from the lower was so adjusted that its marked end still pointed north, but with a greatly diminished force. A small thermometer was placed on the glass of the compass, to indicate any change of temperature that the vibrating needle might undergo; and another thermometer was placed in the vessel containing the needle under trial, with its bulb close to that needle, and not touching the bottom of the vessel. Water, of as low a temperature as could be obtained, without employing chemical means, was then poured into the vessel containing the needle under trial; the temperature of this needle and also of the vibrating needle having been noted, the time of vibration of the latter was determined by two successive trials, and the temperature of both needles was again ascertained. Water of a higher temperature was then poured into the vessel, and the whole well agitated; and as soon as the temperature became uniform, the foregoing observations of temperature and time of vibration were repeated. In this manner, the temperature of the needle was successively raised to the highest temperature at which observations had

* Philosophical Transactions, 1825, p. 61.

† Annales de Chimie, tom. xxx. p. 113.

been made by Captain BACK; after which it was lowered, by as nearly as possible the same intervals, to the lowest at which the experiments began; the temperature and time of vibration being similarly determined in all cases. The needle under trial being removed, the time in which the trial-needle made 100 vibrations was again ascertained. The needle, in all cases, commenced vibrating from the same arc 35°; the time, however, of commencing the vibrations was reckoned from its first passing zero, and the time of completing each ten vibrations, at the same point, was noted, up to one hundred.

The following Table exhibits the observations that were made with the needle No. II. belonging to Captain BACK's dipping instrument. When under the influence of this needle, the time of vibration of the trial-needle was so much increased that 50 vibrations were performed in nearly the same time as 100 had been made when it was uninfluenced; and the vibrations could not have been conveniently counted much beyond this number. In all cases, the time was determined by two observations. In this Table, Thermometer II. indicates the temperature of the needle No. II., and Thermometer N, nearly that of the trial-needle.

Trial-needle uninfluenced.			Trial-needle under the influence of the needle No. II.							
	First observation.	Last observation.								
Beginning, Therm. II.	60°·0		....	46°·2	60°·0	72°·6	84°·6	72°·0	59°·8	46°·2
Beginning, Therm. N.	57·2	60°·2	....	58·2	59·6	60·0	61·0	61·0	61·0	60·6
Time of 100 vibrations	147s·8	147s·8	Time of 50 vibrations	157s·2	155s·6	153s·8	152s·6	154s·0	155s·5	157s·1
	148·0	147·9		157·0	155·7	154·0	152·8	154·0	155·6	157·1
Ending, Therm. II.	60°·0		....	47°·8	59°·6	71°·6	82°·8	72°·0	60°·8	47°·0
Ending, Therm. N.	58·0	60°·2	....	59·0	60·0	60·6	62·0	61·0	60·8	60·4
Mean, Therm. II.	60·0	....	....	47·0	59·8	72·1	83·7	72·0	60·3	46·6
Mean, Therm. N.	57·6	60·2	....	58·6	59·8	60·3	61·5	61·0	60·9	60·5
Mean time of one vibration	1s·47875		....	3s·142	3s·113	3s·078	3s·054	3s·080	3s·110	3s·142

The first observation commenced at $1^h\ 0^m$ P.M. 5th March, and the last concluded at $4^h\ 35^m$ P.M.

If we call the terrestrial force acting upon the vibrating needle, M; the force with which the needle II. acts upon it, at any given temperature, m; the time of vibration of the trial-needle, when acted upon by the terrestrial force alone, T; and its time of vibration, when influenced by the needle II., that is, when acted upon by the difference of the two forces M and m, t; then we shall have

$$\frac{M - m}{M} = \frac{T^2}{t^2};$$

and

$$\frac{m}{M} = 1 - \frac{T^2}{t^2} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (16.)$$

Substituting in this equation the observed times of vibration at different temperatures, we shall obtain the values of $\frac{m}{M}$, that is, the measures of the intensity of the needle II. corresponding to these temperatures. The following Table contains the values of $\frac{m}{M}$ thus deduced, and in the last column are given the differences in the value of $\frac{m}{M}$ corresponding to a change of one degree in the temperature of the needle No. II.

Therm. II.	Differences.	Therm. N.	Values of $\frac{m}{M}$.	Differences.	Difference in value of $\frac{m}{M}$ corresponding to difference of 1° in Therm. II.
47°·0		58°·6	·7784982		
	12°·8			·0041462	·0003239
59·8		59·8	·7743520		
	12·3			·0051603	·0004195
72·1		60·3	·7691917		
	11·6			·0036425	·0003140
83·7		61·5	·7655492		
	11·7			·0039416	·0003369
72·0		61·0	·7694908		
	11·7			·0045710	·0003907
60·3		60·9	·7740618		
	13·7			·0044364	·0003238
46·6		60·5	·7784982		
				Mean....	·0003515

There are here, certainly, considerable discrepancies in the differences in the value of $\frac{m}{M}$ corresponding to a difference of 1° in the thermometer II. These, I consider, have arisen in a great measure, if not wholly, from the thermometer II. not indicating, in all cases, precisely the temperature of the needle No. II.: and this is one of the principal difficulties which occurs in an inquiry into the effects produced on the intensity of magnets by changes of temperature. From experiments which I long since made*, and from others which I have made more recently, I consider that the differences in the values of $\frac{m}{M}$ corresponding to a change of 1° in the temperature of a magnet increase with the temperature; but the foregoing results can scarcely be considered to indicate such a law. For the purpose, however, at present in view, this is not of great importance; and with regard to the discrepancies I have noticed, I may remark, that if these have arisen from the cause I have assigned, their effect on the mean result will be extremely small; for in this case the errors in the results arising from errors in the divisors would tend to destroy each other. In order that the results should be accurate, it is necessary, either that the temperature of the trial-needle should be the same throughout the observations, or that a correction should be applied for the changes which may have taken place in that temperature. This correction might be determined by observations similar to the preceding, but in this manner the final correction would form an infinite series. In these observations the

* Philosophical Transactions, 1825, p. 63.

indications of the thermometer N were not constant, but, as the whole difference did not amount to 3°, I do not consider that this can materially affect the result. It is, however, probable that the difference in the temperature of the needle N did not even amount to this: for in consequence of the glass shade under which the needle vibrated being too small to contain a thermometer, that instrument was placed on the outside, and would therefore be more affected by small changes in the temperature of the room than the needle which was inclosed.

If we take the mean of the values of $\frac{m}{M}$ corresponding to the indications 59°·8 and 60°·3 of the thermometer II., we shall have ·7742069 as the value of $\frac{m}{M}$ corresponding to the temperature 60°·05 of the needle II. Adding ·0000175 to this value, for the difference 0°·05, we have ·7742244 for the value of $\frac{m}{M}$ at the temperature 60°. If now we consider the intensity of the needle II., or the value of $\frac{m}{M}$ at 60° Fahr. to be 1, we shall have,

The increment in the value of $\frac{m}{M}$ for each 1° above or below 60° $= \frac{\mp \cdot 0003515}{\cdot 7742244}$
$= \mp \cdot 0004540.$

Let $I_{,}$ be the measure of the terrestrial magnetic intensity resulting from observation, at any station, of the time of vibration of the needle No. II., at the temperature $60° \pm \theta$; and I the measure of the intensity at the temperature 60°: then

$$I_{,} = I \mp \cdot 000454\, I.\theta;$$

and

$$I = \frac{I_{,}}{1 \mp \cdot 000454\,\theta} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (17.\ II.)$$

By means of this formula, the measure of the intensity with the needle II. at any temperature $60° \pm \theta$ may be reduced to the measure of the intensity at the standard temperature 60° Fahr.

In order to determine the corrections to be applied, for difference of temperature, to the observations made with the horizontal needles No. 1, No. 3, and the Lozenge-needle, experiments similar to those which I have described were made with these needles. As these experiments were made consecutively, it is necessary that I should give them in the order in which they were made.

With the Lozenge-needle, two sets of experiments were made. In the first set, this needle occupied the same position precisely as that in which the needle No. II. had previously been placed. The results are given in the following Table:

	Trial-needle under the influence of the Lozenge-needle.			Trial-needle uninfluenced.
Beginning { Therm. L.	46°·0	79°·4	46°·0	
Beginning { Therm. N.	64·6	68·0	65·0	63°·0
Time of 100 vibrations	174ˢ·9	174ˢ·4	174ˢ·6	147ˢ·4
	174·8	174·4	174·8	147·6
Ending { Therm. L.	48°·0	77°·4	47°·6	
Ending { Therm. N.	66·0	66·0	66·0	67°·6
Mean { Therm. L.	47·0	78·4	46·8	
Mean { Therm. N.	65·3	67·0	65·5	65·3
Mean time of one vibration	1ˢ·7485	1ˢ·744	1ˢ·747	1ˢ·475

The observations commenced at 7^h 8^m P.M., and concluded at 8^h 45^m P.M. 5th March.

Finding that in this position of the lozenge-needle the times of vibration of the trial-needle were so little affected by changes in the temperature of the former that a small error in these times would materially affect the results, I made a second set of observations, in which the lozenge-needle was raised ·84 inch, its distance from the trial-needle being reduced to 3·06 inches. The following Table contains the results of this set:

	Trial-needle uninfluenced.		Trial-needle under the influence of the Lozenge-needle.		
	First observation.	Last observation.			
Beginning { Therm. L.			46°·8	80°·0	49°·0
Beginning { Therm. N.	60°·0	61°·6	59·6	60·0	60·0
Time of 100 vibrations	147ˢ·8	147ˢ·8	216ˢ·8	215ˢ·4	216ˢ·8
	147·7	147·9	217·2	215·4	216·3
Ending { Therm. L.			48°·4	77°·0	50°·2
Ending { Therm. N.	59°·2	61°·2	60·0	61·0	60·2
Mean { Therm. L.	....	....	47·6	78·5	49·6
Mean { Therm. N.	59·6	61·4	59·8	60·5	60·1
Mean time of one vibration	1ˢ·478		2ˢ·170	2ˢ·154	2ˢ·1655

Note.—The first observation with the trial-needle uninfluenced commenced at 0^h 5^m P.M.; then followed the observations with that needle under the influence; 1st, of the lozenge-needle; 2nd, of needle No. 3; 3rd, of needle No. 1; and the last observation with the trial-needle uninfluenced concluded at 4^h 50^m P.M. 6th March.

Substituting the times of vibration in the first set of observations in the equation (16.), we have the following results:

Therm. L.	Differences.	Therm. N.	Values of $\frac{m}{M}$.	Differences.	Difference in value of $\frac{m}{M}$ corresponding to difference of 1° in Therm. L.
47°·0 78·4 46·8	° 31·4 31·6	65°·2 67·0 65·5	·2900090 ·2863406 ·2887895	·0036684 ·0024489	·0001168 ·0000775
				Mean....	·0000972

Taking the mean of the values of $\frac{m}{M}$ corresponding to the indications 47°·0 and 46°·8 of the thermometer L, we have ·2893993 as the value of $\frac{m}{M}$ corresponding to the temperature 46°·9 of the needle L. Subtracting from this ·0000972 × 13·1, or ·0012733, we have ·288126 for the value of $\frac{m}{M}$ at the temperature 60°. If we take the value of $\frac{m}{M}$ at the temperature 60° to be 1, we shall have,

The increment in the value of $\frac{m}{M}$ for each 1° above or below 60° $= \mp$ ·0003374.

Substituting the times in the second set of observations in the equation (16.), we obtain the following results:

Therm. L.	Differences.	Therm. N.	Values of $\frac{m}{M}$.	Differences.	Difference in value of $\frac{m}{M}$ corresponding to difference of 1° in Therm. L.
47°·6 78·5 49·6	° 30·9 28·9	59°·8 60·5 60·1	·5360947 ·5291772 ·5341648	·0069175 ·0049876	·0002239 ·0001726
				Mean....	·0001982

From these, taking a mean as before, we obtain ·5351298 as the value of $\frac{m}{M}$ corresponding to the temperature 48°·6 of the needle L; and subtracting ·0001982 × 11·4 from this value, we have ·5328704 for the value of $\frac{m}{M}$ at the temperature 60°. Taking the value of $\frac{m}{M}$ at the temperature 60° to be 1, we have,

The increment in the value of $\frac{m}{M}$ for each 1° above or below 60° $= \mp$ ·0003719.

The mean of the two results gives

The increment in the value of $\frac{m}{M}$ for each 1° above or below 60° $= \mp$ ·0003546.

We therefore obtain, for the correction of observations made with the Lozenge-needle, the equation

$$I = \frac{I_{\prime}}{1 \mp \cdot 0003546\,\theta} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (17.\ L.)$$

In the experiments with HANSTEEN's cylindrical needle No. 3, that needle occupied the same position which the lozenge-needle had previously in the last set, the experiments with the two needles immediately following each other. The results obtained with this needle are given in the two following Tables:

	Trial-needle uninfluenced.		Trial-needle under the influence of the needle No. 3.		
	First observation.	Last observation.			
Beginning { Therm. 3.......			47°·6	76°·4	48°·0
Beginning { Therm. N.	60°·0	61°·6	61·1	62·0	60·2
Time of 100 vibrations .... {	147ˢ·8	147ˢ·8	205ˢ·8	204ˢ·2	205ˢ·7
	147·7	147·9	205·6	204·2	205·9
Ending.. { Therm. 3.......			49°·0	75°·0	50°·0
Ending.. { Therm. N.	59°·2	61°·2	61·2	62·4	61·0
Mean.... { Therm. 3.......	....	....	48·3	75·7	49·0
Mean.... { Therm. N.	59·6	61·4	61·15	62·2	60·6
Mean time of one vibration ..	1ˢ·478		2ˢ·057	2ˢ·042	2ˢ·058

Therm. 3.	Differences.	Therm. N.	Values of $\frac{m}{M}$.	Differences.	Difference in value of $\frac{m}{M}$ corresponding to difference of 1° in Therm. 3.
48°·3	27°·4	61°·15	·4837261	·0076128	·0002778
75·7	26·7	62·2	·4761133	·0081145	·0003039
49·0		60·6	·4842278		
				Mean....	·0002909

Adopting similar methods of reduction to the preceding, from these results we obtain, for the correction of the observations made with the needle No. 3, the equation

$$I = \frac{I_{\prime}}{1 \mp \cdot 0000052\,\theta} \quad \ldots\ldots\ldots\ldots \quad (17.\ 3.)$$

The needle No. 3 being removed, its place was occupied by the needle No. 1, with which the following results were obtained:

	Trial-needle uninfluenced.		Trial-needle under the influence of the needle No. 1.		
	First observation.	Last observation.			
Beginning { Therm. 1.......			45°·4	79°·0	46°·0
Beginning { Therm. N.	60°·0	61°·6	60·0	60·8	60·6
Time of 100 vibrations .... {	147ˢ·8	147ˢ·8	202ˢ·4	200ˢ·1	201ˢ·9
	147·7	147·9	202·3	200·3	201·9
Ending.. { Therm. 1.......			47°·0	77°·0	49°·0
Ending.. { Therm. N.	59°·2	61°·2	60·0	62·0	61·0
Mean.... { Therm. 1.......	......	......	46·2	78·0	47·5
Mean.... { Therm. N.	59·6	61·4	60·0	61·4	60·8
Mean Time of one vibration..	1ˢ·478		2ˢ·0235	2ˢ·002	2ˢ·019

Thermometer 1.	Differences.	Thermometer N.	Values of $\frac{m}{M}$.	Differences.	Difference in value of $\frac{m}{M}$ corresponding to difference of 1° in Therm. 1.
46°·2	°	60°·0	·4664903		
	31·8			·0115205	·0003623
78·0		61·4	·4549698		
	30·5			·0091396	·0002997
47·5		60·8	·4641094		
				Mean......	·0003310

Again, making use of similar methods of reduction with these results, the equation for the correction of the observations made with the needle No. 1 becomes

$$I = \frac{I_{\prime}}{1 \mp \cdot 0007181\,\theta} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (17.\ 1.)$$

Reduction of the Observations.

Having pointed out the methods which I adopted for determining the constants which enter into the equations requisite for the reduction of observations, made with these needles at different temperatures, to results at a standard temperature, and given the equations necessary for such reduction, I now resume the consideration of Captain BACK's observations for the determination of the relative terrestrial magnetic intensities at different stations.

I propose first to determine these intensities from the observed times of vibration of the dipping needle No. II. in the plane of the meridian, and then to inquire whether the results derived from the times of vibration of the horizontal needles are in accordance with these.

In order to determine the intensities from the times of vibration in the meridian, it is necessary to divide the observations into two classes; first, those from London to Fort Reliance; and secondly, those from Fort Reliance to Point Ogle, on the coast of the Polar Sea, and thence to London.

Taking the reciprocal of the square of the time of vibration as the measure of the intensity at the temperature at which an observation was made, this measure is to be reduced by means of the formula (17. II.), in order to determine the measure of the intensity at a standard temperature. If t is the time of vibration of the needle at the temperature $60° \pm \theta$, and I the intensity at the standard temperature 60°, then

$$I = \frac{1}{t^2 (1 \mp \cdot 000454\,\theta)} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (18.\ II.)$$

Taking the times of vibration of the needle No. II. and the temperatures already given, the corresponding measures of the intensity at the different stations, as deduced from this equation, are given in the following Table, and likewise the relative intensities, that at London being taken as unity. In deducing the latter, two kinds of comparison were necessary. At New York the times of vibration were only determined with the face of the needle to the face of the instrument; and I have therefore compared these observations with those in London, where the needle was vibrated in the same position. At the other stations the observations were made with the face of the needle to the face of the instrument, and likewise reversed; and these observations are compared with the similar observations in London.

Place of observation.	Date.	Time of vibration of needle.	Thermometer.	Measure of intensity at temp. 60°.	Ratio of intensity to that at London.
	1833.	s	°		
London	February 9.	1·3625	50·0	·5362407	1·00000
New York	April 1.	1·28572	69·0	·6074147	1·13273
London	February 9.	1·3828	50·0	·5206021	1·00000
Fort Alexander	June 10.	1·25315	71·4	·6400997	1·22954
Cumberland House ..	July 6.	1·26505	62·75	·6256439	1·20177
Isle à la Crosse	July 17.	1·2750	74·25	·6191539	1·18930
Fort Chipewyan	July 31.	1·2715	95·0	·6283987	1·20706
Fort Resolution......	August 9.	1·2500	64·8	·6413976	1·23203
Fort Reliance......	October 9.	1·27455	41·9	·6105560	1·17279
	1834.				
	May 21.	1·2772	49·63	·6101570	1·17202
	October 9.	1·27567	29·81	·6061936	1·16441
			Mean ..	·6089689	1·16974

From these results it is very evident, that, from some cause or other, very possibly from having been subjected to a high temperature, the magnetism of the needle suffered a permanent change in the interval between the observations at Fort Resolution on the 9th of August, and those at Fort Reliance on the 9th of October. Judging from the results of the observations at Fort Reliance in May 1834, and those in October of the same year, it would not appear that the magnetism of the needle underwent any material change during that interval; for although the intensity, as deduced in this Table, is somewhat less in October than in May, yet, as will be seen in the Table which I shall immediately give, taking the vibration with the face of the needle to the face of the instrument alone, the intensity appears to be rather greater in October than in May. Whether the magnetism of the needle suffered any change in the interval between the observations in London and those at Fort Resolution, cannot be determined; but it is at least not probable that it did so from New York, and the result at that city would not lead us to suppose that it had previously. We may therefore consider that no exception can be taken to these results on this ground. With regard to the results at Fort Reliance, the observations that were made in London, subsequent to the expedition, indicate that they are considerably in defect, as will be seen by the comparison which I shall now make between the observations at Fort Reliance and those at stations subsequently visited.

In the observations which were made in the course of Captain Back's perilous voyage to the mouth of the Thlew-ee-choh,—which river, in justice to its discoverer and first navigator, should, henceforward, be named *the Back*,—the needle was, in consequence of other most pressing calls on his time, only vibrated with its face to the face of the instrument, excepting at Point Ogle, where a vexatious detention afforded more time for these observations. In comparing, therefore, the results from these observations with those at Fort Reliance, I have only taken those derived from observations made there in the same position of the needle. I have, however, deduced the measure of the intensity at Point Ogle both from the observations made in this position of the needle, and also from a mean of these and of those with the needle reversed on its axis. In the following Table are given:—the measures of the intensities at the temperature 60°; the relative intensities, taking the mean of the intensity at Fort Reliance before quitting, and on the return to that station, as unity; and likewise the relative intensities, taking that at London, on Captain BACK's return, as unity.

Place of observation.	Date.	Time of vibration of needle.	Thermometer.	Measure of intensity at temp. 60°.	Ratio of intensity to that at Fort Reliance.	Ratio of intensity to that at London.
	1834.	s	°			
Fort Reliance	May 21.	1·28440	49·13	·603192		
	Oct. 9.	1·27813	27·62	·603416		
		Mean		·603304	1·00000	1·25450
Musk-Ox Rapid	July 2.	1·28726	64·0	·604584	1.00212	1·25717
Rock Rapid	July 23.	1·28000	86·75	·617855	1·02412	1·28473
Point Beaufort	July 31.	1·2975	72·5	·597388	0·99020	1·24220
Montreal Island	Aug. 2.	1·2885	74·12	·606212	1·00482	1·26055
Point Ogle	Aug. 12.	1·26563	53·0	·622317	1·03152	1·29404
	1836.					
London	Feb. 12.	1·4368	44·0	·480910	0·79713	1·00000
Fort Reliance	May 21. Oct. 9.	Mean { needle direct and reversed }		·608175	1·00000	
Point Ogle	Aug. 12.	1·27507	54·06	·613426	1·00863	1·26576

On the hypothesis of two magnetic poles not far removed from the centre of the earth, to which I have already adverted, if I represent the intensity of the force in the direction of the dip, then

$$I = \frac{\mu}{\sqrt{(3 \cos 2 \delta + 5)}} \quad . \; . \; . \; . \; . \; . \; . \; . \; . \; . \quad (19.);$$

where μ is a constant, whose value may be assumed in a comparison of the intensities corresponding to different values of δ, or may be determined from the observed values of I.

If we assume the intensity at the magnetic equator to be 1, then $\mu = 2\sqrt{2}$, and the equation becomes

$$I = \frac{2\sqrt{2}}{\sqrt{(3 \cos 2 \delta + 5)}} \quad . \; . \; . \; . \; . \; . \; . \; . \; . \; . \quad (20.)$$

In the Table which follows I have given:—the dip as already determined from Captain BACK's observations; the intensities as deduced in the preceding Tables, taking the mean of the results at Point Ogle; the values of I deduced from the last equation; and, for comparison with these, the relative intensities, assuming the intensity at London to be the theoretical value so determined. I have also given the values of μ resulting from the equation

$$\mu = \text{I}. \sqrt{(3 \cos 2 \delta + 5)} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (21.),$$

by assuming for I the ratio of the intensity to that at London, as deduced from the observations; and taking the mean of these values, (excluding that for London, on account of its incongruity with all the others,) as the value of μ in the equation (19.), I have deduced the values of I from that equation, and given the differences between these values and those resulting from the observations.

Place of observation.	Dip.	Ratio of intensity to that at London.	Computed value of I, equation (20.).	Value of I deduced from observation.	Difference.	Value of constant μ, equation (21.).	Difference between values of μ and mean.	Computed value of I, equation (19.) $\mu = 1{\cdot}7927$.	Error of computed value of I.
London	69° 43′	1·0000	1·7166	1·7166	+·0000	1·6496			
New York	72 49	1·1327	1·7804	1·9445	+·1641	1·7995	+·0068	1·1285	—·0042
Fort Alexander . .	78 54	1·2295	1·8973	2·1107	+·2134	1·8330	+·0403	1·2025	—·0270
Cumberland House	79 30	1·2018	1·9073	2·0630	+·1557	1·7822	—·0105	1·2088	+·0070
Isle à la Crosse . .	79 28	1·1893	1·9068	2·0416	+·1348	1·7642	—·0285	1·2085	+·0192
Fort Chipewyan. .	81 1	1·2071	1·9306	2·0726	+·1420	1·7684	—·0243	1·2237	+·0166
Fort Resolution . .	82 3	1·2320	1·9450	2·1150	+·1700	1·7917	—·0010	1·2328	+·0008
Fort Reliance. . . .	84 1	1·2545	1·9682	2·1535	+·1853	1·8028	+·0101	1·2475	—·0070
Musk-Ox Rapid. .	85 54	1·2572	1·9851	2·1581	+·1730	1·7915	—·0012	1·2580	+·0008
Rock Rapid	87 40	1·2847	1·9951	2·2055	+·2104	1·8214	+·0287	1·2645	—·0202
Point Beaufort . .	88 3	1·2422	1·9965	2·1324	+·1359	1·7598	—·0329	1·2654	+·0232
Montreal Island. .	87 36	1·2606	1·9948	2·1639	+·1691	1·7874	—·0053	1·2643	+·0037
Point Ogle	89 24	1·2799	1·9997	2·1971	+·1974	1·8103	+·0176	1·2674	—·0125
					Mean . .	1·7927			

Admitting the accuracy of the results by which the intensities at the American stations are connected with the intensity at London, the results in this Table are, I consider, quite conclusive against the correctness of the formula on which the value of I depends, and, consequently, against that of the hypothesis from which it is deduced, if applied to the whole of this extent of the earth's surface; the intensities deduced from observation at the American stations, as compared with the intensity at London, being, without any exception, considerably in excess of the theoretical results. But if we look to the values of μ in the sixth column, excluding that for London, we cannot fail to be struck by their remarkable agreement with each other; and I must candidly confess, that although, previously to deducing these results, I might expect something like a tendency to agreement, yet I by no means anticipated such an accordance as is here manifested. If we examine the differences between the values of μ and its mean value, excluding that for London, we shall see that only in one instance does this difference amount to one forty-fifth of the mean, and rarely to one sixtieth. Although a comparison of the observed and computed intensities must lead to the same conclusions, I have considered it would be satisfactory that such a comparison should be made. A most striking agreement is here manifest between the computed values of I and those deduced from observation, in every instance from New York to Point Ogle. It will be seen that the greatest error in the computed value of I, that corresponding to the observations at Fort Alexander, does not amount to a forty-fifth of the intensity; and if a mean of all the errors, without regard to their signs, be taken, it will be found that this mean error does not amount to the one hundred and fourth part of the mean of all the intensities. Such differences as are here indicated are quite within the limits of the errors to which observations of this nature, when carefully made, are liable, and are much less than are, generally, to be expected in any comparison of results with a formula that ought to represent them, when those results are deduced from the vibrations of a needle. It certainly does appear that the intensity did not in all cases increase with the dip; but it is probable that these discrepancies have arisen either from small errors in the observations, or from local causes affecting the intensity of the terrestrial force. Upon the whole, I think we are fully warranted in concluding that in the track of country embraced by Captain Back's observations, from New York to the Arctic Sea, the phenomena of terrestrial magnetic intensity are very correctly represented by the formula with which I have compared them.

I now proceed to discuss the observations made with horizontal needles for determining the intensity.

In order to determine the measures of the horizontal intensity resulting from the observed times of vibration of the three needles given in a preceding Table (p. 397), it is necessary to apply corrections for the difference of temperature, as indicated in the equations (17. 1.), (17. 3.), (17. L.); and in the following Table I have given the results so corrected:

Place of observation.	Needle No. 1.			Needle No. 3.			Lozenge-needle.		
	Time of one vibration.	Therm.	Measure of horizontal intensity at Temp. 60°.	Time of one vibration.	Therm.	Measure of horizontal intensity at Temp. 60°.	Time of one vibration.	Therm.	Measure of horizontal intensity at Temp. 60°.
London, Feb. 7, 1833	s 4·445	° 56·0	·0504675	s 4·36167	° 56·0	·0524378	s 1·8525	° 50·0	·290366
Montreal	No observations made.			4·82857	56·5	·0428001	No observations made.		
Fort Reliance Oct. 11, 1833	7·7000	45·5	·0166925	7·4790	46·0	·0177276	3·1535	46·0	·1000563
Fort Reliance Feb. 8, 1834	No observations made.			7·4941	45·25	·0176483	3·14844	35·0	·0999945
Fort Reliance May 21, 1834	7·6893	51·0	·0168047	7·42692	50·5	·0180258	3·1650	51·0	·0995105
Fort Reliance Oct. 9, 1834	No observations made.			7·6281	30·0	·0168793	3·1423	30·0	·1002096
Musk-Ox Rapid	No observations made.			8·8909	71·0	·0127353	No observations made.		
Rock Rapid	No observations made.			13·0286	82·0	·0059707	No observations made.		
Point Beaufort	No observations made.			18·5000	74·0	·0029468	No observations made.		
Montreal Island	No observations made.			16·7750	67·5	·00356986	6·880	63·5	·0211526
Point Ogle	No observations made.			22·7125	62·13	·00194097	8·825	63·5	·0128561
London, Feb. 12, 1836	4·6632	45·0	·0455006	4·5588	45·25	·04769145	1·8944	44·75	·277152

If we compare the measure of the intensity in London previous to Captain Back's departure with its measure by the same needle on his return, it is evident that each needle must have lost intensity during the expedition. The loss of intensity by the needles No. 1 and No. 3 appears to have been nearly the same, but that by the lozenge-needle is proportionally less than one half that by either of the others. With two of the needles, No. 1 and the Lozenge, it is not possible to determine whether this diminution of intensity took place previous to the arrival at Fort Reliance or subsequent to the final departure from that station; but with the other, No. 3, it is clear that it lost intensity during the progress of the expedition from Fort Reliance to Point Ogle, and its return to the former station. The results do not indicate that any material change took place in the intensities of any of the needles during the residence at Fort Reliance. From the results with Nos. 1 and 3 it would appear that at Fort Reliance the horizontal intensity was rather greater in May than in the preceding October; but those with the lozenge-needle indicate the reverse; and this cannot be attributed to any loss of intensity in the needle itself, for the observations with that needle in the following October, on the return to Fort Reliance, give an intensity greater than any preceding.

If, in deducing the intensity in the direction of the dip from the horizontal intensity, we take the mean of the results in London, and the mean of those at Fort Reliance previous to quitting and on the return there, we shall have the following as standards for comparison:

	Mean measure of horizontal intensity.		
	Needle No. 1.	Needle No. 3.	Lozenge-needle.
At London......	·047984	·0500646	·283759
At Fort Reliance..	·0167486	·0173400	·100032

Assuming these and the measures of the horizontal intensity in the foregoing Table, corresponding to the respective stations, and dividing by the cosine of the dip, we obtain the results in the following Table for the measures of the intensity in the direction of the dip:

Place of observation.	Dip.	Needle No. 1.		Needle No. 3.		Lozenge-needle.	
		Measure of intensity.	Ratio of intensity to that at London.	Measure of intensity.	Ratio of intensity to that at London.	Measure of intensity.	Ratio of intensity to that at London.
London	69° 43′	·138417	1·00000	·144429	1·00000	·818545	1·00000
Montreal	77 6	....	....	·191714	1·32479		
Fort Reliance......	84 1	·160675	1·160803	·166348	1·15185	·959637	1·17237
Musk-Ox Rapid....	85 54	....	....	·178122	1·23337		
Rock Rapid	87 40	....	....	·146653	1·01547		
Point Beaufort	88 3	....	....	·086601	0·59965		
Montreal Island....	87 36	....	....	·085249	0·59029	·505126	0·61710
Point Ogle........	89 24	....	....	·185352	1·28344	1·22769	1·49984

There is but little agreement between these results and those obtained from the times of vibration of the needle No. II. in the plane of the meridian; and in some cases they are quite incongruous. If we suppose that the needles retained their intensities unimpaired from the time of the last observations at Fort Reliance until the observations were made in London, that is, if we take the results of the latter observations as standards for comparison, the agreement will in general be greater; but still similar incongruities will exist. The results thus obtained are given in the following Table:

Place of observation.	Needle No. 1.		Needle No. 3.		Lozenge-needle.	
	Measure of intensity.	Ratio of intensity to that at London.	Measure of intensity.	Ratio of intensity to that at London.	Measure of intensity.	Ratio of intensity to that at London.
London	·131253	1·00000	·137573	1·00000	·799485	1·00000
Fort Reliance........	·160675	1·22416	·161929	1·17704	·959637	1·20032
Musk-Ox Rapid......	....	....	·178122	1·29475		
Rock Rapid	....	....	·146653	1·06600		
Point Beaufort	....	....	·086601	0·62949		
Montreal Island......	....	....	·085249	0·61966	·505126	0·631815
Point Ogle..........	....	....	·185352	1·34730	1·22769	1·53560

Whatever may be the law according to which the terrestrial magnetic intensity may vary, it is evident that the results at Rock Rapid, Point Beaufort, and Montreal Island, in either of these Tables, cannot be in accordance with those at Fort Reliance, Musk-Ox Rapid, and Point Ogle; and it may be worth inquiring to what this discordance, and that between these results and those with the dipping needle No. II., are to be attributed. That there may have been errors in the observations of the times of vibration of the needles is very possible, but not to the amount that such discordances would indicate; and I therefore attribute the want of agreement in the results to the inefficiency of HANSTEEN's method for the determination of the absolute intensity in such cases, rather than to errors of this description. When the dip is great, a small error in its determination will introduce a large one in the determination of the absolute intensity from the horizontal; and to such errors I consider that these discordances may, in a great measure, be attributed. In order to determine the errors in the dip necessary to account for this want of agreement between the results obtained with the dipping needle No. II. and with the horizontal needles, let i be the measure of the horizontal intensity, and δ the dip at the place of observation, I the measure of the absolute intensity at London with the same needle, and M the ratio of the intensity at the place of observation to that at London, as determined by the time of vibration of the needle No. II., then

$$\cos \delta = \frac{i}{\text{I M}} \quad \text{. . . . . (22.)}$$

In the following Table are given the values of δ deduced from this formula by substituting for M its values in the Table at p. 408, and for I its values in each of the two foregoing Tables:

Place of observation.	Observed Dip.	Needle No. 1. Computed dip $\cos \delta = \frac{i}{I M}$ I = ·138417.	Needle No. 1. Difference of computed and observed dip.	Needle No. 3. Computed dip $\cos \delta = \frac{i}{I M}$ I = ·144429.	Needle No. 3. Difference of computed and observed dip.	Lozenge-needle. Computed dip $\cos \delta = \frac{i}{I M}$ I = ·818545.	Lozenge-needle. Difference of computed and observed dip.
	° ′	° ′ ″	′ ″	° ′ ″	° ′ ″	° ′ ″	° ′ ″
Fort Reliance......	84 1	84 27 54	+ 26 54	84 30 29	+0 29 29	84 24 35	+0 23 35
Musk-Ox Rapid....	85 54	....	....	85 58 40	+0 4 40		
Rock Rapid	87 40	....	....	88 9 21	+0 29 21		
Point Beaufort	88 3	....	....	89 3 32	+1 0 32		
Montreal Island....	87 36	....	....	88 52 35	+1 16 35	88 49 31	+1 13 31
Point Ogle........	89 24	....	....	89 23 54	−0 0 6	89 17 49	−0 6 11
		I = ·131253.		I = ·137573.		I = ·799485.	
Fort Reliance......		84 9 43	+ 8 43	84 14 1	+0 13 1	84 16 34	+0 15 34
Musk-Ox Rapid....		....	....	85 46 38	−0 7 22		
Rock Rapid		....	....	88 3 51	+0 23 51		
Point Beaufort		....	....	89 0 43	+0 57 43		
Montreal Island....		....	....	88 49 14	+1 13 14	88 47 50	+1 11 50
Point Ogle........		....	....	89 22 6	−0 1 54	89 16 48	−0 7 12

The differences between the observed and computed dips at Fort Reliance, Musk-Ox Rapid and Point Ogle, particularly in the latter part of this Table, are quite within the limits of errors in the determination of the dip. The difference at Rock Rapid may possibly be considered to exceed this; but it is to be observed that the value of M in the Table, p. 408, is at this place manifestly in excess, and I have before remarked that the vibration of the needle No. II. appears to have been there influenced by some particular cause which would render the value of M, deduced from its time of vibration, doubtful. With regard to the differences at Point Beaufort and Montreal Island, these are much greater than we can attribute to the errors to which the observations for the dip could be liable, considering the care which Captain Back appears in all cases to have bestowed on these observations. All circumstances, however, indicate that the dips deduced from the observations at these two stations are less than the truth; and as there is one error which it is possible may have been made in registering the observations, it is proper that I should here advert to it. The value of the angle $'\theta$ at Point Beaufort is 89° 35′ (Table, p. 380); and if we suppose that this arc was read on the southern limb of the instrument, as was the case at Point Ogle, instead of the northern, as it had been previously at Rock Rapid, and as it is registered, then the true value of $'\theta$ would be 90° 25′. This value would give the dip at Point Beaufort 88° 28′ instead of 88° 3′. If we suppose the same error to have been committed at Montreal Island, then the value of $'\theta$ there would be 91° 13′ 30″, and the dip 88° 48′ 30″ instead of 87° 35′ 49″. These results, particularly that for Montreal Island, from a comparison with those at Rock Rapid and Point Ogle, and also with those in the foregoing Table, are certainly very probable, and the error I have indicated is one which may easily have occurred; but I must not omit to state, that on calling Captain Back's attention to the circumstance, and referring to the register of the observations, he could recall no circumstance that could induce him to think that in these observations the reading of the needle was beyond 90° on the northern limb, though he perfectly remembered remarking that such was the case at Point Ogle, and that the angle registered was that on the southern limb, and so marked.

I have already stated my opinion of the inapplicability of Hansteen's method of determining the intensity, to cases where the dip is great—but my objections to the method are by no means limited to such cases—and I may notice another source of error, besides that to which I have adverted, to which results deduced from the times of vibration of a horizontal needle are in these cases peculiarly subject,—local influence. The directive force acting upon the horizontal needle is, in these cases, greatly diminished, and consequently the relative effect of an extraneous force is, with little exception, increased; so that masses of rock which are magnetic, although without polarity, may, by their position, exert an influence on the time of vibration of a horizontal needle, which would be altogether insensible on that of the dipping needle. That the times of vibration of the horizontal needle at Point Beaufort may have been thus affected, is not altogether improbable. On the observations there Captain Back has this remark: "Instrument in perfect adjustment; stand on shingle at the base of a gneiss rock three or four hundred feet high." There is no remark on the position of this rock with respect to the needle, and I cannot now consult Captain Back on the subject; but that in particular positions such a mass would affect the horizontal needle, and even the dipping needle, is more than probable. At Montreal Island the stand was "placed on firm sand, about sixty yards from some low rocks"; so that here there does not appear any particular cause for suspecting local influence. It is, however, proper to give a remark of Captain Back's relative to these observations: "No. 3 vibrated slowly, and on the first trial stopped dead at 10°. Two kettles, twenty yards off, were then taken further away, and I took off my brace-buckles; it then vibrated regularly, but made a long rest at each extreme, as if disposed to remain there. We have only made twelve miles N.W. $\frac{3}{4}$ W. from the last place, so that one would imagine some local cause, such as the rock, to account for the difference in the interval of vibrations." But I must now close my remarks on the observations at these two stations, although I may, very unwillingly, leave some degree of uncertainty attached to the results deduced from them.

Whatever uncertainty may attach to the results of the observations at Point Beaufort and Montreal Island, every circumstance tends to confirm the correctness of the observations at the more important station, Point Ogle, and to indicate the very near approach which was here made to the northern pole of verticity. If any doubts could be entertained with regard to the amount of the dip at this station, as determined from the observations, they must be completely removed by Captain Back's remarks on the difficulty of adjusting the horizontal needles,—which, it will be borne in mind, were delicately suspended by fibres of silk,—and the uncertainty of their zero points, at Point Ogle, totally unconnected as these remarks are with the cause of this difficulty and uncertainty; and I cannot omit to give them precisely as they are appended to the observations: "This needle (No. 3) was extremely difficult to get into adjustment, and was so dull and heavy in its motion, that to have marked the precise time when it turned at each extremity would have required a fixed reading-glass. At the conclusion it settled within half a degree of its zero, but in five minutes after altered, without any apparent cause, 6°. I then made the following set (the second set of vibrations). This did not correspond with the former, neither did the needle settle at the same zero I began from, but returned to the first, and what I supposed to be the correct one." With respect to the lozenge-needle, he remarks: "There was a difference of no less than 22° between the north points of this and No. 3, though this agreed with DOLLOND's light needle for adjusting the dip instrument. As usual, it was more active, and, in this instance, far more regular (in its vibrations). Nevertheless another set was taken: the needle remained in perfect adjustment *."

If we contrast the difficulty here manifest, in determining the direction of the magnetic meridian by means of needles delicately suspended, with the facility with which its direction was, apparently, determined by Sir JOHN ROSS at Victory Harbour and Padliak, at which places he states that he ascertained the dip to be 89° 55′ and 89° 56′, we cannot but conclude that such results are greatly in excess. With such a dip, all determinate direction in a horizontal needle, arising from the force of terrestrial magnetism, however delicate might be the suspension of the needle, is quite out of the question; and if a horizontal needle, so situated with respect to the pole of verticity, had a determinate direction, it must have been due to the force exerted upon it by some mass in its vicinity. The dip at Victory Harbour, according to Captain JAMES ROSS's observations †, is 88° 55′, and at Padliak 89° 17′; but even with this amount of dip I do not consider that the direction of the magnetic meridian could be ascertained, with anything like precision, by means of a KATER's azimuth compass, however accurate might be its construction, and with whatever care it might be used. At Cape Isabella, where Captain JAMES ROSS observed the dip 89° 22′, the north point of a KATER azimuth compass was directed to the north-west, but "its action was uncertain to eight or ten degrees ‡." Captain BACK remarked this sluggishness of the compass-needles from the time he quitted Rock Rapid; his own,—a small KATER's azimuth very probably, certainly one of very delicate suspension,—he remarks, "frequently remained wherever it was placed, without evincing the slightest tendency to recover its polarity §." I have referred to these circumstances of the two expeditions, because they all tend to show, quite independently of the agreement which I have noticed among the results deduced from the observations, that at Point Ogle, at

* For further remarks on these observations, see Captain BACK's Narrative, p. 415.

† Philosophical Transactions, 1834, p. 52. ‡ Ibid., p. 49. § Narrative, p. 378.

least as near an approach was made to the northern pole of verticity as at Padliak or Cape Isabella; and because the observations at Rock Rapid, the last point where, probably, the direction of the magnetic meridian could be ascertained with something like precision, would assign a position to this pole different from that assigned to it by Captain James Ross. As, however, I propose on some future occasion, investigating the positions which the observations on the continent and in the archipelago of North America would assign to the poles of verticity and convergence, I shall not now pursue the subject further.

I cannot conclude this discussion of Captain Back's highly interesting observations without expressing my own obligation to him for having placed them at my disposal, and, at the same time, my sense of the zeal he has shown in the prosecution of scientific inquiry. The undivided responsibility which rested upon Captain Back during the expedition, and particularly during the progress from Fort Reliance to the sea, by a navigation of unparalleled danger, was of no ordinary kind; and it was scarcely to be expected that, under such circumstances, any other observations than those absolutely requisite for the prosecution of the voyage would have been made. We however find that during this perilous and unknown navigation, Captain Back availed himself of every opportunity for making observations, necessarily tedious in their nature, and requiring much care and attention, but which he considered requisite for the attainment of particular scientific objects; and I feel I should be committing injustice were I not to express that I consider science is greatly indebted to him for the zeal and ability he has manifested in its cause.