VI. *On the Spontaneous Electrical Currents observed in the Wires of the Electric Telegraph.* By W. H. Barlow, *Esq., M. Inst. C.E.* *Communicated by* Peter Barlow, *Esq., F.R.S.*

Received May 15,—Read May 25, 1848.

THE observations described in the following pages were undertaken in consequence of certain spontaneous deflections having been noticed in the needles of the electric telegraph on the Midland Railway, the erection of which was carried out under my superintendence as the Company's engineer.

The telegraph is on the principle patented by Professor Wheatstone and Mr. Cooke, and the signals are given by deflecting a magnetic needle suspended in a coil of fine wire, to the right or left, by means of a galvanic battery.

Each wire has an earth connection at its two extremities, and when a current is made to pass along the wire by means of the galvanic battery, it returns by the conducting power of the earth.

When the telegraph instruments are not working, the batteries are put out of circuit, and the wires remain with a simple earth connection at both extremities.

It was in this condition of the wires that spontaneous currents were observed to arise in them, producing occasionally large deflections in the needles. These deflections were sometimes to the right and sometimes to the left; at times they changed rapidly from right to left, at others they continued in one direction for periods varying from a few minutes to one or more hours.

The system of telegraphs which centres at Derby, consists of four main lines, viz.—

1st. From Derby in a southerly direction to Rugby.

2nd. From Derby to Birmingham, which approaches a south-westerly direction.

3rd. From Derby in a northerly direction to Leeds.

4th. From Derby in a north-easterly direction to Lincoln.

When these four telegraphs were brought into operation, it was observed that the spontaneous deflections were almost invariably simultaneous on all the instruments, and that when in the Birmingham telegraph the deflection was such as to indicate that the current was passing from the telegraph wires to the earth at Derby, the current in the Rugby wires was also passing towards the earth at Derby, while the two other telegraphs showed the current to be passing *from* the earth at Derby along the wires proceeding in a northerly and north-easterly direction. It was also found that when the current took a reversed direction in one telegraph, it was reversed in all. There were some exceptions to this rule, but they were rare, and always of short duration.

The spontaneous deflections of the telegraph needles had been observed on other lines of railway as well as on the Midland, and they had been attributed to atmospheric electricity passing by the wire through the coil to the earth, or *vice versâ* from the earth to the atmosphere. This supposition was apparently strengthened, because during thunder-storms it has frequently occurred that the wires in the coils have been fused, the poles of the needles reversed, or the needles de-magnetized; but it is difficult to conceive any effect of atmospheric electricity that would account for the relative positions of the needles of the telegraphs proceeding from Derby northwards as compared with those proceeding southwards*.

My attention was strongly drawn to the subject by the constancy of these effects, when a circumstance occurred which imparted a new interest to the inquiry. On the evening of the 19th of March, 1847, a brilliant aurora was seen, and during the whole time of its remaining visible, strong alternating deflections occurred on all the instruments. Similar effects were observed also on the telegraphs on several other lines of railway.

Regarding with much interest these effects, which appeared to open a new field for investigation, I determined on making a systematic set of observations on the subject.

Each of the lines of telegraph centring at Derby consists of several wires; from Derby to Birmingham, and Derby to Rugby, there are five wires. From Derby to Lincoln there are three wires, and from Derby northwards there are seven wires.

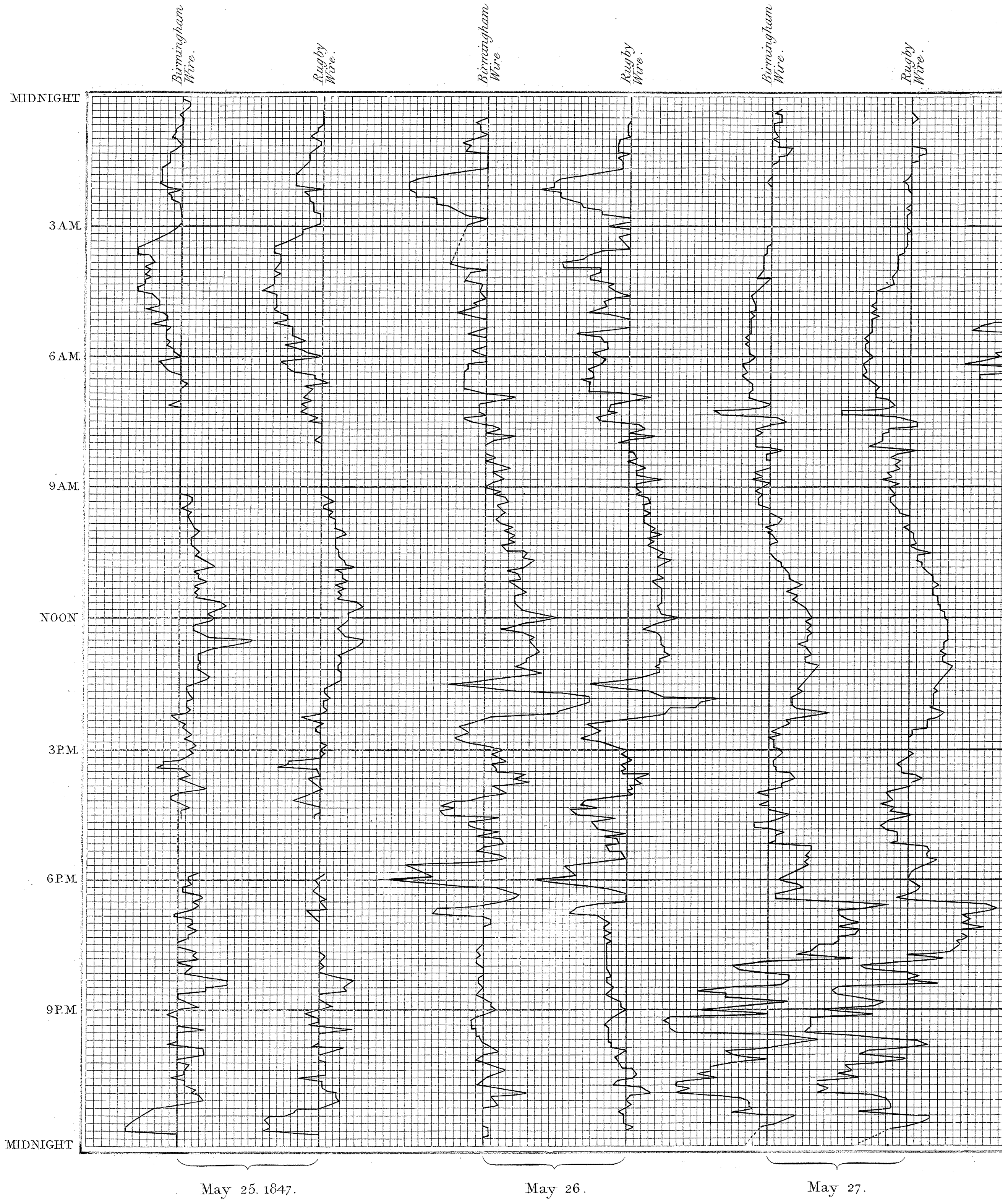
At the time of commencing these experiments only three wires had been put in operation for telegraph business. There were two spare wires of the railway telegraph from Rugby and Derby, and thence to Leeds, unoccupied, and two others from Birmingham to Derby and from Derby to Normanton belonging to the Telegraph Company, and intended to form a portion of the commercial telegraph, which were also at liberty.

I applied to Mr. Hatcher, the engineer of the Telegraph Company, for permission to make use of their spare wires in the proposed experiments, which was freely accorded; and I am much indebted to this gentleman and to Mr. Culley, under whose management the Midland districts is placed, for the valuable assistance and information they have afforded me in this inquiry.

My first object was to make two delicate galvanometers, which was readily accomplished by making use of the "*detectors*" employed in ascertaining any defect in the insulation of the wires.

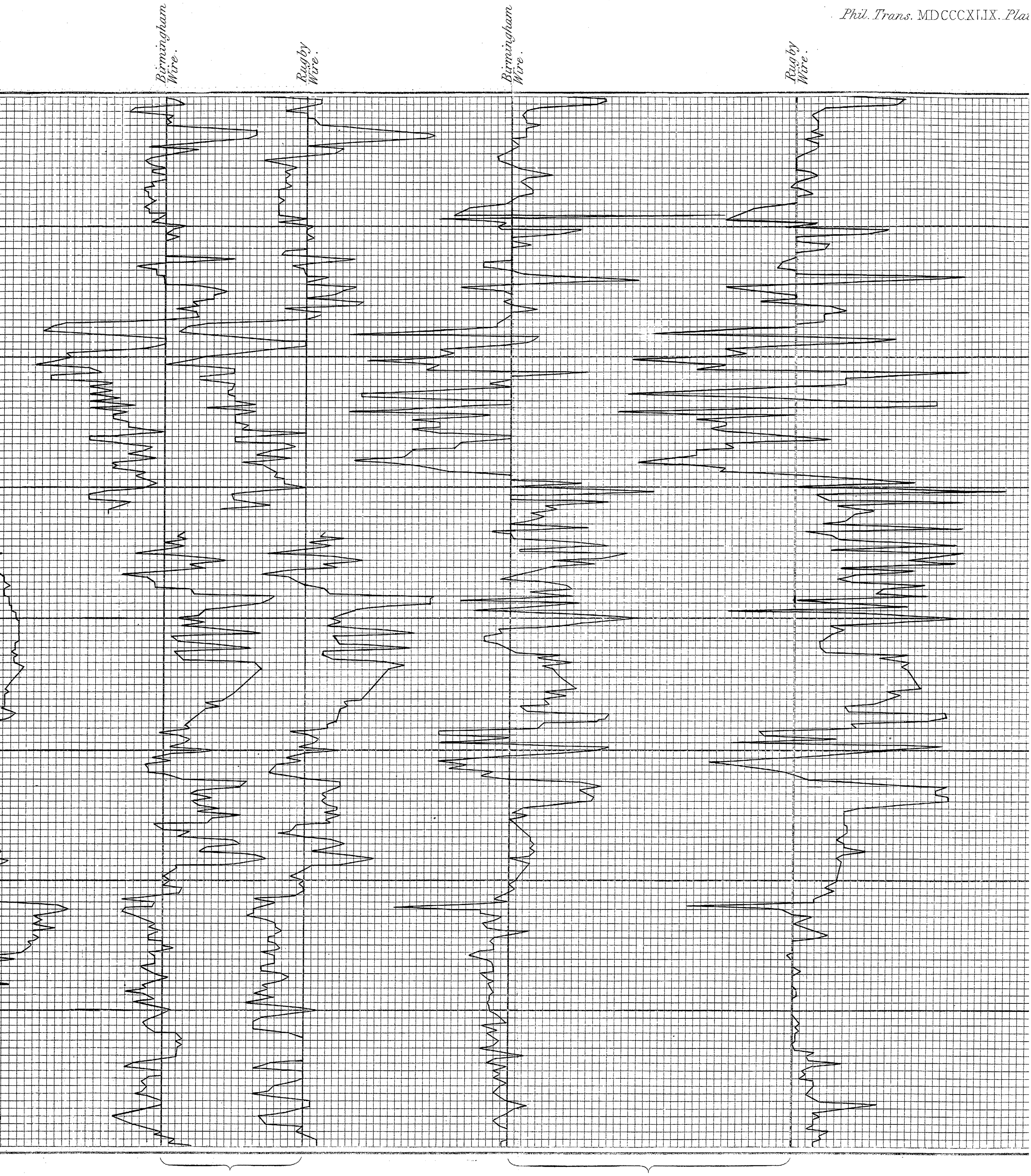
These instruments are similar in principle to those employed in working the telegraph, having a coil of fine wire about 1000 feet in length, in which an astatic needle

* Since this was written I have received a communication from Mr. Culley, in which he points out an important distinction between the effects of lightning and the aurora on the instruments of the telegraph needles, which I beg to add as a postscript to this paper.



Birmingham Wire.
Rugby Wire.
Birmingham Wire.
Rugby Wire.
Birmingham Wire.
Rugby Wire.
MIDNIGHT
3 A.M.
6 A.M.
9 A.M.
NOON
3 P.M.
6 P.M.
9 P.M.
MIDNIGHT
May 25. 1847.
May 26.
May 27.

DIAGR



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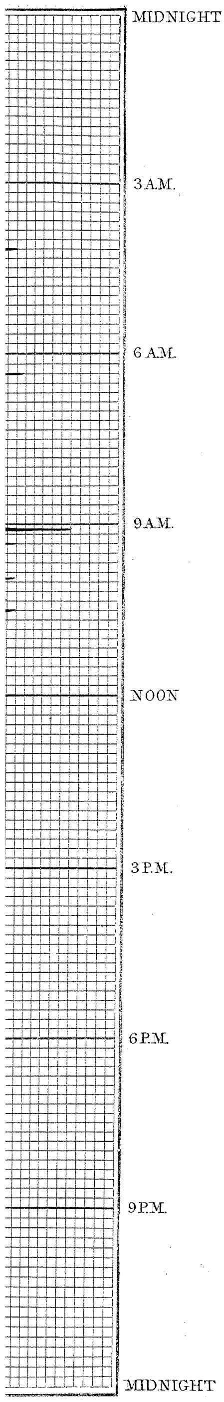
AGRAM No. 1.



J. Basire sc

is suspended, of which the lower end is made to preponderate, so that the natural position of the needle is vertical. The only alteration made to adapt this instrument to the purpose was supporting the needles on knife edges instead of circular bearings, and diminishing the gravitating preponderance of the lower end of the needles, which alterations increased the sensitiveness in a high degree.

The preliminary experiments were directed towards ascertaining whether the deflections were attributable to the electricity passing from the atmosphere along the wire to the earth. The observations were frequently repeated on wires from forty to fifty miles in length, and their results may be briefly stated as follows:—

Wires insulated from the earth throughout their entire length produced *no* deflection in either instruments.

Wires having an earth connection only at one extremity produced *no* deflection.

A complete circuit made by uniting both extremities of two wires, each forty-one miles long, and insulated from the earth throughout their length, produced *no* deflection.

But in every case deflections were obtained from a wire having an earth connection at both extremities.

Two wires having earth connections at both extremities produced a larger deflection than one wire.

A later experiment on the same subject showed that a wire having an earth connection at one extremity, and another earth connection near the middle of its length, gave a deflection on the part of the wire between the two earth connections, but none on the part beyond.

In watching the operations of the galvanometers when in circuit with a wire having two earth connections, it was observed that the needle was rarely found to remain in the same position many minutes, large variations taking place sometimes in a few seconds, and it became interesting to ascertain if these changes coincided at both ends of the wire.

In order to submit this to experiment, simultaneous observations were made at intervals of five minutes for twenty-four hours on two galvanometers, one at Derby and the other at Birmingham, each connected to the same wire.

Mr. Culley took the observations at Birmingham, while I took those at Derby, each being assisted by an intelligent telegraph clerk. In addition to the galvanometers, the wet and dry thermometers were also noted at every observation.

The results of these observations are given in diagram No. 1, and allowing for the difference in delicacy of the two galvanometers, there is enough to show that the currents were simultaneous in all their changes; it was also evident from this experiment that the direction of the current was the same at both extremities of the wire.

This fact, together with those previously mentioned, indicates that the currents which produce deflections do not arise from the transit of electricity between the atmosphere and the earth, but that from whatever cause the currents originate, they travel along the wires from one earth connection to the other, alternating first in one direction and then in the other.

In examining the results obtained from this experiment, there appeared a general movement of the needle to the right from the commencement of the observations in the morning until midnight, then changing over to the left until nine or ten o'clock in the morning, when it again passed to the right, large and rapidly alternating deflections having occurred during the night, the effects of which were visible on the ordinary telegraph instruments. The general direction of the needle, however, independently of these irregular influences, appearing to exhibit some regularity, I followed up the experiments with the galvanometer at Derby, and found that a similar motion of the needle occurred daily.

This discovery led me to establish a series of observations for fourteen days and nights, on two wires simultaneously, one from Derby to Birmingham, and the other from Derby to Rugby, the position of the needle being recorded every five minutes, day and night. The mean position of the needles during each hour, as obtained from these observations, is given in Tables Nos. I. and II., and the mean result for each week is given in the right-hand column.

The path described by the two needles during the week, ending May 29, 1847, is also exhibited in the diagram No. 2.

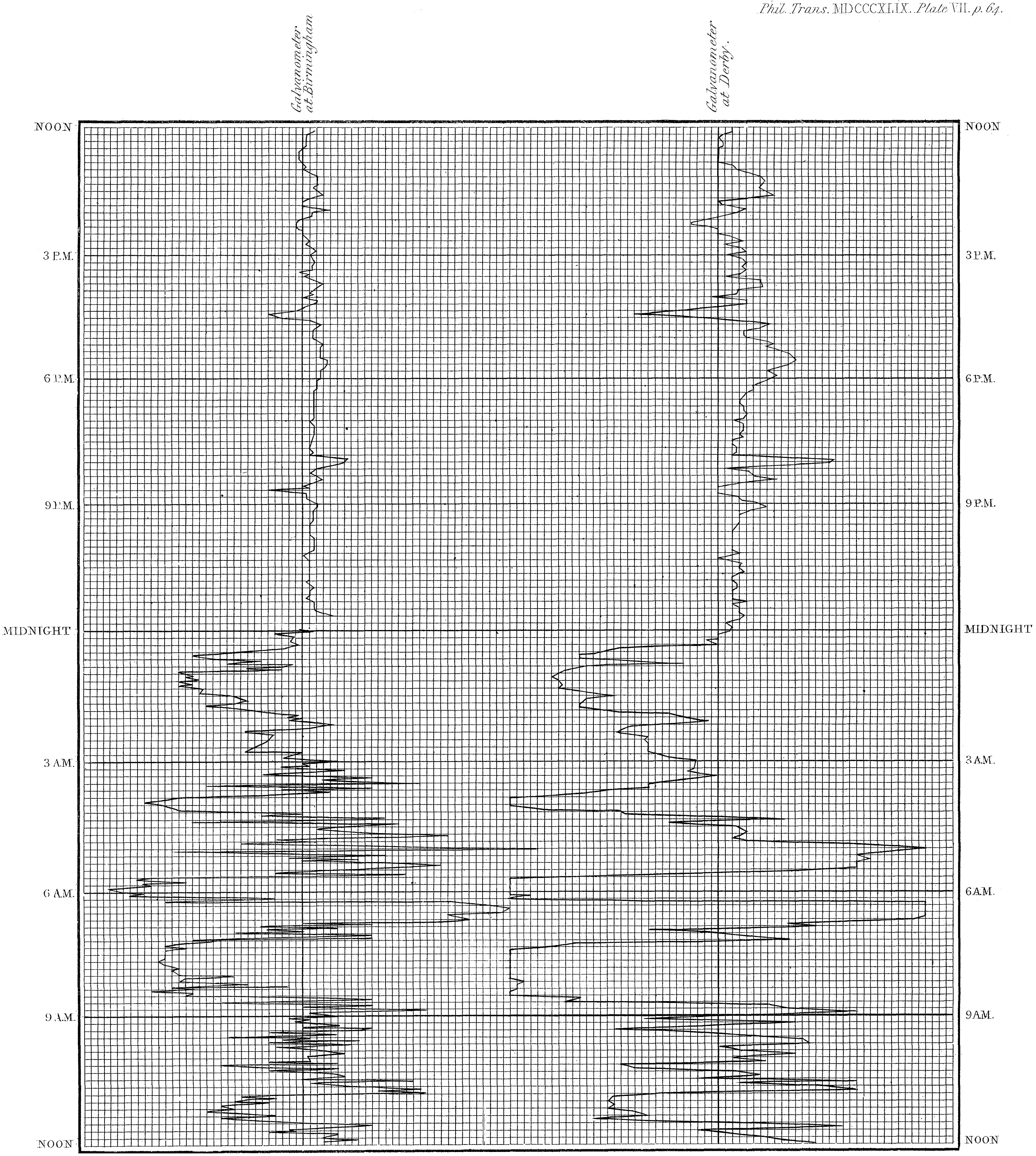
In order to explain the directions in which the currents traversed the wires in these experiments, it is necessary to state that the two extremities of the coil in the galvanometers are attached to two brass screw pegs, technically called "terminals," which stand up on the top of the case of the galvanometer, one on the left hand and the other on the right, and the coil was so arranged that when the copper pole of a battery was connected with the *left* hand terminal, and the zinc pole with the right, the deflection (which in all cases refers to the upper end of the needle) was to the left; and assuming that the current flows from the copper to the zinc pole, a deflection to the left in these observations indicates a current flowing along the wire towards Derby, and a right-hand deflection shows the current to be flowing from Derby to the extremity of the wire.

In addition to the above-mentioned experiments, simultaneous observations were made with galvanometers on the wires proceeding from Derby northward and southward, the results of which showed that the currents producing the regular diurnal deflections followed the same law as to their relative directions in the four different lines of telegraph centring at Derby, as that which had been observed on the telegraph instruments during periods of the large spontaneous deflections.

The broad feature elicited by these observations may therefore be stated to be,—

1st. That the path described by the needle consisted of a regular diurnal motion, subject to disturbances of greater or less magnitude.

2nd. That this motion is due to electric currents passing from the northern to the southern extremities of the telegraph wires, and returning in the opposite direction.



May 7. 1847.

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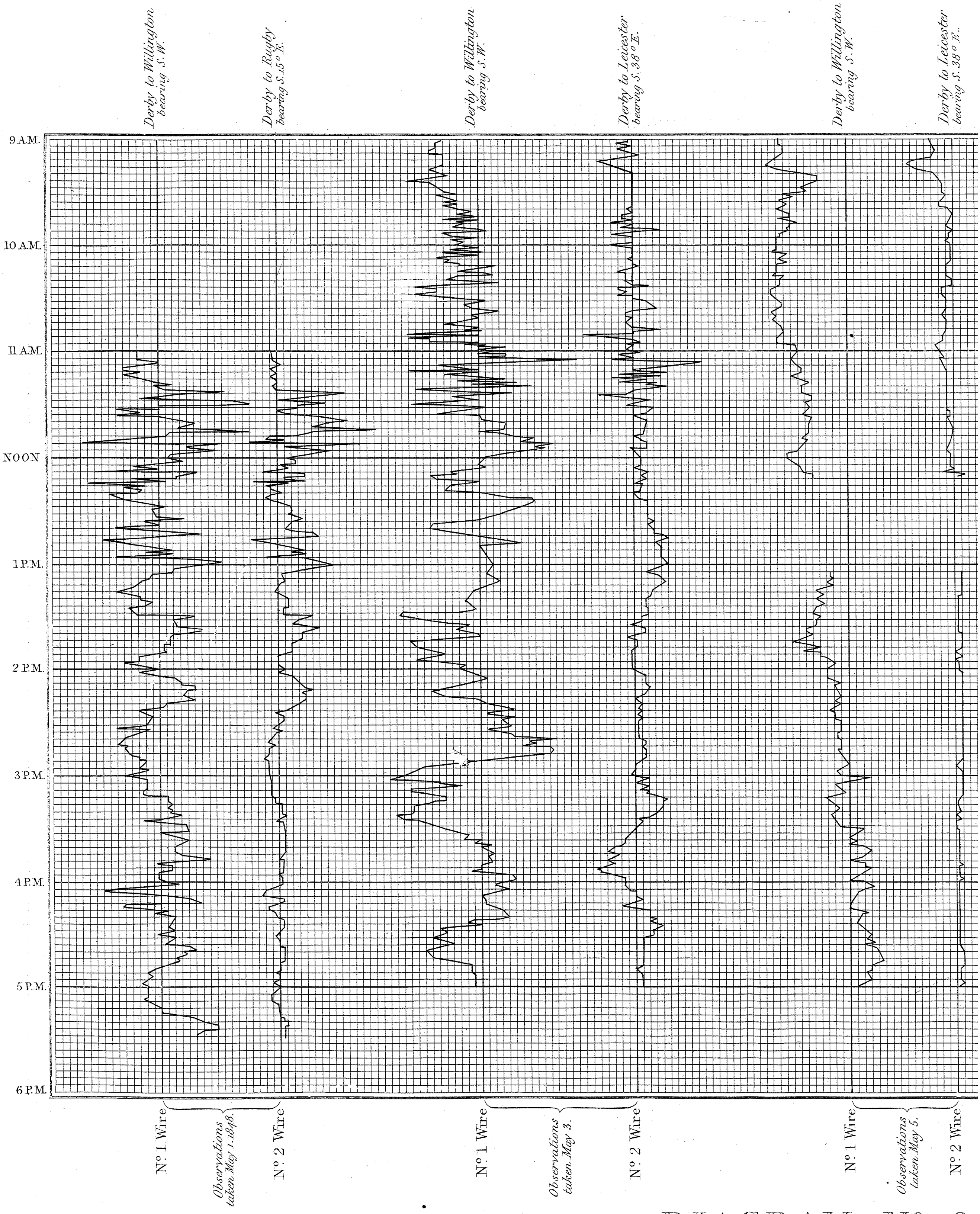
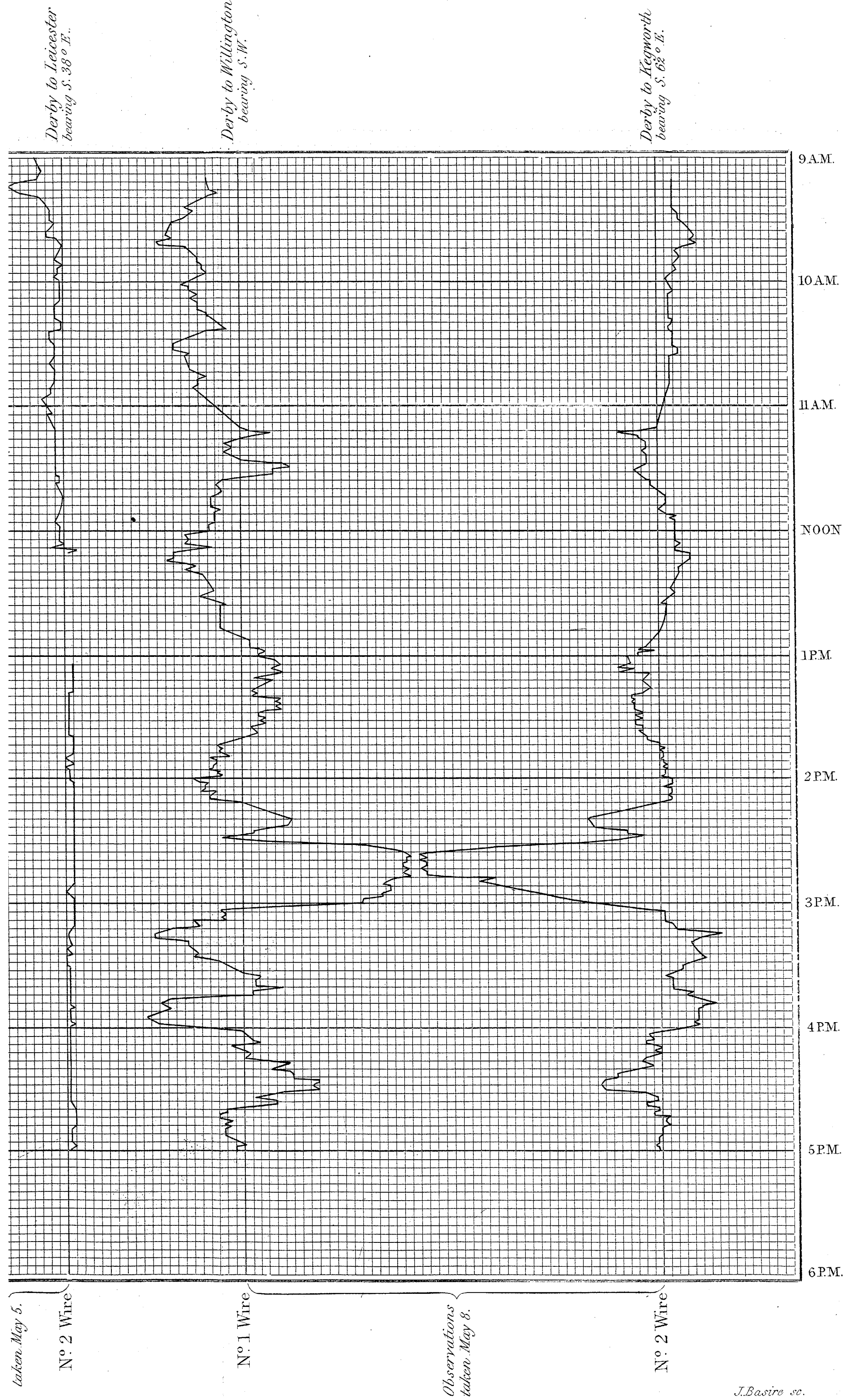
DIAGRAM No. 2.



Derby to Willington bearing S.W.
Derby to Rugby bearing S.15° E.
Derby to Willington bearing S.W.
Derby to Leicester bearing S.38° E.
Derby to Willington bearing S.W.
Derby to Leicester bearing S.38° E.
9 A.M.
10 A.M.
11 A.M.
NOON
1 P.M.
2 P.M.
3 P.M.
4 P.M.
5 P.M.
6 P.M.
N° 1 Wire
Observations taken May 1. 1848.
N° 2 Wire
N° 1 Wire
Observations taken May 3.
N° 2 Wire
N° 1 Wire
Observations taken May 5.
N° 2 Wire

DIAGRAM N° 3



J. Basire sc.

Nº 3.

3rd. That exclusive of the irregular disturbances the currents flowed in a southerly direction from about eight or nine A.M. until the evening, and in a northerly direction during the remainder of the twenty-four hours.

The next experiments were made with a view to ascertain if any immediate relation existed between the motion of the galvanometers and the daily variation of the horizontal magnetic needle.

For this purpose I caused a temporary observatory to be erected in my garden at Derby (about a mile from the railway station, where the galvanometer experiments were made), and furnished it with a very delicate declinometer.

On making observations with the two instruments, it became evident that, although generally that part of the day in which the currents flow southwards (that is, from eight or nine A.M. until the evening) the variation of the horizontal magnetic needle is westerly, and that during the night and early part of the morning (at which time the currents travel northwards) the variation is easterly; yet simultaneous observations showed no similarity in the path described by the magnetic needle and the galvanometer.

It had however been mentioned by Colonel SABINE, when my former paper on this subject was read, which described large deflections having occurred on the evening of the 19th of March, 1847, that unusual disturbances had been observed at the same time in the magnetic needle not only in England but abroad; I therefore waited for an opportunity to repeat the experiments with the declinometer at a time when the telegraph needles were unusually deflected.

On the 24th of September 1847, I was enabled partially to carry out this intention; and on the 27th I obtained a set of simultaneous observations on the galvanometer and the magnetic needle, the galvanometer being attached to a wire having its earth connections at Derby and Rugby.

These observations show unusual disturbances on both instruments on the days mentioned, particularly on the 24th, when it was excessive.

From communications I have been favoured with, it appears that the deflections of the telegraph needles on the 24th of September were general throughout the kingdom. They were observed on the South Devon line and in Scotland, as well as on all the lines in this part of the country; and it is worthy of remark, that all the reports of the telegraph clerks agree nearly in the time of the commencement of the disturbance, the earliest time stated being 11·35 A.M., and the latest noon.

The 23rd of October was another day of strong deflections, and a partial register was kept of them in London by Mr. HATCHER. They were equally strong on the Midland line, and I have accounts of them as far as Newcastle. The 24th being Sunday, there was no register kept; but they continued on the 25th, and were again registered by Mr. HATCHER in London, who has favoured me with his observations; but beyond the fact of the unusual disturbance, they throw no additional light on this subject.

I have no magnetic observations on the 23rd, 24th, or 25th of October, but I have since learnt that an unusual magnetic disturbance occurred on these days, and there appears no doubt of the coincidence of these great disturbances in both instruments.

On the three occasions mentioned, namely, the 19th of March, the 24th and 25th of September, and the 23rd, 24th and 25th of October, aurora was visible; and in every case which has come under my observation, the telegraph needles have been deflected whenever aurora has been visible.

It only remains now to describe the experiments made to ascertain the line of direction in which the currents alternate, and it will serve to render this part of the subject more clear, to state in this place that, from numerous experiments, it appears that from whatever cause the currents are produced, the direction of the current at a given time in any wire depends on the relative positions of the earth connections, if the insulation is good, however circuitous may be the route of the wire itself. For example, the telegraph from Derby to Rugby, forty-nine miles in length, proceeds for ten miles about S.E. by E. to Kegworth; then for nineteen miles it takes a S.E. direction to Leicester, and the remaining twenty miles to Rugby is about S.S.W.

Having one earth connection at Derby, if the other be made at Rugby, the bearing of which place from Derby is S. 15° E.; the deflections accord with those of the wire to Birmingham, bearing S. 29° W.; but if the earth connection of the Rugby wire be changed from Rugby to Kegworth, the bearing of which from Derby is S. 62° E., the deflections produced are in the contrary direction to those of the Birmingham wire.

I do not consider that this fact in itself proves that the currents are generated in the earth, for they might arise from other causes, and yet exhibit the same result. I only mention the fact in this place to facilitate the consideration of the direction in which the currents alternate, and to indicate that when the direction of the current between any two places is described, it is not meant that the wire is laid in a direct line between the two points, but that the earth connections are so placed.

Referring the direction of deflection in every case to those produced by the Birmingham wire, and denoting those which accord with it by the sign +, and those which exhibit a contrary deflection —, the results of the experiments on direction were as follows:—

Derby to Willington, bearing	S.W.	+
Derby to Birmingham, bearing	S. 29° W.	+
Derby to Rugby, bearing	S. 15° E.	+
Derby to Leicester, bearing	S. 38° E.	+ —
Derby to Loughborough, bearing . . .	S. 50° E.	doubtful.
Derby to Kegworth, bearing	S. 62° E.	—
Derby to Nottingham, bearing	N. 80° E.	—
Derby to Lincoln, bearing	N. 60° E.	—
Derby to Chesterfield, bearing	N. 5° E.	—
Derby to Normanton, bearing	N. 3° W.	—

The observations were made with galvanometers on two or more wires simultaneously, and the motions of the needles observed for several hours. It frequently happens that, from some difference in the earth connection, there is a slight permanent action, so that in making these observations it is not simply the position but the motion of the needles that distinguishes the direction of the current. If on trying two wires, one causes the galvanometer needle to move from right to left, when the other moves from left to right, the currents are in opposite directions.

Mr. Culley has favoured me with another set of observations obtained from the telegraph instruments at Normanton, during large deflections.

Normanton is a central station from which seven telegraphs branch off. Each telegraph has an earth connection at Normanton, and the other extremities of the telegraphs are connected with the earth at Rugby, Derby, Manchester, Leeds, Newcastle, York and Hull.

Calling those telegraphs in which the deflections accord with that to Manchester +, the results are as follows:—

From Normanton to Rugby. . .	S. 5° E.	+
From Normanton to Derby . . .	S. 2° W.	+
From Normanton to Manchester .	S. 65° W.	+
From Normanton to Leeds . . .	N. 35° W.	doubtful —, very small deflections.
From Normanton to Newcastle .	N. 8° W.	doubtful, generally —.
From Normanton to York . . .	N. 40° E.	—
From Normanton to Hull . . .	N. 87° E.	—

The general result derived from these two sets of experiments may be stated as follows:—Taking one earth connection as a point of reference when the bearing of the other earth connection lies between S. and W., or between N. and E., the action is strong and decided, the one being + and the other —.

In the experiments made from Derby as a central point, the action of the current is reversed when the earth connection is changed from S. 15° E. to S. 62° E. I have tried numerous experiments between these two directions, and there does not appear to be any line in which all action ceases, but in approaching the S.E. direction the motion of the needles becomes undefined.

The direction in which the currents travel being supposed to be at right angles to that in which the reversed action takes place, will be between S. 28° W. and S. 75° W., and apparently strongest when the earth connections are about N.E. and S.W.

As the fact above mentioned, namely, that the direction of the current in any wire at a given time depends on the relative positions of the earth connections, and not on the direction of the wire itself, is of great interest, I have recently repeated some of the observations on this subject, the results of which are given in diagram No. 3.

In these observations, a spare wire from Derby to Willington, length $6\frac{1}{2}$ miles, bearing S.W., was used as a standard of comparison, and simultaneous observations were made on it, and on a wire from Derby to Rugby, varying the position of one of the earth connections of the Rugby wire as described below.

First Day's Observations, May 1st, 1848.

The positions of the earth connection were,—

No. 1 wire. Derby and Willington, bearing S.W.

No. 2 wire. Derby and Rugby, bearing S. 15° E.

The path described by the two galvanometer needles is shown in figs. 1 and 2, and it will be seen that there is an obvious similitude throughout all their movements.

Second Day's Observations, May 3rd, 1848.

The position of the earth connections were,—

No. 1 wire. Derby and Willington, bearing S.W.

No. 2 wire. Derby and Leicester, bearing S. 38° E.

The movement of the galvanometers is shown at figs. 3 and 4. There is a partial similarity in the forenoon, but none afterwards.

Third Day's Observations, May 5th, 1848.

Earth connections the same as in the last experiment.

The paths of the galvanometers is shown at figs. 5 and 6. There is no similarity in the movement of the needles, excepting that the general march of both needles is from the left in the morning, towards the right in the afternoon.

Fourth Day's Observations, May 8th, 1848.

The position of the earth connections were,—

No. 1 wire. Derby and Willington, bearing S.W.

No. 2 wire. Derby and Kegworth, bearing S. 62° E.

The movement of the needles is shown at figs. 7 and 8.

In this case we have a contrary direction of the current clearly marked and rendered more evident by the larger deflections which occurred on this day.

These experiments are satisfactory as verifying the former observations made on this subject from time to time during the last twelve months.

It should be mentioned that no part of the Rugby wire was *disconnected* in these experiments, but that the whole length of wire was in action, and therefore exposed to the same influences from atmospheric currents, induction, or thermo-electric action. There was no alteration whatever made in the wire excepting the *change of position of one of its earth connections*; and consequently the reversing of the direction of the current in the wire, as compared with that of the Willington wire, cannot be attributed to any other cause.

The question naturally presents itself, from whence do these currents arise?

On this subject an important fact was ascertained during the large deflections which occurred in September and October, namely, that spontaneous deflections of precisely the same character as those described in the foregoing part of this paper, were found to take place on the short telegraph from the Electric Telegraph office in the Strand to the Nine Elms Station, the wires of which are *laid underground in tubes throughout their length.*

Taking this fact in connection with those before mentioned, viz. that no deflection is produced in a wire suspended throughout its length in the air, that no deflection is produced with a wire having only *one* earth connection, but that in every case deflections are exhibited in a wire having two earth connections, and that the direction of the current in the wire at any given time is dependent on the relative positions of the earth connections, the most probable explanation appears to be that the currents are terrestrial, of which a portion is conveyed along the wire, and rendered visible by the multiplying action of the coil of the galvanometer.

POSTSCRIPT.

(*Copy.*)

My dear Sir, Derby, May 8, 1848.

It has often occurred to me, that if the deflections were caused by atmospheric electricity, they should occur before and during storms. I have never observed this to have been the case; the needles are seldom moved by lightning, and if they are, it is in spasmodic twitchings, perfectly different to the most rapidly varying deflections; but the bells are generally rung if a storm occur at any point of their circuit: on the other hand, deflections, unless exceedingly powerful, do not ring the bells.

A marked difference is always observed in the effect on the bells, between lightning and deflections, the first causing them to ring only a second, the last for several minutes.

I have twice this winter foretold an aurora; the connection between this phenomenon and the deflections is indisputable.

In the great storm at Leeds, Huddersfield, and the neighbourhood, of a few Sundays since, I had four pair of needles demagnetised at Normanton, one at Skipton, and a discharge between the points of the conductors at Bradford. The wires were disconnected from the instruments for safety, and a discharge took place from the free ends; still the needles were not deflected in the least degree, either before or after the storm, nor at any time when the instruments were in circuit during its continuance.

I had an excellent opportunity at Normanton last Monday of testing the direction of the line of "no-action."

The Manchester and the Derby instruments were each strongly deflected. I opened the circuit on one needle from Manchester to Derby, leaving the other needles on the earth at Normanton as usual. The deflections continued as before on the circuit from Derby to Normanton, and Manchester to Normanton, but disappeared on the Derby to Manchester circuit, these places lying nearly in the line of "no-action," as determined by your experiments.

I find the line from London to Derby but slightly affected, and that from Normanton to Leeds is almost entirely free.

I am, my dear Sir, yours very truly,

(*Signed*) R. S. CULLEY.

W. H. BARLOW, *Esq.*, *Derby*.

Table I.

Mean deflections in each hour exhibited by a galvanometer at Derby, in connection with a wire extending to Rugby, for fourteen days, commencing May 17, 1848. (The means are taken from twelve observations in each hour.)

Rugby Instrument.

Time.	May 17.		May 18.		May 19.		May 20.		May 21.		May 22.		May 23.		Mean.	
	L.	R.	L.	R.	L.	R.	L.	R.	L.	R.	L.	R.	L.	R.	L.	R.
1 A.M.	...	...	...	2·42	3·92	...	...	...	...	2·71	4·12	...	0·14	...	0·61	
2	...	...	6·29	...	5·37	...	...	...	3·87	...	2·21	...	0·50	...	3·65	
3	...	...	...	4·50	5·87	...	...	...	...	1·42	3·87	...	0·71	...	0·91	
4	...	...	...	2·50	...	3·00	...	...	2·00	...	1·17	...	0·40	...	...	0·38
5	...	...	...	1·83	...	1·75	...	...	1·58	...	...	0·83	...	...	...	0·71
6	...	...	...	1·50	0·25	...	...	...	0·92	...	2·83	...	...	...	0·62	
7	...	...	0·45	...	2·25	...	...	...	...	0·21	2·00	...	...	...	1·12	
8	...	...	3·09	...	6·83	...	...	...	0·66	...	3·66	...	...	...	3·56	
9	...	...	5·66	...	2·17	...	...	...	1·87	...	...	0·87	...	...	2·21	
10	...	...	4·16	...	...	3·08	...	1·46	0·33	...	...	3·75	...	...	...	0·76
11	...	...	0·42	...	...	2·50	...	2·00	...	3·09	...	5·33	...	...	...	2·50
12 Noon.	...	...	...	3·17	...	5·08	...	3·25	...	1·62	...	5·08	...	...	...	3·64
1 P.M.	...	...	...	5·17	2·25	...	...	1·79	...	4·71	...	2·42	...	...	...	2·37
2	...	...	...	9·75	...	2·42	...	3·64	0·32	...	...	1·08	...	...	...	3·31
3	...	...	...	7·08	...	0·33	0·66	...	...	2·17	...	1·05	...	...	...	1·99
4	...	9·11	...	9·60	...	0·46	...	4·50	...	2·54	...	1·29	...	...	...	4·58
5	...	7·12	...	6·20	...	...	...	6·25	...	0·62	...	2·12	...	...	...	4·46
6	...	10·82	...	11·33	...	...	2·05	...	...	3·46	...	1·33	...	...	...	4·98
7	3·12	...	...	5·37	...	...	...	10·42	...	4·25	...	1·25	...	...	...	3·63
8	7·83	...	2·33	...	...	...	...	5·58	...	6·12	...	3·08	...	...	...	0·92
9	12·34	...	2·50	...	...	...	6·83	...	...	1·00	...	2·54	...	...	3·62	
10	12·12	...	4·58	...	...	...	...	4·25	...	5·71	...	2·00	...	...	9·5	
11	0·33	...	5·73	...	...	...	4·87	...	0·42	...	...	2·14	...	...	1·84	
12 Midnight.	3·29	...	6·46	...	...	...	6·04	...	4·79	...	...	0·00	...	...	4·12	

Time.	May 24.		May 25.		May 26.		May 27.		May 28.		May 29.		May 30.		Mean.	
	L.	R.	L.	R.	L.	R.	L.	R.	L.	R.	L.	R.	L.	R.	L.	R.
1 A.M.	...	...	0·25	...	0·25	...	...	0·08	...	4·79	...	4·70	...	...	...	1·81
2	...	...	2·40	...	3·37	...	...	0·41	0·66	...	...	1·08	...	...	0·98	
3	...	...	1·50	...	6·41	...	0·29	...	3·04	...	2·41	...	...	...	2·73	
4	...	...	5·62	...	3·54	...	0·95	...	...	0·16	...	2·25	...	...	1·50	
5	...	...	6·87	...	3·41	...	4·16	...	...	2·75	...	2·83	...	...	1·77	
6	...	...	4·08	...	2·79	...	5·79	...	7·58	...	2·12	...	...	...	4·47	
7	...	...	2·62	...	3·45	...	5·58	...	12·41	...	1·20	...	...	...	5·05	
8	...	...	1·04	...	0·91	...	3·83	...	8·16	...	4·41	...	...	...	3·67	
9	...	...	zero.		...	1·08	2·37	...	4·33	...	6·95	...	...	...	2·51	
10	...	...	...	1·29	...	2·29	1·33	...	7·50	...	...	11·08	...	...	...	1·24
11	...	...	...	2·70	...	4·16	...	1·29	...	1·33	...	13·70	...	...	...	4·63
12 Noon.	...	...	...	3·66	...	4·62	...	3·63	...	6·83	...	10·70	...	...	...	5·88
1 P.M.	...	1·62	...	3·79	...	4·37	...	4·75	...	6·54	...	7·70	...	...	...	4·79
2	...	1·29	...	1·68	...	3·45	...	3·87	...	9·0	...	13·56	...	...	...	5·47
3	...	0·62	0·12	...	1·87	...	...	1·62	...	2·00	...	8·70	...	...	...	1·82
4	...	0·58	1·41	...	...	0·45	0·62	...	0·25	...	...	4·58	...	...	...	0·55
5	...	0·50	1·28	...	4·66	...	2·45	...	...	2·37	...	6·95	...	...	...	0·24
6	...	0·37	...	0·16	4·05	...	...	1·22	...	3·50	...	6·93	...	...	...	1·35
7	0·12	...	0·16	...	3·62	...	...	4·95	4·08	...	...	1·00	...	...	0·34	
8	...	0·04	...	0·20	2·54	...	...	4·50	4·41	...	...	0·95	...	...	0·21	
9	...	0·95	...	1·75	1·66	...	5·08	...	4·33	...	...	0·20	...	...	1·36	
10	...	2·37	...	0·29	1·95	...	7·87	...	2·75	...	...	0·70	...	...	1·53	
11	...	0·54	...	0·79	...	0·29	7·91	...	2·58	...	...	2·58	...	...	1·05	
12 Midnight.	...	0·29	3·50	...	0·08	...	1·56	...	1·12	...	...	4·37	...	...	0·26	

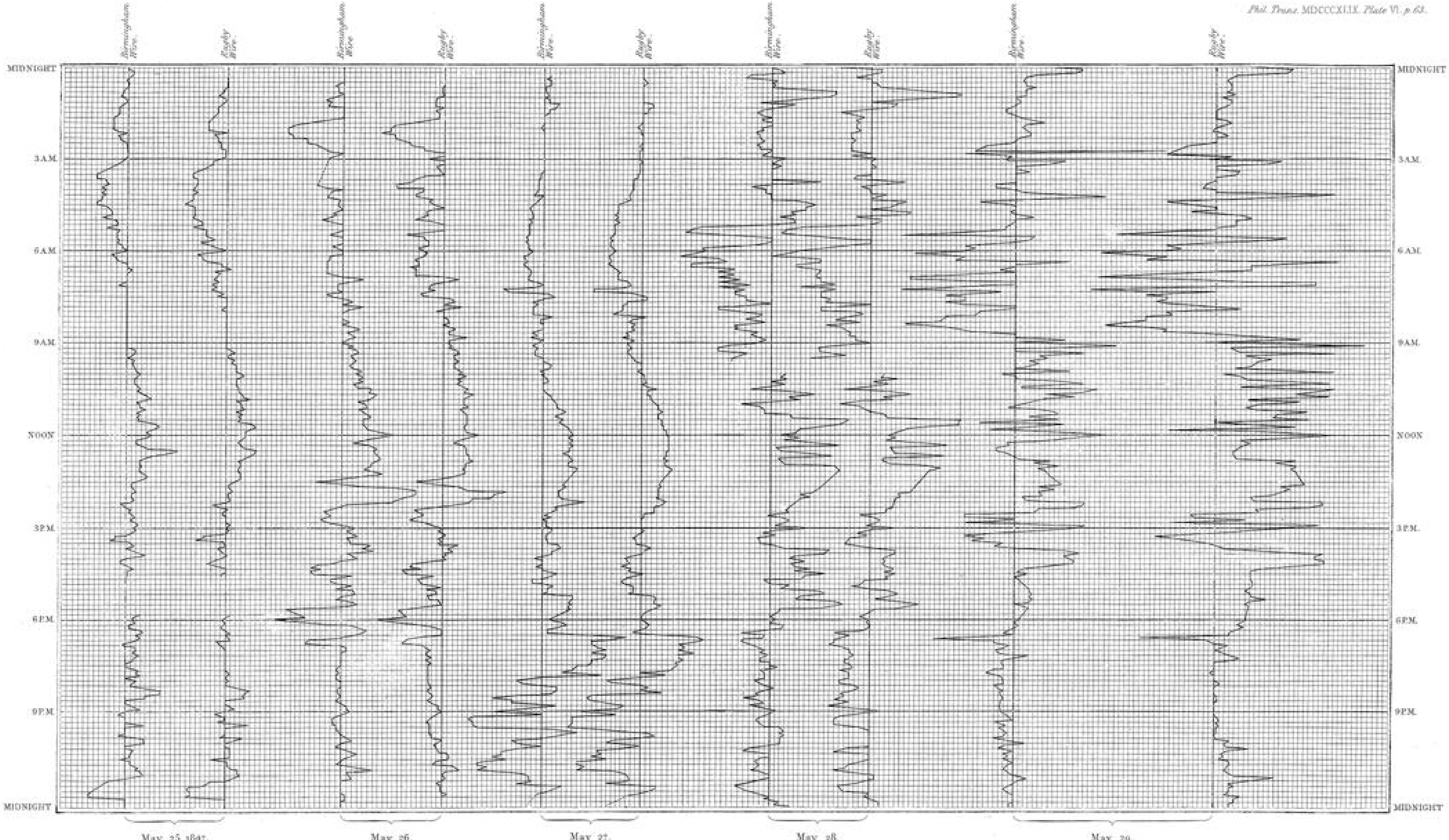
Table II.

Mean deflections in each hour exhibited by a galvanometer at Derby, in connection with a wire extending to Birmingham, for fourteen days, commencing May 17, 1848. (The means are taken from twelve observations in each hour.)

Birmingham Instrument.

Time.	May 17.		May 18.		May 19.		May 20.		May 21.		May 22.		May 23.		Mean.	
	L.	R.	L.	R.	L.	R.	L.	R.	L.	R.	L.	R.	L.	R.	L.	R.
1 A.M.	...	...	...	3·21	2·00	...	15·92	...	...	1·80	13·24	...	4·12	...	5·04	
2	...	...	3·75	...	5·25	...	1·50	...	6·02	...	6·25	...	5·66	...	4·74	
3	...	...	...	11·37	14·50	...	...	5·66	...	0·50	10·75	...	5·16	...	2·15	
4	...	...	...	8·10	...	2·50	0·50	...	3·83	...	6·25	...	4·30	...	0·71	
5	...	...	...	7·04	...	9·25	...	7·10	8·25	...	2·25	...	...	...	...	2·58
6	...	...	...	4·29	...	4·75	5·00	...	1·85	...	8·16	...	...	...	1·19	
7	...	...	0·66	...	4·25	...	5·83	...	...	0·58	7·50	...	...	...	3·53	
8	...	...	10·66	...	15·16	...	8·60	...	3·50	...	12·22	...	...	...	10·03	
9	...	...	9·50	...	4·33	...	1·25	...	8·42	...	0·42	...	...	...	4·78	
10	...	...	3·66	...	...	5·60	0·92	...	6·75	...	...	12·33	...	...	...	1·32
11	...	...	...	4·83	...	4·21	...	5·83	...	11·92	...	18·70	...	...	...	9·10
12 Noon.	...	...	...	15·29	...	16·37	...	11·25	...	6·16	...	16·21	...	...	...	13·06
1 P.M.	...	...	...	15·79	...	6·50	...	7·92	...	18·88	...	10·41	...	...	...	11·90
2	...	...	...	18·92	...	11·80	...	15·21	...	3·66	...	8·10	...	...	...	11·54
3	...	...	...	19·42	...	7·12	...	5·00	...	13·54	...	5·88	...	...	...	10·19
4	...	22·00	...	22·85	...	14·46	...	14·75	...	12·10	...	8·66	...	...	...	15·80
5	...	19·85	...	3·10	...	19·00	...	12·17	...	3·50	...	12·08	...	...	...	11·61
6	...	22·21	...	18·04	...	17·46	0·01	...	...	10·42	...	5·73	...	...	...	12·31
7	2·54	...	...	10·12	...	15·71	...	11·12	...	17·33	...	7·00	...	...	...	9·79
8	13·83	...	1·66	...	...	10·33	...	8·87	...	16·08	...	11·62	...	...	...	5·23
9	20·08	...	2·65	...	...	0·01	12·83	...	...	0·25	...	9·42	...	...	4·31	
10	13·71	...	4·71	...	4·75	...	...	7·00	...	10·16	...	7·83	...	...	...	0·30
11	...	1·83	7·00	...	...	6·50	12·83	...	2·04	...	...	7·42	...	...	1·02	
12 Midnight.	2·16	...	4·10	...	24·42	...	10·30	...	10·83	...	3·04	...	...	...	9·14	

Time.	May 24.		May 25.		May 26.		May 27.		May 28.		May 29.		May 30.		Mean.	
	L.	R.	L.	R.	L.	R.	L.	R.	L.	R.	L.	R.	L.	R.	L.	R.
1 A.M.	...	...	0·20	...	0·54	...	...	0·83	...	3·58	...	3·87	...	...	...	1·50
2	...	...	1·79	...	3·04	...	...	0·75	0·20	...	...	0·83	...	...	0·69	
3	...	...	0·75	...	6·08	...	zero.		1·50	...	...	1·16	...	...	1·43	
4	...	...	4·12	...	0·75	...	0·50	...	...	0·70	...	1·00	...	...	0·73	
5	...	...	4·29	...	1·62	...	1·79	...	...	3·50	...	2·04	...	...	0·43	
6	...	...	1·70	...	0·79	...	2·79	...	6·29	...	4·91	...	...	...	3·29	
7	...	...	0·62	...	1·54	...	3·04	...	10·79	...	6·91	...	...	...	4·58	
8	...	...	0·12	...	...	0·04	1·79	...	5·91	...	8·66	...	...	...	3·28	
9	...	...	zero.		...	1·04	0·75	...	3·58	...	8·25	...	...	...	2·30	
10	...	...	...	1·20	...	2·16	0·37	...	6·64	...	...	5·37	...	...	...	0·34
11	...	...	...	2·46	...	4·37	...	0·79	...	1·54	...	6·87	...	...	...	3·20
12 Noon.	...	...	...	3·79	...	5·08	...	4·18	...	5·83	...	4·50	...	...	...	4·67
1	...	4·66	...	4·33	...	5·62	...	5·33	...	6·04	...	2·41	...	...	...	4·73
2	...	3·71	...	2·16	...	5·33	...	4·62	...	10·00	...	6·00	...	...	...	5·30
3	...	0·87	...	1·02	...	4·58	...	2·41	...	3·35	...	3·95	...	...	...	2·69
4	...	0·37	...	0·25	...	2·54	...	1·25	...	2·45	...	1·25	...	...	...	1·35
5	...	0·10	...	0·28	2·33	...	...	0·25	...	4·83	...	3·54	...	...	...	1·11
6	...	1·04	...	2·00	2·25	...	...	3·86	...	7·35	...	2·50	...	...	...	2·41
7	...	1·04	...	1·62	0·29	...	...	8·29	1·66	...	2·66	...	...	...	...	1·06
8	...	0·83	...	1·37	0·29	...	...	7·16	1·08	...	2·25	...	...	...	...	0·95
9	...	1·71	...	2·70	...	0·08	2·83	...	1·70	...	2·62	...	...	...	0·44	
10	...	3·00	...	0·75	0·37	...	6·04	...	...	0·33	1·83	...	...	...	0·69	
11	...	0·70	...	1·29	...	1·37	7·87	...	1·91	...	1·33	...	...	...	1·29	
12 Midnight.	...	0·45	3·20	...	...	2·91	0·62	...	1·25	...	0·20	...	...	...	0·32	



J. Basire sc.

DIAGRAM No. 1.

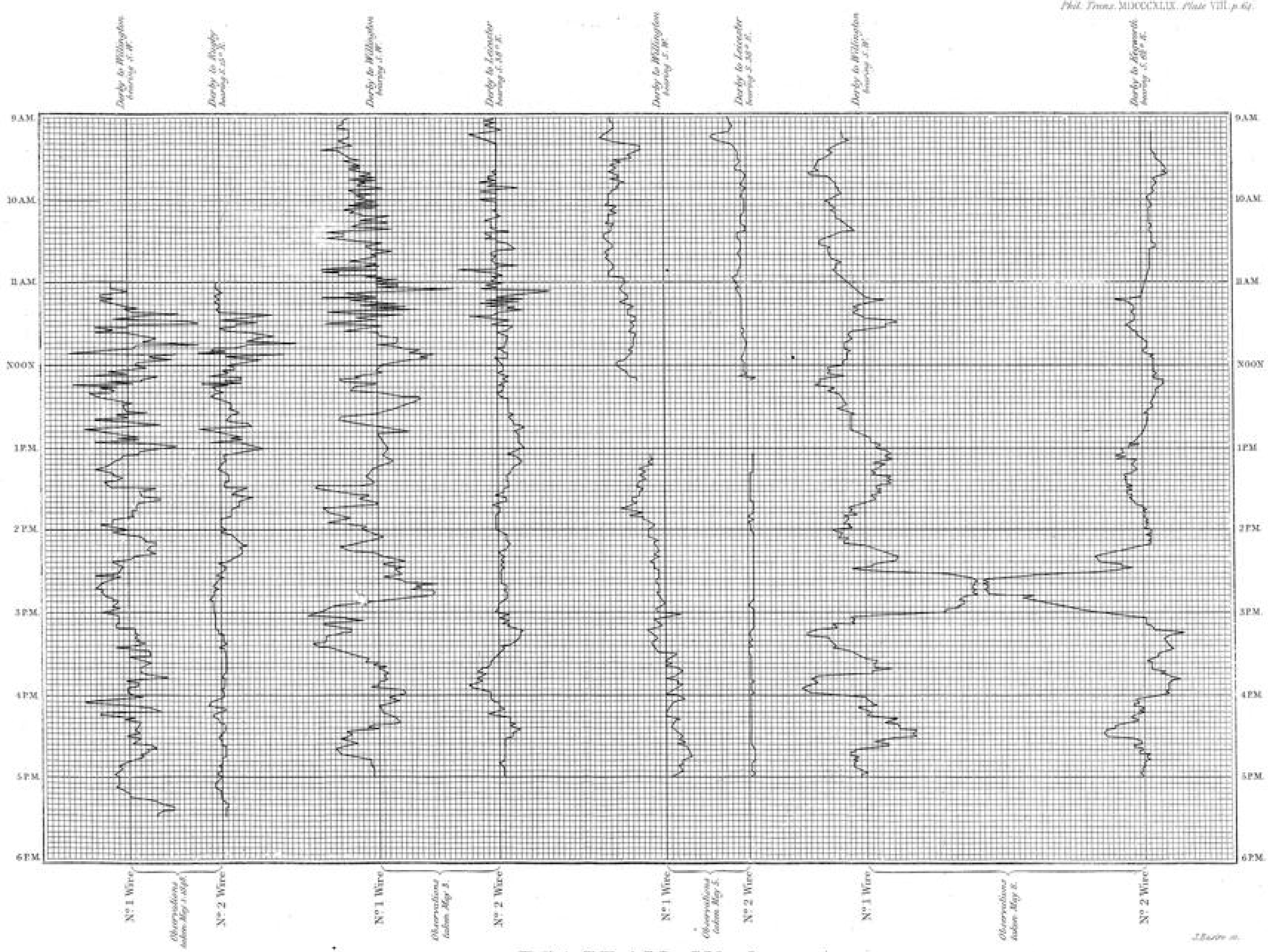

Derby to Willington bearing S. W.
Derby to Rugby bearing S. 25° E.
Derby to Willington bearing S. W.
Derby to Leicester bearing S. 38° E.
Derby to Willington bearing S. W.
Derby to Leicester bearing S. 38° E.
Derby to Willington bearing S. W.
Derby to Kegworth bearing S. 68° E.
9 A.M.
10 A.M.
11 A.M.
NOON
1 P.M.
2 P.M.
3 P.M.
4 P.M.
5 P.M.
6 P.M.
No. 1 Wire
Observations taken May 1 1848.
No. 2 Wire
No. 1 Wire
Observations taken May 3.
No. 2 Wire
No. 1 Wire
Observations taken May 5.
No. 2 Wire
No. 1 Wire
Observations taken May 8.
No. 2 Wire
J. Basire sc.

DIAGRAM No. 3.