

XVI. *Report of a Geometrical Measurement of the Height of the Aurora Borealis above the Earth.* By the Rev. JAMES FARQUHARSON, LL.D. F.R.S., Minister of the Parish of Alford. Communicated by Major SABINE, R.A. F.R.S. &c.

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WHEN, in 1833, I observed the “instructions for observers of the aurora borealis,” circulated by the British Association for the Advancement of Science, I became desirous of aiding in the attainment of the objects the Association have in view; the chief of which are, the determination by geometrical measurement of the height of the meteor above the earth, and of the altitude and azimuth of the point to which the streamers seem to converge, and which has been named the centre of the corona.

The full accomplishment of my purpose has been delayed by impediments, the chief of which will be referred to in the progress of this Report. I have, however, at length obtained such results as I conceive will be deemed of importance, and I beg leave respectfully to present them to the notice of the Royal Society.

I had soon an opportunity for determining, with sufficient accuracy, the altitude and azimuth of the point in the heavens to which the streamers seem to converge; and as this constitutes an important element in enabling us to form a clear conception of the whole definite arrangement and progress of the meteor, and of the extent of reliance to be placed on the method afterwards had recourse to for measuring the height above the earth, and as that distinguished observer, Major SABINE, has since determined the dip of the magnetic needle at this place, which agrees with the angle of altitude of the point of convergence of the streamers, I shall proceed, first, to detail, from my notes made at the time, my observations on this point.

On the 29th December, 1833, during the progress of a hard gale at nearly due west, temperature 42° FAHR., there occurred here an aurora borealis, more nearly than any other I have seen, like the one seen by me here on the 29th of September, 1828, contemporaneously with a luminous arch seen by DAVIES GILBERT, Esq. P.R.S., at Rosemorran in Cornwall, as described by me in a letter to the President, which was honoured with a place in the Philosophical Transactions*. The chief difference of the two consisted in there being, on the 29th of December, 1833, many more arches of great length from east to west, well-defined, and separated, when in the plane of the magnetic dip, by clear lanes, from all the other arches and lights in other parts of the sky.

* Philosophical Transactions, 1829, pp. 103–120.

At 6 P.M. innumerable groups of brilliant streamers, and nebulous patches of light, appeared in almost all parts of the sky, but arranged into narrow arches, with clear lanes between them, near the plane of the magnetic dip. The sky was clear of clouds, with the exception of one cloud of low elevation at south-east. When the meteor was first noticed, there was one narrow distinct arch, almost continuous from the eastern to the western horizon, a little north of, and parallel to, the plane of the magnetic dip. This arch made a rapid progress southward, always preserving its parallelism to the plane of the magnetic dip, and in four or five minutes passed into that plane, where its vertex presented the appearance named by observers a corona, well-defined and brilliant. The appearance of the corona is that of innumerable pencils, or brushes of light radiating in all directions from a centre. In the present instance the pencils pointing northward and southward were short, ending at the edges of the arch, which was only 4° or 5° broad; and those that pointed eastward and westward became blended with the streamers which formed its east and west ends. A small space in the centre of the corona had a nebulous, rather than radiated appearance. This was only about one degree broad, but prevented the determination of the centre, excepting by approximation within half a degree.

At the moment when, in the southward progress of the arch, the centre of the corona became best defined, I had a good resource at hand for determining its place in the heavens, approximately, within such limits as the nebulous central light allowed. This consisted in marking, on an outside stair rail, the precise point from which the centre of the corona was exactly seen, over an extreme projecting point on one of the corners of the Manse here.

The distinct arch of the aurora now described, continued to make a rapid progress southward, preserving always a parallelism with its earlier positions, and with the plane of the magnetic dip. The short streamers to the north of the centre of the corona became more shortened; and those to the south of it became proportionally longer, preserving in this way the vertex of the arch of a mean breadth with that of the other parts of it, till at length the corona lost the whole rays that had a northerly direction. The whole arch, as it went on still further towards the south, became gradually enlarged in its lateral dimensions, that is, in breadth from north to south, as I have described other arches to have done, in the letter to the President of the Royal Society above referred to.

My attention was soon withdrawn from this arch by another now approaching the zenith from the north. This was composed of much more brilliant streamers than the former. It was considerably wider from north to south, and less evenly defined at its north and south edges, appearing there fitfully rugged, but quite distinctly separated from the numerous other lights in the sky by lanes clear of any form of the meteor. Expecting that it too would pass southward, and form a corona, when it reached the position where the other had done so, I provided a long straight-edged ruler, to ascertain by it whether the streamers in all parts of the sky were directed

to the centre of the corona. The arch soon passed southward into the plane of the magnetic dip, narrowing in breadth till it reached that position, and forming when there a corona, exactly like the former one, the centre of which had the same altitude and azimuth. On looking at the centre of the corona over the straight edge of the ruler at one of its ends, while it was held out at arm's length, and at the same time bringing the other end round to all parts of the sky, it was found that everywhere the streamers were directed lengthwise to the centre of the corona.

This latter arch passed southward as the former had done; and like it also, increased its breadth from north to south in its onward progress from the plane of the dip. It was succeeded by many other arches and fragments of arches, that is, arches cut short in their east and west dimension, all of which behaved themselves in a manner analogous to the two first arches, or to corresponding portions of them. About an hour and a half after the aurora was first seen, the phenomena became faint at all points, and the sky soon after became obscured by clouds.

On the day following these observations, I measured, by means of a small graduated semicircle, with plummet, the angle that the line, joining the mark on the stair rail and the projecting point on the corner of the Manse, made with the horizon, and found it about 72° . Major SABINE afterwards, on the 27th and 29th of August, 1836, by 160 readings of his dipping-needle, determined the dip at this place to be then $72^\circ 19'5''$. I also laid down a horizontal line in the azimuth of the two points; and having suspended over it, by means of a silk fibre, a horizontal magnetic needle, found that the needle came to rest parallel to the line.

It has been a matter of more difficulty to arrange the means, and find a fit opportunity, to determine the height above the earth, by the method recommended by the British Association, namely, by instrumental measurements of the angular elevations of an arch, made contemporaneously at two stations on the magnetic meridian, sufficiently distant from each other to give a clear and satisfactory parallax.

With the view of effecting this, I entered into arrangements with a gentleman whose residence is about six miles north of this place, and very near its magnetic meridian. There intervenes the ridge of the Coreen hills, extending in length from east and west about ten miles, in breadth from north to south about four miles, and elevated at many points about 1000 feet above the level of the two stations. After looking out for some years for corresponding observations of the same arch, although there was no want of appearances of the aurora, the gentleman and I found that the observed conditions and circumstances were so discrepant, as to prohibit the inference that we had at any time witnessed the same phenomenon. We had agreed that each should observe to the northward of his own station.

In the mean time I obtained information which I deemed highly valuable for determining the locality of the stations that might be next selected. The Rev. JOHN MINTO, a native of this parish, and schoolmaster of Clatt, which is on the north side

* Major SABINE's Observations on the Direction and Intensity of the Magnetic Force in Scotland, 1836.

of the Coreen hills, had frequent occasion to pass between this place and Clatt. His path over the hills is, at its most elevated part, nearly in the line of the magnetic meridian. He informed me that he had passed in this line several times after dark, on occasions when the aurora borealis was visible. At these times he had travelled in the northerly direction only; but after seeing the whole meteor to the northward of his place, while ascending the south side of the highest part of his path, when he reached the valley on the north side, he then saw the aurora wholly to the south, and at such a low elevation as could not be accounted for by the known movement of the meteor itself, without taking into account its apparent change of place occasioned by his own movement northward. This circumstance occurred to him several times; and he became impressed with the conviction, that the place of the meteor on these occasions was the Coreen hills, and that it was at no great elevation above them. Mr. MINTO's conclusion coincided with those I have had reason to form, from many observations of the meteor, respecting the lowness of the region in which it is visible; and admitting the conclusions to be correct, it became obvious that the two stations, from whence to determine its height, would be both most expediently chosen on one side of the ridge of hills. This choice of stations was therefore had recourse to, and with a completely satisfactory result, as will be afterwards stated.

But previously to presenting the observations that were made at the selected stations, it seems necessary, for a right appreciation of their value, to make some remarks on an obvious misapprehension that yet seems to be entertained of the arrangement and progress of the aurora. I had shown that its arrangement and progress are definite in relation to the lines of magnetism of the earth, in a paper published in the *Edinburgh Philosophical Journal* in April, 1823*, and afterwards in the letter addressed to the President of the Royal Society, and published in the *Philosophical Transactions*, 1829, above referred to. In the latter publication, after describing various appearances of the aurora, I stated that these appearances indicated the following necessary results:—

“1st. That the aurora borealis always presents itself in definite and very curious relations to the lines of magnetism indicated by the needle.

“2nd. That the streamers, in the direction of their length, coincide with the plane of the dip of the needle, or nearly so; and that each individual streamer is, in fact, parallel to the dipping-needle.

“3rd. That they [the streamers] form a thin fringe, stretching often a great way from east to west at right angles to the magnetic meridian.

“4th. That the fringe moves away from the north magnetic pole, by the extinction of streamers at its northern face, and the formation of new ones, contiguous to its southern face.

“5th. That the invariable regularity of its appearance, as seen by many observers, when it comes fully within command of the eye near the zenith, shows the apparent

* Vol. viii. p. 303.

irregularities, when it is seen either more northerly or southerly, to be only optical illusions.

“6th. That the region which it occupies is above, and contiguous to that of the clouds, or that in which they are about to form.”

Some terms employed in the “Instructions” of the British Association, and some also employed by M. ARAGO, in a passage of his printed in the Edinburgh New Philosophical Journal*, show, that these inductions of mine, regarding the arrangement and progress of the meteor, have been misunderstood or not admitted as accurate. In the “Instructions” it is said, “the determination of elevation can scarcely be applied to streamers of aurora, except when some sudden incurvation, or change, occurs which may happen to be noticed at two stations; but the arches are of a less evanescent nature.” This obviously implies that the streamers and the arches are two distinct and unconnected branches of the phenomena. The terms of M. ARAGO imply the same thing. He says, “when in our climates the aurora borealis is complete, when one part of its light pictures on space a well-defined arch, the culminating point of *this arch* is in the magnetic meridian; and its two points of apparent intersection with the horizon are at equal angular distances from the same meridian. When it projects luminous columns, [by which he evidently means streamers,] from different portions of the arch, their point of intersection, called by certain meteorologists the centre of the cupola, is found in the magnetic meridian, and precisely upon the prolongation of the dipping needle.” Here too the arches and the streamers are considered as distinct objects. But an *arch* of the aurora is composed of a number of *streamers* grouped and aggregated together within a defined stereometric space, whose bounding planes bear certain relations to the lines of magnetism of the earth. It is this fact that I announced in the Edinburgh Philosophical Journal in 1823, and afterwards in the letter to the President of the Royal Society; and if the arrangement is not yet understood, it may have been owing to a misapprehension of the terminology I employed; or, more probably, to my not having, in the letter to the President, entered into a detail of the varieties of the arches that often present themselves, as I had done in the Edinburgh Journal. I would endeavour now to supply the deficiency, by defining the terms, and entering into some more detail of the varieties, or rather apparent varieties of the arches; for the numerous observations of the aurora I have since made, convince me more fully of the existence of that definite order of its arrangement and progress which I have formerly described, and that it is worthy of being understood, however much I may have hitherto failed clearly to explain it.

The terms *arch* and *streamer* of the aurora, I had used without defining them, because I conceived them to be in common use among observers; and I shall now perhaps be able best to define them, after presenting anew one part of the description of the whole meteor, which I had given in the Edinburgh Philosophical Journal

* Vol. xxv. p. 419. I regret that I cannot more particularly indicate M. ARAGO's publication, having seen the passage only in the Magazine.

in 1823, which is as follows. "In this latitude, (about $57^{\circ} 12' N.$) the aurora borealis, on those evenings when it is visible, *generally* first shows itself, after dark, like a bright but circumscribed twilight on the visible horizon, the centre of which is exactly on the northern point of the magnetic meridian. So long as the bright space continues low, its light often nearly resembles the pale blue white light of the real twilight; but varies momentarily by incessant and undefined fits of gleaming and obscuration. By degrees the meteor enlarges itself, rising higher, and extending more from east to west on the horizon. The play of the fitful gleaming light becomes gradually better defined; and the whole luminous space presents the appearance of pencils, or bundles, of rays pointing upwards, and, when viewed in narrow compartments, maintaining a parallelism among themselves, similar to that exhibited by the rays of the sun when he shines through broken clouds athwart a hazy atmosphere. The rays which are on the magnetic meridian are parallel to that line, pointing exactly to the zenith; and those which are considerably to the eastward or westward of that meridian are directed to a point which appears within the limits of 10° [18°] to the southward of the zenith. The bluish white light changes into a beautiful pale green, which when the meteor rises quite above the horizon, as will be afterwards described, becomes tinged at the lower extremity of the rays with blue and violet, and at their upper extremity with yellow and orange. The rays are very various in their intensity of light, as compared with one another; their higher and lower portions also frequently differ from each other in that respect; and the whole appearance of each ray varies incessantly. It now breaks off, and disappears for a considerable space at its higher or lower extremity, and then immediately becomes again luminous to its former extent; now seemingly runs from east to west or from west to east through 5° or 10° or 12° , during the space of a second or two, preserving correctly its parallelism with other rays, which it approaches or passes in its progress; then remains stationary for a second or two, undergoing various changes of vividness; and afterwards disappears instantaneously, to have its place supplied by another ray, created as rapidly as its predecessor was annihilated. This magnificent and beautiful light gradually extends itself towards the south, and at length separates itself from the northern horizon at the point of the magnetic meridian, and forms a flat luminous arch in the northern part of the heavens. The arch still goes on to make progress towards the south, its convex or upper part approaching the zenith, and its concave or lower side becoming more widely separated from the horizon. When it reaches an elevation of about 45° , it presents the appearance of a broad [curved] zone, occupying from north to south the space of from 25° to 35° at its vertex, and having its eastern and western extremities resting on the visible horizon."

In this passage, both the streamers and the arch of the aurora are described. The streamers are the narrow pencils, or bundles, of rays whose upper extremities are directed to that point in the heavens which forms the upper prolongation of the line of the dipping needle. They are severally in a state of incessant extinction and reno-

vation. An arch is the curved zone of light formed by an aggregation or grouping of a great number of streamers into a definite form. Although composed entirely of parts (streamers) which are severally evanescent, yet the perpetual renewal of these within a definite space, or in a definite direction in relation to the place of the extinct ones, renders the arch relatively permanent; and it often continues for several hours, shifting however gradually towards the south.

In continuation of the above passage taken from the *Edinburgh Philosophical Journal*, I had described the further progress of such an arch as that mentioned in it, and shown, that it passes at length into the plane of the magnetic dip, gradually contracting its breadth, from north to south, as it nearly approaches that plane, the streamers of which it is composed still pointing, in every part of it, to the point which is on the prolongation of the dipping needle; and that, when it at last reaches the plane of the magnetic dip, it forms a narrow zone, seldom exceeding 4° or 5° from north to south, stretching across the heavens at right angles to the magnetic meridian, and composed now, in its east and west ends, of streamers which no longer cross its breadth, as they did while it was in a more northerly position, but are parallel to the zone itself, and therefore pointing east and west. In that journal, I had added to the description of the arrangement and progress of the longer and more complete arches that present themselves, a description of some of the varieties, or shorter arches, which at various times occur, either by themselves, or mingled up with the longer arches. I shall quote from the *Edinburgh Philosophical Journal* the account I had given of these varieties, because, in the letter to the President of the Royal Society, I neglected to describe them along with the more lengthened arches; and the neglect may have occasioned misapprehension of the whole subject on the part of those who have seen only the letter to the President.

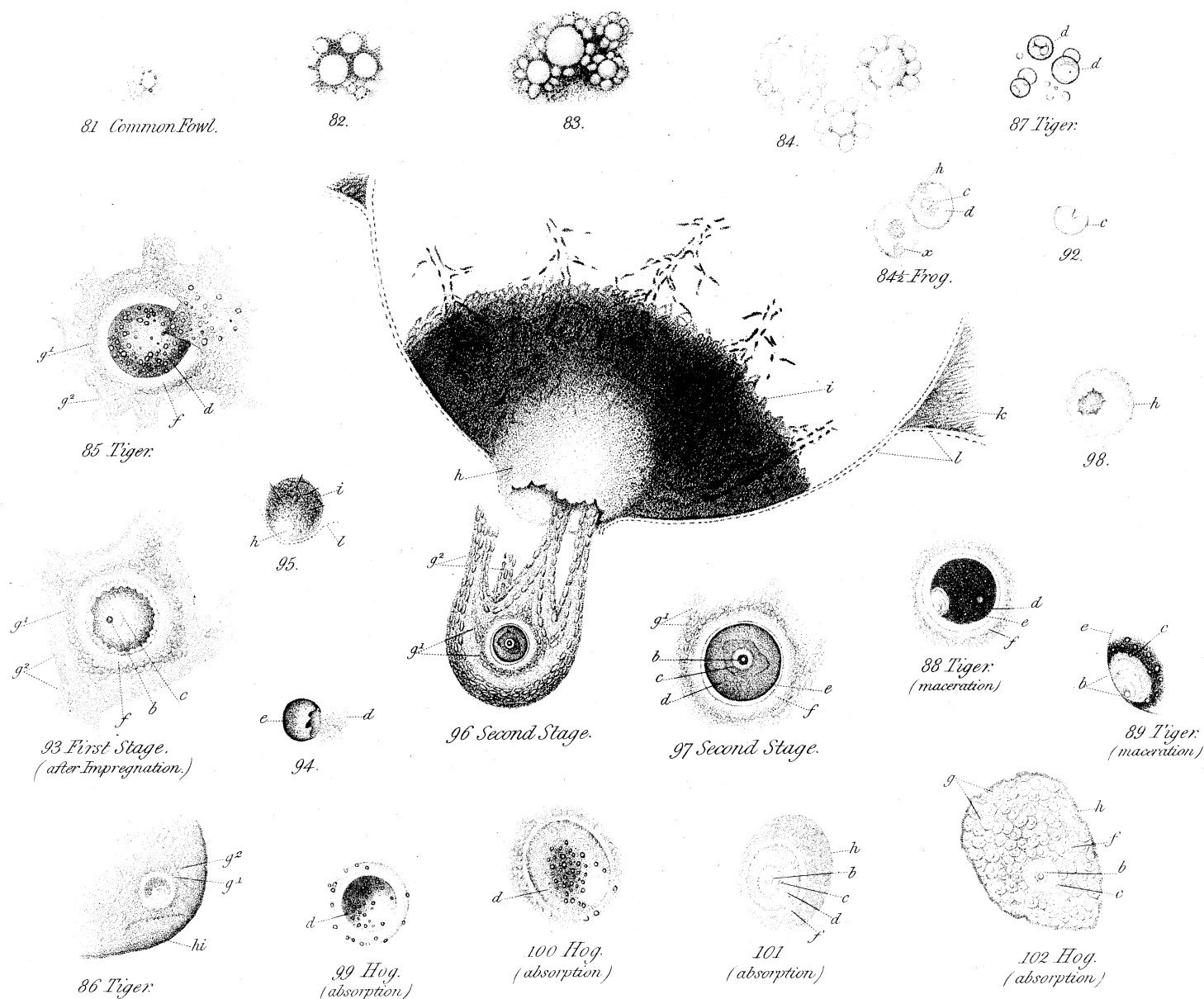
In the *Edinburgh Journal*, after a description of the more lengthened arch, and its progress, it is added, "such is the order of appearances presented by the aurora borealis, when it is observed under the most favourable circumstances. It is very seldom, however, that all the successive phenomena, now described, have been observed continuously on the same evening; but those observed at any one particular time have always been entirely consistent with the above description; and I shall now enter a little into a detail of the varieties which present themselves. It very frequently happens, that the twilight-like appearance on the northern horizon is all that is visible, and the phenomenon begins and ends with that. In this case the meteor is seldom of long continuance; but during the time that it lasts, the luminous space gradually enlarges itself towards the south. It then gradually disappears; frequently to be succeeded by another, appearing low on the horizon, to enlarge, and afterwards disappear, as its predecessor had done. It happens also, very frequently, that, even when it makes more progress towards the south, it becomes gradually extinct long before it reaches the zenith; for it is liable to a total extinction in every stage of its advancement; but while it does continue, it follows the order above described, presenting the longest

pencils of rays when about 45° elevation, and more dense, compact and shorter ones near the zenith. It also very frequently happens that the meteor is suddenly formed high above the horizon, at first by feeble detached rays, becoming quickly more condensed and luminous. But in whatever stage it first begins, the succeeding relative progress is the same as above described. It was chiefly those meteors, which were first formed above the horizon, that were observed to pass over the zenith. Those formed further northward generally disappeared before reaching that point. There is another modification of these appearances, and that is, when the meteor is entirely to the eastward or westward of the magnetic meridian; and this is of not unfrequent occurrence. In this case, the appearance and progress of the whole exactly agree with those of corresponding portions of the above described zone, which is formed when the meteor extends across the magnetic meridian. The extremity of the luminous space which is nearest the magnetic meridian becomes first elevated above the horizon; the pencils of rays are directed, longitudinally, to a point a little south of the zenith; and the meteor moves gradually towards the south, contracting gradually its lateral dimensions as it reaches the prime vertical to the magnetic meridian, where it assumes the appearance of a nearly vertical column of brilliant light, 3° or 4° in diameter, composed of pencils of rays parallel to itself. After passing some degrees to the southward of the prime vertical, the meteor begins to enlarge gradually in width, in an order the reverse of that in which it had become narrowed. Some other apparent irregularities have been at times observed. Thus the pencils of rays have sometimes been seen separated into detached groups; but each group consistent in its appearance and position with those of the other groups, so that, had the spaces between them been filled up, a complete zone, such as above described, would have been formed. A detachment into distinct groups sometimes takes place immediately previous to the disappearance of the meteor; but sometimes also it is not immediately followed by that disappearance, but the zone becomes again complete, or nearly so, at a further stage of the progress southward. But no [real] anomalies have been at any time observed; nothing that is inconsistent with the described order of the phenomena*."

In addition to this detail of the varieties taken from a former description, it seems necessary here to add, that although the most frequent appearance of the meteor consists of one, or a few regular zones behind each other in a north and south direction, of great length from east to west, yet sometimes, as on the evenings of the 29th September 1828, and 29th December 1833, the lengthened zones are accompanied with

* Major SABINE, while here in 1836, and observing the range of the Coreen hills, northward of this place, to run exactly at right angles to the magnetic meridian, suggested that the great regularity of the appearance and progress of the aurora here might be dependent on that circumstance. The suggestion is highly worthy of attention. The natural tendency of the meteor to the described order may be aided by the position of the hills; and hence a peculiar regularity here; but that the tendency is not altogether dependent on the locality, is proved by the crown of a lengthened arch being, in all places in Britain, on the magnetic meridian, and by the narrowness of the zone of light in the plane of the dip, as witnessed and reported by many observers.

Embryology.



(Where the name of the animal is not given the Figure is from the Rabbit.)

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|---|--|
| b. Germinal Spot | g ² Retinacula |
| c. Germinal Vesicle | h. Ovisac |
| d. Yolk.—Yolk-globules (vesicles) | i. Proper covering of the Ovisac—Corpus luteum |
| e. Membrane originally investing the Yolk—Yolk-ball | hi. Graafian vesicle |
| f. Thick transparent membrane of the ovarian Ovum—“Zona pellucida.” | k. Stroma |
| g. Peculiar Granules (vesicles) of the Ovisac | l. Peritoneum |
| g ¹ Tunica granulosa | x. Nucleus |

all the described varieties, placed in the intervals between them. The whole hemisphere is, in such instances, pervaded by the meteor; and, on looking northward or southward, no regularity in the arrangement can be readily distinguished. But on looking up in the plane of the magnetic dip, the described order is there immediately discovered. The meteor there presents the appearance of intermingled longer or shorter narrow belts of fitful light, at right angles to the magnetic meridian, or columns at the east or west, having all clear intervals between them, and all making progress towards the south, preserving at the same time their parallelism with each other. It seems also necessary to add, that the light of the several belts differs greatly in intensity; some being composed of closely crowded and very brilliant streamers, and others of a few feebly-lighted, ill-defined ones.

It is now apparent, from the description, that the streamers are not phenomena distinct from the arches, but that the latter are just aggregations of the former within certain stereometric spaces, whose bounding planes bear definite relations to the lines of magnetism of the earth. In the letter to the President of the Royal Society I named these aggregations fringes; and, in fact, they resemble long fringes composed of threads, the threads being represented by the individual, nearly vertical streamers, or lengthened narrow straight pencils of rays of light. The length of these filled stereometric spaces, at right angles to the magnetic meridian, is often very many miles, extending over head, when they come to the zenith, from the east to the west horizon, although they are frequently cut short in this dimension. Their depth in a nearly vertical direction, or more properly in the plane of the magnetic dip, is determined by the length of the individual streamers that fill them. This length of the streamers seems to vary considerably; as some of the arches at about 45° elevation may be seen about 20° broad from north to south, and others 30° and upwards. The streamers in the same space, too, are not equal in length among themselves, their inequality in this respect causing the jagged appearance of the north and south edges of the arches; but in this respect also there are great differences, the edges of some arches, especially on very calm evenings, being even and regularly defined. The thickness of the filled spaces from north to south appears to be always much less than their depth in the plane of the magnetic dip. This thickness from north to south is clearly seen when the meteor comes into that plane, in its progress southward. When there, an arch that at 45° elevation may have been 20° or 30° broad from north to south, generally appears no broader than 4° or 5° , or even than 2° or 3° in some cases*. It is the regular southward progress of the meteor that gives opportunity for the determination of the depth and thickness of the spaces filled with streamers. When the meteor is considerably to the north, its depth is more or less directly seen; when in the plane of the dip, its thickness from north to south is seen; and when in that station, also,

* For a long time, I had not observed zones, in the plane of the dip, broader than about the measures here stated; but in later years I have witnessed some very considerably broader. These are, however, not of frequent occurrence, and present a like arrangement and progress with the narrower zones.

its progress southwards is seen to be occasioned by the extinction of streamers at its northern face, and the formation of new ones at the southern face ; and when it proceeds further south than the plane of the dip, its depth comes again more or less directly into view. It is obvious that the stereometric spaces thus filled with streamers, when of considerable length from east to west, necessarily present to the eye the appearance of arches of light ; but the peculiar direction of the streamers gives to the arch, when in the plane of the dip, a very different aspect from what it has in a more northerly or southerly position. I have so frequently seen the northerly arch pass into the plane of the magnetic dip, and assume there a very different appearance, as to leave no room for the suggestion in the "Instructions" of the British Association, that the arches in the two positions may be of different origin.

We are now prepared to make some observations on M. ARAGO's reference to "luminous columns projected from different points of the arch." Such an appearance is often seen, that is, luminous columns *seeming* to spring out of a lower and regular arch ; but it is only seeming ; for the columns belong to another arch composed of fewer streamers, more near the place of the observer, and therefore seen at a higher angle of elevation. This is discovered when both the appearances come southward towards the plane of the magnetic dip. Then the columns are seen to be advanced southward of the arch ; and there is observed an interval, frequently a wide one, clear of lights, between the two appearances. The space occupied by the *columns* (*streamers*) may become more densely crowded with additional streamers in its onward progress, in which case it will become a well-defined arch, before it reach the plane of the dip ; or the streamers may not increase in number, yet, when it gets into that plane, it will be seen as one of those feebly lighted belts composed of few streamers which I have recently described. I have so frequently seen one or other of these results, in the case of columns *seeming* to project from a lower arch, as to leave no doubt that the appearance was an optical illusion, and that the columns were much nearer the eye than the arch.

I trust it will be admitted, that we are now able to decide, under what conditions of its appearance, we shall effect a satisfactory geometrical measurement of the height of the aurora above the earth. No measurement of this kind, it is obvious, can be obtained, as M. ARAGO justly observes in the passage I have referred to, by taking elevations of the centre of the cupola, or corona, when the meteor is in the plane of the magnetic dip. When the meteor is there, each observer sees a centre peculiar to his own station, and which is in the line of the upper prolongation of the dipping needle ; just as in a row of persons placed under the key-stones of a bridge of masonry, each one sees a joint of the masonry vertical to himself, and different from the joints over the others. But, as in the case of the bridge, when we remove ourselves quite from beneath it, and to some distance from it, we can then easily determine the height of either the upper or lower parts of the key-stones, by means of a combination of parallaxes, so we may in like manner measure the height of an arch, or

fringe, of aurora, which is placed considerably to the northward or southward of the stations we may select for determining the elevations.

But in the case of the aurora there are serious impediments to the process, in the generally fitful unsteadiness of the object, and equally fitful irregularity of its edges. To avoid the latter inconvenience, the British Association direct the angles of elevation to be taken at the lower edge of the arch (which, it is said, is always best defined) at its summit. I have not observed this edge better defined than the other, excepting on the occurrence of a dark mass under the luminous space, which sometimes takes place, as stated in the instructions. On such occasions, however, the lower edge of the luminous space is always comparatively low, and therefore no clear parallax could be obtained from two stations, unless they were very remote from each other. Besides, the dark mass and defined lower edge are of rare occurrence here, not having been seen for several years.

I have observed already, that in very calm weather the upper edge of the arches is sometimes well-defined; and as that edge, generally, in the arch which first appears here in the evening, is clear from interference with subsequent arches, which for the most part appear only under it, I made preparation for taking elevations of such an arch from two stations, by obtaining the favour of the Rev. HUGH M'CONNACH, the schoolmaster of this parish, to make the observations at one of the stations.

The stations were chosen with reference to the aurora being probably immediately over the Coreen hills, as indicated by Mr. MINTO's observations. The Manse here answers, in this view, for one station, being by measurement 15,700 and 12,500 feet distant from the two nearest elevated summits of the hills respectively; the nearest of the two being almost on its magnetic meridian. The other station could not be placed at a sufficient distance on the north side of the Manse for the river Don intervening. It was therefore placed at Hillhead of Kingsford, on the magnetic meridian of the Manse, and 6810 feet distant from it towards the south. A further extension of the base line in this direction was prevented by a rapid descent of ground, a little beyond the south station, which would have placed the observer out of sight of the Coreen hills. Besides, it was considered inexpedient to have the stations more remote from each other, as it seemed very desirable for the observers to meet before commencing their operations, that they might, on trial, discover how nearly they would agree in taking the elevation of the vertex of the arch of the aurora, an object, in the most favourable case that they could anticipate, somewhat undefined.

After having looked out a considerable time for a proper display of the meteor, and allowed many to pass which had not the requisite conditions, at length, on the 20th of December, 1838, a little after 6 P.M., a very low complete arch, having a well-defined and regular upper edge, presented itself over the Coreen hills. There was a dead calm at the time, with a clear sky; thermometer 39° FAHR. The arch rose slowly upwards, becoming more bright, and promising to be of some continuance. Mr. M'CONNACH and I met soon after its appearance; and on repeated trials with two

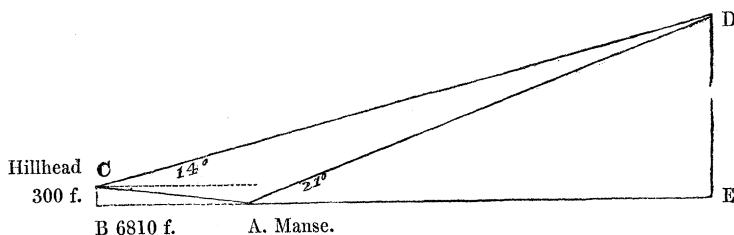
small quadrants with plummets, attached to poles for fixing in the ground, found we agreed in determining the angle of elevation of the vertex of the upper edge of the arch within the limits of half a degree. We then adjusted our watches to the same time; and Mr. M'CONNACH went with an assistant to Hillhead of Kingsford, to take elevations at every five minutes by the watch, while I remained at the Manse, to take elevations contemporaneously with his, and notice and describe the appearances of the aurora.

It may be best to give a brief account of the successive appearances of the arch, and of those of the contemporaneous phenomena, before presenting the measures of its elevations. When first seen, its lower edge was not yet above the northern hills; but at half-past six o'clock it was quite clear of the horizon at its vertex, and at that point was about 9° broad. The light at this time was nebulous, and equally clear in all its parts, with no certain display of streamers. The upper edge vanished off from the brightest light within the limits of rather less than a degree. At the lower edge the vanishing off was considerably broader. At 6^h 35^m P.M. a brilliant display of streamers suddenly appeared over Callievar, a detached mountain three miles due west of the Manse, somewhat higher than any part of the Coreen hills; and over that mountain a solitary dense cloud was formed, two or three minutes after the appearance of the streamers there. These phenomena were quite disjoined from the arch, which in the mean time rose gradually higher above the horizon, and in place of the nebulous light began to exhibit, especially near the vertex, streamers or pencils of rays pointing upwards. These were not very brilliant, but quite defined. At 6^h 40^m, a few detached very brilliant streamers, whose lower ends were concealed by the hills, appeared under the arch a little to the eastward of its vertex. These seemed to flit with great velocity from west to east, and from east to west, and appeared and disappeared in quick succession for about the space of five minutes. Their upper ends passed the lower edge of the arch, but never extended so high as the upper edge. When they disappeared the lower edge presented the same regularity and gradual vanishing off of the light as before their appearance. At 7^h P.M. the play of streamers across the arch had become somewhat more brilliant; and its edges remained equally even and well-defined as at the earlier periods, the upper one still maintaining its superiority over the lower in that respect. The arch was at this time about 12° broad; and a few very small clouds appeared in its west end, concealing the light at their places, but the edges were clear. At 7^h 5^m, although the clouds had increased in number, they formed no impediment to the determination of the elevations; but by 7^h 10^m the whole sky had become too much obscured to admit of longer continued contemporaneous observations. At 7^h 25^m an opening in the clouds permitted the vertex of the arch to be seen, at the Manse, when it was observed to be still regular in its edges, and to have become of higher elevation.

Observed Angular Elevations of the vertex at the upper edge of an arch of aurora borealis, by the Rev. JAMES FARQUHARSON, at Manse of Alford, and contemporaneously by the Rev. HUGH M'CONNACH, at Hillhead of Kingsford, on the same magnetic meridian with Manse of Alford, distant from it in a southerly direction 6810 feet, and about 300 feet higher in level.

	At Manse of Alford.	At Hillhead of Kingsford.
	Angle of elevation.	Angle of elevation.
At 6 ^h 45 ^m P.M.	16°	
6 50	17½	
6 55	19	
*7 0	21	14°
7 5	22	15
7 10	arch obscured by clouds at both stations.	
7 25	28°	seen only at Manse of Alford.

In making out the calculations of the height from these data, it is obvious that we may disregard the corrections for the rotundity of the earth, the difference of refraction at the two stations, and the difference of the horizontal and inclined distances of the stations, as they are all within the limits of the effect of the probable errors in observing a somewhat undefined object like the edge of the arch. But there is a considerable correction to be made in the angle observed at the Hillhead of Kingsford station, arising from its height above the level of Manse of Alford. Several years ago I had occasion to determine this, and found it about 300 feet by the barometer. This correction and the mode of calculation will become evident by means of the following diagram, which represents the first contemporaneous observations at seven o'clock.



Calculating from these data, we have the height $D E = 5693$ feet.

Thus the height of the upper edge of the aurora was 5693 feet above the level of the Manse of Alford. The vertex of the arch is found from these observations to have been 14831 feet northward of the same place, that is, over the nearest summits of the Coreen hills, two of which, it has been stated, are respectively 12500 and 15700 feet distant in the same direction. The most continuously elevated ridge of the same hills is about two miles farther north, and it was probably over it that the arch had its commencement.

At the time of the contemporaneous observations, whose results are given, the

* Mr. M'CONNACH did not reach Hillhead of Kingsford to get observations before seven o'clock.

arch was 12° broad. This gives by calculation 3212 feet for the vertical extension of the fringe of streamers, and leaves 2481 feet for the height of the lower edge above the level of Alford. The tops of the Coreen hills are about 1000 feet higher than that level; and thus the lower edge of the arch, whose elevation was measured, was only about 1500 feet above these hills at their highest points.

The result of this measurement agrees sufficiently with that of incidentally contemporaneous observations made by the Rev. JAMES PAULL of Tullynessle and me, on the 20th of December, 1829, as reported by me in a communication to the Royal Society, honoured with a place in the Philosophical Transactions of 1830*, and by which it appeared the aurora of that evening was within the limits of 4000 feet above the earth. These observations, although not made with instruments, were too decisive in all their conditions of the length of base line, clearness of parallax, and certainty that we had both seen the same phenomenon, to admit of doubt of the very limited elevation above the earth. The result agrees also with the ingenious observation of Mr. MINTO, and with that which might have been considered decisive of the question, namely, the observation of Captain PARRY and Lieutenants SHERER and Ross, on the 27th of January, 1825, of the light of the aurora coming between them and a neighbouring height.

JAMES FARQUHARSON.

Alford, May 13, 1839.

P.S. I delayed making this Report, in expectation of finding other opportunities of making similar measurements, with the view of determining the variations of height to which the aurora is liable. My former communications upon the subject went to show that the height is dependent on that of the clouds, an inference which it will be observed is strengthened by some things contained in this Report. There have been many displays of aurora since the 20th of December last, but none that I have seen having the necessary conditions for obtaining a just measurement of the height; and as the ordinary season of its appearance is now over, I do not longer withhold the Report.

* pp. 104, 105, 106.