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THE AURORA OF JANUARY 25 to 26, 1938 AND ASSOCIATED MAGNETIC STORM

BY

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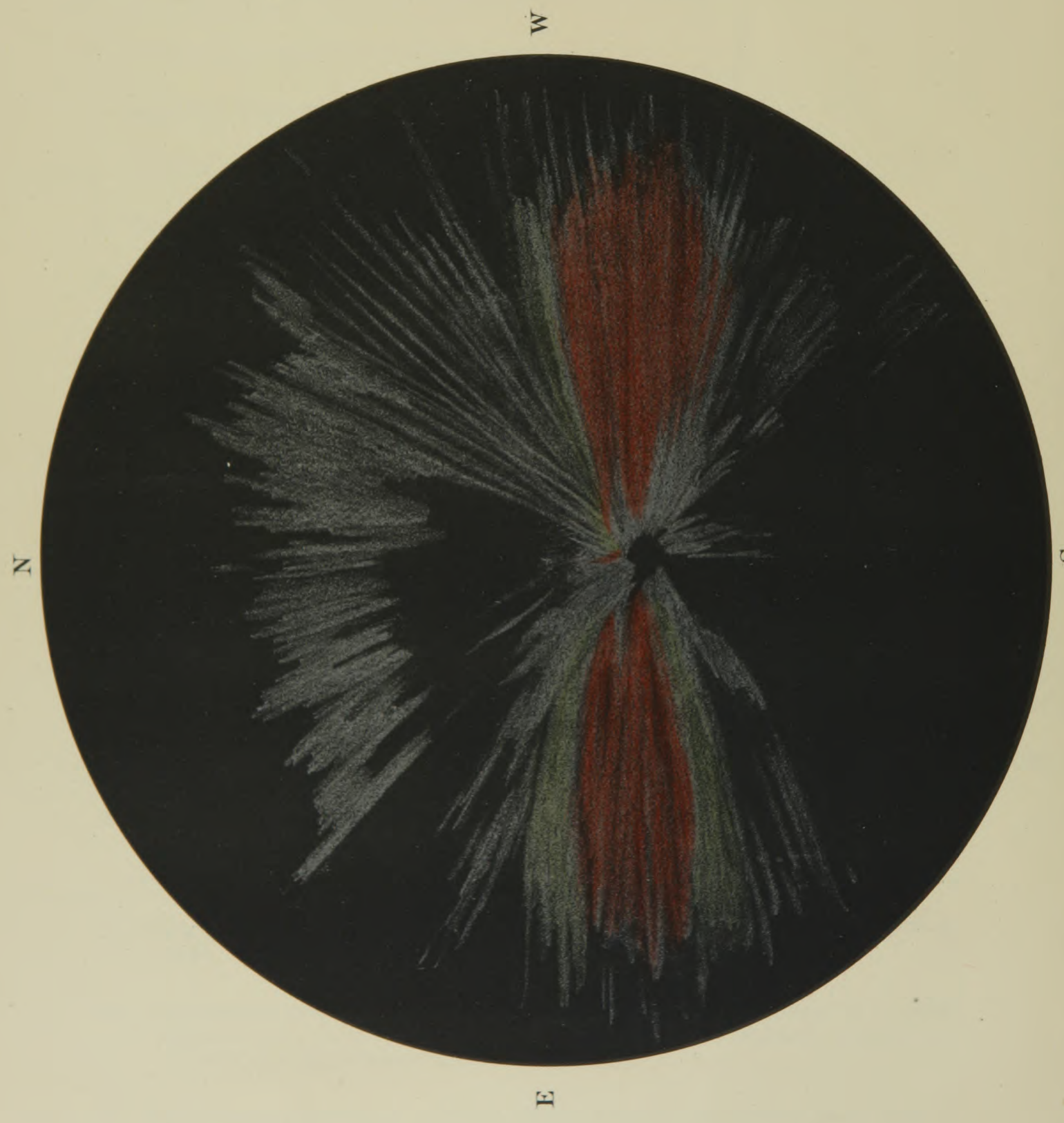

FIG. I.– DRAWING OF AURORA MADE BY Mr L. L. ALEXANDER AT ABBOTSINCH.

THE AURORA OF JANUARY 25 to 26, 1938 AND ASSOCIATED MAGNETIC STORM

PREFATORY NOTE

This memoir was written shortly after the occurrence with which it deals, and was ready for publication in 1939. Recent researches could have occasioned the amplification of some sections, but, since the memoir is primarily descriptive, it has been considered preferable to publish only what was in print when war intervened.

§ 1—INTRODUCTION

On the night of January 25–6, 1938, a display of aurora borealis occurred which was visible over a very large area, including most of western Europe and extending as far south as Madeira. The aurora was seen in America, and aurora australis was also seen. Skies were practically cloudless until about midnight over most of the British Isles, and arising out of a special mention of the occurrence in the "News Bulletin" issued by the British Broadcasting Corporation at 21h. the display after that hour was seen by an unusually large number of people. Although it was the most brilliant aurora seen in the British Isles for many years it was probably no more remarkable than that of November 15, 1905 or those which occurred in 1882.

Distinctive Features—The outstanding features of the display were the variety of auroral types observed, and the predominance of red in the colours present. Homogeneous arcs, rayed bands, diffuse surfaces, coronæ and flaming aurora were all noted, several appearing simultaneously at times. The predominance of red accounted for the newspaper descriptions of "flaming aurora", but in technical language the term "flaming" implies only resemblance in to sheets of flickering flame and may be applied to displays of any auroral colour. Red colouration is not common in the north, but has appeared in most of the prominent displays which extended unusually far south. This is due to a feature commented on by the British Polar Year Expedition of 1932–3 to Fort Rae, Canada[1],* that auroræ are red most frequently during the most active displays and when associated with the most severe magnetic disturbances; it is only these rather intense displays that are visible at comparatively low latitudes. "A bright reddish colour" was also reported from Newfoundland where, as in Europe, the aurora extended far south and its brilliancy "practically turned night into day"[2].

The most remarkable auroral type, the corona, was seen frequently in Scotland and northern England where it persisted for long periods, but it appeared only momentarily and on isolated occasions further south. A corona consists of a large number of rays along the lines of magnetic force. Perspective causes them to appear to converge to a point which is usually the magnetic zenith (in Great Britain about 10° from the geographical zenith and at an azimuth of 165° from north). Most of the coronæ seen on January 25 were in such a position, but, according to an observation at Cranwell, the point of convergence appeared to veer from 154° azimuth at 19h. 35m. to 165° at 20h. 45m. and to west of south at 1h. 30m. on the 26th.

The daily press devoted many columns to the description of the display and statements from eminent scientists and others.

* The index numbers refer to the bibliography on p. 16

§ 2—SUMMARY OF THE VISUAL OBSERVATIONS OF THE AURORA

Over fifty descriptions of the aurora have been received from observers in all parts of the British Isles; the experience of the observers and their methods of observing differed greatly. The following account is an attempt to summarise the principal features.

The earliest appearance of the aurora noted was, appropriately enough, from the magnetic and auroral observatory at **Lerwick,** where a green band of rays flashing upwards through a glow to the zenith was reported at 17h. 30m. by Mr. O. M. Ashford. The colour changed to red, and soon there were both red and green bundles of rays present with patches of similarly coloured light appearing at intervals in different parts of the sky. The corona was first seen at 18h. 35m., and the most striking formations were at 19h. 49m., when the corona appeared to rotate anti-clockwise, and at 20h., when the northern rays were green and the southern rays red. Observations at Lerwick were interrupted at times by cloud (and hail showers), but from about 19h. to 21h. most of the activity was in the southern sky, only isolated faint rays and glow appearing to the north. This at once showed the unusually southern position of the aurora.

The mainland observations show that from 18h. to 19h. 30m. green and red arcs over Scotland and northern England were the chief features. Rays developed at times, and the arcs showed pulsations both from west to east and from east to west. The most brilliant period of the whole display in east Scotland was at 19h. when a multi-coloured corona was the outstanding feature. At **Montrose** Mr. H. H. Lamb noted that the rays were red, green, gold, purple and white, but in no consistent order, and pulsations appeared to move up the rays as in flaming aurora; simultaneously, at **Leuchars,** only about thirty miles away, a similar phenomenon was observed by Mr. S. T. A. Mirrlees, Mr. D. W. Cruickshank and Mr. J. R. Sandison, but there the pulsations appeared to move outwards and downwards from the apex of the rays.

As observed from **Boscombe Down,** Wilts., by Mr. C. V. Ockenden and Mr. W. R. Hanson, the first sign of auroral light was at 18h. 30m. By 19h. 10m. a white arc extended from azimuth 275° to 41°, with a central elevation of 14° and vivid brick red patches to north-west and north-east. At 19h. 12m. a continuous red arc formed above the white one, with numerous rays shifting in position and varying in intensity. At 19h. 45m. the display was particularly magnificent, with bright patches of a colour "best described as that of red-hot steel." Greenish white colouration was present both to north and south of the red band.

The observers at **Abbotsinch** aerodrome in west Scotland, Mr. L. L. Alexander and Mr. H. E. Heaton, described the aurora in the following terms:—"It was first observed at 19h., and at that time was an arc of milky whiteness extending across the sky from 250° at an elevation of 10° to 64° at an elevation of 40°. Development occurred very rapidly, and by 19h. 15m. the arc had taken on a fan-shaped formation with the apex of the fan orientated at 250° but below the horizon. The rays stretched upwards to the zenith, and, in addition, there were detached portions, resembling patches of dense cirrus cloud, to the north-east at a zenith distance of about 45°. The central portion of the fan-like structure was of a light red colour, and the rest silvery in its denser parts but becoming pale and diaphanous near the zenith and on the outer edges. By 19h. 30m. the display had assumed an entirely different aspect and was at its greatest brilliance; the illumination was spread out over a considerable part of the sky. The focal point of the display was at an elevation of 66° and bearing 170°, and took the form of a star-shaped centre from which rays extended fanwise to north, east and west. The predominant feature was a deep red colouration which appeared in two narrow bands, one to the east reaching from an elevation of 30° up to the focal point, the other reaching from the horizon up to the focal point. The exact orientation of these bands was 64° and 250° (see Fig. I). The main colour of the aurora at its maximum intensity was silver with a greenish tinge oscillating over the whole. A very small milky-white curtain was observed on the horizon due north and detached from the main aurora. A slow movement of the rays about the centre from north to south was noticeable.

At 19h. 50m. a cumulonimbus cloud obliterated the display but by 20h. it was seen again as in Fig. I. Very slowly the rays lost intensity, spreading more in a northerly direction, and by 20h. 20m. there was a streaky curtain of milky whiteness extending from the focal point (still at 170°, elevation 66°) in all directions between east and west through north. Another shower cloud interrupted the view at this point, and after it had passed little remained of the aurora except some faint milky white patches in various parts of the sky. It was noticed that a considerable difference in the visibility had now taken place. It appeared as though the moon were shining whereas previously, even when the aurora was at maximum brilliance, it was quite dark. The display was interrupted again and reappeared at 22h., very faint without any colouration and without change in measurements. This slowly faded and by 23h. 30m. nothing was to be seen except a faint luminous appearance of the sky to the south. The intensity varied considerably, and when it was increasing and also when at about the maximum for the particular phase, faint reddish horizontal ripples in the light could be noticed flowing rapidly towards the focal point. These ripples were noticed only in the northern part of the display."

Several observers comment particularly on the intense ray activity between 19h. 40m. and 19h. 50m. Mr. E. H. Back writes, from **Marlborough,** " A streamer sprang up in the west (at 19h. 40m.) and reached Cassiopeia while four vertical beams in the north-east divided into seven. The whole sky, except the southern horizon, reddened, particularly near the Plough. Streamers were observed coming from the northern horizon, while considerable flickering occurred. A strong green glow began to expand from the northern horizon upwards, and a further streamer appeared in the north-east and diverged into six or seven."

Between 19h. 45m. and 20h. the display was at its greatest brilliance over most of the British Isles, and the corona effect was seen momentarily at **Hastings** by Miss C. M. Botley and at other places in the south of England. At almost exactly 20h. the corona was observed simultaneously at several places showing that at least the whole of Scotland must have been covered by a system of brilliant rays. In a corona which formed a few minutes earlier a remarkable colouration was noted by Mr. W. R. Morgans at **Catterick,** the rays appearing green near the point of convergence and red at the lower extremities. The maximum intensity at Catterick during this period was 3+ on the international scale of 0—4. The observer in this case was an officer who had taken part in the British Polar Year Expedition to Fort Rae in 1932–3. Apparently the brightness was not so exceptional elsewhere as Mr. P. A. Sheppard, who was also with the Fort Rae Expedition, stated definitely that at **Salisbury,** Wilts., the intensity never reached 3 on the international scale. He was, however, handicapped by the nearness of the lights of the city.

A general impression of the aurora at this period as seen from the north of **Skye** is given by Mr. Seton Gordon in these terms : " With the passing of a heavy hail squall at about 19h. 45m. the stars paled before a remarkable aurora display. In the heavens, high up in the south-west, was a great pool of deep pink as though the last of a sunset of beauty suffused in visible clouds here. Shafts of pale green shot up from the sky, from east, south, west and north and converged like searchlights on some point near the zenith. Another pool of glowing pink lay toward the south. Five minutes later a lake of pink lay in the sky towards the west. The pink was so deep that it seemed almost to fade away and merge into a velvety black. Near this, there was primrose light and from the north pale green fingers shot out towards the zenith. Throbbing zones of light, as from the beat of a heart, pulsed over the heavens, to fade at the zenith. A few minutes later the display faded to a cold glow in the south sky, a glow such as might have heralded daybreak."

Although other observers mentioned pulsations and colour fluctuations there are few estimates of the periods of these variations. Near 20h. Miss M. C. L. Bowden observed from **Dovercourt,** Essex, yellow rays appearing from a double red arc at intervals of about three minutes, and at 20h. 8m. Mr. W. S. Garriock saw from **Cranwell** white rays to the south-east pulsating at approximately one second intervals, a rate corresponding more nearly to " the beat of a heart " referred to in the description quoted above.

The brightest periods of the display were described by the Rev. J. B. Boyan, of **Ampleforth,** Yorkshire, in the following terms : " By 19h. 45m. the first period of maximum disturbance had developed. The sky to the east and west was a brilliant crimson and there were streamers of greenish light darting from the north. This died away fairly quickly and by 20h. was almost gone. The streamers ceased and there was no red in the eastern sky by 20h. 5m. The western sky decreased in colour, but this was partly due to a great bank of nimbus which came up from the west and precipitated a slight amount of fine rain. After this the sky was cloudless for the rest of the evening. At about 20h. 15m. the colouration in the west increased and suddenly the east again became red and in a flash a red band joined them spreading continuously from east to west and slightly south of this position. The disturbance quickly developed and a ' pole ' appeared about 10° south, from which the whole effect seemed to emanate. It is variously described as being ' just north of the Pleiades ' and ' filling the space between Capella and β Tauri '. The ' pole ' itself was crimson and from it radiated shafts of yellow light to the north, east and west but not to the south. The streamers were not stationary but darted about rather after the fashion of searchlights. The stars could be seen through the red glow of the sky. This phenomenon lasted at its maximum intensity till about 20h. 45m., and appeared to one observer like the inside of an enormous circular circus tent with its ' pole ' and the ' streamers ' of canvas radiating away from it. By 20h. 50m. it was still visible but much less clearly than before."

There is considerable divergence of opinion as to whether or not the stars were dimmed by the contrasting brightness of the aurora. At Ampleforth the stars " could be seen through the red glow of the sky ", but Mr. Seton Gordon writes " the stars paled before a remarkable auroral display ", and Mr. J. G. Balk from **Oxford,** notes that at 20h. 40m. the constellation of Orion was seen dimmed by a fairly bright patch of the glow. On the other hand Mr. J. M. Brierley who saw the display while motoring in Somerset and Devon remarks that Vega was conspicuous in the glow, but this was at about 18h. 30m.

It was at about 20h. that the display was at its brightest in the **Mediterranean** ; H.M.S. *Shropshire* from just south of Almeria saw rays reaching an altitude of nearly 60° at 20h.5 m. (Fig. 2).

At 20h. 30m. red bands were seen at Catterick to join up into a pulsating band and a corona developed shortly afterwards. This development was also seen as noted above at Ampleforth, Yorkshire, where the corona persisted for about half an hour, although as seen from Catterick it quickly degenerated into red diffuse surfaces which moved northwards and were, with isolated pulsating pencils, the only features visible for some time.

An observer living near **Ampleforth** noted that, although there was no moon, he could see to the edge of the Cleveland Hills, 16–20 miles to the north at 21h. as clearly as on the very brightest moonlight night. At the same time the Rev. H. Buckton, of **Bridgwater,** Somerset, could walk about his garden " without stumbling into beds and bushes, and in a wall facing north could distinguish the separate bricks and stones ", although aurora was his only light. Mr. J. M. Brierley also in **Somerset** found that the display gave " quite a distinct pink hue to the parts of the buildings facing north-west." Mr. E. W. Barlow at **Wadhurst,** Surrey, found that " the aurora at its brightest threw a definite shadow of one hand on the palm of the other." Mr. R. Forbes Bentley at **Holyhead** could read the headlines in the *Daily Telegraph*, so intense was the illumination, and at Boscombe Down it was possible to tell the time by a small wrist watch.

From Boscombe Down increasing activity was evident from 20h. 30m. to 20h. 45m., the rays converging to a point near β Tauri.

Between 20h. 30m. and 22h. according to Mr. D. W. Rhead and Mr. J. B. Shaw various coronal types formed over **Eskdalemuir,** often taking the form of a pulsating surface, parallel bands from east to west moving southwards through it.

Over **Edinburgh,** at 21h. 35m., Mr. J. Paton observed the corona to appear to the west-north-west, with red flaming aurora which Catterick observed as a diffuse homogeneous red arc.

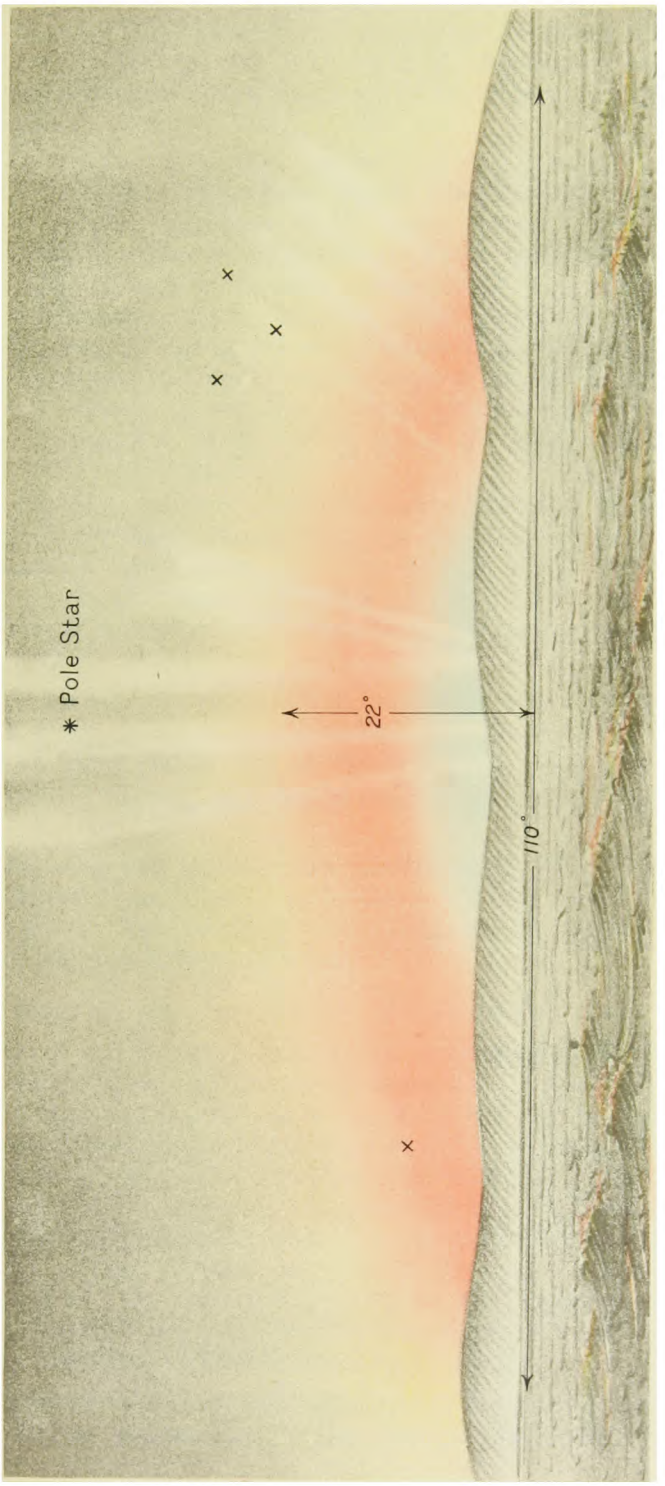

FIG. 2.- DRAWING OF AURORA AS SEEN FROM H.M.S. SHROPSHIRE IN THE MEDITERRANEAN

There was considerable activity during the next half-hour, arcs moving across the sky with frequent rays. An arc to the south of Edinburgh remained almost stationary from 22h. to 23h. 45m. with occasional patches of red light in the west and north-west. Just before midnight this arc became multiple and faded, but another formed across the zenith and pulsated before disappearing. Flaming aurora developed and spread to the zenith ; a corona appeared at 0h. 8m., and for a time the rays covered the whole sky. Activity decreased after 0h. 17m. and was confined to a narrow band across the zenith from west-north-west to east-south-east. Remarkable colour changes were noted at this time by a **St. Andrews** observer : " The colours were constantly changing and blending, from sapphire to turquoise, turquoise to amethyst, amethyst to topaz, ruby and rose."

Further south the colours were less varied but the display was very brilliant at about midnight. Mr. T. H. Applegate wrote from **South Farnborough :** " At 23h. 55m. I looked out again and was amazed at the splendour of the sky. From west-south-west through north to east-north-east there was an extensive curtain of white brilliance reaching to about 50° with sharp boundaries composed of wide red shafts to west-south-west and east-north-east. The whole thing hovered, grew in brilliance and diminished, while long shafts of white light stabbed through it from the north. During this time waves of white light travelled along about the centre of the curtain from east to west and then travelled back at a slightly lower angle from west to east. These waves seemed to consist of patches of light progressing swiftly in the directions given. There was a constant impression of flickering about the whole thing, and the white brilliance was often overspread with a deep pink glow."

There was a renewal of activity at about 0h. 40m. but by this time cloud had made observation difficult. H.M.S. *Shropshire* reports that the aurora disappeared at 1h. on the 26th after being visible for about 6½ hours, but over the British Isles activity recommenced at about 1h. 30m. ; the corona reformed over Catterick at 2h. and the display was still brilliant near Ampleforth at 3h. The last observations were from Lerwick where pulsating surfaces were still visible at 5h.

Illustrations.—Several of the descriptions received were accompanied by sketches, in a variety of media. The most successful drawings are those made by Mr. L. L. Alexander of Abbotsinch in pastel on black paper, one of which is included as Fig. 1.

Fig. 2 is taken from a crayon and pencil sketch made on board H.M.S. *Shropshire* off the [illegible]sh coast.

Only one observer obtained satisfactory photographs, Mr. A. B. Chatfield, of Crewe, who sent prints showing rayed bands, but the features are not sufficiently well marked to justify publication. These and the sketches mentioned above are available for inspection on application to the Director. Meteorological Office, London.

§ 3—HEIGHT AND POSITION OF AURORAL ARCS AND RAYS

It was hoped that from the large number of observations received it would be possible to compute the height and position of some of the auroral arcs and rays. Closer study of the data revealed that in fact only very few of the observations could be applied to this purpose ; some observers have estimated positions to the nearest 10°, and others have described the positions by reference to the stars, but only mention constellations. Even where angles have been measured with a theodolite, or positions referred to individual stars, only very few calculations are possible owing to the lack of simultaneity in the observations or to the difficulty of determining whether measurements at two stations referred to the same arc or ray. The great wealth of auroral features present at any one time constituted an immediate difficulty in this connexion. Thus, because of the impossibility of co-ordination, many accurate measurements could not be used, or could only be used by making certain assumptions.

Arcs—The positions of a few arcs have been established, assuming their edges to be approximately straight, parallel to the earth's surface and perpendicular to the plane of the magnetic

meridian. From data supplied by Holyhead and Porton, the main arc at about 18h. 30m. was calculated to be 130 Km. above the earth and 90 Km. north of Holyhead. Another at 19h. 15m. was at about the same height but a little further north. These figures are confirmed by the elevations noted at Croydon and Boscombe Down. At 21h. 30m. a diffuse band stretching from the eastern to the western horizon was centred overhead at Cranwell and its edge nearly reached the zenith at Porton. From the elevations given, this appears to have been at a height of about 100 Km. though the southern edge was possibly higher than the northern. At 21h. 41m. the positions of three points on a green arc were measured at Boscombe Down where it extended from within 4° of the north-east horizon to almost due west. Störmer[3], from photographs taken in Norway at almost the same time, computed the position of this arc, assuming its base to be at a height of 95 Km., that found for other arcs on the same evening. He found that it extended from Osel in the Baltic across Denmark and the North Sea to south-west Scotland. Assuming the same height, the Boscombe Down figures confirm this position to within about 50 Km., and also show that the arc curved south-westwards to at least 200 Km. west of south Ireland.

The southern edge of another arc at 22h. 30m. appears to have been slightly lower, the observations from Leuchars, Driffield and Porton agreeing in giving the height as about 90 Km.

Rays—The consideration of rays was attended by the usual difficulties. At Boscombe Down and Cranwell the positions of the ends of several rays were noted. Unfortunately they do not appear to have observed any simultaneously, and the following figures have been calculated

Station	Time	Direction	Height of Base (Assumed)	Distance of Base	Height of Top
	h. m.		Km.	Km.	Km.
Boscombe Down ..	19 37	north-west	100	250	250
			150	350	370
			200	460	500
Cranwell	19 45	east-north-east	100	450	350
			150	630	510
			200	790	680
Cranwell	20 00	west	100	200	360
			150	293	550
			200	380	750
Cranwell	20 06	north-east	100	280	175
			150	400	260
			200	520	340
Cranwell	20 32	west	100	270	180
			150	390	270
			200	505	360
Boscombe Down ..	21 46	east	100	220	250
			150	320	375
			200	420	510

by assuming the height of the base of each ray and thence computing the position of the upper end, by the method given by Störmer[4] who found that most rays begin at 100 to 150 Km. but, especially in very active auroræ, may begin as high as 400 Km. and their tops may reach to 800 Km. Such extreme heights only occur in the sunlit portion of the upper atmosphere shortly after sunset at the earth's surface.

The rays measured from Cranwell at 19h. 45m. and 20h. are the most striking; both reached to at least 350 Km. above the earth and probably more.

Rays over Denmark at about 21h. 40m., measured by Störmer, extended from about 100 Km. to a height of 500 Km., and later, when activity was renewed near midnight, rays reached to 650 Km. from the earth's surface.

§ 4—THE MAGNETIC DISTURBANCE

Relative Magnitude—Although cases have been noted of aurora appearing without any perturbations of the earth's magnetic field, and of magnetic storms without locally visible aurora, the most severe storms and the most brilliant aurora usually appear simultaneously. On January 25–6, 1938, a great magnetic storm occurred. At Lerwick the variations of H and D (the horizontal components of the earth's magnetic field in and perpendicular to the magnetic meridian) were probably* greater in this storm than in any disturbance since that of October 15, 1926, but the range of V (the vertical component) in the present case is only half what was recorded in October, 1926, and it has, in fact, been exceeded on three occasions since October, 1926. At Abinger, however, the disturbance was the greatest since September 25, 1909, when, as on the occasion under discussion, an aurora in which red was at times the predominant colour was visible as far south as the Mediterranean. A bright moon and much cloud apparently caused it to escape general notice. The aurora accompanying the disturbance of October 15, 1926, was also obscured by cloud over most of England, but was described by observers in the north and in Scotland as exceptionally brilliant.

As mentioned elsewhere in this memoir a very large sunspot group was visible from January 12 to January 24, 1938, and during this period there were two magnetic storms, but neither was comparable in magnitude with that which began after a quiet interval just before noon on January 25.

Sudden Commencement—There was a typical " sudden commencement ", the time of which, measured on the quick-run magnetograms, was 11h. 51m. 20s. at Eskdalemuir and 11h. 51m. 2s.

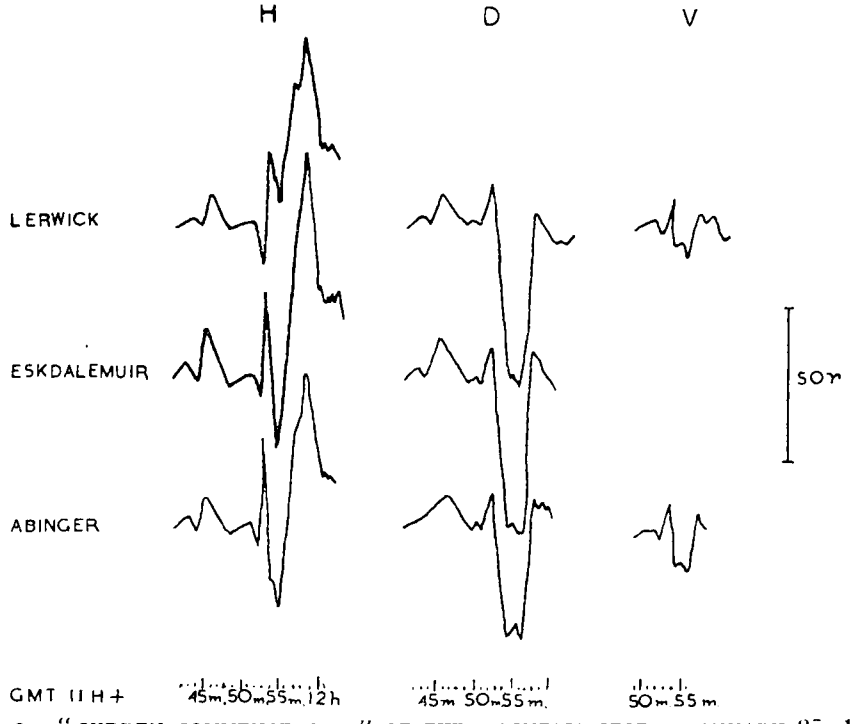

FIG. 3.—" SUDDEN COMMENCEMENT " OF THE MAGNETIC STORM, JANUARY 25, 1938

* On several occasions during previous storms the variations exceeded the limits of registration of the recording instruments and no reliable estimates of the extreme values were possible. This loss of record is eliminated in the new form of instrument now used.

at Lerwick. At Eskdalemuir the time is estimated as correct to within 5 seconds. It is impossible to decide whether the difference is due to an error of timing or is real, but, though it cannot be measured so accurately for Abinger, the commencement there appears to have been earlier than 11h. 51m., suggesting that the commencement occurred earlier in the east than in the west. This is not confirmed by the observations at observatories in other parts of the world. Fig. 3 shows the " sudden commencement " as recorded at the three observatories, the Eskdalemuir V being omitted as it could not be measured with sufficient accuracy. Declination is usually measured as an angle but for Figs. 3 and 4 the variations have been converted into units of force perpendicular to the magnetic meridian. The unit of force employed throughout this section is $\gamma = 10^{-5}$ Gauss (C.G.S. unit).

The changes of D were similar at the three observatories, but the magnitude at Eskdalemuir was less than at Lerwick and that at Abinger was still smaller. The variations of V at Lerwick and Abinger were not only parallel but of equal magnitude. Eskdalemuir and Abinger show similar variations of H both in direction and size, but the Lerwick curve has one important difference. Although the small initial drop and immediate rise closely resemble those for Eskdalemuir and Abinger and the departure from normal of the maximum at 11h. 57m. is similar for the three observatories, the third (downward) movement of the oscillation was much smaller at Lerwick than at the other places.

Features of the Storm—Copies of the magnetograms are reproduced in Fig. 4, the scales having been adjusted to facilitate comparison between the records of the three observatories. The gaps in the Eskdalemuir records are due to the movements of the magnets being too rapid to be recorded. Disturbance increased at 17h. 30m., the time when aurora was first observed, although it was not until 20h. that large fluctuations were recorded at Abinger. The times of the most brilliant and active aurora were about 19h., 19h. 40m.—20h., 20h. 15m.—21h., 21h. 30m. —22h., 24h. and 0h. 40m.—1h. These are also the times when the magnets were most violently agitated and when the extreme values were recorded. The only long period of relative quiet was from 22h.—24h., and this was a time that the aurora was quiescent.

The extreme values and ranges of the three magnetic elements during the storm were :—

		Lerwick		Eskdalemuir		Abinger	
		h. m.		h. m.		h. m.	
H	Maximum	17 35	15,202γ	18 5	17,061γ	20 32	18,673γ
	Minimum	1 5	13,231γ	1 22	15,582γ	0 15	17,643γ
	Range		1,971γ		1,479γ		1,030γ
D	Maximum	18 8	15° 8·6′	19 58	15° 17·4′	20 53	12° 9·5′
	Minimum	0 56	11° 28·4′	22 16	12° 13·1′	19 52	10° 4·0′
	Range		3° 40·2′		3° 4·3′		2° 5·5′
V	Maximum	0 21	47,763γ	0 29	45,362γ	20 34	43,313γ
	Minimum	17 54	46,656γ	19 58	44,297γ	0 20	42,746γ
	Range		1,107γ		1,065γ		567γ

As is usually the case, Lerwick experienced the greatest ranges, but the Eskdalemuir and Abinger ranges are unusually large as compared with those for Lerwick, which is consistent with the deduction from the electric current system (see § 6) that the source of the perturbing field was farther south than usual.

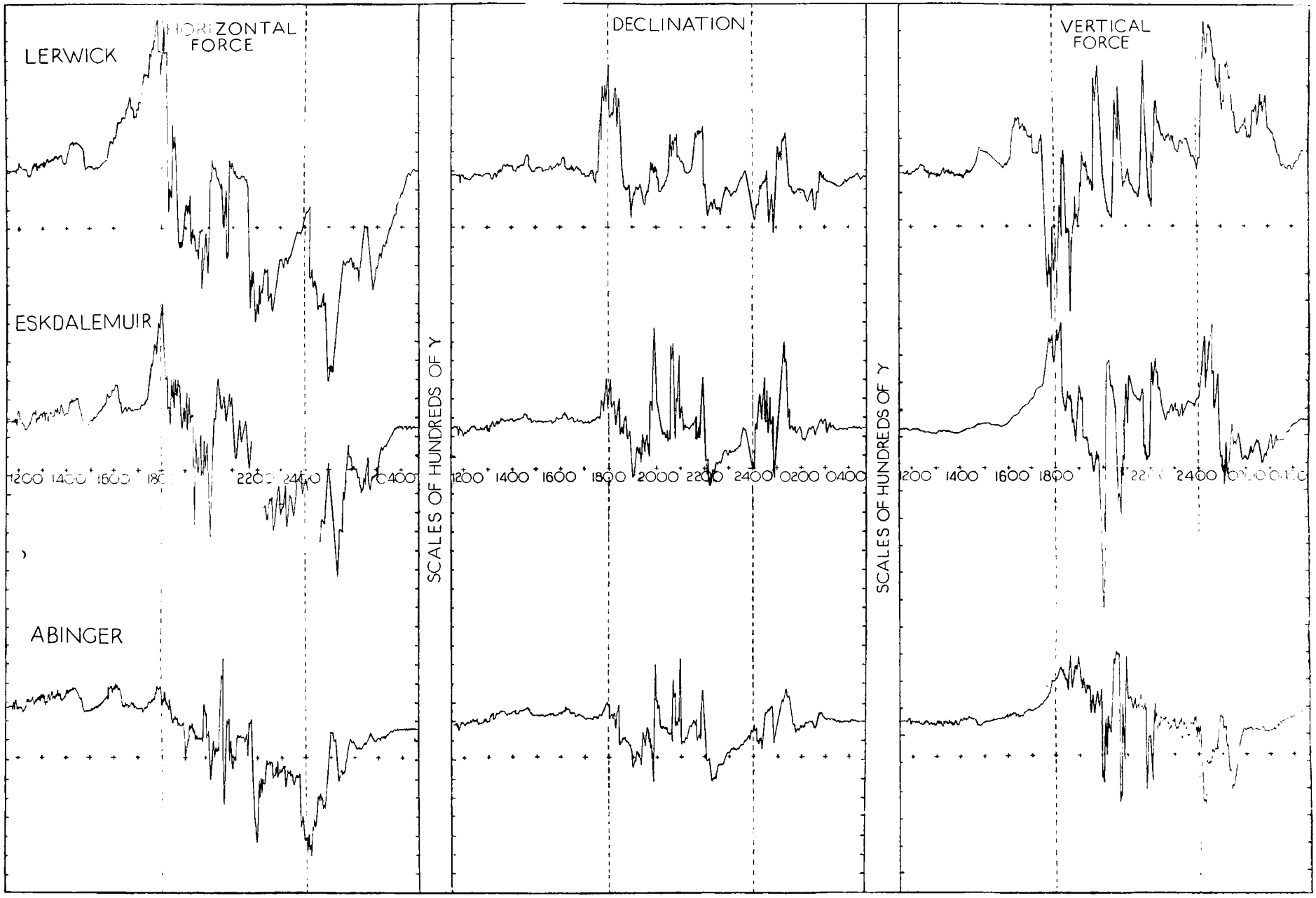

FIG 4.— COPIES OF MAGNETOGRAMS FOR THE PERIOD OF THE MAGNETIC STORM

§ 5—EFFECTS OF THE MAGNETIC STORM

The magnetic disturbance caused considerable interference to radio-telephone services, especially those linking this country with America, but reception in England from Africa, India and the East generally was exceptionally good. Telegraphic circuits were also affected, notably in south Scotland and across the English Channel, and the service between the Air Ministry and some of the meteorological stations was interrupted.

Railway electric signalling apparatus also suffered interference, especially between 18h. 30m. and 19h. 30m.; that in the Woodhead Tunnels on the L.N.E.R. Manchester–Sheffield line was out of action for some time and the trains were held up.

The Western Union Telegraph Company of New York report[2] that their service was seriously affected on the evening (local time) of January 25, the disturbance having increased slowly during the previous three days. The potentials set up by the storm at times exceeded 400 volts and these high values were reached more frequently and more rapidly than in any previous storm. Conditions cleared rapidly after the disturbance had reached its maximum, and by the evening of January 26 all circuits were back to normal.

§ 6—ELECTRIC CURRENT SYSTEM ASSOCIATED WITH THE MAGNETIC STORM

Goldie[5] has described a method of computing the magnitude and position of horizontal electric currents whose magnetic fields would produce perturbations of the terrestrial magnetic field similar to those recorded at Lerwick, Eskdalemuir and Abinger. The apparent inapplicability of any simple hypothesis in cases where aurora is actually present is noted in the same paper and is referred to again in a later paper[6].

An attempt was made to compute the magnitude and position of a current system for several periods of the disturbance of January 25–6, but the same difficulty was experienced, the system being too complex to approximate to any single line current.

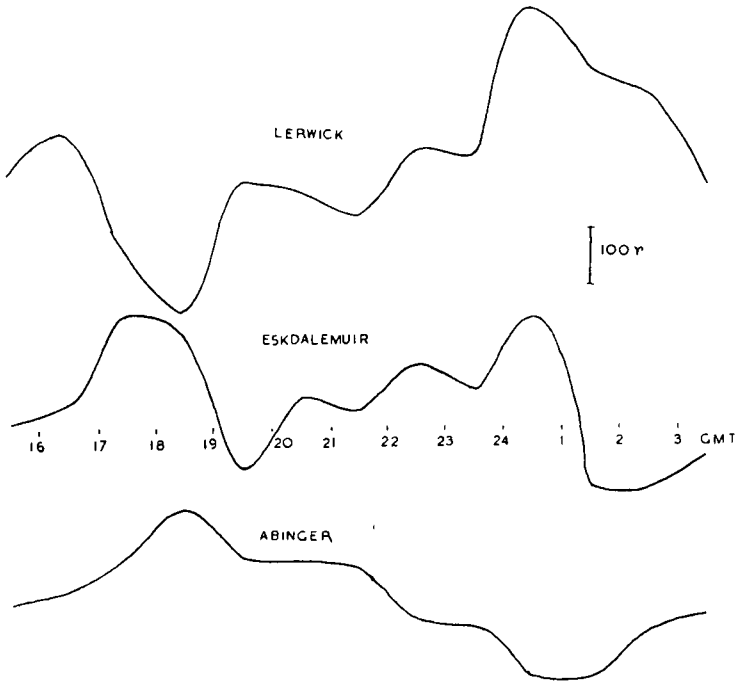

FIG. 5.—VARIATIONS OF THE VERTICAL COMPONENT OF THE EARTH'S MAGNETIC FIELD ON JANUARY 25–6, 1938. HOURLY MEAN VALUES.

Nevertheless, although no determinations of height or magnitude are possible, certain deductions regarding the current position can be made. From the departure from normal of the hourly mean values of H and D we can find for each hour the direction of the current nearest to each observatory, and from the sign of the simultaneous variations of V we can ascertain whether the currents are north or south of the observatory. The mean values of vertical force for Lerwick, Eskdalemuir and Abinger are shown in Fig. 5. The Abinger curve is the only one to approximate to the diurnal variation normally observed in temperate latitudes on magnetically disturbed days. It shows the usual afternoon maximum and early morning minimum and the only unusual feature is that V was above normal until nearly 23h. Except for a short initial rise the Lerwick curve is practically the reverse of that for Abinger. It resembles that for an observatory near the north magnetic pole, and shows that the currents were between the two observatories for most of the disturbance. Even at Eskdalemuir the changes are opposite to those at Abinger from about 19h. to 1h. A notable feature of both the Lerwick and Abinger curves is that the variations after 22h. are, almost as in a mirror image, the reverse of those before 22h.

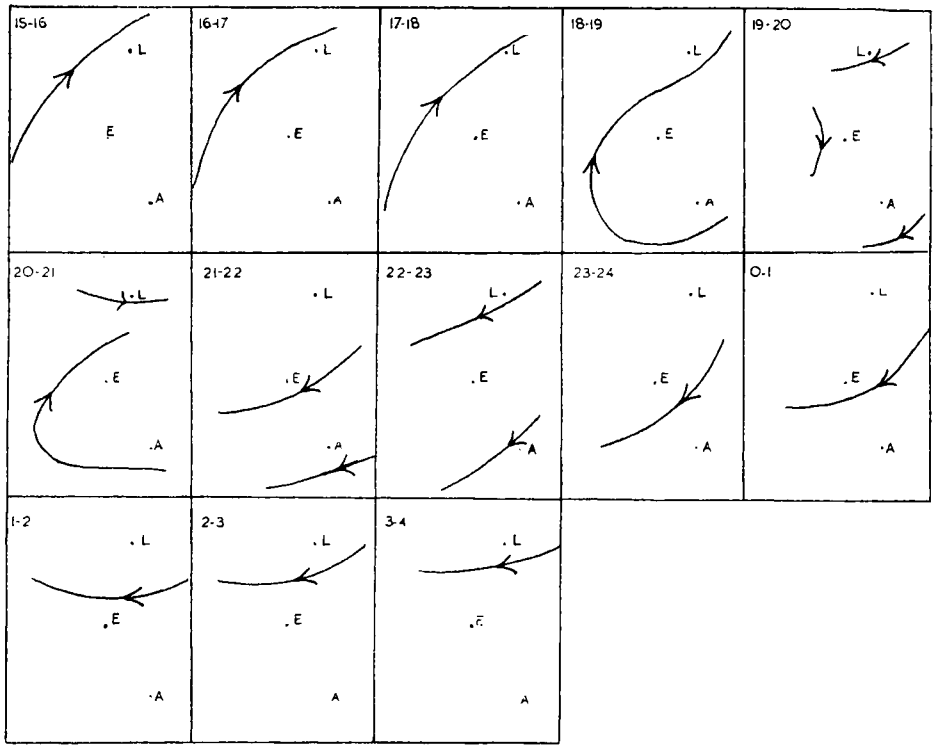

FIG. 6.—APPROXIMATE POSITIONS OF OVERHEAD ELECTRIC CURRENTS ON JANUARY 25–6, 1938, DEDUCED FROM HOURLY MEAN VALUES OF THE TERRESTRIAL MAGNETIC ELEMENTS AT LERWICK (L), ESKDALEMUIR (E) AND ABINGER (A)

Fig. 6 shows the approximate mean current positions deducted from the H, D and V displacements at the three observatories for each hour from 15h. on the 25th to 4h. on the 26th, and these are combined in Fig. 7. Between 15h. and 16h. the direction was from 50° south of west to 23° north of east, and the position north of Lerwick. The curvature of the path increased and the northern end moved south, passing over Lerwick between 17h. and 18h. A little later there is evidence of a current from the north-east, south of Abinger, apparently part of a closed circuit centred over the British Isles. This moved westwards and was followed by an open loop. From 21h. to 23h. at least two parallel currents were present, and after 23h. the only

important current was from 30° north of east to south-west and passing near Abinger. This current veered steadily and moved northwards, passing over Eskdalemuir at about 1h. and being near Lerwick at 4h. This sequence of currents is consistent with that found by Goldie from the average of several storms, illustrated in the paper cited above.

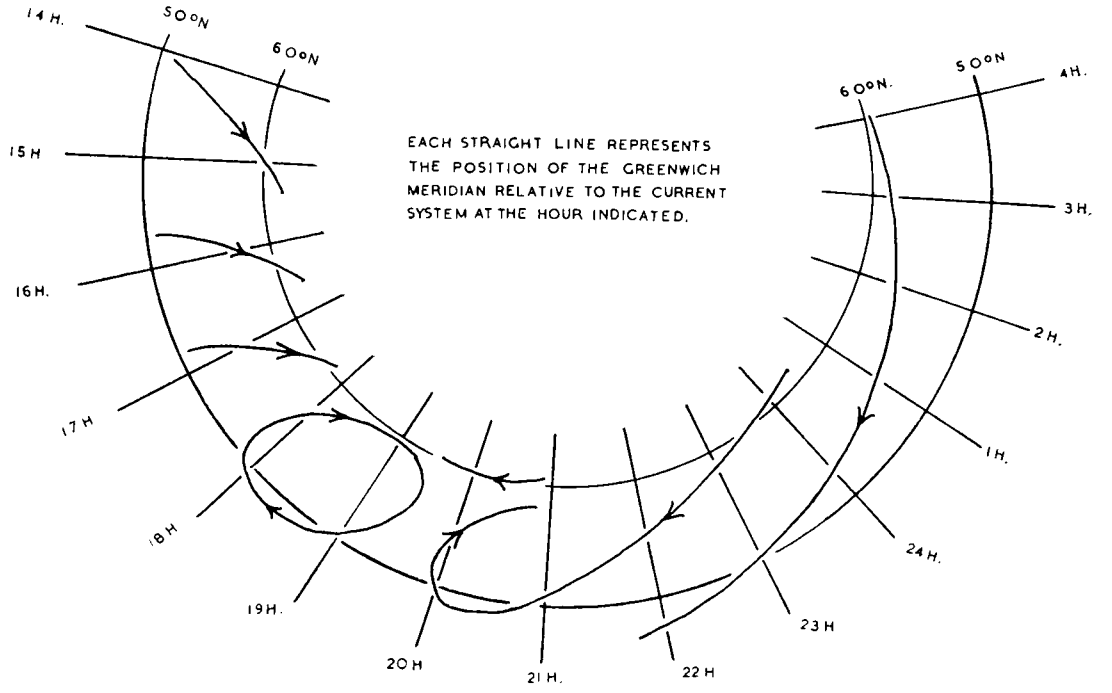

FIG. 7.—APPROXIMATE POSITIONS OF OVERHEAD ELECTRIC CURRENTS ON JANUARY 25-6, 1938 IN THE LATITUDE OF THE BRITISH ISLES

§ 7—SOLAR ACTIVITY

According to the Birkeland-Störmer explanation the aurora is one of the results of the entry into the earth's atmosphere of streams of electrically charged particles. The presumed source of these particles is the sun, since prominent auroræ are usually associated with abnormal solar activity. The most easily observed sign of such activity is an increase in size and number of the sunspots, but the phenomena which appear to be more intimately associated with the aurora are bright eruptions normally visible only with the aid of a spectroheliograph. These usually occur over or near sunspot groups.

A solar eruption occurred early on January 24, and was observed from the Commonwealth Solar Observatory, Canberra, Australia[7]. It is described as brilliant and prolonged, and was centred round a large sunspot group then nearing the western edge of the sun's disc. The eruption probably commenced at 2h. 50m. G.M.T., 33 hours before the magnetic storm commenced, giving a longer period than the average of 26 hours estimated by Hale[8] for the interval between a solar eruption and the corresponding magnetic storm, but less than the highest of the figures on which he bases his average. This gives the particles an average speed of nearly 800 miles per second for their passage from the sun to the earth.

If this eruption was connected with the aurora it is an unusual case in that it was near the edge of the sun's disc, whereas auroræ and magnetic storms are more often associated with the passage of an area of solar activity across the central meridian. This is easily understood if streams of electric particles are ejected radially from the sun and only strike the earth when their source is immediately opposite us. Only one small spot was near the central meridian on

January 25, but Evershed[9] suggests that, since January 25 is approximately five solar revolutions later than September 11, 1937, the aurora is a repetition of that then seen from Cumberland the day after a large spot had crossed the sun's central meridian. He adduces as further evidence that the magnetic storm of September 10 was repeated early in October and on December 1. There have been similar cases in the past of magnetic storms and auroræ recurring at 27-day intervals, although the sunspot apparently associated with one or more of the recurrences did not remain visible. Nevertheless it is more probable that the aurora was caused by the exceptional eruption observed from Canberra on January 24.

§ 8 — POSSIBLE CONNEXION OF SOUNDS WITH THE AURORA

Although the belief that the aurora can be heard is widespread, reliable observations of the sound are very rare.

The sound is usually described as resembling the rustle of silk, and is said to be noticeable more frequently in some years than others. On this occasion only two writers stationed in the British Isles reported sound; one heard faint clicks although his hearing is "by no means perfect" and another heard (at about 19h. 45m.) a sound like that made by deer crashing through undergrowth, though presumably less loud. Unfortunately neither said what type of aurora was present at the time, but it is worth noting that the electric current (see §6) estimated for the magnetic displacements was probably almost immediately over the second observer at 19h. 45m., when the display was at its brightest.

A different account is given by Störmer[3]. Three observers heard sounds "similar to burning grass and spray" when coronal activity was at its maximum over Norway shortly after midnight. The source of the sound seemed to move from south-west to north-east through the zenith, varying in intensity with the aurora, and lasting for ten minutes.

If, as their description might suggest, the auroral noises are the sounds of electric discharge, the first inference would be that they are actually related to the auroral light, as thunder is to lightning. Now the available measurements suggest about 50 Km. from the earth's surface as the lower limit of the aurora, and observations based on detonating meteors[10] point to about 55 Km. as the greatest height from which sound waves could be transmitted.

An alternative explanation is that the sounds are due to "brush discharges", similar to St. Elmo's Fire. Angot[11] quotes three instances of St. Elmo's Fire appearing during aurora, but the probable height of the aurora and the smallness of the electric charges involved make it improbable that any induced effect could be so intense. If such an effect existed it would probably be found in the records of the electrical potential gradient. Many investigators have attempted to find a connexion between the aurora and the potential gradient, but the majority found no such connexion and the others found only very slight evidence of it. On this occasion the autographic records of electric potential gradient at Eskdalemuir and Lerwick showed no movements likely to be associated with the aurora. At Lerwick hail showers occurred during the night and lightning was observed. Any effect of the aurora would probably be masked by the larger local potential gradient variations due to these showers.

Hence it appears unlikely that the sounds can be directly connected with the electrical field in the aurora, but the observations of detonating meteors show that it is just possible for sound waves to reach the earth from the lowest heights at which aurora can occur. According to the observations analysed in § 3, however, there is no direct evidence in this case of auroral arcs lower than 90 Km.

ACKNOWLEDGMENTS

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