M.O. No. 220a.

METEOROLOGICAL OFFICE.

GEOPHYSICAL MEMOIRS, NO. 11.

THE SOUTH WALES TORNADO OF OCTOBER 27, 1913.

WITH A NOTE ON

REMARKABLE PRESSURE OSCILLATIONS OBSERVED ON AUGUST 14, 1914.

Published by the Authority of the Meteorological Committee.

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PREFACE.

AN unusually destructive tornado, involving some loss of life, was experienced in South Wales on the evening of October 27th, 1913.

At the request of Mr Clement Edwards, M.P., Mr H. Billett was sent to collect information on the spot that might throw light upon the meteorological conditions incidental to the occurrence. Mr Billett spent three days in South Wales, and in that time visited the greater part of the region affected by the storm.

In the mean time the records contributed by the observers in connection with the Office had been searched for information bearing upon the subject.

The whole has now been collected and arranged, and is submitted in the accompanying memorandum.

The thanks of the Meteorological Committee are due not only to Mr Clement Edwards, but also to the Municipal authorities and private persons who provided facilities for eliciting the facts in the neighbourhood visited by the tornado.

W. N. SHAW

METEOROLOGICAL OFFICE,
LONDON, S.W.,
23rd September 1914.

Wt. 25894/224 (391)—625—1/15.—N. & Co., Ltd. **Group XV.**

METEOROLOGICAL OFFICE,
SOUTH KENSINGTON, LONDON, S.W.,
22*nd September* 1914.

SIR,

I beg leave to present herewith a report on the Tornado of South Wales of October 27th, 1913, which Mr H. Billett has prepared under my direction.

I am,

SIR,

Your obedient servant,

(Signed) R. G. K. LEMPFERT,
Superintendent, Forecast Division.

THE DIRECTOR
OF THE METEOROLOGICAL OFFICE.

Figure 1.

SYNOPTIC CHART FOR 6 P.M. 27TH OCTOBER, 1913.

The Direction of the Wind is shown by Arrows.

Light to moderate wind ——→ Fresh to strong wind ——→ Gale →——

Weather is indicated by Letters or Symbols.

bc = blue sky, with detached cloud. c = cloudy. o = overcast. q = squally.

p = showery. d = drizzle. ● = rain falling. ⊼ = thunderstorm.

Temperatures shown by Figures, thus: 54°.

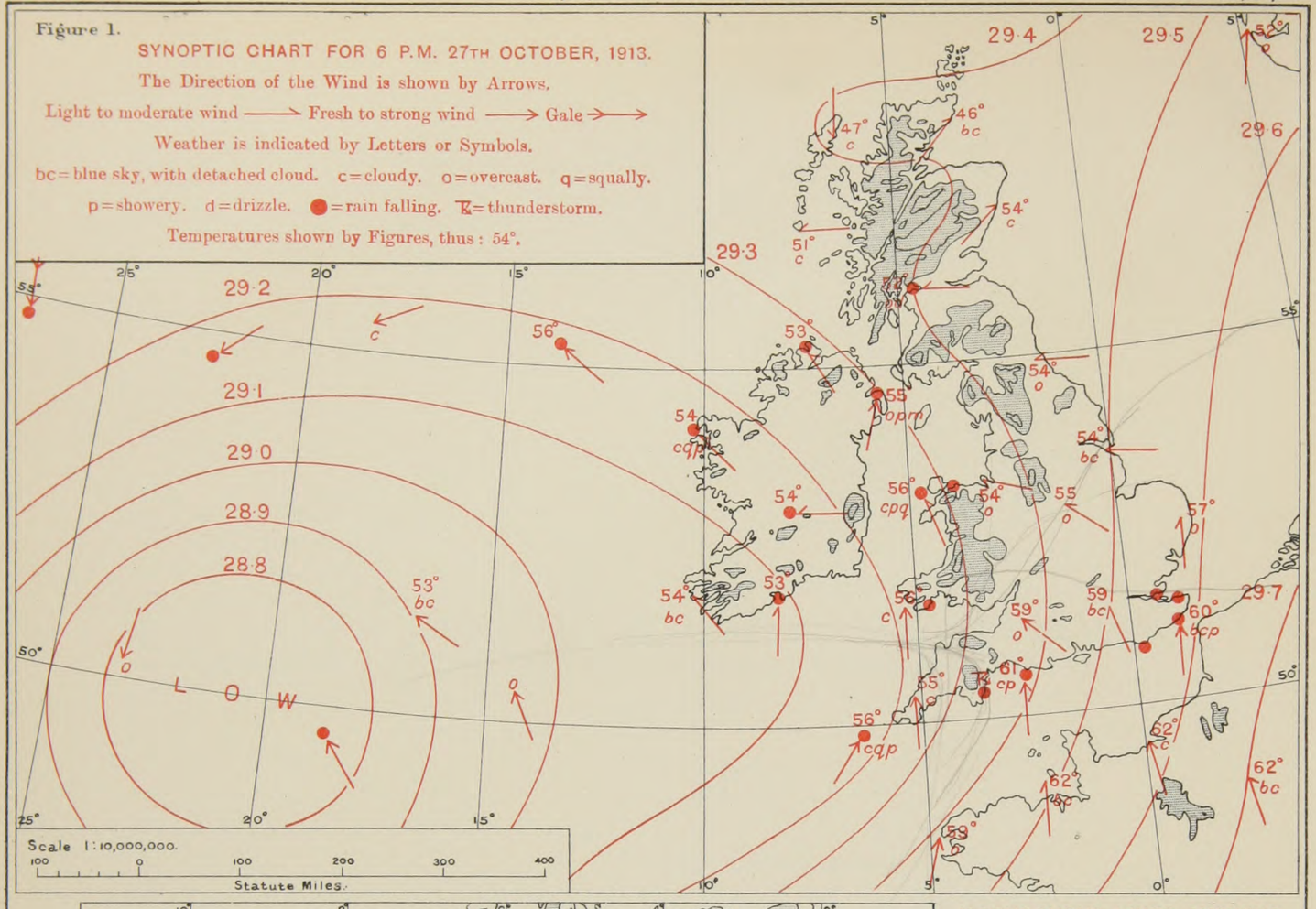


Figure 2.

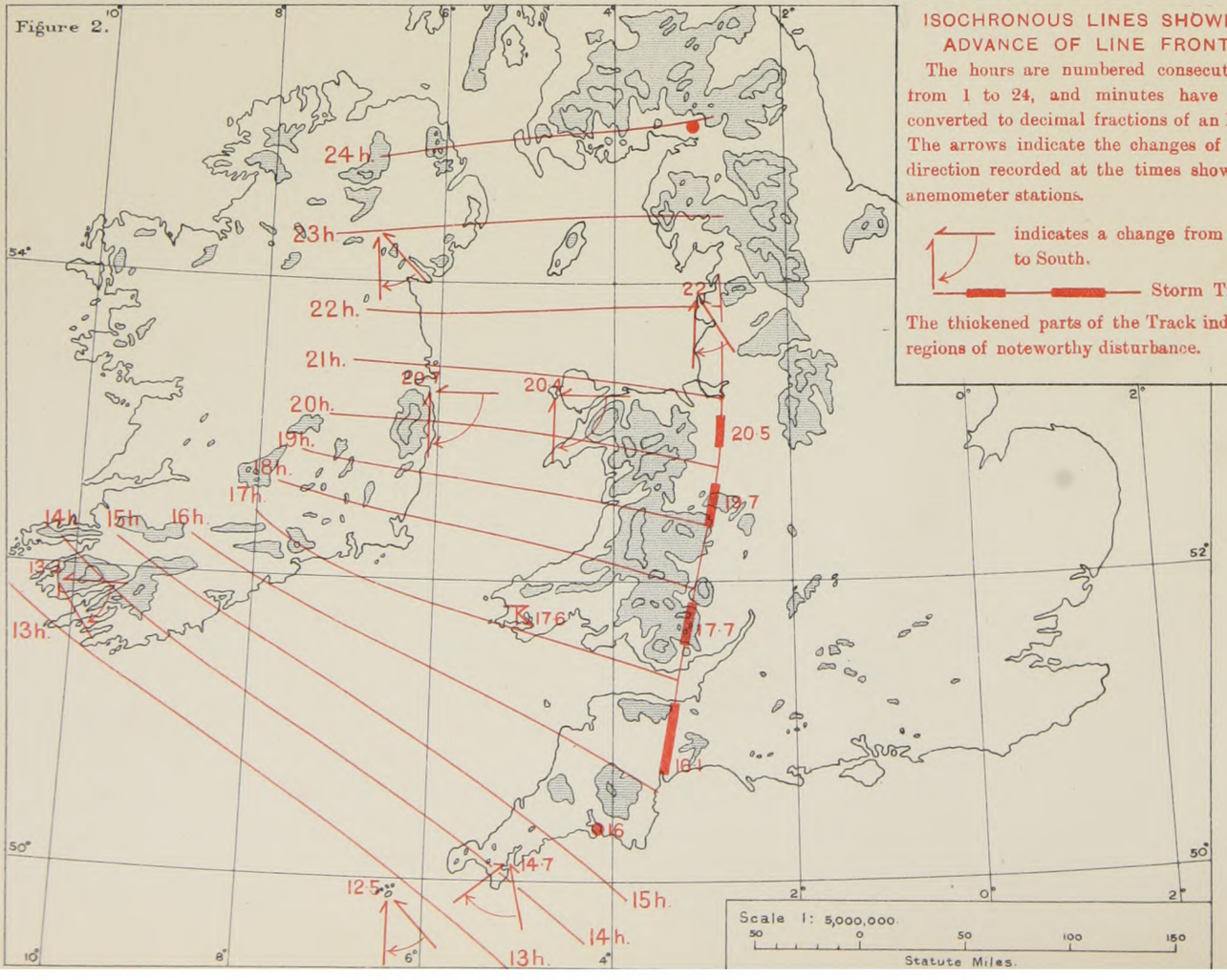
ISOCHRONOUS LINES SHOWING ADVANCE OF LINE FRONT.

The hours are numbered consecutively from 1 to 24, and minutes have been converted to decimal fractions of an hour. The arrows indicate the changes of wind direction recorded at the times shown at anemometer stations.

indicates a change from East to South.

Storm Track.

The thickened parts of the Track indicate regions of noteworthy disturbance.



THE TORNADO OF SOUTH WALES AND WEST OF ENGLAND, MONDAY, OCTOBER 27, 1913.

REPORT BY H. BILLETT, B.Sc., PROFESSIONAL ASSISTANT IN THE FORECAST DIVISION.

ON October 27th, 1913, a severe thunderstorm swept the West of England and Wales, from the South of Devon to Cheshire, and developed locally into a tornado of exceptional violence. Such phenomena were experienced for a distance of about 11 miles up the Taff Valley in Glamorganshire, for about an equal distance in Shropshire, and for about 5 miles in Cheshire.

THE GENERAL METEOROLOGICAL SITUATION.

The general meteorological conditions which prevailed for several days before and after the occurrence showed a high-pressure system over Central Europe and a "low" over the Atlantic. They are illustrated in fig. 1, Plate I., a reproduction of the weather chart for 6 p.m. on October 27th. The wind over the region affected was mainly from South-east or South, while the temperature was distinctly above the average for the time of year, and the weather unsettled.

In order to study the general meteorological conditions, the autographic records collected at the Meteorological Office from stations over the whole of the United Kingdom were examined. As a general rule, the result of this investigation may be said to be negative, but over the South-western part of the British Isles some indications were noted of the advance from the South-west of a disturbance presenting a linear front, though the phenomena were not very definite. The records of pressure and temperature, except from stations near the line of violent disturbance, show no remarkable features, but in the South-west the records of anemometers equipped for recording wind direction as well as wind velocity, show a shift of wind from East or South-east to South or South-west. The advance of the line front can be further identified from reports of thunderstorms or heavy showers. Particulars will be found in fig. 2, Plate I.

THE REGION OF VIOLENT CHANGES.

Violent meteorological phenomena were confined approximately to a straight line running almost due North from the South of Devon to Cheshire. They did not exhibit themselves with equal intensity throughout the length of this line, shown in fig. 2, Plate I.; but there appear to have been four main regions of action:—(1) South Devon, (2) South Wales, (3) Shropshire, (4) Cheshire. Nevertheless,

reports of thunderstorms are to be found in the records from stations lying near this line, which agree sufficiently well in point of time with the occurrence of the violent phenomena to justify us in regarding the whole as a connected phenomenon travelling with a definite velocity from South to North. Reports of thunderstorms enable us to prolong this line into Lancashire.

It is interesting to note that this line marks the approximate Eastern limit of a region of heavy rainfall. Stations to the West of it generally experienced several tenths of an inch of rain, 0·4 inch being exceeded over a large part of Ireland, Wales, and the Cornish Peninsula. To the East of the line the rainfall decreased rapidly. Many stations experienced no rain, while at others the amount did not exceed a few hundredths of an inch. The distribution of the rainfall for October 27th over England and Ireland is shown in fig. 3, Plate II. No trace of the linear disturbance referred to above has been found to the East of the storm track.

The Disturbance in Devon.

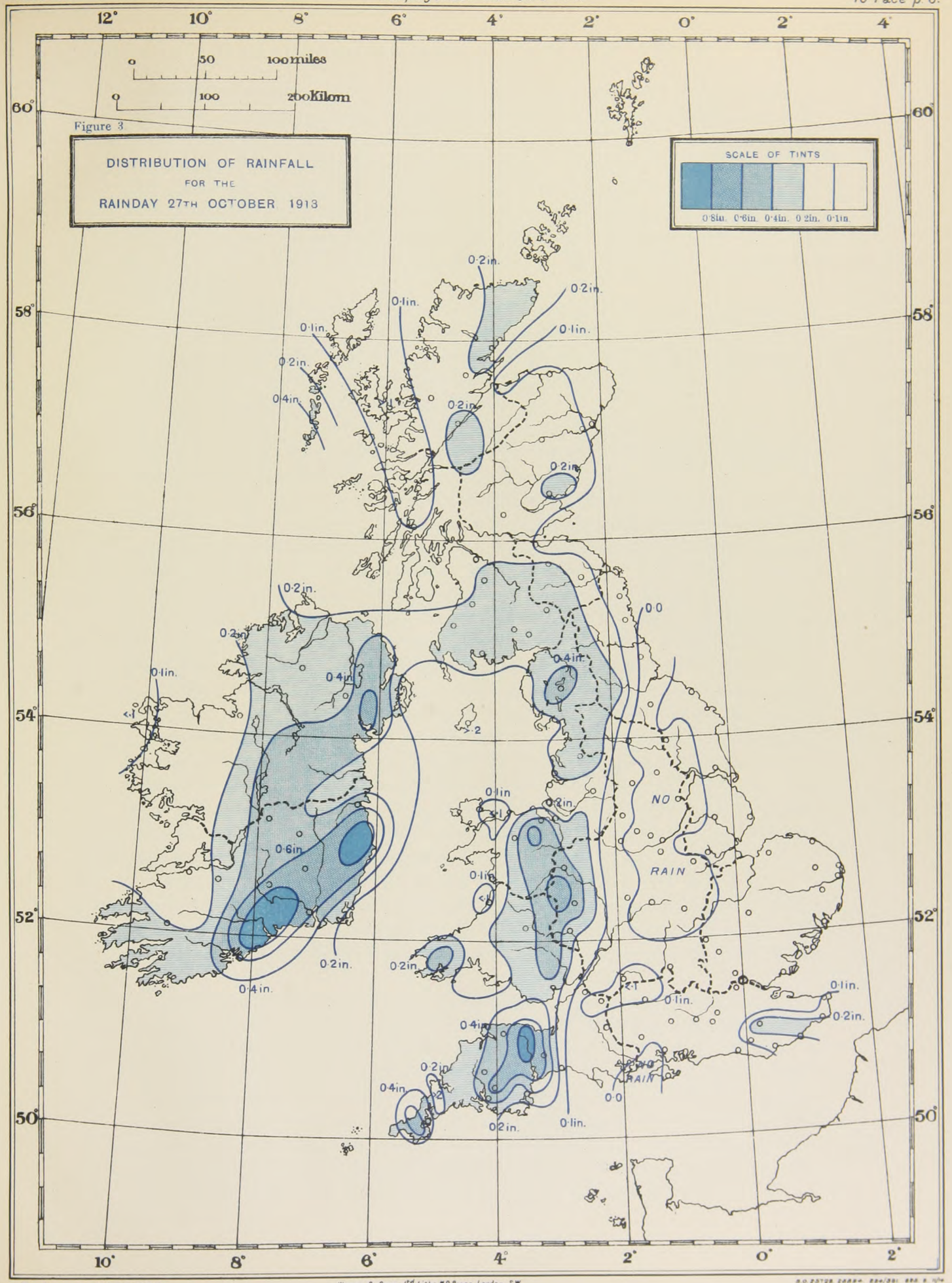
The main feature of the disturbance in Devon was the heavy precipitation. No accounts of high winds have come to hand for this region, but hail fell in great quantity and size. It appears that the exceptional precipitation was confined in the main to a narrow strip of country extending from Exmouth northwards to Watchet on the Coast of Somerset. The following are two accounts of the storm as it appeared in South Devon :—

"I left Exeter in my motor-car on my way back to Ottery St Mary at about 3.45 p.m. The day had been fairly fine, with a few light passing showers, in spite of a South-east wind and a low and falling barometer. It was beginning to rain a little when I started. . . . About 3 miles from Exeter I saw a very black cloud, from which rain was falling heavily, coming up apparently from the South-east. I may have been deceived as to the direction of motion, however, owing to the motion of the car. In a couple of minutes we plunged into it, and I do not think I ever saw such rain out of the tropics. The lightning was very vivid and close, but the flashes were not more frequent than in a fairly bad thunderstorm. . . . Immediately after the storm passed I could see it in the shape of a dense bluish cloud about 10 miles off to the North-west. . . . The cloud only covered a very small breadth, and it had not given any rain to speak of between the place where we stopped, about 5 miles from Exeter, and Ottery."—W. A. Willock, I.C.S., retired.

"The day had been more or less overcast and the temperature high for the end of October, with a falling barometer. At about 3.45 p.m. heavier clouds came up from the South-west, with freshening wind and rain, until at 4 o'clock there were several flashes of lightning with thunder. . . . Then at 4.5 p.m. a perfect deluge of rain fell, followed at once by a terrific hailstorm such as the oldest inhabitant never remembered having seen. . . . This storm lasted over 10 minutes. A noticeable fact was that the temperature was hardly affected either on the grass or in the air."—Murray T. Foster (Meteorological Observer, Collumpton).

The Tornado in South Wales.

The first sign of the storm after crossing the Bristol Channel was a heavy thunderstorm at Aberthaw, on the coast of South Wales, almost due North of Watchet. The


12° 10° 8° 6° 4° 2° 0° 2° 4°
0 50 100 miles
0 100 200 Kilom
60°
58°
56°
54°
52°
50°
Figure 3
DISTRIBUTION OF RAINFALL
FOR THE
RAINDAY 27TH OCTOBER 1913
SCALE OF TINTS
0·8in. 0·6in. 0·4in. 0·2in. 0·1in.
0·2in.
0·1in.
0·4in.
0·6in.
0·0
NO RAIN
Scale 1 : 5,000,000.
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first recorded material damage occurred at Dyffryn Dowlais, about 12 miles inland, to the North of Aberthaw, where light outdoor structures and hayricks suffered severely. Thence the track of the tornado was as shown on fig. 4, Plate III., which depicts the course in the South of England and in South Wales. It runs in a straight line slightly East of North up the Taff Valley by Llantwit Fardre, Treforest, and Pontypridd and on to Cilfynydd, Abercynon, Edwardsville, and Bedlinog. The width of the region of severe damage increased towards the North. At Dyffryn Dowlais it was only 50 yards wide, but it was 200 yards wide at Cilfynydd, and over 300 yards at Edwardsville.

One of the most remarkable features of the storm was the sharpness of its boundaries on either side of the track. Practically no damage was done outside the narrow limits of the course, which nowhere exceeded 1000 feet in width. The tornado was accompanied by very severe lightning and torrential rainfall, and reached its greatest force at Abercynon and Edwardsville, where five deaths occurred.

The following account of the storm, supplied by Mr B. P. Evans, F.R. Met. Soc., Headmaster of the Senior Boys' School, Treharris, who resides at "Arfryn," **Edwardsville,** will give a general idea of the occurrence :—

"At 4.30 p.m. the wind, a gentle breeze, was from S. by E., and by 5 p.m. was due S. At 5.15 p.m. a dead calm set in. The sky from 4.30 p.m. was heavily mottled with dark patches of cumuli in the South, but these clouds presented straight edges in the S.S.E. It was a 'troubled' sky. To the South, as the twilight advanced, a dark sullen sky was noted. The cumulus form had disappeared except in the East, where a heavy mottled appearance was still observable until darkness came on swiftly. During about half-an-hour of calm the atmosphere was oppressive, giving one a sense of great uneasiness, and a remark was made that rain would probably ease the tenseness.

"Rain began to fall at 5.20 p.m. The first flash of lightning (red) was noted at 5.25 p.m., coming from a dark cloudbank in the South. The rain ceased in about 10 minutes, and the red-coloured was followed by intensely blue lightning, flashing at frequent intervals. Very few peals of thunder were heard, these being sharp, with an absence of reverberation, and from about 5.40 p.m. the thunder was not evident. The blue lightning was appalling. When the flash occurred, which was most frequent, there seemed to be three or four interweaving flashes, all of a deep blue, and, what was strange, the waves of blue fire seemed to be rolling on the ground.

"A few seconds before 5.50 p.m. we heard a noise resembling the hissing of an express locomotive. The sound grew rapidly in volume, at last resembling the rushing speed of many road lorries racing along. The oppressiveness that had been previously noticed increased, and the heat and air-pressure were pronounced during the rushing noise.

"We endeavoured to move out of the room to the passage for greater safety, because a hurried remark was made that the engines of these supposed passing loaded steam lorries had collided before the house, and were about to burst, when the panes of our window were broken by stones, tiles, slates, dried cement, and splintered timber. The missiles broke the Venetian blinds and struck the opposite walls. We made for the rear of the house, but all these windows were being bombarded also by small material and corrugated iron sheets. We could distinctly hear the chimney-pots fall on the roof, and material sliding off being dashed on the pavement and doorstep. We could see the kitchen clock from the hall passage. It had stopped at 5.51 p.m. It

was not struck by any object. It is the largest clock in the house. Two smaller clocks in other rooms were not affected.

"After this crashing had ceased (this only lasted from 60 to 90 seconds), rain fell in torrents. The lightning set fire to the tar which had been sprayed some three weeks previously on the main Cardiff and Merthyr road, some 12 yards from our house door. A distinct smell of sulphur pervaded the air. The lightning continued fitfully and much less intense for about 5 minutes after the climax of the storm had passed, and thunder occurred during the rushing, crashing, roaring noise."

Particulars of Damage Experienced (from Notes collected by Mr Billett).

The positions of the places referred to are shown on the map of the Taff Vale, given in fig. 5, Plate III.

The first signs of damage were noted at **Dyffryn Dowlais** to light structures such as hencots and outhouses. A haystack was partially removed. The width of the track was about 50 yards. The storm then bore slightly East of North to the house of Mr Rees, the coroner, at **Llantwit Fardre,** uprooting several trees on the way, but not carrying them any distance. Mr Rees' house was damaged, but the houses on either side did not suffer except for the removal of a few slates. The force of the wind had increased, as is shown by the fact that a heavy wooden stable was toppled over, and part of a shed on the tennis-lawn carried for a considerable distance over a mound 20 feet high situated to the North. The instruments at the Post Office were put out of order by the lightning. The path continued in the same direction past **Lleiyon** Cottages—where the top of a dog's kennel was blown 100 yards, to the vicarage, in a North-east direction—to **Nant-yr-arian** Cottages, close to the vicarage, which was undamaged and marks the eastern limit of the storm track.

The storm then passed over the hill to the North of the vicarage, and does not seem to have done much damage till it got to **Treforest,** about a mile distant in a direction a little East of North, where the first building to suffer was the generating station. This stands on rising ground to the East of the town. The iron stack at the South of the power-house fell on to the roof. The Western side of the building, which was made of corrugated iron sheets, was blown *outwards completely.* At the same time all the lights went out. The width of the storm track at this point was not more than 150 yards. In the Northerly direction, the church and vicarage, both of which had part of the roof removed, mark the Western extremity and the Intermediate School the Eastern.

The course of the storm over the golf-course was traced by the schoolmaster at Cilfynydd, who had been all over the ground. The club-house on the Western side of the track was just touched, while the walls, marked on the map, were blown down.

The storm had gained in strength by the time it reached **Cilfynydd,** and its width had increased to 200 yards. On the west side of the track stood a co-operative store, with a roof of corrugated iron sheets supported on steel arches. These sheets were completely removed and carried over considerable distances. A sheet found ½ to 1 mile away, so firmly wrapped around a fallen telegraph-pole that it could not be removed, probably came from this store; no nearer origin could be assigned to it. The North side of a chapel close by was blown inwards, while great damage was done to roofs and interiors of houses in Richard Street and Wood Street. A number of hencots in allotment gardens vanished

Figure 4.

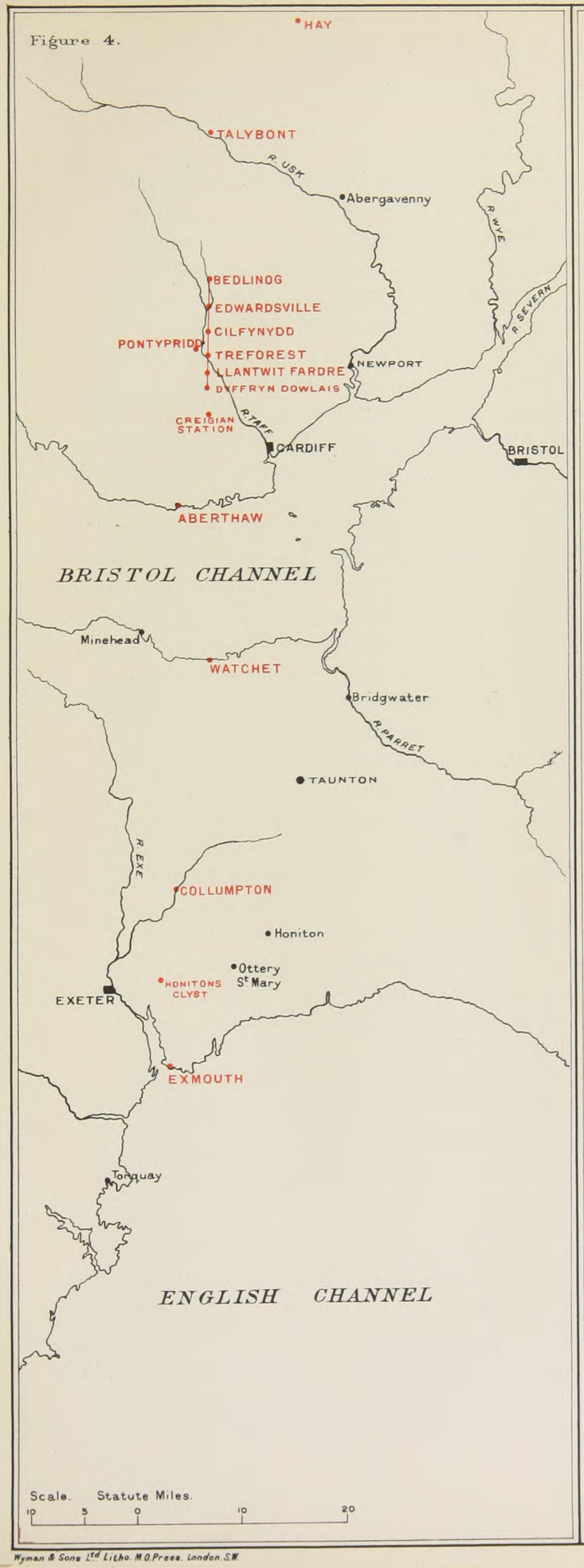
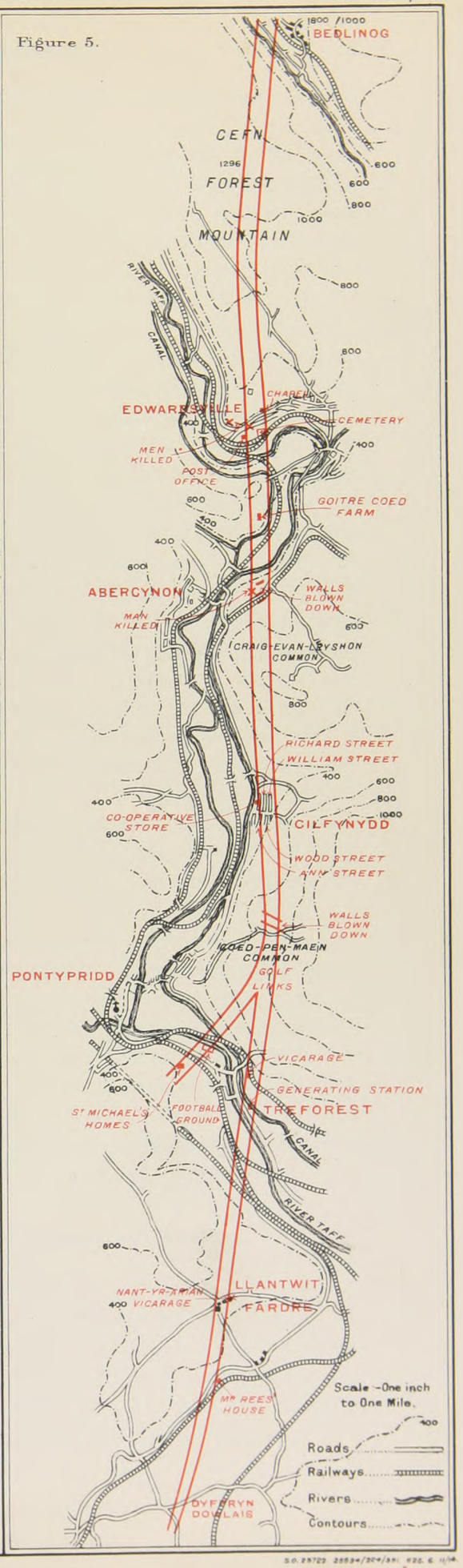


Figure 5.



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completely. On the road Northward to the Workman's Hall a man was blown into the canal 30 yards away.

From Cilfynydd the storm track continues in the same direction, skirting along the Eastern side of the valley to **Abercynon.** It crosses three parallel walls lying approximately at right angles to it. These walls were blown down for a space of about 150 yards, and it is interesting to note that, in the case of the first two, the Eastern half had fallen to the North and the Western to the South, while in the second wall there was a portion of about 15 yards in the middle left standing. The third wall was sheltered from the South by a bank 30 feet high, and was blown Northward. In the field between the second and third walls a man who had been walking along the road was found dead about 50 yards from the road, having pitched on his head. Across the valley to the North, at Abercynon, the wind attained tremendous violence. At one row of thirteen houses (Fairview) the roofs and joists were completely removed, except in the case of three or four houses in the middle of the row, while the partitions in the interior were smashed to bits. The row runs S.S.E. to N.N.W., and the force of the wind was felt at the back or East side. A photograph shows a roof blown away and lodged with one half hanging over the East wall of the house. In a field to the East a tree, which had been uprooted, was blown a distance of 80 yards, while considerable damage was done in a coppice to the South, the general lie of the trees being towards North. The track northward as far as **Edwardsville** has been mapped by Mr Thomas, the District Surveyor at Mountain Ash. It passes over Goitre Coed Farm, Penbwlcha Farm, Beech Grove Farm, and to Edwardsville (Quakers Yard). At Goitre Coed Farm a horse and cart were blown Northward against the South wall of the outbuildings. These buildings have walls $\frac{1}{2}$ yard thick, and were extensively damaged, the roof being quite gone.

At Edwardsville the storm seems to have reached its climax. It swept across the church, laying down most of the tombstones and wrecking the Cemetery Chapel. Considerable damage was done to slates in Nantdda Street. At the Post Office the windows were blown in.

The Congregational Chapel was wrecked, the pews inside being huddled up against the West side. A great tree was uprooted at the cross road, and lay towards the North-west. At these cross roads two fatalities occurred, one man being blown about 30 yards up the road to the Westward, and killed, either through concussion or through being struck on the head with a piece of flying slate, while a little boy was buried under a falling wall. Several pieces of slate were found buried to a depth of $1\frac{1}{2}$ inches across the grain of trees. The width of the track at Edwardsville was about 1000 feet. From this point the force seems to have abated, but further North, at **Bedlinog,** damage was done to roofs and trees.

Secondary Storm at Treforest.

Signs of a second disturbance were noted to the North of Treforest. This started on the high ground at the West of the town, at the St Michael's Cottage Homes. Its course did not run parallel with the main storm, but crossed the valley, blowing down a fence around the football-ground and breaking branches of trees. Finally it passed over a quarry on the East side of the valley and joined the main storm at Pentrebach Farm. The width was about 100 yards. The impression of the people is that the

storm came from the South-west, and the damage to the houses supports this view. The trees uprooted lie North-west, and this is also the case with the fence around the football-ground. The fence was on the right-hand side of the storm, so that it is probable that this subsidiary storm went to meet the main one and was not a deflection of it. The track of the subsidiary storm meets that of the main storm at an angle of about 45°, as shown on fig. 5, Plate III. The time of this occurrence agrees, within the probable error of the reports, with the time of the main storm.

The Storm in and around Shropshire.

The continuity of the disturbance in Shropshire with that in South Wales is shown by reports of severe thunderstorms in Talybont-on-Usk (see fig. 4, Plate III.), which is almost exactly in the extrapolated line of the South Wales tornado, about 15 miles North of Bedlinog, and at Hay, Herefordshire, 25 miles from Bedlinog and about 8 miles to the East of the line. The tornado proper again appeared about ½ mile South of **Ragdon,** near **Church Stretton,** and about 50 miles North of Bedlinog. Reports of severe thunderstorms with heavy hail come from Wistanstow, 3 miles South of Ragdon. The track of the tornado runs through Ragdon, Hazler Coppice (Church Stretton), All Stretton, and through Inwood Coppice and Lower Wood, as shown in figs. 6 and 8, Plate IV., the details for which have been supplied by the Rev. W. M. La Touche, Rector of Wistanstow. As in South Wales great damage was done to houses and trees. The width of the track was about 300 to 400 yards. At Ragdon a piece of corrugated iron was carried ½ mile to the Northward. There was also a well-defined track for a short distance at Shrewsbury. The whole distance from Ragdon to Shrewsbury is about 12 miles.

The Storm in Cheshire.

Further to the North, tornado winds appeared in parts of Cheshire. The places affected lie in the prolongation of the line of the tornado in South Wales and Shropshire. The following account of the phenomena is taken from an article by Mr A. H. Hignett, published in Symons's *Meteorological Magazine* for February 1914 :—

"A storm which did an immense amount of damage passed through Cheshire at about 8.30 p.m. on October 27th. It was preceded and accompanied by very heavy rain, which, together with the lateness of the hour and small population of the district, may account for there having been no human casualties. The few people who heard it describe the sound as that of 'hundreds of motor cars crashing through the trees.' It lasted 4½ minutes, and its track was about 150 yards wide. It was accompanied by very vivid lightning, which ran about over the ground, and was said to be prismatic in colour.

"After doing much damage in the neighbourhood of **Wem** and **Whitchurch** (respectively 10 and 18 miles North of Shrewsbury), the cyclone, which was travelling in a due northerly direction, appears, on entering the county of Cheshire, to have risen into the air, and passed over about seven miles of country, most of which is covered with very fine timber, without doing any damage. It then pounced down on a single tree standing alone in a field near Bulkeley Grange, smashing it to pieces. It then rose again for a further 1¼ miles, doing no damage until it reached a farm at **Peckforton Moss,** which lies at the foot of the Peckforton Hills, a range of hills about 600

to 700 feet above sea level. On first returning to the earth it appears to have divided into two tracks, which passed on either side of the farmhouse, destroying all the trees and buildings on each side, but leaving the house undamaged. These tracks joined again about half a mile or so further on, and the cyclone then travelled along the foot of the hills in a line parallel to them.

"It was here that the worst damage was done. The country is thickly covered with a very fine timber, and for a distance of over a mile hardly a single large tree was left standing in the track of the cyclone, 150 yards wide, any small ones which were not uprooted having most of their branches torn off. One large uprooted tree was found in the centre of a field, and could not be identified; it had evidently been carried a considerable distance.

"In several parts of the track of the cyclone the trees were laid down in *every* direction, which, with the way the tops were screwed off—many trees having only the trunks standing—would point to the 'whirlwind' nature of the storm.

"Several cows were lifted over a high hedge into an adjoining field, and three of them killed. Hen-houses, pig-styes, and hay-barns were carried away bodily, the galvanised iron sheets and the dead bodies of hens being found hung up in the branches of the fallen trees.

"The whole of the nearly new glass-houses and vineries in the gardens of Peckforton Castle, which lie in a very sheltered spot at the foot of the hill, were carried away, and some of the glass was found two miles further on, whereas, at the Castle itself, nothing was heard or known of the storm until the following morning.

"The Castle stands on the top of the hill, about 200 feet above and 400 to 500 yards to the west side of the track of the cyclone.

"It then travelled past the foot of the rock on which the ruins of **Beeston Castle** stand, unroofing a farm on its eastern side, and continued in a northerly direction, doing much damage at Willington Hall, **Kelsall,** and eventually passed into Lancashire near **Runcorn.**"

According to newspaper accounts, winds of sufficient violence to blow off the roof of a grand stand were experienced at Widnes and Runcorn. No accounts of structural damage have been received from places in Lancashire, but reports of thunderstorms come from places as far North as Blackpool.

Tornado in Gloucestershire on October 28th.

To avoid confusion at a later date, it may be as well to put on record here that tornado-like phenomena occurred in Gloucestershire on the day following the South Wales occurrence, *i.e.* October 28th, at about 5.20 p.m. The following account is taken from the *Times* newspaper of Saturday, November 1st, 1913:—

"A correspondent writes that on Tuesday, October 28th, the day after the storm in Wales, at 5.30 p.m., a small cyclone, about 150 yards wide, swept over Witcombe Park, Gloucester, from the South. It took, first of all, a haystack on the top of a hill, and scattered it to the four winds. It took the roof off a barn, and blew down some large trees, blocking the high road to Stroud for some distance. It then passed over Witcombe Wood, on a north slope, without doing damage. In the Park below it uprooted all the young oaks in its path, and flung them some distance, and completely stripped the old oaks of all their branches. Lower down the hill still it laid the whole

of the trees in one orchard flat, and most of those in a second orchard. It levelled the wall of the kitchen garden and many fruit trees in the garden, travelled over a farm beyond, taking elms on its way, by which a lane was blocked up, and died out about a mile further on. About £700 worth of damage was done. A thunderstorm was raging at the time, but it was not so severe as at other places. The whole atmosphere during the three minutes was a thick mass of whirling leaves, and the sky was yellow."

Rate and Progress of the Storm.

The information of the times at which the storm passed the places has been collected and put in order, to get an idea of the rate of travel of the disturbance. These are tabulated below, together with the distances and the calculated rate of travel. The figures show that where a distance sufficiently large is taken, and where, therefore, the effects of accidental errors of reckoning time are reduced, the mean rate of travel for the whole distance from Clyst Honiton to Runcorn is about 36 miles per hour.

	Place.	Storm passed. p.m.	Distance from Clyst Honiton. Miles.	Rate of Travel.
Devon	Clyst Honiton	4·0	...	...
	Collumpton	4·5	10	...
S. Wales	Llantwit Fardre	5·42	58	34 miles per hour.
	Treharris	5·51	65	35 ,, ,, ,,
Shropshire	Wistanstow	7·35	121	34 ,, ,, ,,
	Shrewsbury	7·45	137	37 ,, ,, ,,
Cheshire	Runcorn	about 9·0	179	36 ,, ,, ,,

It was not possible to determine the rate of travel by comparing the times of occurrence of corresponding phenomena over short distances such as the length of the track in South Wales. The margin of error attaching to the times reported from different places is too great to justify any such procedure. The duration of the storm at any one place was variously estimated at times ranging from 2 seconds to 5 minutes. On the assumption that the storm was circular in shape, and that its centre progressed with a speed of 36 miles per hour, we can calculate its maximum duration at any place from the width of the track within which damage was done. Taking this as 300 yards, the time works out at 17 seconds.

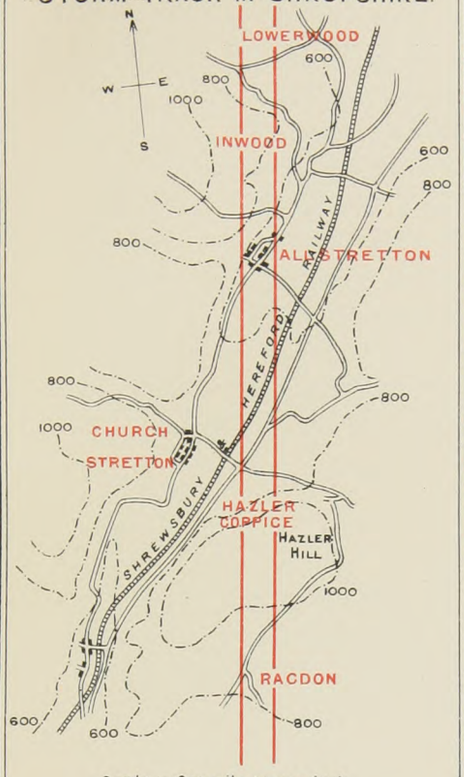
Internal Structure of the Storm.

The evidence in support of the rotatory character of the storm is strong. It was generally reported that the violent wind was felt first from one direction and then from the opposite, the rotation being against the hands of the clock.

Taking the places in order:—(*a*) At the house of Mr Rees at Llantwit the front door facing East was blown inwards, while the tennis-shed on the lawn at the rear of the house was blown Southward. The stable in the middle of the track was blown over Northward, and the roof blown over a mound 20 feet high, parts being found near Llantwit Church. (*b*) Further on, between Cilfynydd and Abercynon, stood the three approximately parallel walls previously mentioned, with their West side blown Southward and their East side Northward. The part left standing in the

Figure 6.

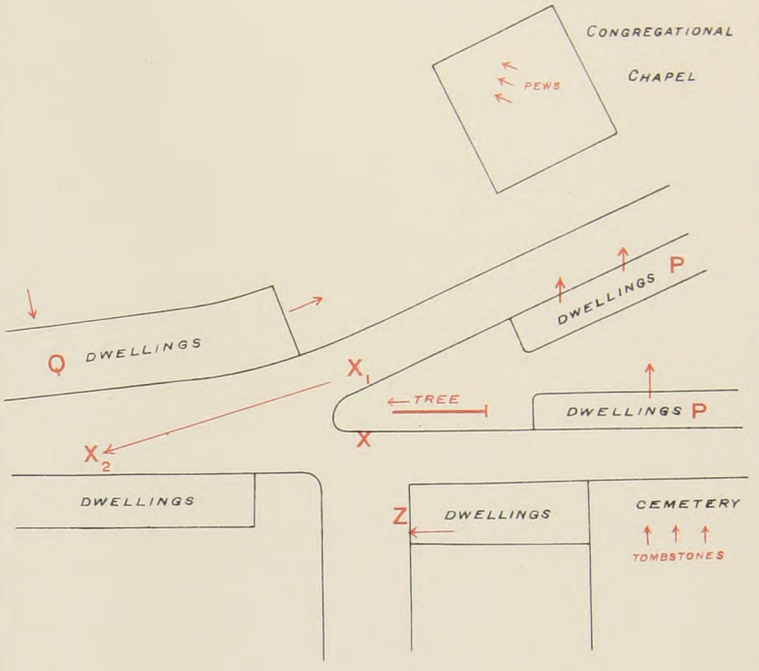
Storm Track in Shropshire.



Scale :- One mile to one inch.

Figure 7.

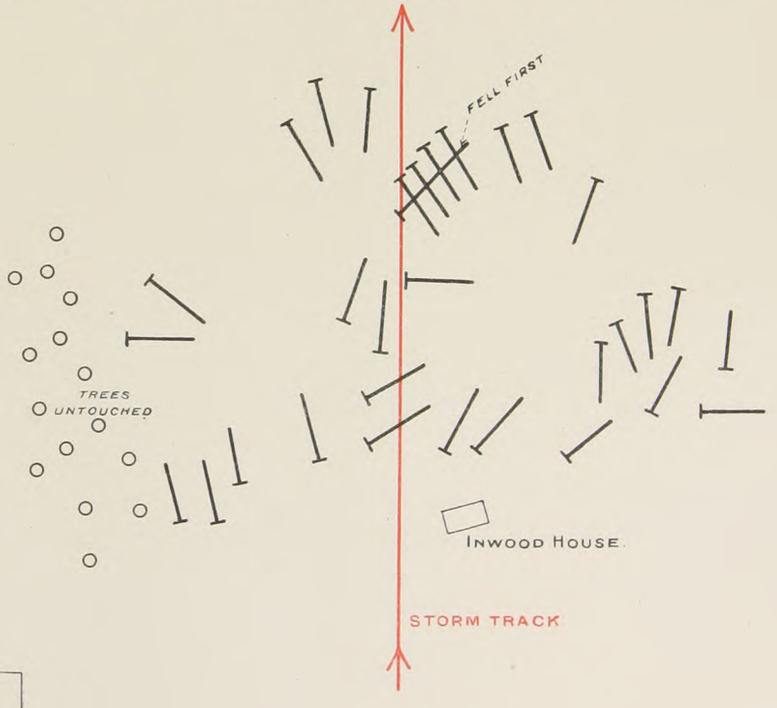
Damage at Edwardsville.



Arrows show the direction of motion of débris.

Figure 8.

Damage at Inwood Coppice, All Stretton.



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middle of one is probably due to the wind being along and not at right angles to the walls in the centre of the track. (*c*) At Edwardsville the dwellings on the East of the track (P, fig. 7, Plate IV.) had their roofs blown in a Northerly direction; and the same has happened to the majority of the tombstones in the churchyard, though these were set for the most part with their planes East and West. The Congregational Chapel had its pews and roof swept in a North-west direction, while a large tree on a spare plot of land at the junction of the two main roads was up-rooted and laid Westerly. The houses at Q felt the force of the wind at their back, the windows being blown inwards. A man was blown from X_1 to X_2, as previously related, and killed, while two men sheltering under the wall at X, on the South side, were not hurt. A little boy was also killed by the wall Z falling on him. (*d*) Further North, at Bedlinog, the East side of the roofs and plate-glass windows fell inwards on the right of the storm. (*e*) The sketch of the damage done in Shropshire, shown in fig. 8, has been supplied by the Rev. W. M. La Touche.

Lightning Effects.

Concomitantly with the height of the storm, a number of people saw globular lightning. The following are extracts from two letters received.

Mr W. M. Morris, of Cardiff, was travelling from Pontypridd to Cardiff, and what he says is verified by four or five other people in the same compartment:—

"Repeated flashes continued for four minutes, and the train travelled slower than usual, till we reached Creigiau Station, at 5.23 p.m., when I clearly observed a ball of fire, apparently the size of my hat, flashing along with a blinding sheet of lightning, and travelling from South to North. I remarked to others about the thunderbolt, and that great damage would be done somewhere by it."

Mr T. A. Thomas, Wood Street, Pontypridd, writes:—

"I saw nothing out of the ordinary run of thunderstorms until I had reached a point a little beyond Wood Street Schools. Here I observed a flash of lightning, which seemed to assume a globular shape, sending out a long tail-like stream of light. This was followed almost instantly by the first crash of thunder, which was peculiar in its sound. It reminded me forcibly of the rattle peculiar to small artillery, with the noise intensified."

The following also saw a similar appearance:—

Mr A. Thomas, Architect,
Mr J. Davis, Schoolmaster,
Mr J. Edwards, Penheolely Farm, and
Mr Rees' son. } Cilfynydd.

In this connection it may be pointed out that the storm had lasted for ½ hour to 1 hour with practically incessant lightning and thunder, so that people could distinctly distinguish objects a mile away. Therefore, at the time at which globular lightning is reported, the observers would have become accustomed to ordinary lightning. Again, the reports are not isolated, and come from places miles away from each other.

It is remarkable that so little damage by lightning has been found. Many people saw lightning playing about their houses.

The following effects may be attributed to lightning, but the evidence that they were so caused is not definite :—

(*a*) Under the hill North of Cilfynydd, where the parallel walls were blown down, is a disused colliery railroad. On its South side this had its turf removed, and in one case, where the process had not quite taken place, cracks on the turf were seen.

(*b*) At the same place evidences of charring were found on the stone, and a cinder exhibited what looked like little globules of fused lead.

(*c*) At Goitre Coed Farm two unmortared walls and hedges were distinctly charred, and fences around showed signs of burning, while a rock having a horizontal cleavage about half way down was blackened in this cleavage, but not on the top.

(*d*) Fresh tar sprayed on the road at Edwardsville caught alight, and the surface seemed to have an air space beneath it.

Pungent Smell.

Another feature which was widely reported was the smell of what were termed sulphurous fumes when the storm was at its height, and in many cases this smell is said to have persisted for days in clothes. It is possible that this smell was due to oxide of nitrogen formed during the electrical discharge. The action of the lightning might cause the formation of the higher oxides of nitrogen from the constituents of the air. The rain would dissolve these fumes and form nitric acid, which would give a persistent smell in clothes. The above process is one way in which nitrates are "fixed" in the soil. In this connection it may be observed that "sulphurous fumes" are reported to have been noticed during the tornado at Americus on July 18, 1881. (See "Report on the Character of Six Hundred Tornados," by J. P. Finlay, *Professional Papers of the Signal Service*, No. VII.)

Records of Autographic Instruments from Places near the Storm Track.

Wind Records.—Unfortunately the track did not pass over or near a station equipped with an autographic anemometer, and thus no measurements of the wind velocity attained in or near the tornado are available.

Barograms.—It has already been stated that the barograms collected from different parts of the country for the most part show no noteworthy features. Records from places near the line of the disturbance show a sudden fall of the barometer of a few hundredths of an inch as the tornado passed, followed by a return to the original value after an interval of about $\frac{1}{4}$ to $\frac{1}{2}$ an hour. Barograms from the Cwmcynon and Merthyr Vale collieries, situated respectively 3 miles and $1\frac{1}{2}$ miles to the west of the track, show dips of about ·03 inch. Records from Merthyr, about 6 miles to the North-west of Bedlinog, the northern extremity of the tornado track in South Wales, show no trace of disturbance, but a slight dip appears on a barogram for a place only 4 miles from Bedlinog, in the same direction.

A record lent by Mr T. M. Howell, Shrewsbury, taken in a house situated only about 150 yards from the tornado track in Shropshire, shows a dip of about ·07 inch. At Wistanstow, about 3 miles South of the southern limit of the Shropshire tornado, the dip amounted to ·03 inch.

The most interesting record comes from the Albion Steam Coal Colliery, situated

only a few yards from the South Wales track. The record shows a fall of pressure from 29·20 to 28·91 inches, followed by an almost immediate rise. The discontinuity on the chart appears as a single vertical line. This fall of 0·3 inch, or $\frac{1}{100}$ of the normal atmospheric pressure of 15 lbs. to the square inch, means a sudden change in the atmospheric pressure of 0·15 lb. per square inch, or about 20 lbs. per square foot. Such a change of pressure, if applied suddenly to the outside of a closed building, must produce an effect similar to an explosion from within, and it is thus easy to understand how windows or even whole walls are blown outwards, as at the generating station at Treforest. It may be argued that the full value of 20 lbs. per square foot would not be attained, owing to partial equalisation of the pressure through chimneys, windows, doors, or other openings, but against this must be set the fact that at places actually within and not merely near the track the sudden fall of pressure was in all probability considerably greater.

The evidence collected shows that the storm was a genuine tornado of the type common enough in parts of America, but fortunately of rare occurrence in this country. The straight track with clean cut lateral limits, the violent electrical phenomena, the heavy rainfall, the roaring noise, the sudden decrease of barometric pressure resulting in the blowing out of the walls of buildings, as if by explosion from within, are all features which are common in descriptions of American tornados. The width of the track, 300 yards, and the rate of advance, 36 miles per hour, are of the same magnitude as in American tornados.

Only one account has been received which suggests the typical funnel-shaped tornado cloud stretching down to earth. It is from Mr Dan Williams of Treharris, who saw a dark cloud extending from sky to earth and suggesting to him a huge waterspout. Probably, if the event had occurred earlier in the day, while daylight was stronger, this phenomenon would have attracted more general attention.

It is commonly claimed that in America tornados generally occur under conditions of great difference of air temperature over short distances. This was certainly not the case on the present occasion, as will be seen on referring to the temperatures shown on the map, fig. 1.

Tornados, though rare in this country, are by no means unknown, and the index to Symons's *Meteorological Magazine*, in which such phenomena are generally put on record, give references to forty similar occurrences, most of them, no doubt, less violent than the one under discussion, in the years from 1866 to 1895.

In the absence of observations in the upper air no hypothesis can be put forward as to the probable cause of the disturbance. The surface conditions, as revealed by the meteorological observations collected at the Meteorological Office, afford no clue to the reason for the development of a region of great atmospheric instability near Exmouth, and for its subsequent travel along the path described into Cheshire.

[P.T.O.

NOTE ON PRESSURE OSCILLATIONS OBSERVED ON AUGUST 14, 1914.

Striking variations of pressure occurred on August 14–15, 1914, over a wide area in the British Isles. A selection of barograms is reproduced on Plate V. Most of the curves show periodic oscillations of the following approximate periods and amplitudes :—

	Period in Minutes.	Amplitude in Millibars.	Time of Commencement.		
			h	m	
South Kensington micro-barogram . . .	9	...	0	20	(15th).
Ditcham Park (Petersfield) micro-barogram .	12	...	22	24	(14th).
Kew photo-barogram	10	0·3	0	10	(15th).
Falmouth float-barogram . .	10	0·5	8	10	(14th).
Benson (Oxon) float-barogram . . .	8	0·5	23	20	(14th)

At Portland Bill the curve was of a different type. The chief characteristic was a sudden rise of pressure of about 3 mb., followed about $2\frac{3}{4}$ hours later by a return to almost the original value. The trace is too thick and the time scale too contracted for one to decide whether periodic oscillations similar to those above were also present. The curve for Dungeness is similar in general features to that from Portland.

The pressure distribution at 6 p.m. on 14th August showed high-pressure systems to the northward of Scotland, and between the Azores and Spain, with an extensive and shallow low-pressure system covering Ireland and the South-west of England.

The evening map shows easterly winds on the East of England, with variable airs further westward, and light westerly winds in the extreme West, beyond the region of lowest pressure values.

Thunderstorms occurred extensively in the West. Their distribution is shown in the small map on Plate V. The easterly wind maintained itself in the eastern counties throughout the night, and thunderstorms did not advance eastward of a line running from Beachy Head to Holyhead.

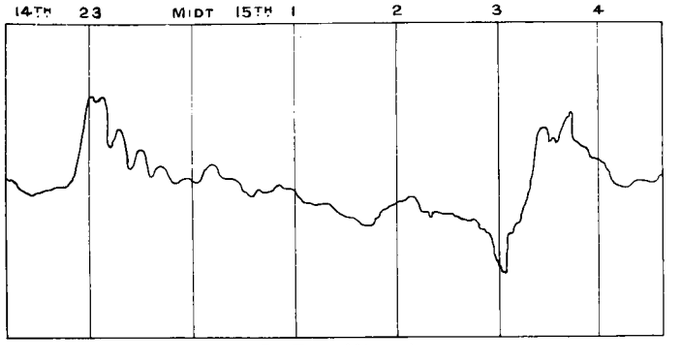
Thunder was violent in the neighbourhead of Portland Bill about the time of the commencement of the rapid variations of pressure; and it is interesting to note that if the times of commencement of the oscillations in the South-east of England be plotted on a map, they lend themselves to the construction of the set of isochronous lines shown in the last figure on Plate V. The suggestion that the heavy thunderstorm near Portland Bill may have been in some way the cause of the periodic oscillation noticed further to the East and North-east is an obvious one, but the oscillations at Valencia and Falmouth do not fit in with the scheme of isochronous lines, and their cause must be sought elsewhere.

Similar oscillations of pressure have been noticed on barograms with open time scales on other occasions. A selection of curves was shown at the Meeting of the British Association at Dublin in 1908, and reproduced in connection with a discussion on "Wave Motion in the Atmosphere," held by Section A.

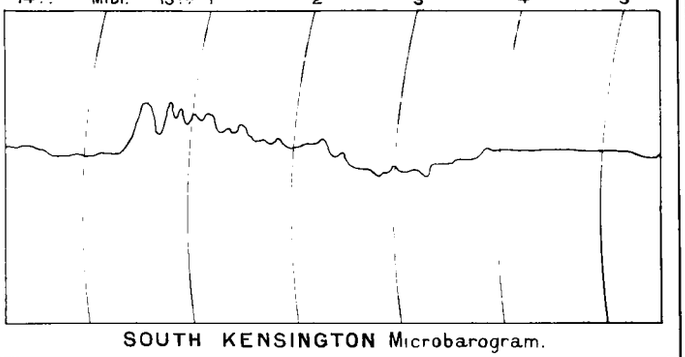
There is reason to believe that the phenomenon is due to an oscillation at the horizontal boundary of two strata of air of different densities. It has formed the subject of mathematical investigations by Helmholz (*Berl. Sitzb.*, 1889 and 1890), Kelvin (*B. A. Report*, 1876; *Math. and Phys. Paper*, vol. iv. p. 457), and Lamb (*Proc. Roy. Soc.*, 1910, vol. 84, pp. 551–572), and other writers.

Theory shows that the period of the oscillation can be calculated from a knowledge of the height of the separating surface, the relative velocity of the two layers, and the magnitude of the discontinuity of temperature occurring at the boundary. All these particulars could be got from a combined registering and pilot balloon ascent, but, unfortunately, no ascents are available for August 14th, and it is thus not possible to apply the theoretical considerations to this particular case in order to see how far the theoretical deductions are confirmed by observations.

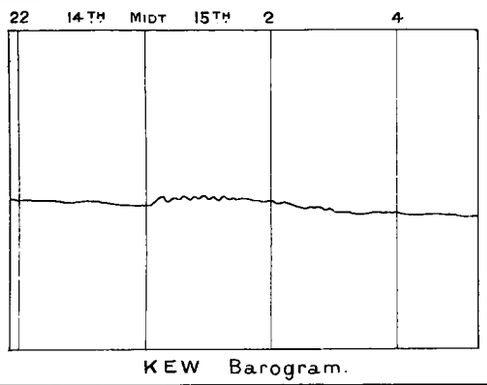
PRESSURE OSCILLATIONS ON AUGUST 14TH TO 15TH 1914.



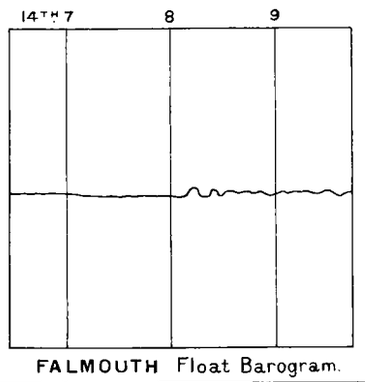
DITCHAM PARK Microbarogram.



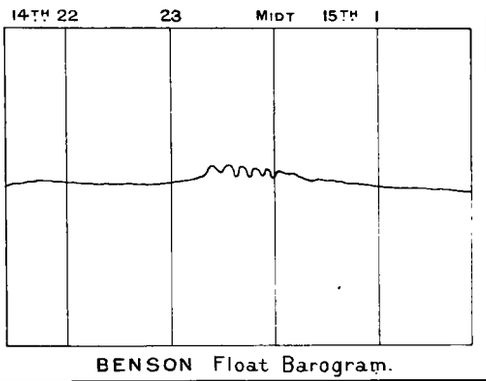
SOUTH KENSINGTON Microbarogram.



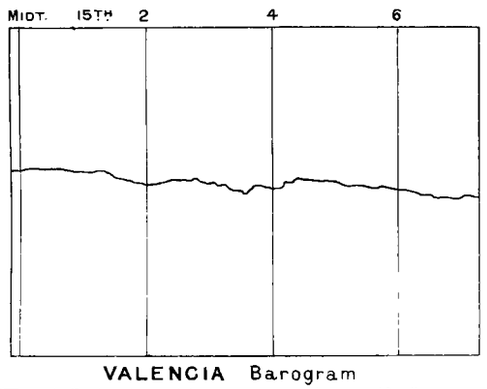
KEW Barogram.



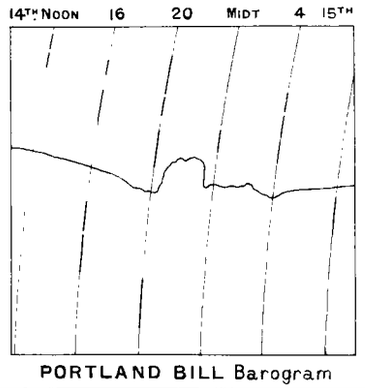
FALMOUTH Float Barogram.



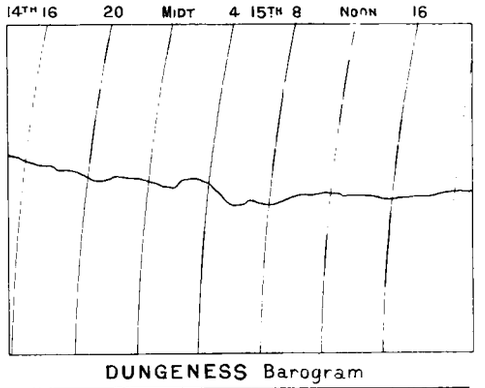
BENSON Float Barogram.



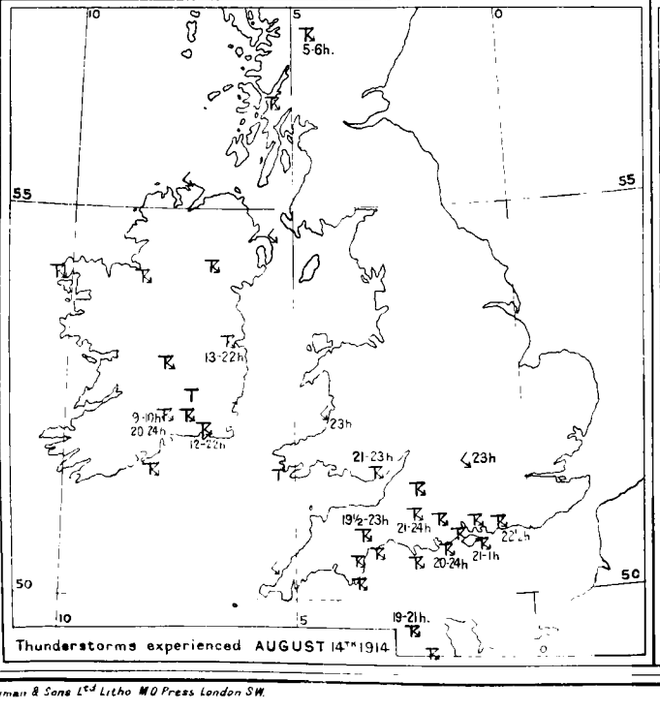
VALENCIA Barogram

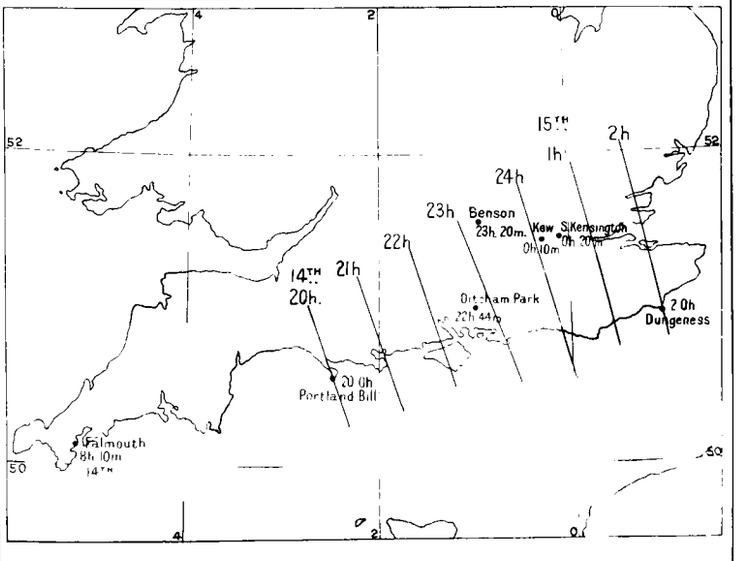


PORTLAND BILL Barogram



DUNGENESS Barogram





ISOCHRONOUS LINES SHOWING COMMENCEMENT OF OSCILLATIONS OVER SOUTH-EAST ENGLAND.

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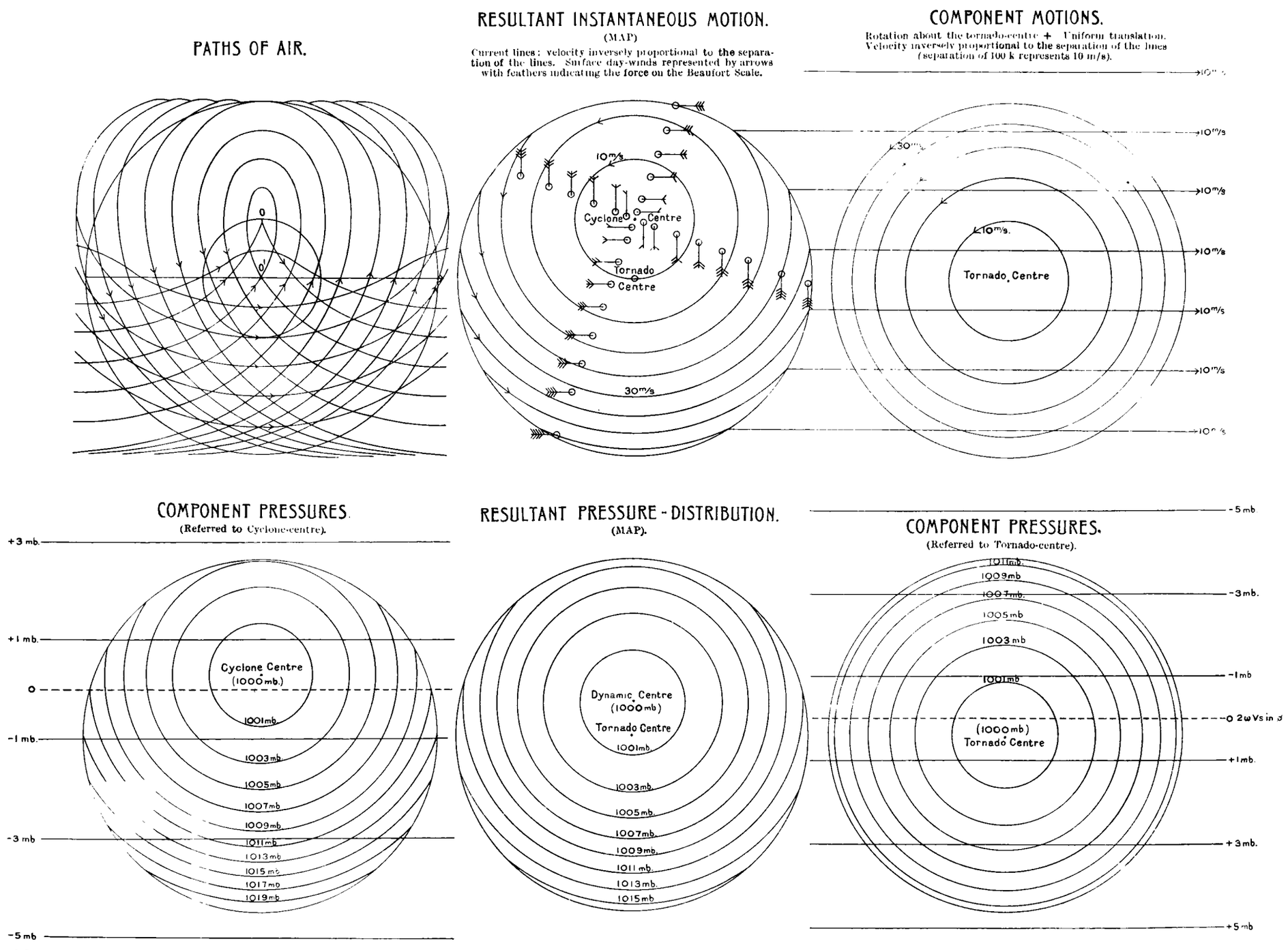
Graphic Analysis of the Motion of Air in a Cyclone of Uniform Vorticity (10 m/s per 100 k) travelling at 10 m/s in Latitude 52° N. and of the Pressure-distribution appropriate for its Persistence.



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