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1877

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EXECUTIVE DOCUMENTS

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IN SEVENTEEN VOLUMES:

Volume 1....No. 1, Foreign Relations, parts 1, 2, and 3.
Volume 2....No. 1, part 2, War, parts 1, 2, and 3.
Volume 3....No. 1, parts 3 and 4, Navy and Postmaster.
Volume 4....No. 1, part 5, Interior, parts 1 and 2.
Volume 5....No. 1, part 6, and No. 2.
Volume 6....Nos. 3 and 4.
Volume 7....Nos. 5, 36, 124, and 187.
Volume 8....No. 6 to No. 57, inclusive, except No. 36.
Volume 9....No. 58 to No. 122, inclusive.
Volume 10....No. 123 to No. 141, inclusive, except Nos. 124 and 133.
Volume 11....No. 133, Coast Survey.
Volume 12....No. 142 to No. 210, inclusive, except Nos. 143, 183, and 187.
Volume 13....No. 143, Commercial Relations.
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Volume 16....No. 220 to No. 255, inclusive.
Volume 17....No. 256 to No. 290, inclusive.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1874.

Sailors, drowned, &c.

Drowned	2	7	11	11	9	4
Killed by fall, &c		3	3	2	2	1
Seriously injured	4	6	...	1	3	1
Total						64

PAPER 30.

WAR DEPARTMENT, OFFICE OF THE CHIEF SIGNAL-OFFICER,
Washington, D. C., July 26, 1873.

SIR: I have the honor to report as follows: Having, in accordance with Special Orders No. 67, arrived at the scene of the tornado in Iowa, I there, to the best of my ability, endeavored to carry out the special instructions which I had received. The result is contained in the report herewith submitted.

Very respectfully, your obedient servant,

JAS. MACKINTOSH,
Observer-Sergeant Signal Service, U. S. A.

Gen. ALBERT J. MYER, *Chief Signal-Officer of the Army.*

WAR DEPARTMENT, OFFICE OF THE CHIEF SIGNAL-OFFICER,
DIVISION OF TELEGRAMS AND REPORTS FOR THE BENEFIT OF COMMERCE,
Washington, D. C., May 26, 1873.

SERGEANT: Upon arriving at Washington, Iowa, in compliance with Special Order No. 67, O. C. S. O., of this date, you will at once proceed to the scene of the recent tornado near that place, and locating the point where it first struck the earth, will follow its path as far as its progress can be distinctly traced, giving particular attention to the following points suggested by the Chief Signal-Officer:

1. Trace accurately the course of the tornado, and determine whether its movement was direct, or whether it swerved at any time from a direct course, and, if so, the cause of such deflection.

2. Ascertain the velocity of wind in the whirl of the tornado; estimating this, when more accurate data cannot be had, from its effect upon inanimate objects, as for example, weight of objects moved, with area of surface of such objects exposed to the action of the wind.

3. Ascertain if objects were carried directly upward in the interior of the whirl without a whirling motion and thrown out at top, or whether they ascended in circles, whirling upward with the whirl of the tornado.

4. State if there are any evidences that the center of the tornado was a vacuum, as for examples: were trees wholly stripped of bark; did houses explode outward, &c.?

5. Ascertain if the tornado appeared to be attached at its upper extremity to masses of clouds, or to a single and small cloud.

6. Were there any electrical discharges accompanying the tornado?

7. Was the tornado seen, before its complete formation, as a tongue of cloud hanging down from a mass of clouds?

8. Did it any time cross a body of water; and, if so, did it assume at that point the character of a water-spout?

9. Did the tongue of cloud, reaching toward the earth, distinctly whirl itself, or was it stationary, with a whirling column of air rushing up its interior?

10. Collect reliable data as to the greatest height to which objects were elevated, and their weight.

11. Ascertain the condition of air outside the tornado, and whether the wind blew toward it from all directions.

12. Were there any premonitory signs of an approaching storm before the tornado struck the earth?

13. Where did the tornado originate, and where terminate?

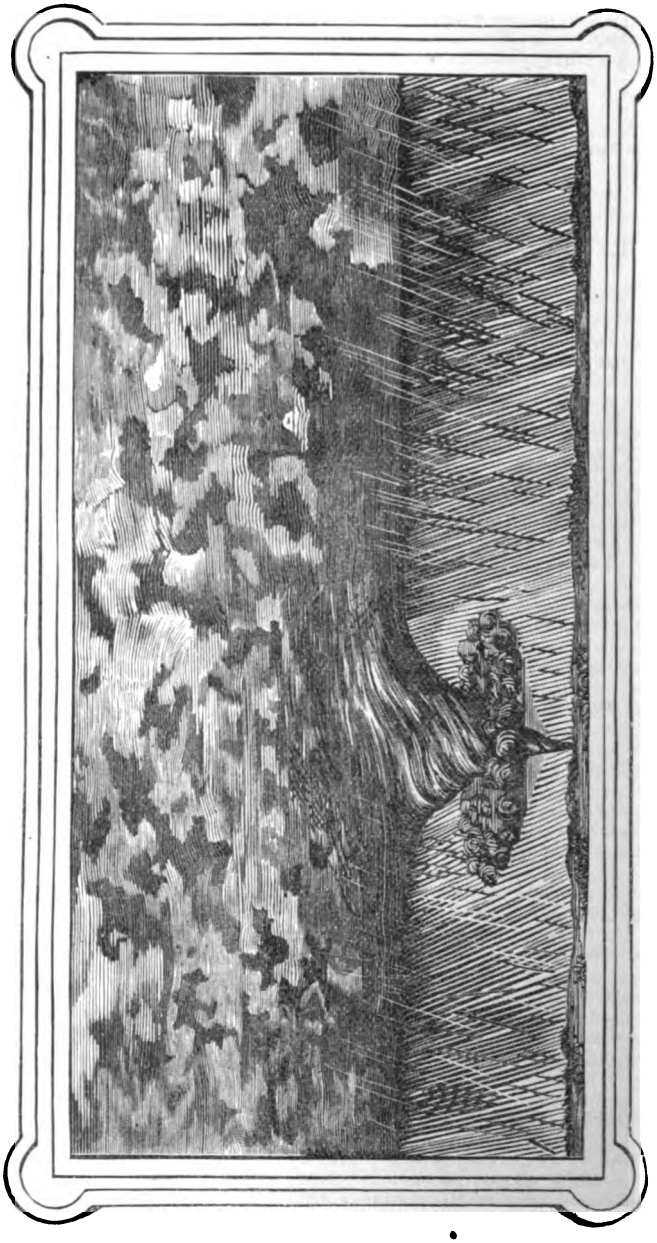
14. Determine particularly whether the cloud from which the tongue of cloud depended had a rotary motion, or whether the tongue of cloud itself had one.

15. Duration of tornado, and progressive velocity.

16. Actual width of belt affected by the tornado.

17. Note the general direction of prostration of trees, being careful to allow for the change of direction caused by striking the earth.

18. You will prepare a series of questions to which answers will be obtained from the most intelligent citizens living in and along the track of the tornado, so that the same questions may be answered by different persons.



In addition to these points, you will investigate such others as will tend to give a connected and full record of the origin, progress, and disappearance of the meteor.

Having completed your investigation of the Iowa tornado, you will proceed to the location of the one reported in Illinois as raging on the same date, and follow out the same course of inquiry as for the Iowa storm.

Take ample time to do the work thoroughly, and report your location from time to time by telegraph.

Very respectfully, &c.,

H. W. HOWGATE,
Second Lieut. and Bvt. Capt., Acting Signal Officer and Assistant.

Sergt. JAS. MACKINTOSH,
Observer Signal-Service, U. S. A., Washington, D. C.

THE IOWA AND ILLINOIS TORNADO OF MAY 22, 1873.

STATEMENT OF THE FACTS.

This tornado could not by its destructive efforts upon trees, buildings, &c., be traced farther back than section 35, Warren Township, Keokuk County, Iowa. At the point where the destruction commenced, the South Skunk River bends southward and then again to the east, thus half inclosing a low level area of about one mile in length by half a mile in breadth. This bottom-land is surrounded by bluffs about 70 feet in height on nearly all sides, the river flowing close to the bluff on the southwest. It was at the northeast edge of this natural amphitheatre that the tornado first attained force sufficient to demolish fences. These fences were thrown down by a southwest wind for a space forty rods wide. The buildings of W. W. Morrow, situated half way up the bluff, were partly destroyed. But although its first destructive efforts were here manifested, it by no means follows that this was the starting point of the tornado. On the other side of South Skunk River, directly opposite, there was a strong wind, accompanied with some hail and rain, while to the north and west a tremendous rain fell, preceded and accompanied by large hail. The storm evidently arrived at Morrow's farm a well-nigh full-formed tornado. To trace it backward over a country where its phenomena were only those of a violent thunder-storm, I found to be difficult and deemed unnecessary.

The attempt to prove a connection between this tornado and the thunder-storm near Des Moines of May 22, 4 a. m., has not been successful. For although the Des Moines storm exhibited tornado-like power, since the distance between Des Moines and Morrow's farm is only seventy miles, and since the Des Moines storm occurred ten hours previously, its rate of motion, if it is identical with the Keokuk County tornado, cannot have exceeded seven miles per hour in a straight line. But, as will afterwards be shown, the tornado traveled more than twenty-nine miles per hour. This objection is by no means insuperable when viewed in the light cast upon the subject by the general modes of movement of storm-centers across the continent. These tornadoes, however, exist as something independent and automatic within the limits of areas of low barometer, and since their motion is governed by laws peculiar to themselves, it must meanwhile be accepted as valid. Besides, a hail-storm traversed Keokuk and Washington counties May 22, at 6 or 7 a. m. There is much more probability of a connection between this hail-storm and the Des Moines storm of 4 a. m. than between the latter and the tornado which occurred eight hours subsequently.

In the Neosho County Journal, of May 24, is an account of a highly destructive tornado which desolated a portion of Lincoln county six miles long by one-half mile wide. This tornado was apparently every whit as violent as that in Iowa. The time at which it occurred is given as about 3 p. m. It cannot, therefore, be identical with the subject of this paper.

The conclusion follows that, wherever this tornado may have originated, it first attained to desolating violence on Morrow's farm. Its previous history was only that of a thunder-storm, accompanied, perhaps, by an unusual tumult and whirling of the clouds. In tracing its development and progress, therefore, I probably labor under no disadvantages which do not necessarily attach to the history of all such meteors except those arising from the circumstance that the tornado was not at any point of its progress witnessed by a skillful meteorologist.

Mr. Morrow testified that neither he nor any of his people noticed any funnel-shaped appearance or tongue of cloud approaching the earth. There was a strong wind for a minute, but the destructive gust appeared to be instantaneous. A smart shower of hail followed the gust. A whirling of the clouds was observed several minutes before the wind. A little lightning was seen. The storm traveled east-northeast over Andrew

Surber's farm, blowing down fences, with a southwest wind. He saw the clouds whirling like a great wheel 35° in width before the storm, but did not notice any funnel appearance. A few hail fell with the wind, and a considerable shower of rain after it.

The same phenomena were repeated on J. E. Storer's farm. A steady roar was heard as it approached. No lightning seen.

About forty rods north of the line of destruction on these farms resides William P. Liske. He saw two clouds, one in the southwest and the other in the northwest, which appeared to rush together in the west. As the tornado came up, and about twenty minutes before it arrived, the wind changed to the north and blew so strongly that the door had to be held to prevent it from being blown in. Saw no lightning and heard but little thunder. Saw no funnel appearance.

Elleot Utterback was sixty rods south of the tornado at this place. He saw the clouds come whirling. The height of the whirling clouds was about 60° and the width about 30°. Saw lightning and heard thunder once or twice. Hail followed the wind in small quantity, and rain fell in considerable amount three-quarters of an hour later. During the day the direction of the wind was southerly.

John Malcum, section 30, Lancaster Township, testified: Was one mile south of tornado when it occurred. Heard a roaring like steady thunder in the west about a quarter of an hour before the storm came. Saw no lightning. A cloud covered the western, the northern and the northeastern portion of the sky. It extended somewhat beyond the zenith. The rest of the sky was clear. Saw a whirling mass of clouds. Could distinctly see them whirl contrary to the hands of a watch. The whirling mass appeared to be about 60° high when directly opposite. A smart shower fell some time after the tornado.

On Malcum's farm, the roof of a stable was blown to the southeast. This was the first damage done by a northwest wind. Two hundred yards south of the stable a fence was blown toward the northwest and north. This was the first evidence of a destructive southeast and south wind. The storm after becoming destructive had traveled one and a half miles before it developed force sufficient to commit destruction by a northwest and southeast wind.

T. Dawson, section 31, Lancaster Township: The tornado passed directly over the farm-buildings. He testified: Saw tornado approaching like two dark clouds with an intervening lighter-colored space between them. These two clouds together presented a funnel-shaped appearance; the upper end of the funnel entered the overhanging mass of cloud, which covered the half of the sky and extended to the southeast a little beyond the zenith. Its lower end did not touch the earth. It whirled contrary to the hands of a watch. Its elevation appeared to be about 60°, and its width at summit 40°. Heard some thunder previous to tornado. Did not see any lightning. After the tornado, there fell a few small hail and a little rain.

The breadth of fences thrown down on this farm was about sixty rods. The outhouses, &c., were damaged. A cultivator weighing about two hundred pounds was carried or dragged 30 feet. It presented to the wind a surface of not more than 3 square feet. If it was carried, the lifting force of the wind must have been between sixty and seventy pounds per square foot. The ground showed no signs of its having been dragged.

M. Williams, lawyer, section 32, Lancaster Township, testified: Time, probably 2.10 p. m; it was a few minutes after 2 p. m. Watched the storm as it approached for about one hour. A cloud rose in the west, which, stretching to the northwest, presented the appearance of heavy rain. Previous to the approach of this cloud, the sky was nearly clear. The wind during the day was southerly. About twenty-five minutes after the tornado the wind was again from the southwest. The storm-cloud did not extend far past the zenith to the south. Saw the funnel distinctly. It alternately lengthened and contracted, rose and fell. When it contracted, it appeared as if the narrow point next the earth was cut off, leaving the lower end broader. At times the upper end appeared to reach the overhanging clouds, and at times to be not so high. Its shape was something like [redacted] It was of a dark-blue color when two hundred and fifty yards distant. When [redacted] three hundred yards distant it subtended an angle of about 75°. The angle subtended by the top of it at that distance was about 55°. It had a zigzag motion. Half an hour previous to the tornado, there was incessant lightning in the northwest. Heard no thunder. There was no lightning in the tornado. A little rain and hail fell just before the tornado, and a smart rain-shower about twenty minutes after it. Have heard that to the northward there was a terrific storm of rain and hail accompanied with thunder and lightning. The wind was south generally during the day. As the tornado approached, the wind changed to a little east of south. Saw the dark funnel strike the ground on my farm. Saw it whirling contrary to the hands of a watch.

This witness was stationed about twenty-five yards south of the funnel when nearest to it. The fences were generally thrown toward the center on either side; but where the dark cloud touched they were carried away for a space sixty yards wide. We have

here the first evidence of the dark cloud touching the earth in perfect funnel-form. But its touch is yet only temporary; like a child learning to walk, its footsteps are yet uncertain. It proceeds with a wavy, zigzag, circular-pendulum motion. By and by its tread will make the earth tremble.

The storm traversed Jones's farm, throwing down fences, until it struck the Wolfden school-house, which lay near its center. The school was in session when the tornado struck it.

Richard Weller, teacher, testified that this occurred at 2.15 p. m. precisely. This time is valuable, and I have adopted it as one of the data for calculating the velocity of the storm. The school-house was moved with the children and teacher in it to the east, the north end 30 feet, the south end 20 feet. It was not overturned. The windows, roof, &c., were much damaged, but there were no evidences of explosive forces. The weight of the building was given by Mr. Williams as probably thirty thousand pounds. The surface exposed was 360 square feet, besides the slanting roof. The slant of the roof was about 45°. The foundation was stone. It became very dark as the tornado struck. After leaving the school-house, which is situated in a slight ravine-like depression, the fury of the tornado abated somewhat. Hence, although it was nearly central over the hamlet of Hayesville, the frail houses were scarcely touched.

S. U. Alford, who lives a quarter of a mile south of Hayesville, saw the tornado-cloud swinging round in a circle like a flock of birds, and every now and again making a dip to the ground and darting up again as high as the top of a tree. Its color was very dark, inclining to green. The wind, which was south before the tornado, changed to north after it. A little hail fell as the tornado passed.

John Stephenson, Hayesville, a little south of the center, testified: Saw no lightning; heard no thunder; considerable rain about a half an hour after the wind.

G. G. Konkricht, postmaster, Hayesville, testified: Tornado passed about 2 p. m.; clearly perceived the clouds whirling contrary to the hands of a watch as the storm approached; saw lightning to northwest, and north of the tornado-cloud; heard no thunder.

J. W. Hayes, Hayesville, testified: Watched it for a half an hour previous to its arrival; saw two clouds, one in the southwest, and one in the northwest, which rushed together and appeared to create a whirl; saw the clouds whirling.

H. C. Dickey, who was at Hayesville, saw a cloud rush north, and then strike south with amazing rapidity; these were under-clouds; the whole northern heavens were covered with clouds; saw the funnel; it was of a dark green color and raised and lowered itself at the bottom; saw no lightnings; heard no thunder.

A. N. Bucher, one mile east of Hayesville, and about ten rods south of the tornado: Saw a funnel-shape, large at top, small at bottom, of a dark green color. It looked like a kettle of soup boiling over. The funnel ended in a large cloud, which did not extend much south of the zenith. The bottom of the funnel kept bulging up and down. Wind was from the south previously. It changed to the northwest as it passed and it grew cooler. At this place only a few fences were thrown down.

W. H. Hawkins, Jordan farm, section 24, Lancaster Township, half a mile north of the storm, and not far from widow Jacob's house, which was destroyed. Testimony: There appeared at first to be two storms coming up—one from the west and the other from the northwest. A little rain and hail fell before the tornado, and rain in considerable amount after it.

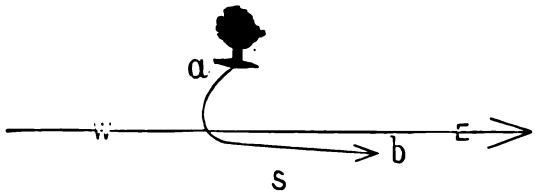
The storm up to this point had been traveling east-northeast. Since leaving South Skunk River, it had been traversing a rolling prairie, with numerous sloughs, as they are called, but nothing like a water-course. A little to the east of the last witness it struck Troublesome Creek, the banks of which are well wooded. No sooner did it do so than it increased greatly in power, changed its path temporarily to due east, and developed the phenomena of two or more funnels or branches of a funnel. Down in the hollow, among the trees, stood the house of widow Jacobs. It was completely demolished, but without signs of explosion. The storm-traces were already in great part obliterated, and a new house rebuilt. The path of destruction was two hundred yards wide at this point, and the general aspect of the fallen trees within this limit presented all the appearances of a complete cyclone revolving contrary to the hands of a watch, although nothing particularly worthy of notice presented itself. About a quarter of a mile from the main track to the south, a swath about fifty yards wide was cut through the fences by a southwest wind. This swath appeared to curve toward the main storm-path, but it was not possible to follow it until it reached it, because of the sparseness of the fences, and because there had everywhere on that side of the storm been a strong southwest wind, and this swath was merely exceptionally strong.

The storm-center next traversed the Grout farm, now occupied by Samuel Brunt, and passed about one hundred yards to the north of the village of Lancaster. Here its operations became more interesting.

Samuel Brunt testified: Heard it roaring a long time before it arrived; as it approached saw two funnels distinctly; their summits were lost in the overhanging

mass of dark cloud. Saw funnel on the south side, which was the smaller, swing around in a half circle and join the larger one. The funnel had a pendulum motion. When it struck the ground it seemed to smoke, the smoke surging up like spray upon a wave-beaten rock. The wind felt cold as it passed. Saw lightning during tornado. The breadth of the dark apex of the main tornado when it touched the ground appeared to be about 100 feet. There the wheat was mown as with a scythe.

The breadth of the path of the storm of sufficient power to throw down fences was here two hundred yards. The fences on the north side were blown south, those on the south side north, while along the center everything was carried east with the storm. An apple-tree, 7 inches in diameter, which had stood on the north side of the center, was carried first fourteen yards south, with a little westing, then round in a regular curve twenty-four yards toward due east, and then due east for seventy yards. A beam 2 inches by 4 inches by 14 feet, and weighing twenty-five pounds, was driven into the ground 3 feet 9 inches at an angle of 35°, after having been carried thirty-five yards from the barn-roof. The following is a sketch of the path of the apple-tree: it stood at *a* and was carried to *b*:

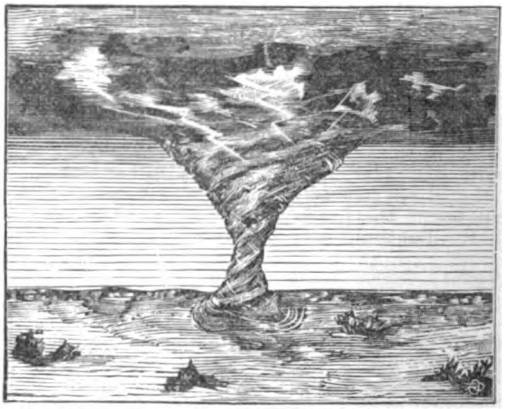


J. B. Jacobs, Lancaster Village, witness: Saw distinctly two whirls, the north one being the largest.

William Davis, Lancaster Village, witness: Watched it for perhaps an hour previous to its arrival. Heard it for half an hour. Saw funnel when half a mile distant. The summit of it was lost in very dense clouds. It was funnel-shaped. The elevation of its summit was about 15°. It appeared to be about as high as the summit was broad. The top was twice or thrice as broad as the base. The clouds above it did not appear to whirl. Saw lightning during the tornado and heard thunder above the roar of the tornado. Previously the wind blew from the southeast strongly. After it passed, it blew from the northwest. Saw boards whirling round in the funnel.

Mr. Beall, witness: Was on north side of storm, half a mile from its edge. It appeared like a funnel, and perfectly black. Saw rails whirling in it. The upper cloud into which the funnel went did not whirl. It subtended an angle of 55°.

Fred. Tollman, Lancaster Village, testified: Was within the edge of the tornado. Was whirled like a top for fifty yards and lodged against a fence. Observed it for more than fifteen minutes before it came. Saw trees twisting in the grove half a mile distant. Saw the funnel whirling contrary to the sun. Its summit was lost in overhanging cloud. Thinks the upper cloud was also whirling. Saw only one funnel. Saw lightning flash up and down the funnel. Saw a tree thrown out from the top of the funnel about one foot in diameter. Top of funnel 60° high when seventy yards off. There were two funnels with the small ends together, thus, the upper one being the largest:



The above description all refers to the lower one. It hailed before the tornado about as large as hen's eggs.

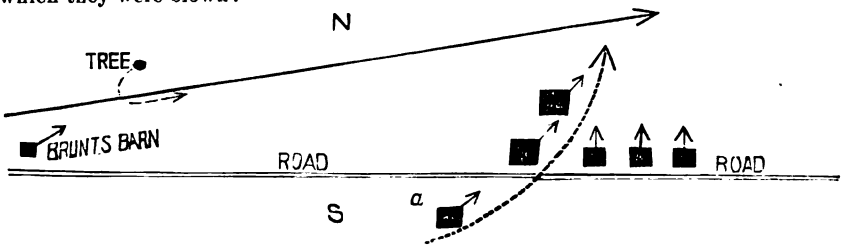
Austin Jacob, about half a mile north of the edge of the tornado. Testimony: Saw two funnels seperimposed, with the small ends together. The upper funnel was much the darker and larger.

L. W. Low, Lancaster Village: Mr. Low's house stood south of the principal portion of the village, and near the center of the tornado. Testimony: Was in the house when the tornado came. The southwest corner was lifted off the ground. The floor was then driven in toward the roof, and the house went to pieces. Was severely injured. Was wet and covered with mud. Felt very cold. Felt warm soon afterward. Seemed to be surrounded with a heavy mist. Saw only one funnel. Saw lightning on both sides of it.

The last witness has weak eyesight.

J. C. Jacobs, Lancaster Village: Witness was one hundred yards south of the edge. Shape was like a funnel, point up.

This completes the evidence for the village of Lancaster. It is somewhat discordant, or, rather, various. Some saw only one funnel; some two funnels, side by side; and others two funnels superimposed, with the small ends together. The discrepancies are, however, easily accounted for. As the cloud approached, it grew very dark. The tornado doubtless changed its form rapidly. The observers took a glimpse at it and ran to attend to their houses; or, as in the case of Follman, had to watch it under difficulties. Those who saw two funnels appear to have seen through the center of what appeared to those at a greater distance as only one funnel with the larger end down. The evidence afforded by the ruins in the path of the storm gives no support whatever to the belief that there were two distinct whirlwinds. The two dark clouds touching the ground worked together in the strictest harmony in producing such effects as would be produced by one tornado whirling contrary to the hands of a watch. But, as already instanced, streaks of wind of unusual power curved in half circles toward the center at certain places. One of those streaks passed in a northeasterly direction through the town of Lancaster, while the main whirl was one hundred yards to the north of it. This streak was at first only a few yards broad, but rapidly increased in width as it proceeded. It first unroofed a frail stable, without injuring the house beside it. It then increased in force, throwing down four or five houses, and unroofing as many more. The following shows the position of the houses and the directions in which they were blown:



The long arrow denotes the main track; the curved arrow the streak mentioned; the short arrows show the direction of the destructive wind which threw down the various buildings. Between the building *a* and the main storm-path there is a space of fifty yards comparatively uninjured. The sketch does not pretend to be strictly accurate as to distances, but to give the relative positions of the houses.

Leaving Lancaster, the whirlwind traveled down the declivity toward North Skunk River in a direction somewhat east of northeast. It leveled the fences in its path, in the way already described, and never varied from its commencement to its end. The house of widow Dogget, situated about a quarter of a mile south of the river, stands a little to the northwest of the storm-center, at the commencement of the level bottom-lands. Here two deep ravines, one from the south and one from the east, meet. In these ravines the storm developed enormous power, smashing up the timber terribly. The roofs of the house and barn were carried south and somewhat west. The trees on the north side of the center were thrown down toward the center, some pointing southwest and south, but the majority southeast. On the south side of the center they lay pointing northeast, north, and northwest. An oak-tree, 12 feet in circumference at the base, was broken across 12 feet from the ground. At the bottom of the narrow, steep ravine, running east and west, trees were lying just as they fell, some pointing east and some west.

Mrs. Wimar testified: That difficulty was experienced in preventing the wind from bursting in the door and windows; that it felt cool as the storm was passing; that a few hail as large as hens' eggs fell before the hurricane, and a great deal of rain afterward; and that the point of the lightning-rod upon the barn was partially melted by a flash of lightning.

One-quarter mile beyond Mrs. Dogget's house the tornado reached North Skunk River, which it then followed for over two miles in a southeasterly direction until it came to the southerly bend of the river, opposite Kohlhaus's saw-mill, when it suddenly turned to the northeast. The bottom-lands on both sides of the river are here covered with tall timber, and through this timber the storm tore its way with resistless fury. All trees within a breadth of about one hundred yards were either overturned or broken off and barked. The barking was evidently the result of three things:

1. Many of the trees barked had been bent, so as to loosen the fibers of the wood. Such bending would infallibly loosen and perhaps break the bark.

2. The air was thick with missiles, which not only broke the bark, but sometimes

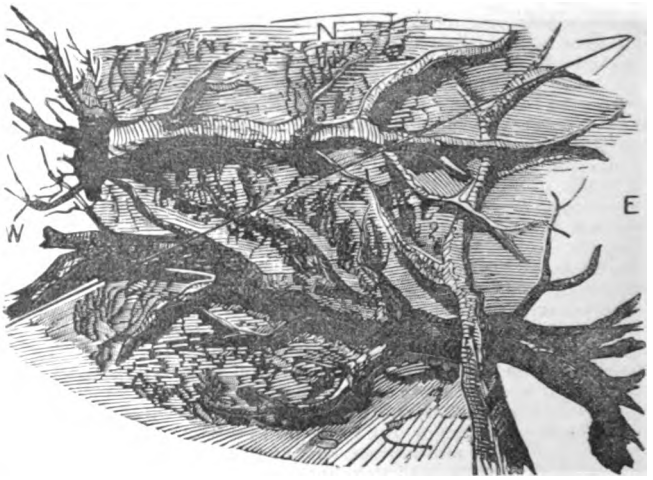
penetrated the wood. I have seen a corn-stump less than two inches in length sticking in the bark of a large tree which it had penetrated.

3. The peeling-off of such loosened and broken bark would be a light task for such a tremendous blast. There was not the slightest evidence of electric action or of vapor explosion.

Broken trees had the bark torn off, both up and down, from the point of breakage. Trees half-broken and bent to the ground were similarly stripped.

At the place of rupture, the trees generally presented that broom appearance, in which the supporters of the theory that electricity is the principal agent in the production of tornadoes have seen conclusive evidence of its truth. It will afterward be shown, when this phenomena becomes more common than could be expected on the soft soil bordering North Skunk River, where trees were more easily uprooted than broken, that this broom appearance is due to the excessive bending and straining of the fibers of the wood, and their rupture, in succession, from the exterior inward.

The river, being impassable, rendered the examination of the general position of the fallen trees more difficult. Everything, however, corroborated the evidence already so abundantly adduced, that the tornado was a whirlwind of powerful centripetal tendency, circling contrary to the hands of a watch. The following arrangement of fallen trees was selected as being typical. It was found on the north side of the river, near the center of the tornado.



No. 1 is a tree 3 feet in diameter, but much decayed, blown down from the east-southeast. No. 2 is a tree one-half foot in diameter, blown down from south-southeast. No. 3 is a tree 2 feet in diameter, blown down from the west. No. 3 lies above No. 2, and No. 2 above No. 1. It occurred just where the storm left the river.

That the force of the storm was enormously increased immediately after reaching North Skunk River is proved by the greatly extended width of its path. At A. Dogget's and B. C. Moore's houses, three-quarters of a mile distant from the storm-center, the out-buildings were damaged and the fences thrown down by a southerly wind. Mr. Dogget testified that the tornado appeared somewhat like two funnels with the smaller ends together, and that when apparently three and a half miles distant, the column subtended an angle of about 25°. The houses of these gentlemen are situated on the summit of the bluffs facing the river, which are perhaps 200 feet high.

The house of Joseph Ash, situated on the face of the bluff, and distant from the river about half a mile, was blown to the south-southwest. Large trees were at this distance blown down in the ravines running to the river. Mr. Ash testified that the wind lasted a few minutes, and that it changed to the northwest after the passage of the tornado. A little hail fell before the storm, and a small shower of rain after it. Saw lightning and heard thunder. It grew cool as the storm passed.

Matthias Gengler's house stands on the summit of the bluff, one mile distant from the river. Due north of this farm was the saw-mill of Joseph Kohlhaus, where the tornado turned to the northeast. Mr. Gengler testified that it presented the appearance of a column rising from the river to the clouds. Its width at the top was twice as great as at the bottom. It was perfectly round and perpendicular. It moved steadily along, without jumping up and down and from side to side. The angle of elevation

was 55° when opposite. The wind blew very strongly. Mrs. Gengler said that the bottom was the blackest, and that the top looked like clear, solid water. She could see it spin around and upward like a screw, contrary to the hands of a watch.

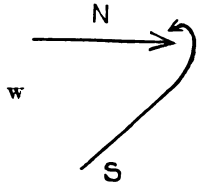
Matthias Hotel's house is a quarter of a mile east of Gengler's, and at the same distance from the river. He testified that it appeared to him like a big tower. Sometimes it was wider at the top than the bottom, and sometimes at the bottom than the top. All afternoon previous to the storm it was very dark in the north. As the tornado approached, the wind grew very high from the south, endangering the buildings. The height of the summit, when nearest, was 55° or 60°. Saw something like prairie-chickens whirling in the air; believe now they were sheep. Do not know whether any one has lost sheep.

The Black Hawk mills are situated about one and a half miles farther down the river than the point where the tornado left it.

Eli Walker, proprietor, testified that he heard a roaring for perhaps an hour previous to the arrival of the tornado. Saw it approaching apparently in a straight line for witness. It seemed to move slowly, and was perfectly steady, without any oscillating motion. Could not in the column itself recognize a whirling motion, but the light clouds around the summit of it were whirling. The top of the column had an elevation of about 30° when nearest. Saw it suddenly bend to the northeast at Kohlhaus's. Before the tornado approached the northern sky was black with clouds, which extended eastward. The south was generally clear. A hail stone or two fell as the tornado came up, and a light shower of rain afterward. Saw no lightning. Heard thunder previous to the tornado. While the whirlwind was on the river, the water ceased to flow over the dam, although the river at the time was high.

E. Stout was at Black Hawk mills. He testified: Saw it distinctly in funnel shape. Could see it as far as Lancaster from the summit of the mill-buildings. The top of it appeared, when one and a half mile distant, to be 15° in height. Saw two funnels come together and form one. The smaller one came from the south and joined the other. The top of the funnel looked like a solid body of water. Saw flashes of lightning from top of funnel, apparently northward. The small end of the funnel was up, but there was not much difference in size. The clouds above the funnel appeared to be whirling and approaching the center. The funnel which came from the south was of a lighter color than the other. The wind changed as the tornado advanced, and blew strongly toward it. The clouds above the narrow top of the funnel appeared to whirl in funnel form, with the wide end upward.

The following represents the apparent direction of motion of the two funnels as they approached each other:



Henry Lundy was at Black Hawk mills. He testified that he saw it whirling contrary to the hands of a watch. Thought he could see the top of it, and that it did not reach the clouds.

Matthias Bevens was one mile southwest of the storm. He testified that the column resembled very black coal-smoke, and went right from the ground to the clouds. It whirled with great rapidity contrary to the hands of a watch, rising at the same time like the spirals of a revolving screw. The top of it was about three times the size of the base. Little dark clouds appeared to fly out and around the dark column. When one mile distant, it subtended an angle of 30°. Saw no lightning; heard no thunder.

The house and steam saw-mill of Joseph Kohlhaus stood directly in the path of the meteor, at the distance of a quarter of a mile from the river, on the north side.

Mr. Kohlhaus testified as follows: The tornado appeared to stand still for several moments at the bend of the river, and then all at once bounded forward to the house. While standing still, it seemed to shoot or grasp out first on the one side and then on the other, as if discharges of artillery were taking place on these sides. The roaring was terrific. It resembled the sounds of machinery magnified a million times. It was a combined woo-oo-oo and whirr-r-r-r. Watched the column as it approached. It was funnel-shaped, but changed its appearance. It twisted around and up like a screw. Could not recognize bodies in the column; it was too black, and when the funnel came near it grew as dark as midnight. All the clouds were very low. They did not all revolve. Saw lightning before the storm.

The building stood upon the summit of a rising ground, about thirty feet high. Between it and the river is a half pool, half marsh. It was completely emptied of water. The breadth of the path of wholesale destruction was, upon the summit of the hill, two hundred and seventy yards. The house stood one hundred yards from the eastern and one hundred and seventy yards from the western extremity of this path. The timbers and contents of this house were carried in a half-circle first to the northwest, then to the west, then southwest, then south, and finally to the northeast, the heavier articles being generally sifted out first, thus marking the way the ruins went.

On the eastern edge of the path was an orchard, and on the western a wood. The trees in the orchard were blown down from the southeast and south; the trees in the

wood from the north and northwest. Portions of the clothing from the house and shingles from the roof lay among the trees in the wood, or stuck among the branches. There were no signs of explosion, the doors and windows having been blown in. The inmates were all more or less injured. The width over which fences were blown down was here about three-quarters of a mile. An iron plow, weighing two hundred pounds, was carried forty yards. The sheet-iron chimney was carried two miles to the northeast. An iron sausage-machine, six inches by eight, and weighing fifteen pounds, was blown away. Part of it was found twelve hundred yards distant. The wheels of wagons were smashed, and the tires twisted.

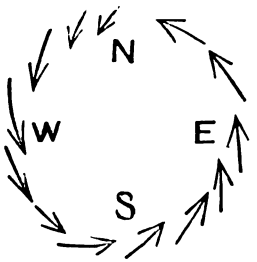
[The cut on page 1055 is a representation of the effects of the whirlwind at this place.]

After leaving the mill, the storm ascended a hill some 200 feet in height, leveling the fences, but with evidently diminished violence.

Peter Randolph, about two hundred yards distant from its northern edge, distinctly saw it whirling contrary to the hands of a watch. Lightning struck a tree on the farm about half an hour before the tornado. This tree I saw myself. There was a light shower of rain after the tornado.

John Wehr said it looked like the cylinder of a threshing-machine, and spun around like a screw.

Passing over the top of the hill in a northeast direction, it struck Rock Creek, which here runs south, with a little easting. Immediately altering its course, it went straight up the creek for about half a mile, developing prodigious power. The large trees which lined the banks were torn and peeled and overthrown in promiscuous ruin. At a point where there is a small circular island, and a considerable amount of stagnant water around, the storm would appear to have stood still for a moment. The following shows the position of the fallen trees at this point:



There were no trees on the island itself. There was no evidence whatsoever that the barking of the trees had been effected by electrical action or sudden evaporation. Everything tended to prove that the bark had been loosened and broken by the excessive bending of the trees and by flying missiles. One of the steers killed at this creek had an oak rail driven completely through its shoulders.

On reaching a slough which enters Rock Creek from the northeast the tornado followed it. Beside this slough and close to the creek was a small grove of young trees belonging to John Stein. This grove was completely carried away, nothing remaining, except a few barkless twigs. At no point in its course did the storm develop greater energy than at this grove. Generally young saplings, over which the center of the storm passed, were, although stripped of bark and twigs, left standing. Here the ground was whipped as bare as though the grove had been lashed with a whirlwind of fire. The tornado then passed between the houses of William Goeldern and John Stein, sweeping the fields, within the narrow path of its greatest violence, clean of grass, wheat, and corn-stumps, while the ground was torn and furrowed by flying rails and trees. The rails and broken timber had been gathered from the fields; but John Stein assured me that they lay thickest along the center of the storm. Along the sides of the path of greatest violence, many rails were driven deeply into the soil, end foremost.

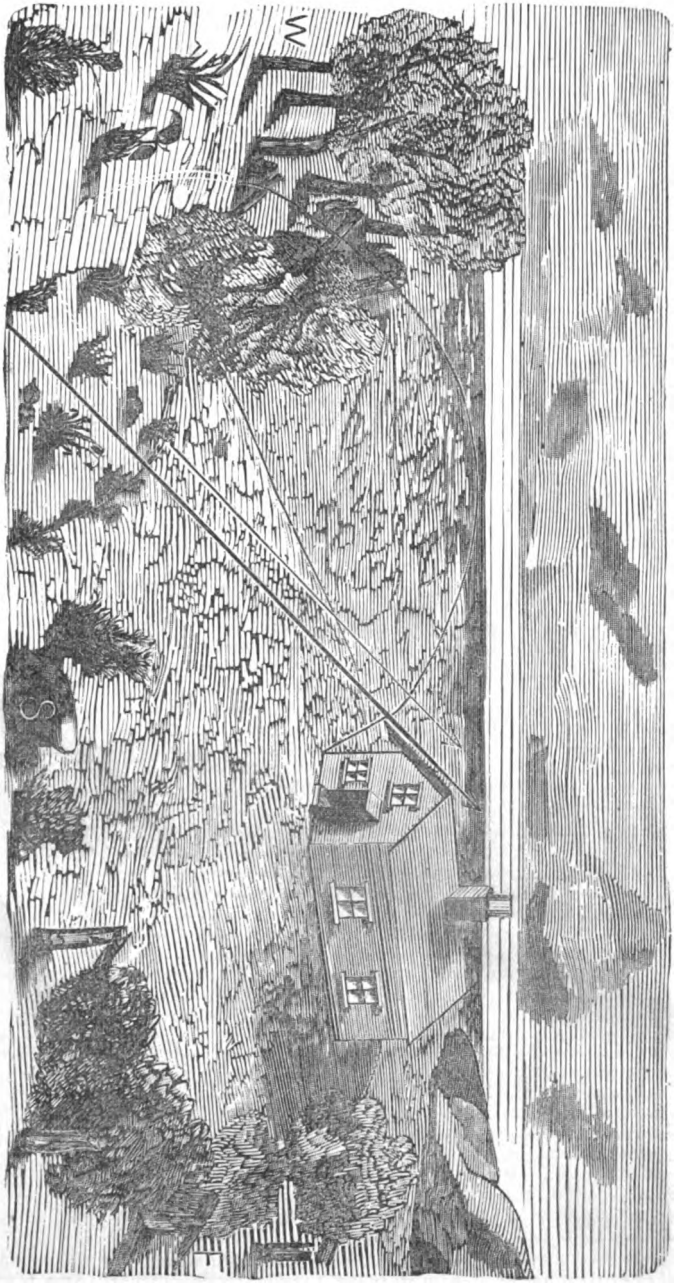
While the main whirlwind thus pursued the path described, there were smaller offshoots or arms which played havoc on its southeast side. Such an arm cut a swath about twelve yards wide through Schild's orchard from southwest to northeast, the swath widening as it went. It was not possible to trace it until it reached the main storm, for reasons similar to those already given. It seems probable, however, that it joined it at the little island above mentioned, where the storm appears to have momentarily stood still. The relative positions favor such a surmise. This streak of strong southwest wind was a quarter of a mile distant from the center of the main tornado.

A similar streak leveled the fences close to the house of John Stein for a width of fifty yards, while nearer the main tornado the fences remained standing. This streak, I surmise, joined the main storm at the grove above mentioned. A similar arm tore down the new barn of F. A. Latz, about a quarter of a mile farther on, without injuring weaker buildings close beside it. The path of this streak is said to have been very distinct among the fences until it joined the whirlwind near the house of Peter Marsh. The fences were, however, already restored.

George Starr, three-quarters of a mile southeast of the tornado, witness: About 1 p. m. it commenced to thunder and lightning in the northwest. The storm advanced along the northern sky, and it lightened terribly there previously to the arrival of the tornado. A big cloud extended from southwest to northeast. It cleared up immediately

after the tornado, both here and in the north. Lost eighteen head of cattle at Rock Creek. One was perforated by a rail.

John Marsh's house stood a little to the northwest of the center of the storm. His

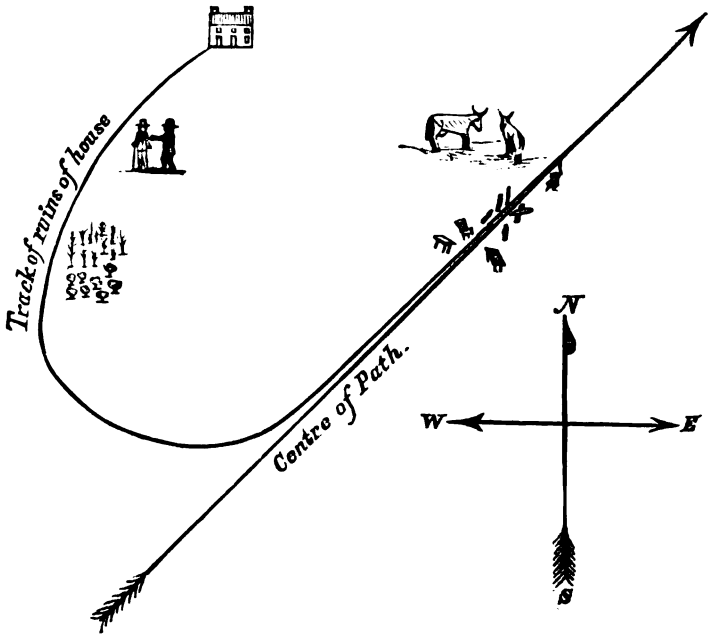


Effects of the whirlwind at the house of Joseph Kohlhaus.

testimony: Watched it as it came directly toward me. It deflected a little from side to side, with a zigzag motion. It turned and twisted like a screw in revolution. All the family were in the house, the house having no cellar. It became as dark as mid-

night. The windows and doors were blown in, in spite of our resistance, and we knew no more until we found ourselves lying in the slough severely wounded.

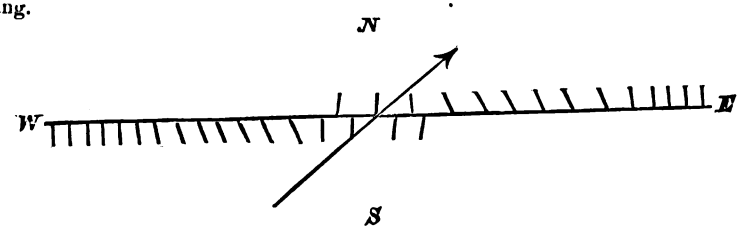
The destruction at this house was most complete. The house was carried forward from its foundations bodily; but as it was going down a declivity toward a slough, it failed to strike the ground until it went to pieces. The heaviest timbers and the inhabitants were deposited in a slough, about one hundred yards south-southwest of where the house stood. One child was killed instantly, and Mrs. Marsh has since died. The fragments of the house were carried, as was easy to trace, first to the southwest, then in a curve to the south, the southeast, the east, and then along the center of the storm to the northeast, the heavier articles sitting out as they went. I found ears of corn two hundred yards to the southwest and south of the house, and a fragment of heavy wood four hundred yards to south-southwest. Two cows and thirteen hogs were in a yard a little nearer the center of the storm than the house. They were carried one hundred yards to the southeast, and killed or fatally injured. A stone from the foundations of the house, weighing about one hundred pounds, was said to have been carried about one hundred yards south; but I could not find it. Sewing-machine, cultivators, wagons, &c., were wholly carried away, and left not a wreck behind. The timber was generally reduced to the dimensions of fine fire-wood, and thickly strewn along the path of the storm to the northeast. The width over which fences were thrown down was here about a half a mile.



Sketch of the path of the ruins of Marsh's house.

A quarter of a mile to the north of Marsh's house stood the house, barn, &c., of M. Fuh. They were blown to the southwest, but without being carried away. The next house struck was that of M. E. Harris, the storm-center passing about twenty yards to the northwest of it. The fiercest of the storm was here only one hundred yards wide, but fences were blown down for over five hundred yards. The doors and windows of the house were driven in by the wind and the flying missiles, and immediately the house went to pieces. The house and out-houses were carried away, broken to small pieces, and deposited for a mile or two along the path of the storm. The trees around the house, which were not plucked out by the roots, had their tops and branches broken off and their bark stripped from them. The stripping of the bark was evidently due to the causes already assigned. The stripping was most complete on the southwest side of the trees. A fence four hundred yards in length, and running east and west, was deprived of its boards, the posts still remaining in the ground. Where the storm-center crossed it, the direction toward which the posts were leaning was

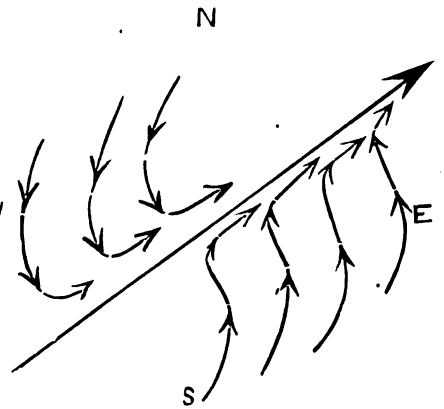
indeterminate. On the west of the center the posts were leaning south, with a little easting, and on the east of the storm-center they were leaning north, with a little westing.



The above is something like the disposition of the posts along the line of the fence. The length of fence thrown down east of the center was about one-quarter greater than that thrown down on the west of it.

The corn-stalks in a contiguous corn-field were thus disposed: Those on the southeast side of the center curved around from pointing nearly due north to nearly due west. Those on the northwest side curved around from pointing nearly due south to nearly due east. Along the center all pointed with the storm. This shows the direction of the last wind, strong enough to alter the position of the stalks.

Matthias Linen, a quarter of a mile northwest of the edge of the storm, testified that it presented the appearance of a great column, reaching from the ground to the clouds, and whirling contrary to the sun. It seemed to remain almost still at some places, and then would dart forward. Hail four inches in diameter fell as the storm passed. They were very irregular in form.



Corn-field.

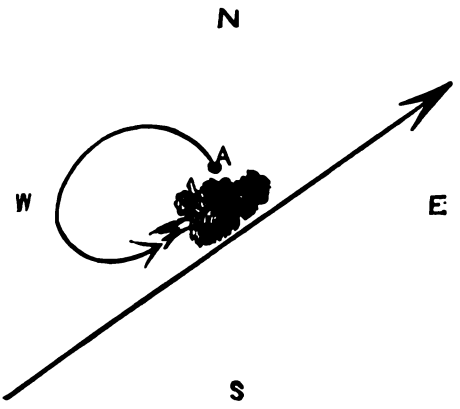
Paul Ritter, Clear Creek Township, section 9, testified that the tornado looked like a big tree, only it was five times greater at the top than the bottom. It turned like a wheel in a mill. Its direction of evolution was against the hands of a watch. At the distance of a mile, its top, when it entered the cloud, made an angle of about 60°. Hail as large as pigeon's eggs fell before the storm, and it rained very hard after it. Saw lightning in the west previously.

Mr. Ritter's house stands about seventy yards to the northwest of the storm-center. Its path is here about two hundred yards wide. The arrangement of stalks in a corn-field was the same as that already given. The roof of the house was carried south. A stump-cutter, which was standing by the house, was carried—the iron portion fifty yards south, the wooden portion half a mile to east-southeast. Wheels which came within the reach of the storm were dashed to pieces, and the tires twisted into all sorts of shapes. An oak tree, 3 inches in diameter, and which stood exactly in the storm-center, was split by a fragment of a board one inch thick. The board was originally probably 6 inches broad and 8 feet long. Of the two small fragments remaining in the tree, the longer was only 17 inches in length. The board was driven into the tree from the southwest. The path of extreme violence, about fifty yards wide, was strongly marked in the grove of young oaks. They looked as if they had first been lashed against a pile of stones and then trailed in the mud. Portions of bark were struck off and the smaller branches shattered and peeled. This grove stands upon the edge of a steep declivity about 100 feet in height, at the bottom of which flows Clear Creek. Here is a circular hollow nearly enclosed by high bluffs, and within it the storm raged with demoniac fury, smashing trees of 4 feet in diameter to pieces.

The following instance was found on the opposite declivity, up which the storm raved with undiminished power:

The tree stood at A originally. Its root was partly decayed, and it must have fallen with the first strong gust. The path which it traveled was cut out in the grass by its root. This path was forty-seven yards in length and was nearly circular. It first moved to the northwest and then round in a curve, until it lay pointing to the northeast, with its top almost touching the spot where its root had formerly been. The tree stood to the northwest of the storm-center, and was two feet in diameter.

Crossing the summit of the rising ground, which was thoroughly plowed up, the storm traversed a wooded ravine, where for a width of fifty yards it deprived the young trees of their twigs and of much of their bark, besides throwing down the full-grown.

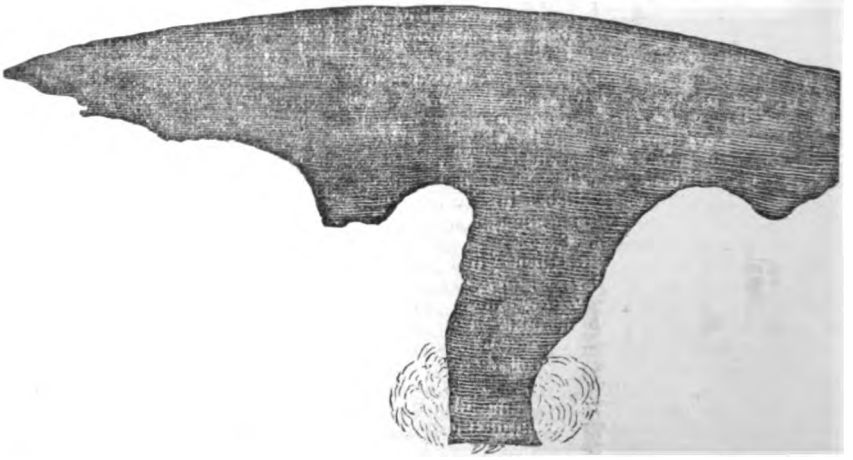


Nick. Engledinger, section 10, Clear Creek Township. His house stood about one hundred yards from the southeast edge of the tornado. From any indications which the remains presented, the timbers must have first been carried north. Two persons were killed—one of them being torn to pieces. A hog weighing four hundred pounds was carried one mile and a quarter in the line of the storm.

The house of Jacob Koerth stood fifty yards within the northwest edge of the storm. The timbers went south. The people tried to prevent the wind from blowing in the doors and windows, and could not. The wind entered and blew the house asunder, leaving the floor in its proper position. Hogs weighing three hundred pounds were carried to the northeast across a ravine and deposited three hundred yards away. A horse, a cow, and a bull were similarly carried two hundred yards. Sheep were carried four hundred yards. In addition to the accidents inseparable from such an aerial voyage, the bodies of the animals were driven full of pieces of wood. On this account, the bodies of all animals which perished in the storm were burned.

A horse-power machine, partly wood, but chiefly iron, and weighing two thousand four hundred pounds, was pushed or carried six yards. It was resting on the ground, and was separate from all other objects. There were no marks upon it arising from violent collision with other bodies. It exposed a surface of about two square feet to the wind. It lay close to the ground. The master of this house was absent, and information, owing to the invalid condition of the inmates, was hard to obtain.

The storm now turned somewhat more to the northward, traversed several fields, demolishing the fences, until it struck the house of R. F. Campbell, Lafayette Township, on the borders of Clear Creek Township. The exact position of this and the two immediately preceding houses was difficult to determine upon the map, because of its very defective condition, and because their owners could not tell me what section they were in.

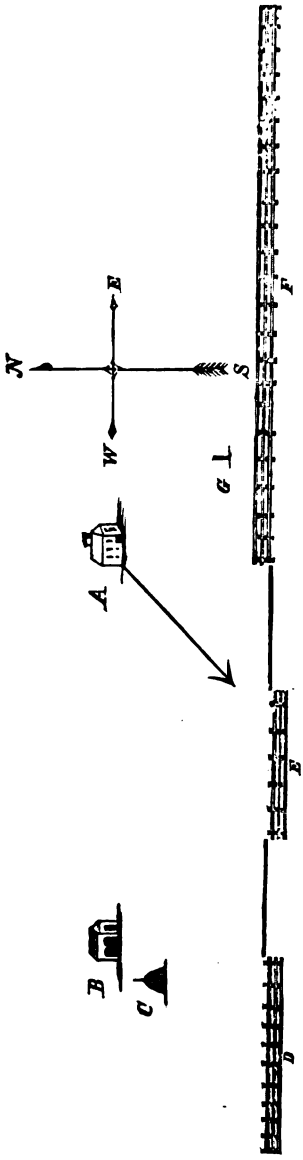


Mr. Campbell testified: That previous to the tornado he observed several currents above one another among the clouds. The wind was from the southeast. The lowest current of clouds from the southwest, the next from the northwest, and the highest from the northeast. It commenced hailing about fifteen minutes before the storm. The hail was, in some instances, three inches in diameter, and fell in considerable

quantity. It was calm when the hail fell. The hail was very cold. When two were put together they immediately froze. The north was full of black clouds previous to the tornado, in which the lightning flashed incessantly. Heard a dull, thundering noise in the northwest previous to the tornado as of falling hail. There appeared to be rain or hail falling on both sides of the vortex as it approached.

The preceding cut shows the appearance it presented at the distance of seventy yards. There appears to be two incipient funnels, one on each side:

A post 8 feet in length and 4 inches in diameter, and driven into the soil 3½ feet, was pulled out by the wind. It stood without attachment.



The width of the storm here is one hundred and sixty yards. The house stood within twenty yards of the northwest edge. It was tilted up on its corner bodily, inmates, floor and all, and deposited on its roof seventeen yards to the southwest of its former position, and then went to pieces. There was no indication of explosion. The accompanying is a plan of the effects of the storm at this house:

A is the house, which was carried in the direction of the arrow. B is a stable and C a haystack, both untouched. These were twenty yards from the house. D, E, and F are portions of a fence which were thrown down. D and E were thrown south, leaving the intervening portions untouched. F was thrown north. G is the post already mentioned.

This was the last destruction in Keokuk County. The tornado ceased to touch the earth on Mr. Campbell's farm. It drew itself up into the cloud from which it had come down. Hitherto it had traversed a country full of deep and well-wooded ravines. Here it entered upon a flat, bare country, in fact a watershed. It continues much the same for the seven miles which the tornado here skipped.

J. Yeats Brockway's farm, Lafayette Township, witness: Saw whirling in the clouds, after the tornado lifted, contrary to the hands of a watch. Watched it for ten minutes at least afterward, and it continued to whirl. The whirling portion of the clouds did not appear to be wide.

Mrs. Fobes, who resides about one mile northwest of the line of the tornado, witness: Saw the funnel. It seemed to stand still. Then it took a bend to the east. Then it grew so dark she could not see it. It grew lighter, and she could see it distinctly to the northeast of Campbell's house. It vanished suddenly, and she saw it whirling at a furious rate in the clouds contrary to the hands of a watch. Did not notice any more roaring after the tornado lifted.

H. Case: Resides about one and a half miles from the line of tornado had it continued. It rumbled a long time before the tornado. The sky was clear in the southeast. Saw no lightning. Hail of large size fell before the tornado approached. The center of the hail was shaped like a bird's egg, and pieces of transparent ice—like rock-candy—were stuck all around it. There was scarcely any rain afterward. The wind was blowing from the southwest at first and changed to the east as the storm came near.

Katie McLoud, school-teacher, witness: The school is a little to the northwest of the line of the tornado had it continued. It must have been about 3 p. m. when the tornado was here. Distinctly saw the funnel whirling contrary to the hands of a watch. Watched it until I could not see it for heavy rain. It had hailed about half an hour previously. The wind, while it rained, came from the northeast, blowing nearly straight toward the storm.

R. H. Simpkins, Keota, witness: Thinks the sound continued after the tornado lifted, but not so loud.

Joseph Charlton, Keota, witness: Saw the funnel distinctly reaching from the earth to the clouds. The clouds were very low. Saw the tornado disappear. It had only

to rise a little way when nothing, except the low cloud, was visible. The dense low clouds continued the same and the funnel only disappeared. The southern sky was clear.

J. R. Turner, Keota, witness: There was a very heavy rain, mixed with enormous hail. One hailstone was 7¾ inches in circumference, after lying some time.

T. D. Melville, Keota, witness: It commenced to hail about twenty minutes before the tornado disappeared. Further to the north it commenced sooner. The low cloud allowed only a small portion of the tornado to be seen. At three miles distance the funnel only subtended an angle of 15°. The rain came about twenty minutes after the hail. Weighed a hailstone of four and a half ounces, measuring 3 inches in diameter. It lightened a little.

T. N. Smock, Keota, witness: It hailed before the tornado disappeared. Saw some lightning in the direction of the tornado. The direction of the wind, while the hail was falling, was from the northeast; but it was light. There was not much wind with the rain afterward.

G. W. Erwin, Keota, witness: Remembers that when the tornado lifted the sound ceased.

W. R. Charlton, Keota, witness: Did not not notice the noise after the tornado lifted. Heard it long and loudly before.

Robert Renfrew, Keota, witness: The town was all scattered with oak-leaves as the tornado passed. The wind previously was southwest. It changed to east as the tornado approached, and during the east wind the oak-leaves fell. After the oak-leaves fell, the sound suddenly diminished. Saw an elm fence-board 8 feet by 6 inches by 1 inch, and weighing from fifteen to twenty pounds, taken out of the ground. It was driven about 4 feet into the soil at an angle of about 45°.

Dr. D. McFarlane, Keota, witness: Was five miles on the southeast side of the line of the tornado had it continued. Heard in the west a roaring for perhaps twenty minutes previous to and after seeing a smoky appearance.

J. F. Wilson, postmaster, Keota, witness: About 3 p. m. was making up the mail. The storm was then coming up.

The storm having ceased to act as a tornado upon the surface of the earth, I proceeded to Westchester, Washington County, where it was reported to have struck. There can be no doubt, however, that a strong, though not a destructive wind, was felt over the intervening space, and that it obeyed the usual law of cyclones by blowing in spirals toward the point over which clouds continued to whirl like a great wheel.

G. W. James, station agent, Westchester, witness: Saw the main cloud whirling rapidly contrary to the hands of a watch. Saw an arm come down and strike the plowed field. Could hear roaring overhead. The roaring was louder before the storm arrived then when it was here. A few large hail fell and a little rain.

J. T. Robertson, Westchester, witness: The arm which came down carried up considerable quantities of mud and cornstalks. A few fences were blown down and a small wooden building damaged. There were only a few gusts. The revolving cloud was only a little way above the tops of the houses.

Mrs. Thomas Gavin, Westchester, witness: The wind blew down the blacksmith's shop in the rear of our house. The house itself was shaking. Hail fell as large as hens' eggs. It grew quite dark when the house was struck. Everything was blown toward the northeast.

S. W. Wilson Cedar Township, three-quarters of a mile northwest of Calvin Craven's farm: Heard roaring for more than an hour previous to the advent of the tornado. Watched the cloud as it came along. Saw the tree-tops whirled by it. It appeared to be only 10 feet above the tree-tops. Hail as large as pigeons' eggs fell previous to the tornado, and a great quantity of rain after it.

T. B. Coffman, Cedar Township, section 33: (The tornado passed about a quarter of a mile southeast from witness.) Heard roaring like a heavy train of cars. Saw a whirling cloud in shape of a funnel. Hail not so large as hens' eggs fell immediately after the tornado passed. The top of the funnel was about 40° high when it was nearest.

Rev. J. P. Coffman, Cedar Township, section 33, witness: The tornado arrived about 3 p. m. Heard the noise for more than one hour previously. When it was hailing heard the sound just as distinct as before. Did not hear roaring after the storm passed. The wind before the storm was nearly due south. After the storm, and with the rain, the wind came from the north and northwest. Have learned that two or three miles to the north the rain was tremendous. There was lightning in the northwest previous to the tornado. As it approached, saw light, fog-like clouds, rushing, with the greatest rapidity, from the north. Its form was not so distinct before as after it passed, when it presented a decided funnel appearance. It was nearly clear in the south. When the funnel was distant about one mile it appeared to subtend an angle of about 25°. The funnel might have entered the dark, overhanging clouds, but it appeared to be wholly in view. There seemed at one time as if

there had been a violent explosion in the revolving mass, as it was somewhat broken up. Hail larger than pigeons' eggs fell with the south wind before the storm.

The tornado passed over Mr. Coffman's house, blowing down fences about a quarter of a mile in width, and damaging buildings. It was all done by a southwest wind.

Calvin Craven, Cedar Township, section 33, witness: Previous to the storm the wind blew briskly toward it from the east. The cloud, as it approached, extended from southwest to northeast, covering the whole northern sky. Heard the roaring of the tornado, like several trains in motion, about thirty minutes previous. Saw white, foggy clouds darting through one another with frightful velocity as it came near. Above these whirling clouds was a dense black cloud. A few hail fell before the tornado, and a little rain after. Have heard that a most tremendous rain fell about one mile and a half to the north. It was extremely warm before the storm.

J. C. Brown, Jackson Township, witness: Was on the northeast of Calvin Craven's. Noticed the tornado first as it was tearing his fences, &c. At this time there was one whirl which reached the earth. It was not a jet black, but the color of coal-smoke. There was a big cloud directly over, but, although in commotion, it did not whirl. Went into a ditch to escape the hurricane. I then saw other two funnels, one on the south side and the other on the north side of the main one. All three moved forward toward me; but the outside ones also moved toward the central one. In a short time they joined the central one, which then appeared to stand still, and whirl around and around for a moment. The side ones did not whirl. They were bent forward at their lower ends where they touched the ground. The middle one did not whirl. It moved due east, and then northeast, and then due east again. The tops of all these were several times wider than the lower portions. Saw no lightning. A little hail fell before and a little rain after. The wind blew from the southeast before and from the north-northwest after the tornado.

William Scranton, Cedar Township, section 27: Scranton's house stands on the northeast edge of the storm. The roof of the barn was carried 150 feet due east. A tree in the orchard was blown toward east-northeast. The center of the storm passed over the center of the farm. The fences on both sides of it were thrown down toward it. The width of the path here is half a mile. The storm appeared to Mr. Scranton like two clouds coming together, one from the southwest and the other from the northwest.

R. H. Craven, Cedar Township, section 27, witness: A little hail fell before the tornado, and a little rain after it. The wind was northwest when the rain was falling. It cleared up about half an hour after the rain. In two places on the road east of Scranton's house ten to fifteen rods of fence were blown down, leaving the intervening fence standing. The fences on this farm were blown as usual.

W. H. Burham, Cedar Township, witness: Was on the edge of Scranton's farm. Heard the storm a long time before it came. Saw it about twenty minutes. The wind before the storm came from the south quite strong. Then it grew calm. Then there came a very hard wind right from the north. An intensely black cloud, apparently about 4 feet wide at the bottom, and swelling out like a large haystack, passed three hundred yards to the south. The top of it, when it entered the clouds, appeared to be about 45° high. It moved up and down, now striking the ground, and now passing over it. When it struck the ground it tore up everything. Saw it whirling contrary to the sun. Hail as large as walnuts fell before the storm, and a hard rain-shower after it, and then it cleared up immediately. Heard there was a heavy rain two miles to the north, washing away culverts and bridges. It felt cool as the storm passed, but grew very warm afterward. Saw rails flying out from the summit. An average rail weighs about forty pounds.

Frank Brown, Cedar Township, section 26, witness: Distinctly saw the funnel revolving contrary to the hands of a watch. Its height at one and a half miles distance was about 15°. Its top was five times broader than the lower end. Saw it strike the ground after it passed. Dark clouds appeared to strike the ground and rebound like spray. Saw only one funnel. The cloud extended from southwest to northeast, covering the whole northern sky. Observed sheet-lightning in the tornado several times. It grew slightly cold as the storm passed. When the tornado had passed about one and a half miles it appeared to stand still, and a strong gale, with rain, blew directly from it, so that I thought the storm was coming back. Almost everything on the farm which was blown down was blown toward the northeast. The breadth of path is a quarter of a mile.

Mr. Brown's house stands on the southeast edge of the storm.

J. S. Philips, Cedar Township, section 26, witness: Was holding the window looking west to prevent it from being blown in, and noticed that it was 3.15 p. m. Hail fell, between a tea-cup and a hen's egg in size.

Mr. Philips's house is one-half of a mile southeast of the storm-center.

W. W. Cook, Cedar Township, section 25, witness: (House four hundred yards southeast of the edge of the storm-path.) About twenty minutes before the storm came up the wind blew briskly from the south. When the tornado was passing it blew a strong

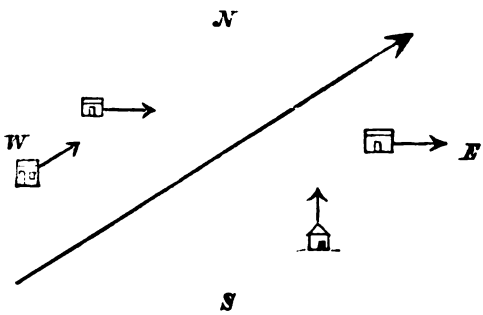
gale from the southwest. It rained after the tornado, and during the rain the wind blew from the west.

The son of this witness was two miles to the southeast during the storm. Hail as large as pigeons' eggs fell there and a little rain.

J. W. Plumber, Cedar Township, section 26: (House on southeast edge of the storm.) When the tornado was several miles off saw a mass of clouds come from the northwest and another from the southwest, and rush together. The angle between the southern limit of the southwest clouds and the northern limit of the northwest clouds, when several miles distant, was about 45°. The angle of elevation was about 35°. Besides these underclouds, there were overhanging masses of cloud. Saw the funnel-form distinctly after the storm passed. It appeared to be twice as broad at the top as the bottom. It looked like a screw turning contrary to the hands of a watch. When three-quarters of a mile distant, it subtended an angle of 25°. Hail fell about half an hour before the storm, with a gentle east wind. When the storm had approached within half a mile, the wind came so strongly from the south as to blow a man off his feet. It rained a little some few minutes after it passed, with a west wind. About twenty minutes after the tornado, a light shower fell, accompanied with a northwest wind of about twenty-five miles per hour. Saw lightning in the northwest before the storm.

John Maughlin, Cedar Township, section 25: The storm-center passed right over Mr. Maughlin's house. He testified that he saw a complete funnel-form about two hundred yards distant, and that it went up into an overhanging mass of cloud. The funnel was perfectly opaque, and left a fog behind it so that nothing could be seen for several moments after it passed. At the distance of two hundred yards, it appeared to be only 15° in height. Saw no lightning.

The outhouses on this farm were badly damaged. The accompanying sketch shows the position of the ruins. The arrows point in the direction toward which the buildings were blown down. The fences were blown toward the storm center. Those at the center were carried away.



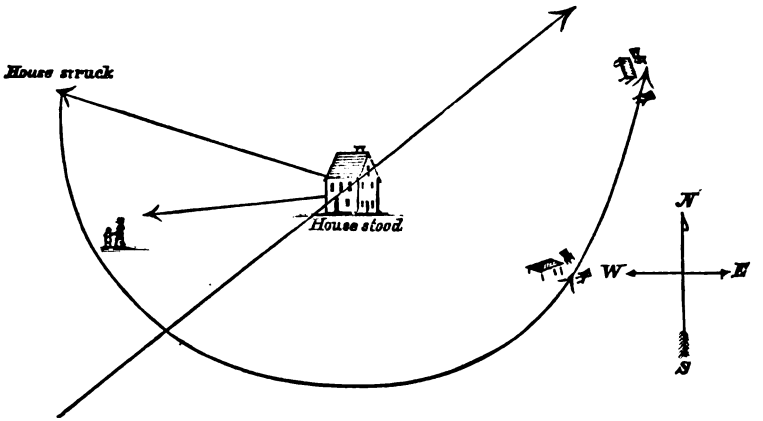
Andrew McKee, Cedar Township, section 30, witness: The time was 3.10 p. m., precisely. The clock, which had just been cleaned and regulated, was thrown down and stopped at 3.10 p. m. Previous to the tornado, the lightning was warping incessantly like a snake among the dark-blue clouds in the northwest. Chunks of ice about one inch in diameter fell previous to the tornado, accompanied by a light east wind.

I, myself, saw the clock above mentioned. It still pointed to 3.10 p. m. Mr. McKee's house stands fifty yards within the northwest limit of the storm-path. The buildings were partly pushed, partly blown down toward the south-southeast. The fences were blown to the southeast. A little empty house about forty yards to the east was blown to the southeast, and some of it was carried clear across the path of the storm.

The hedges along the east and west road are here filled full of *débris*, such as corn-stumps, &c. On the southeast of the storm-center the *débris* is driven into the hedge from the south, and on the northwest side from the north, but there is a greater extent of hedge with *débris* driven into it from the south than from the north. The position of the *débris* driven in from the north seems frequently to have been subsequently affected by a west wind. The hedges running north and south have *débris* driven into them on the north of the center from the east, and on the south of the center from the west, but the extent of hedge with *débris* driven into it from the west is greater than that with *débris* driven into it from the east. The hedges over which the storm passed looked as if they had been whipped violently against a wall, and then trailed in the mud. They were smashed and partially barked, and sometimes carried away. This description applies to the hedges over which the whirlwind passed at any part of its course.

George Gilchrist, Cedar Township, section 29, (house directly in the center of the storm-track,) witness: When the storm struck the house Mrs. Gilchrist, a boy, and a child were in front of the west door trying to reach the cave, the boy and child being a step or two in advance. The boy and child were instantly carried several rods to the west, while Mrs. Gilchrist was thrust back into the house. The house immediately went bodily, going a little to the north of the boy, who saw it go past like the railroad, as he expressed it. Its sills struck the ground forty yards from their former position and the house tumbled over and went to pieces, leaving the inmates comparatively unhurt. As it went to pieces it was struck by a west and southwest wind, the furniture being carried far to the east and northeast. It grew dark as midnight when the tornado struck.

William Caldwell, Cedar Township, section 29, witness: When the storm struck the house the inmates were in the kitchen, which was a separate building. The wind blew so hard as to threaten to blow in the south door. Four strong men placed them-



Sketch of effect of storm at Gilchrist's house.

selves against it. The hinges and lock were partly broken. These four men barely held the door with their utmost strength until the house went in a body. The men found themselves, together with the other inmates, a few yards to the north, lying among *débris*. The door was found a quarter of a mile away. It presented to the wind an area of 18 square feet.

Mr. Caldwell's house stood on the southeast edge of the most violent vortex. It was first pushed 6 feet to the northwest, plowing up the ground. The resistance of the ground and of tree-roots here stopped it. It then turned up on its edge, and was lifted over the tops of trees 20 feet high, without injuring them, and carried 100 feet to the northeast, falling entire, and going to pieces as it fell. The house stood with its end to the south. The area of this end was 280 square feet or thereabout. The area of the floor of the house was 480 square feet or thereabout. The weight of the house could not have been less than twenty tons. The trees over which the house was carried are young, and were probably so bent as to allow the house to rise at an angle of 45°.

A heifer, weighing seven hundred pounds, was carried away by the wind, and thrust head foremost into wet soil until her forequarters were buried.

R. M. Stevenson, Jackson Township, section 25, witness: The wind blew from the southeast as the storm came up, changing to north as it passed. The rain came with the north wind. Saw the funnel make two dips and touch the ground. The top of the tornado, when seven hundred yards distant, appeared at an angle of 35°.

The house of this witness stood a quarter of a mile southeast from the center of the storm. The outbuildings were somewhat damaged.

T. P. Harbaugh, Cedar Township, section 13, about one mile from edge of storm, testified: That he saw it go straight forward without stopping. Saw it rising and falling.

A. Booth, Cedar Township, half a mile northwest of storm: Saw it twenty or thirty rods northeast of Frank Brown's. Saw it whirling against the sun. The wind came from the east before the storm and from the northwest after it.

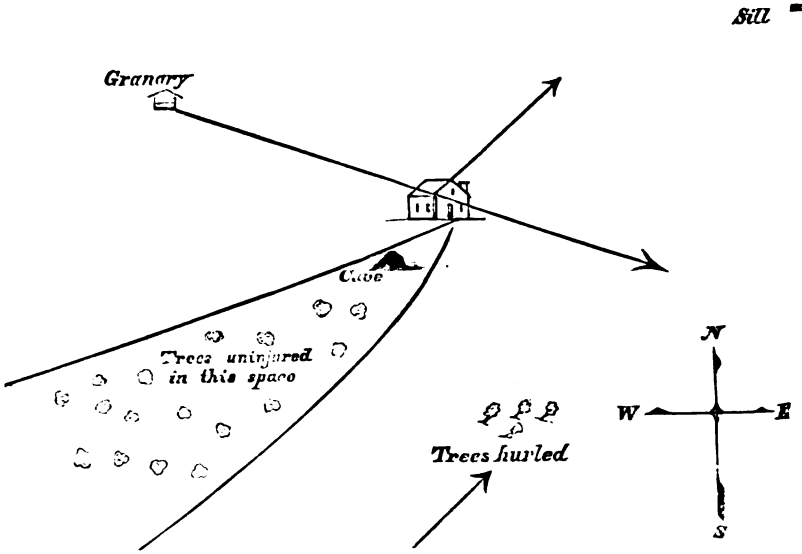
R. Finney was on the northwest side of the center, about one mile distant. He testified: When it was directly opposite, it appeared to reach up to the clouds. It subtended in width an angle of about 35°. In height it appeared to subtend an angle of about 40°. The bottom of the funnel was perfectly black. When it struck a house, could not see the house. Thinks it was lighter a little way up. Could see a roof carried up and fly to pieces. About fifteen minutes before the storm it hailed a little, and it rained for ten or fifteen minutes after. The wind, when the hail was falling, was from the northeast.

John Gordon, Cedar Township, section 25, one-half mile southeast of the center: It hailed about half an hour previous, with a southeast wind. The wind was from the west, as the tornado was opposite. No lightning was seen.

Laurie B. Mauck, teacher at Prairie Flower school, witness: Called in the children at 3 p. m. The tornado was opposite certainly not later than ten minutes afterwards.

Thomas Waters, Jackson Township, section 19, witness: Saw the tornado coming rolling on the ground like a wave. Went to the cave and called upon Mrs. Waters to follow. She would not. Stood in the mouth of the cave, which was eight yards south

from the house, and facing it, and saw the house blown away. It was struck from the southwest. First, a portion of the roof was blown off, then the house went bodily like lightning. When the house had gone I came out of the cave and was blown to the east-southeast.



Sketch of Mr. Waters's house.

Mr. Waters's house was 30 by 16 by 11 feet without the roof. It was carried, sill and all, twenty-four yards down a declivity without being turned round or tilted over. When it struck the ground, it at first merely shaved it with the foremost sill, gradually going deeper until the resistance became so great as to cause the house to turn over, when it went to pieces. The ground was plowed up about two feet at the deepest point. The house had fallen three feet in traveling twenty-four yards. Its weight was at least ten tons.

Between the cave, which was only about four feet above the surface, and the house, but nearer the cave, stood a small tree. Against it a spade was leaning. Mr. Waters testified that it was not blown down. Two yards east of the tree stood a bucket containing a small quantity of lime, and weighing ten pounds. It was not disturbed. To the southwest of the cave the trees were comparatively uninjured over a triangular space, while on either side they exhibited signs of the greatest violence. An oak sill which had evidently been carried with the house until it struck, and then hurled due east, was driven four feet into the soil at an angle of 45°. Its dimensions are 16 feet by 8 inches by 8 inches, and its estimated weight three hundred pounds. It was found eighteen yards east of where the house struck.

Mrs. Waters was carried with the house until it went to pieces, and received injuries of which she died. The fragments of the house were carried far in the line of the storm.

Alexander Gibson had two houses, both situated as nearly as possible in the center of the storm. The first house struck was taken away without touching the ground and went to pieces in the air. The other house, in which were seven persons, was swung round on its northwest corner, as on a pivot, the south end traveling 36 feet and cutting up the ground as it went. It then turned over and was demolished. During this journey the floor was broken up and three persons fell into the cellar. The house was a large one. It afforded no good basis for calculation on account of the irregularity of its shape. A granary was pushed due east 14 feet. Its dimensions are 16 by 16 by 8 feet. It is strongly built of generally hard wood, and divided into compartments. It was full of grain. The weight of the building and grain was given at 60,000 pounds. The resistance to its forward motion was very great, because it was surrounded with wet straw and rubbish, of which it had pushed quite a pile before it. It was racked by the strain which had been put upon it. Missiles had been driven through three hardwood planks, in succession, of an inch thick. They consisted of small pieces of wood, but had been removed. A plank 16 feet long, 2 inches thick and 1 foot wide, was driven 4 feet into the soil, at an angle of 45°. A corn-sheller, weighing six hundred and forty pounds, was carried four hundred yards and destroyed. Trees were barked,

but without any symptoms of electric action or of explosion. The general position of trees and ruins was entirely corroborative of what has been already proved by an overwhelming mass of evidence, viz, the rotation and direction of rotation of the storm.

J. K. Marbourg, Jackson Township, section 17, witness: (House eighty yards from storm-center, with an excellent view of Gibson's house.) Watched the storm a long time before it came. The west was first filled with clouds which extended until they covered all the western and northern heavens reaching a little beyond the zenith. The tornado first appeared as two clouds, one from the southwest and the other from the west rushing to one point. Together they presented somewhat the appearance of an arrow, thus—

The whirl was seen forming when they met. Above them were dark, heavy clouds When the tornado came nearer it presented the appearance of one funnel, revolving contrary to the hands of a watch, and drawing everything up, thus—

When at Gibson's house, where I had the best view of it, and where it was one hundred and twenty rods distant, it presented the appearance of two funnels uniting in one, at the height of 40 or 50 feet. The bases of the two funnels were about 200 feet apart. They presented somewhat like the following appearance. The two funnels did not appear to revolve around each other. The first came to the east of Gibson's house, took his stable, and then turned back to his house. The two then appeared to unite. Could

not see the two afterward. The tornado disappeared behind a building. It grew very dark. The funnels were of a dark blue. Everything in them was rising. The

timbers from Gibson's house flew up. Did not see clear sky through the open space between the two funnels, but a bright yellowish hue. The upper funnel extended to the clouds above. Hail, or rather chunks of ice, from a pigeon's to a hen's egg in size, fell before the tornado column came in sight. The wind then blew gently from the east. After the tornado had destroyed the school-house, there came a violent gust of wind from the northwest, which considerably damaged my out-buildings. I had started to go to the school-house, and it carried me several yards before it. Immediately there fell a torrent of rain, with cold wind from the north. Was near where the school had been, but could not see anything. Suddenly saw the teacher and children, as if they had sprung out of the earth. They were coming toward me. They were shivering. They could give no account of what had befallen them. Never saw such miserable-looking beings in my life. I had four children there, and did not recognize them. The mud was pelted into their skins, so that it could not be washed out. It is not all washed out yet. A dead child was found forty yards northwest of the school-house. The storm opposite my house was a mile wide. An oak-post 4 inches in diameter was perforated by an oak-board 4¼ feet by 4 inches by 1 inch. (It had been thrown among the other rubbish and was not to be found.)

James Clancey, residing with J. K. Marbourg, testified that he viewed the tornado from the same position as Mr. Marbourg and saw only one funnel. I do not, however, estimate his observing powers so highly as those of his employer.

David Canier, Jackson Township, section 20, witness: Watched the funnel as it approached. It was perfectly dark in it. Could see boards flying out at the top of it. It was very large at the top and small at the bottom. It grew dark as night. Six persons took refuge in the cellar. The house went immediately like the clap of a hand, and the darkness was already gone. Then it turned pretty dark again, and rain fell in a sheet. It did not fall in drops. It was all over in a minute. Things in the cellar were not much disturbed. Bottles stood where they were.

Alexander Gibson, witness: Was at Mr. Canier's house. Hail as large as pigeons' eggs fell about twenty minutes before. Heard the noise about half an hour previous to the storm. Saw clouds coming from the north and south, and rushing together. Saw the funnel when three miles distant. Watched it when thirty or forty rods distant. It was then as black as night, with boards flying around it. A very strong wind was blowing. It grew dark as midnight. Rushed down into the cellar, and was barely down when the house was struck with a sharp, instantaneous rap, and in a moment it was gone. It was dark when I went down into the cellar. It was pretty clear as soon as the house went. It then grew darker again, and a tremendous rain came down. Saw no lightning. Heard no thunder. On my farm a beam was driven right though a hog.

Mr. Canier's house was 24 by 28, by 14 feet to the eaves. It was pushed 18 feet due north without touching the ground. Its edge then came in contact with the soil and with tree-roots, having fallen two feet from its original position, and the house toppled over, and was blown to fragments. The ruins were carried first to the northwest and then around to the northeast. Heavy oak-sills were carried hundreds of yards and broken. The strongest iron-bound machinery was knocked to pieces, and carried away. The sickle-bar of a Buckeye machine was carried thirty rods. A beam 14 feet by 6 by 6¼ inches was driven 3 feet into the soil in a slanting position. The beam weighed about fifty pounds.

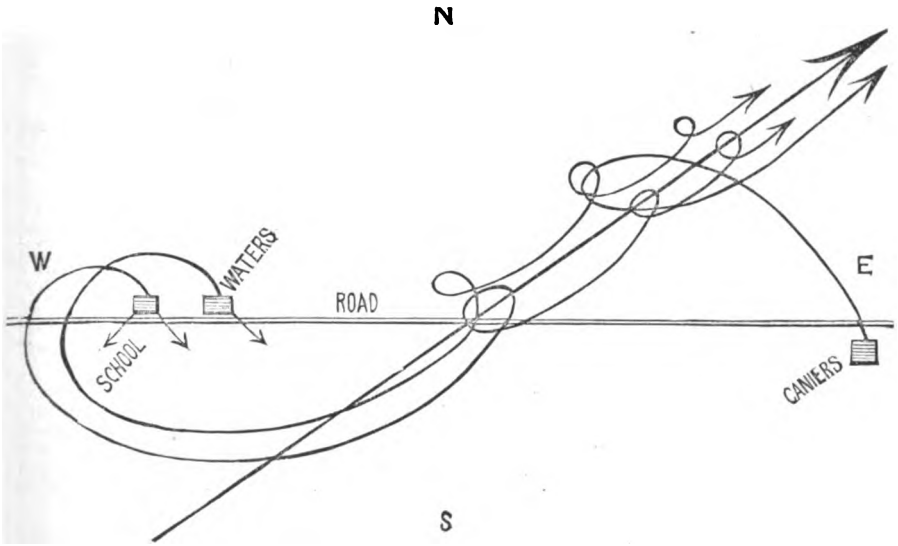
A half mile to the west of Mr. Canier's house stood the school-house already mentioned and a house occupied by Henry Waters. Between these buildings and Canier's house, and about one hundred yards to the northwest of the latter, passed the storm-center. The house occupied by Mr. Waters and the school-house were first blown to the northwest, and then in a circle by the south around to the northeast. A hedge ran along the road which connects the houses. It presented the appearances already described.

The house occupied by Mr. Waters was first blown to the northwest, the sills remaining. The sills were afterward blown to the southeast. The sills of the school-house had likewise, after being deserted by the house, been pushed to the southwest, and finally the position of the *débris* among the ruins showed there had followed a violent wind from the northwest; thus a tree lay across the foundation of the school from the northwest.

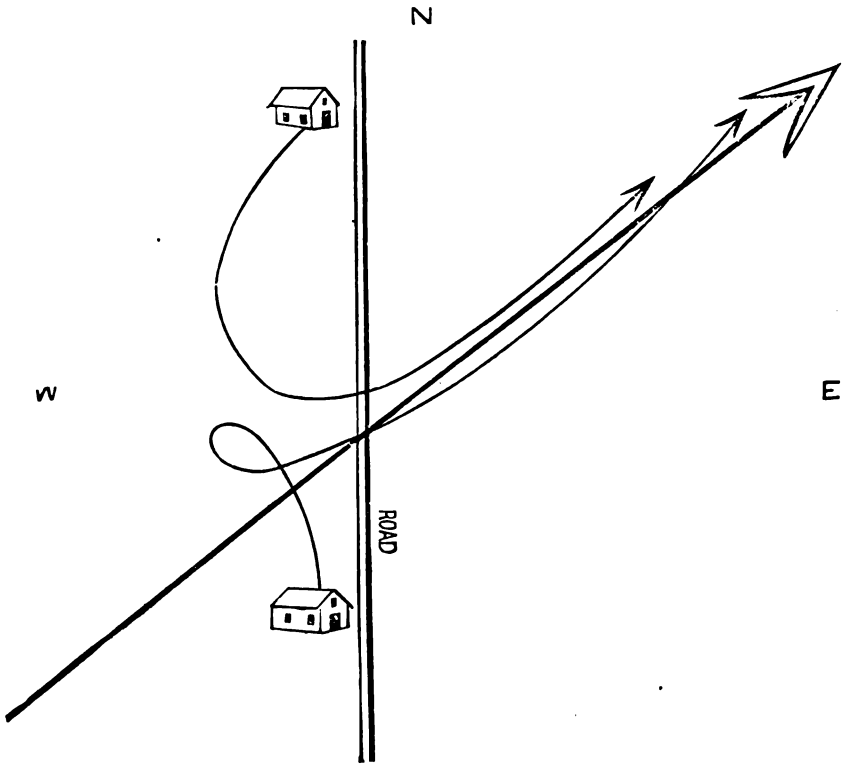
L. B. Babcock, son of J. P. Babcock, Jackson Township, section 17, witness: Hail fell before the storm as large as pigeons' eggs. Ran to get into the cellar. Cellar-door was blown over me as the house went. Came out of the cellar immediately, and was blown south. The rain then came down in sheets, with a north wind. The shutters from the house were carried three or four miles at least. Jacob Zeck got only partly down the cellar-stair and was hurt in the head.

J. P. Babcock's house was 34 by 26 by 14 feet to the eaves. The gable-end faced the wind. The house was pushed bodily toward the north, crushing the northern foundation; tore up the ground a short distance, toppled over, and went to pieces. It stood on the southeast of the storm-center.

Jacob Zeck, Jackson Township, section 17, witness: Was going down Babcock's cellar-stairs when his house flew away, and injured my head severely.



Representation of effects of the storm at these houses.



Sketch of the effects of the storm at Babcock's and Zeck's.

Mr. Zeck's house stands on the northwest edge of the storm. It was pushed from its foundations 12 feet to the south-southwest, plowing up the ground. The windows on the north side were smashed in. The windows on the south and east were blown out. A hay-stack was entirely blown away. It went, as could easily be traced, first south-southwest, and then round in a circle to the northeast. It went forty rods south before turning east.

The distance between these two houses was about half a mile. At this point the storm-path turned a little nearer north than northeast.

J. H. Laughhead, Jackson Township, section 16, witness: A little hail fell before the storm. It rained awfully for half an hour after it. Wind, during the rain, was from the northwest. It was very dark. Saw no lightning.

The house of this witness stands on the northwest side of the storm-center, about one-third of a mile distant from it. The fences were blown the usual way.

Levi Moothart, Cedar Township, about two miles north of the path of storm, witness: There fell the heaviest rain I ever saw; also hail as large as hens' eggs. The rain lasted about an hour, and the whole country was under water. The wind, during the rain-storm, changed from south to west and north, and at times it was very strong.

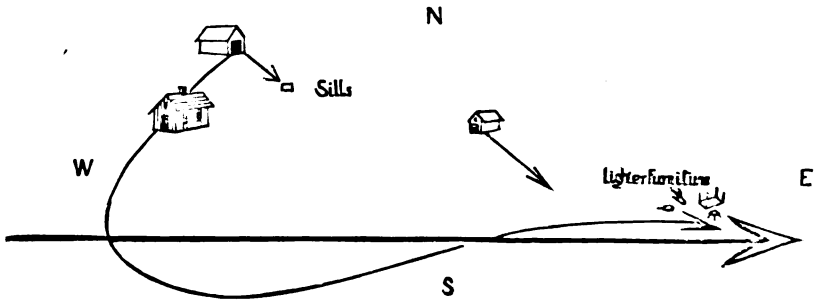
F. M. Curry, Jackson Township, section 9, tenant of John Flack's house, witness: The family went to the cellar. The house went south. No one injured. Eighteen pigs blown away.

The house was pushed 45 feet due south and then went to pieces. No explosion. It was situated to the northwest of the center.

E. N. Wright, Jackson Township, section 10, witness: Was on the southeast side of the storm. Saw distinctly, at the distance of two miles, the tornado in funnel-shape. The small end was down. Saw wood whirling. Heard its roaring after it went east. There appeared to be a mist or steam in front of it. It rose and fell. A few hailstones fell before the tornado and an exceedingly violent rain after it.

Mr. Wright's house stands on the northwest of the center of the storm-path, about fifty yards from it. A wood-house and kitchen were blown southwest. The dwelling-house, a large, strong structure, was moved one inch to the east. A stove weighing four hundred and fifty pounds, and exposing to the wind a surface of 3 feet by 21 inches, was pushed 12 feet to the southwest, where it was stopped by obstructions. A bell, weighing one hundred and fifteen pounds, not under any circumstances exposing a greater surface than one square foot to the wind, and mounted 12 feet high, was broken from its fastenings and carried 60 feet south. A granary, measuring 28 by 16 by 12 feet, and weighing, together with the grain, fifty-five thousand pounds, was carried twenty-one yards to the southeast. After plowing up the ground 2 feet in depth it tumbled over and went to pieces. It was carried down a declivity, falling 6 feet. The width of the storm-track here was half a mile.

J. T. Anderson, tenant of J. C. Cunningham, witness: Was at Grand Prairie U. P. church, three-quarters of a mile northwest of storm-center. The wind blew so strongly as to endanger the building.



Plan of ruins of Cunningham's house.

J. C. Cunningham, Jackson Township, section 11: The house of Mr. Cunningham stood on the northwest of the center of the storm-track, yet within the most violent vortex. The house was blown to the southwest; but the east door having been blown in, the house went to pieces without tumbling over, and the floor remained upon the ground. The lighter furniture, &c., was carried far to the east. The granary stood to the northeast of the house. Its contents were emptied into the house-cellar. The sills of the granary had remained when it was carried away. They were afterward pushed to the southeast. A barn was blown to the southeast. A hog, weighing two hundred pounds, was carried five hundred yards. A cow, weighing one thousand pounds, was carried two hundred yards.

There were four persons in the house and none were killed. The path of the storm s here five hundred yards wide and nearly due east.

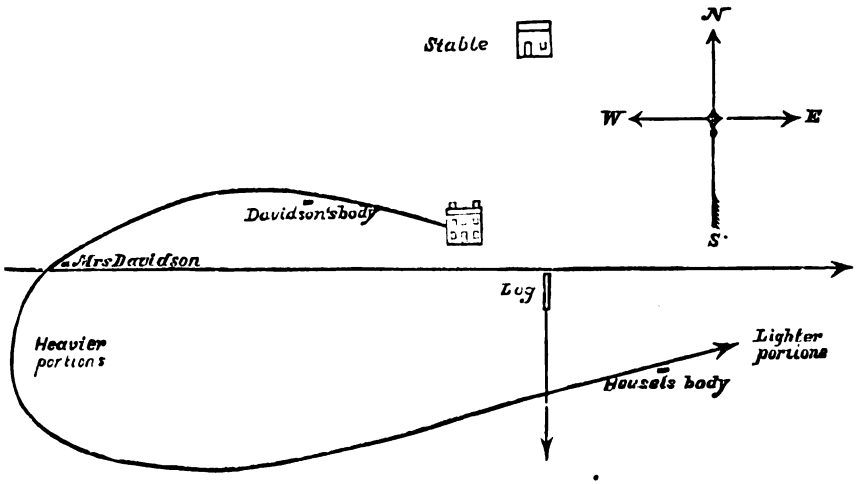
D. T. Carringer, Jackson Township, section 15: The house stood on the south edge f the storm. It was carried to the northeast 17 feet, going deeper into the soil as it vent. It then turned over and was blown away in fragments. The straw among the rees showed that the last gust came from the northwest.

Josiah Condit, Jackson Township, section 11, witness: No hail fell before the tornado. It rained terribly right after it. The wind was blowing from northwest as the ain fell. Saw no lightning.

Mr. Condit's house stands upon the southeast edge of the storm, which here traveled nearly due northeast. There seems to have been a streak of exceptionally strong northwest wind, which struck the barn and corn-crib, and cut its way through the garden fences. The center passed along the fields, producing upon fences and hedges the same effects as those already described.

The next house struck was that of J. M. Davidson, Highland Township, section 7: It stood precisely in the storm-center, which here, as if conscious that this was its last victim in Iowa, seems to have exhausted its utmost violence. The house, 18 by 12 by 14 feet, was blown bodily from its foundations down a declivity toward a slough. It never touched the ground, but was shattered in the air. It seems to have been carried first nearly due west, and then the lighter portions round in a curve to the east. The body of Mr. Davidson was found twenty yards west of where the house stood. The child was blown still further in the same direction. Mrs. Davidson was carried about one hundred yards west. The body of Leyden Housel was found to the southeast. The heavier portions of the house were found some hundreds of yards to the west. Mr. Housel's body had evidently been carried west with the fragments of the house and then back to the east. Mrs. Davidson and the child escaped with their lives.

A log of green water-elm, 7 feet in circumference, 8 feet in length, and weighing at least a ton, was carried fifty yards straight south. A horse, weighing one thousand and eighty pounds, was carried forty-five yards. A hog, weighing three hundred pounds, was blown thirty yards. The stable and barn were blown south. An iron plow, with wooden handles, was carried one hundred and fifty yards. The strongest iron-bound machinery was utterly destroyed. The young trees in the orchard were either barked or torn out. The storm was exceedingly violent for a breadth of one hundred and fifty yards, but fences were blown down for nearly a mile wide. At the house of Thomas Davidson, a quarter of a mile to the north, the wind blew so strongly that the door had to be held. The north wind was evidently subsequent to the east wind, because the house could not have stood such a wind.

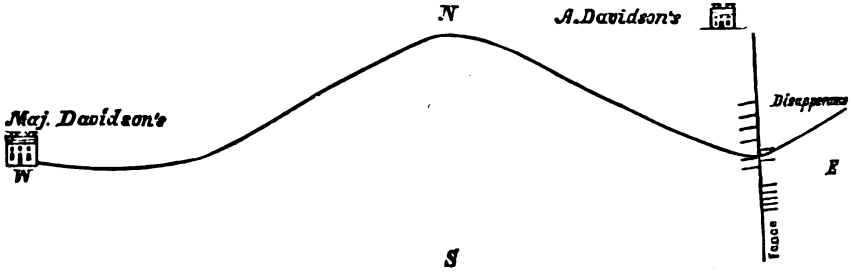


Plan of the ruins of J. M. Davidson's house.

A. Davidson, Highland Township, section 7, witness: It commenced to rain about ten or twenty minutes before the arrival of the tornado. Shingles and other stuff began to fall with the rain. Then went out to see where they came from. Saw the tornado about thirty rods distant. It appeared to be coming toward me. Saw it bend to the southeast. It was funnel-shaped and as black as possible. It whirled. Thought it whirled with the hands of a watch. It passed twenty rods to the south of the house

and bent again to the northeast. When thirty rods distant from the house it suddenly disappeared. Afterward saw another funnel, not reaching to the ground, traveling toward the northeast. When first seen it appeared to be only 60 feet above the ground at its lower end. The farther it went the higher it seemed to get.

Mr. A. Davidson's house is situated one-half a mile east of where J. M. Davidson's house stood, and a little north. The shingles and other material he saw falling came from his brother's house. The following sketch shows the direction of the storm-path after leaving Major Davidson's place until it ceased to touch the earth as a funnel.



Twenty rods south of A. Davidson's house it crossed a fence, exhibiting the same appearances as those already described. I was particularly careful upon this point, because of Mr. Davidson's belief that the funnel whirled with the sun. I thought it possible that the tornado, before lifting from off the ground, might have changed its direction of rotation. But the evidence to the contrary was so striking that Mr. Davidson at once, upon my pointing it out to him, admitted that he must have been mistaken. He had not paid particular attention to the matter, and it was very dark when his observations were being made. The fence in question ran north and south. It was only thrown down for a space of sixty yards, and the boards were not carried away except in the middle. The posts remained in the ground, those on the north of the center leaning west and those on the south leaning east. The posts in the center were leaning some one way, some another. The funnel disappeared upon a knoll in the midst of a hollow about one-half of a mile in diameter. There was no *débris* deposited at this point, nor were there any signs of a cataract of water having poured down. The wheat, however, was mown as low as possible, and the ground looked as if it had been baked, according to Mr. Davidson's statement. The funnel had narrowed to a point before it disappeared.

After leaving Mr. Davidson's the tornado-cloud traveled to the southeast. Its progress was now difficult to trace, because of the little attention usually paid to a dark cloud, a high wind, and a rain-storm. Considerable time had also now elapsed since the meteor passed.

James M. Mace, Highland Township, section 8, had several panels of fence blown down by a westerly wind. A few small hail fell before the wind and a very heavy rain after it.

J. W. Haskett, Highland Township, section 9, witness: Six or eight panels of fence on my farm were blown to the southeast. A few hail and some rain fell. The wind was from the northwest when raining. Saw some lightning. Heard roaring about one-half an hour before it came. Saw funnel strike the ground. Saw it rise at Davidson's. Saw it strike the ground afterward. The wind blew very hard.

This witness's house is two miles from Davidson's.

William Dennis, Highland Township, section 10, witness: A few panels of fence blown down to the east. Small pieces of boards, shingles, and laths were dropped. It hailed a little before and rained a good deal after. The wind during the rain was from the northwest.

John W. Guthrie, Highland Township, section 11, witness: A few panels of fence were thrown down to the east.

George Wallace, Highland Township, section 11, witness: Heard roaring. It grew very dark. A high wind about one-half mile to the south of witness.

J. H. Lyttle, Highland Township, section 12, witness: Had nearly half a mile of fence thrown down. The east and west fences were blown south; the north and south fences east. Heard roaring an hour before the storm came. The roaring was louder before it came than after it was here. Did not hear it after it passed. Saw the funnel until it came within three miles' distance. The whole northern portion of the sky was covered. Saw a cloud rushing from the south and another rushing to meet it from the north. The clouds rushing north appeared to be the lowest. After the clouds came overhead could see the lowest clouds rushing rapidly from the south. These were broken clouds. Through them could see a higher current rushing from the north. A

little hail and rain fell. The wind changed from the south to the west and northwest as the storm passed. The width of fence blown down was about one hundred and fifty yards.

Michael McGuire, Highland Township, section 12: One-half mile of fence on the farm was blown down. The chimney was blown off and some trees leveled. All was done by a northwest wind. It hailed a little and rained very heavily.

The storm now passed out of Washington County into Louisa County, traveling southeast.

Joshua Luckey, Louisa County, Union Township, section 17, witness: The path of fences blown down on my farm was about six hundred yards wide. The fences on the west of the center were thrown north; those on the east were thrown south. A few hail fell and a smart shower of rain. Heard no roaring after it passed.

Charles Crim, Union Township, section 20, witness: Fences, two hundred yards wide, thrown down to the southeast. The roaring was very loud for an hour previous to its arrival. Did not hear it after it passed. Saw no lightning. Saw a tongue of cloud shaped like a funnel hanging from the clouds. It did not reach the earth. At first it was hanging perpendicular. Then it commenced whirling like the tail of a suspended snake.

At this point I lost track of the tornado and could not recover it, although I spared neither time nor pains. Only now and again could one find a man who could give any information even of what happened on their neighbors' farms a week or two before.

John Colton, Columbus Junction, witness: There was some hail, a brisk wind, and a tremendous rain.

Mrs. Snyder, Oakland Township, section 9: Heard roaring distinctly. There fell a very heavy rain, which continued until nearly dark.

Peter Attig, Johnson County, Tremont Township, section 22, witness: About 4 p. m. there was a terrific rain-storm, with hail as large as hickory-nuts, and accompanied with thunder and lightning. My barn was struck by lightning. Perkins's barn was also struck.

Lone Tree Station: About 4 p. m. there was a violent storm of rain, hail, thunder, and lightning.

Nichols Station: There was here a high wind, with heavy rain and hail, and accompanied with thunder and lightning.

At this point I gave up the search and took train for Illinois. Previous to describing its effects there, the following testimony may find a place:

H. C. Vittitoe, Warren Township, Keokuk County, about three miles northwest of the tornado, witness: Saw a little south of the zenith the white under-clouds rushing in circles to a center. The gyration was contrary to the hands of a watch. The funnel had not yet touched the earth. The wind came from the northwest pretty strong after the passage of the tornado, bringing with it a little rain and hail.

Dr. W. D. Hoffman, Sigourney, witness: Mrs. A. T. Page collected a number of the largest hailstones. When melted it was found that they had contained a quantity of twigs, leaves, dry grass, and mud, all reduced to fine proportions. Hail weighing from four to eight ounces were common. One hailstone which was shaped like an apple, measured 4½ inches in diameter. The roaring was heard about twenty minutes before the hail began. It rose and fell like the cannonading in a battle. During the hail the wind came from the northeast, but it was very light. Sigourney is four miles north of the storm.

Isaac Farley, Foote Town, Iowa County, twelve miles north of Keota, witness: There was very little rain and no hail, but the sound was loud and distinct.

E. R. Eldridge, Washington, Iowa, witness: Watched the tornado from the roof of a house. Did not see a funnel appearance. The roaring was very loud and the cloud very black. The cloud appeared to bend forward. The elevation of its summit was about 35°. The distance five miles. Its summit was completely hidden by an overhanging cloud, which extended south a little beyond the zenith.

Arthur Howell, who was at Yalton, Iowa Township, five miles north of the tornado, testified that hail larger than hens' eggs fell, and a terrific rain of an hour's duration, accompanied by incessant thunder and lightning.

Extracts from a communication received from R. L. Jay, Harper, Keokuk County, physician:

"Was in the village of Baden, Keokuk County, German Township, three miles to the northwest of the storm-path.

"The tornado maintained an upright position. It moved rapidly at times, at others seeming to remain quite still. It was apparently about a quarter of a mile in height, and was funnel-shaped and very dark and angry-looking. It whirled with the hands of a watch. There was a continual whirling of the clouds above the funnel. This was observed for some time after the storm had passed. Saw no lightning and heard no thunder. It was impossible to hear thunder owing to the noise of the storm, which was terrific. The direction of the wind was northeast until the storm had passed, when it changed to the northwest. Rain fell in torrents. Quite an amount of hail fell of all conceivable shapes. Three were picked up weighing one-half of a pound each. Half an hour after the storm the thermometer stood at 92°."

G. W. Brockway, Talleyrand, witness: No rain nor hail fell here. A heavy rain fell about one mile to the north. The edge of the cloud did not reach the zenith by a few degrees.

Extract from the Sigourney News, May 28, 1873:

"While the cyclone was mowing its path a few miles south and east of Sigourney a tremendous hailstorm visited this locality. We saw one hailstone which weighed eight and one-half ounces. The hailstorm was followed by a heavy rain, after which the sun came out bright and pleasant for the rest of the day."

Extract from the Washington County Press of May 28, 1873:

"The writer was in a street-car, half way from Moline to Rock Island, at 4.30 p. m., on Thursday, when it was struck dead ahead by the most terrific wind and rain-storm we ever experienced."

S. J. Mather, editor Wilton Chronicle, Iowa, witness: Between 4 p. m. and 6 p. m. a very dark cloud passed over, which poured down a very heavy rain.

Extract from the Chicago Tribune, May 25, 1873:

"At Muscatine the rain came down as if the flood-gates of heaven had been opened, followed by hail. Between there and Wilton Junction, at Monona, Fredonia, and other stations along the southwestern division of the Chicago, Rock Island and Pacific Railroad, the country was flooded."

The tow-boat Victory lost her pilot-house and smoke-stack when near Buffalo, on the Mississippi. The tug Nonesuch lost her smoke-stack and pilot-house at Moline. She was driven ashore.

A. H. Swan, editor of the Monmouth Review, witness: There was an exceedingly heavy rain, a little hail, and a great deal of lightning about 5 p. m. The atmosphere smelt as of brimstone previously. It was oppressively hot; perhaps 95°.

The temperature and pressure on May 22, 1873, at places near the tornado:

	Davenport.		Keokuk.		West Union.	
	Bar.	Ther.	Bar.	Ther.	Bar.	Ther.
7 a. m	29.73	64	29.64	69	29.49	61
2 p. m	29.60	77	29.51	85	29.46	65
9 p. m	29.69	66	29.71	72	29.53	64

The condition of the barometer and thermometer at West Union was obtained from Frank McClintock, correspondent of the Smithsonian Institution, who also furnishes the following noteworthy fact: "Wind changed from the south to the west rapidly at 3.45 p. m. It worked back to the south before 9 p. m." The relative humidity at—

	Davenport.	Keokuk.
7 a. m	94	85
2 p. m	77	54
9 p. m	94	85

We do not, therefore, overrate the relative humidity when we estimate it at 65 per cent. at 2 p. m. The average temperature at the earth's surface in the line of the tornado at 2 p. m. was, from the above, probably 76°, but in the wooded hollows much greater.

Mr. Jay, however, of Harper, Keokuk County, states that the temperature was 92° half an hour after the storm. The day was generally described as being very warm.

Having arrived at Prairie City, Ill., I endeavored to find out the exact locality where the tornado first began to overthrow fences, damage buildings, &c. On the farm of James Williams, Point Pleasant Township, Warren County, there was a strong wind, but not sufficiently so to prostrate fences. About one mile to the east is the farm of Israel Jared, Point Pleasant Township, section 24. Mr. Jared testified as follows: Saw streaks of cloud moving from the north and south toward each other before anything touched the earth. Saw a cloud in the form and about the size of a haystack strike the ground on my farm. A few minutes before, hail of moderate size and in small quantity fell, followed, as the whirlwind was passing, by a smart shower of rain. The wind, which had been southeast, changed to the west after the tornado passed. It was pretty warm before, and cool after it. Heard roaring some five minutes previous to the arrival of the storm. Fences were blown down for two hundred yards wide. They were blown toward the east. Saw some lightning. There was a heavy cloud to the north as the storm approached.

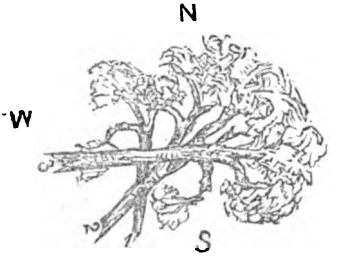
Mr. Jared's house stands about two hundred yards north of the storm-path. The tornado was here traveling a little to the north of east.

John F. Tatman, Israel Jared's farm, testified that he saw the funnel strike the farm and that he heard the roaring for a long time previous.

Before leaving this farm the storm had developed all the characteristics of a tornado, except that the east wind was not yet powerful enough to destroy. The whirlwind then passed along a ravine full of tall timber. Nearly all the trees were uprooted or broken, but generally the latter. They appear to have had a firmer hold of the soil

than those in Iowa. The breaking usually occurred about six feet from the ground and the barking was almost entirely confined to the broken trees. The bark was torn off both up and down from the place where the timber was broken. The trees, when sound, were seldom broken clean across. Half or more of the wood was severed, and the remainder was bent so as to allow the tree to rest upon the ground. The broken timber, when sound, invariably presented the appearance of a broom. The fibers of each year's growth were loosened from the others and split. It was easy to obtain pieces ten feet long and as thin as a wand. This separation of the fibers had evidently been brought about by the excessive straining and bending of the tree before it fell. Each year's growth had apparently been snapped asunder by itself, beginning at the outside. The trees all lay as they had fallen, being, when once down, protected by the surrounding timber. If they had, after falling, been subjected to a wind from another direction, so as to break them off entirely, they would have presented the precise appearances which have, by certain meteorologists, been attributed to the action of electricity. Many of these broken trees were two feet in diameter. When a tree, still standing, had its bark torn off at any point, an examination generally showed that the fibers of the tree were separated and perhaps partly severed at that point.

No. 1 lay beneath, diameter 8 inches; No. 2 lay above No. 1, diameter 26 inches; No. 3 lay above No. 2, diameter 26 inches. As the tornado increased in power the position of the overthrown trees varied more and more from a westerly direction; some weak ones lying from the south-southeast south of the center.



Sketch of fallen trees.

The following is a sketch of trees found in the center, one-quarter of a mile farther east than the above:

Nos. 1 and 2 lay beneath, diameter 6 inches; No. 3 lay above Nos. 1 and 2, diameter 18 inches; No. 4 lay above No. 3, diameter 15 inches.

Mason G. Buck, village of Swan Creek, witness: Saw a distinct funnel-shaped form. It appeared to jump up and down 50 feet at a time. It hailed a little before the storm and rained a little after it. Heard a roaring about twenty-five minutes before it arrived. Saw no lightning. Saw only one funnel. Trees were blown down in my yard from the northwest. My house is a half mile south of the center.

Leroy Putnam, near Swan Creek Station, witness: It looked like a top and whirled contrary to the hands of a watch. Saw it rising and falling. My house is about half a mile south of the center. It blew very strongly here. The tornado at this point was traveling east-northeast.

William Huston, Swan Township:

Mr. Huston's house stands on the north edge of the storm-path. The roof of the barn was blown to the southeast. A corn-stump about two inches in length was driven through the bark of a large tree, leaving its impress upon the wood.

John Worden's unoccupied house, one-quarter of a mile east of Huston's, was completely demolished. It stood near the center. The orchard was uprooted. Trees which had stood one hundred and twenty yards southwest of the building lay with their branches upon the foundations. The larger timbers of the house lay a few yards to the west and north. The lighter were blown away. The breadth of desolation was here one hundred and fifty yards. At this place the tornado seems to have made one of its sudden dips, the trees on the west and south being uninjured.

Shortly after leaving Worden's house the tornado entered the timber on the north bank of Swan Creek. It increased greatly in power and width as it did so. So long as it followed Swan Creek, fences were thrown down over a space of from one to one and a half miles wide.

Franklin Booth, Swan Township, section 18, witness: Hailed just before the storm as large as hazel-nuts, with a northeast wind. It did not rain much. Saw lightning toward the south. Mr. Booth's house stands on the north edge of the storm.

Abraham Stanfield, Swan Township, section 18: The storm-center is one-quarter of a mile south-southeast of Mr. Stanfield's house. The fences were generally thrown south. Among Mr. Stanfield's timber, near the creek, the storm wrought complete ruin. Three typical groups of fallen trees may be selected. Group I, a little north of center: Nos. 1 and 2 were blown down from the east and lay below Nos. 3 and 4. They were between one and two feet in diameter. Group II, a little south of center, and seventy-five yards distant from Group I: No. 1, blown down from the southeast, lay below No. 2, blown down from the southwest. No. 1 is 15, and No. 2, 10 inches in diameter.

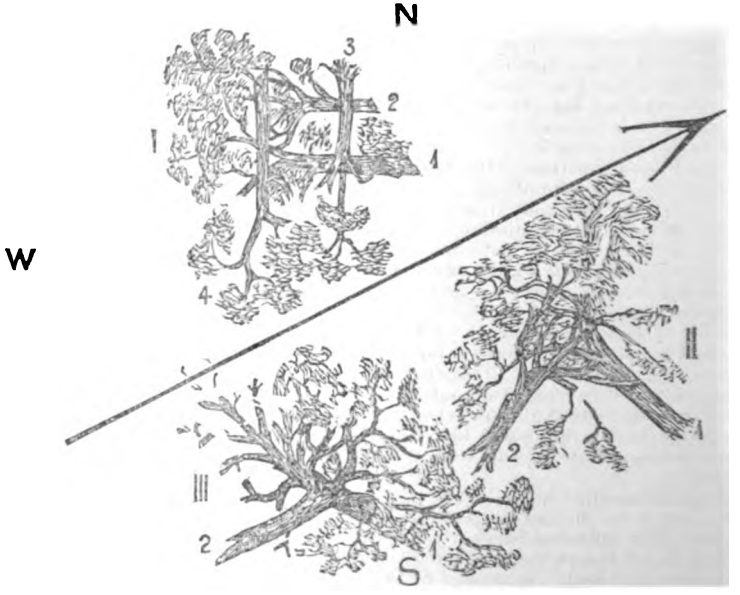
Group I.

Group III, a little further south of center than Group II, and near it: No. 1, a decayed tree 16 inches in diameter, lay under No. 2, 14 inches in diameter.

Group III.

Group II.

The storm at this point overthrew all trees of any dimensions for a width of two hundred and sixty

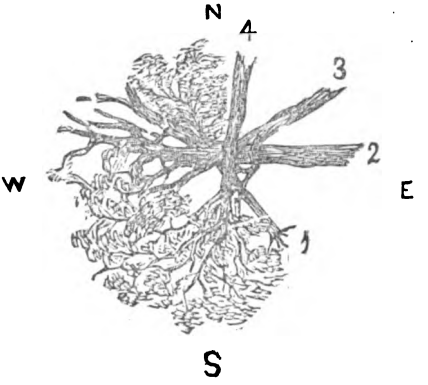


The three groups combined.

yards. The following group of trees was found about one-half a mile further on. It was just within the most violent vortex of fifty yards in width, and a little to the north of the center. The trees lay as they fell: No. 1, 12 inches in diameter, from the southeast; No. 2, 18 inches in diameter, from the east; No. 3, 14 inches in diameter, from the northeast; No. 4, 16 inches in diameter, from the north. No. 1 was lowest, No. 2 next, No. 3 next, and above all lay No. 4.

The path of the tornado was here exceedingly well marked among the young trees. It could be followed by the eye as far as the ground permitted. They were

orn and bare, while all around was green. This barking of the young trees took place within much narrower limits than those within which grown timber was overthrown. Generally they did not extend over twenty to thirty yards in width, and were sometimes much less, and even disappeared altogether. The trees exhibited the marks of the greatest violence on the side from which the storm came. The twigs were smashed and broken off, the bark partially removed, and even the timber bruised. These results were evidently the effect of a rush of missiles against the trees.

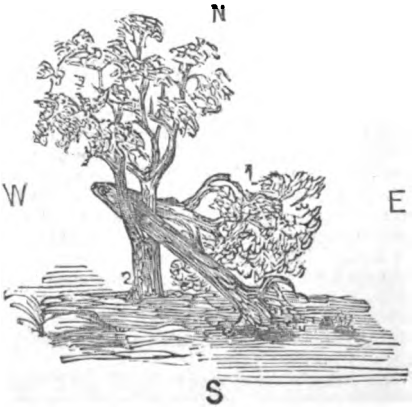


The tornado at one point suddenly narrowed the path of extreme violence from fifty yards to twelve yards, at the same time changing its course to the southeast. This change of direction brought it toward Swan Creek, along the northern bank of which it had hitherto been raging. Just as it struck the creek the track was nearly south-southeast. Immediately thereafter it turned nearly due east, following the creek. The bottom of the ravine within which Swan Creek flows is about two hundred yards wide, is surrounded by steep and lofty bluffs, and was covered with large trees. Among these trees the whirlwind raved with the utmost fury, developing an energy surpassed at no other point in its career. Trees from three to four feet in diameter were snapped or uprooted. Many large trees were broken off at a height of about 40 feet and left without a twig. By far the greater number of trees along the ravine were thrown down from the southwest. The same broom-like appearance was generally presented by the broken trees as already mentioned.

Thomas Warmoth's house stood in the bottom of the ravine. Mrs. Warmoth testified as follows: Heard a roaring first. When the storm came near the roaring was louder than thunder. A few hail fell just before the tornado blew. It was immediately preceded by a very bright flash of lightning. Went into the house and got upon my feather-bed, together with my child, because I was afraid of the lightning. A large tree was blown down, catching the side of the house. The house went to pieces, the tree, however, keeping the floor in its place. Found myself under the feather-bed with my child. The bed was pinned to the earth by pieces of timber. Was soaking wet. Everything was covered with mud. Heard no thunder. The lightning struck a tree, depriving it of its bark.

I was unable to find this tree. Mrs. Warmoth's testimony is valuable as a curiosity. It was generally impossible to obtain any information from the ladies. If one questioned them rigorously they took it as an insult, and if allowed to tell their own story they immediately commenced running such a muck among the prodigious and the incredible that one was glad to make his escape. In this connection it is also worth mentioning that although invariably offering payment for any necessary hospitalities, I soon learned the wisdom of always addressing myself to the master of the house when asking for such.

No. 1 is a tree 18 inches in diameter. No. 2 is a tree 2 feet 6 inches in diameter, but forked at the height of 15 feet from the ground. No. 1 was blown from the southeast between the forks of No. 2 and then half broken close to the forks and blown from the northwest until its top nearly touched its root.



Group of trees near Warmoth's house.

After leaving Warmoth's house the tornado-center crossed to the south bank of the creek, where it continued for nearly a mile farther, although somewhat increasing its distance from the creek. It crossed to the south bank, where a smaller creek joins Swan Creek from the south. This brought it nearer to the house of A. J. Caton, Swan Township, section 15, which stands about five hundred yards from the center of the whirlwind. Part of the roof was blown to the southeast and part to the northeast. A smaller house was blown a few yards to the northeast and inverted. A house on Mr. Caton's farm, tenanted by N. J. Reynolds, 14 by 20 feet and one story high, was carried

eight yards to the northeast bodily. It then struck the ground, tumbled over, and was blown to fragments. Its four inmates were carried from fifty to sixty yards, but not killed. It stood a little south of the center. After passing Mr. Caton's farm the tornado entirely left Swan Creek. Before tracing its further progress, it will be better to give the evidence of people living at or near Youngstown, about one mile south of the center:

Charles McCormick, Swan Township, witness: The tornado looked as large as a house when three miles distant. A little rain and hail fell. The wind with the rain was from the west. There was no wind to do any damage. House a quarter of a mile south of Swan Creek. Time, about 5.45 p. m.

H. W. Simmons, Swan Township, section 28, witness: The time when the tornado passed was about 5.40 p. m. Have good grounds for this assertion. A few minutes before its arrival I noticed a very black cloud in the west with a lighter space on each side of it. My house is three-quarters of a mile from Swan Creek. Did not hear the roaring very distinctly until it was nearly opposite. Then it was an awful ocean-like roaring. Then it presented the appearance of a funnel apparently only a few rods across at the bottom. The top of it appeared to be from three to four times wider than the bottom. Did not notice whether it entered an overhanging mass of cloud. It hailed a little when it was opposite. Fences were blown down fully a mile and a half to the south of Swan Creek.

H. A. Folger, M. D., Youngstown, one mile south of Swan Creek: The tornado was opposite about 5.45 p. m. Saw dark clouds in the west-northwest for an hour previous. There were several bright flashes of lightning after the tornado. A few hailstones as large as bullets fell as the tornado was passing. It rained very hard for a few minutes after. It was quite dark for a little time. Saw clouds rolling and tumbling. The strongest gust came from the west-northwest.

In Youngstown a few chimneys were blown off and similar damage done. One house was moved from its foundations to the northeast. Trees, in a few cases, were blown down, and all to the east. It is to be noted that, while at McCormick's house, a quarter of a mile south of Swan Creek, along which the tornado passed, no damage was done by the wind, at Youngstown, three-quarters of a mile further away, the gale was almost strong enough to blow down houses. McCormick's house is somewhat lower down and stands among trees.

After leaving Swan Creek the storm traveled east-southeast. The first house which came in its way was that of Absalom Vandevere, Swan Township, section 15. He testified as follows: I have reliable information that two or three miles to the north the clouds were seen rushing south. The clouds came also from the south toward the tornado. Streaks of unusually strong wind seemed to come now and again from the south side and run into the main whirl. The wind on the north side was not nearly so strong as on the south side. Twice as much fence was blown down on the south as on the north side. Its noise resembled that of machinery, only very loud. The dimensions of my house were 36 by 42 by 18 feet.

Samuel Larkins, Swan Township, section 15, witness: Was at Mr. Vandevere's house when the tornado struck it. Heard roaring about fifteen minutes before it came. When I first saw the funnel it did not touch the ground. Saw it whirling contrary to the hands of a watch, and the clouds were drawn in toward it on all sides. It did not lighten before the storm. It lightened a great deal immediately after it in the west. It did not hail nor rain. Did not see clouds in north or south. There appeared to be only a narrow strip of clouds. A McCormick reaper, weighing probably one thousand pounds, was carried ten rods from the south. Two horses were blown, the one fifty the other forty yards. An axle-tree, torn from a wagon, was carried a mile and a quarter to the southeast. A shingle was driven through a half-inch ash-board. It is in the possession of a Mr. Thomas. A rafter, 8 feet by 2 by 4 inches, was driven through three hogs, and thrust into the ground a foot and a half. All three were on it when it was found. A picture-frame was picked up with the glass unbroken. The wind blew very strongly for about two minutes.

Mr. Vandevere's house, 36 by 42 by 18 feet to the eaves, stood north and south lengthwise. It was moved due north half the length of the house, tumbled over, and blown to pieces. It stood with its north end exactly in the center of the vortex. There were nine persons in the cellar and two in the house. One of those in the cellar was killed by a log. The trees around the house and within the narrow path of the greatest violence, all pointed to the east-southeast, the direction in which the storm was traveling.

W. J. Jones, Swan Township, witness: Vandevere's house is forty rods to the north. Myself and wife were in my house when it was blown away. It grew dark as midnight just then. There was a little hail before. Did not notice any rain. The house did not go very fast.

Mr. Jones's house was 22 by 16 by 12 feet to the eaves. It was pushed entire five feet to the northeast. It then toppled over and was blown to pieces.

The arrow in the sketch should point E.SE.

Sketch of storm-effects at Larkins's, Vandevere's, and Jones's houses.

The fragments in Illinois had already been gathered from the fields, rendering it more difficult to trace the ruins in their flight.

David Smalley, Swan Township, section 22, witness: There was quite a strong wind all day previous to the storm from the southeast. Saw some lightning before the storm. A little hail fell before it and a moderate shower of rain after it. The house stands on the south edge of the storm and was blown east-northeast one inch. It was very warm that day.

Edmund Jennings, Swan Township, section 22, a quarter of a mile south of the center, witness: While the storm was still in the west saw two funnels come together, the one from the north and the other from the south. They appeared to be both whirling, but contrary to each other. When they were still at a distance the sky was cloudy overhead. Their summits appeared to be lost in cloud. Saw lightning and heard thunder previous to the tornado. There fell a little hail before the storm and some rain after it. The trees, chimneys, and fences were thrown down to the northeast.

William Thomas, Swan Township, witness: The center of the storm passed a quarter of a mile to the north. An unoccupied house stood in its way. It was lifted from its foundations and then broken to pieces. Horses were carried a good way and killed. A rail was driven through one of the cattle, going in beneath her tail and coming out at her shoulder. Saw only one funnel.

Robert Wearmouth, Swan Township, witness: The storm-center passed three hundred yards to the north. It was traveling nearly southeast. Horses and cattle were blown a considerable distance. Saw two flashes of lightning before the tornado. Hail fell just before it, and as it was falling heard some thunder. It was so dark when the storm was on us that it was impossible to see anything flying.

Charles Thomas, Swan Township, two hundred yards north of the center and directly north of Wearmouth's, witness: The wind, which blew down trees, unroofed outhouses, &c., came from the northeast and north. Fences were thrown down nearly a mile wide.

Charles Perry, Swan Township, section 24, witness: House, 16 by 24 by 15, with gable-ends facing south and north, was carried to the southeast. There were four inmates, one of whom was mortally injured. Mrs. Perry, who weighed two hundred pounds, was carried one hundred yards and stripped of her clothing. Two horses were carried one hundred yards. Hogs had rails driven through them.

Mr. Perry's house stood near the center of the storm. The west side of the house was blown in and the house instantly broken up.

Caridan Johnson, Greenbush Township, witness: My house is three-quarters of a mile north of the storm-path. Saw no funnel-shaped appearance. Saw some lightning and heard thunder before the tornado came. A few small hail fell before the storm and a very hard rain after it.

B. A. Reid, Swan Township, section 24: Mr. Reid's house stood one hundred yards north of the storm-center. The north side of the house was not blown away, but blown down from the north. The wind had evidently driven in the windows and then burst the house asunder. Hogs, weighing two hundred pounds, were carried two hundred yards.

B. A. Reid, sr., Swan Township, section 25, witness: Saw two clouds, one in the northwest and one in the southwest, rushing together with great rapidity. A whirling commenced right where they met, assuming the form of a funnel. Saw it whirling with the hands of a watch at the distance of about two miles. These low clouds were overhung by a heavy mass of clouds. The funnel reached up to this mass. There was a little hail and a little rain. My house is less than half a mile south of the center.

J. P. Reid, witness, Swan Township, section 25: There was incessant lightning to the northwest before the storm. Heard thunder also. When the storm was one and a half miles distant its angle of elevation was about 75°. Saw the funnel distinctly.

H. H. Hewitt, Greenbush Township, section 29, witness: Fences thrown down here for half a mile wide.

P. A. Vaughn, Greenbush Township, section 20, witness: Center of storm passed three hundred and fifty yards south of my house. The strongest gust of wind came from the northeast and north. Three trees, about ten inches in diameter, were carried one-quarter of a mile to the southeast.

Mr. Nichols, Greenbush Township: Mr. Nichols's house stood about one hundred and sixty yards north of the center. It appeared to have been turned over without being first pushed forward in a mass. It broke into large pieces, which were only carried a few yards. Eight persons were in the house and none of them were killed.

David Stookey, Greenbush Township, section 27: Mr. Stookey's house stands three hundred yards south of the storm-center. The corn-crib was thrown to the northeast. Mr. Stookey testified that he did not hear a great roaring, and that it was very dark.

Barney Sloey, Greenbush Township, section 26, witness: My house is forty rods south of the center of the destruction. Outhouses were damaged by a southwest wind. A wheel of a corn-planter was carried from Nichols's farm, on the north side of the storm-center, and deposited at my house, one mile distant, and on the south side of the center. A wagon-tire was carried two miles in the line of the storm. There was an ugly-looking cloud in the northwest for hours before the storm came up, and lightning was playing in it. When the storm came near, its roar was like that of a cataract.

John Woods, Greenbush Township, section 25, witness: Heard no roaring. House is on south edge of the center. Had two miles of fences blown down; one horse carried forty rods; one cow perforated by a rail.

J. E. Gustine, Lawrence farm, Greenbush Township, section 16, directly north of Prairie City and one hundred and fifty yards to the south of the storm: When the cloud came up it became very dark, and the roaring was louder than thunder. Did not see any lightning. A little hail fell and a little rain. The lamp was lighted in the house, it was so dark.

John Van Winkle, Union Township, Fulton County, section 30, witness: The storm-center passed thirty rods to the north of the house. Remained out of doors all the time. Saw the funnel-appearance touching the ground a half mile distant. The roaring was so loud that I could not hear the breaking of the buildings. There was no crashing, but a whirring like that of a thousand threshing-machines. Everything on the south side was thrown toward the center. Most of the wood was deposited along the center. The storm lay in the northwest a long time, and during that time the wind was steady from the southeast. There seemed to be a dark cloud to the southwest, another in the northwest, and a clearer space between. The wind blew from the northwest as the storm passed.

E. G. Roe, Union Township, Fulton County, section 30, eighty rods north of Van Winkle's, witness: My house is forty rods north of the center of the storm. For an hour before the tornado arrived a heavy cloud had been lying in the northwest, with lightning playing in it. Clouds kept rising in the southwest and passing over to the northwest. From the clouds three points came down, from which rain appeared to be falling. There was clear sky between these points. The ruins of my barn were carried first a little north, then forty rods west, and then distributed along the storm-path for half a mile east. They could easily be traced, because the barn was painted red. At Joliet Creek, on this farm, the storm either widened or a branch came down the creek. The storm struck us a little before 6 p. m.

J. B. Hatch, Union Township, section 29, twenty rods to the south of the storm-center, witness: The storm struck us a little before 6 p. m. As the cloud and darkness came over, everything appeared to be enveloped in a white mist. There were no drops, but it wet everything. The carpets in the house had to be taken up and dried. The paper on the walls was covered with mud and fine-ground leaves. The strongest wind came from the southwest. Everything was collected to the center of the storm-path. Did not feel any choking sensation when surrounded by the mist. Did not feel cold. Boy felt chilly. It had been a very warm day. Saw lightning right in the storm.

An unoccupied house ten rods south of the storm-center was parted. The kitchen was carried to the north; the main body to the south.

Cornelius Ackerman, Union Township, a half mile east of Hatch's house and five rods south of the storm-center, witness: Saw storm gathering in the northwest and southwest for some time. Hail nearly the size of hens' eggs fell before the storm. A south wind took the roof off the house. A northwest wind then still further demolished it. The wind took me off my feet. My hired hand, Cornelius Rice, was thrown down by the wind and then pushed along the ground for several rods. He leaned on his elbow as he went. He first traveled north, and then in a curve round to the east, when he stopped his further progress by clinging to the branches of a tree. The ground was rather dry before the tornado. It was quite wet after it. Several hogs were transfixed with timbers. A shingle was driven into the sound butt of a white-oak beam measuring 4 by 4 inches. The darkness was black. The direction of the storm-path at this point was still east-southeast.

William McBride, Union Township, section 32, witness: Hail and heavy rain fell before the tornado. It then became black darkness. Three-quarters of a mile south from my house chimneys were blown down.

Mr. McBride's house stands apparently near the center of the storm, which here

seems to have mitigated its fury somewhat. The barn-roof was blown to the north-northeast. The barn itself was moved four inches to the south.

R. Johnston, Union Township, section 33: The wind commenced to blow very hard from the south. Went into the cellar. Two small buildings were first blown to the north. The kitchen was blown southeast. The barn and other buildings went south. The main building was pushed a few feet to the southwest. It grew so dark that one could not see ten feet. Some hogs and pigs were carried away, I do not know where. Some of the former weighed two hundred and fifty pounds.

Mr. Johnston's house stood exactly in the center of the whirlwind.

Thomas Poole's house stood to the east of Johnston's. It was demolished. I could not see him.

Andrew Maholland, Union Township, witness: It was near 6 p. m. when the storm struck us. Felt the air to be very hot, like steam, before the storm. The wind at first came strong from the east and was accompanied by a driving wet. The roof of the house was blown to the southwest.

Mr. Maholland's house stands fifty rods to the north of the center.

R. S. Gorham, Union Township, section 33, forty rods south from Maholland's, and rather on the north edge of the center: The house was carried entire a few yards to the northwest, struck the ground, toppled over, and went to pieces. The kitchen was moved a few yards and broke up, leaving the family upon the floor. Trees were blown down from the northeast.

D. H. Gorham, Union Township, section 34, witness: The tornado arrived at my house at 5.55 p. m. Saw the storm gather in the west-northwest one and a half hours before it came. Saw a little lightning as it approached, but none after it arrived. Saw two clouds, one in the southwest and one in the northwest, with a red streak like sunset between them. Afterward saw only one cloud, rolling forward like a wheel. Heard a roaring a little before the storm arrived. It grew so dark that I could not read—a black darkness. First there came a blow from the southeast. After that there came a slight lull, and hail as large as hens' eggs fell straight. Then there came a harder blow from the northeast. Then for three minutes there fell a perfect torrent of rain. Rode out immediately, and the water on the road reached to the horse's belly. My outbuildings were damaged by the northeast wind. Fences were thrown down a mile wide.

Mr. Gorham's house stands fifty rods north of the center of the storm.

A. H. Miller, Union Township, section 35: The house of Mr. Miller stands on the north edge of the storm. There fell a tremendous rain as the storm passed.

At D. M. Kline's farm fences were thrown down a mile wide. They were thrown toward the center from both sides. The storm at this point had greatly diminished in violence.

O. Chatterton, Lee Township, section 1, witness: Heard the roaring only a few minutes before the storm came. The wind blew first from the southwest, then from the northeast, and then from the north. Saw no lightning. A tremendous rain fell about eighty rods south from the house. Thinks that this heavy rain did not extend far south. The Council Corner school-house was turned round.

John Schneider, Ellisville Township, had some fences blown down on the northwest bank of Spoon River.

H. Caril, village of Ellisville, witness: A very heavy rain fell during three-quarters of an hour. For six miles to the north everything was flooded. There was not much lightning. Heard a roaring, but not very loud.

Isaac Sechleider, Deerfield Township, section 7, across Spoon River: Mr. Sechleider's house stood near the summit of the bluffs which face the river. It measured 16 by 22 by 12. It was blown southeast three rods, and deposited on its roof. The five inmates were not much injured. The storm smashed the timber somewhat on the southeast bank.

About a mile farther on it became impossible to track the storm. Before proceeding to where it next struck, it may be advisable to insert some testimony from Prairie City and the neighborhood. Prairie City is about one and a half miles south from the storm-path.

The editor of the Prairie City Herald testified that he thinks the storm was opposite a little before 6 p. m.

C. H. Hemenover, Prairie City, testified that oak-leaves fell during the storm, and that the wind blew very strongly from the south. He keeps a thermometer, but did not look at it that day. Thinks temperature was not over 70°.

L. B. Day, Prairie City, witness: Saw a cloud in the northwest of a funnel-shape; heard a roaring sound for perhaps five minutes. The wind blew strongly from the southeast all of a sudden, accompanied with hail about the size of pigeon-eggs. There was an undercurrent of clouds from the southeast overhead. Just as this southeast wind blew it grew very dark. After the tornado passed the wind changed to the northwest, and a smart shower fell. Then it cleared up, and the sun shone.

J. M. Kershaw, hotel-keeper, Prairie City, witness: It grew dark about 6.05 p. m.

saw clouds from southeast sent a-whirling as they struck the northwest clouds; saw continual lightning as the storm approached; heard roaring after the storm passed.

J. H. Day, Lee Township, about one mile south of the center of the storm, witness: There fell a very heavy rain, with north wind, so heavy as to flood everything in a minute. It filled a small creek so that I could not get home that night. I was one-half mile farther south than my house. The windows were smashed with hail on the north and east.

Wm. Henry, Lee Township, section 4, witness: Saw a heavy cloud in the northwest, and a less heavy one in the southeast. There was a lighter space between, but could not see the sky there. The wind blew first from the east, and damaged the outhouses. Afterward there came a northwest wind, with a terrible rain.

Samuel Taylor, Lee Township, section 20, four miles south of storm: It rained a little from southeast, and then the wind came more from the south.

A. T. Irvine, station-agent, Prairie City: The telegraph was not disturbed by free electricity during the passage of the tornado. It only ceased to work between this and Avon after the wires were broken by the wind. The wind blew from the southeast as the storm approached. It rained quite a while from the southeast. Then it changed to the southwest, still raining, and when the rain somewhat ceased, it came from the northeast.

H. M. Torseman, Prairie City, witness: Between Ellisville and three miles north of it, there fell a most tremendous rain. Logs and rails were carried into the roads by the water.

Having learned that the tornado had made another descent at Utica, near the Illinois River, I proceeded thither.

Jacob McCan, Utica, Banner Township, Fulton County, witness: Storm came about 6.30 p. m.; saw lightning and heard thunder in the northwest, where a heavy cloud had long been gathering; saw two under-clouds, one in the southwest and the other in the northwest, moving toward each other. They were wind-clouds. Above them was a dark-green cloud. The two clouds were whitish, and were boiling up. The sky to the east was clear at this time, the storm coming up as an isolated, solid mass of cloud. The wind commenced to blow hard from the southwest. Then there came a brief lull; then a second blow from the northwest. With the northwest wind there came a blue smoke. It came in through the broken window. It came right in the fury of the gale. It was all dark in front of the window with it. This northwest wind was pretty cool. It hailed a little before the storm, and it rained very hard after it.

Nearly all the houses in Utica were more or less damaged, and several were blown down. The village stands on the bottom-lands of a small creek running into Illinois River. High bluffs rise all around. The tornado was here traveling southeast. It came down about one-half mile to the northwest of Utica. It continued to overthrow trees until it reached Illinois River, which is distant from Utica about one mile. It then turned abruptly to the northeast, traveling up the stream, which it then followed for about fifteen or more miles in a straight line, but much farther counting the bends in the river.

Charles Rice, Fulton County, Banner Township, one and a half miles from Illinois River, just at the commencement of the wooded swamp bordering the river, witness: The wind blew down two trees in my orchard. It was a north wind. The storm-center was at least one-half mile nearer the river. There were a few hail at the commencement, and a heavy rain afterward.

M. B. Murray, Peoria County, Timber Township, section 31, and one mile distant from the river: The storm blew down a great deal of timber along the banks. Some trees were also blown down on the other side of my farm, on the summit of the bluff. A heavy rain immediately followed the wind.

A. King, Peoria County, Timber Township, section 31, witness: My house is one and a quarter miles from the river to the northwest. My fences were blown down.

A. Dempsey, village of Kingston, Peoria County: A few chimneys were blown off in the village, and similar damage done. Two cows were killed by lightning. Some timber on the river was blown down.

Kingston is situated on the bottom-lands of the Illinois River, and close to it.

Mapleton, Peoria County: Here there fell hail as large as hazel-nuts, and a very heavy rain, accompanied by thunder and lightning. It occurred after 6 p. m. William Harrison testified that he saw trees in considerable numbers which had been blown down in the storm of May 22.

Pekin: The ferryman testified that there was a big rain-storm with high wind. The smoke-stack of his boat was somewhat damaged by it. Mr. Tazewell stated that the high wind came first, then the hail and rain.

Fred. Netz, Washington, Illinois, witness: It blew very hard about 6.15 p. m. There was a heavy rain.

Thomas Handsacker, editor of the Washington Herald, Washington, Illinois: The storm came at 6.10 p. m., or very nearly. I watched the cloud. Did not see any funnel-appearance nor any whirling. There was a very heavy rain, accompanied with thun-

der and lightning. The wind blew down numbers of trees in different directions, but mostly from the southwest. Heard that at Eureka there was a considerable storm.

I accordingly went to Eureka, but found nothing of importance. Before closing the statement of facts, a few data may be adduced, showing the widely-extended area over which the storm, or portions of it, manifested itself:

Special dispatch to the Chicago Tribune.

OTTAWA, ILLINOIS, *May* 23.

The tornado which passed through Central Iowa seemed to have spent its force here last evening. An enormous quantity of rain fell in an incredibly short time, and the trains on both railroads were delayed for hours. Bridges were swept away and much damage done. Ottawa lay directly in the line in which the storm was traveling when I ceased to follow it.

Special telegram to the Chicago Times.

SPRINGFIELD, ILLINOIS, *May* 23.

A very heavy storm of wind, rain, and hail passed over this city last night.

Special telegram to the Chicago Times.

PEORIA, *May* 24.

The severe storm of Thursday night did much damage in Princeville, this county. A narrow strip of wind passed through Southern Village, almost literally demolishing the house of Oliver Moody.

The following is an extract from a letter by B. Whitaker, chairman of the meteorological committee, who resides two and three-quarter miles east of Warsaw, Illinois, in correspondence with the Chief Signal-Officer:

"On Sunday, May 22, about 3 p. m., or perhaps a little later, while planting potatoes in the field, a roaring noise was heard a little west of north. Being familiar with the noise of railroads, steamboats, &c., was at a loss to account for it. We stood and listened five minutes. The continued roaring noise indicated great force. A perceptible indication of its moving more to due north was manifest. After resuming our work the noise was heard for some time—ten or fifteen minutes or more. A dark cloud occupied the heavens in that direction, the point or foremost end moving to the northeast. The motion of the cloud was not easily indicated, on account of intervening and adjacent clouds. My place of observation is two and a half miles due south of the signal-station Keokuk, and two and three-quarter miles due east of Warsaw, and the distance to the path of the hurricane at least sixty miles."

Mr. Whitaker adduces a number of names of respectable parties in support of his remarkable statement as being co-witnesses.

Such is a statement of the facts connected with the Iowa and Illinois tornado of May 22, 1873, so far as I have been able to collect them. I spared no pains in order to render it scientifically complete, sometimes traveling miles under a fierce sun, and with a temperature among the nineties, in order to obtain the evidence of one man. The information given by any witness by no means represents the number of questions asked him. These were extensive and calculated to extract all the knowledge on the subject possessed by those under examination. For instance, the following question was addressed to all and sundry: Did you observe any pointed objects, such as lightning-rods, posts, &c., tipped with flame, during the progress of the tornado? But being uniformly answered in the negative, has not been formally inserted in the statement of facts. Also, a description of the sound was exacted from all witnesses, but only a few typical ones have been inserted. I regret this at present, because I have learned from experience that very important questions may attach themselves to a description of the sound. While interrogating parties the utmost vigilance was exercised to prevent them from giving conclusions for what they saw and heard. This was a very troublesome point, and caused the interrogator to appear in many cases in the highest degree rude; while it also excluded from these pages the names of persons who observed accurately, but who are unable to distinguish between the *esse* and the *ergo*.

No opportunity was allowed to pass of obtaining information. Whether at home, on the road, or in the field, all met were questioned. Of course by far the majority could give no information worth taking.

It will be noticed that the statement of facts for Iowa is much more exhaustive and instructive than that for Illinois. There are several reasons for this:

1. Some weeks had already elapsed since the tornado, and its traces were becoming rapidly obliterated, both in the memories of the witnesses and upon the surface of the earth.

2. It was later in the day when it occurred, thus hiding the light of the sun more

completely by the tornado-clouds as they approached, and rendering it more difficult to observe accurately their forms and proportions.

3. The storm in Illinois seems to have been of a somewhat different character from that in Iowa, by its form rendering observation more difficult.

It may perhaps not be deemed irrelevant to mention that the best information was uniformly obtained from those who are not natives of the localities in which they live, but have settled there from other States or other countries. The reason of this may perhaps be that Iowa and Illinois are but recently settled, and that consequently the native-born population have not yet had time to arrive at years of discretion, whereas the original settlers are in the prime of manhood or verging toward old age.

With regard to the angles of elevation given, it must be borne in mind that they are only approximations. Very few indeed of the witnesses have accurate conceptions of angles. I generally made them point in the direction in which an object was seen, and so estimated the angle.

CALCULATIONS AND CONCLUSIONS.

The idea of a tornado in general.

The tornado consists essentially of a rapidly-ascending current of air. This involves two other functions: first, a rushing in of the air at the under part of the ascending current or column; secondly, an outrushing at the upper. Upon the former of these functions, combined with modifying circumstances, depends the peculiar character and career of the undercurrents and of the clouds they bear; upon the latter, combined with the same circumstances, the proportions and direction of motion of the upper currents and of the heavy masses of clouds they bear. There appears to be nothing in the nature of the tornado itself which can determine the motion of either the upper or under current more toward any one point of the compass than toward the others. This direction of motion relative to the ascending column depends upon the direction and velocity of motion of the latter, and of the atmospheric strata in which the influx and efflux take place, modified, to some extent, by the differing velocities of revolution of the surface of the earth at different parallels of latitude, by the form of the earth's surface, and by the variation in the constitution of the atmosphere. If the tornado column, and the atmospheric strata which it penetrates, move in the same direction and with the same velocity, the influx and efflux will take place in nearly equal quantity on all sides of the column. If they move with different velocities the directions of exaggeration and diminution of the influx and efflux can be calculated in the same way as the direction of a wind-vane on a ship's mast, giving the directions and velocities of the motion of the wind and of the ship.

General idea of the tornado of May 22, 1873, in Iowa.

A huge, dark cloud covered an area at least thirty miles in diameter. Under the southwest edge of this cloud there moved a perfectly opaque funnel-shaped appearance, reaching from the ground to the clouds. Toward its base, the wind, in spirals, rushed violently from all sides, overthrowing, when in immediate proximity to or within the opaque vortex, whatever opposed its progress. Toward its summit, where it disappeared in overhanging horizontal cloud, long streaks of clouds rushed in spirals from all directions. Viewed from a distance they appeared to come from opposite directions, and move swiftly toward each other at right angles to the observer's line of vision. Between the surface-current and these centripetal clouds the air doubtless obeyed the same forces, and rushed in spirals with ever-increasing velocity toward the opaque funnel.

Under the remainder of the lofty cloud which defined the limits within which the outspreading of the ascending air was taking place, and which lay chiefly to the northeast of the rising column, there raged a tremendous storm of hail and rain, accompanied by incessant and brilliant electrical phenomena.

More particular description.—Dimensions of the meteor, and of the centrifugal or upper current.

Mr. B. Whitaker, (p. 1081) when sixty miles distant, saw the summit of the dark cloud in the direction of Washington, Iowa. Of this fact there can be little doubt, the time agreeing precisely. In order that its summit might barely reach the level of the rational horizon the cloud would require to have an elevation of $\sqrt{(4000)^2+(60)^2}=0.46$ mile nearly. Mr. Whitaker simply states that a dark cloud occupied the heavens in that direction. This supposes that it reached to a considerable distance above the horizon. If we suppose it only reached 15° above it an additional elevation of over

sixteen miles, or a total height of between sixteen and seventeen miles, would be required.

Mr. Whitaker's evidence as to the immense height of the cloud receives corroboration from the evidence of a great many of the witnesses, who state that they saw the black cloud in the west for hours before the tornado came. Since the storm traveled thirty miles per hour, if the cloud was seen two hours in advance at an elevation of 15° above the rational horizon, and it would scarcely have attracted attention when lower, then it must have been sixteen miles in height.

The data for determining the horizontal extent of the cloud are not very precise. There is a general concurrence of the witnesses that it reached only a few miles to the south of the tornado, and that very little rain or hail fell there. G. W. Brockway (p. 1072) testified that at Talleyrand, about two and a half miles southeast from the track of the tornado, there fell neither hail nor rain, and that the cloud did not reach the zenith. Isaac Farley (p. 1071) testified that at Foote, Iowa County, fifteen miles north of Talleyrand, there was but little rain and no hail. E. R. Eldridge (p. 1071) testified that at Washington the cloud reached a little beyond the zenith. At Lone Tree and Nicholl's Stations I found by personal inquiry that there was a very heavy thunderstorm. These stations lie eighteen miles north-northeast of Washington. It is evident, moreover, that the cloud must have extended considerably beyond the area over which it rained. It is probably, therefore, no exaggeration to assign thirty miles as the diameter of the cloud from south-southwest to north-northeast.

Arthur Howell (p. 1071) testified that at Yalton, five miles north of the tornado, three fell a heavy rain of about an hour's duration. The storm traveled about thirty miles per hour. This would give the cloud an extent in the direction in which the storm traveled of more than thirty miles. There is a general agreement among the witnesses that a little hail fell some few minutes before the advent of the funnel, and a little rain immediately after its passage. The whole appears to have occupied at least thirty minutes in passing. This would give the cloud at the funnel a width of at least fifteen miles in the line of its progress. Probably it was considerably greater. We may, therefore, safely conclude that we are within the limits when we assign to the centrifugal cloud an average horizontal diameter of thirty miles.

I have no data for determining the elevation of the under side of the centrifugal cloud beyond what is involved in those for measuring the altitude of the centripetal. There must, however, have intervened a very considerable space between the two. For if there was nothing intervening there could be nothing to prevent the under, and specifically lighter, air from taking the shortest way up. There could be no reason why it should first rush to a center, ascend there, and then rush from it.

Dimensions of the centripetal current.

The data for determining these are still less precise than the preceding, but yet sufficiently so to give a more definite idea than any mere description in general terms.

H. C. Vittitoe (p. 1071,) saw, when three miles to the northwest of the tornado-path, white underclouds rushing to a center a little south of the zenith. A. Vandevere, whose evidence may be here adduced, although it refers to the tornado in Illinois, states: I have reliable information that two or three miles to the north the clouds were seen rushing south. The clouds came also from the south. Nearly all the witnesses who watched the approaching storm tell of clouds seen darting toward each other from opposite directions. It was impossible, however, to obtain anything like accurate measurements, owing to the distances being unknown. If we suppose that the centripetal clouds had a horizontal diameter of four miles, we may obtain a determination of elevation from the data given by E. R. Eldridge, (p. 1071.)

At four miles' distance, the point where the lower clouds seemed to join the higher appeared to him to have 35° of elevation. Deducting two miles from the distance for the assumed diameter of the centripetal clouds, we have an elevation of 1.4 miles.

J. W. Plumber (p. 1062) gives the angle subtended by the centripetal clouds when several miles distant, at about 45°, and the angle of elevation at about 35°. If we assume the distance to have been five miles, we should have over 4.6 miles as the diameter of the centripetal clouds, and 3.5 as the altitude, which latter figure is, perhaps, though not necessarily, too great.

The assumed distance of five miles refers to the base of a perpendicular from the summit of the cloud to the ground, and it is probably not too great since it corresponds to only ten minutes' motion of the storm. These clouds attracted attention by the great rapidity of their motion toward a common point; but their velocity gradually diminished from the center to their outer limits. They undoubtedly commenced the journey with a velocity by no means striking, and in much smaller and less dense masses. Hence the probability is that they extended much farther than they were observed with sufficient attention to leave an impression upon the memory. Moreover, the current in which they originated must have been in motion toward the vortex before they were formed, because they owed their existence to the circumstances con-

nected with that motion. It is, therefore, probable from these data that in assigning ten miles as the diameter of the centripetal current at the altitude of these clouds we do not overrate it.

There is good reason for believing that the diameter of the centripetal current was not less at a considerable elevation than at the earth's surface, because of the many obstacles there opposed to its progress. Yet R. L. Harper testifies that, at Baden, three miles northwest of the storm-center, the wind changed from northeast to northwest as the storm passed. This implies that it blew at least some few minutes from a northerly direction, and also with force sufficient to attract attention. Suppose it blew 20 minutes in all from a northerly direction, we should have, since the storm was traveling thirty miles per hour, a diameter of nearly twelve miles for the surface centripetal current.

It is here necessary to the force of the reasoning to call attention to the fact that the wind, on the 22d of May, was, in accordance with the barometric gradient, southerly.

William P. Lisk (p. 1048) states that about twenty minutes before the arrival of the tornado the wind blew from the north. This would give a diameter of twenty miles, that is, assuming the northwest quadrant to be as extensive as the northeast.

M. Williams, (p. 1048,) a very careful witness, states that about twenty-five minutes after the passage of the whirlwind, the wind came again from the southwest. This also gives a diameter of twenty miles. The witnesses (see Keota evidence, &c.) generally testify that hail fell from 15 to 30 minutes before the whirlwind, and rain for as long a period after. They further, almost unanimously, say that the wind was easterly with the hail and westerly with the rain. If we assume 20 minutes as the duration of each of these winds, we again obtain twenty miles as the diameter of the inrushing winds at the earth's surface.

If the disturbing influences were not much greater at the earth's surface than at a higher altitude, the dimensions of the whirl should, within the limits of the centripetal wind, owing to the absence of friction, vastly increase as we ascend. Moreover, since the funnel was first formed at a considerable elevation, and since it touched the ground with a narrow point, and merely incidentally, as it were, since it for long distances ceased to strike the earth, and yet proceeded with undiminished energy; since, in short, both the originating and sustaining sources of its power seem to have mainly existed high in the atmosphere, we have the strongest reasons for concluding that the horizontal dimensions of the centripetal current were very much greater at its more elevated portions than at its base. It would therefore appear to be not unlikely that the diameter of the centripetal current was not greatly exceeded by that of the centrifugal.

Since writing the above I have received a communication from Frank McClintock, correspondent of the Smithsonian Institution, West Union, Iowa. He states that there was a thunder-storm in the morning and another in the afternoon; that the wind changed from the south to the west rapidly at 3.45 p. m., and that it worked back to the south before 9 p. m. This change of the wind agrees with the time at which the tornado passed Washington, Iowa, allowance being made for the interval which must elapse before the atmospheric disturbance could travel over the one hundred and twenty intervening miles. This change of the wind may, however, have been due to the thunder-storm mentioned. We are not, therefore, entitled from this solitary instance to conclude that the tornado had a radius of one hundred and twenty miles, although it renders it somewhat probable that it did.

The following is also a late communication. Capt. J. W. Stewart, of the steamboat Victory, states:

The tornado occurred opposite Buffalo, Iowa. The time was approximately about 4 p. m. The sky-light, pilot-house, and chimneys were blown overboard. The wind came in three heavy gusts, accompanied by very heavy rain, in fact, almost a waterspout, and the darkness was intense. The duration was not more than five or seven minutes.

The dimensions of the funnel.

The height and size of the opaque funnel varied, as seen by the eye of an observer. At times it barely touched the ground with a narrow point, at others it stood on a broader base, while for long distances it ceased to touch the ground altogether. The clouds into which its summit disappeared, appear not always to have preserved the same elevation. These changes, however great they may have seemed to the eye witnesses, are yet in themselves insignificant when we realize that this funnel-shaped phenomenon was the base of an ever-widening column ten to fifteen miles high.

The data for calculating the dimensions of the visible portion of the funnel are more numerous than precisely accurate. In criticising them, it is to be remembered that the apparent height depended not merely upon the distance, but also upon the fact that on account of the inclination of its sides a greater portion of the funnel was seen by observers at the distance of a mile or two than by those nearer.

To Mr. R. L. Jay, the funnel when three miles distant appeared to be about one-fourth mile high.

M. Williams (p. 1048) states that when the funnel struck the ground the fences for 60 yards were carried away. It does not appear probable, however, that the base of the funnel was 60 yards wide at this point. But suppose we assume that it was, and also assume that the width of the summit was five times that of the base, which his description warrants. When at the distance of 300 yards the angle of elevation was supposed to be about 75°. From these data the distance of the witness from the base of a perpendicular from the edge of the summit would be 180 yards. This gives an elevation of 672 yards.

Sam Brunt testifies (p. 1049) that the breadth of the funnel, when on his farm, appeared to be about 100 feet.

Wm Davis (p. 1050) places the angle of elevation at 15° when half a mile distant. This gives an elevation of 235 yards.

Fred. Tollman (p. 1050) at 70 yards distance estimated the angle of elevation of the summit of the lower funnel at 60°. This gives an elevation of 121 yards.

Matthias Gengler (p. 1052) from an elevation of 200 feet and a distance of one mile estimated the angle at 55°. This gives an elevation of 2,580 yards.

Matthias Hotel (p. 1053) viewing it from the same distance and direction, but from a lower level, gave the angle at from 55° to 60°. This may be regarded as identical with the last.

Eli Walker (p. 1053) gave 30° at the distance of one and a half miles. Hence we have an elevation of 1,524 yards.

E. Stout (p. 1053) one and a half miles, 15°, and elevation of 707 yards. This refers only to the lower funnel.

Rev. J. P. Coffman (p. 1060) one mile, 25°, and elevation 821 yards.

F. Brown (p. 1061) one and a half miles, 15°, and elevation 707 yards. Mr. Brown estimated the breadth of the top at five times that of the base.

J. W. Plumber, (p. 1062,) three-fourths mile, 25°, and elevation 615 yards.

John Maughlin, (p. 1062,) 200 yards, 15°, and elevation 54 yards.

R. M. Stevenson, (p. 1063,) 700 yards, 35°, and elevation 490 yards.

The smallest of the results is 53 yards, and it may be safely discounted, because, at the distance of 200 yards, the darkness was great and the wind very strong. The time for observation also in such a position, with the storm directly approaching, was brief. The most reliable results are those obtained from observations taken on the south side of the storm-path, and at a distance of at least a mile from it. There the base-line could be accurately determined, and ample opportunity was had for calm observation. I therefore value the data on the subject of elevation afforded by Matthias Gengler and Matthias Hotel above all others. Their elevated positions gave them a splendid opportunity of watching the magnificent spectacle. The tornado was moving steadily along North Skunk River, without jumping up and down and skipping from side to side. Eli Walker and E. Stout, while occupying a position otherwise good, could not so well determine the distance of the meteor, because it was approaching them. Besides, the figures of E. Stout refer only to the lower funnel. These four witnesses watched the meteor at the same time. I therefore conclude that the tornado column was, from a favorable position, visible at some parts of its course to a height of between one and two miles.

In this connection it should be remembered that the data furnished by E. R. Eldridge (p. 1071) gave an elevation of one and a fourth miles to the cloud which he saw bending forward, but did not recognize as funnel-shaped.

Wherever there was evidence of the funnel having touched the ground there was, to a greater or less breadth, what I have designated as the vortex of extreme violence, varying from 100 yards in breadth to nothing. Without having positive evidence, and notwithstanding that there was everywhere a gradual diminution of violence from the center to the circumference except in the remarkable phenomenon of streaks or arms, and no abrupt transitions, I could not help concluding that the path of greatest violence was identical, or nearly so, with the diameter of the base of the funnel when it touched the ground. This would give it an average diameter of about 30 yards. The witnesses are generally agreed that the summit was several times wider than the base. The exceptional case in which two funnels are superimposed will hereafter be treated. If we assume that the visible top was five times the diameter of the base, we have, say for the altitude of one mile, a diameter of only 150 yards. I think, however, that, owing to its great elevation and the optical delusion connected therewith, and the general belief of the spectators, the funnel was, at the very utmost, only a few hundred feet high; the diameter of the summit was very much greater.

The changes seen in the funnel.

Some observers saw only one funnel; others saw two funnels superimposed, with the narrow ends together, and the smaller one beneath; while a good many saw two

and even three funnels, side by side. The evidence on all these points is beyond question. At first I was inclined to believe that two or more funnels had actually touched the ground and traveled side by side. The sketch of the storm by R. F. Cambell seemed to favor this explanation. It shows a protuberance on each side of the funnel, which looks like an inceptive funnel. The fact that a second funnel should travel along on the southeast side of the main one without disturbing the symmetry of the action of the latter, as exhibited by the ruins, did not appear altogether incredible, for it is abundantly evident from the statement of facts that the damage was done by a wind blowing in the path of the tornado when the black funnel hovered above or slightly touched the ground. Thus an incipient funnel, moving along the southeast side of the main funnel, and occasionally making a dip, would produce no appreciable discord in the disposition of the ruins. An insuperable objection to this theory was found in the unanimous testimony of the eye-witnesses that the funnels approached each other and combined to form one. Another objection was found in the lack of unity thus introduced into the conception of the magnificent whole. Finding this explanation untenable, I endeavored to think the possibility of smaller auxiliary funnels, each of them a perfect whirl, moving in spirals nearly or altogether identical with those pursued by the confluent winds. This I found to be more difficult than the first. The chief objection was the total lack of a conceivable cause of the existence of these smaller whirls. The second was the peculiar circumstance that while one observer saw two funnels, another in the same position saw only one, or saw two superimposed with the smaller ends together. No possible arrangement of two independent funnels with the smaller ends down could produce the optical illusion of two funnels superimposed, with the smaller ends together. I found what I believe to be the key to the difficulty while considering Mr. Marbourg's delineation of the two funnels joining in one funnel, (p. 1065.) The other observers who saw two or more funnels evidently had the whole of their attention confined to these, and did not observe what was above them. He saw the two combine at what he estimated an altitude of fifty feet and form one. Another witness, at the same place and time, saw only one funnel. At Lancaster, some saw only one, others saw two superimposed, and others saw two side by side, and all at the same time. There was, therefore, an unavoidable necessity for some explanation which could reconcile these antagonistic appearances.

Explanation.

There is excellent evidence to show that the funnel moved at its base with a sort of pendulum motion; that it seemed to stand still for a moment and then to bound suddenly forward. The evidence on this point is so general that we need not recapitulate it. But we have no reason for supposing that this oscillating motion extended to any considerable distance above the ground, for it is only in the want of homogeneity of the atmosphere and the resistance opposed to the free course of the winds by the earth's surface, that we can find a cause for this pendulum motion. Let us suppose that the funnel is over a well-watered and well-wooded ravine, with its path at right angles to it. It is evident that the air at some distance above the ground will offer much less resistance to the forces drawing it into new paths than that on the surface, where the friction is so important an element. In the forward march of the tornado the base would thus be somewhat left behind. The warm, moist air of the ravine would increase this tendency, on account of its specific levity. The funnel would become bent thus:

But the inrushing winds follow the path of least resistance toward the area of greatest rarefraction. The bending, therefore, cannot proceed far, before the southwest winds, whose direction of motion is carrying them away from the base of the inclined funnel, will find less resistance and a shorter path toward the greatest rarefaction, by striking up into the nearest point in the side of the funnel.

A streak of rarefaction great enough to produce condensation is thus generated. This arm of the funnel, affording the shortest way for the winds, will increase with rapidity. The other will decrease, becoming mainly confined to the northwest winds. Meanwhile the intervening air will become rarefied and set in motion; the two arms will suddenly unite, and the funnel present again its original proportions. These transformations must take place within a brief space of time, for the tornado is traveling at the rate of half a mile per minute. When we consider, in addition, the darkness, we will be at no loss to conceive why these two branches should present the appearance of one funnel with its smaller end down, and why, to a less favorably situated or more superficial observer, the whole should appear as one.

One difficulty yet remains to be obviated. Since the arm moves forward in a spiral to the center, and the velocity of the inrushing winds at the funnel far exceeds one hundred miles per hour, how is it possible for the observer, in the darkness, to notice the appearances distinctly? Mr. Marbourg gives the distance between the two arms

at 200 feet. This space would be traversed in one second by winds of so great velocity, and the condensed vapor would fill the whole space before it had time to disappear. The very velocity itself would render distinct vision difficult. We must not, in short, confound the path of the winds with the winds themselves. While the winds were rushing up in a slanting and curving direction along these arms, the arms themselves might be moving forward with a much less rapid motion. If it were possible to determine the inclination of these arms to the perpendicular it would aid in calculating the force of the wind. Mr. Marbourg stated that the distance between the bases of the two arms was 200 feet, and the height, when they joined together, 50 feet. He gave 80 to 100 feet, however, as the height, to the editor of the Washington County Press. His own delineation favors the belief that the height was greater than 50 feet. He could easily judge of the distance between the arms, but was very liable to be mistaken in estimating the height. The error, therefore, will probably not be great if we assume that the funnels joined together at the height of 100 feet. This would give these arms an inclination of 45°.

The direction in, and the velocity with which the tornado traveled.

From its starting-point on South Skunk River until it reached North Skunk River, a distance of ten miles, the tornado traveled in an east-northeast direction. It then turned a little south of east and followed the course of that river for two miles. It then went east-northeast until it came to Rock Creek, when it turned a little west of north and followed the course of the creek for a short distance. It then traveled northeast until it ceased to touch the ground three miles from Keota. After lifting itself from the ground it traveled about east-northeast, striking again at Westchester, Washington County. From this point until it reached Enoch Wright's, a distance of over nine miles, its course was nearly straight, varying between northeast and east-northeast. Its course then became very crooked, bending in curves from northeast to southeast, and *vice versa;* but on the whole traveling east until it came within a mile of the confines of Washington County, when it made a decided turn to the southeast. Here its path lay down the declivity toward the well-wooded ravine of Goose Creek. When within half a mile of the creek its traces became so feeble that it was impossible to track it farther. It was at this point, within one and a half miles of Iowa River, the course of which is here nearly parallel with that of the tornado. The crookedness of its path reached its maximum within the last half mile of its career, before ceasing to touch the ground, as a black funnel at A. Davidson's farm, Highland Township. Within this half mile it bent first a little to the southeast, then to the northeast, then to the southeast, and again back to the northeast, when it disappeared.

After leaving Crooked Creek, at the commencement of its career in Washington County, and until it reached to near Goose Creek, the tornado traversed an elevated, well cultivated region, almost totally devoid of trees and water-courses. There was apparently nothing in the configuration of the ground over which it passed which could account for its changes of direction. These changes, moreover, were not generally abrupt, the tornado sweeping in graceful curves from one direction to another. It is to be noted, however, that the curving of its path commenced after it came within the influence of the moister, warmer air of the Iowa River, and that the general deviation of its course from the northeast direction, which it had on the whole hitherto followed, led it down the valley of the Iowa River.

In order to determine the velocity with which the meteor traveled, it was necessary to obtain the precise time of its arrival at different points. The difficulty of obtaining precise time in an agricultural district is always considerable. In addition, no one thought of looking at his clock or watch; hence, although every witness was questioned on this point, there were but few who could even approximate to the time. The majority thought that they had a remarkably definite idea when they could tell between what hours it occurred. Reliable time, it is believed, was obtained at least at two places in Iowa, at Wolfden school-house, Lancaster Township, Keokuk County, and at A. McKee's house, section 23, Cedar Township, Washington County. The times obtained at these places were corroborated by the testimony of those likely to be best informed. The tornado struck the school at 2.15 p. m.; it arrived in section 23, Cedar Township, at 3.10 p. m. The distance between these places in a straight line is twenty-seven miles. This gives a velocity of 29.4 miles per hour. The crookedness of its course, though not great, would bring its velocity along its path to thirty miles per hour at least.

The direction of the centripetal winds.

The wind blew in spirals toward the center of the vortex, the direction of revolution being contrary to the hands of a watch throughout the whole course of the storm. The evidence in support of this, as given in the statement of facts, is overwhelming, and recapitulation unnecessary. The mere fact that all who had an opportunity of

seeing the funnel saw that it was circular is sufficient to prove that it was a whirlwind, for on no other hypothesis could the circular form be accounted for. Then the witnesses, almost without exception, saw this funnel whirling contrary to the hands of a watch. Then the illustration of the position of the ruins of the houses and of the fallen trees, &c., proves beyond a doubt that a merely centripetal wind could not have done these things. Again, that the wind was not blowing in circles round the center is sufficiently demonstrated by the fact that everything, except within the most violent vortex, was thrown toward the center. The ruins invariably lay most thickly there. The only form of motion capable of producing these effects is a mean between the circular and the direct centripetal, to wit, the spiral. The illustrations give copious ocular demonstration that such was the case. The ruins of houses, whenever they could be distinctly traced, proceeded in a curve toward the center, which apparently was always reached before the completion of an entire revolution. This does not imply that the centripetal winds never performed a complete revolution before reaching the center, but only that from within about 100 yards of the center this did not take place. Ruins carried from that distance seemed generally to reach the center in about two-thirds of a revolution. This led me to assume that at about 100 yards from the center the wind generally made an angle of about 25° with the tangent. This gives a centripetal component compared with the circular as .42262 is to .90631.

Besides its horizontal motion, the wind had necessarily an ascending motion, which reached its maximum at the center and its minimum at the circumference. The necessity for this lies in the proof of the centripetal motion of the wind; otherwise the centripetal motion of the wind would require to double itself at half the radius from any point toward the center. This would soon give it a motion infinitely great, which is absurd. There would also be no means of escape for it at the center. We have, besides, ocular demonstration. To a great many excellent witnesses the funnel presented the appearance of a screw with its thread running upwards. In addition, all objects within the sphere of the tornado seem to have been partly lifted, partly pushed forward. We have seen that at A. Gibson's house the arms made an angle with the perpendicular of probably about 45°. Since these arms, as there is every reason to believe, were inclined in the normal direction of the winds, which is that of least resistance, we are justified in assuming that in the black funnel itself the inclination of the winds to the horizon was at least as great, and probably greater.

The velocity of the wind.

This is a very difficult topic. The task would have been much easier if we had been dealing with a horizontal wind merely. If even the perpendicular and horizontal components were invariable, the hope of a tolerably accurate solution of the problem would be much greater; but while the former decreases from the center to the circumference, the latter increases. Neither is it possible to do more than approximate to the relative strength of these components at any point. In order that no chance of a solution might be lost, I collected the following heterogeneous data:

1. A school-house, weighing 30,000 pounds, was pushed 25 feet from its foundations. The surface exposed to the wind = 360 square feet + the roof, which had a slant of 45°, (p. 1049.)

2. A beam, 14 feet by 2 by 4 inches, weighing 25 pounds, was carried 35 yards, and driven into black mold 3 feet 9 inches, at an angle of 35°. (p. 1050.)

3. An iron sausage-machine, 6 by 8 inches greatest exposure of surface, and weighing 15 pounds, was carried away, (p. 1054.)

4. An oak tree, 3 inches in diameter, was perforated by a board 6 by 1 inches and (probably) 8 feet in length, (p. 1057.)

5. A hog, weighing 400 pounds, was carried a mile and a quarter. A cow and horse were carried 400 yards, (p. 1058.)

6. A horse-power machine, weighing 2,400 pounds, and exposing a surface of 2 square feet, was pushed forward 6 yards, (p. 1058.)

7. A post, 8 feet long and 4 inches in diameter, and which had been driven 3½ feet into the soil, was pulled out by the wind, (p. 1059.)

8. An elm fence-board, 8 feet by 6 by 1 inches, was driven into the soil 4 feet, at an angle of 45°, (p. 1060.)

9. A door, exposing a surface of 18 square feet, was held by four men against the wind, (p. 1063.)

10. A house, exposing 280 square feet to the wind, having a floor of 480 square feet, and weighing 20 tons, was pushed 6 feet from its foundations. It was then lifted over the tops of trees 20 feet high, (p. 1063.)

11. A heifer weighing 700 pounds was carried away, (p. 1063.)

12. A house presenting to the wind a surface of 176 square feet without the roof, and weighing 10 tons, was carried 24 yards while falling 3 feet, (p. 1064.) The wind struck it nearly on the end.

13. An oak sill, 16 feet by 8¼ inches, and weighing 300 pounds, was driven 4 feet into

black loam at an angle of 45°. It was carried 25 yards northeast with the house, and 18 yards east after parting from the house, (p. 1064.)

14. A granary, exposing 128 square feet of surface, and weighing 60,000 pounds, was pushed 14 feet, (p. 1064.)

15. A plank 16 feet by 1 foot by 2 inches, was driven 4 feet into the soil at an angle of 45°, (p. 1064.)

16. A corn-sheller, weighing 640 pounds, was carried 400 yards, (p. 1064.)

17. An oak board, 4½ feet, 4 by 1 inches, was driven through an oak post 4 inches in diameter, (p. 1066.)

18. A house, exposing a surface of 392 square feet, + the slanting roof, and weighing 20 tons, was carried forward 18 feet while falling 2 feet, (p. 1066.)

19. A house, exposing 533 square feet, and weighing about 25 tons, was pushed from its foundations, (p. 1068.)

20. A beam 14 feet by 6 by 2½ inches was driven 3 feet into the soil in a slanting direction. Its weight was 50 pounds, (p. 1066.)

21. A stove, exposing a surface of 3 feet by 21 inches, was pushed 12 feet, (p. 1068.)

22. A granary, exposing a surface of 256 square feet to the wind, and weighing 55,000 pounds, was carried 21 yards while falling 6 feet, (p. 1068.)

23. A bell, exposing a surface of 1 square foot, weighing 115 pounds, and suspended 12 feet high, was carried 60 feet, (p. 1068.)

24. A hog weighing 200 pounds was carried 500 yards, (p. 1068.)

25. A green log of water-elm, 8 feet long by 7 feet in circumference, and weighing 2,000 pounds, was carried 50 yards, (p. 1069.)

26. A horse, weighing 1,080 pounds, was carried 45 yards, (p. 1069.)

It will be better to treat all similar examples together, and first let us examine the data concerning the houses.

If we estimate the static friction of a frame house upon a stone foundation or upon posts firmly fixed into the ground, and to which it is nailed, at one-half the weight of the house, it does not seem likely that we shall err by excess. Upon this basis it is easy to calculate the minimum velocity of a horizontal wind necessary to push it from its foundations. The difficulty is that we are dealing with a wind having a perpendicular component to its velocity. If the wall of the house was perfectly smooth, and since the air is nearly perfectly elastic, the only force exerted upon it by a wind blowing at any angle to its surface would be perpendicular to that surface. Moreover, whatever force the perpendicular component may exercise upon the wall, owing to its roughness, must have upon the house the effect of an overturning rather than a lifting power. But, since friction is independent of extent of surface, this overturning power would not assist in overcoming friction. The fact, also, that the houses, while being carried bodily through the air, were not made to spin round on an axis by this perpendicular component, there being then no resistance, beyond inertion, to motion in a circle, would seem to prove that its effect was not great. It would, therefore, appear that an approximation may be made to the velocity of the horizontal wind by simply calculating upon the given assumption of the relation of weight to friction the minimum force required to push these houses from their foundations. The following are the results for the given cases:

1. Pressure per square foot 41.7 pounds. Velocity of wind 91.3 miles per hour.
10. Pressure 71.4 pounds. Velocity 119.5 miles.
12. Pressure 56.8 pounds. Velocity 106.6 miles.
14. Pressure 234.3 pounds. Velocity 216.5 miles.
18. Pressure 51 pounds. Velocity 100.9 miles.
19. Pressure 46.9 pounds. Velocity 96.8 miles.
22. Pressure 107.4 pounds. Velocity 146.6 miles.

The roofs in these calculations have been neglected when the wind struck the side of the house, because if the wind was ascending at an angle of 45° it would not strike the roof at all, and even a much less angle of inclination would produce a comparatively small effect; for if the wind were blowing horizontally 70 per cent. of its total force would be exerted perpendicularly to the roof. This 70 per cent. would be resolved into two components of 70 per cent. each, or of 49 per cent. of the force of the wind, one of which would add to the weight of the house and consequently increase the friction by one-half its amount, while the other would aid in overcoming the friction. Thus, even in the case of a horizontal wind exerted upon a roof sloping at 45°, only 24½ per cent. of its total amount is effective to aid in overcoming friction; that is, neglecting the friction of the wind against the roof.

Only one of these buildings was not, in addition to being pushed from its foundation, carried away, viz, case 14. It, however, was pushed through a dense mass of tough rubbish, and its sides were bent from the perpendicular. Owing to its small surface and great weight the force of the wind exceeded the minimum required to push the building from its foundations less in this case than in any of the others. Hence we have the great velocity of 216.4 miles per hour, or of 317.4 feet per second, in a horizon-

tal direction. It is also probable that in this case the kinetic friction was greater than the static, and that it increased every moment until the building came to a stand.

In the case of the other houses the maximum velocity of the wind was by no means necessary to push them from their foundations. They were in addition shot forward as if from a cannon, without touching the ground while almost grazing it, and at the same time maintaining their normal position. We have the testimony of one eye-witness that the house went like the railroad; of another that it went like lightning. Since the house in the former case only traveled 40 yards, (p. 1063,) and in the latter only 24 yards, the above expressions would appear to justify the assumption that the acceleration of the houses could not have been less than that produced by gravity, or 32 feet per second. This would require a force double of that necessary to overcome friction on the assumed basis. This gives in case 12 a pressure of 113.6 pounds, or a velocity of 150.7 miles per hour.

There is yet another way of calculating the velocity of the wind from these houses. We have seen that in several cases they went forward in a well-nigh normal position, close to the ground, and falling as they went.

The perpendicular component of the wind's force exerted upon the side of the building should, we have seen, if effective, tend to make the building revolve, and so throw it out of its normal position. Since this did not take place we assume that the force was not effective. If, therefore, we find by comparison of the force required to impart motion to a body sufficient to enable it to travel over the horizontal distances given, while the force of gravity is drawing it through the perpendicular spaces given, that it is unreasonably great, we shall have good grounds for concluding that there was somehow a lifting power exerted other than that due to the perpendicular component of the force of the wind.

Let us examine case 12. The house falls 3 feet while traveling 24 yards. In the time during which it traveled, therefore, the motion of the house due to the force of the wind was 24 yards or 72 feet, while that due to the force of gravity amounted only to 3 feet; that is, the acceleration caused by the wind was 24 times greater than that caused by gravity. Now the force is as the square of the acceleration. Hence, if no lifting power had been exerted, the force of the wind must have been 576 times that of gravity. This gives a total pressure upon the side of the house of 5,760 tons, or 32.7 tons to the square foot, which is absurd, for the force generated by a difference of pressure cannot exceed that generated by a difference of a whole atmosphere, and that amounts only to about 3,350 pounds per square foot. We are, therefore, irresistibly drawn to the conclusion that the houses, while being driven forward, were partially supported by the wind. We may learn how this was accomplished by studying case 10. The house was first pushed from its foundation for 6 feet, then turned upon its edge, and afterward lifted over the tops of trees 20 feet high. Probably the trees were so bent as to allow the house to ascend at an angle of 45°, thus reducing the height to be ascended to about 16 feet. The problem is how to apply a wind in order to generate the force required. We have the evidence of L. W. Low, (p. 1050,) that as soon as his house turned up on its edge, the flooring flew to the roof. This is probably the usual procedure in similar cases, and its cause is this: as soon as the edge of the house is lifted the wind rushes in, and finding its further progress barred, becomes instantly compressed by the wind in rear. It thus exerts over the whole interior of the house a pressure nearly equal to that exerted upon one side of it by the wind. If the house is a weak one the immediate result is that it is burst asunder. If it is a strong one, as it evidently was in this case, the compressed air, acting on the one side on the ground, and on the other side on the inside of the house will, if the compression is sufficiently great, lift the house. The area of the floor of the house in question was 480 square feet, and its weight was twenty tons. The pressure per square foot exerted perpendicularly to the area of the floor, required, in order to lift the house, was therefore 83.3 pounds. But the force actually exerted did not alone suffice to lift the building. It must have raised it in a very brief period to a height of 16 feet; for the action of the wind urging it forward was yet in full operation. If we suppose that it occupied one second in ascending these 16 feet, the lifting power exerted must have been double that of gravitation, or 166.7 pounds per square foot. Moreover, by the hypothesis, the force in these calculations has to be applied perpendicularly to the base. But actually it was not, the house being tilted up on its edge. Some of the power of the wind would also be lost by escaping through openings. Further, as soon as the house was lifted from the ground the resistance to the wind, and therefore its compression in the interior of the house, would be in a great measure removed. A pressure of 200 pounds per square foot would appear, therefore, inadequate to accomplish the work; that is, a pressure of the wind, or a velocity of two hundred miles per hour.

It is readily perceived that a body which is being accelerated by the wind will, if it partially presents its under surface to it, have the action of gravity upon it counteracted according to the extent of the surface exposed, &c. Such, I conceive, was the manner in which the houses, while traveling forward, were in the main partly relieved of the effects of gravity.

The extreme difficulty of obtaining even an approximation to the velocity of the wind is very appreciable in these calculations. In my opinion the best case is that of 14, because of its remaining firmly on the ground. The total weight of itself and contents was also easily obtained. I therefore conclude that since the wind in this case had a velocity exceeding two hundred and sixteen miles per hour, that it had a velocity equally great over a large portion of its path, and at particular points sometimes greater.

A horse or a cow of 1,000 pounds weight does not probably expose a greater surface to the wind than 12 square feet. Many cows and some horses of this weight were carried long distances. The lifting force of the wind, therefore, must in these cases have exceeded $1,000 - 12 = 83.3$ pounds per square foot, and its velocity 129.8 miles per hour perpendicularly.

21. A stove weighing 450 pounds and exposing 7¼ square feet of surface was pushed 12 feet. Estimating static friction at one-half the weight the pressure must have been 30.7 pounds per square foot, and the velocity 78.3 miles horizontally.

25. A log of water-elm, exposing a surface of 17.8 square feet and weighing 2,000 pounds, was carried 50 yards. It was probably barely lifted from the ground, if it was carried, because it did not strike deeply into the soil when it stopped. Its path could not be traced by marks left on the ground. The lifting power of the wind, in order just to balance gravity, must have been 112.3 pounds per square foot, representing a perpendicular velocity of 149.8 miles. It may be asked how a perpendicular wind was possible close to the ground. The answer in regard to the log is that the horizontal wind would become compressed between the bulge of the tree and the ground. In that case, however, the surface exposed is not so large. The whole bears ample evidence of a terrific but incalculable wind.

3. An iron sausage-machine, exposing a surface of 48 square inches, and weighing 15 pounds, was carried away. The lifting power must have exceeded 45 pounds per square foot, which corresponds to a perpendicular component of 94.8 miles.

6. A horse-power machine, exposing a surface of 2 square feet, and weighing 2,400 pounds, was pushed along the ground for 6 yards. The machine lay close upon the ground, allowing very little scope for lifting power. The static friction could not have been less than one-fourth the weight. Allowing one-fourth the weight of the machine for the lifting component of the wind, which is undoubtedly an exaggeration, there still remains a pressure of 225 pounds per square foot, horizontally, or a velocity of two hundred and twelve miles per hour.

2. A beam, exposing a surface of 7 square feet, and weighing 25 pounds, was driven into the ground 3 feet 9 inches, at an angle of 35°. The area of the end of the beam was 8 square inches. A columbiad 10-inch shell, when filled, weighs about 100 pounds. At the distance of 100 yards such a shell penetrated compact earth 33 inches. Its velocity at the time of impact would be about 1,200 feet per second. The earth into which the beam was driven was black mold, which had never, beyond the depth of a few inches, been disturbed by the plow. It was wet at the time. If we estimate its resistance at half that of compact earth it is not likely we shall overrate it. The columbiad shell on these premises would have penetrated the mold 66 inches. The area of a great circle of the ball is 78.54 inches. The weight, therefore, for the square inch of resisting surface amounts to $100 - 78.54 = 1.27$ pounds. The weight of the beam per square inch of its end is $25 - 8 = 3.1$ pounds. We have, therefore, the following equation:

$$\frac{1.27 \times 45 \times (1200)^2}{3.1 \times 66} = X^2$$

when X is the velocity of the beam in feet per second, = 634 feet. This gives the beam a velocity of 432.3 miles per hour, which is evidently erroneous, for it was accelerated to this enormous velocity within a space of 35 yards. Gravity acting through this distance could only have produced a velocity of 82 feet. Since the force is as the square of the velocity, the following equation gives the force of the wind upon the beam:

$$\frac{(775)^2 \times 25}{(82)^2} = \text{force} = 2{,}233 \text{ pounds pressure.}$$

Since the surface upon which this force was exerted did not exceed 0.7 square foot, the above pressure has to be increased by one-fourth its amount in order to obtain the pressure per square foot. The result is therefore evidently very erroneous.

Calculations from similar data give like stupendous results. Perhaps, however, the apparently prodigious velocities imparted to these flying timbers may point to the fact that at some elevation above the ground the velocity of the wind was vastly greater than at the surface. It may be also that the timbers were carried to a great elevation, and thus owed a large part of their rapidity of motion to gravity. There is also much uncertainty concerning the resistance of soils. I shall, therefore, leave the remaining data uncalculated, as involving too many unknown quantities.

The amount of the precipitation.

It was impossible to obtain more than generalities on this head. There were no rain-gauge measurements so far as I could learn. At Davenport, however, a few miles from where damage was done on the Mississippi, there fell, on May 22, 1.35 inches, as shown by the signal-service reports. From the description of the rain to the north of the funnel, in Washington County, a greater quantity than this must have fallen at many places. It is not, therefore, likely that we shall overestimate the amount when we assume that two inches of rain fell over an area ten miles in width. Since the tornado traveled thirty miles per hour, this gives a rain-fall per minute of $\frac{2\times(10\times\frac{1}{2})\times3097600\times9\times144}{1728} =$ 23,232,000 cubic feet.

Tornado dynamics.

A cubic foot of water weighs 1,000 ounces. The weight of water which fell per minute was, therefore, $\frac{23232000\times1000}{16} = 1{,}452{,}000{,}000$ pounds. It is not, probably, an exaggeration to assume that this mass of water fell on an average 6 miles or more. This gives a horse-power of $\frac{1452000000\times(6\times5280)}{33000} = 1{,}393{,}920{,}000$ generated by the falling water.

From the calculations of the velocity of the wind, it is not probable that, when we assume, at the distance of 100 yards from the center, an average velocity of 120 miles per hour, we overrate it. The angle (p. 1088) which the wind made with the tangent was probably about 25°. The wind, therefore, on these bases, enters a cylinder of 100 yards radius at the rate of 50 miles per hour or 4,400 feet per minute.

From the calculations of the height of the centripetal current, we have seen that it probably extended over two miles. Let us assume that its height was two miles. Let us assume also that the velocity with which the wind entered the cylinder was equally great throughout its length. We have then the following data for calculating the quantity of air which enters this cylinder of 100 yards radius, or 628.318 yards circumference per minute. It amounts to $(628.318\times3)\times4{,}400\times(2\times1{,}760\times3)$ cubic feet $=$ 87,582,502,656,000 cubic feet. Since this volume is calculated from the mechanical effects or force of the wind, and since the relation between the force and the velocity of the wind is calculated for the average pressure, it matters not in calculating the mass of the above volume of air what the barometric pressure was at the distance of 100 yards from the center. The difference of pressure due to elevation must, however, be calculated. Since the average pressure at sea-level is about thirty inches, at an elevation of one mile about 24.60 inches, and an elevation of two miles about 20.20 inches, and taking into account the correction due to the elevation of the country over which the tornado passed, 24 inches would be about the mean pressure up to two miles of elevation. The density of the air varies with the temperature. From the data given on page 1093, the temperature around the tornado must have been, at a fair exposure, about 76°, but was in deep-wooded ravines no doubt much greater. Since the temperature diminishes 1° for every 300 or 400 feet of elevation, we may assume the average temperature to have been within the limits of the centripetal current about 60°. The relative humidity (p. 1072) was about 65 per cent.

The weight of a cubic foot of air, at a pressure of 24 inches, a temperature of 60°, and a relative humidity of 65 per cent., is 426 grs., or thereabout. The total weight of air, therefore, entering the column per minute amounts to $\frac{87582502656000\times426}{7000} = 5{,}330{,}020{,}875{,}922$ pounds. This weight of air moves by hypothesis at the rate of one hundred and twenty miles per hour, or of 170 feet per second. This velocity is acquired from the acceleration due to gravity in falling through a space of 481 feet. The power, therefore, generated by this mass of air moving with the given velocity amounts to $\frac{5330020875922\times481}{33000} = 77{,}689{,}092{,}161{,}166$ horse-power.

The latent heat of evaporation amounts to about 1,000°. Consequently the condensation of 1,452,000,000 pounds of vapor is accompanied by the evolution of 1,452,000,000 × 1,000 calorics or pound-degrees of heat. The specific thermal capacity of air, as compared with water, is as .237 to 1. The number of degrees, therefore, which this amount of heat would raise 1 pound of air, is $1{,}452{,}000{,}000{,}000\times\frac{1000}{.237} =$ 6,126,582,278,481 degrees. But the pressure remaining the same, air expands $\frac{1}{491}$ part of its volume for every accretion of 1 degree of temperature. This amount of heat would, therefore, expand 1 pound of air, 6,126,582,278,481 ÷ 491 = 12,477,764,315 times. A cubic foot of air at 30 inches pressure, 60° temperature, and having a relative humidity of 65 per cent., weighs 538.6 grains. A pound of such air, therefore, occupies 7,000 ÷ 538.6 = 12.99 cubic feet = or very nearly 13 cubic feet. A pound of air, therefore, in doubling its volume must, the pressure remaining 15 pounds per square inch, raise a

weight of $13 \times 144 \times 15 = 28{,}080$ pounds through 1 foot. The total amount of work, therefore, performed by one pound of air, while expanding under a pressure of 15 pounds per square inch to 12,477,764,315 times its original bulk, is $12{,}477{,}764{,}315 \times 28{,}080$ foot-pounds. This amount of work accomplished per minute demands $\frac{12477764315 \times 28080}{33000} = 10{,}617{,}443{,}089.8$ horse-power.

We thus see that the power generated by the condensation of the amount of vapor estimated as having been precipitated is much less than that calculated to have been produced by the velocity of the centripetal winds. Theoretically this power should be diminished by the amount of expansion counteracted by the removal of so large a mass of vapor. Practically, however, it seems probable that this removal of vapor, while increasing the specific gravity of the air, yet when taking place with great rapidity serves rather to increase the rarefaction.

The horse-power required to raise 5,330,020,875,922 pounds to a height of five miles per minute amounts to $\frac{5330020875922 \times 5 \times 1760 \times 3}{33000} = 4{,}264{,}016{,}700{,}737.6$ horse-power.

These figures convey a better idea of the tremendous power of the tornado than any mere verbal description could do. They also show that the power evolved by the condensation of vapor, while enormous, is by no means sufficient to supply the whole energy developed by the tornado. We must therefore look for another source of power. This is no doubt to be found in the destruction of the atmospheric equilibrium by an abnormally-warm southerly current flowing under a much colder and consequently specifically heavier stratum of air. This brings us to the consideration of the general atmospheric conditions under which the tornado originated.

General atmospheric conditions.

An area of low barometer existed in the Mississippi and Missouri Valleys on the 20th, 21st, and 22d of May, which moved very slowly northward. This induced a southerly current, abnormally warm for the season, over a large portion of the interior of the continent. The result was a series of violent local storms, or spasmodic atmospheric convulsions, along the whole southern declivity of low barometer. These storms were generally accompanied by hail, and always by lightning. They reached a climax in the tornado, which is the subject of this paper, and in that which simultaneously devastated a portion of Kansas. The circumstances under which these terrible meteors arise are, therefore, easy of comprehension. They are the same as those which produce the beneficent thunder-shower, only they exist in greater intensity. The warm southern current, drawn toward the center of low barometer, passes under much colder and heavier air. So long as the greater specific gravity of a given volume of the upper stratum of air, which is due to a lower temperature, is balanced in the lower stratum by the greater density, consequent upon greater pressure of the same volume of air, so long may the atmosphere remain in a state of unstable equilibrum. Any disturbing cause may, however, destroy this state of unstable equilibrum, because the moment the pressure upon the underlying warm air becomes equal to that upon the upper stratum, it becomes the less dense, and, therefore, specifically lighter. Consequently, as soon as an opening is broken through the upper strata, the state of unstable equilibrium is immediately destroyed, and a powerful ascending current formed. It is manifest that the state of unstable equilibrium may continue until the density arising from the lower temperature exceeds that arising from the greater pressure. The moment this occurs, the unstable equilibrium is destroyed. The nearer the atmosphere approaches to this condition, the more intense will be the consequent convulsion. It seems probable that in the case of tornadoes this total destruction of equilibrium is a frequent, if not a constant, accompaniment.

The electrical phenomena.

On this subject there is a general harmony among the witnesses. In the lofty centrifugal cloud there was incessant thunder and lightning; but very little, if any at all, in the centripetal cloud and the funnel. One object, a tree, was struck in the path of the storm; but the discharge took place a half hour before the arrival of the funnel. The lightning-rod said to have been melted on Widow Dogget's barn might have been struck long before, and only noticed then because it was blown down.

There was no evidence of electrical action upon the trees, which were peeled and shivered by the storm, although there was that broom appearance where the trees were broken, which has been referred to the action of electricity. This, however, was clearly due to the straining of the tree before it broke.

No one saw any objects tipped with electrical light during the progress of the meteor. The telegraph was not interrupted until the wind blew down the wires.

The electrical phenomena must, therefore, be regarded as merely secondary, as the result of the very rapid condensation of the vapor of water due to atmospheric disturbances arising from other causes.

Explosion from rarefaction.

It is the generally accepted opinion that in tornadoes houses are frequently burst asunder when the center of the whirlwind comes over them. This is supposed to be accomplished by the great rarefaction, which is said to exist in the center, suddenly relieving the air within the houses of a large portion of atmospheric pressure. The air thus relieved of pressure immediately expands and blows the house asunder as with gunpowder. There was not, so far as I was able to learn, a single case in which a house was so destroyed. The houses were invariably demolished or blown from their foundations by a wind blowing in a certain direction. They were generally pushed or carried a considerable distance bodily, floor and all. After striking the ground with the foremost edge they turn partially over, thus exposing the floor to the wind. The wind being obstructed by the wall of the house resting on the ground became immediately compressed by the pressure from behind. The floor, unable to stand this pressure, went upward, and the whole interior of the building became subjected to a strong pressure due to the compression of the air. This pressure was more than balanced on the side struck by the wind. On the other sides there was nothing to resist it, and the house was accordingly burst asunder. Some of the houses, which were carried forward, evidently reached the center before striking the ground. Traveling with rapidity, they would cross the narrow interval of calm in the eye of the tornado, if such there be, in a small fraction of a second. Being then struck by a contrary wind they were shattered into fragments and dispersed. Such may have been the case with the houses of M. Davidson and Peter Marsh.

Some houses went to pieces the moment the doors and windows were blown in. This takes place by the same kind of explosion as that mentioned above, and which is due to the law that fluids press equally in all directions. If a window is blown in on the windward side of the house, and there is no outlet for the inrushing wind, the whole interior of the house is immediately subjected to a force equal, or nearly so, to that of the wind. Explosion accordingly takes place. In a case of explosion of this kind the floor of the house generally remained, and once at least the windward side of the house had merely fallen forward, when the other sides had left it. We have, therefore, ample proof of explosion by compression, but none whatever of explosion by rarefaction. When the tornado was raging with full fury no house could possibly stand on its foundations until the center came over it. If the tornado was not strong enough to blow down a house before it reached the center, the house remained standing, or was demolished by the winds in the rear of the storm-center.

The belief that at the center of the tornado there exists a rarefaction almost amounting to a vacuum, is the product of the formerly widely entertained theory that tornadoes are mere whirls of wind, generated by some such mechanical agency as the meeting of two opposing currents. According to this theory the low barometric pressure towards the center is the result of the centrifugal force generated by the whirl throwing the air away from the center. Now, that we know that the whirling motion is merely a result impressed upon the winds rushing toward the center of low pressure by secondary causes, our views respecting the amount of rarefaction in the eye of the tornado must undergo a change. Without doubt, the pressure there reaches its minimum, because thither the winds tend. That the progress of the inrushing winds is delayed by centrifugal force is certain, and as soon as the centrifugal force becomes equal to the centripetal the wind will cease to be accelerated toward the center. At that point they will ascend circling, and losing part of their circular motion by friction will be drawn nearer the center until it becomes the focus of most rapidly ascending winds.

The fact that there were no evidences of the bark of trees having been torn off by the sudden evaporation of the juices of the trees, due to the relief from pressure, has already in the statement of facts been sufficiently insisted upon.

The temperature at the center.

A great many witnesses felt somewhat cold as the storm passed over them. The temperature is easily calculated. We have assumed, from the data, an average temperature of 76° on the surface of the ground, and a relative humidity of 65 per cent. This gives a dew-point of 63° or thereabout. This sudden decrease of 13°, together with the wet, is sufficient to account for the coolness experienced.

The amount of rarefaction necessary to produce this diminution of temperature.

The lowering of the temperature at the center of the tornado is due to the work performed by the air in expanding under diminishing pressure. The amount of this expansion, and consequently of the diminution of pressure, is easily obtained from the equation $\frac{a+t}{a+t_1} = \left(\frac{v_1}{v}\right)^{\kappa-1}$, (Zeuner's Grundzüge, p. 131,) where a = co-efficient of expansion = 491, t = initial temperature − 32, t_1 = final temperature − 32, v = initial

volume, v_1 = final volume, and x = the relation between the thermal capacities of the air with constant volume and with constant pressure = 1.41. The initial temperature in the case of the tornado = 76°, and the final temperature 63°. Consequently, $t = 76 - 32 = 44$, and $t_1 = 63 - 32 = 31$. Let us take $v = 1$. Then $\frac{491+44}{491+31} = \left(\frac{v_1}{1}\right)^{1.41-1}$, or $\frac{535}{522} = v_1^{.41}$, $v_1 = \left(\frac{535}{522}\right)^{\frac{1}{.41}} = 1.8219$. A cubic foot of air, therefore, expands in passing from the circumference to the center to 1.8219 cubic feet. But the pressure is inversely as the volume. Therefore, since the initial pressure was 28.5, $\frac{1 \times 28.5}{1.8219}$ = the pressure when the dew-point is reached and the funnel commences, = 15.69 inches. This gives a diminution of 12.81 inches, corresponding to a pressure of about 6.40 pounds per square inch, or 922 pounds per square foot, an amount of potential energy more than sufficient to account for all the phenomena.

The form and dimensions of the visible funnel did not, therefore, depend upon the diminution of pressure alone, but also upon the temperature and relative humidity of the inrushing winds. Its presence accordingly does not indicate a certain invariable velocity of the wind. When the air is moist, as it always is over the sea, a very small diminution of pressure, and consequently a comparatively light wind, would suffice to develop the phenomenon of a visible funnel. When, on the contrary, the air is very dry, winds of the utmost possible violence could be produced without a visible funnel. The funnel of dark cloud, therefore, by no means indicates the limits of the ascending current. This renders the explanation of the hovering up and down of the lower end of the funnel easy of comprehension. Varying humidity along the path of the tornado would be sufficient to produce this phenomenon.

As the air ascends the pressure diminishes, and the funnel consequently increases in width. The diminution of pressure perpendicularly is symmetrical, and the result is the symmetry of the form of the funnel.

Did the tornado carry up water? Beyond a doubt; but just as it carried up any other body. Water, readily separating into small portions under the action of the wind, would be much more likely to reach the summit of the cloud than particles of solid matter, however fine. It is a common belief, not merely among the many but among men of science, that evaporation takes place rapidly within the vortex of the tornado or water-spout. The fact that the dark funnel is merely a cloud formed by the condensation of the vapor of air, the temperature of which has fallen below the dew-point, is sufficient to show the impossibility of this. Water, therefore, does not add to the power of the tornado. It passes up as a liquid and comes down as a liquid or solid. Even if it were evaporated by the tornado it would require precisely the same amount of heat to evaporate it as it would give forth upon being again condensed.

The sound.

Its loudness was extreme, yet of such a nature as to drown all other sounds without stunning. A man could stand by his house, as it was shivered to pieces, and not hear the noise of its breaking. Many likened it to heavy railroad-trains. To a few it appeared like the hum and whir of innumerable machinery. To others it resembled the roaring of the ocean, along a rocky shore, in a storm. To the soldier it recalled the rolling thunder of the battle-field. Those who were nearest to it were not aware of its terrific loudness.

B. Whitaker heard it, together with others, at the distance of sixty miles. He says that even at that distance it indicated great force. Doubtless it was heard much farther, but excited no attention, being attributed to some other cause. The barometric gradient inclined from Mr. Whitaker to the tornado, consequently the propagation of the sound received no help from the wind. Thunder has very seldom been heard at a greater distance than ten miles. The sound of the tornado was therefore six times louder than the loudest thunder. Heavy cannonading has been heard, it is said, at the distance of ninety miles, and "the report of a volcano at St. Vincent was heard at Demerara, three hundred miles off." The voice of the tornado is, therefore, one of the strongest known to art or nature.

The distances to which bodies were carried.

Leaves fell at Keota and Prairie City which must have been carried four miles. Shutters were carried three miles. A tire of a wagon-wheel was carried two miles. A pig was carried one and one-fourth miles. Doubtless many heavy bodies were carried much farther than any of these instances. Wagons and pigs, &c., disappeared, and the owners could find no trace of them. Only the ruins which were carried the shortest distance were recognized. There is no evidence, however, of anything heavier than

leaves and mud having traveled farther than a mile from the vortex. They were carried along with it, it may be, for ten miles. This proves that these bodies either never reached so high as the centrifugal cloud, or, if they did so, were carried again into the vortex before reaching the ground. Hail fell at Sigourney, four miles from the center, containing fragments of grass and leaves, and particles of mud. These, therefore, were carried up into the centrifugal cloud, and were probably scattered over the whole region visited by the rain and hail storm.

Why the hail generally preceded the rain.

A drop of rain of the largest dimensions, falling through air of an average pressure cannot exceed a velocity of 34 feet per second. A hail, however, weighing ¼ pound and measuring 4 inches in diameter can acquire a much greater velocity. The area of a circle 4 inches in diameter is 12.566 inches, or say 12¼ inches. Before the motion of the hail ceases to be accelerated the air must oppose it with a resistance equal to its weight. A spherical surface experiences theoretically in its passage through the air only half that opposed to a plain surface. The roughness of the hail would considerably increase the retardation; but this would probably be more than counterbalanced by the fact that all of the hail were, more or less, flattened and cake-shaped, thus allowing the hail to assume in falling a position of least resistance. Hence, the air must oppose the hail with a pressure of $\frac{144}{12\frac{1}{4}} = 11.5$ pounds per square foot before its motion ceases to be accelerated. This corresponds to a velocity of forty-eight miles per hour, or 70.4 feet per second. Since the resistance of the air is directly as the density, the velocity possible to be attained would be doubled at the height of three or four miles. We thus perceive that the hail, although perhaps formed at a greater elevation than the rain, can yet, when large, reach the ground before it.

The enormous height from which the hail fell, and the vast thickness of the cloud, does away with the difficulty which many have experienced of conceiving how hail can be sustained a sufficient length of time in the air to allow it to grow to such large proportions.

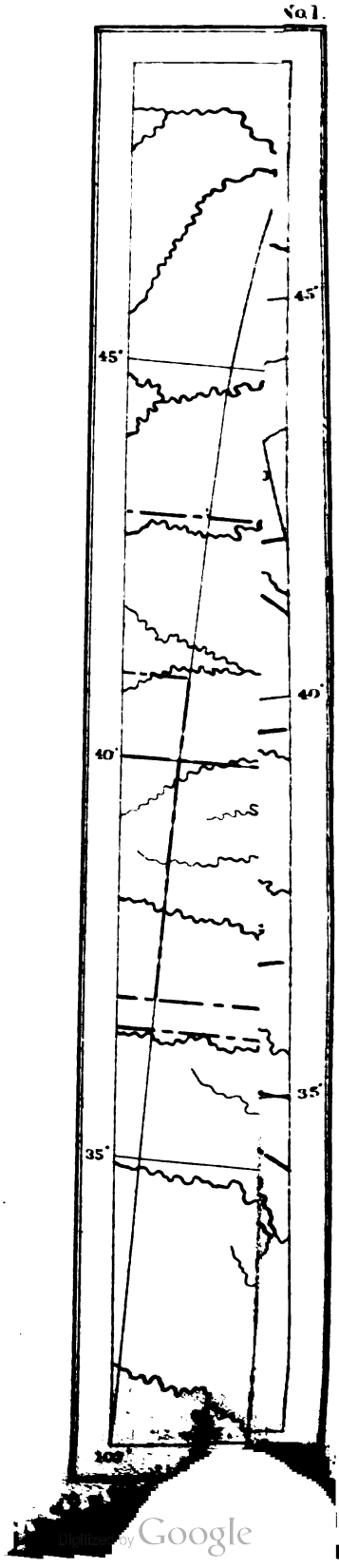
The light which the tornado throws upon the higher currents of the atmosphere is valuable. At a height of from ten to fifteen miles, there was in Iowa a rapid current to the northeast.

The predominance of winds blowing parallel to the path of the tornado.

The width of the destruction on the right of the center of the storm-path was, we have seen, always greater than that on the left. Another fact of the same significance is that the tornado, when it first commences its destructive career, and when the black funnel hovers over the surface of the ground without touching it, manifests itself as a wind blowing in the line of the storm. The reason is evident. The winds blowing in spirals toward the center had, in addition to a motion along the spirals, a motion as constituent parts of the storm in the direction of its path and at the rate of thirty miles per hour. This increased the velocity of the winds on the right of the center, and diminished that of those on the left of it. The general barometric gradient being inclined from south to north, tended also to increase the velocity of the southerly winds and diminish that of the northerly.

The tornado in Illinois.

The general appearance of the tornado, as a whole, in Illinois, was somewhat different from that which it presented in Iowa. The ascending column of air was no longer on one side of the centrifugal cloud, but apparently near its center. Hence the witnesses generally describe the cloud, as it approached, as consisting of a dark cloud to the northwest, a less dark to the southwest, and a clearer space between. Mr. Roe saw what he conceived to be three streaks of rain, when the tornado was yet miles from him, with clearer spaces between them. My own conception is that the rain fell so densely on both sides of the whirl as to be perfectly black, and the clearer portion, through which some of the witnesses saw the sky, was directly under the whirling clouds, and before the funnel reached to the earth. Mr. Roe, I believe, saw the two descending sheets of rain and the funnel, now reaching to the earth, extending down between them, with clearer intervals on either side. The fact that the cloud now extended on both sides of the funnel, and that the sun was bending toward the western horizon, from which the storm was approaching, rendered accurate observation very difficult. Hence comparatively few persons saw the funnel distinctly. Hence the disagreement of the witnesses as to the direction of revolution. In Iowa all circumstances had combined in order to render precise observation easy. In Illinois the very reverse was the case. I shall, therefore, treat this portion of the subject in a few general remarks.



The tornado developed energy in this State quite as great as that displayed in Iowa. Its direction of revolution was the same. The disposition of the ruins was precisely similar. It showed the same, and even a greater, partiality for water-courses, turning abruptly from its course in order to follow them. Its direction varied between northeast and southeast, and was in the main easterly. At the moment when its velocity diminished, and before reaching Spoon River, it poured down, close to the whirlwind, and even on its very path, a perfect cataract of water. The height of the cloud must have been very great, for it was seen in the west for hours previous to its advent. There was less hail, and the sound was not so generally noticed as in Iowa.

The identity of the tornado in Iowa with that in Illinois.

When lost track of, the Iowa tornado was close upon the Iowa River, and traveling to the southeast. Its general course had, however, been easterly. A very severe rainstorm passed over the district between its point of disappearance and the Mississippi River. Trains were delayed by it and bridges washed away. On the Mississippi itself some damage was done to shipping by a violent gust of wind, which accompanied the rain. At Monmouth there was a severe thunder-storm. Twenty miles to the south of it the tornado again struck the ground. It was at Youngstown at 5.45 p. m., or thereby. From A. McKee's house, north of Washington, Iowa, to Youngstown, is a distance of about sixty-three miles in a straight line. The tornado was at McKee's house at 3.10 p. m. The difference between 5.45 and 3.10 is 2.35. The discrepancy due to longitude is four minutes, very nearly. The time, therefore, consumed by the storm in traveling from opposite Washington, Iowa, to Youngstown, Ill., was 2 hours 31 minutes, or $2\frac{1}{2}$ hours; $63 \div 2\frac{1}{2} = 25\frac{1}{5}$, which is, therefore, the velocity of the storm, in miles per hour, in a straight line. The length of the journey was materially increased by the crookedness of the path. This brings the velocity nearly up to that with which the meteor traversed Keokuk and Washington Counties, Iowa. These facts, taken in connection, irresistibly lead me to the conclusion that the tornadoes in the two States are one and the same.

The point where the tornado first struck the ground, on South Skunk River, is situated in 92° 20′ west longitude and 41° 15′ north latitude. It was finally lost track of near Peoria, in 89° 37′ west longitude and 40° 40′ north latitude. The whole motion of the tornado, therefore, was 2° 43′ east and 35′ south, or one hundred and forty-three miles east and forty-one miles south. The mean direction of its path was 24° 51′ south and 65° 9′ east, and its whole motion one hundred and forty-nine miles. The crookedness of its path renders its actual motion considerably greater.

My warmest thanks are due to Elias Colbert, of the Chicago Tribune, and the editors of the local newspapers at Washington and Sigourney, Iowa, for assistance rendered, and especially for publishing an extensive list of questions concerning the tornado, which secured for me valuable information from persons residing at a distance.

JAS. MACKINTOSH,
Observer, Signal-Service, U. S. A.

PAPER 31.

THE STORM OF APRIL 14-18, 1873.

(With 9 maps.)

A storm-center that was found to exist in Dakota on the morning of April 13, continued developing itself slowly over Nebraska and Kansas during the afternoon and night, with threatening weather and southeasterly winds in the Upper Mississippi and Missouri Valleys. Breckenridge, Minn., reported heavy snow the following morning, with high northerly winds. The storm now commenced moving eastward toward the lakes, where cautionary signals, ordered up on the previous day, heralded its advent. Central in Iowa on the afternoon of April 14, it appeared to be moving remarkably slow, while the pressure was diminishing very rapidly eastward to Lake Erie. After reaching Illinois, the midnight reports of April 15 showed that the storm-center had divided itself into a number of small but very distinct areas of barometric depressions, extending eastward to the Alleghanies, with threatening and rainy weather in the Ohio Valley. The several small storm-centers united again during the following day, with the exception of one, which moved southeastwardly into the Carolinas. The former storm-center now changed its easterly course to a northeasterly direction, moving toward the lower lakes, but making very little progress; so much so, that the center remained almost stationary in Southern Michigan for sixteen consecutive hours.