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The Great Meteor of March 24, 1933

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The meteoric display of March 24, 1933, over New Mexico and adjoining states may be recorded as an important event in the history of meteoritics; not only because of its great magnitude, but also by reason

FIGURE 1.
Picture taken by Mr. Chas. M. Brown while meteor was in flight. Kodak facing altitude of about 40° as meteor approached the zenith.

of the good fortune which attended the use of several cameras for its recording, thus contributing in a unique way to our knowledge of meteoric phenomena.

For the first time we are able to present satisfactory photographs of

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a meteoric cloud of great magnitude. These photographs were taken from several locations such as to render possible reliable deductions as to height, size, luminescence, and drift. But most important, we are able to present a photograph of the meteor in motion, taken under conditions which made possible satisfactory calculations as to the magnitude and form of the train as it was left in the immediate wake of the projectile and the great luminous spheroid which enveloped the meteorite at the instant the picture was taken.

In a ranch house located in a narrow valley, some 25 miles southwest of Clayton, New Mexico, Chas. M. Brown, locally known as Charlie, foreman on the Lyon ranch, was just ready to sit down to breakfast as the clock struck five on that eventful morning. The meteor flashed, lighting up the sky like midday.

The No. 2 A Brownie folding pocket kodak lay on the radio to the right and back of Charlie's breakfast chair. It was not there for any special purpose only that in a small crowded ranch house it had to be somewhere and this chanced to be its place. It was seldom used but happened to have a partially exposed roll in it that morning. The chores had been done and breakfast was called. Brown approached the table; but just as he did so the sky suddenly lighted.

At the first flash he grabbed the kodak and made for the door, opening the Brownie as he went. When he reached a point about eight steps from the door he was clear of the trees. He trained the instrument on the approaching meteor and snapped the shutter. When he again looked up the meteor was disappearing over the house.

I had Mr. Brown go through the motions again just as he had done that morning, and found it required eight seconds for him to get the picture, from the time the light first flashed.

The writer was both fortunate and unfortunate in his location at the time this event transpired. He chanced to be at Clovis, New Mexico, approximately 130 miles south of the meteor's course. This location should have afforded an excellent view but for the fact that the northern sky was obscured by clouds. From Melrose, 25 miles to the west, the meteor was seen to emerge from behind this cloud bank making a brilliant display. Starting from this location I was enabled to interview witnesses on all sides of the meteor's terminus on the day of its fall. Thus my first notes were free from the bias which may have entered into those which were gathered later after witnesses had been reading false newspaper reports.

All data used in the preparation of this paper were obtained from witnesses by personal interview in the locations from which the observations had been made, or from photographs. Witnesses were interviewed at points in New Mexico as follows: Melrose, Cantara, Krider, La Lande, Gallegos, Mosquero, Solano, Roy, Mills, Springer, Wagon Mound, Las Vegas, La Cueva, Buena Vista, Sapello, Raton, Hot Springs, Albuquerque, and Clayton; in Colorado: Trinidad, Walsenburg, Pueblo, Colorado Springs, Denver, La Junta, and Burlington; in

Kansas: Kanorado, Beardsley, Oberlin, Liberal, Syracuse, Johnson, Pratt, Kingman, and Wichita; in Texas: El Paso, Odessa, Lubbock, Plainview, Tulia, Texline, Dalhart, Amarillo, Canyon, Perryton, and Stratford; in Oklahoma: Guymon, Knowles, Logan, Texhoma, Hooker, and Optima.

The Light Phenomena

The light phenomena of the meteor of March 24 may be conveniently considered under two divisions: The moving fireball or fireballs, and the after-glow, which came from the cloud or persistent train which remained in the meteor's wake.

The various witnesses disagree as to whether there were one, two, or several fireballs. From Melrose and Ft. Sumner, witnesses described a cluster or procession of from three to several fireballs scattered along a length of about one degree. Mr. Bishop of Canyon, Texas, declares there was only one ball until it reached a point 22° west of north from him where it separated into two distinct parts which appeared to travel side by side to the finish. Several others, particularly those who saw it from long distances, report more than one fireball traveling in a group. It is probable that in the latter part of its course the meteor consisted of a cluster but for those who were near, the light was so brilliant as to render the detection of the separate units impossible; while for those farther away the various components became distinguishable.

The majority of witnesses who were within 50 miles of its terminus indicate that one or more "explosions" occurred during the meteor's course and that after the last such bursting two or more fireballs were seen gradually to fade into redness and then to disappear. Mr. McClure, two miles N.W. of Mills, New Mexico, saw a pillar of fire rise from the eastern horizon to an altitude of about 35° or 40° where it parted, sending one smoking missile past him on the north. Thinking this was going to strike his barn he did not notice any other result of the "parting" except some patches of cloud that remained for "some time afterward." Drawings by Victor Martinez of Wagon Mound, New Mexico, also indicate a bursting into three parts near the terminus of the meteor.

Several factors may be responsible for discrepancies between the reports of various witnesses regarding the behavior of a meteor at its finish: Let us suppose a meteor divides into four parts at its last bursting which takes place at, let us say, an altitude of 15 miles. The four resulting fragments have sufficient velocity so that they continue to burn for a distance of one or two miles; but they are of different sizes and their lights are of different intensities so that for persons as near as 30 miles, all would be visible, while for those 70 miles away only the two largest could be seen. From a distance of 125 miles no individual fragments could be distinguished, but the meteor would appear simply to emit a puff and then vanish.

Again, if a meteor consists of several very brilliant fireballs, each of a

sufficient brilliance to dazzle and almost blind the eyes, as seems to have been the case with the subject of this paper, they may, as pointed out in a preceeding paragraph, appear as one to observers within a certain radius, while for those at greater distances such that they cease to produce the blinding effect, they may be distinguishable as separate lights, providing they are separated from each other by sufficient distances. Finally, however, as we recede from them a distance will be reached from which their spatial separation will not be sufficient to enable the eye to resolve them into separate units and they will appear as one. The latter condition is well illustrated by the headlights of an automobile approaching from a distance. Again, the distribution of the various units of a multiple meteor may render them distinguishable to observers from certain angles, while for those in a different position two or more would fall into the same line of vision and appear as one.

We must also allow for differences in optical efficiency on the part of observers as well as interest, effort, fear, and other psychological factors.

After going over all of the evidence, I am led to believe that, subsequent to the bursting depicted by Bishop and other witnesses, we had at least a double and perhaps still later a multiple meteor. According to our survey the spherical cloud which was sketched by Bishop is the same as that photographed by Brown. It will be noted that there are two prominences on the forward end of the spherical ball in the Brown photograph. It seems reasonable to conclude that these are the points from which two fragments are about to emerge.

A careful study of the Brown photograph together with a large number of related data was made by Mr. J. D. Figgins, Director of the Colorado Museum of Natural History, and the writer. We conclude that the most satisfactory explanation of this photograph is to be found in assuming that the meteor was produced by a huge meteorite of unsymmetrical form such that when it encountered the atmosphere it produced results analogous to those produced by an irregularly shaped pebble thrown into the water, describing the very erratic course recorded in the more distant portion of the Latham photograph. As it recovered from the first shock of impact, it acquired a certain equilibrium traveling in the spiral course so graphically shown in the Brown photograph. By the time the last explosion occurred the mass had been so mutilated by its aerial conflict that it was rent asunder, producing the two missiles depicted by Bishop, as fireballs which indeed they continued to be for many miles.

The large incandescent spheroid shown in the photograph presents a difficult problem for interpretation. As has been previously stated, this picture actually represents an object no less than six miles in diameter. What was the nature of this spheroid?

We may safely assume that the meteorite, as it drove its course earthward, carried a rapidly accumulating column of air in front of it. The core of this column would be very effectively insulated. This buffer of air, between the increasing resistance in front and the terrific drive

from the rear, was compressed until, at the instant of its maximum stress, a temperature was developed in its axial core directly in front of the meteorite as great as or perhaps greater than that which was attained where the air-blast impinged on the face of the stone.

It has also been suggested by Dr. E. J. Workman, University of New Mexico, that a difference in electrical potential between the invading meteorite and the earth may result in electrical discharges between the meteorite and the surrounding air accompanied by enormous production of heat. An examination of the fragments thrown down while the fireball was in transit indicates that the temperature in the vicinity of the meteorite was sufficiently high so that discharged fragments were seared over by a fusion crust within a brief fraction of a second.

This severe temperature was productive of much ionization and perhaps even more violent forms of atomic disintegration which spread outward with the violence of an explosion—not of the meteorite—but of compressed air. This process temporarily relieved the pressure and the meteorite sped onward, gathering another air cushion as before. There may be one or several such explosions during a meteor's flight before its spatial momentum is reduced to the point where it ceases to be able to generate sufficient heat for the process. According to the best witnesses there were four such explosions or flashes exhibited by the subject of this discussion.

It is the writer's belief that the disruption of meteorites during their passage through the atmosphere is due to these violent explosions in front of the moving body, together with the electrical discharges between the meteorite and its enveloping air envelope rather than to the various other causes which have been assigned by previous writings on the subject.

The After-Glow and the Cloud

A most puzzling aspect of this meteor was the after-glow which various witnesses reported as "as bright as the sun"; "much brighter than the moon"; "like burning magnesium"; "like that produced by a short in a power line"; "too bright to look at," etc. Mr. Walker, the railroad agent at Springer, New Mexico, stepped outside his office 30 minutes after the passage and found the cloud bright enough to cast a shadow against the eastern side of the depot.

It has been argued that this glow was due to light from the sun which reached this stratosphere cloud and was reflected to the observer. The writer must admit a prejudice in favor of this explanation during the early part of his survey and will confess that he refused to admit the possibility of a self-luminous cloud for longer than a very few minutes after the meteor's flight.

However, when Professor A. W. Recht, astronomer at Denver University, calculated the position of the sun at the moment of the meteor's passage, he found that the cloud could not have received direct sunlight unless its elevation had been 79 miles or more. No part of the visible

cloud was ever above 51 miles and the greatest luminescence was below 35 miles. Hence we were compelled to admit that the cloud was self-luminous.

The photographs also prove that the cloud emitted light at least as late as 5:30. In Figure 2 we see a large area of the sky illuminated. This picture was taken at 5:15 with the camera facing 30° south of east.

FIGURE 2.

The luminous train of meteor as it appeared from Timpas, Colo., at 5:15 A.M. Distance from photographer about 146 miles to middle of cloud. Lens 3½-in. focus. Photographer C. R. West.

The sun will appear 45 minutes later almost exactly due east. The picture clearly shows an illuminated area about the cloud which could not come from the sun. The Brooks picture was taken facing a direction 25° north of east. The dawn shows clearly in the right end of the picture; but no shadow is cast on any part of the clear white meteor cloud. It appears to be self-luminous, as indeed Mr. Brooks, the photographer, insists it was. He, being accustomed to the use of magnesium light, compared it with the burning of magnesium. Bear in mind, this picture was taken almost 30 minutes after the meteor passed. Scores of men and women who saw it declare the cloud was luminous for at least 45 minutes.

The temperatures which are assumed to exist at high altitudes seem to render it quite improbable that this luminescence was due to incandescent particles of the meteorite. It is much more probable that it was, in accordance with the conclusions of Trowbridge,[1] due to ionization of the atmosphere or meteoritic dust, or both.

The texture of the stones from this fall is such that it would have disintegrated rapidly when subjected to great vibration or strain. Indeed, it appears to be like volcanic dust or tufa more than like anything else. The immense cloud which continued to float in the sky long after all luminescence had disappeared was doubtless composed of dust from the disintegrated meteorite.

It is regrettable that in view of our many modern facilities for com-

munication and rapid travel, both on land and in the air, there has not yet been a serious effort put forth to explore and analyse these meteoritic clouds, several of which are produced within reach of civilized man each year. Such an exploration would no doubt throw important light on the composition and magnitude of the meteorites which produce them.

In a case of the kind under discussion it would have been possible also to carry out a project of spectrum analysis with a considerable degree of success, even though no advance preparation had been made.

FIGURE 3.
Portion of cloud from Timpas, Colorado, at 5:25 A.M.
Lens 7½-inch focus. Photographer C. R. West.

This has lead me to suggest that there should be established a Laboratory for Meteoritic Research which, in addition to other activities, should serve as a clearing house for information on important meteoritic phenomena and thus coördinate the work of many institutions. In this instance, telephonic communication could have brought into use instruments in several state institutions, resulting in important additions to our knowledge in this field. It has seemed to the writer that meteor clouds offer some of the greatest opportunities for fruitful investigation to be found in the field of meteoritics, and, fortunately, in this instance we have photographic proof of the cloud's magnitude.

When a cloud more than 200 miles in length and 3 miles in diameter throughout 100 miles of this length is left in the wake of a meteor one half-hour after its passage, there is little use to dispute the contention that enormous quantities of meteoritic matter are discharged into the atmosphere before any meteorite has traveled through even the upper half of the earth's air blanket; and any contention that visible meteors of ordinary nightly occurrence at an average distance of 100 miles from the observer may be occasioned by minute particles, and yet survive to register a visible course 15 to 30 miles in length is, in the judgment of

the writer, entirely untenable.

That the train of the meteor of March 24 persisted and in its later appearance did not show any light phenomena foreign to ordinary clouds, is considered by the writer as evidence that it was composed of finely divided meteorite dust mixed with such gases as resulted from its aerial conflict, and had been dispersed by the powerful out-rushing air-blasts in all directions from the front and sides of the meteorite. The surface markings on all freshly fallen meteorites indicate that during flight they are subjected to conditions comparable to the holding of an icicle in the blast from an acetylene welding torch, namely, a very rapid liquifaction, volatilization, and dispersion at the surface while the interior remains unchanged. The behavior of the cloud, as described by witnesses and as recorded in the photographs, was what would be expected in a cloud of various-sized dust particles, namely, a noticeable sinking and a gradual thinning, the while drifting with the wind, as would an ordinary vapour cloud. It would be interesting to know what weight of material was represented by the large cloud here described.

No definite conclusion has been reached as to the exact length of time the cloud remained visible, but we may be certain that it was visible for at least 90 minutes. Some witnesses assert that traces of it were still visible three hours after its formation. The drawing by Martinez shows quite a heavy cloud 51 minutes after the meteor's passage. Dr. Strong records its visibility at 6:15 and we know that he and the cloud had been, during this interval, moving away from each other until at that moment they were approximately 350 miles apart. The cloud could not have been very small to be visible at that distance.

The Plotted Course

I shall not encumber this account with all of the various testimonies from the many witnesses but shall merely point out the important facts which these interviews (a hundred or more) established.

Those who witnessed the meteor from points between Melrose and Ft. Sumner, New Mexico, saw it moving in an apparently horizontal, or nearly horizontal, course from east to west, only a few degrees above the horizon. From Tucumcari and neighboring points it was viewed in the same general direction and showed a slight declination to the westward, but was seen at an apparent elevation of about double that witnessed from points 50 miles farther south.

Those who viewed the display from Raton, New Mexico, and from Trinidad and Timpas, Colorado, looked southeastward and saw it about the same apparent altitude and traveling in an apparently almost horizontal course comparable to the view had by those at Tucumcari, except that they viewed it from the opposite direction.

For those who were interviewed in Stratford, Texas, Texhoma, Oklahoma, Texline, and Clayton, New Mexico, the meteor passed almost over head, and its course seemed to lie in an almost vertical plane whence it

vanished about 12° S. of W.

To the people who were fortunate enough to see the fireball from Wagon Mound, New Mexico, it appeared to rise out of the horizon from a point 12° north of east and when it had reached an altitude of about 20° to 30° (estimate) it vanished.

These reports made it very easy to arrive at a fair understanding of its general course; but when it came to a matter of definitely plotting

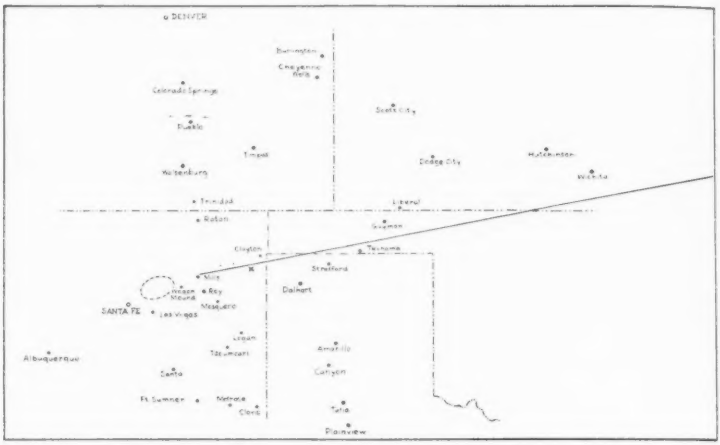
FIGURE 4.

Luminous train as it appeared about 2 min. after meteor's passage, from a point 22 miles north of Dalhart, Texas. Photographer Bert D. Latham.

it the case was more difficult. Disagreements among even the best observers as to the exact location and direction persisted in spite of all efforts to harmonize them. A few days later, when Dr. Strong's report had been received stating that "it wobbled in its course" matters began to clear up and when finally the photographs by Brown and Latham arrived, the warped train of the meteor was definitely established.

From the start, some few persons who happened to see the meteor from its very earliest appearance had insisted that it changed its course.

While at first this seemed improbable we now know that such was the case. Near the beginning of its visible course it is shown in the photograph, Figure 4, and the drawing by Martinez, to have borne strongly to the southward and then turned toward the west, following subsequently a zigzag course over a line which bears about 12½° southward from a due east-west line. (See map.)



Map showing the general course of the meteor of March 24, 1933, and the principal towns where interviews were held with witnesses to its flight. X shows location from which Mr. Brown's photograph was made. Midway between Mills and Clayton meteorite fragments have been found.

The terminus of the visible course seems to have been a few miles northeast of Mills, New Mexico, as determined by numerous interviews which were plotted in surrounding points and from impressions received in interviews in the immediate vicinity. There is, however, strong evidence of the extension of this visibility for those near enough to see its reduced luminescence. Unfortunately, no very definite conclusion could be reached from this point westward.

We may be fairly certain that the vanishing point was about 17 miles above the location designated and we may be sure that the angle of descent was not far from 8½°. This angle was determined as 7° to 9° by the use of an altitudometer on the best observers, and by using the sound period as recorded by observers near Stratford, Texas. The photographs which later arrived, however, establish it at 8½° with the horizontal at the point of disappearance.

Drifting of the Cloud

A number of people commented on the movements of the cloud after the meteor had disappeared. Several who were near the line of flight

reported a whirling motion of "the vapour." This motion is what would be expected in the wake of any rapidly moving and rotating object; but a much more significant movement in the cloud was its rapid drift to the eastward or slightly northeast. Because of the very great distances from which it was viewed, its apparent motion was slow and did not impress the majority of those who saw it; but in reality its motion must have been very rapid as described by those who took account of it.

FIGURE 5.

Luminous cloud as it appeared about 5:30 A.M. from Albuquerque, New Mexico. Distance from photographer about 240 miles. Lens 6½-inch focus. Photographer H. A. Brooks.

Mr. Brooks emphasized the difficulty which he had in getting his camera set up in time for the picture because the cloud looked as if it were going to sink behind the Sandia Mountains before he could complete his arrangement. It should be noted that from Albuquerque, Mr. Brooks was looking at the cloud almost end on and from a distance of 156 miles from its terminus. But according to Mr. Reynolds of the same city, who saw the meteor almost throughout its entire flight, it disappeared behind the mountains before it was extinguished, and this would mean that the cloud, seen and photographed by Mr. Brooks, was in reality still farther away, since it was produced previous to the terminal point. Also, the cloud had been drifting, or as it appeared from Albuquerque, sinking during 27 minutes before the picture was taken. Mr. Brooks estimated that it "sank" through a distance equal to the vertical thickness of the cloud as shown in his photograph during the 7 or 8 minutes he was setting up the camera.

Observers at Trinidad indicated to me the apparent rate of motion, a few nights later, in cumulus clouds which were drifting past the moon. The motion indicated was one degree in 12 seconds or 5 degrees per minute. However, the exact direction of the cloud when photographed

from Trinidad, Colorado, proves that it had drifted about 45° previous to the making of the exposure, which, judging from the light in the sky, must have been about 30 minutes after the meteor's flight. By measurement on this photograph,* using landmarks plainly shown in the picture and comparing the locations thus established with that of the terminal cloud as previously determined by our survey, we find that the cloud had drifted 82 miles in approximately 30 minutes. Mr. West, 60 miles to the northeast, also photographed the cloud, recording the time of his photograph and the direction in which the camera was pointing. It is probably safe to conclude that the cloud drifted at a rate of about 165 miles per hour. The fact that its direction of drift was almost exactly the reverse of its previous flight may or may not be significant.

Detonations

The detonations produced by this meteor were described in the usual manner, as like thunder, an aëroplane in trouble, the back-firing of a tractor. The only difference noted by the writer was the fact that these sounds were heard to greater distances from its line of flight than is usual. In some cases more than a hundred miles. Like all other meteors which have been studied by the writer, the sounds were less noticeable near the end of the flight than on each side of the latter part of its visible course, a phenomenon which has been nicely explained by Pickering in connection with the great meteor procession of February, 1913.[2]

The whizzing or whining noise as of flying projectiles subsequent to the meteor's disappearance was not reported in connection with the meteor of March 24, 1933, save in a few instances and these were too indefinite to be given much weight. But this may be due to the fact that their flight was over almost entirely uninhabited territory after they had reached a level that should have rendered their passage audible. However, after examining fragments of the metorite the writer is led to doubt the survival of any large mass much beyond the vanishing point of the fireball.

A widely circulated report that windows were broken in Texline, Texas, by the percussion proved upon investigation to be incorrect.

As with all of the meteors which the writer has investigated, there were many people who in this instance reported hearing a swishing or whining noise at the instant of the fireball's passage. Of course it is at once evident that a sound from the meteor passing 50 or 100 miles from an observer would require minutes to reach him, yet one meets with this same story so frequently as to raise the question whether there may not be a method of sound transmission at the velocity of ether waves. Dr. E. H. Sellards has called attention to this same problem in his description of the great meteor of June, 1923.[3] The explanation usually offered is the psychological one that observers unconsciously associate the meteor with the passage of an ordinary rocket and that their

*A photograph which could not be secured for publication.

memory of the event also associates the sound of the rocket's passage, assigning it as an accompaniment of the meteor's flight. However, reports of sound simultaneous with the passage of the meteors come so frequently and in many cases under circumstances which seem to justify serious consideration of the problem. In several instances witnesses have testified emphatically regarding various meteors, that such a swishing noise first drew their attention and led them to seek its source when as yet buildings or other objects hid the meteor from view. One, of course, feels that the unexpected lighting of the landscape may have been the real stimulus which aroused them and that confused recollections led them later to assign as the cause the sounds which really arrived later. However, to assign such an explanation in many instances which have come under my personal notice seems rather presumptuous.

While the present paper has been in preparation the writer was given the following account by Mr. J. H. Bruer of Crawford, Nebraska, who witnessed the daylight fall of August 8, 1933, at 10:20 A.M.

Mr. Bruer is an implement dealer whose building faces the south and the door which is about 10 feet square was standing open that morning. He was talking to a customer, while uncrating some implements, about 22 feet (measured by the writer) back from the open door when he heard what he supposed was the "banking of an aëroplane." Being somewhat interested in aëronautics he said to the customer, "I wonder who that fellow is," and started walking toward the door. (I had him repeat this action while holding a watch on him and concluded it was about three seconds from the hearing of the first sound until he reached a point where he could see the meteor.) When he reached a point near the door he expressed his surprise and called the customer to come and see; for he beheld a huge fireball moving across the sky. It was almost due south when first seen and our survey, later completed, proved that it was about 100 miles away, moving from S.S.E. to N.N.W. It vanished about 20 miles S.W. from where Bruer was standing.

After standing for perhaps a minute looking at the cloud left by the meteor and commenting upon the strange event they walked back and he resumed his work, whereupon they were again startled by a rumbling sound which resembled that made by the passing of a huge army truck with solid rubber tires (such a truck from the nearby fort passed in front of his building daily).

Mr. Bruer is a man of intelligence and one who is not at all excitable and it can hardly be doubted that he actually heard two different sounds as above described. That both came from the meteor cannot be proved but all inquiry failed to reveal that any aircraft was afloat at that hour in the vicinity of Crawford or to bring forward any other explanation of the strange sound. Several widely scattered observers reported the hearing of similar sounds at the moment of passage while others failed to record any sound whatever. The above is one of many such instances which have led the writer to believe that there may be, in connection with meteors, ethereal as well as aerial propagation of sound.

Without exception, those who have reported this peculiar phenomenon describe the sound as a sort of hum, whine, or a swishing noise, occasionally comparing it with the noise produced by thrusting hot iron into cold water. Seldom has there been indicated any resemblance to the detonations which arrived later. This distinctive character of the sound would argue against the idea of confused recollections above mentioned. I prefer to leave the matter as an open question as to whether there may be propagation of sound by more rapid means than that with which we are acquainted.

Velocity

Attempts were made to ascertain the velocity of the meteor by various methods. Several persons who witnessed the greater part of its entire flight from points a hundred miles or more on either side of its course were asked to indicate its rate of travel by motion of the pointing finger while being timed. Others who were indoors when it first appeared and walked or ran out, in order better to see the finish, went through the same motions again while being timed by the watch. The estimate of the meteor's duration thus arrived at varied from 12 to 23 seconds, with an average of 16.6 seconds. The visible course of the meteor extended approximately 440 miles but it is estimated that the average extent of the path for those used in the velocity determination was 335 miles, which would give the meteor an average velocity of slightly more than 20 miles per second.

Dr. Strong[4] estimated that the meteor was visible from his location at Springer, New Mexico, for only about 5 seconds, and this estimate was checked by the railroad conductor and must be given considerable weight. It happens, however, that the location of Dr. Strong's train was such that a hill cut off about 5° from the normal horizon. This, together with the earth's curvature, doubtless prevented his seeing it during its earliest visibility. Another factor which must have shortened his period of visibility was the fact that he was located some miles west of the vanishing point which might require that it travel some distance after developing luminosity before becoming visible from a point beyond its terminus. Mr. Norton, who was about 150 miles farther east first saw the meteor low in the northeast appearing as a flickering star somewhat brighter than Venus at her best. It is quite certain that in this condition it would not have been visible a hundred miles farther away. I think we may assume that Dr. Strong's description refers only to the latter part of the display.

It is probable that the first impact with the atmosphere took place at a relative velocity of about 40 miles per second which would be consistent with the calculated velocity of meteorites in space at 26.16 miles per second, if we allow for the almost opposite direction of the earth as would be the case at this hour of the day.

Height

The height of the meteor's course was determined by means of altitude measurements as given by those on each side of its trajectory who were in position to best recall what they had seen. In several instances buildings were in the foreground which made the records quite dependable. A second method was that of measuring on the photographs taken and leveling up with the horizon from the spot on which the camera was set. A third method was by having observers who were directly under its course go through the same motions which they remembered having gone through between the seeing of the fireball and the arrival of the detonations.

Of these methods certainly the most dependable was that of measuring photographs after having visited the spots from which the photographs were made and carefully recording the angles for the boundaries of the picture. Here our only source of error came in the movements of the cloud which may have taken place after its formation. Unfortunately, no photograph showed the end point as they were taken some time after the flight (except the Brown photograph) and the end point had probably faded out.

Mr. Chas. Brown remembered that the clock on the shelf behind him was striking five just as he was approaching the breakfast table when the light first appeared. Later when the sound arrived he noticed the time and found it was 3 minutes after five. The position of the clock hands with reference to striking was checked by the writer and this would not allow for an error of more than 15 seconds. This reading then should be 2 min. 45 sec.

At Stratford, Texas, two men were timed while re-enacting their experiences of the morning the meteor passed and they gave 2 min. 30 sec. as the time for the sound to reach them. In their case, however, their activities were such as to make this estimate of only average value.

The height at first appearance of the meteor can be fairly relied upon as it was seen by several persons slightly above buildings and these altitudes were measured by instruments on the spot from which it was seen —in two cases through windows by observers seated at desks. The height was thus determined as 78 miles above a point not far from Howard, Kansas. The height at the finish was less certain. It was surely not less than 12 miles and may have been as much as 18 miles above the surface.* Our best measurement of height is the one based on Mr. Brown's notation of 2¾ minutes for the sound to reach him at the point marked X on the map. If we allow an average velocity of 800 feet per second for sound to reach him from the rarefied atmosphere in which it arose, we conclude that the nearest point to him was 26 miles.

*Just before going to press with the report an interview was had with Mr. E. H. Wolf of Pueblo, Colorado, who watched the meteor from his window just over the top of a school building across the street. Bearings taken from the window by means of an instrument establish the height of the end point as 17 miles.

Unfortunately, the velocity of sound at this level is problematical.

The Point of Landing

Due to the very erratic course which the projectile was traveling during its visibility the location of the fall is a very difficult matter to determine. The course is indicated on the accompanying map and the angle of descent was approximately 8.5 degrees with the horizontal at the vanishing point. If we allow that the course subsequent to the time when the light was extinguished ended midway between the vertical and the point where the projected visible path would meet the earth, and assume a height of 12½ miles for the vanishing point, then the landing should have taken place somewhere about 20 miles west and 5 miles south of Wagon Mound, New Mexico, and either north or south of this point, depending on the deviations from a regular course. As a matter of fact it has been impossible to determine satisfactorily the height at which the light disappeared, which may have been as much as 18 miles. This renders the location of the fall quite questionable. Practically all of the country west of Wagon Mound is sparsely settled and much of it is very rough, hence the finding of the fall will be very difficult.*

Just before going to press a trip along the line of flight some 35 miles back from its point of disappearance resulted in the recovery of a few fragments from this great fireball, one of which had been picked up immediately after its fall. The texture of the stone, which is very friable, renders it unlikely that any considerable mass landed intact.

The location of these fragments proves that our survey had correctly located the path of flight.

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*Since establishing the height at which the fireball vanished as 17 miles, the location of the landing of the main mass (if such a mass landed) should be considerably farther west.