

³ W. F. Denning, *J.R.A.S.C.*, 7, 404, 1913.

⁴ M. Davidson, *Jour. Brit. Astron. Assoc.*, 24, 101, 1913.

⁵ W. H. Pickering, *Pop. Astron.*, 30, 632, 1922, and 31, 96, 443, 501, 1923; W. J. Fisher, *ibid.*, 36, 398, 1928.

⁶ C. C. Wylie, *Science*, 118, 125 and 726, 1953.

⁷ C. C. Wylie, *Pop. Astron.*, 48, 306, 1940.

⁸ Axel Nielsen, *Meddelelser fra Ole Römer-Observatoriet*, No. 17, 217, 1943.

⁹ E. J. Öpik, *Irish Astron. Jour.*, 1, 80-96, 1950. On pp. 84 and 85 of this paper, Öpik makes the following critical comments on some of Wylie's procedures: "Wylie is not content with, justly, casting doubts on the value of the velocities derived from casual observations; he undertakes to correct them *post factum*. The procedure is not justified even where average values of the velocity are concerned, unless systematic errors are derived for all the observers — which is impossible. Wylie, however, corrects individual values. . . . There is the case of the Pultusk meteorite of January 30, 1868 — one of the observers was an astronomer, another a trained army officer, with a number of other reliable observers — for which the famous German astronomer J. G. Galle found a hyperbolic velocity practically beyond doubt. . . . Wylie, not in possession of Galle's original paper, 'curtails' the observations in order to make an elliptic case of it, too."

¹⁰ Lincoln LaPaz, Chap. 19, *Physics and Medicine of the Upper Atmosphere*, Univ. of New Mexico Press, 1952, 354-5, 367-8, and footnote 16, 391.

¹¹ Lincoln LaPaz, *C.S.R.M.*, 3, 42; *P.A.*, 50, 441-2, 1942.

¹² J. G. Galle as translated by Walter H. Haas, *C.S.R.M.*, 3, 43-50, 51-8, 1942; 3, 124-8, 129-33, 1944; and *P.A.*, 50, 442-9, 501-9, 1942; 52, 43-7, 94-8, 1944.

¹³ C. C. Wylie, *Contr., Univ. of Iowa Obsy.*, No. 9, 292, 1940.

OBSERVATIONS OF THE GREAT FIREBALL PROCESSION OF 1913 FEBRUARY 9, MADE IN THE UNITED STATES *

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I. REVIEW OF PREVIOUS WORK

On the evening of Sunday, 1913 February 9, the inhabitants of an extended portion of the United States and Canada witnessed a meteoric display that, if not quite without parallel, is unquestionably preëminent of its kind. From northwest to southeast, a procession of majestically slow skyrocket-like fireballs passed over southern Ontario, burning and crumbling as they went, into clusters of smaller

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meteors; some of these were extinguished, but many continued onward until lost to sight in the southeast. The spectacular display caused a sensation in the Toronto region, and Professor C. A. Chant, the Editor of *The Journal of the Royal Astronomical Society of Canada*, immediately undertook an investigation. His conclusion was that the meteors had been traveling almost horizontally at an altitude of not more than 30 miles (in many places loud rumblings were heard, as would be expected at so low an altitude). The geocentric velocity of these objects was in the neighborhood of 6 miles per second. Most surprisingly, he received reports of a phenomenon of unmistakably the same character from Regina, Saskatchewan, and from Bermuda — places 1200 miles distant from Toronto and in opposite directions from it. His conclusion, therefore, was that the bodies were temporary satellites of the Earth, maintaining a sensibly circular orbit practically parallel to the Earth's surface, while slowly being consumed by atmospheric friction, and that the same objects had been seen by all the observers. He chose for the orbit a great circle passing within 20 miles of Toronto, and cutting the equator in longitude 32° W, at an azimuth of $54\frac{1}{2}^\circ$.¹

Thus these processional fireballs appeared to have traveled nearly twice as far as others of their kind, which have never (as far as I know) been tracked for more than 1500 miles. Yet Pelion was shortly piled upon Ossa, for W. F. Denning of England was able to discover two marine observations, patently of the same sort of "procession," which extended the observed path by no less than 3000 miles south-eastward, giving a total length of 5600 miles.² Assuming that the same objects were seen at all stations, we may conclude that they had traveled nearly a quarter of a complete orbital revolution around the Earth when last sighted near Fernando de Noronha Island, south of the equator off Brazil — and were still apparently "going strong." There is nothing in the annals of meteoritics that can compare with this path-length.

In a series of papers appearing some 10 years after the event, Pickering considered the data in more detail, but was not able to reconcile the times recorded, which seemed to indicate a velocity only half the necessary 5 miles per second (orbital velocity for satellites near the Earth); the observations also failed to lie well on a great circle, and he was forced to assume that the procession seen in Saskatchewan was not following the same course as that seen from Toronto to the equator.³ In 1928, W. J. Fisher⁴ pointed out for the first time that such slow-moving bodies traveling over such great distances would *not* appear to describe a true great circle, but a course curved toward the west, as the Earth rotated beneath them; this fact disposed of the difficulty in fitting all the points to a single trajectory, altho if one examines the data it turns out that the curva-

ture of the path is rather too great to be satisfactorily accounted for by a velocity as high as 5 miles per second.

A much more serious discrepancy was the *impossibility* of the supposed orbit, because of its excessive closeness to the Earth. A body traveling only 30 miles above the ground in Ontario would, as Fisher pointed out, collide with the equatorial bulge of the Earth before it reached the equator; the air resistance in any case would prohibit any such long flight except by bodies of enormous size. The simple picture drawn by Chant was consequently rejected, or at least modified. Attempts were made⁵ to re-interpret his height determination (26 miles) or to disregard it altogether, by accepting something like 40-45 miles instead; but this procedure was too arbitrary. The alternative was to assume that the peculiar slow-traveling processions seen at the different stations were not identical after all, but were merely related manifestations. It could be imagined that a vertically-extended swarm, or rather "stack," of large meteorites, whose lower end reached down to the 30- or 40-mile-level, was the actual satellite, and that the processions witnessed along its path were caused by the successive "peeling off" of its lower members by the air as the stack slowly lost altitude in its orbital flight. This assumption would account for the striking similarity of the display at all the points of observation without requiring any single meteorite to traverse more than a fraction of the whole trajectory. This hypothesis of continuous replenishment by fall-in was suggested by Davidson⁵ and by Hoffmeister,⁶ and endorsed by Fisher in his review of 1928.

Another and more radical way of dealing with the problem is to deny that there was any connection whatever between the various observations, and to explain each as a local phenomenon whose linkage with the others is only a product of the imagination. This approach was first adopted by Charles Fort in 1923, who suggested that what was seen near Toronto was a fleet of extraterrestrial spaceships, whereas what was seen elsewhere may have been ordinary meteors.⁷ In 1939, C. C. Wylie presented an analysis of the Toronto observations intended to show that they could be interpreted as a "meteor shower" localized over that area, and unconnected with the distant observations.⁸ Wylie's views, presumably because they were regarded as the most "conservative," have been accepted by some,⁹ altho they are not likely to seem plausible to those who have examined the extensive observational data. There has been no original contribution on the subject since Wylie's study in 1939.

II. RESULTS OF THE PRESENT WORK

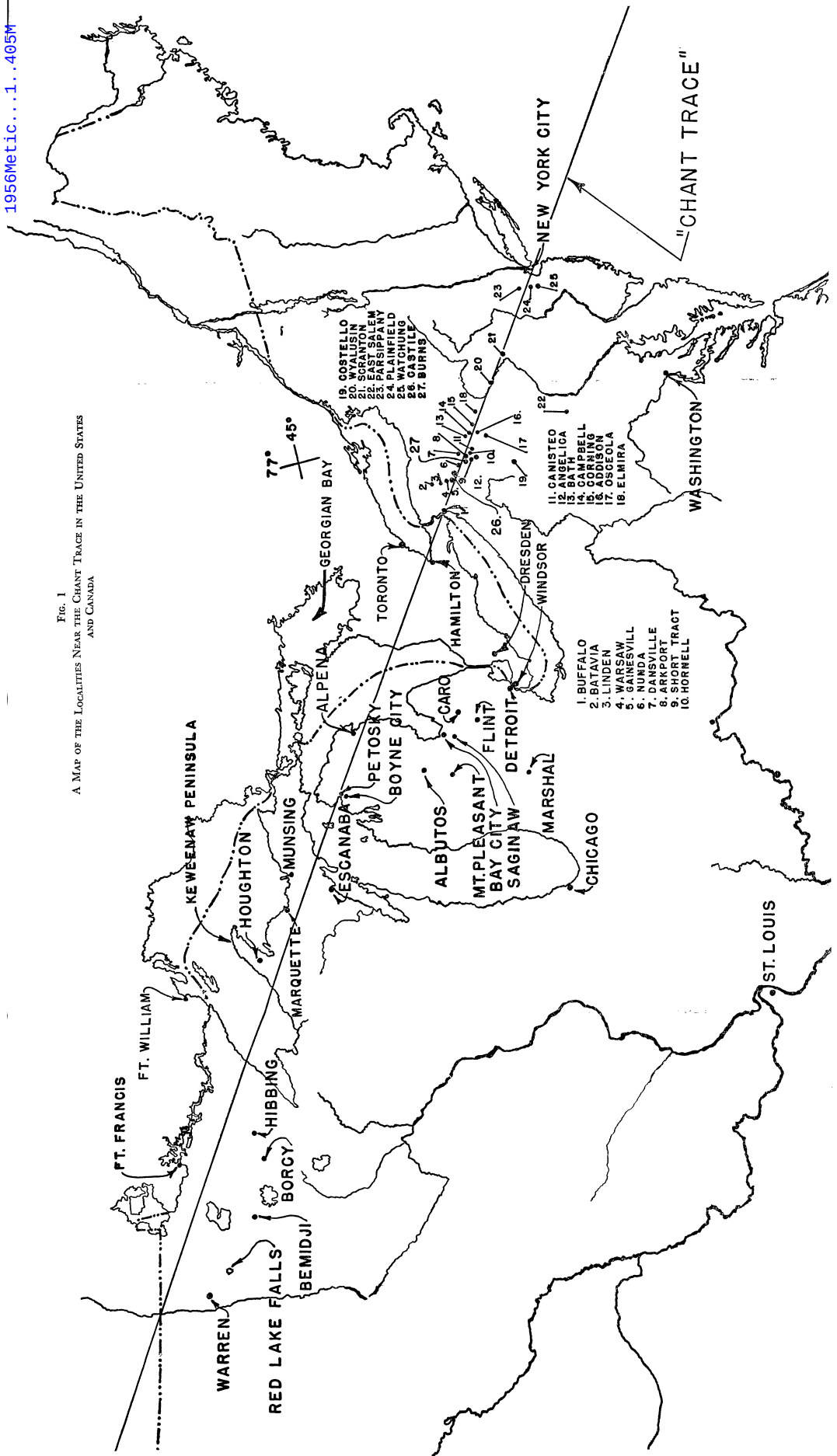
All the attempts at interpretation have been based upon the observational material collected in 1913-22 by Chant, Denning, and

Pickering. This material consists of about 100 reports from the Toronto area, a number from the Georgian Bay region of Ontario, and 4 from more westerly parts of Canada (Mortlach and Pense in Saskatchewan, Fort Frances and Fort William in western Ontario), as well as one from Bermuda and 5 from ships in the North Atlantic. Data from the United States, which Chant made no attempt to obtain, are conspicuous by their absence, altho he did secure 2 observations: one from southern Michigan and another from Watchung, New Jersey. Yet, if the procession were indeed continuous or quasi-continuous, it ought to have been seen in far-northern North Dakota, Minnesota, and perhaps Wisconsin, in both halves of Michigan, in western New York, in northeastern Pennsylvania, and in northern New Jersey. On the other hand, if it were a discontinuous phenomenon, as suggested by Wylie, one would not expect to find any indication of connection between the different, known observations, when the intermediate areas were investigated: the pattern of observation developed should not reveal a linear concentration, but a diffuse distribution of randomly scattered and inconsistent reports of meteoric activity on that evening. An attempt to unearth hitherto uncollected observational evidence, therefore, seemed likely to help clarify a confused situation.

During the past 18 months, the writer has carried out extensive inquiries of newspaper editors in the 7 states just named. For the most part, only those within 50-75 miles of the Chant trace were queried, but in Michigan and in eastern Pennsylvania the canvass was carried as far as 200 miles to the southwest of the trace. It cannot be claimed, however, that *every* newspaper within possible observational distance has been questioned. Of some 615 newspapers asked to search their files, 274 have been generous enough to do so, altho in only 27 instances was anything relevant found. In addition, weather bureaus of all the states, and local historians in New York, have been questioned; in New Jersey, several newspaper files were obtained thru the courtesy of local public libraries. A number of editors coöperated with the research to the extent of carrying the appeal for information in their columns, and those appeals produced several valuable observations. In Pennsylvania and New Jersey, advertizements also were placed in newspapers near the supposed track of the procession.

The results of this extensive canvass have been somewhat meager in view of the effort expended (both on our part and that of the newspaper editors and others who coöperated in the search), but a certain amount of new evidence has been obtained, which, if it does nothing else, at least definitely serves to rule out both the spaceship interpretation of Fort and the ordinary meteor-shower interpretation

Fig. 1
A MAP OF THE LOCALITIES NEAR THE CHANT TRACE IN THE UNITED STATES
AND CANADA



of Wylie. The new observations will be summarized in west-to-east order. The locations, with respect to the trace on the Earth of Chant's path, of the various towns and villages referred to in the sequel, are given on the map (Fig. 1) that accompanies this paper.

In *North Dakota*, at 8 PM, Central Standard Time, on 1913 February 9, cloudy skies prevailed over the northeastern part of the state; the 3 newspapers that replied to our inquiries reported negative findings.

From *Minnesota*, 4 reports were received. The first, from the extreme northwestern corner of the state, is a first-hand report of a brilliant fireball, a single large body that "lighted up the entire country" and produced a rumble like that of railway trains or distant waterfalls, but this report is included only provisionally, since definite confirmation of the date and direction of travel have not yet been obtained. A hundred miles to the SSE, at Red Lake Falls, an old man, now dead, "observed the spectacular train for a number of days." It was verified that "train" here meant "procession," but the date and the direction are again subject to question. The first definite evidence, from the Bemidji *Pioneer*, states that "a loud noise as of thunder was heard here, while others saw the appearance of a comet, which produced a swishing noise in going thru the air"; the date is said to be 1913 February 11. The fireball as seen at Bovey, 80 miles to the east, is briefly described in the Bemidji *Sentinel* as "a sudden salmon-pink burst of light jumping out of the air and making a good deal of noise — it proved to be only a meteor"; the date is indefinite, early or mid-February, but the identification seems reasonable. In Hibbing, 20 miles east of Bovey, the newspaper account agreed in all features with expectation: "At 8 o'clock last night, a shower of stars more than 30 in number coursed across the sky from north to east, finally scintillating much in the manner of a skyrocket; the display illuminated the sky for more than a minute." Time, appearance, and duration agree precisely with what was seen in Fort Frances, 90 miles NNW of Hibbing, and render acceptable the identification of the Bemidji and Bovey observations with this procession.

No information of any consequence has been received from *Wisconsin*, where only a few inquiries were made; in the upper peninsula of *Michigan*, two observations were obtained. At Houghton, on the Keweenaw Peninsula, a weather observer saw a large fireball appear on the northwestern horizon. "When it had risen to a height of about 20°, it separated into 2 bodies, each about half the size of the Moon; when these reached the zenith, they burst into a great number of small bodies, which continued almost to the southeastern horizon." The time given was 8:15 PM, or the same as in Saskatchewan and Ontario. The second observation was at Escanaba, 120 miles

due southeast of Houghton, where the display was described as “a shower of shooting stars that filled the northern horizon for several minutes; the stars came out of the west toward the east, and when they first appeared were so thick as to resemble sparks thrown from a locomotive.” According to the *Escanaba Press*, the end of the world was apprehended by many — a common reaction to the awe-inspiring sight of the procession. Both observations are correctly dated and are unambiguous.

Eleven (11) observations have been obtained from the intensively canvassed lower peninsula of Michigan. In the Petoskey-Boyne City area across the lake from Escanaba (some 110 miles ESE), 2 comet-like objects “heading east” were seen on February 9; the *Petoskey News-Review* gives the time as 7 PM, and says “one was following directly in the path of the other, and in the wake of the last one were numerous little stars.” At Boyne City, 2 eyewitnesses have been found, both of whom are positive as to the date: one recalls seeing only one large fireball, “the size of a bushel basket, heading kind of southeast — no fiery trail behind it”; the other remembers “a lot of them racing thru the sky — a lot of us who saw the meteors were certainly frightened, and there was quite a bit of talk about it at the time.”

At Alpena, 80 miles east of Boyne City, fairly detailed observations were recorded by the *Alpena News*: “There may have been anywhere from 2 dozen to 50 fire-red balls with trails of sparklike fire, moving at a slow, regular speed. Starting from a point low in the southwestern sky, they described an arc clear across the heavens until they disappeared in the northeast; the awe-inspiring display continued for probably 3 minutes.” The Weather Bureau at Alpena gave the following description:

“There was a short but brilliant meteoric shower observed during the evening of the 9th, between 8:15 and 8.30 PM (Central Standard Time). A group of about 10 brilliant meteors, one following the other in a straight line, appeared in the northwest and passed over the city in an easterly direction. Each gave off a faint reddish trail of light. Shortly another group, irregularly arranged, appeared in the southwestern sky, apparently traveling in the same direction. Following this display there were seen in the southwest a number of single meteors whose general direction was from west to east.”

This description corrects the obvious typographical error in the directions given by the newspaper, and adds the very significant fact that other meteors traveling on a *parallel* course were noted. Altho this feature of the event may be guessed at from other data, this is the only one of the new observations to assert it definitely.

It has not been possible to obtain any other observations within 100 miles of Alpena. At Arbutus, a small town 100 miles SSW of

Alpena (and about the same distance SSE of Boyne City), "a shower of meteors was seen passing overhead and moving southeast at 8 o'clock Sunday night." Thirty (30) miles farther to the SSW, the Mount Pleasant *Times* tells of "a brilliant display of 2 large meteors with long tails, coming from the northwest and going southeast. After the flight of the meteors a dozen or more smaller stars followed them thru the sky. This fiery display lighted up the heavens for a minute or more. The papers make account of probably the same phenomenon as it appeared in other parts of the state." The time is given here as 8:10 PM, and the phenomenon seen is recognizably identical with that described at Petoskey. Four (4) other observations clearly refer to these 2 conspicuous bodies. In the Bay City-Saginaw region, 40 miles east of Mount Pleasant (at the head of Saginaw Bay), "one of the most remarkable meteoric phenomena ever witnessed here was reported from many sources. . . . The first meteor, appearing like a ball of fire, passed from the northwest to the southeast, and with its tail of fire was visible until it apparently had reached the horizon. It was followed, at an interval, by a second, altho not of such proportions. The stars, as they appeared to fall, diminished in brilliancy." (Bay City *Tribune*.) The Saginaw *News* says that "2 enormous meteors passed; . . . with their passage a shower of stars was seen to fall." Twenty-five (25) miles farther east, at Caro, "some say there were more than a dozen, while others saw only 2, but with long tails of fire, which to some eyes might appear in sections," and the spectacle is likened to "fiery trains of cars shooting thru the heavens" — the same sort of simile that occurred to Canadian observers of the fireball procession. Forty (40) miles south of the Caro-Bay City line, the Flint *Journal* mentions only a single bolide: "It was exactly at 8:05 PM; . . . those who saw the display say the meteor rose out of the northern sky and sailed thru space toward the east, finally breaking into about 50 pieces like the explosion of a skyrocket." About 80 miles southeast of Caro and Flint are the towns of extreme-southern Ontario (Windsor, Dresden, &c.), where observations were obtained in 1913 by Chant; thus, the Michigan observations unquestionably link up with those of the Toronto area, and we have a continuous chain of observations spaced not more than 120 miles apart, all describing something of a processional nature traveling southeastward, from the Keweenaw Peninsula to Ontario.

The display was seen also by the Weather Bureau at East Lansing, and this datum and that at Houghton are the only two to offer *quantitative* information. The record may be quoted substantially in full:

"At 8:09 PM, a number of meteors, probably 15 or 20 in all, crossed the sky about 30° above the northern horizon. The first one seen was a small cluster, such as is seen when a skyrocket bursts; the

others followed in quick succession, some singly, others in clusters, like a straggling flock of birds. The rate of motion was apparently about like that of a skyrocket, which they all much resembled. The apparent direction was from about West 10° North. Some of the smaller ones burned out, but the larger ones were lost in the distance in the northeast."

The altitude indications deducible from this report will be taken up in the discussion.

The remaining observation from Michigan is that from Marshall, which was the only one known to Chant in 1913; it is anomalous, since stones are said to have fallen, altho Marshall (near Battle Creek) is a good 200 miles southwest of Chant's plotted path. This point seems to have been cleared up by the finding that the Marshall item was in large part "cribbed" from the account printed at Saginaw. I quote both:

Saginaw News: "Two enormous meteors, with tails many rods in length, passed over the skies here at about 8:30 Sunday night. The heavens were brilliantly illuminated, and with the passage of the meteors a shower of stars was seen to fall. It lasted for many seconds."

Marshall Chronicle: "Miss Vera Murray and Carl Schnaitman, . . . when returning to the city last evening, saw two enormous meteors, with tails many miles in length. This happened shortly after 8 o'clock. They reported that they had seen an airship going east. The heavens were brilliantly illuminated, and with the passage of the meteors a shower of stones was seen to fall. The display lasted for many minutes."

It is obvious that most of this is the *Saginaw News* item as rewritten by an editor who knew that meteors are large and that "falling stars" are really meteoritic stones. Subtracting this, we find that what remains is the statement that the observers thought that they had seen an airship going east, and that the display was visible for minutes rather than merely seconds. The incongruous "shower of stones" is only the Marshall editor's misleading contribution!

All of the *Ontario* observations have been given by Chant. According to his plotted trajectory, the meteors continued onward, passing directly over Buffalo and eventually leaving the continent only a few miles south of New York City. It was expected that it would be easy to check this prediction, because, by the time they reached the neighborhood of Hamilton, Ontario, loud rumbling sounds were being given off by the low-flying meteors. Since in Wylie's picture of the event all sounds were attributable to a single bolide that exploded over Hamilton, a clear-cut test of the correctness of this reconstruction would be furnished by an inquiry about sounds heard farther along the Chant trajectory. It turned out that

the characteristic sounds were indeed heard for a distance of at least 150 miles, and probably 200, beyond Hamilton. This circumstance was fortunate, since the sky in western *New York* was partially cloudy on the night of the procession. Ten (10) visual and 14 aural observations were secured in the state.

According to the *Buffalo Express*, "meteoric showers of exceptional brilliancy were seen in the northern skies; they had the appearance of batteries of skyrocket, and shot from the northeast [*sic*] clear across the heavens to the southeast. There were half-a-dozen volleys, and some say that they heard a rumbling resembling thunder after the last flight of the meteors." This story, complete with misprint, was reprinted in a number of New York and New Jersey newspapers. In Batavia, 35 miles to the east, the *News* stated that, altho few Batavians had seen the meteors, many had heard the noise and supposed it was thunder; in Linden, a few miles to the south, "several men owning horses rushed to their barns, thinking the animals were kicking." This particular error was made also in several places in Ontario. In Gainesville, 38 miles southeast of Buffalo and directly on the supposed track, "there was much discussion about the strange noise heard Sunday evening about 9:30; a few saw a strange display in the heavens"; an eyewitness wrote in the *Western New Yorker* that "A shower of burning meteors crossed the sky to the eastward, leaving a trail of fire and smoke that hid the stars for several minutes. Immediately after their passing a rumbling crash of thunder followed." People in 4 other towns in this neighborhood are said to have heard the sounds, without recognizing their cause; at Castile, a few miles east of Gainesville, "at first it appeared like a thunderstorm; many people thought it was caused by their horses in the barns and started out to locate the trouble. A few moments later the second report came. It appeared to come from the southwest, traveling northeast [*sic*]" (*Western New Yorker*, Warsaw). Another report from the same newspaper mentions that "2 people saw something like balls of fire passing in a westerly direction; some balls seemed to burst and separate. Whatever this was, there was no noise" (*i.e.*, no *immediate* noise; the observers, like everyone else, later heard the rumbling sounds, tho the time interval is not given).

Ten (10) miles farther along the Chant path, and directly beneath it, near Nunda, "the atmospheric mutterings lured more than one man to the barn to see what the horses were about; . . . Mr. and Mrs. John Colton were fortunate enough to be eyewitnesses to the phenomenon, which occurred about 9:20 PM, Eastern Time. The stars shot upward from the horizon in the northwest and appeared to explode when near the zenith, followed by the thunder-like mutterings that disturbed so many people." This report appeared in the

Nunda *News*, and has been confirmed by Mr. Colton, who is still alive, and who adds that the meteors were seen between broken clouds, and that he never heard of any stones' being picked up. The Nunda *News* spoke of "startling reports told here of large meteoric stones that fell at Short Tract and Gainesville Sunday night," but correspondence has not uncovered any confirmation of the rumor that meteorites fell. Between Nunda and Hornell, 30 miles farther to the southeast, inhabitants of 4 more small towns heard the sounds; in Burns and Arkport, windows were shaken, according to the Hornell newspaper, while at Angelica (20 miles south of Nunda), where the sky was overcast, the thunder-like roll lasted "nearly a minute" (Angelica *Advocate*). In Dansville, 12 miles east of Nunda, a resident remembers the event well, and says that many people there were so frightened that they feared the end of the world was at hand; here the fireballs were visible "in streaks" thru the clouds, just as at Nunda. At Canisteo, near Hornell, an eyewitness writes that it was lucky the phenomenon happened in the winter, "for if it had happened in the fall during dry weather it would have started many fires in this region," but unfortunately no details could be obtained. There seems to have been a general opinion, which may have some basis, that meteorites fell in this part of New York. Between Hornell and Corning (30 miles ESE), the sounds were heard at Bath and at Campbell (where, according to my informant, his father "went to the barn, thinking perhaps the stock were in trouble"); also at Addison, a few miles west of Corning. At Addison, the meteors were seen; the observer "said there was an explosive sound when one of the fireballs appeared to fall out as the swarm passed over that vicinity." This fact has been confirmed by an observer in Osceola, Pennsylvania (8 miles southwest of Addison and just over the state line), who recalls that "it made a noise like a cannon when it went over Osceola — there were awful explosions — it made our house just tremble. People said there were 35 lights, and it looked as if they were strung on a wire. It was going southeast." Osceola is 150 miles southeast of Hamilton, Ontario, and only 10 miles southwest of the trajectory plotted by Chant.

The final New York observation is found in the Elmira *Advertiser* for February 11; it contains more details than any other:

"Mr. and Mrs. J. R. Casterline witnessed a strange phenomenon about 9 o'clock Monday [*sic*] night. They heard a sound like the rumble of thunder, followed by a flash like lightning. They went to the window and saw what appeared to be a shower of falling stars passing across the sky from northwest to south, high above the horizon. The queer part, Mr. Casterline said, was that the stars passed very slowly. They left sparks and trails of fire behind them, and there

were sounds like revolver shots. The exhibition continued for 5 minutes or more, until 10 or 12 stars had passed slowly across the sky and vanished one after another in the south, 2 or 3 being in sight at once, part of the time."

In *Pennsylvania*, observations are almost non-existent. In the 110-mile stretch supposedly traversed by the procession, only one aural and one visual observation have been discovered. Part of the reason for this difference from the abundance of the New York observations may be the much smaller number of newspapers near the path, much of which lay over the Pocono Mountains.

Forty (40) miles southeast of Elmira, near Wyalusing, "several people heard a noise, apparently in the sky, between 9 and 10 o'clock on Sunday night. It sounded like the exhaust of an aeroplane engine. It came from the southeast [*sic*] and seemed to be traveling toward the northeast [*sic*]. Perhaps it was a comet, or a meteor, but, if so, the sky would have been illuminated." The coincidence of time and place seems significant, tho the direction given does not agree with expectations, and clouds must be assumed to account for the lack of visibility.

Thirty-seven (37) miles farther on, Scranton lies almost directly below the supposed path. When our inquiry was published there, thru the courtesy of the Scranton *Times*, a reply was received from Mrs. Eleanor Archer, who remembers seeing fireballs there at the age of 8. She is positive of the year, the month, and the day of the week, but she cannot be sure of the direction of travel. "I heard a swish and saw some faintly colored things in the sky — they passed right overhead — I thought the end of the world was coming." The fireballs were small and not very bright; no sound was heard except the "swish," which the observer likened to the noise produced by a jet plane. Thin clouds were present, hiding the stars. The time was approximately correct for the "procession."

In the last state supposedly traversed by the meteors, *New Jersey*, intensive effort has produced only one observation that *may* refer to the "procession," together with confirmation of the Watchung observation known to Chant in 1913. The Chant trace across this small state is only 75 miles in length, but there are 65 newspapers within 25 miles of it, in addition to those of New York City. None of these newspapers gives any indication that anything of a meteoric nature was seen that night, except the Plainfield *Courier-News*, which carried the following item:

"As the congregation was leaving the musical service last evening at Watchung, the members were astonished to see 7 stars shooting across the sky from northeast to southwest [*sic*]. They followed each other in rapid succession, and 5 of them passed out of the line of

vision, but the remaining 2 seemed to explode like skyrocket and burst into a thousand tiny stars. The 7 lights resembled balls of fire rather than stars."

There seems to be little doubt that this observation is in every way characteristic of the "great fireball procession," and that the directions given must be in error. Watchung is precisely on the line drawn by Chant.

The other New Jersey observation is from Parsippany, 13 miles north of Watchung, and was obtained as a result of a newspaper appeal. The observer is certain that the date was 1913 February 9, and the time shortly after 9 PM, when he was startled by the appearance of a fireball "as bright as an acetylene torch," which crossed the sky and disappeared over the horizon after being visible for 10 or 15 seconds. It emitted a hiss "like a skyrocket," but no rumbling sound was heard. The fireball passed supposedly to the east of the observer (Mr. S. H. Card), traveling in a SSE-NNW direction. If it can be supposed that a 180° error in orientation was made, the observation would fit well with the Watchung one, but in this case it is difficult to believe that the observer, who was on his own farm at the time, could have made such an error.

The weather over New Jersey was clear or partly cloudy at the time (partly cloudy at Sandy Hook, which the "procession" supposedly traversed on its way out to sea), so that overcast skies do not seem to be available as an explanation for the paucity of observations. It is certain that nothing was seen in New York City, 20 miles northwest of the Chant trace.

This concludes the list of observations obtained that can with likelihood be assumed to refer to "processional" meteors moving along approximately the path laid down by Chant. Several others do not seem so assignable, but in no case has any report been received of what would seem to be "ordinary" meteors or fireballs on this night. In Costello, Pennsylvania, we have what seems unquestionably to refer to a procession traveling parallel to the Chant trace and some 50 miles farther to the southwest. (Costello is about 50 miles south of Angelica, New York, where the meteors were heard, but not seen, because of clouds.) Mrs. Julia Williams, who was 11 years old at the time, writes that her attention was attracted to the sky by a noise like that of a jet plane, which proved to come from a "ball of fire with 5 or 6 smaller ones connected by fiery chains" (she draws a picture showing all connected in tandem), which passed to the northward, at an elevation of probably less than 45°, traveling from northwest to southeast. The weird object was visible "about a minute, may be longer"; she had time to summon her parents before it disappeared. In this case it is only the *sounds* heard that prevent identification with the "35 lights strung on a wire," seen 50 miles

to the northeast, but this conclusion may be a weak argument, since the properties of the hissing sounds produced by meteors are very poorly known. (The sound is presumed to have been due to radio waves transformed into sound by various objects on the ground.¹⁰) It will be noted that this hissing sound is recorded for only the Pennsylvania and New Jersey observations; in one of the Michigan observations (Caro), it was specifically listened for, but was not heard.

Another aberrant observation, which *may* refer to the "procession," comes from Warren in northwestern Minnesota, where Miss Esther Erickson saw "a vast area of strange lights coming and going" in the east or southeast, the phenomenon fading out after 20 minutes. The date is not certain, but it was in the winter of 1912-13.

In East Salem, Pennsylvania (near Lewiston), 110 miles to the southwest of the Chant trace, Miss Cora Clouser saw a group of some 20 or more orange "stars" moving slowly toward the *north*, somewhat to the east of her position. The date and time have been definitely verified as correct, and the observation would agree with expectations if it were possible to suppose that a mistake had been made as to the direction; however, this interpretation is uncertain. No newspaper in the surrounding area reports anything similar. The whole eastern half of Pennsylvania was canvassed as a "control area" to test the possibility that fireballs might have been seen generally on the night in question (rather than in the neighborhood only of Chant's line), but this was the only positive result obtained from some 34 replies. Its interpretation is not clear.

In conclusion, we may state that there have been 3 observations with the unexpected property of agreeing in all respects except *time*. In Munising, Michigan (upper peninsula), a few miles north of the Chant trace, nothing is recorded for 8 PM, but Mrs. Bessie Kelly replied to a newspaper inquiry that she had seen a fireball with a long tail of sparks like a skyrocket, passing slowly from northwest to southeast on a trajectory north of Munising, "some time after midnight — early morning of February 9th." This fireball, characteristically, was visible for "several minutes," and "disappeared over the horizon," and so it was clearly of a processional character, but it cannot be assimilated to the known 8 PM display. The date and time have been verified. What may have been the same fireball in a later state of disruption was seen at 2:30 AM on the morning of February 10th (not 9th as reported by Mrs. Kelly), 700 miles to the southeast of Munising, at Delaware Water Gap, between Pennsylvania and New Jersey. The observer, Mr. Arch Keller, remembers the awe-inspiring spectacle in detail, and has described and sketched a parade of meteors of gradually decreasing size, each size-class arranged in regular ranks except for the "go-as-you-please brigade" of red sparks that brought up the rear. "The main body, which oc-

cupied more space than the full Moon, was definitely dark, surrounded by incandescent light very much like the corona of the Sun in eclipse. . . . There were 5 or 6 following meteors, about half the size of the leader, and in perfect alinement; they seemed to revolve as tho geared together; there was only a slight darkening toward their centers. They flared and flamed, belching back exploding sparks and fire; . . . then came another array, about twice as many, of half the size; . . . soon the sky was filled with exploding sparks; . . . 20 minutes later there were still streaks of sparks across the heavens." A sound was heard, but Mr. Keller considers that it may have been caused by a distant train rather than by the meteors. This fantastic spectacle, a "procession" in its fullest glory, was seen directly on the Chant trace, but some 5 hours later than expected.

A confirmatory witness was found in Mr. George Lee, who remembers seeing a comet-like object with a long tail, low on the northern horizon and visible for many minutes, from the glassworks in Clarion, Pennsylvania, 125 miles southwest of the Chant trace; the date is not certain, except for the year, but the time was 2:30 AM.

The existence of this later procession on the same trajectory is verifiable by a consultation of Chant's data, p. 215: observer A. W. Brown, near Thamesville, saw "a series of meteors at 2:20 AM, *apparently following the same course as the one at 9 PM*, but visible somewhat longer; the whole display lasted about 20 minutes, and the meteors seemed to travel right down to the Earth in the distance. All seemed to have a stream behind them like a rocket." This important evidence seems to have been missed previously, because Mr. Brown, like so many observers, misreported his directions; comparison with other observers' reports in his vicinity leaves no doubt that what he saw at 9 PM was, of course, "the great procession," or one of its members.

The observations of the 2:30 AM procession have been mentioned here in concluding this account of observations obtained in the last 18 months, but no explanation can be offered for the repetition of the phenomenon over the same route after the Earth had turned thru a 75° angle. It will be recalled, in this connection, that, on the afternoon of February 10th, 3 groups of dark objects passed from west to east over Toronto; Chant suggested the obvious, tho inexplicable, conclusion that these were "something of a meteoric nature," repeating the procession once more on precisely the same course as before.

III. DISCUSSION AND CONCLUSIONS

The filling in of the gaps in the Chant observation leaves much to be desired, but there can be no doubt that over much of the

Chant trace in the United States, the characteristic processional character was certainly seen. Two of the hypotheses that have been proposed appear to be unacceptable in view of the new data. The first is Fort's supposition that the procession consisted of spaceships (flying saucers). This view is able to account for the otherwise enigmatic *repetition*, and seems to accord with the peculiar structures of the procession described by Mrs. Williams and Mr. Keller, but it is ruled out by the fact that none of those who saw the procession at close range described it as other than meteoric in character. The only definite assertions that vessels were seen were made by the observers at Marshall, Michigan, and at North Bay, Ontario — in both cases at the extreme distance of 200 miles. More favorably placed observers unanimously recognized the lights as incandescent meteorites. The appearance of "chains" connecting the fireballs is characteristic of processional (slow-speed) bolides, and should not, of course, be interpreted as an actual structure.

The other hypothesis that may be discarded is that the display was due simply to a "meteor shower," unless the group of meteors produced by the atmospheric ablation of a slow fireball may be classified as a "meteor shower." (Many of the observers used the term in this way, but they were hardly authorities on meteoritical terminology!) It is clear that the meteors seen were not the ordinary, small, unconnected individuals emanating in all directions from a meteor radiant, but were rather members of clusters of closely related fragments originating from the partial or complete disruption of larger bodies. Wylie's reading of the Ontario observations is definitely contradicted both by the prior observations in Michigan and by the later observations in New York.

On the other hand, it seems probable that the original Chant picture of complete continuity also is untenable. The well-developed procession seen in Hibbing, Minnesota, is surely not identical with the body seen at Houghton, Michigan, which did not break up until near the zenith; and this in turn, tho probably identical with the swarm of sparks seen at Escanaba, can hardly be identical with the 2 large fireballs observed across lower Michigan. The single-file procession across Alpena must be distinguished from the less regular procession (the 2 large fireballs?) that passed to the south of Alpena; and since *both* of these evidently crossed the lake to Ontario, it must be suspected that Chant erred in fitting all of his observations to a single line. On the other hand, it seems possible that all of the New York observations from Buffalo to Elmira refer to a single group of fireballs, whereas the New Jersey observation at Watchung must relate to a different group, since no sound was heard.

The question of *sound* in itself shows that the data cannot be accommodated in the original framework of horizontally-moving

satellitic meteors; there must have been some falling downward, even if the angle was so shallow as to be not easily noticeable by the observers. The westernmost data, at Bemidji and Bovey, mention the thundering sounds of air-racked meteorites; it is not certain whether this phenomenon was noticed at Hibbing, but, if all the observations refer to the same display, we can assume that it was. Yet all across Michigan nothing of the sort was heard, and explosive sounds began to be noticed for the first time only 35 miles west of Hamilton, Ontario; thereafter, they were conspicuous at least to Elmira, and they were probably the same sounds heard 50 miles farther on in Pennsylvania. At Watchung, the display was again without aural component. It is clear that the Michigan meteors must have begun at a higher level in the atmosphere, gradually dropped downwards, and finally burnt themselves out somewhere in Pennsylvania after roaring over western New York at a destructively low altitude. If continuity be assumed from Petoskey to Elmira, the path-length of individual objects was at least 500 miles; if continuity be assumed from the 90th meridian (west of the Keweenaw Peninsula) to Elmira, the path-length was 750 miles. Path-lengths of this order are commonplace in processional fireballs.

An estimate of the inclination of the trajectory must await treatment of the data by someone more competent than the present author; what is needed is to get two altitude estimates of the same group of bodies at different points. From the East Lansing and Alpena data, one may tentatively place the Michigan fireballs about halfway between East Lansing and Alpena, and at a height of about 50 miles, but these bodies could not have been the same ones as those measured by Chant at Toronto, but must have passed at least 50 miles south of his trace. (Conceivably, these meteors made up the procession seen at Costello, Pennsylvania.) Thus, the two altitudes cannot be directly compared.

Perhaps the most remarkable result of the present investigation was its revelation of the extreme spottiness with which celestial phenomena are observed. There can be no possible doubt that spectacular sights were visible in such places as Marquette and Detroit, Michigan, and Corning, New York, yet the newspapers of those cities gave no indication of anybody's having noticed anything out of the ordinary. The more southerly procession passed directly over the "thumb" of Michigan; in one newspaper there (in Caro) it was reported as having caused a sensation, but in 8 others, nearby, there was no mention whatever of the event. This pattern of unpredictable observation appears to be characteristic; the only region in which a majority of the towns reported noticing the phenomenon over their heads was western New York, where loud noises forced it upon the attention of the inhabitants. It is likely that much of this neglect

was due to the cold weather and the lateness of the hour, but a large part of it must be attributed simply to the infrequency with which human beings notice what is going on in the sky.

I should like to conclude with an expression of appreciation for the continued interest and coöperation of Professor Lincoln LaPaz, whose permission to use the name of the Institute of Meteoritics is largely responsible for such success as this investigation has had, and who has maintained an active and helpful association with it for nearly two years, in spite of the many other demands upon his time.

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THE DETONATING FIREBALL OF 1956 FEBRUARY 12*

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ABSTRACT

This paper describes the orbit, size, brightness, and sounds of a meteor that appeared over Southern California on 1956 February 12, at 1^h 7^m 40^s P.S.T. Parabolic elements were computed that indicate that the meteorite overtook the Earth in a direct orbit of low inclination. The luminous envelope was found to have a diameter of at least 0.1 mile. Finally, factors favoring the possible recovery of fragments are discussed.

At 1^h 7^m 40^s P.S.T., on Sunday morning, 1956 February 12, a brilliant fireball appeared over the Southern California coast near Port

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