CANADA

DEPARTMENT OF TRANSPORT

METEOROLOGICAL BRANCH

Technical Memoranda

SOUTHWESTERN ONTARIO TORNADOES
17 APRIL 1967

by

W.D. LAWRYNUIK

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CANADA - DEPARTMENT OF TRANSPORT - METEOROLOGICAL BRANCH
315 Bloor Street, West,
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ABSTRACT

Tornadoes occurred in Southwestern Ontario on April 17, 1967. This paper describes the atmospheric conditions under which these storms occurred. Radar pictures show the development of the storms. Damage caused by these storms is demonstrated with photographs and by a review of eyewitness reports.

TORNADES DU 17 avril 1967 DANS LE SUD-OUEST DE L'ONTARIO

par

W. D. Lawrynuik

RESUME

Le mémoire décrit les conditions atmosphériques qui existaient le 17 avril 1967, au moment où des tornades se produisirent dans le sud-ouest de l'Ontario. Des images radar montrent le développement des tempêtes. L'auteur démontre, au moyen de photographies et d'une revue des déclarations des témoins oculares, l'étendue des dommages que causèrent ces tempêtes.

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(Manuscript received April 22, 1969)

Introduction

On April 16, 1967, severe thunderstorms and several tornadoes were reported in the area to the west and southwest of Lake Michigan. A tornado was reported near Southbend, Indiana at 1700 GMT. The severe weather abated subsequently but motion of the weather system indicated the strong possibility of severe local storms developing over the eastern portion of lower Michigan and/or southwestern Ontario the next day.

Thunderstorms did develop over eastern lower Michigan early in the afternoon of April 17th. C-band weather radar at Toronto International Airport picked up a line of hard echoes just inside the 200 mile range of the set shortly after 1400 EST. A severe thunderstorm warning was issued by the Toronto Weather Office at 1430 EST for the Lake Huron region of southwestern Ontario. The line of thunderstorms swept across southwestern Ontario during the late afternoon and early evening. Tornadoes occurred near Hensall about 35 miles northwest of London and near St. Jacobs just north of Waterloo. Several sightings of a funnel not touching the ground were reported near Guelph. Hail was reported over the Bruce peninsula.

This paper will present the pertinent synoptic, dynamic and thermodynamic factors associated with this development. Radar plots and pictures will also be presented. The site of the Hensall tornado was visited by the author the day after the occurrence and several interesting pictures will be included. The track of the Hensall tornado was carefully plotted from touchdown to lift. An aerial survey was carried out on April 19th. Pictures and descriptions taken during the flight will be presented for both the Hensall and St. Jacobs tornadoes.

Synoptic Situation

A long-wave trough existed along the west coast. Since early April several deep short waves from the Gulf of Alaska had moved southward along the west coast. Each of these forced a major short wave out of the long-wave trough position. These moved northeastward across the continent then dropped southward into the long wave

trough off the east coast. A very intense shortwave moved out of the west coast long wave trough position on April 11th and continued slowly northeastward toward the Great Lakes then eastward to the east coast long wave trough. The next short wave came out of the southwest on the 15th and moved much more quickly than its predecessor and passed through the Great Lakes region on the 16th and 17th.

Surface charts showed that the previous storm to move through the area produced a cold outbreak that stalled just south of the Great Lakes. Fig. 1 shows where the front had stalled and frontalized on 160000 GMT. Subsequently a low with an associated cold front moved eastward from the Rocky Mountains. Fig. 1 shows the location of the fronts at 170000 GMT. Attention is drawn to the front in northern Indiana. This front makes very little northward progress on succeeding charts until after 171500 GMT. The front moved north of Windsor between 1500 and 1600 GMT. It then continued northward rapidly and hourly reports indicate it passed London just after 1800 GMT. Hourly reports are available at Hamilton and Kitchener only until 2100 GMT and both were on the cold side of the front at that time. The reported maximum temperatures for the day at both locations indicated that the warm air reached them. Toronto International Airport's reports indicated the warm front did not pass that station. The warm front did not get as far north as Mount Forest. Extrapolating the motion of the front northward from London at the same speed as the motion between Windsor and London would place it just north of Hensall at 2100 GMT (4 pm EST). A similar analysis places the cold front in the vicinity at that time as well.

The frontal positions for 0000 GMT April 18th indicate that very rapid occlusion had taken place and the frontal wave at that time was south of Lake Ontario with a trowal extending northward just east of Toronto and west of Muskoka.

The 171200 GMT 850-mb chart indicated a moist tongue, with dew points greater than 10°C, oriented along a line from Lake St. Clair to Saginaw Bay with a sharp dew point gradient to the west of it (Fig. 2). An 850-mb jet existed along the line Columbia-Southbend-Mount Forest. The strongest reported winds were 50 kts at Flint and Columbia.

The 180000 GMT 850-mb chart showed no dew point above 6°C. The remainder of the moist tongue was along a Trenton-Rochester line (Fig. 3). The 850-mb jet lay along a line Chicago-Flint-Trenton.

Low temperature-dew point spreads were evident on the 171200 GMT 700-mb chart along a line Pittsburg-London-Sault Ste. Marie, with much drier air to the West. The strongest winds

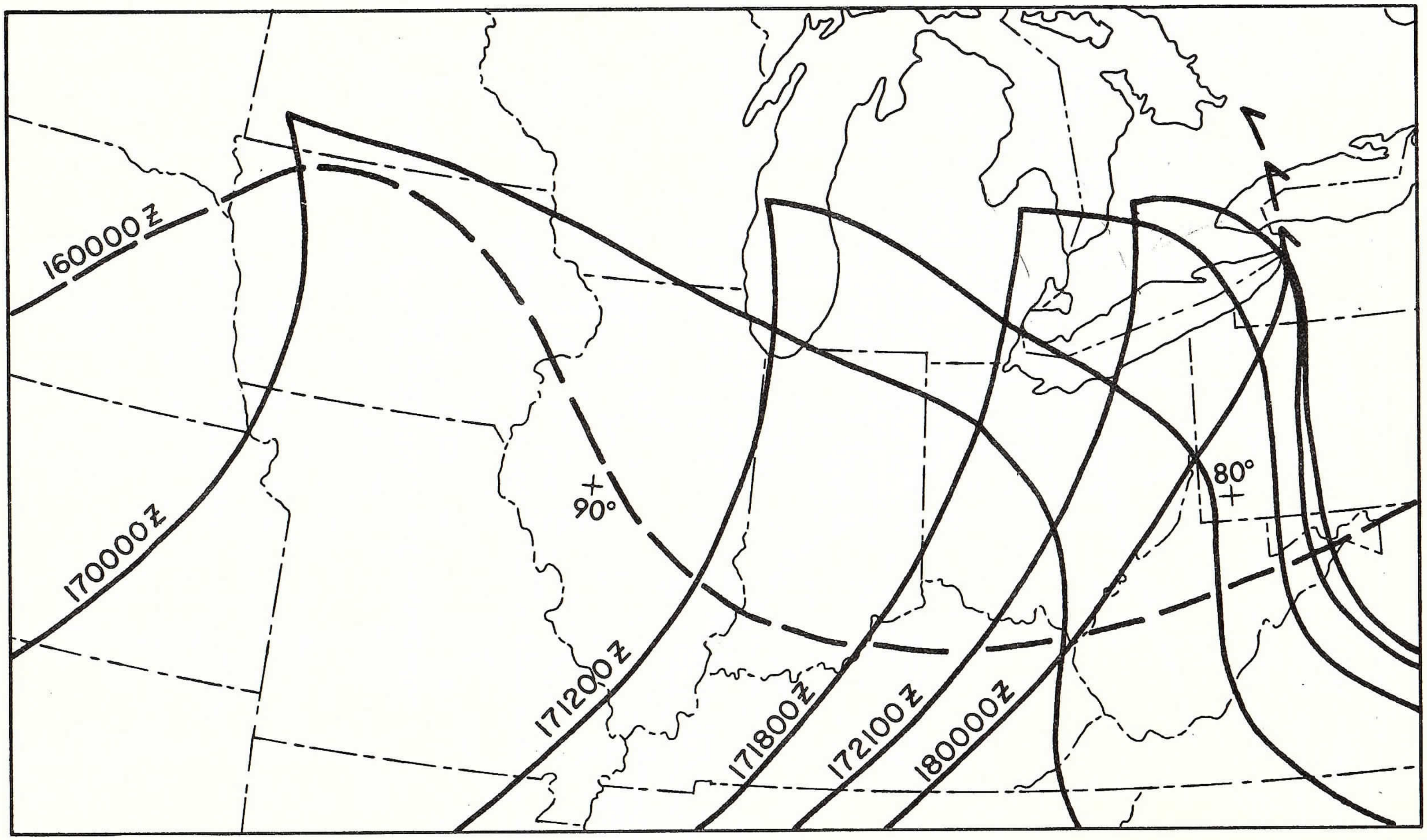

Figure 1.
Frontal Positions

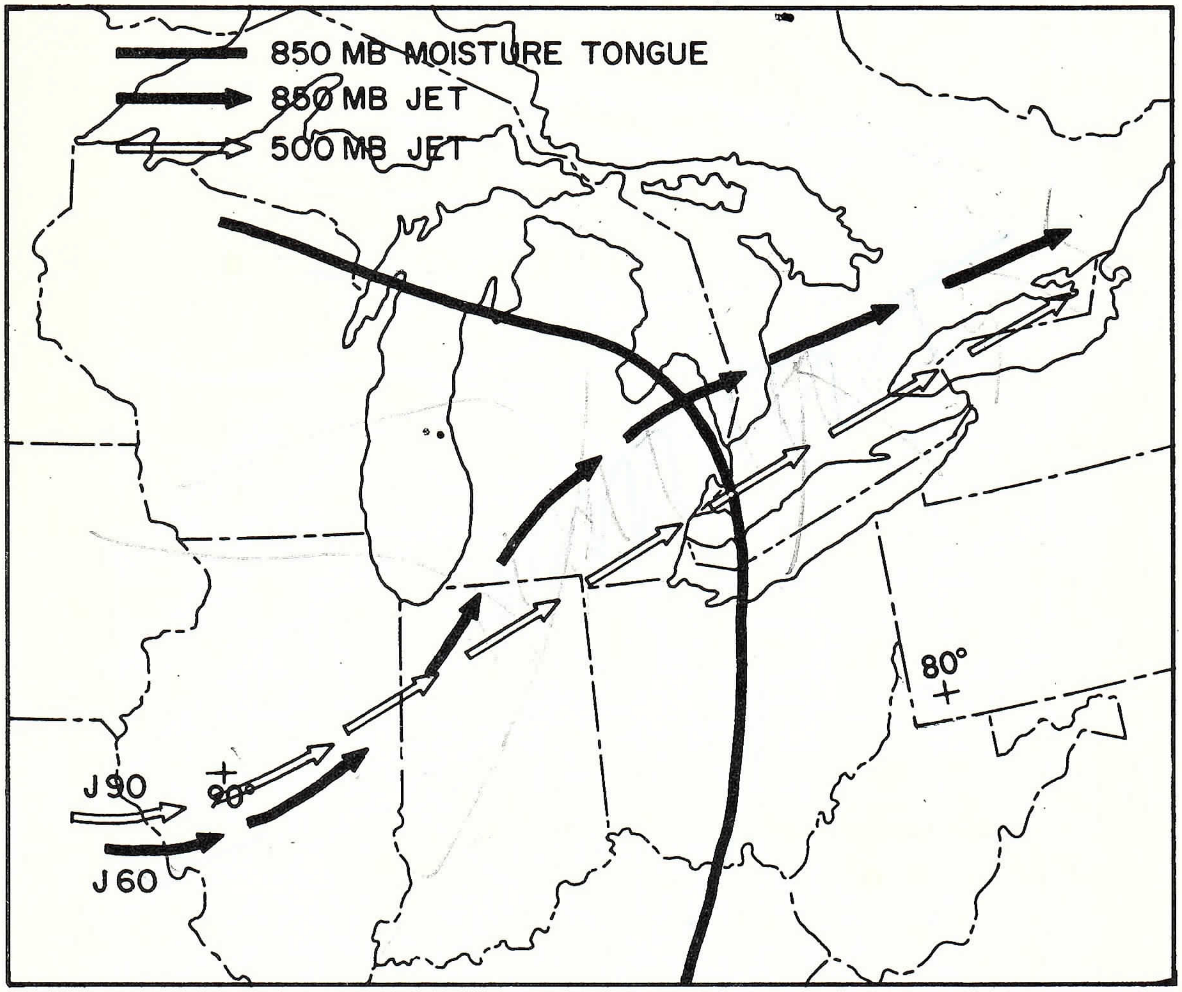

Figure 2.
Significant Dynamic Features at 171200GMT

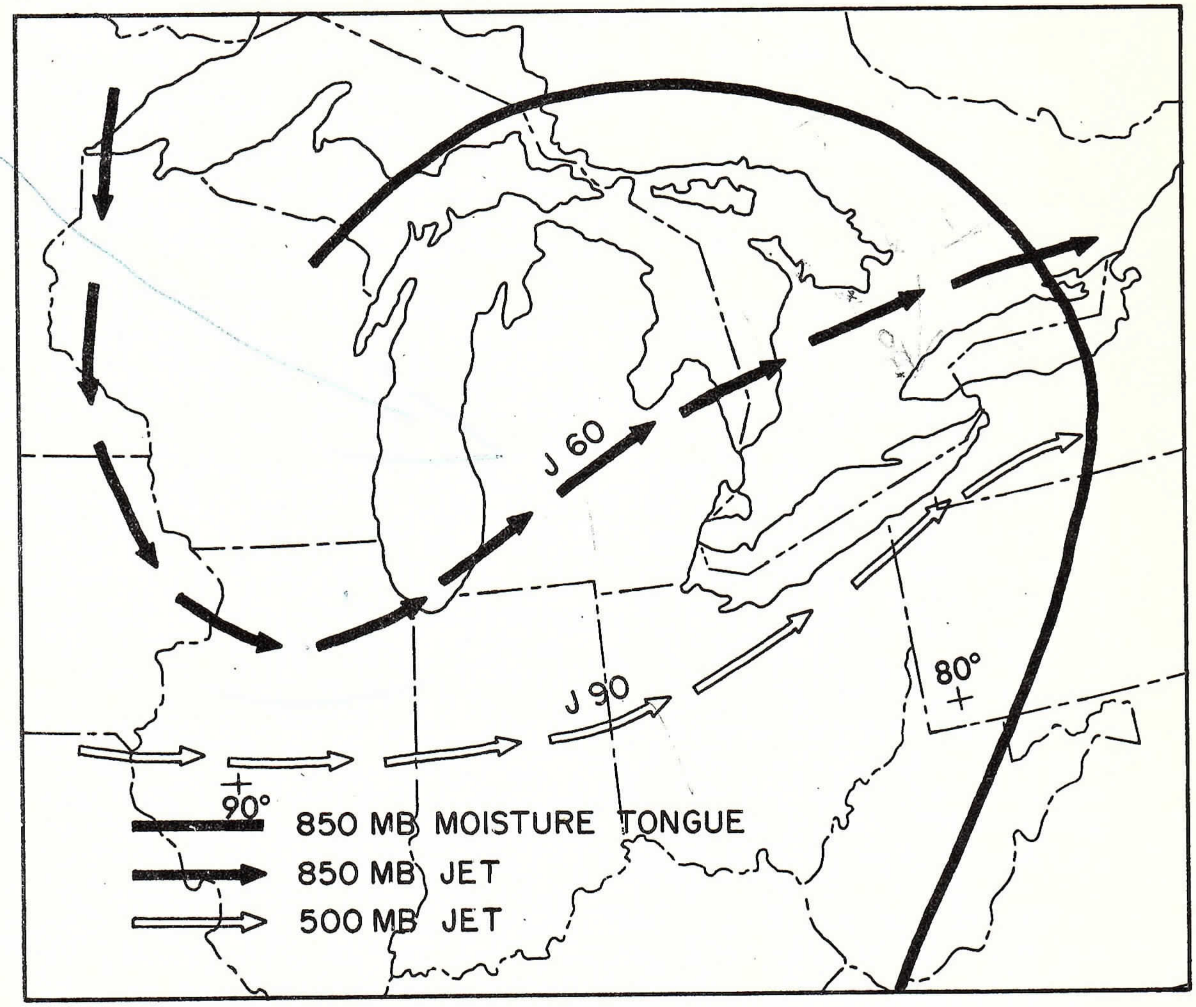

Figure 3.
Significant Dynamic Features at 180000GMT

were on a line Peoria to Flint with Peoria reporting 65 knots. At 180000 GMT the 700-mb moist tongue was on an Albany-Ottawa line with the jet from Dayton to South of Buffalo.

The 500-mb jet at 171200 GMT (Fig. 2) was between Omaha and Topeka, just south of Peoria and over Windsor. The 90-knot jet maximum was located between Peoria and Omaha. The 500-mb contour ridge lay along the line Sudbury-Buffalo-just east of Pittsburg. The 1000 to 500-mb thickness ridge was along the line Marquette-Flint-Huntington. The 180000 GMT analysis (Fig. 3) shows the 500-mb jet south of Peoria-Dayton-Buffalo. The contour ridge was on a Seven Islands to New York line and the thickness ridge was along a line Trenton to Washington (Crumrine (2)).

The warmest air at 500-mb was -13°C at Flint at 1200 GMT and it was -19°C at 0000 GMT. Extrapolation of the temperatures in the wind field indicated a -15°C as the likely 500-mb temperature AT 4 p.m. EST over southwestern Ontario.

The Central Analysis Office vertical velocity charts for 171200 GMT showed a vertical velocity maximum of 8 mb/1000 secs over northern lower Michigan. At 180000 GMT the maximum vertical velocity was 4 mb/1000 sec over eastern Lake Ontario. Interpolation takes the track of maximum vertical velocity parallel to the track of the severe storms and less than 50 miles north of the tornado area.

The high level jet stream at 171200 GMT was along a line south of Omaha - North Chicago - Wiarton - Muskoka - Nantucket. Wind maxima were located over New England and West of Peoria. At 180000 GMT the jet stream was along the line Peoria - North of Dayton - South of Buffalo with a wind maximum near Dayton.

The axis of the coldest air at 200-mb lay in an east-west line just south of the western end of Lake Erie at 171200 GMT. A -65°C isotherm was present. This cold pool moved eastward to north of New York at 180000 GMT and the axis of coldest air rotated to a southwest-northeast orientation.

Inspection of the 171200 GMT and 180000 GMT vorticity analysis produced by the ESSA NWP Unit indicates marked positive vorticity advection across Michigan and southern Ontario. The zero relative vorticity line extended along the Ohio-Indiana border then northward across Michigan to west of Saulte Ste. Marie at 171200 GMT and by 0000 GMT the zero relative vorticity line lay in a north-south line between Toronto and Trenton. Interpolation of this motion places the zero relative vorticity line slightly ahead of the tornado activity at 2100 GMT.

Fig. 4 is an attempt to construct an atmospheric sounding for the period 2100 to 2300 GMT April 17th for the tornado area. Interpolation gives cooling to -15°C at 500 mb. There is little evidence of any significant changes taking place in the airmass at the 850-mb level but cooling of about one degree seems likely at 700 mb.

Interpolation of computed vertical velocities gives an average lift of 6 mb/1000 sec at 500 mb. An analysis of the wind speeds and 500-mb trough speeds shows the air streaming through the area of lift. This allows the lift to operate on an air parcel for a relatively short time, approximately 3 hours. Hence a lift of 60 mb is estimated at the level of non-divergence. This implies 40 mb lift at 400 mb, 30 mb at 700 mb and 20 mb at the 300-mb level and at 850 mb.

Calculation of stability indices based on this prognostic sounding give these results, Slowalter and Lifted indices minus 5. 5 (Knox (1)), Totals index 57 (Millar (3) Ch. 8).

Summary of atmospheric conditions at time of tornado occurrence.

(1) Warm front lay just north of the line of tornado occurrences.

(2) A cold front was approaching from the west. Tornadoes occurred near the frontal wave in a rapidly occluding situation.

(3) A marked 850-mb moist tongue existed with a sharp dew point gradient on its western edge.

(4) The 500-mb jet intersected the 850-mb moist tongue.

(5) The tornadoes occurred about 100 miles west of the 1000-500 mb thickness ridge.

(6) There was marked positive vorticity advection in the area of tornado occurrence and the zero relative vorticity line was slightly east of the tornado area.

(7) The 300-mb jet axis was just south of the tornado area, the 850-mb jet axis was north of the area. The left front exit at 300 mb was over the right front exit at 850 mb.

(8) The 200-mb level temperature minimum with temperatures below -60°C was located just south of the tornado area.

(9) Thermodynamic analysis showed stability indices in the severe weather range in the area at time of tornado occurrence with significant destabilization occurring in the prior nine hour period.

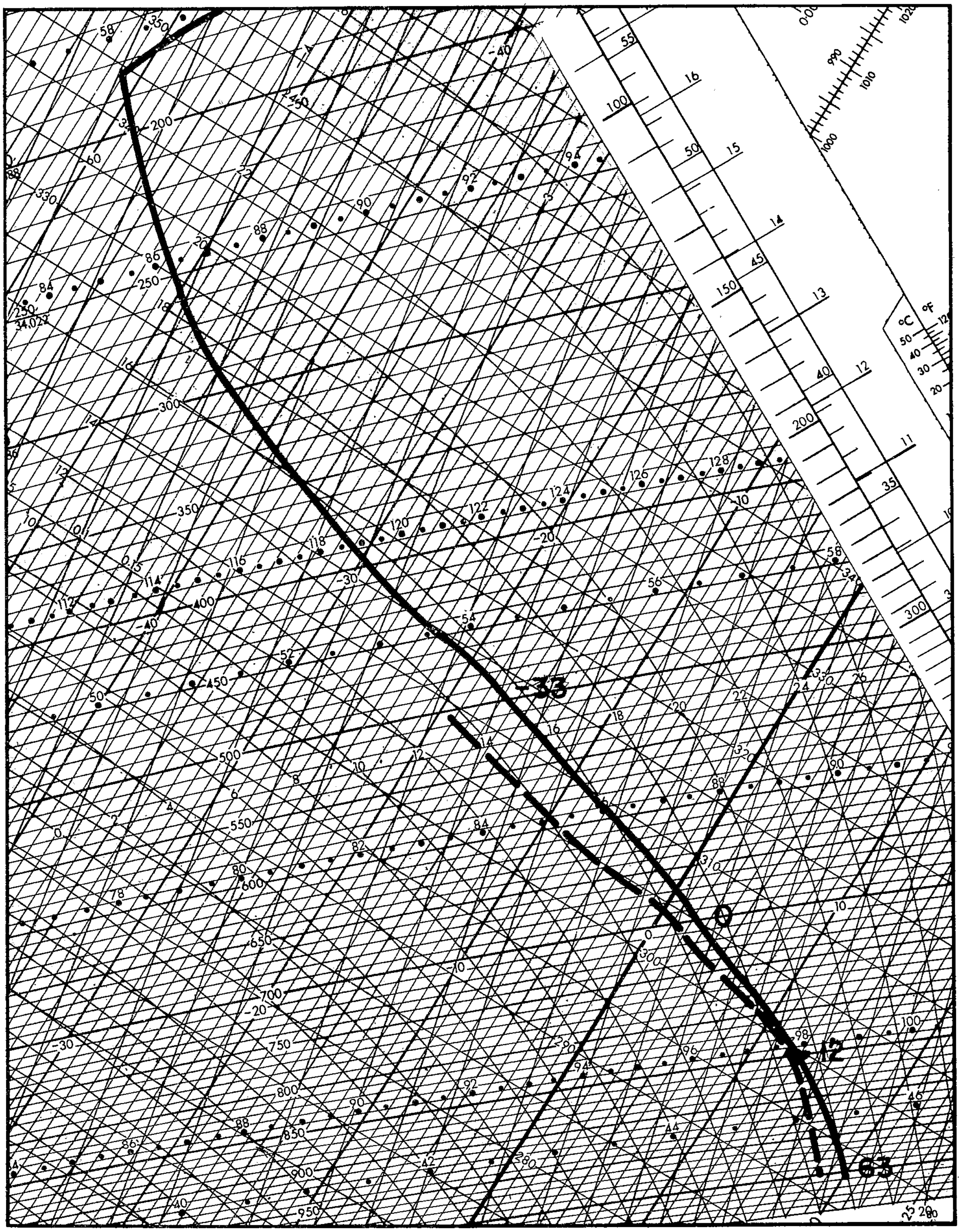

Figure 4.
Prognostic Sounding for 172100GMT

Tornado Tracks

The tornadoes occurred on an approximately east-west line from Hensall to Guelph (Fig. 5) but the tornado tracks were at an angle to the left of this line. The Hensall tornado moved along a track toward 060 degrees magnetic until the last 2 miles at which point it veered to 040 degrees magnetic. The tornado at St. Jacobs moved along 055 degrees magnetic.

The track of the Hensall tornado was the more continuous. It stayed down for 15 miles from just southwest of Hensall to about 2 miles northeast of Dublin. Slight damage was discernable for another two miles at either end. This is an unusually long track but there was no evidence of more than one tornado on this path. The track of the St. Jacobs tornado was less than 5 miles long and it appeared to skip. If this tornado had stayed down the hamlet of St. Jacobs would have been wiped out since the tornado path passed directly over its main intersection. Lines drawn through the end points of the two tornado tracks intersect northeast of Guelph. This is the area where a funnel was sighted but little damage was reported.

Good time checks are available for calculating the speed of the Hensall tornado and of the cyclone which generated these tornadoes. The clock at the Hensall service station was stopped at 3.57 p.m. The clock at the Waterloo Rod and Gun Club was stopped at 5.12 p.m. If tornadoes were spawned from the same part of the cloud then the cloud must have been moving at 36 m.p.h. The Ontario Hydro high voltage line 8 miles northeast of Hensall was cut 9 minutes after the service station was demolished. This gives the tornado a speed of 53 m.p.h. Another check on the speed of this tornado is to assume that it retains the same east-west position relative to the cyclone then the geometric calculation gives a speed of 52 m.p.h.

Radar Information

Radar pictures show the development of an echo line west of Lake Huron just after 1800 GMT about 160 miles west of Toronto International Airport. This line crosses the lake and moves onshore after 2000 GMT. Considerable echo development is evident but it is difficult to separate the change due to storm development from change due to the fact their motion brings them within shorter range. Attention is directed to the echoes that show up between 255°T and 270°T.

At 1959 GMT there are two echoes in the direction 255°T to 270°T. These echoes move eastward (from 260°T) and develop. Between 2023 GMT and 2035 GMT the two echoes merge but separate again by 2059 GMT with both having developed significantly. The picture for 2135 GMT shows that the line has broken up again. The picture taken at 2059 GMT is of particular interest since it is within two minutes of the destruction of the service station at Hensall.

Other features of the radar pictures conform with patterns associated with severe weather (Staff-Essa (4)). Pictures at 2035 GMT and 2059 GMT show the development of intersecting lines. The main group of echoes is aligned north to south. There is a group of weaker echoes forming a line in advance of the main echo grouping at 2035 GMT. The two lines move relative to each other in such a way that at 2059 GMT they are intersecting at the southern end. The Hensall tornado occurred near this intersection. It is also associated with the southern most echo in the pattern.

No hook echoes were identifiable in these pictures but this does not preclude their existence. The photoplot at the Toronto Weather Office photographs the radar sweep for 3 minutes on each picture. In order to get a hook echo, the feature producing it would have to be greater than 1.8 miles in diameter taking into account the known speed of the tornado. A second difficulty appears in the fact that at a range of 83 n.m. the radar beam passes above low level features. The photoplot became inoperative at 2135 GMT and the tornado at St. Jacobs occurred at 2215 GMT.

Tornado Damage

The author and Mr. L. Shenfeld of Ontario Hydro drove to Hensall to survey the damage the day after the tornado. The system of county roads enabled us to criss-cross the tornado track at frequent intervals (twenty two times). The path of destruction varied in width from 100 yards to a quarter of a mile. There was an impressive amount of damage. Every frame structure along the path was demolished. These consisted mainly of barns but one half of one of the houses was missing and the service station at Hensall (Picture 1) had been a frame structure. Most brick buildings sustained only minor damage. Many of the roofs were damaged but we did not see any that had been completely lifted. Many windows were shattered. An old abandoned brick school house was completely demolished (Picture 2).

One death was attributed to this tornado. This occurred north of the village of Dublin. Two men took refuge from the storm in a barn. One was killed and the other injured when the structure was destroyed.

The pattern in which the debris was laid down is of some interest. The wood, mostly roof materials, was laid down in a spiral to the left of the tornado path. Straw and hay that were under these roofs had a spiral path with much less curvature but stayed to the right of the track and did not appear to cross the path. Picture 7 and Fig. 6 shows this pattern.

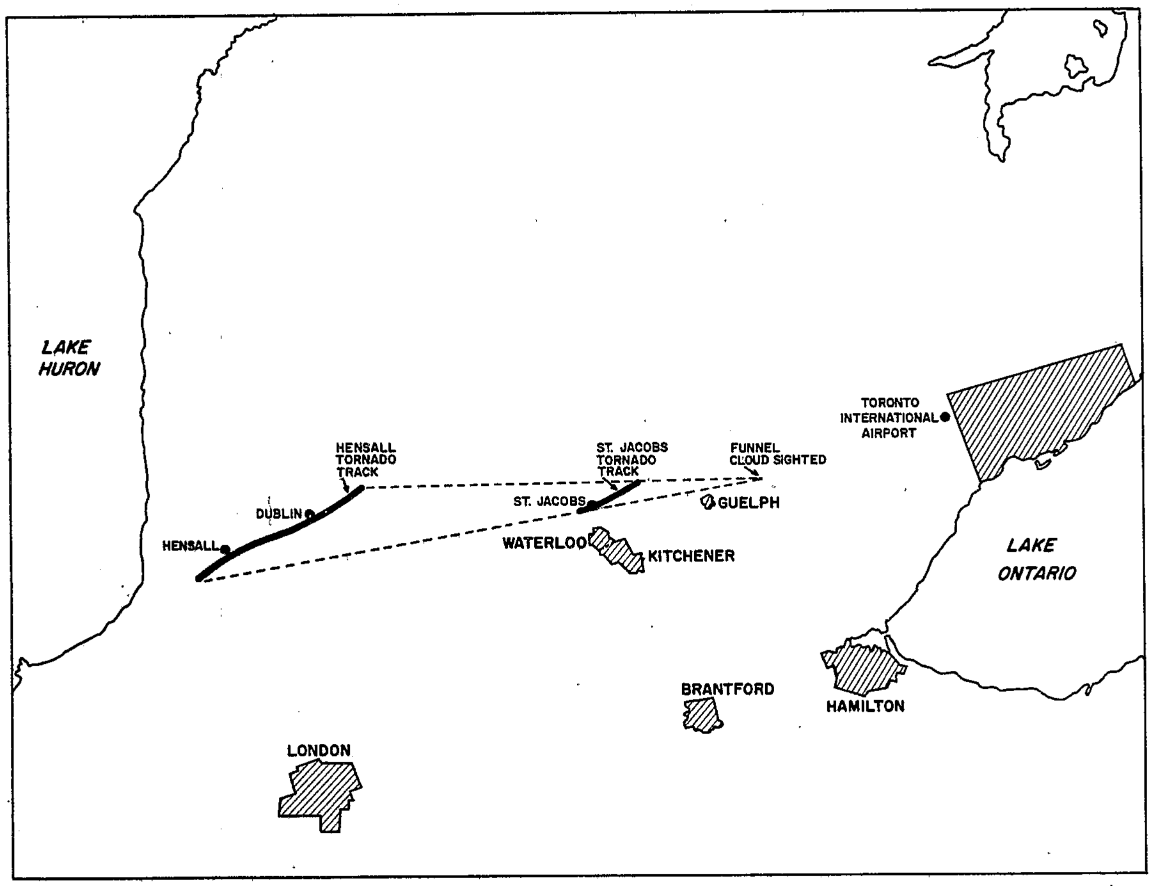

Figure 5.
Tornado Locations and Tracks

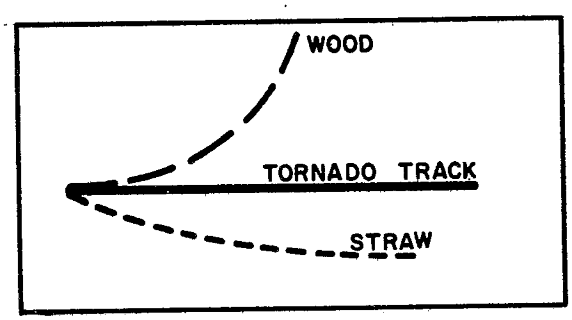

Figure 6.
Debris Pattern

Several pictures show the momentum attained by the flying debris. Picture 3 shows a piece of a 2 by 8 beam driven into the ground. It dug a furrow two feet long and the end of it was buried more than 8 inches into the ground. This type of damage appeared frequently but not continuously, i.e. broken-up wood was driven like stakes into nearby fields. On plowed fields this was frequently the only way the path of the tornado could be followed. Picture 4 shows a plank driven through the windshield of a truck. The truck was parked at the time. The nearest damaged building from which this plank could have come was 100 yards away.

Many of the farm yards had trees planted around them and most of these were destroyed. Spruce trees were snapped off about two to five feet above the ground, others were uprooted (see pictures 5,6 and 7). Some trees were snapped off further up along the trunk but these had some weakness at that point.

The vagaries and severity of the tornado damage are described well by some of the eyewitness reports. For example at the St. Jacobs tornado, a piano in the hunt club was reported to have the insides ripped out and scattered across the field, while the piano shell stayed with the building.

Another eyewitness reports "the tornado zig-zagged across the field southwest of the town (Hensall) appeared headed for a school but veered off at the last minute and hit the service station".

"It sounded like a low flying aircraft" another report, "it made a sort of whirring noise". "It was all over in a few seconds after it struck".

At the Waterloo Rod and Gun Club, "the roof flew 300 ft straight up". "It zig-zagged through the field, lifted for a moment then came down again."

Concluding Remarks

Tornado occurrences in Ontario are relatively infrequent and I could find no reference to tornadoes occurring in Ontario so early in the season. The synoptic, dynamic and thermodynamic conditions must have been unusual -- ideal for severe storm production. The conditions actually analyzed have been recognized as favorable for severe storms by various investigators (Millar (2) Ch. 3) in recent years but they coexist only infrequently in Ontario.

Acknowledgements:

I wish to thank Mr. C. I. Taggart of the Satellite Data Laboratory for his assistance with the radar photographs and Mr. M. Hirt for the use of his air photographs of the tornado damage.

APPROVED,

J.R.H. Noble,
Director,
Meteorological Branch.

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2. Crumrine, H. A. 1965. "The Use of The Horizontal Temperature Advection, The 850-500 mb Thickness and The 850-500 mb Shear Wind as an Aid in Severe Local Thunderstorm Forecasting". Paper presented at AMS Conference on Severe Local Storms at Reno, Nevada.

3. Millar, R. C. 1967. "Notes on Analyses and Severe Storms Forecasting Procedures of The Military Weather Warning Centre". Air Weather Service Technical Report 200 Ch. 3 and 8.

4. Staff, ESSA, Weather Bureau, National Severe Storms Centre, Kansas City (1967). "The Use of Radar Summary Chart in Sels Operations". Paper presented at AMS Conference on Weather Forecasting for Synoptic and Mesoscale Phenomena at Fort Worth, Texas.

Figure 7.
Radar Picture 171805GMT
120 NM Range

Figure 8.
Radar Picture 171829GMT
120NM Range

Figure 9.
Radar Picture 171929GMT
200NM Range

Figure 10.
Radar Picture 171959GMT
120NM Range

Figure 11.
Radar Picture 172011GMT
120NM Range

Figure 12.
Radar Picture 172023GMT
120NM Range

Figure 13.
Radar Picture 172035GMT
120NM Range

Figure 14.
Radar Picture 172059GMT
120NM Range

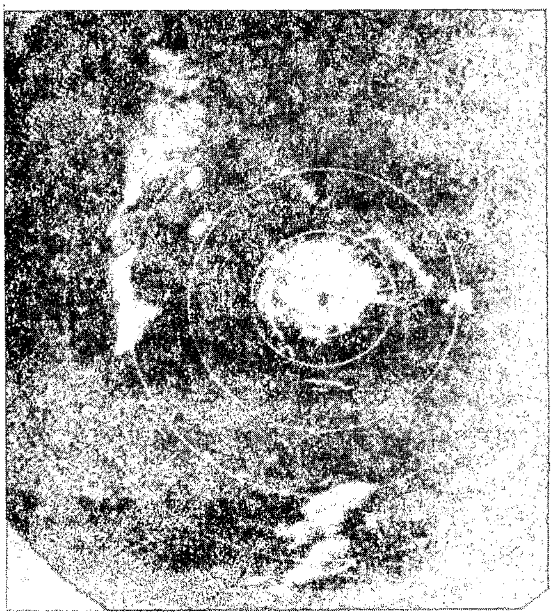


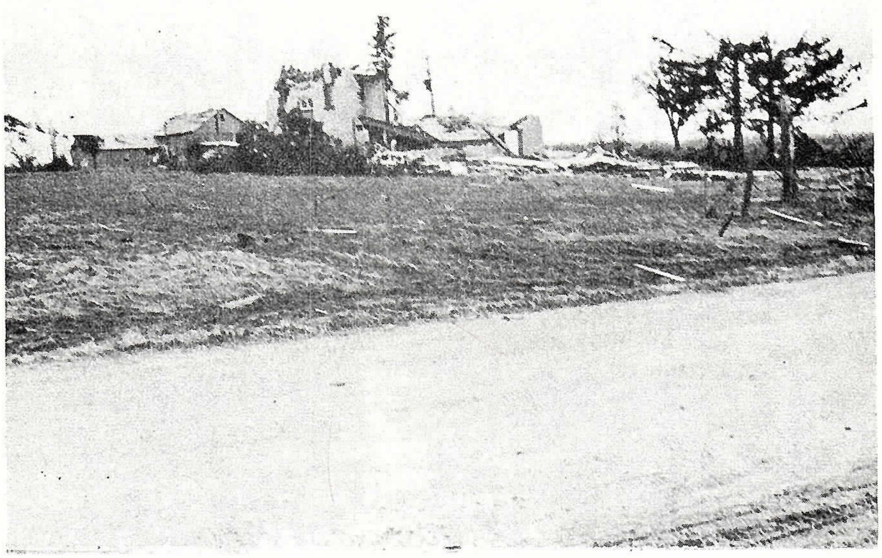
Figure 15.
Radar Picture 172105GMT
120NM Range

Figure 16.
Radar Picture 172123GMT
120NM Range

Figure 17.
Radar Picture 172135GMT
120NM Range

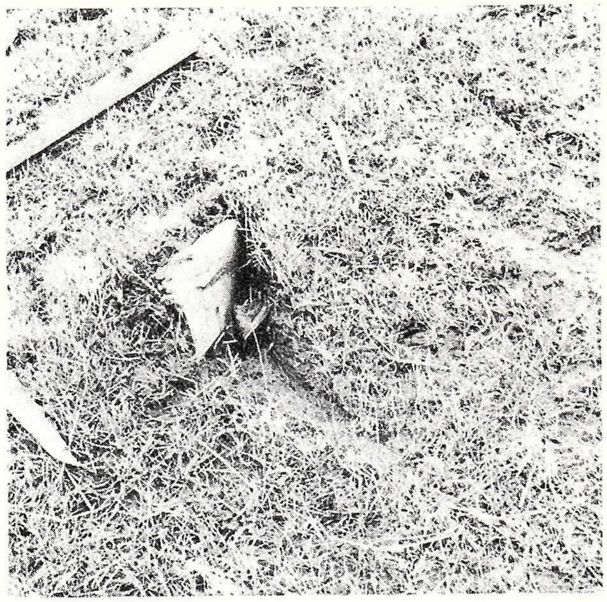
Figure 18.
Radar Picture 172305GMT
120NM Range

Picture 1.
Service Station at Hensall on No.4 HIGHWAY



HENSALL

Picture 2.
Old Schoolhouse

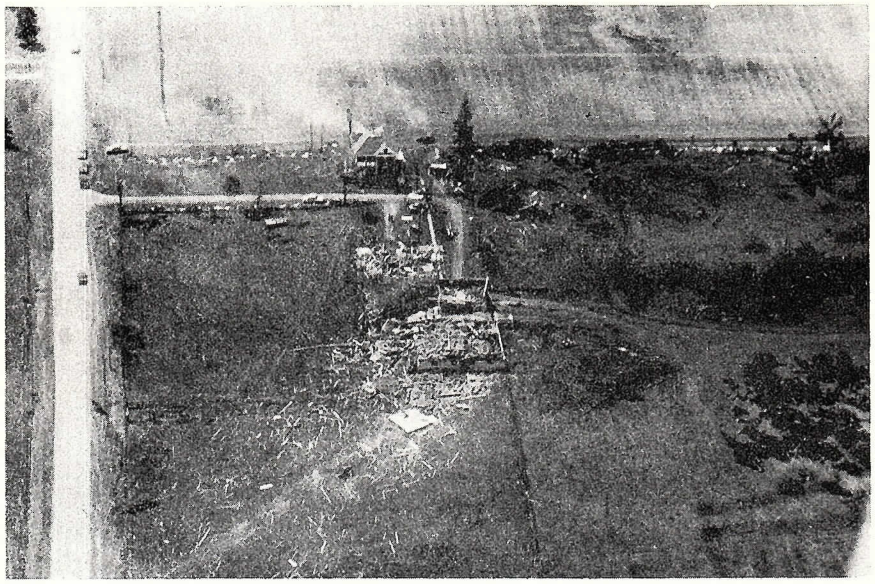


Picture 3.
Piece of 2 x 8 Planking

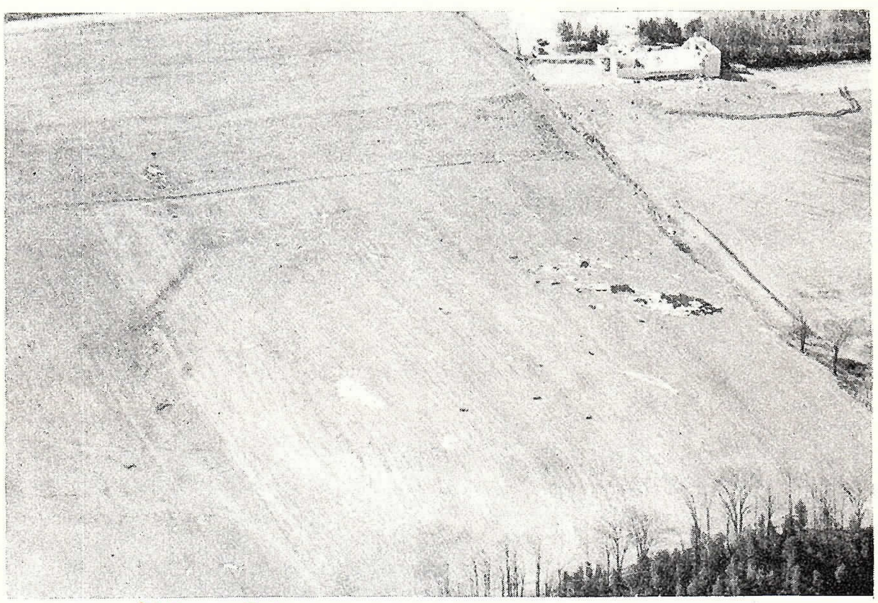
Picture 4.
Nearest Demolished Building 200 ft. Distant

Picture 5.
Row of Spruce Snapped Off Above Ground Level

Picture 6.
Deciduous Trees Uprooted



Picture 7.
Debris Pattern



ST. JACOBS

Picture 8.
Waterloo Gun and Rod Club in Upper Right
Its Roof in Field Centre Right

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