

# TRIP A-8

## A TOUR OF DAMAGE SITES AND A PROPOSED EPICENTER FOR THE CORNWALL-MASSENA EARTHQUAKE OF 1944

(This afternoon trip will follow Workshop W-2)

**Gary N. Nottis**

1605 W. Market St., Lewisburg, PA 17837

[gnottis@yahoo.com](mailto:gnottis@yahoo.com)

### INTRODUCTION

September 5, 1944. It was a warm late summer night in Massena, New York. World War II still raged. The local ALCOA plant was involved in the war effort with the manufacture of aluminum structural parts for the wings of American war planes. During the previous year, Nazi saboteurs had been caught near Long Island, New York with plans for the ALCOA plant. Many residents knew that. At 12:38 Eastern War Time (04:38 UTC), an ominous rumbling and hard shaking of the ground and buildings shocked the residents of Massena. The shaking lasted for what seemed like an eternity. Some had no idea what was happening. Others thought the Nazis had succeeded in landing a V-1 bomb on the ALCOA plant. Still others knew it was an earthquake. When the shaking was over, numerous homes, businesses, and other buildings along with their contents had been considerably damaged in the vicinity of Massena and Cornwall, Ontario. Many would never forget that night, and many, after more than 50 years, would call it the most upsetting night they had ever known, even those who fought in the war. During this fieldtrip we will visit some of the damage sites, recall what happened on that night in 1944, and consider a proposal for where the epicenter of the 1944 earthquake might have been.

### ASPECTS OF THE MAINSHOCK

The Cornwall-Massena earthquake has been the largest known earthquake in New York State history. It took place within the southern end of the Western Quebec Seismic Zone which was identified by Basham and others (1982). This area of continuing activity (see Fig. 1) has produced large damaging earthquakes, such as the magnitude ( $M_w$ ) 6.2 Timiskaming event of 1935. Depths determined for earthquakes in the seismic zone are known to reach between 20 and 25 km (Lamontagne and others, 1994), and in one case up to 31 km deep (Mohajer, 1992). A moment magnitude ( $M_w$ ) of  $5.8 \pm 0.3$  and a focal depth of  $20 \pm 2$  km has been determined for the Cornwall-Massena earthquake by Bent (1996) with the modeling of regional waveform recordings of the event. The location of the epicenter is less precisely known.

An epicenter of  $44.975^\circ\text{N}$  and  $74.898^\circ\text{W}$  was computed by Milne (1949) using arrival times from seismograms of the earthquake. His epicenter lies roughly 5 km north of Massena. Later, Dewey and Gordon (1984) recomputed the epicenter along with those of two early aftershocks using a two-step relocation method. Their new mainshock epicenter lies at  $44.958^\circ\text{N}$  and  $74.723^\circ\text{W}$ , which is approximately 15 km east-southeast of the Milne epicenter. They found that this calculated location has an associated error of about  $\pm 10$  km. Given the magnitude of the event, it is reasonable to assume that the Cornwall-Massena mainshock and early aftershocks would have taken place in approximately the same area. If Dewey and Gordon's locations of the mainshock and two aftershocks along with their location errors are considered, it can be seen that all three events overlap a small common area with a radius of 3-5 km centered at  $45.000^\circ\text{N}$  and  $74.692^\circ\text{W}$ . This will be referred to as the Dewey and Gordon composite epicenter. The composite epicenter is positioned about 17 km east-northeast of the Milne

epicenter and 4 km northeast of the Dewey and Gordon mainshock epicenter. The locations of all three epicenters discussed are presented in Figure 2.

The modeling of the mainshock's regional waveforms by Bent (1996) resulted in a determination of its focal mechanism. Bent found that the event likely occurred on a northwest-striking fault with a rupture time of about 3 seconds and nearly equal components of thrust and strike-slip motion. This type of faulting is not unusual in the Western Quebec Seismic Zone.

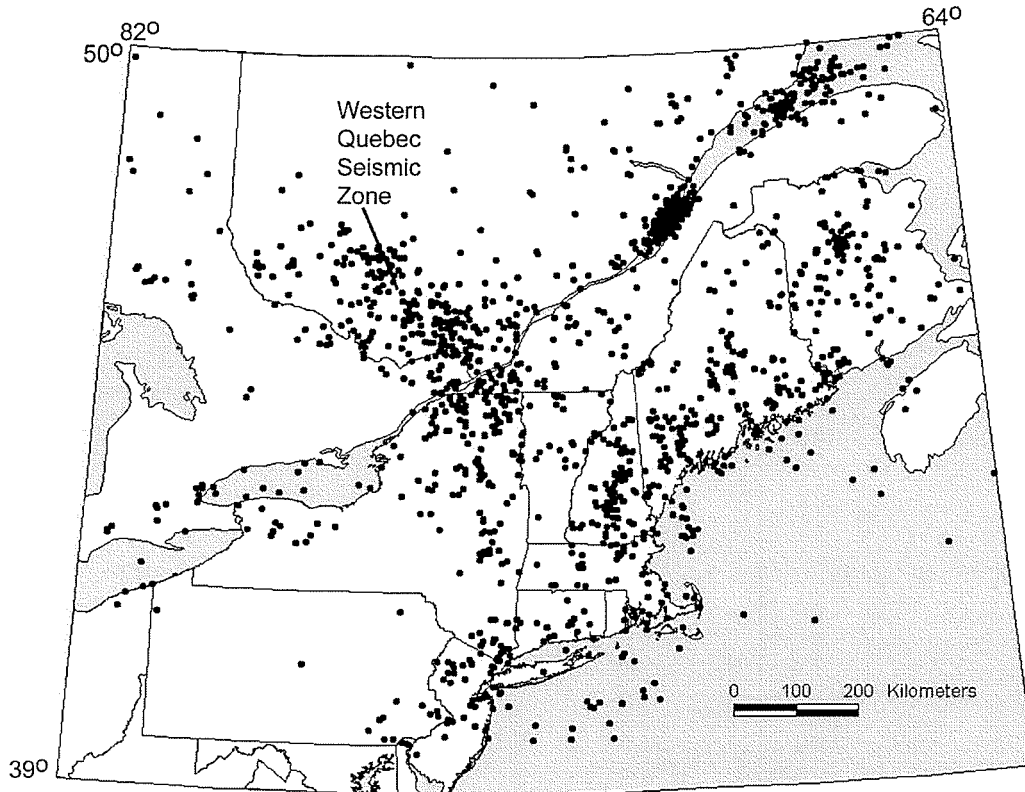


Figure 1. The location of the Western Quebec Seismic Zone as defined by instrumentally recorded earthquake activity in northeastern North America for the period of October 1, 1975 through December 31, 2002. The zone extends from northern-most New York State in a northwesterly direction along the western boundary of the Canadian province of Quebec.

### FELT AREA AND DAMAGE ESTIMATES

The Cornwall-Massena earthquake was felt over an area of about 1.1 million km<sup>2</sup> (Stover and Coffman, 1993). Its vibrations were felt from New Brunswick in eastern Canada to as far west as Lake Michigan, and from James Bay in Canada to as far south as Virginia in the United States (see Figure 3). Bollinger and others (1993) estimated that the total damage area, felt effects of intensities VI (MM) to VIII (MM), covered 25,740 km<sup>2</sup>. The area of considerable damage (intensity VIII [MM]), based on the observations of Berkey (1945), was confined to an elliptical area of 1,017 km<sup>2</sup> that included the communities of Massena, NY, Massena Center, NY, and Cornwall, ON. Estimates of the total property damage in the Massena and Cornwall area were reported by Hodgson (1945) as between \$1.75 and \$2.0 million 1944 dollars (\$18.9 to \$21.0 million in 2003 dollars).

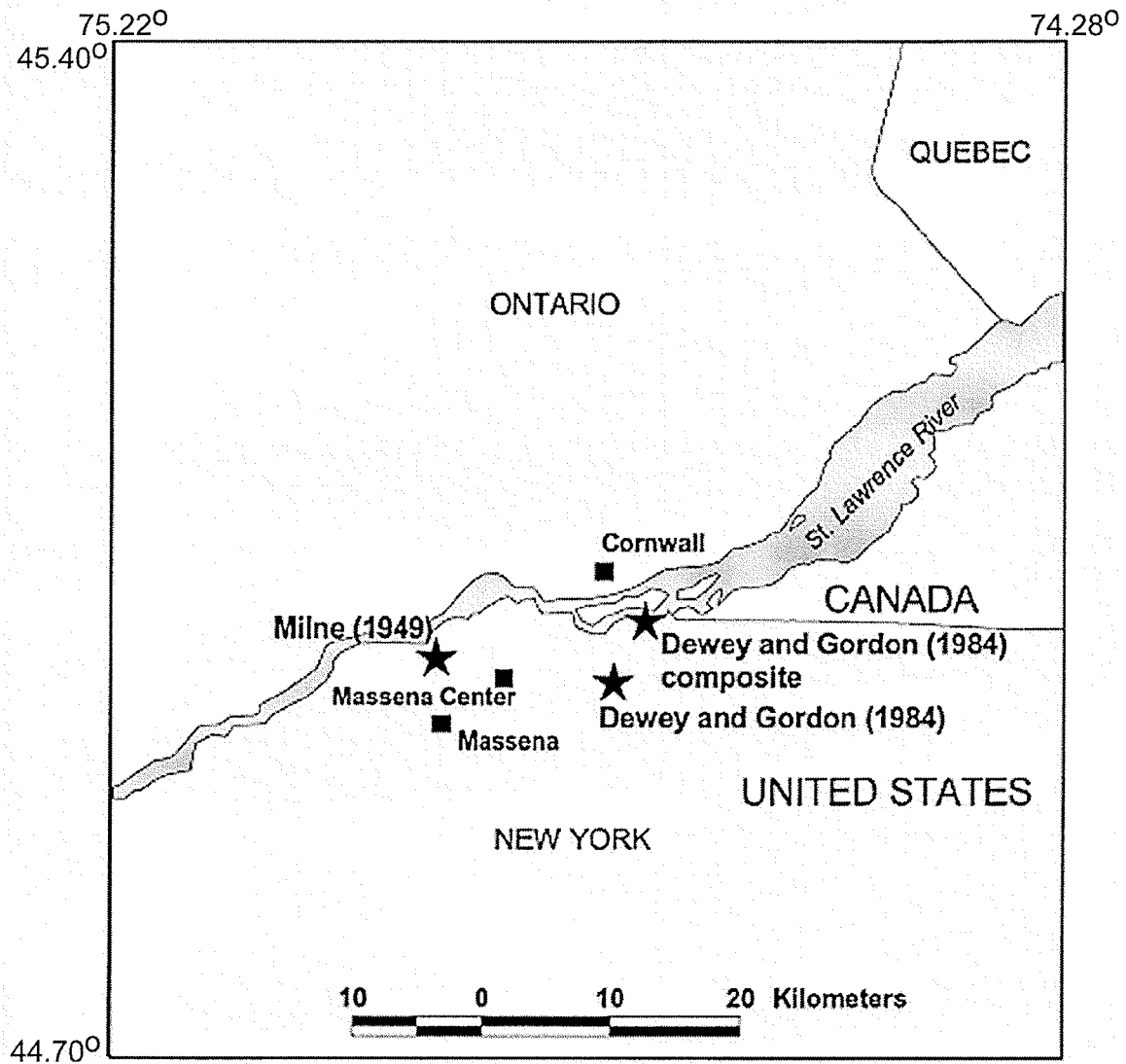


Figure 2. Positions of possible epicenters for the Cornwall-Massena earthquake as discussed in the text. Note also the locations of Massena and Massena Center in New York, and Cornwall in Ontario.

### SUMMARY OF FELT EFFECTS IN THE EPICENTRAL AREA

The following damage descriptions were obtained from examination of newspaper microfilms for the *Massena Observer* (Massena, NY) and the *Daily Standard-Freeholder* (Cornwall, ON) over the period of September 5<sup>th</sup> through October 31<sup>st</sup>, 1944. Of equal importance in the composition of the descriptions was the information contained in the works of Berkey (1945), Hodgson (1944, 1945), and Webb (1944).

#### Non-Industrial Buildings

**Residences.** Residential damage in Massena, NY, Massena Center, NY, and Cornwall, ON was primarily of a non-structural nature. Approximately 2,500 to 3,000 chimneys in Massena and Massena Center, and nearly 3,000 chimneys in Cornwall lost bricks, collapsed down to roof lines, or peeled away from homes. Of particular note was the occurrence of up-bumped chimneys at Massena Center and

Cornwall. Those chimneys really did not lose bricks, but had their bricks separated and left in a loose pile at the top of the chimney. That type of chimney damage may be caused by upward traveling seismic waves. Many chimneys exhibited up-bumping in Cornwall while nearly all chimneys in Massena Center did so, implying that Massena Center was nearer to the epicenter of the mainshock than was Cornwall.

Residential chimneys not obviously damaged on the outside usually were damaged within the walls of residences. Damaged chimneys and fireplaces posed a significant fire hazard. Figure 4 shows an example of a damaged fireplace. In spite of the onset of cold weather following the earthquake, home owners were asked not to use their fireplaces until chimneys could be repaired or inspected. The mayors of both Massena and Cornwall were pressed to find enough materials and skilled workers to complete repairs of chimneys before winter.

Some residences in Cornwall and two residences in Massena had damage to both structural and non-structural brickwork. In those cases brick walls bulged outward, some bricks peeled away and fell from interior walls, or cracks opened in exterior walls that extended into the interior of the buildings. At least one two-family residence in Cornwall had to be condemned and demolished. Most residences in Massena and Cornwall suffered from damage to interior ceiling and wall plaster. Some of the plaster was merely cracked while in other cases large amounts fell. In a few cases, wood frame homes in Massena were shifted several inches on their foundations. Some home foundations in Massena and Massena Center, composed of field stone or unreinforced masonry, were cracked or severely damaged.

A few Massena residents reported that hot water pipes were snapped off at the point where they went through downstairs flooring. Most residences in Massena, Massena Center, and Cornwall had disruptions of interior contents. Some of the contents that moved, fell, or were broken included pictures, mirrors, books, bookcases, light to heavy furniture, dishes, and preserved foods.

**Government Buildings.** Several government buildings were damaged in the earthquake. Among those were the Town Hall and Post Office in Massena, and the Counties Building and Village Hall in Cornwall. At the Massena Town Hall the 12" stone veneer bulged outward on the lower front third of the building. The stones separated away from a 12" brick inner wall. Repair of the stone work necessitated that each stone was numbered and removed before the veneer was reconstructed (refer to Fig. 5). The building interior suffered damage when a main support was moved at its base by the earthquake. The plaster walls of the auditorium on the building's second floor were badly cracked as was some of the ceiling plaster, which fell. The United States Post Office in Massena, erected in 1936, suffered interior plaster damage and some minor damage to the exterior brickwork. No disruption to postal services occurred as a result of the damage.

The Counties Building in Cornwall developed a serious bulge on the east side, and the main building separated from its window frames by as much as 14" in some spots. The building's chimneys were damaged. Interestingly, two prisoners were trapped in their cells for 10 minutes following the mainshock because the cell doors were jammed in their frames. At the Cornwall Village Hall bricks were dislodged from exterior walls, and large cracks appeared in the sides of vaults which had walls about 1' thick.

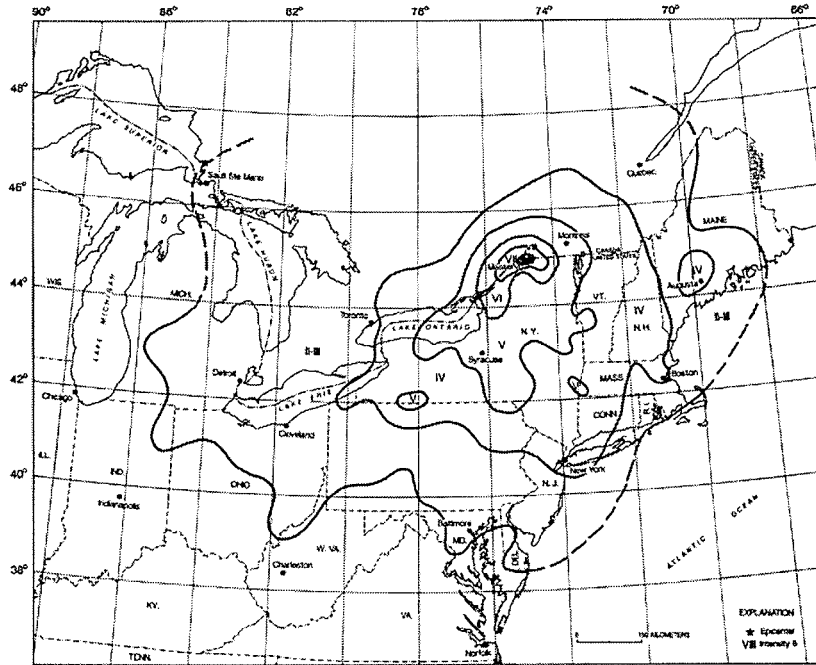


Figure 3. Map of the felt area and felt effects distribution for the September 5, 1944 mainshock as determined by Stover and Coffman (1993). Felt effects are described in terms of the Modified Mercalli Scale of 1931.



Figure 4. Damaged fireplace in the home of Mr. and Mrs. Charles G. Stubbs, 16 Danforth Place, Massena, New York (Tour Stop #2). The photo is from page 1 of the September 8, 1944 *Massena Observer*

**Businesses.** Businesses in both Massena and Cornwall generally had damage to plate glass windows, interior plaster, and large quantities of stock which were thrown down from shelves or displays. The most heavily damaged building used for business in Massena was the C-M (Cubley-MacDonald) building, next to the Town Hall. The building housed a dance studio, a barber shop, doctor's offices, dentist offices, insurance offices, and the Massena Observer newspaper offices. The south wall of the building buckled outward. It had to be completely rebuilt. The buckling of the wall caused large cracks to form in the plaster wall of the second floor dance studio. It is not known how the wall damage impacted the normal course of business in the affected offices.

In Cornwall the types of damages experienced by businesses was similar to that in Massena. Some business buildings did have damaged cornices and chimneys. The Orange Block in Cornwall, a three-story tall building which housed various businesses, suffered a 4" bulge in one wall. The wall was stabilized with ropes and cables and the building closed until repairs could be made. Unlike Massena, Cornwall businesses also had to endure the theft of goods from damaged window displays.

**Hospitals.** No damage was reported at the small wooden single story Massena Memorial Hospital. It did, however, have to operate for several hours with battery power for lights due to a power outage in Massena following the mainshock. The Hotel Dieu (Cornwall) and the Cornwall General Hospital did experience non-structural damage. At the Hotel Dieu there were broken lights at the entrance arch and fallen interior plaster. Similar damage occurred at the Cornwall General Hospital. Some minor damage to the brickwork at the top of the elevator shaft was also found at Cornwall General.

**Schools.** The schools in Massena, Massena Center, and Cornwall suffered significant damage. At Massena High School at least 150 window panes were broken. There was moderate to considerable plaster damage within the school. At nearby Washington School the chimney was damaged, blackboards popped-off of walls, and several truckloads of plaster fell. The fall of plaster in varying amounts appears to be the only damage reported for other Massena public schools and for the parochial school as well.

The unreinforced masonry school at Massena Center was so badly damaged that it was found to be unsafe for further use. School classes were thereafter held in the adjacent wood-frame Methodist Church. The school was eventually torn down.

In Cornwall the Collegiate and Vocational School and the Public School were extensively damaged. The Collegiate and Vocational School had structural and non-structural damage. Large portions of brick coping on the middle section of the school were shaken loose in the front and back. One section of brick coping broke loose and fell through the timber roof of the girl's gymnasium. That damage is shown in Figure 6. The school's main chimney was badly damaged, cracks developed in the brick walls, and considerable plaster fell inside the school.

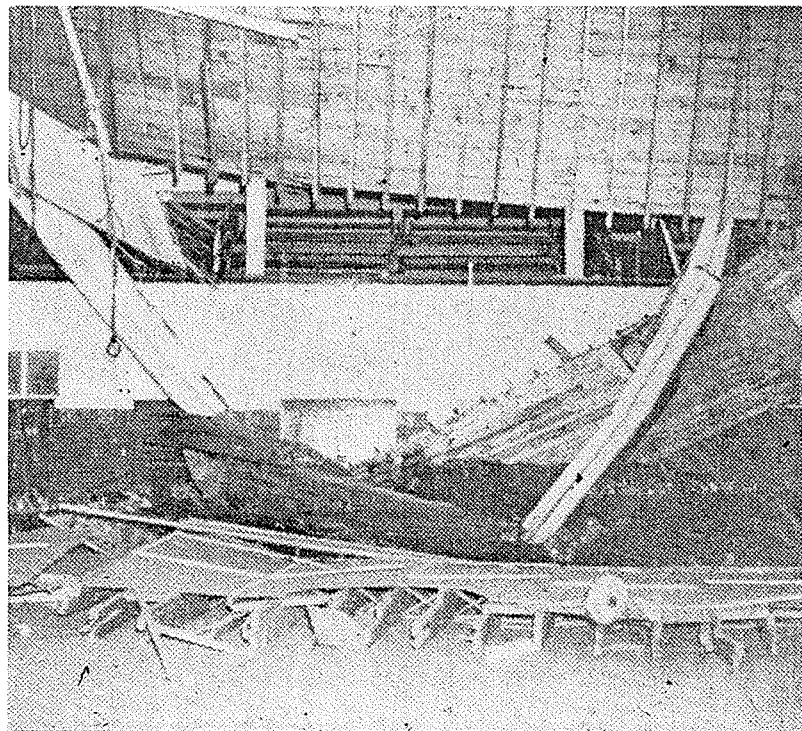
At Cornwall Public School portions of heavy brick coping fell outward from the building and inward through the roof into classrooms. The fallen coping exposed wall and roof connections. Cracks also developed in brick walls and there was considerable fall and damage of interior plaster.

The occurrence of the earthquake and the resulting damage caused the Massena public schools to be closed for one day for clean-up, inspections, and repairs. The parochial school did not close. The start of classes in Cornwall at the two damaged schools was delayed. In particular the Cornwall Public School did not open for classes until October 4, 1944. The school opened with limited classes. By October 17<sup>th</sup> most classes were in session using a staggered class schedule.

Figure 5. Repair work being done to the front stone work of the Massena Town Hall. The stone work bulged outward on the front bottom third as a result of the earthquake. The picture is from page 14 of the September 18, 1944 *Watertown (NY) Daily Times* (Tour Stop #10).



Figure 6. Destroyed timber roof of the girl's gymnasium at the Cornwall Collegiate and Vocational School in Cornwall, Ontario. A portion of exterior brick coping broke loose from the back of the school and fell through the roof. Photo is from Lamontagne and Bruneau (1993).



**Churches.** Most churches in the epicentral area had plaster and chimney damage as a result of the September 5<sup>th</sup> earthquake. The First Baptist Church in Massena had some minor cracking of the brick walls at various points (refer to Figs. 7 and 8). The majority of damage was confined to cracked interior plaster, especially bad in the sanctuary. St. John's Episcopal Church experienced glass and plaster damage along with damage to the marble altar. Brick supports within the altar collapsed and allowed the marble to shift. One church at Massena Center suffered structural damage and was eventually torn down.

In Cornwall the damage to churches was generally worse than in Massena. Trinity Anglican Church had ornamental stones at the peak ends of the roof and small minarets thrown down. A square Norman tower on the church was badly cracked above the roof line. Stones around the east stained glass windows were thrown out. Outer plain glass windows on the north side were broken. In addition there was interior plaster damage. St. Columban's Roman Catholic Church suffered from cracked walls, which in some cases showed signs of buckling. Three corner towers of the main altar were broken, the Tabernacle was damaged, and the main porch of the church was damaged. An organ loft was also damaged and its projection over the auditorium had to be braced. Further damage included a twisted east tower of the church and a great deal of fallen plaster. St. Columban's was closed for repairs and inspection, and was later reopened.

Other Cornwall churches that were impacted by the earthquake included the Knox United Church and St. John's Presbyterian Church. Besides significant interior plaster damage at Knox United Church, the inner walls of the steeple were weakened and had to be strengthened. Portions of the chimney fell, plaster fell, and the pipes of the church organ were damaged at St. John's. Knox United Church was closed for repairs until October 1, 1944.

**Lifelines** Electricity, domestic water, and telephones were impacted by the September 5<sup>th</sup> mainshock. Immediately following the earthquake power was lost in Massena for 1 to 2 hours, and for an unspecified short time in Cornwall. Homeowners reported numerous breaks in water line connections between residences and water mains in Massena. One 6" water main was reported to have broken in the northern portion of the village of Massena. Some 10", 12", and 18" underground water lines at the ALCOA plant in Massena were broken by the earthquake. Those lines also provided water for the public water system in Massena. While those lines were being repaired at the plant, the village experienced low water pressure for about two days.

Telephone service was disrupted in both Massena and Cornwall. With power out in Massena, the phones continued to operate through the use of either an emergency generator or batteries. No damage to phone equipment or lines was reported. However, in Cornwall about 50 phone lines were broken. That resulted in some phone service disruption for about 36 hours in some parts of Cornwall. The primary disruptions to phone service in northern New York and southeastern Ontario came from increased phone use by panic stricken residents wanting information about the mainshock. That increased usage overtaxed operators and phone circuits that created delays in obtaining dial tones and placing calls (up to 3 hours in Cornwall).

**Industry** Damage was reported at the ALCOA plant in Massena and at the following plants in Cornwall: (1) Canada Bread Company, (2) Canadian Cottons Ltd., (3) Canadian Industries Ltd., (4) Cornwall Chemicals Ltd., (5) Courtaulds (Rayon) Ltd., (6) Howard Smith Paper Company, (7) Ives Bedding Company Ltd., and (8) Powdrell and Alexander. It should be noted that Massena only had the one manufacturing plant.

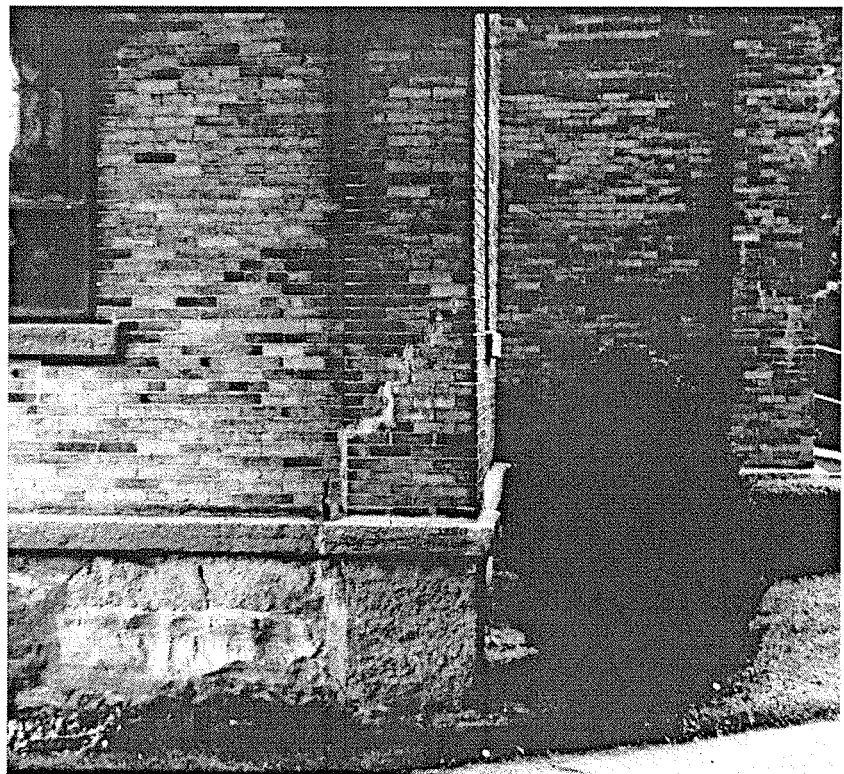


Cracked tall chimneys, some of which required temporary reinforcement and repair, were noted at several of the plants. Those chimneys in a few cases were up to 220' tall and cracked from the top

Figure 7. Cracked brick work above the main door to the First Baptist Church in Massena, corner of Main Street and East Orvis Street in Massena (Tour Stop #9). The cracks above the entrance are about 1" to 2" wide. This photo was taken in 1993.



Figure 8. Cracked brick work on the lower north side wall of the First Baptist Church near the front of the building. The crack is generally 2" wide. Photo was taken in 1993.



down by as much as 35'. Some plants were found to have cracked brick walls and damaged plastering. At Canadian Cottons, bricks fell from exterior walls of the Stormont Mill, while at the Dundas Mill a wall moved outwards by as much as 1". At the Ives Bedding Company the plank roof of the main building was found to have shifted out of position. A large bread oven was cracked at the Canada Bread Company.

A testament to the force of the ground shaking from the earthquake lies in the fact that some large industrial equipment was moved from positions. At the ALCOA plant in Massena, seven out of eight 1" steel pins used to align the shaft of a 70 ton fly wheel sheared off, bent, or popped out of place. Three 200 KVA transformers on concrete mats shifted at Powdrell and Alexander. In the main building of that plant, 71 box looms had broken cast iron supports. A heavy safe in an office was also reported to have moved 6" there as well.

**Transportation** There were no reports of disruptions to automobile traffic, except perhaps in some spots where bricks or broken glass might have fallen in the streets. Street lights did go out in both Cornwall and Massena due to power outages. There was a report of humped-up pavements on Maple Street and North Main Street in the north section of Massena near the bank of the Grasse River. It is not known if this hindered traffic. Railroads and the street car system in Cornwall were also not impacted. Overall the transportation infrastructure was found to be unaffected.

**Social Impacts** Several minor injuries were reported in the newspapers as having occurred as a result of the earthquake. However, none of those injuries were treated at the Cornwall or Massena hospitals. One man did suffer severe electrical burns and was treated at the Massena hospital. The man was an employee at the ALCOA plant. When power was restored to Massena and the plant after the earthquake, a "pot" used to melt aluminum was damaged by a power surge. This resulted in the burns. The victim later recovered.

One of the greater social impacts of the earthquake was the occurrence of post traumatic stress. Shortly following the earthquake, residents of both Cornwall and Massena could not sleep and suffered from varying degrees of anxiety. Jittery, tired, and nerve-shattered were some adjectives used to describe people in Cornwall and Massena. For a number of people, these same symptoms continued for at least two months or more. Of note was a series of interviews conducted by the author in Massena in 1994. Several of the people interviewed 50 years after the earthquake still expressed some anxiety about the earthquake. One resident who fought during World War II noted that the earthquake had far more impact on him than did the battles he was in.

**Cemetaries** A number of cemeteries in the Cornwall and Massena area had damage to monuments or gravestones. Of 30 cemeteries visited by investigators following the earthquake, 13 had monuments that had markedly rotated, shifted, or fallen over. Figure 9 gives an idea of the distribution of the cemetery monument damage. Those monuments that were composed of more than one part sometimes had individual parts rotated in opposite directions. An interesting feature of the cemetery damage is that the majority of monuments on the Canadian side of the St. Lawrence River had counter-clockwise rotations, while those on the American side had clockwise rotations. It should be noted that the numbers of monuments damaged and the degree of damage generally increased as one approached the area containing Massena Center, NY and Cornwall.

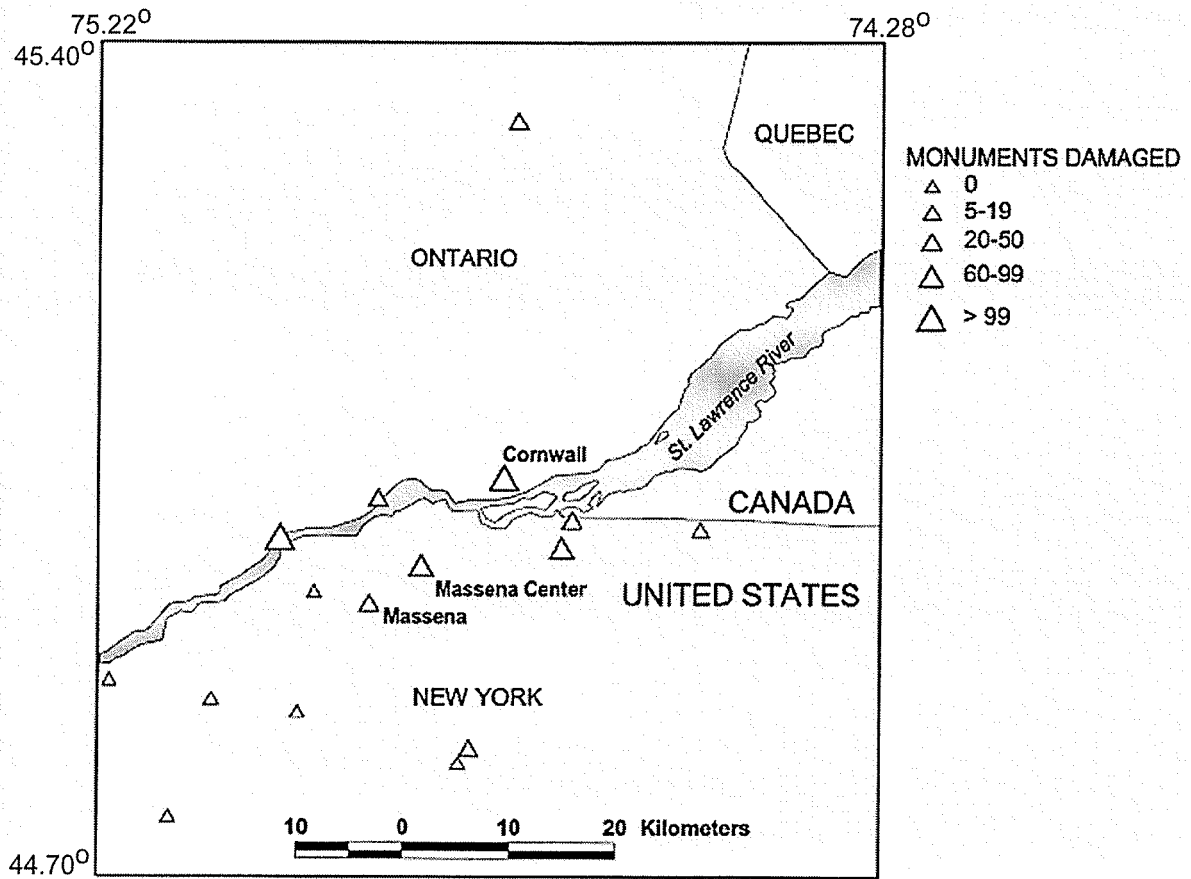


Figure 9. Distribution of some cemeteries investigated for damage following the 1944 Cornwall-Massena mainshock along with total numbers of damaged monuments at each locality. The numbers of monuments damaged and the degree of damage generally increased as one approached the area containing Massena Center, NY and Cornwall.

## GEOTECHNICAL AND HYDROLOGICAL OBSERVATIONS

### Influence of Local Surficial Deposits on Damage Distribution

Both Berkey (1945) and Hodgson (1944, 1945) noted that the locations of the most severe damage were controlled by surficial materials. Buildings constructed on outwash sands and gravels, and especially on silts and marine clays were greatly damaged. Those structures on boulder till were not significantly damaged. In Cornwall the greatest damage occurred on a belt of marine clays and associated silts that are situated in the central portion of the community. Massena's damage was found primarily in areas of glacial outwash. At Massena Center, marine clays with some outwash sands and gravels lay beneath the foundations of damaged structures.

### Liquefaction

Earlier in this article it was noted that fairly large water mains in Massena and at the ALCOA plant were broken in the earthquake. Pavements were also humped-up in one part of Massena along the northern bank of the Grasse River. These locations seem to lie in deposits of marine clays with pockets

of sand and gravel outwash. The pavement and underground pipe damages were probably caused by permanent ground displacements as a result of liquefaction induced lateral spreading.

A definite occurrence of liquefaction took place at the W.G. Hooper Farm, about 2 km northwest of Massena Center. In the yard behind the farmhouse two north-south trending fissures of about 1" to 2" in width and up to 100' in length opened and white sand and water flowed out (Berkey, 1945). A third fissure from which sand and water flowed was found about 300' to the west across the local road. A back-hoe investigation of the farm site in the early 1990s by Tish Tuttle and Noel Barstow of the Lamont-Doherty Earth Observatory of Columbia University found sand dikes and diapers formed by the liquefaction of a 4' thick layer of white sand lying 8' beneath marine clays and silts. A photo of a sand dike at the Hooper Farm site is presented in Figure 10.

### **Impacts on Water Wells and Springs**

Water wells in the vicinity of Massena, along the north shore of the St. Lawrence River, and particularly around Massena Center either dried-up or increased their flow following the earthquake. The same could be said of some springs near Massena Center (Berkey, 1945; Hodgson, 1945). Berkey (1945) found that most of the productive farm wells around Massena Center were shallow and dug into outwash sands and gravels. It was his opinion that compaction of the overburden by the earthquake might have caused the water flow changes.

## **AFTERSHOCKS**

It is not unusual for large earthquakes in eastern North America to be followed by a series of aftershocks. The Cornwall-Massena earthquake was no exception. Smith (1966), in his earthquake catalog, lists 26 instrumentally recorded and 2 reportedly felt aftershocks from September 5, 1944 through November 10, 1949. The aftershocks had reported Richter magnitudes ( $M_L$ ) of 2.0 to 4.6. A detailed catalog of felt aftershocks made by H.R. Horton, a Massena Center resident, lists 49 aftershocks for the period of September 5, 1944 through January 2, 1946 (Berkey, 1945). Additional reports of felt aftershocks were made in the pages of the *Massena Observer* and the *Daily Standard-Freeholder* (Cornwall, ON) from September 5<sup>th</sup> through October 31<sup>st</sup>, 1944. If aftershock reports are combined from all sources for September 5 through October 31 of 1944, then at least 43 aftershocks are known for that period.

The largest aftershock occurred on the morning of September 5<sup>th</sup> at 4:51 a.m. (08:51 UTC) and had an estimated body wave magnitude ( $m_{bLg}$ ) of 4.5. It was generally felt in northern New York and southern Ontario. The second largest aftershock took place at 7:24 p.m. (23:24 UTC) on September 9<sup>th</sup> (Dewey and Gordon, 1984). That magnitude ( $m_{bLg}$ ) 4.0 event caused further masonry damage in Massena and Cornwall.

Aftershock reports for September 5<sup>th</sup> through October 31<sup>st</sup> suggest that more aftershocks were felt in Massena Center than in either Massena or Cornwall. It appears that the newspapers in Massena and Cornwall made good efforts to report all felt aftershocks. Assuming their record keeping was as good as that of H.R. Horton at Massena Center, then a look at the distribution of felt aftershock reports between the three communities may provide a clue as to where the September 5<sup>th</sup> mainshock might have been. A consideration of the aftershock reports shows that 8 events were felt in Massena, 19 events in Cornwall, and 37 events in Massena Center. This distribution of felt reports is suggestive that the mainshock and the following aftershocks might have had a source between Massena Center and Cornwall, but closer to Massena Center.



Figure 10. Sand dike found in trench at the site of the former William G. Hooper farm, Massena Center, New York (Tour Stop #15). Shovel is for scale. Note disrupted soil structure defining the sand dike. Photo is courtesy of Tish Tuttle.

## WHERE WAS THE EPICENTER?

Earlier in this article three possible epicenters from Milne (1949) and Dewey and Gordon (1984) were presented. The likely epicenter of the Cornwall-Massena earthquake should probably lie in the area most heavily impacted by the event and its aftershocks.

It is known that chimney damage took place in northern New York and southern Ontario, with considerable damage in Massena, Massena Center, and Cornwall (Hodgson, 1944; Berkey, 1945). Figure 11 depicts the distribution and degree of chimney damage in the region. The heaviest damage was at Massena Center. Recall that up-bumped chimneys, suggesting damage by upward traveling seismic waves, were found at Massena Center and Cornwall, with a higher number at Massena Center. Also recall from the description of cemetery damage that the largest number of impacted monuments and the highest degrees of damage were found in the Massena Center to Cornwall area.

Additional evidence suggestive of where the epicenter was comes from the location of impacted water wells in the vicinity of Massena Center, the fact that obvious evidence of liquefaction was found near Massena Center, and that most aftershocks were felt at Massena Center and Cornwall, with more felt at Massena Center than anywhere else.

If all of the evidence is considered, then it seems that the earlier named Dewey and Gordon composite epicenter (refer to Fig. 2) is the closest of the three discussed epicenters. To better fit the felt effects information described above, a new epicenter location of 44.99°N and 74.79°W is proposed. The position of that proposed epicenter is shown in Figure 12 along with the distributions and degrees of chimney and cemetery monument damages in the Cornwall and Massena area for emphasis.

## CONCLUSION

The Cornwall-Massena earthquake of 1944 was the largest seismic event so far known in New York State. Based on damage distributions, liquefactions, water well disturbances, and a series of reported felt aftershocks, a new epicenter approximately 5 km northeast of Massena Center, New York is proposed. This magnitude ( $M_w$ ) 5.8 event represents a good scenario earthquake for emergency planning. While typical large earthquakes in eastern North America originate at depths of 10 km, the Cornwall-Massena event, in spite of its greater depth ( $\approx 20$  km), could be used as a model for much for New York State. Earthquakes of this size generally cause considerable damage in a somewhat limited area and can be felt widely. The impact of this earthquake would have been much greater if it had occurred near a larger population center. If it did so today, then damage estimates in a metropolitan area could easily run in the billions of dollars.

Figure 11. Distribution and relative numbers of chimneys damaged by the September 5, 1944 mainshock.

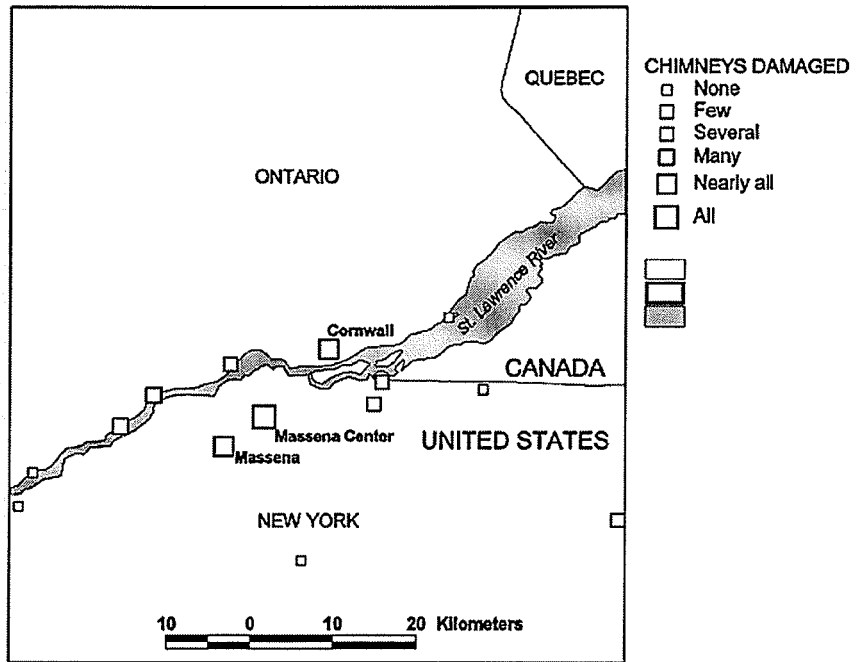
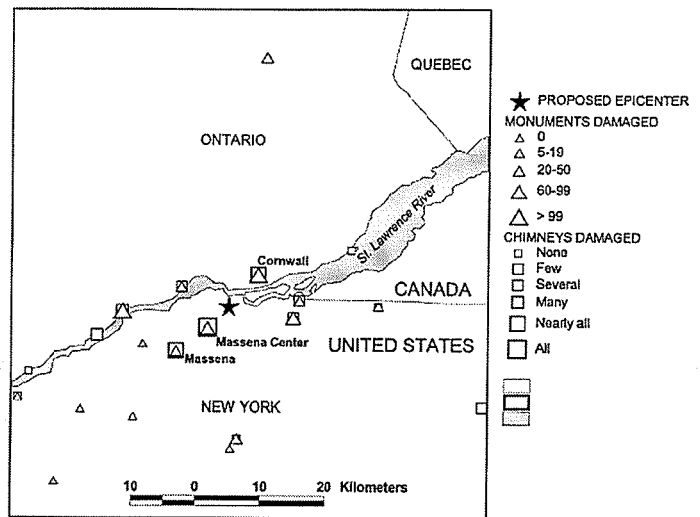


Figure 12. Proposed epicenter location of the Cornwall-Massena mainshock. The damage locations and degrees of damage for chimneys and cemetery monuments are shown as support for the proposed epicenter.



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## WALKING TOUR AND ROAD LOG FOR DAMAGE SITES IN MASSENA AND MASSENA CENTER, NEW YORK

This tour is actually a combined walking tour of sites in downtown Massena and a driving tour from Massena to the Eisenhower Lock of the St. Lawrence Seaway north of Massena Center. Travel to downtown Massena and park behind the Massena Town Hall on Main Street. Proceed south from there on foot to the northwest corner of Main Street and West Orvis Street. The walking tour, which is about 1.4 miles in length, will start there. A map of the walking tour, Sites 1-12, is presented on Figure 13.

### Walking Tour

Site Number	Location	Purpose of Stop
1	Former Site of New York Telephone Company Office, 3 West Orvis Street	Discussion of communication disruption in the earthquake.
2	Former home of Mr. and Mrs. Charles Stubbs, 16 Danforth Place	Discussion of residential damages.
3	Old Cemetery on West Orvis Street.	Search for rotated cemetery monuments.
4	Former home of Mr. Herbert Hatch, 2 Ransom Avenue.	House has chimney repaired from the 1944 mainshock.
5	Former home of Mr. and Mrs. Leonard Prince, 61 Bridges Avenue.	Discussions of residential building contents damage and psychological trauma.
6	Former site of Massena High School, Bridges Avenue	Discussion of damage to the school, and other schools in Massena and Cornwall.
7	St. John's Episcopal Church, 141-143 Main Street	The chimney at this church appears to have repaired cracks from the earthquake. Marble altar was also damaged.
8	United States Post Office, 98 Main Street	Discussion of earthquake damage to the building and about unreinforced masonry buildings in general.
9	First Baptist Church, Corner of Main Street and East Orvis Street	Church exhibits repaired cracks in exterior brick work from the earthquake. Discussion of church damage in Cornwall and Massena.
10	Massena Town Hall, Main Street	Discussion of damage to this building.
11	C-M Building, 60 Main Street	Examination of north wall which was torn-out and replaced because of earthquake damage.
12	Former Site of the Sunshine Store, 10 Main Street	Discussion of damage to the former business here and the earthquake's impact on small business in the Massena and Cornwall area.

Please return to your vehicle at the Massena Town Hall and begin the driving portion of the tour.

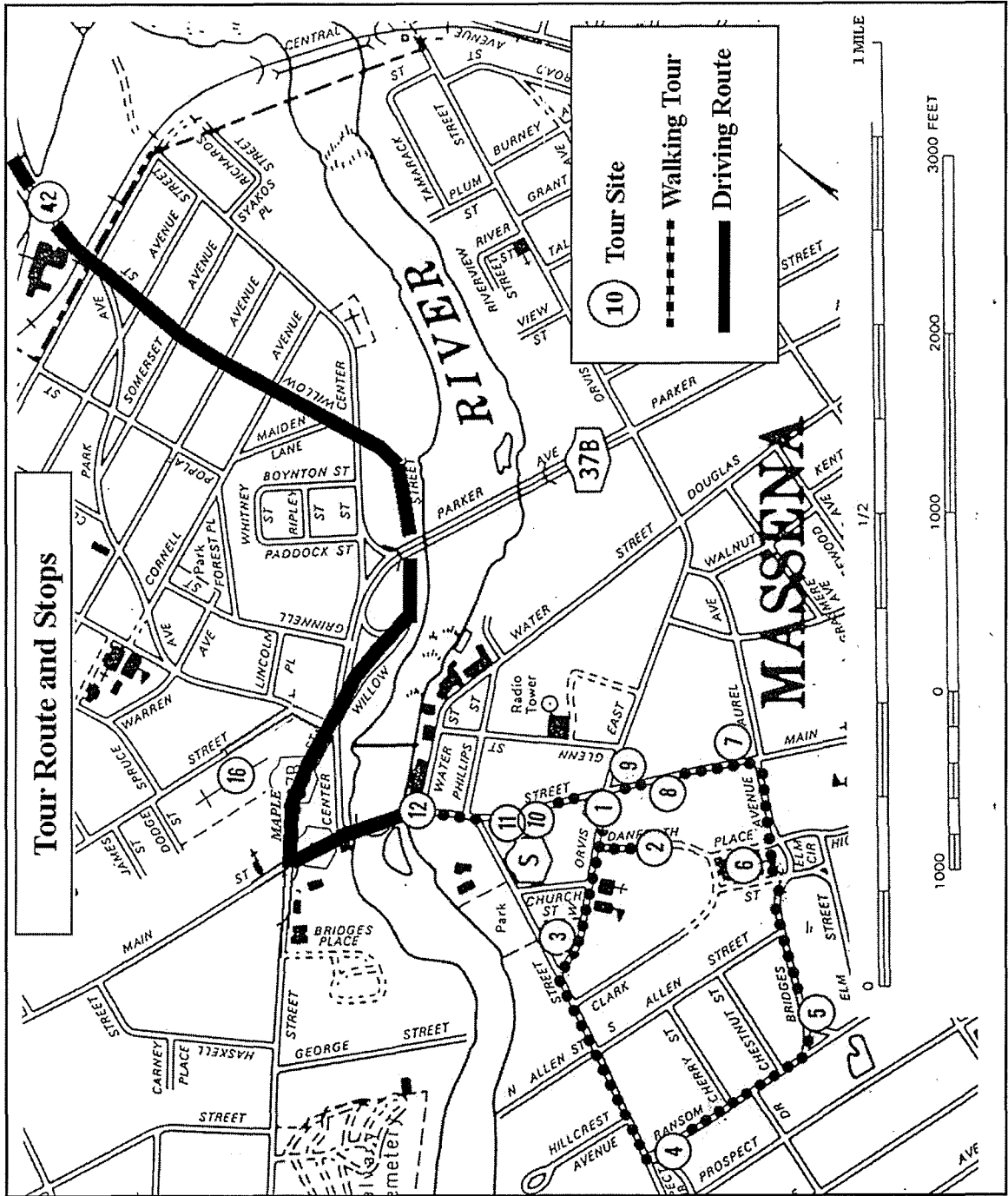


Figure 13. Map of downtown Massena, New York and the Walking Tour Sites.

## Road Log

The route for this portion of the tour is shown on Figures 13, 14 and 15.

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Approx. Cumulative Mileage	Approx. Miles From Last Point	Route Description
0.0	0.0	From the Massena Town Hall turn left and proceed north on Main Street over the Grasse River Bridge
0.2	0.2	Turn right (east onto Maple Street).
0.3	0.1	Continue east onto Willow Street (Route 42)
1.3	1.0	STOP 13 on right shoulder east of ALCOA Road.

### STOP 13. OVERVIEW OF THE ALCOA PLANT.

This plant suffered minor cracking to brick walls and interior plaster damage. Five large chimneys ranging in height from 80' to 220' were cracked by the earthquake. The chimneys were cracked at points ranging from 8' to 30' down from the tops. It was on the plant grounds that 3 large water lines were broken by the earthquake due to apparent lateral spreading of the ground. One ALCOA employee was severely burned at the plant when a power surge damaged equipment after power was restored following an earthquake caused power outage. Return to the vehicle and continue on Route 42 to Massena Center.

3.4	2.1	Continue east on Route 42, past intersection with Route 131.
3.6	0.2	STOP 14 – Massena Center Cemetery

### STOP 14. MASSENA CENTER CEMETERY

Many of the monuments in this cemetery were rotated, shifted, or knocked-down by the earthquake. At this stop please take some time to find some of the damaged grave stones. Just across the stream to the east of the cemetery is Massena Center. All of the chimneys in this area were up-bumped. The old Massena School, once located across the stream and north of the road was severely damaged in the earthquake and had to be demolished. Return to the vehicle. Turn left and return to the intersection of Route 42 and Route 131.

3.8	0.2	Turn right (north onto Route 131).
5.8	2.0	STOP 15 on access road next to Robinson Creek.

### STOP 15. FORMER SITE OF THE WILLIAM HOOPER FARM

This is the site of the liquefactions or “sand boils” that occurred during the 1944 earthquake. The farm well also went dry here. A discussion of work done on the site, liquefaction, and the earthquake’s impact on local water wells will be conducted here. Please return to the vehicle and turn right (north) on Route 131. Follow the signs to the Eisenhower Lock.

6.3	0.5	STOP 16 – Parking lot of the Eisenhower Lock
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### STOP 16. EISENHOWER LOCK

This stop is near the location of the H.R. Horton Farm where the majority of the Cornwall-Massena earthquake aftershocks were felt. The aftershocks will be discussed here as well as the evidence for the proposed epicenter.

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**END OF FIELD TRIP**

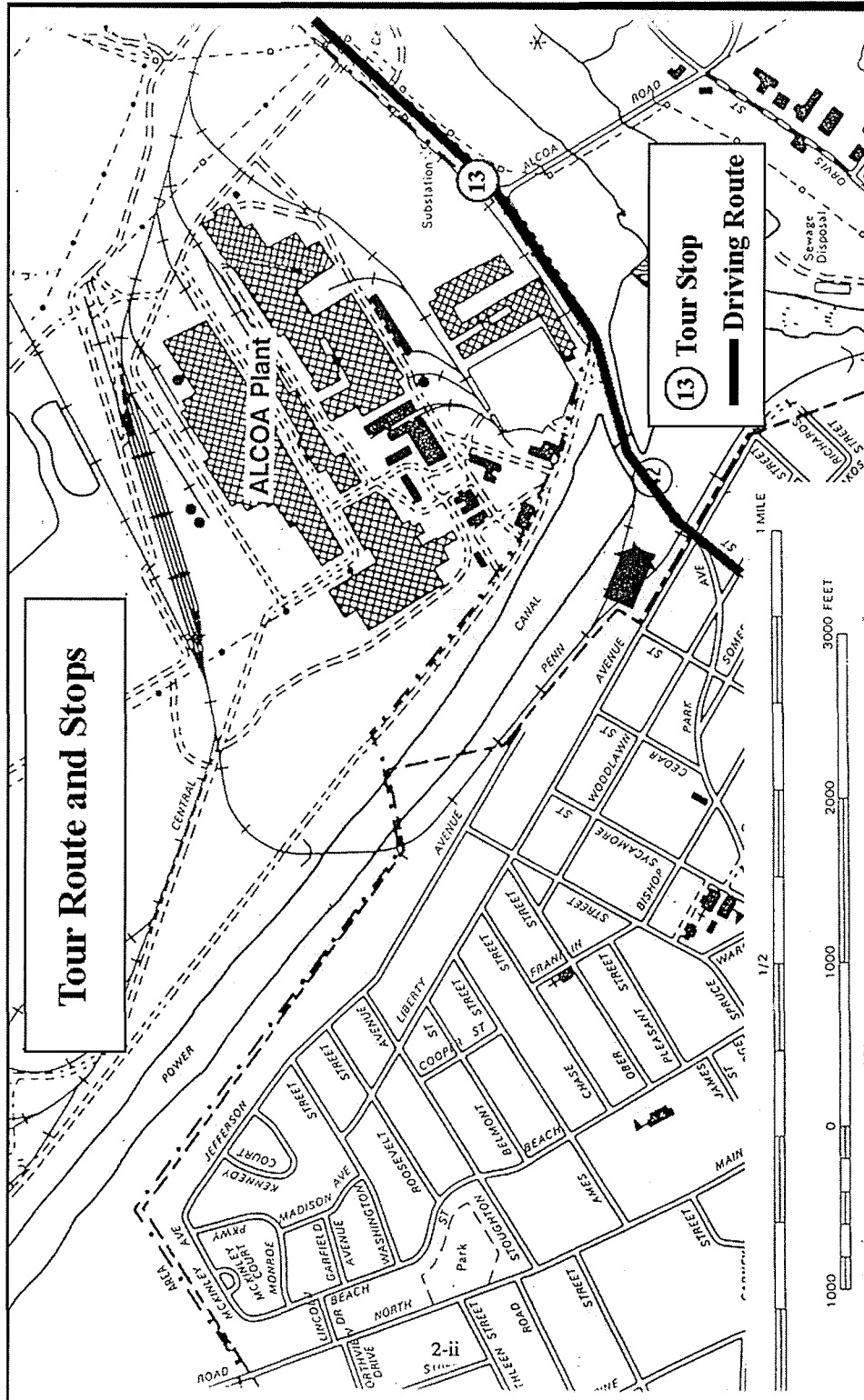


Figure 14. Driving Tour Route and Stops traveling from Massena towards Massena Center.

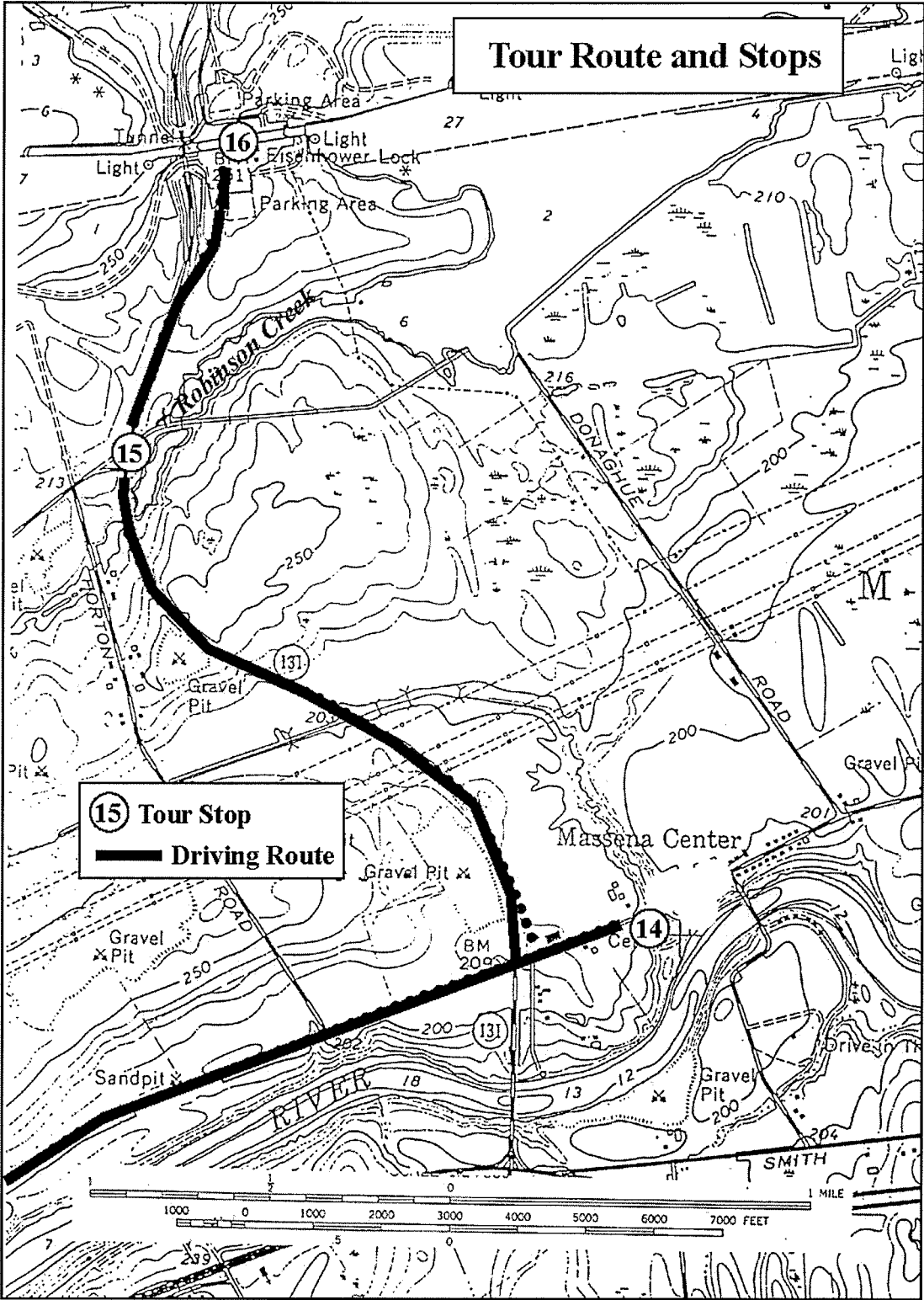


Figure 15. Driving Tour Route and Stops around Massena Center.

