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OPEN FILE 8739

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Canada

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The 1791 magnitude (Mw) 5.5 earthquake, Charlevoix, Quebec: interpretation of macroseismic information

M. Lamontagne

Abstract

The December 6, 1791 magnitude 6 Charlevoix earthquake occurred at approximately 8:00 p.m. local time (December 7, 1791, 01:00 U.T.). Based on felt reports, the epicentre of the main shock is located near the St. Lawrence River in the area enclosing on the North Shore, Baie St-Paul and the Île-aux-Coudres and on the south shore, the town of Kamouraska. These three places sustained the most damage from the earthquake, mostly to house wares and masonry chimneys. The churches of Bas-des-Éboulements (now St-Joseph-de-la-Rive) and Kamouraska were damaged. In the following weeks, dozens of aftershocks continued to shake the epicentral area, keeping local residents on high alert.

The 1791 earthquake is one of five known moment magnitude 5.5 to 7 events that have occurred in the Charlevoix Seismic Zone (CSZ) between 1663 and the present. Given that this earthquake occurred in the late 1700's and far from major cities, felt accounts and newspaper reports are limited in number. It was felt in Quebec City but not reported felt in Montreal, New England or New Brunswick. This Open File Report presents the macroseismic information and its ratings on the Modified Mercalli Scale for a total of nine locations in Canada. For each locality, the felt information is rated on the Modified Mercalli intensity (MMI) scale and tabulated in a Microsoft Excel sheet. The text of some of the newspaper accounts were copied. The Open File also provides a GoogleEarth kmz file that allows the felt information reports to be viewed in a spatial tool.

Dedication

This Open File Report is dedicated to the memory of the late Father Pierre Gouin who spent years of his later life documenting earthquakes of the Province of Quebec. His findings and analyses can be found in Gouin (2001). This Open File is largely based on his dedicated work.

Details of his career can be found at:
https://montrealgazette.remembering.ca/obituary/pierre-gouin-1066212192

Introduction

The December 6, 1791 Charlevoix earthquake is significant because it is among the strongest earthquakes recorded in eastern Canada. It occurred in the Charlevoix Seismic Zone (CSZ) where five earthquakes rated at moment magnitude (**M**) 5.5 or more are known to have occurred: 1663 (**M** ~ 7); 1791 (**M** ~ 5.5); 1860 (**M** ~ 6.1); 1870 (**M** ~ 6.6); and 1925 (**M** 6.2; Bent, 1992; Bent, 2009). Due to the number of damaging earthquakes and the repeating lower magnitude earthquakes, the CSZ is recognized as the most active seismic zone of eastern Canada.

The main shock occurred on December 6, 1791 at about 8:00 p.m. local time (December 7th at 01:00 U.T.). It was strongly felt in Baie-St-Paul, Île-aux-Coudres and Bas des Éboulements where damage was reported. According to the December 29, 1791 edition of the Quebec Gazette (Quebec City), a "reliable correspondent" at Baie-St-Paul reported that all of the tremors were felt west to east, and more damage was caused in a region of unknown length and roughly two leagues (at most 10 km) wide (*La Gazette de Québec*, Québec City, December 29th, 1791). In Baie-St-Paul and Île-aux-Coudres, chimneys were damaged or knocked down, some stone houses were cracked and one was almost completely demolished, and many stoves and ovens were thrown down. Finally, a church located on unconsolidated deposits (probably built on the landslide caused by the 1663 earthquake) was damaged in Bas-des-Éboulements.

On the south shore of the St. Lawrence River, damage to the church of Kamouraska is documented in an exchange of letters between the parish priest and the catholic bishop, Monseigneur Plessis, in Quebec City (Paradis, 1948). Gouin (2001) did not mention this evidence. In 1790, the church was located is what is referred to as "the cradle of Kamouraska" (Culture et communications Québec, 2020), a problematic site that was abandoned a few years after the earthquake. It is known that the church was already in a bad state prior to the earthquake: the poor ground conditions of the site led to the slow sinking of the foundations and the walls were badly cracked. The correspondence between the priest and the bishop discusses the impact of the 1791 earthquake buildings

on the south shore of the St. Lawrence. In a letter, dated January 14, 1792, the bishop authorized masses to be served in a chapel, considering the damage suffered by the church during the earthquake and the perceived threat to safety to the assembly (Paradis, 1948; Dufour, 1993). The earthquake brought additional damage to the walls and seriously affected the framework of the church. The earthquake damage was an additional element to convince people that the move to a new church, already being built at the time of the earthquake, was necessary (Dufour, 1993).

The earthquake was also reported felt in La Malbaie and Quebec City. Though residents were alarmed by the shock, the earthquake was less severe in La Malbaie and Quebec City (Gouin, 2001). No newspaper was published in Trois-Rivières at the time but a local impact was not reported in newspapers from elsewhere. Montreal newspapers reported on the earthquake but never mentioned if it had been felt in Montreal. Newspapers in the province of New Brunswick or New England in the United States did not report the earthquake. This contrasts with other more recent moderate earthquakes in Charlevoix.

The assumed epicenter position is 47.4 ºN by 70.5 ºW and corresponds to the area where damage was reported on the north shore. Due to the poor constraints on the position of the source, an uncertainty in epicentre position of at least 25 km is warranted. This region is where most aftershocks were reported felt: in Baie-St-Paul, aftershocks were felt four to five times per day from December 6 – 19, 1791. Another account indicated that during the period of December 6 – 15, 1791 there were approximately 30 tremors felt, nine of which were very strong (Gouin, 2001). On the Île-aux-Coudres tremors were felt until December 16, 1791. No aftershocks were reported from La Malbaie or Quebec City. The correspondence from Kamouraska where the church was damaged did not report aftershocks. Interestingly, the epicentre of the 1870 M 6.5 Charlevoix earthquake is also assumed to be from that region (Lamontagne, 2008). The epicentre of the 1791 earthquake, however, is less constrained than that of 1870.

The maximum intensity is rated as VI or less by Gouin (2001) and VIII by Smith (1962) on the Modified Mercalli Intensity (MMI) scale (Appendix 1). Gouin (2001) appears to

downgrade the maximum intensity based on the lack of adequate foundations and the poor soil conditions of the houses at Baie-St-Paul and the church at Bas-des-Éboulements. To the author, an MMI VII seems more appropriate: "Damage … considerable in poorly built or badly designed buildings, …old walls (especially where laid up without mortar), spires, etc. Cracked chimneys to considerable extent, walls to some extent" (see Appendix 1). The damage suffered by the church of Kamouraska lacks detail but must have been substantial since it contributed to its abandonment.

Rating this earthquake on the magnitude scale is difficult: we have only a few felt reports. This could be interpreted as a low magnitude, but the few newspapers that existed at the time may also be a reason. In the Canadian earthquake catalogue, this earthquake is rated as **M** 5.5 (Johnston et al., 1994; Bent, 2015; Lamontagne et al., 2018) which is a straight conversion from the magnitude 6.0 ML in the Canadian earthquake catalog (Smith, 1962).

If we consider Montreal to be at a sufficiently large distance from Charlevoix that only a difference in magnitude defines the way the earthquake is felt, then the 1791 earthquake is certainly the smallest of the five large Charlevoix earthquake (1663, 1791, 1860, 1870, 1925).

To refine the magnitude, two contradictory sources of evidence exist: the damage in the epicentral region and the felt area. The damage near the epicentre suggests a magnitude approaching 6 but the felt reports from distant sources suggest a magnitude much inferior to those of the earthquakes of 1870 **M** ≈ 6.5, 1925 **M** 6.2 and 1988 **M** 5.9 (Saguenay). The following moderate earthquakes caused minor (less than 1791) masonry damage in their respective epicentral regions: 1997 **M** 4.9 Cap-Rouge (a few concrete blocks; Nadeau et al., 1998) and the 2012 **M** 4.6 Ladysmith, Qc (minor damage; Bent et al., 2015). The 2010 **M** 5.0 Val-des-Bois earthquake caused the chimney of a church to fall in Gracefield, Quebec, and masonry damage in Ottawa, both at some 50-55 km distance. Based on these evidence, we deduce that the 1791 earthquake must have been at least **M** 5.0.

Based on the felt area of about 50 000 km^2, Gouin (2001) rates it as a maximum of m_b(Lg 4.3) (or approximately **M** 3.8) which appears too low a magnitude considering the local damage. In fact, during the instrumental period, no damage was ever reported for an eastern Canadian with a m_{bLg} of less than 4.5 (i.e. about **M** 3.9; see Lamontagne et al. (2018) for a list of significant earthquakes).

A comparison can be made with felt information from more recent Charlevoix earthquakes of similar magnitudes. The **M** 5.3 1939 earthquake for instance is not too different from 1791 in terms of felt areas and damage (chimneys damaged in Rivière-Ouelle, Rivière-du-Loup, Saint-Urbain and La Malbaie, Quebec; Figure 1). The 1952 **M** 4.6 and the 1979 **M** 4.8 (Bent, 2009) also in Charlevoix are probably smaller than 1791 as they were not felt as extensively and caused little damage (Figures 2 and 3). A more recent one, the 2004 **M** 4.7 earthquake did not cause any damage but was reported felt at large distances, including in Montreal, New Brunswick and even New England (Figure 4). This earthquake has a large felt area but the felt reports were Did-You-Feel-It reports, which can sample more people than the old mail-in questionnaires used in the 20^{th} century.

Assuming that focal depth is not a controlling factor, all of these felt areas tend to support a magnitude higher than **M** 5.0 for the 1791 earthquake, not too different from the **M** 5.5 listed in the most recent earthquake catalog (Bent, 2009). Our opinion is that an earthquake of magnitude **M** in the 5.3-5.5 range would be sufficiently strong to cause local damage especially to masonry elements of buildings with poor foundations located on deposits capable of amplifying ground motions. It could also be sufficiently weak to be barely noticeable, hence not reported, in Montreal, New Brunswick and New England.

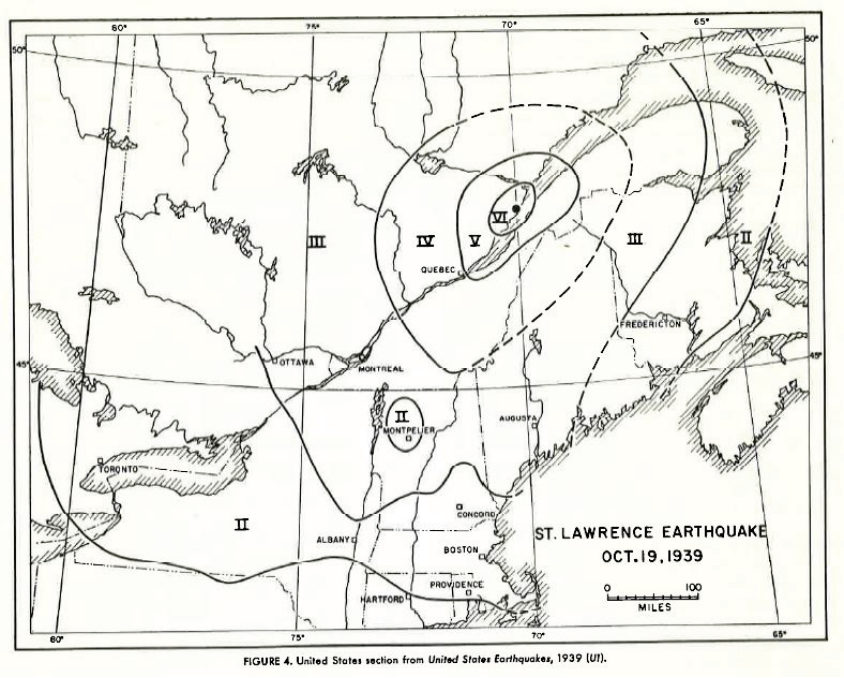

FIGURE 4. United States section from *United States Earthquakes*, 1939 (*UI*).

Figure 1; Macroseismic map, based on questionnaires returned by postmasters, of the **M** 5.3 (Bent, 2009) October 19, 1939 Charlevoix earthquake (Source: Smith, 1966).

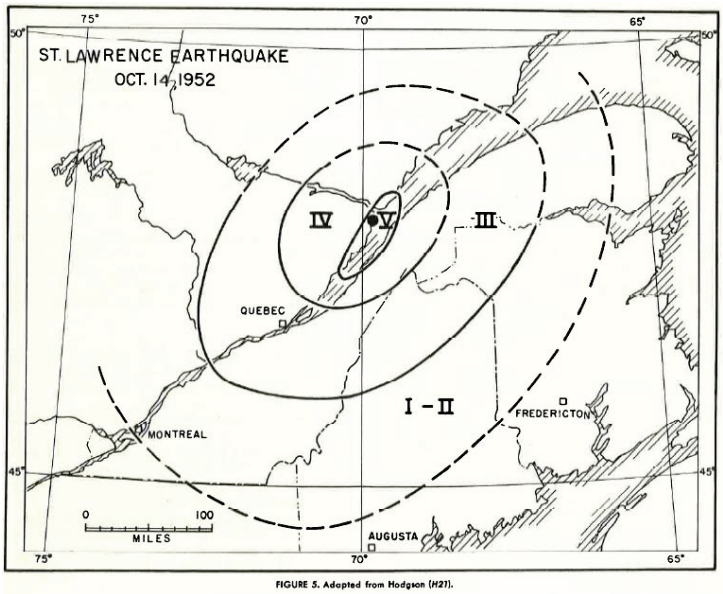

Figure 2; Macroseismic map, based on questionnaires returned by postmasters, of the **M** 4.5 (Bent, 2009) October 14, 1952 Charlevoix earthquake (Source: Smith, 1966).

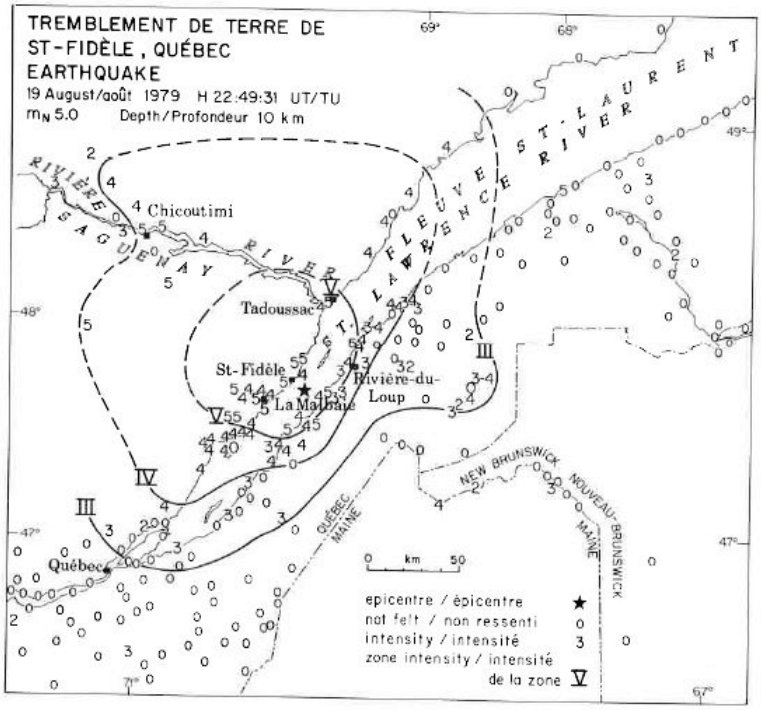

Figure 6. Isoseismal map of the 19 August 1979, St-Fidèle, Québec, earthquake (after Hasegawa and Wetmiller, 1981)
Carte des isoséistes du séisme de St-Fidèle, Québec, du 19 août 1979 (adaptée de Hasegawa et Wetmiller, 1981)

Figure 3; Macroseismic map, based on questionnaires returned by postmasters, of the **M** 4.8 (Bent, 2009) August 19, 1979 Charlevoix earthquake (Source: Hasegawa and Wetmiller 1980).

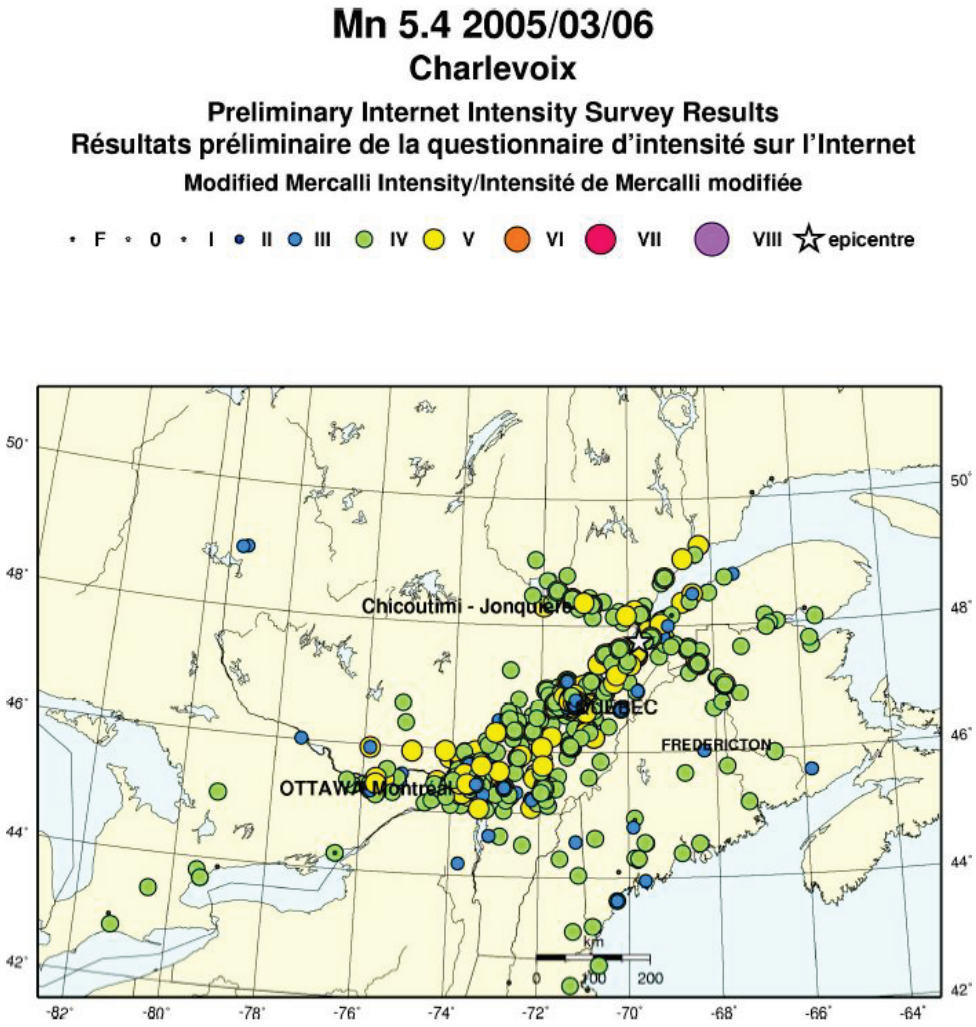

Figure 4; Macroseismic map, based on Did-You-Feel-It Reports, of the **M** 4.7 (Bent, 2009) March 6, 2005 Charlevoix earthquake (GSC, 2009).

Intensity Reports

This Open File Report documents all felt and damage information related to this earthquake in Canada and in the United States. For this, we include for each locality, the felt information rated on the MMI scale tabulated in a Microsoft Excel sheet. Nine MMI reports are listed. The Open File also provides a GoogleEarth kmz file that allows the felt information reports to be viewed in this geospatial tool.

The three main objectives of this Open File are:

1) To centralize in a table the felt reports and interpreted intensities on the Modified Mercalli scale for that earthquake.
2) To provide the text of the original reports in newspapers and other documents that described the impact of the earthquake.
3) To provide a map that shows the distribution of macroseismic reports for that earthquake.

Data and results

Historically, moderate to strong earthquakes have occurred in eastern Canada. For events that occurred before the 20th century, written accounts of earthquakes and of the induced damage are the sole source of information (Bruneau and Lamontagne, 1994). Given the sparse population at the time and limited number of newspapers and other means communication, only a few accounts of the 1791 earthquake were reported (Hodgson, 1944). In 1791 modern orthography was not yet used, and quotes from original sources in the spreadsheet reflect the spelling of at the time. For example, the letter “f” replaced “s” when it was not at the end of a word (Gouin, 2001). These reports generally lack the thoroughness of damage observations needed for reliable engineering assessments.

Seismologists, however were able to estimate the approximate magnitude of the five

damaging earthquakes, including the 1791 Charlevoix event, which occurred prior to the 1900s using the description of felt areas and effects. Although the population distribution was much less than it is today, these earthquakes damaged some construction, mainly masonry chimneys which were the most vulnerable elements in early Canadian homes of wood construction or thick stone masonry.

It is possible that some of the earlier earthquakes (1663, 1791) had limited consequences because of the small inhabited territory at the time and the simple but robust construction of most buildings. The reported impact of past earthquakes is a function of many factors, some related to the earthquake sources (magnitude, focal depth and epicentral distance) and some to characteristics of the inhabited areas. Among the latter factors are the geographic distribution of the inhabited areas at the times of the earthquakes, the characteristics of the building stock (age and type of construction, earthquake resistance), and the thickness and geotechnical properties of the underlying geological materials (Lamontagne, 2009).

A Microsoft Excel spreadsheet contains the basic information on the felt accounts. The MMI ratings of Gouin (2001) are provided. The file folder “Newspapers” contains all scanned or transcribed newspapers articles.

Fields of the Table

Using the Microsoft Excel spreadsheet, a table was created that includes some 9 entries (rows). The columns are the same as published in Lamontagne and Burke (2018). The rows have different colours for each province and some cells have different colours when a special note is added.

The columns of the Excel sheet are:

1. CEEF: A date and time that refer to entries in the Canadian Earthquake Epicentre File (CEEF)

2. Date.time (UTC): date and time of the earthquake in Universal Time.
3. Year_event: Year of the event (YYYY) (Universal Time)
4. Month_event Month of the event (MM) (Universal Time)
5. Day_Event: Day of the event (DD) (Universal Time)
6. Hour-Event: Hour of the event (HH) (Universal Time)
7. Minute-Event: Minute of the event (mm) (Universal Time)
8. Second-Event: Second of the event (ss.s) (Universal Time)
9. MMI Location: Community where earthquake was felt
10. Address: Address where the earthquake was felt (if known)
11. Prov/State: Province or State of the community where the earthquake was felt; NB: New Brunswick; NS: Nova Scotia; PE: Prince Edward Island; QC: Quebec; ME: Maine (USA); MA, Massachusetts (USA) and NH: New Hampshire (USA)..
12. Country: Canada or the USA
13. Postal/Zip: Postal Code or Zip Code of the community where the earthquake was felt (if known). In this Open File, no attempt was made to populate this field.
14. Latitude (°N): Latitude of the community where the earthquake was felt; taken from the original felt reports or more rarely obtained from GoogleEarth. Some latitude coordinates of Gouin (2001) which were with only one digit, were changed by the first author and documented in the excel file.

15. Longitude (°W): Longitude of the community where the earthquake was felt; taken from the original felt reports or, more rarely, obtained from GoogleEarth. Some longitude coordinates of Gouin (2001) which were with only one digit, were changed by the first author and documented in the excel file.

16. Epicentral Distance (km): distance in km between the earthquake' epicentre and the community where the earthquake was felt. The cell calculates the

distance using the formula:

Epicentral Distance (km) = ACOS(COS(RADIANS(90-(lat. site)))
*COS(RADIANS(90-(lat. of epicentre))) +SIN(RADIANS(90-(lat. of site)))
*SIN(RADIANS(90-(lat. of epicentre))) *COS(RADIANS(Lon of site -
(Lon of epicentre)))) *6371

We used the epicentre of Lamontagne (2008), i.e. Latitude 47.4°N and Longitude 70.5°W as listed in the second tab of the spreadsheet.

17. Final Numeric MMI: Based on the felt report, interpreted Intensity on the Modified Mercalli Scale of 1931. Although MMI is defined using Roman numerals, we decided to convert them to Arabic numerals for ease of use.
18. Basis for MMI (English): Aspects of the felt report in English (if available) that were used to rate the MMI (in Arabic numerals).
19. Basis for MMI (French): Aspects of the felt report in French (if available) that were used to rate the MMI (in Arabic numerals).
20. Source of felt report.
21. Precision of location (km): In some cases, it is possible to estimate the radius of uncertainty of the location.
22. Minimum MMI: The minimum value of MMI for a felt report that is interpreted to lie within a range of intensities (e.g.: MMI 3-4; in Arabic numerals).
23. Maximum MMI: The maximum value of MMI for a felt report that is interpreted within a range of intensities (e.g.: MMI 3-4; in Arabic numerals).
24. Interpreter: Author who made the interpretation.
25. Additional notes: Comments of interest on the felt report or its publication.

GoogleEarth file

To ease the consulting of the data and put them in a geographic context, a kml file is

added and can be viewed using the GoogleEarth software that can be downloaded at https://www.google.com/earth/ . Static images of the Google Earth display are shown as figures 5 and 6.

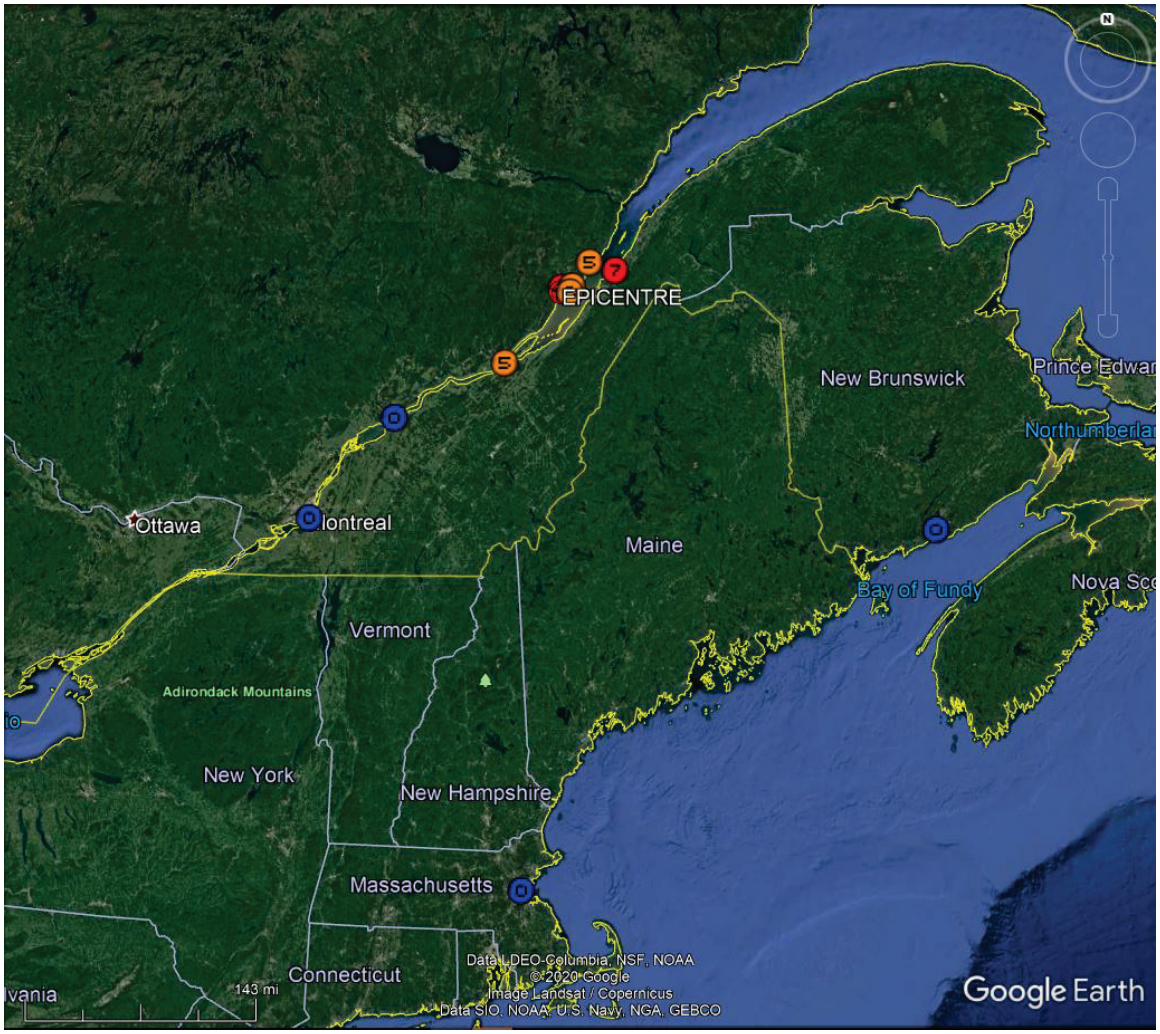

Figure 5. Static image of the Google Earth display that shows the locations of the felt reports on a regional scale.

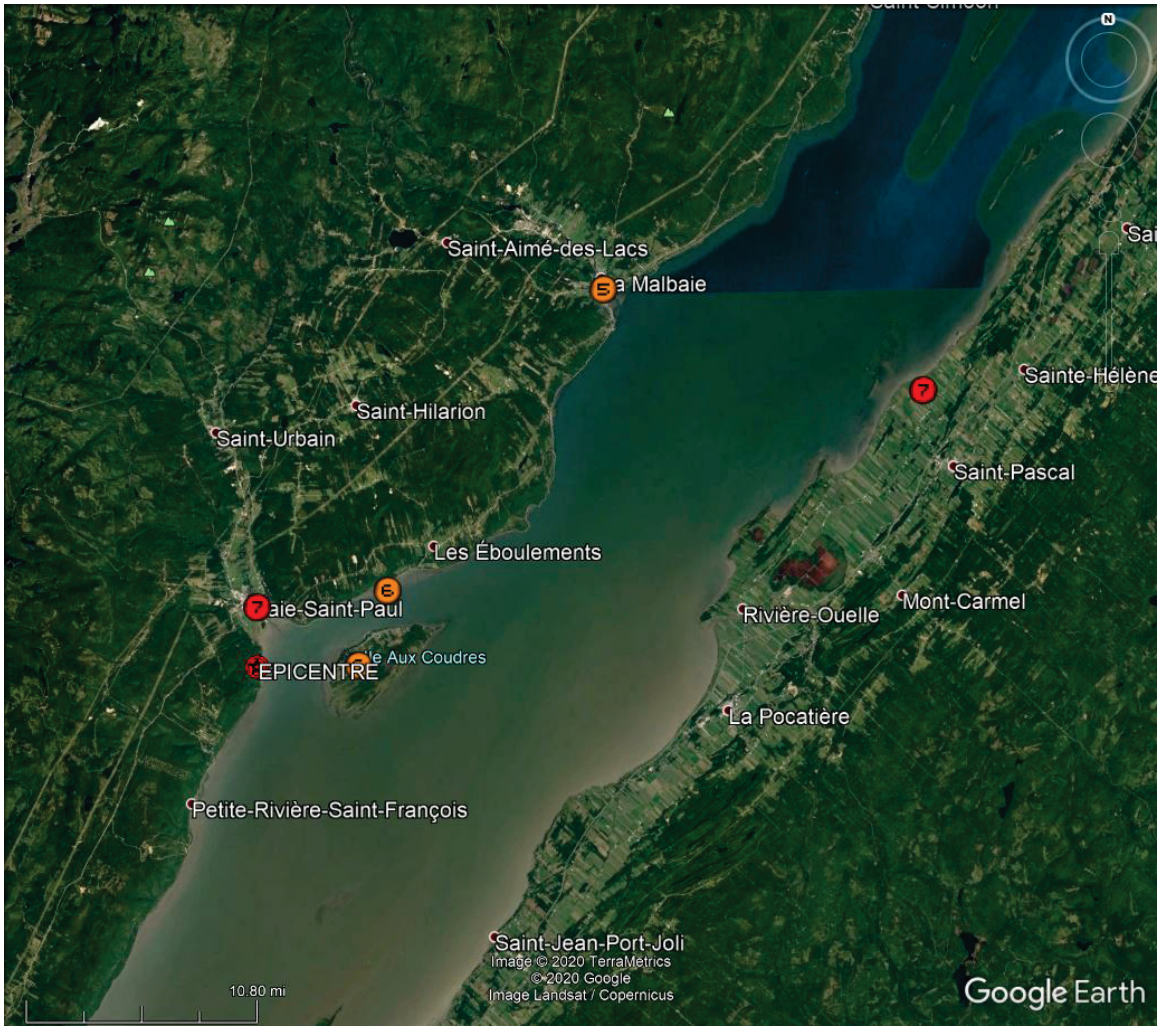

Figure 6. Static image of the Google Earth display that shows the locations of the felt and damage reports in the epicentral region.

Conclusions and recommendations

A new digital repository of felt accounts for the 1791 Magnitude M_w 5.5 Charlevoix earthquake was created. The author is confident that this Open File includes all available information on how this earthquake was felt in the province of Quebec, but will be amended if new information is uncovered. He hopes that it will be useful for research on this earthquake as well as on other intraplate earthquakes.

Acknowledgments

The author thanks Laura Olson for reformatting the available felt information, Dr Ken B.S. Burke of the University of New Brunswick for his review and advice and our GSC colleague Dr Allison Bent for his review of this Open File. We also thank Ms. Heather Crow and Dr Greg Brooks, the project leaders, for supporting this project.

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Appendix 1

References used by Gouin (2001). In the Excel spreadsheet, some quotes refer to the numbers below. We copy here the exact same references published in Gouin (2001).

Newspapers

1 *La Gazette de Québec*, Québec, du 8 décembre, 1791 (1, 2). At the time, a bilingual newspaper.

2 *The Quebec Herald*, Quebec, December 12, 1791. These editions of the *Herald* are not at the BNQ. The texts are quoted from *La Minerve* of 27 January 1831.

[3] *The Quebec Herald*, Quebec, December 19, 1791.

[4] *La Gazette de Québec*, Québec, du 19 décembre, 1791.

[5] *La Gazette de Québec*, Québec, du 22 décembre, 1791 (3, 2).

[6] *La Minerve*, Montréal, du 27 janvier, 1831. Texts transcribed from the *Gazette* and the *Herald*.

[7] *La Gazette de Québec*, Québec, du 29 décembre, 1791 (4, 1 for the English version, 4, 2 for the French version).

Personal Account

[1] Mailloux Alexis. *Histoires de l'Ile-aux-Coudres*, Montréal, Burland-Desbarats 1879, p. 30-31 (Récit de Madame Jean Lapointe, témoin oculaire des événements de 1791, In *Mailloux*, 1879, p. 27-29.) Note : Mrs Lapointe was 12 at the time of the earthquakes; a 12-year old year at the time was considered and adult. At Fr. Mailloux' request, she dictated her testimony. Naturally, the memory slipped once in a while and the report is not to be considered completely reliable.

Appendix 2: Modified Mercalli Intensity Scale (Wood and Neumann, 1931)

I. Not felt -- or, except under especially favorable circumstances.

Under certain conditions, at and outside the boundary of the area in which a great shock is felt:

- sometimes birds, animals, reported uneasy and disturbed;
- sometimes dizziness or nausea experienced;
- sometimes trees, structures, liquids, bodies of water, may sway; doors may swing, very slowly.

II. Felt indoors by few, especially on upper floors, or by sensitive or nervous persons.

Also, as in grade I, but often more noticeably:

- sometimes hanging objects may swing, especially when delicately suspended;
- sometimes trees, structures, liquids, bodies of water, may sway, doors may swing, very slowly;
- sometimes birds, animals, reported uneasy and disturbed;
- sometimes dizziness or nausea experienced.

III. Felt indoors by several, motion usually rapid vibration.

- Sometimes not recognized to be an earthquake at first.
- Duration estimated in some cases.
- Vibration like that due to the passing of light or lightly loaded trucks or heavy trucks some distance away.
- Hanging objects may swing slightly.
- Movements may be appreciable on upper levels of tall structures.
- Rocked standing motor cars slightly.

IV. Felt indoors by many, outdoors by few.

- Awakened few, especially light sleepers.
- Frightened no one, unless apprehensive from previous experience.
- Vibration like that due to the passing of heavy or heavily loaded trucks.

- Sensation like heavy body striking building or falling of heavy objects inside.
- Rattling of dishes, windows, doors; glassware and crockery clink and clash.
- Creaking of walls, frame, especially in the upper range of this grade.
- Hanging objects swung, in numerous instances.
- Slightly disturbed liquids in open vessels. Rocked standing motor cars noticeably.

V. Felt indoors by practically all, outdoors by many or most: outdoors direction estimated.

- Awakened many, or most.
- Frightened few -- slight excitement, a few ran outdoors.
- Buildings trembled throughout.
- Broke dishes, glassware, to some extent.
- Cracked windows -- in some cases, but not generally.
- Overturned vases, small or unstable objects, in many instances, with occasional fall.
- Hanging objects, doors, swing generally or considerably.
- Knocked pictures against walls, or swung them out of place.
- Opened, or closed, doors, shutters, abruptly. Pendulum clocks stopped, started, or ran fast, or slow.
- Moved small objects, furnishings, the latter to slight extent.
- Spilled liquids in small amounts from well-filled open containers.
- Trees, bushes, shaken slightly.

VI. Felt by all, indoors and outdoors.

- Frightened many, excitement general, some alarm, many ran outdoors.
- Awakened all.
- Persons made to move unsteadily.
- Trees, bushes, shaken slightly to moderately.
- Liquid set in strong motion.

- Small bells rang -- church, chapel, school, etc.
- Damage slight in poorly built buildings.
- Fall of plaster in small amount.
- Cracked plaster somewhat, especially fine cracks; chimneys in some instances.
- Broke dishes.
- Fall of knick-knacks, books, pictures.
- Overturned furniture in many instances.
- Moved furnishings of moderately heavy kind.

VII. Frightened all -- general alarm, all ran outdoors.

- Some, or many, found it difficult to stand.
- Noticed by persons driving motor cars.
- Trees and bushes shaken moderately to strongly.
- Waves on ponds, lakes, and running water.
- Water turbid from mud stirred up.
- Incaving to some extent of sand or gravel stream banks.
- Rang large church bells, etc.
- Suspended objects made to quiver.
- Damage negligible in buildings of good design and construction, slight to moderate in well-built ordinary buildings, considerable in poorly built or badly designed buildings, adobe houses, old walls (especially where laid up without mortar), spires, etc.
- Cracked chimneys to considerable extent, walls to some extent.
- Fall of plaster in considerable to large amount, also some stucco.
- Broke numerous windows, furniture to some extent.
- Shook down loosened brickwork and tiles.
- Broke weak chimneys at the roof-line (sometimes damaging roofs).
- Fall of cornices from towers and high buildings.
- Dislodged bricks and stones.

- Overturned heavy furniture, with damage from breaking.
- Damage considerable to concrete irrigation ditches.

VIII. Fright general -- alarm approaches panic.

- Disturbed persons driving motor cars.
- Trees shaken strongly -- branches, trunks, broken off, especially palm trees.
- Ejected sand and mud in small amounts.
- Changes: temporary, permanent; in flow of springs and wells; dry wells renewed flow; in temperature of spring and well waters.
- Damage slight in structures (brick) built especially to withstand earthquakes.
- Considerable in ordinary substantial buildings, partial collapse: racked, tumbled down, wooden houses in some cases; threw out panel walls in frame structures, broke off decayed piling.
- Fall of walls.
- Cracked, broke, solid stone walls seriously.
- Wet ground to some extent, also ground on steep slopes.
- Twisting, fall, of chimneys, columns, monuments, also factory stacks, towers.
- Moved conspicuously, overturned, very heavy furniture.

IX. Panic general.

- Cracked ground conspicuously.
- Damage considerable in (masonry) structures built especially to withstand earthquakes:
- threw out of plumb some wood-frame houses built especially to withstand earthquakes;
- great in substantial (masonry) buildings, some collapse in large part; or wholly shifted frame buildings off foundations, racked frames;
- serious to reservoirs; underground pipes sometimes broken.

X. Cracked ground, especially when loose and wet, up to widths of several inches; fissures up to a yard in width ran parallel to canal and stream banks.

- Landslides considerable from river banks and steep coasts.
- Shifted sand and mud horizontally on beaches and flat land.
- Changed level of water in wells.
- Threw water on banks of canals, lakes, rivers, etc.
- Damage serious to dams, dikes, embankments.
- Severe to well-built wooden structures and bridges, some destroyed.
- Developed dangerous cracks in excellent brick walls.
- Destroyed most masonry and frame structures, also their foundations.
- Bent railroad rails slightly.
- Tore apart, or crushed endwise, pipe lines buried in earth.
- Open cracks and broad wavy folds in cement pavements and asphalt road surfaces.

XI. Disturbances in ground many and widespread, varying with ground material.

- Broad fissures, earth slumps, and land slips in soft, wet ground.
- Ejected water in large amount charged with sand and mud.
- Caused sea-waves ("tidal" waves) of significant magnitude.
- Damage severe to wood-frame structures, especially near shock centers.
- Great to dams, dikes, embankments, often for long distances.
- Few, if any (masonry), structures remained standing.
- Destroyed large well-built bridges by the wrecking of supporting piers, or pillars.
- Affected yielding wooden bridges less.
- Bent railroad rails greatly, and thrust them endwise.
- Put pipe lines buried in earth completely out of service.

XII. Damage total -- practically all works of construction damaged greatly or destroyed.

- Disturbances in ground great and varied, numerous shearing cracks.

- Landslides, falls of rock of significant character, slumping of river banks, etc., numerous and extensive.
- Wrenched loose, tore off, large rock masses.
- Fault slips in firm rock, with notable horizontal and vertical offset displacements.
- Water channels, surface and underground, disturbed and modified greatly.
- Dammed lakes, produced waterfalls, deflected rivers, etc.
- Waves seen on ground surfaces (actually seen, probably, in some cases).
- Distorted lines of sight and level.
- Threw objects upward into the air.