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GEOLOGICAL SURVEY OF CANADA
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Macroseismic information for the seven largest moderate earthquakes of the Charlevoix seismic zone, Quebec, between 1870 and 2021: February 3, 1902, M 4.5; September 30, 1924, M 5.2; January 08, 1931, M 4.9; October 19, 1939, M 5.3; October 14, 1952, M 4.5; August 19, 1979, M 4.8; March 6, 2005, M 4.7

M. Lamontagne, P. Archambault, and S. Halchuk

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Macroseismic information for the seven largest moderate earthquakes of the Charlevoix Seismic Zone between 1870 and 2021: February 3, 1902, M 4.5; September 30, 1924, M 5.2; January 08, 1931, M 4.9; October 19, 1939, M 5.3; October 14, 1952, M 4.5; August 19, 1979, M 4.8; March 6, 2005, M 4.7

M. Lamontagne, P. Archambault, and S. Halchuk

Abstract

This Open File Report provides the available macroseismic information for the seven largest moderate earthquakes that occurred in the Charlevoix Seismic Zone between 1870 and 2021. These earthquakes and their moment magnitude (**M**) are: 1) February 3, 1902, **M** 4.5; 2) September 30, 1924, **M** 5.2; 3) January 08, 1931, **M** 4.9; 4) October 19, 1939, **M** 5.3; 5) October 14, 1952, **M** 4.5; 6) August 19, 1979, **M** 4.8; 7) March 6, 2005, **M** 4.7. Five, possibly six, of these seven earthquakes occurred in the northeast portion of the CSZ, where the largest event of the period, the 1925 **M** 6.2 earthquake, also occurred. For each locality where the earthquakes were felt, macroseismic information is given and interpreted on the Modified Mercalli Intensity Scale. The original mail questionnaires filled by postmasters for earthquakes no. 3, 4, 5 and 6 are lost. Consequently, the main sources of information are the newspaper accounts except for no. 7 for which web-based questionnaires are available. The macroseismic information from localities in Canada and in the US (from NOAA) are tabulated in Microsoft Excel spreadsheets. Most newspaper clippings that have macroseismic information are included. The Open File also provides GoogleEarth kmz files that allow the felt information reports to be viewed in a spatial tool.

Résumé

Ce dossier public fournit les informations macroséismiques disponibles pour six séismes modérés qui se sont produits dans la zone sismique de Charlevoix (ZSC) entre 1870 et 2021. Ces séismes et leur magnitude de moment (M) sont : 1) 3 février 1902, M 4,5 ; 2) 30 septembre 1924, M 5,2 ; 3) 8 janvier 1931, M 4,9 ; 4) 19 octobre 1939, M 5,3 ; 5) 14 octobre 1952, M 4,5 ; 6) 19 août 1979, M 4,8 ; 7) 6 mars 2005, M 4,7. Cinq, voire six, de ces sept séismes se sont produits dans la partie nord-est de la ZSC, où s'est également produit le plus grand événement de la période, le séisme de 1925, de magnitude 6,2. Pour chaque localité où les séismes ont été ressentis, des informations macrosismiques sont données et interprétées sur l'échelle d'intensité Mercalli modifiée. Les questionnaires postaux originaux remplis par les maîtres de poste pour les séismes no. 3, 4, 5 et 6 sont perdus. Par conséquent, les principales sources d'information sont les comptes-rendus des journaux, à l'exception du no. 7 pour lequel des questionnaires en ligne sont disponibles. Les informations macroséismiques des localités du Canada et des États-Unis (provenant de la NOAA) sont présentées sous forme de tableaux dans un chiffrier Microsoft Excel. La plupart des coupures de journaux contenant des informations macroséismiques sont incluses. Le Dossier public fournit également des fichiers GoogleEarth kmz qui permettent de visualiser les rapports d'information sur dans un outil géospatial.

Dedication:

The information of this Open File report is developed from the work of a number of scientists and this OF is dedicated to them. Father Pierre Gouin was central to the description of the 1902 and 1924 earthquakes and a number of federal Government scientists for the others: W.E.T Smith for 1931, 1939 and 1952; and H.S. Hasegawa and R.J. Wetmiller for 1979. The US data was extracted from the NOAA database (NOAA, 2021) with data derived from work from various US scientists.

Introduction

This Open File Report documents felt and damage information related to seven moderate

earthquakes of the Charlevoix Seismic Zone. These earthquakes and their moment magnitude (**M**) are: 1) February 3, 1902, **M** 4.5; 2) September 30, 1924, **M** 5.2; 3) January 08, 1931, **M** 4.9; 4) October 19, 1939, **M** 5.3; 5) October 14, 1952, **M** 4.5; 6) August 19, 1979, **M** 4.8; 7) March 6, 2005, **M** 4.7. Most of the macroseismic information is for Canadian municipalities but additional ratings on the Modified Mercalli Intensity (MMI; see Appendix 1) for the United States are included, mostly from the intensity database of the National Oceanic and Atmospheric Administration (NOAA, 2021). For each Canadian locality, we include the available felt information and its interpretation on the Modified Mercalli Intensity (MMI) scale tabulated in a Microsoft Excel sheet. The Open File also provides GoogleEarth kmz files that allow the felt information reports to be viewed in this geospatial tool.

The main objectives of this Open File are for these seven earthquakes:

1) To provide short descriptions of the methods that were used to gather the felt information.
2) To centralize in a table the felt reports and interpreted intensities on the MMI scale for these seven earthquakes.
3) To provide the scans of available newspapers that included felt and damage reports.
4) To provide maps that show the distribution of available macroseismic reports.

The Charlevoix Seismic Zone (CSZ)

The epicentres of these seven earthquakes are all within the Charlevoix Seismic Zone (CSZ; Figure 1). Due to the its number of damaging earthquakes and its frequent lower magnitude earthquakes, the CSZ is recognized as the most active seismic zone of Eastern Canada (Basham et al., 1982). Five earthquakes rated at moment magnitude (**M**) 5.5 or more are known to have occurred there: 1663 (**M** ~ 7); 1791 (**M** ~ 5.5); 1860 (**M** ~ 6.1); 1870 (**M** ~ 6.6); and 1925 (**M** 6.2; Bent, 1992; Bent, 2009). The georeferenced impacts of these earthquakes can be found in: 1663: Lamontagne and Locat (2021); 1791 (Lamontagne, 2020); 1860 (Lamontagne, 2021); 1870 (Lamontagne et al., 2019) and 1925 (Lamontagne et al., 2021). This OF provides macroseismic information for the seven largest CSZ earthquakes that occurred between 1870 and 2020.

The installation of a permanent seismograph network in 1978 has helped to define the characteristics of the seismicity. More than 200 earthquakes are recorded yearly in the CSZ. Roughly 80% of Charlevoix earthquakes occur in the depth range 5–15 km in Grenvillian basement rocks, with some as deep as 30 km. The Precambrian Shield outcrops on the north shore of the St. Lawrence River or is found beneath Logan's Line and the Appalachian rocks. Hypocentres cluster along or between the mapped Iapetan faults (also called St. Lawrence paleo-rift faults). The largest earthquake of the twentieth century was the 1925 earthquake, and its focal mechanism has one nodal plane consistent with a reactivation of a southeast-dipping paleo-rift fault (Bent, 1992). If we consider the period 1985 to 2020 inclusively, the number and yearly rate of occurrence of earthquakes are: $m_bL_g \geq 5.0$, 1 (1/36); $4.0 \leq m_bL_g < 5.0$: 12 (0.3 per year); $3.0 \leq m_bL_g < 4.0$: 69 (1.9 per year); $2.0 \leq m_bL_g < 3.0$: 667 (18.5 per year).

Between 1870 and September 30th, 1924, Gouin (2001) documented a number of small to moderate earthquakes felt locally in the CSZ with poorly constrained magnitudes and locations. The dates of these events, maximum MMIs in the CSZ (Gouin, 2001) and estimated magnitudes (SHEEF, Halchuk et al., 2015) are: 1877-07-17 (IV-V; not felt in Montreal; M_L 3.0; **M** 2.6); 1888-04-19 (IV; not felt in Quebec City; M_L 3.7; **M** 3.3); 1896-09-16 (IV); 1901-03-11 (III-IV; not felt in Quebec City); 1902-02-03 (IV-V; small objects fell in Rivière-du-Loup; felt in Quebec City; lightly felt in Montreal; estimated at m_bL_g 4.5 according to Gouin, 2001); 1924-03-04 (IV-V; not felt in Montreal; M_L 4.3; **M** 3.9). None of these earthquakes are part of the 150 largest Canadian earthquakes of Bent (2009). Only the 1902-02-03 earthquake is part of our OF which documents moderate CSZ earthquakes. The 1902 earthquake is described last as its interpretation depends on knowledge of the other earthquakes.

This OF provides macroseismic information for the seven of the seven largest CSZ earthquakes that occurred between 1870 and 2020. Before these seven earthquakes are examined in detail, we need to mention the largest earthquake of that period, the 1925 earthquake, and its three moderate magnitude aftershocks.

The March 1st, 1925, M 6.2 Charlevoix earthquake and its aftershocks

The largest earthquake of the period was the 1925-03-01 **M** 6.2 earthquake and its macroseismic impact is described in Lamontagne et al. (2021). This earthquake was followed by a large number of felt aftershocks including three in the **M** 4.6-4.7 range but since they did not cause any damage, they are not included in this OF. These events are (with magnitudes and event number from Bent, 2009): 1925-03-06 **M** 4.7 (83); 1925-03-01 **M** 4.6 (93); and 1925-03-21 **M** 4.6 (94). For two of these earthquakes, Smith (1966) assigns MMIs of V and VI based on Hodgson (1950). Strangely, this source does not contain any indication of the impact corresponding to MMI V-VI (ex: fallen knickknacks, minor cracks in walls).

This is the verbatim of these three aftershocks from Smith (1966):

> "1925 FEBRUARY 28. 11:30:42 p.m. **VI**. Aftershock of No. 282. Felt at La Malbaie, Tadoussac, Chicoutimi, Baie-St-Paul, Quebec City, Lévis and Trois-Pistoles, Que., and recorded at Ottawa.
>
> 1925 MARCH 6. 9:30 p.m. **V**. Aftershock of No. 282. Felt at Pointe-au-Pic. Trois-Pistoles, Rivière-du-Loup, St-Pacôme, Rivière-Ouelle, Tadoussac, Chicoutimi and La Malbaie, Que., and recorded at Ottawa.
>
> 1925 MARCH 21. 10:22:04 a.m. **VI**. Aftershock of No. 282. Reported as felt on board an icebreaker near Richelieu Rapids. Felt also at Misère, St-Adalbert, St-Donat, Rivière-du-Loup, La Malbaie, Ha! Ha! Bay and Quebec City, all in Quebec. Registered on the Ottawa seismograph."

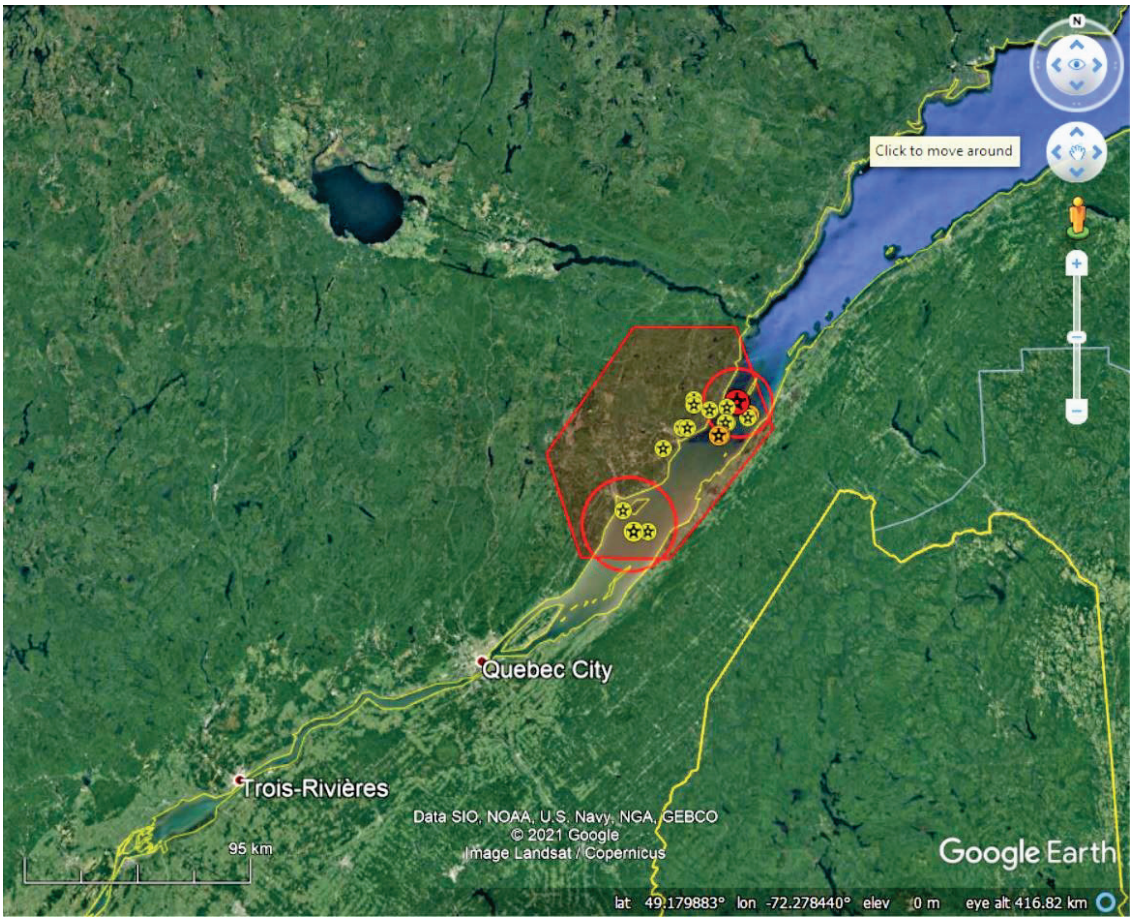


Figure 1. Location map of the CSZ (red hexagon) and of the epicentres of the last six moderate earthquakes studied in this report, plus that of the 1925 earthquake and those of the magnitude m_bL_g 4.0 and larger earthquakes of the period 1978 to 2020. The colours of the epicentres refer to their m_bL_g or **M** (for our seven larger events) magnitudes: 4.0 to 4.49: yellow; 4.5 to 4.99: orange; and **M** 5 and above: red. See Figure 3 for additional explanations on the earthquake epicentres (stars) and zones of concentrated epicentres (circles).

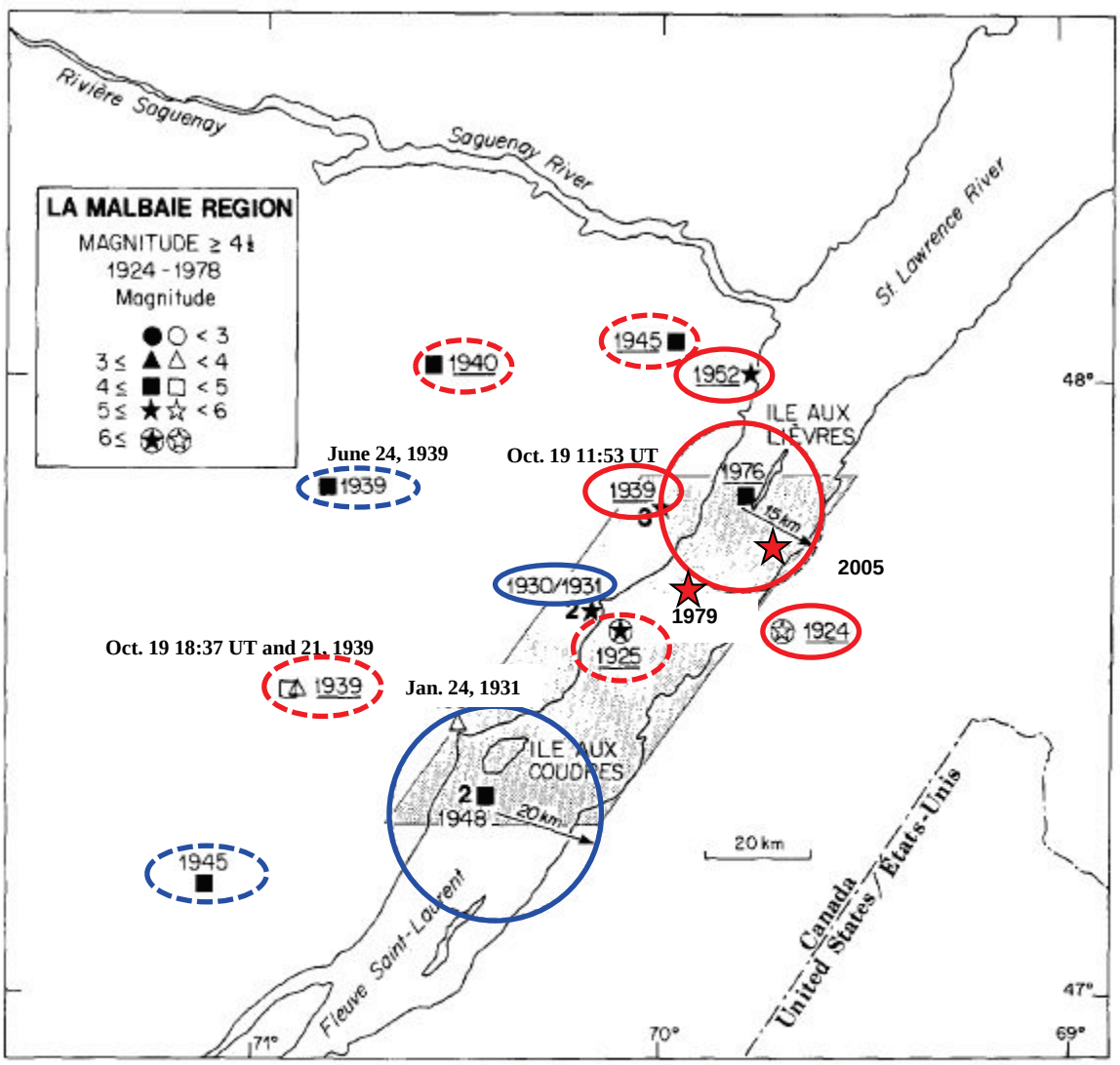
Epicentres

The epicentres of the 1924, 1931, 1939 and 1952 earthquakes (but not the 1902 event for reasons described below) were listed in Smith (1966). Using relative arrival times at stations at regional distances, Stevens (1980) relocated the epicentres and proved that they concentrated at the NE and SW extremities of the seismic zone (called Ile-aux-Lièvres at the NE and Ile-aux-Coudres at

the SW; Figure 2).

Date and Time (UT) (*)	Mag **M**	Latitude	Longitude	Other Magnitude	Number of Data Stns	Phases	Mag.
30 Sep 1924 08:52:30	**5.2**	**47.6**	**69.7**	**M_L 6.1**	**1**		
				$m_b(L_g)$ 5.5			
01 Mar 1925 02:19:20	6.2	47.6 ± 0.4	70.1 ± 0.5	Ms 7		29	58
25 Dec 1930 22:07:34 *		**47.63 ± 0.32**	**70.17 ± 0.30**	**M 4.6**	**3**	**6**	**0**
08 Jan 1931 00:13:37 *	**4.9**	**47.63 ± 0.32**	**70.17 ± 0.30**	**M 5.4**	**3**	**6**	**0**
24 Jan 1931 12:29:12 *		47.45	70.50	M_L 3.4	2	4	1
24 Jun 1939 17:20:21		47.83 ± 0.25	70.83 ± 0.25	M_L 4.8	4	13	2
19 Oct 1939 11:53:58	**5.3**	**47.80 + 0.17**	**70.00 ± 0.30**	**M 5.8**	**6**	**10**	**0**
				$m_b(L_g)$ 5.6			
19 Oct 1939 14:12:16		47.8	70.0	M_L 3.4	1	1	1
19 Oct 1939 18:37:23		47.5 ± 0.5	70.9 ± 0.8	M_L 3.5	2	4	2
21 Oct 1939 08:07:14		47.50 ± 0.58	70.92 ± 0.75	M_L 4.0	6	10	2
27 Oct 1939 01:36:36		47.80 ± 0.17	70.00 ± 0.30	M_L 5.2	5	14	2
13 Oct 1940 19:50:51		48.03 ± 0.20	70.57 ± 0.25	M_L 4.7	5	11	2
18 Jun 1945 15:20:07 *		47.18 ± 0.17	71.12 ± 0.20	M_L 4.7	4	11	2
09 Oct 1945 13:18:44		48.07 ± 0.25	69.97 ± 0.30	M_L 4.9	4	10	3
01 Jan 1948 18:33:45 *		47.33 ± 0.30	70.43 ± 0.25	M_L 4.9	5	14	2
01 Jan 1948 18:44:40 *		47.33 ± 0.30	70.43 ± 0.25	M_L 3.2	3	4	2
14 Oct 1952 22:03:42	**4.5**	**48.02 ± 0.08**	**69.78 ± 0.08**	**M_L 5.6**	**8**	**8**	**3**
				$m_b(L_g)$ 4.9			
23 Oct 1976 20:58:18		47.82 ± 0.02	69.79 ± 0.03	M_N 4.2	38	59	17
19 Aug 1979 22:49	**4.8**	**47.67**	**-69.90**	**M_N 5.0**	**8**	**13**	**10**
06 Mar 2005 06:19:47	**4.7**	**47.753**	**-69.732**	**M_N 5.4**	**7**	**13**	**31**

Table 1. Earthquakes shown in Figure 2. This table is an update with two additional significant earthquakes (in blue) to those of Stevens (1980). All earthquakes locate in the NE zone of larger earthquakes except six of them indicated with a star (*) which locate in the SW circle. The last three columns (Number of Data) refer to the number of: stations (stns) that recorded the event; phases (Phases) used to locate the epicentre; and stations used to compute the magnitude (Mag).



The 18 events studied for this report identified by year and magnitude range. See Table 1 for details. All known earthquakes in this region and period with magnitude ≧4½ are included. A boldface digit beside an epicenter gives the number of earthquakes with the same published epicenter. A filled symbol indicates an epicentral uncertainty not more than 40 km according to the relevant catalog. An open symbol indicates greater uncertainty. An underlined date denotes the 11 earthquakes relocated near Ile aux Lièvres. The remainder (except June 1945) are relocated near Ile aux Coudres. The dashed circles mark the approximate source areas of the relocated events. The shaded area is the microearthquake zone of Figures 6 and 8. For details see the Results section.

Figure 2. This is an update to Figure 9 of Stevens (1980), modified to include the locations of all 6 earthquakes described in this OF. The earthquake parameters are given in Table 1. Stevens (1980) proved that all moderate earthquakes of the period 1924-1980 located in two zones at both extremities of the seismic zone (large circles: red in the NE and blue in the SW). Of the six main earthquakes under study, five locate within the red circle (solid red circle) whereas the 1939 earthquakes (main shock and foreshock; solid blue circle) locate in the SW zone. Other earthquakes studied by Stevens (1980) are stippled circles either blue or red depending on their

relocated epicentres. The epicentres of the 1979 and 2005 earthquakes (red stars) are more precise because they were located with the local seismograph network unlike the previous ones that were located with data from more distant stations.

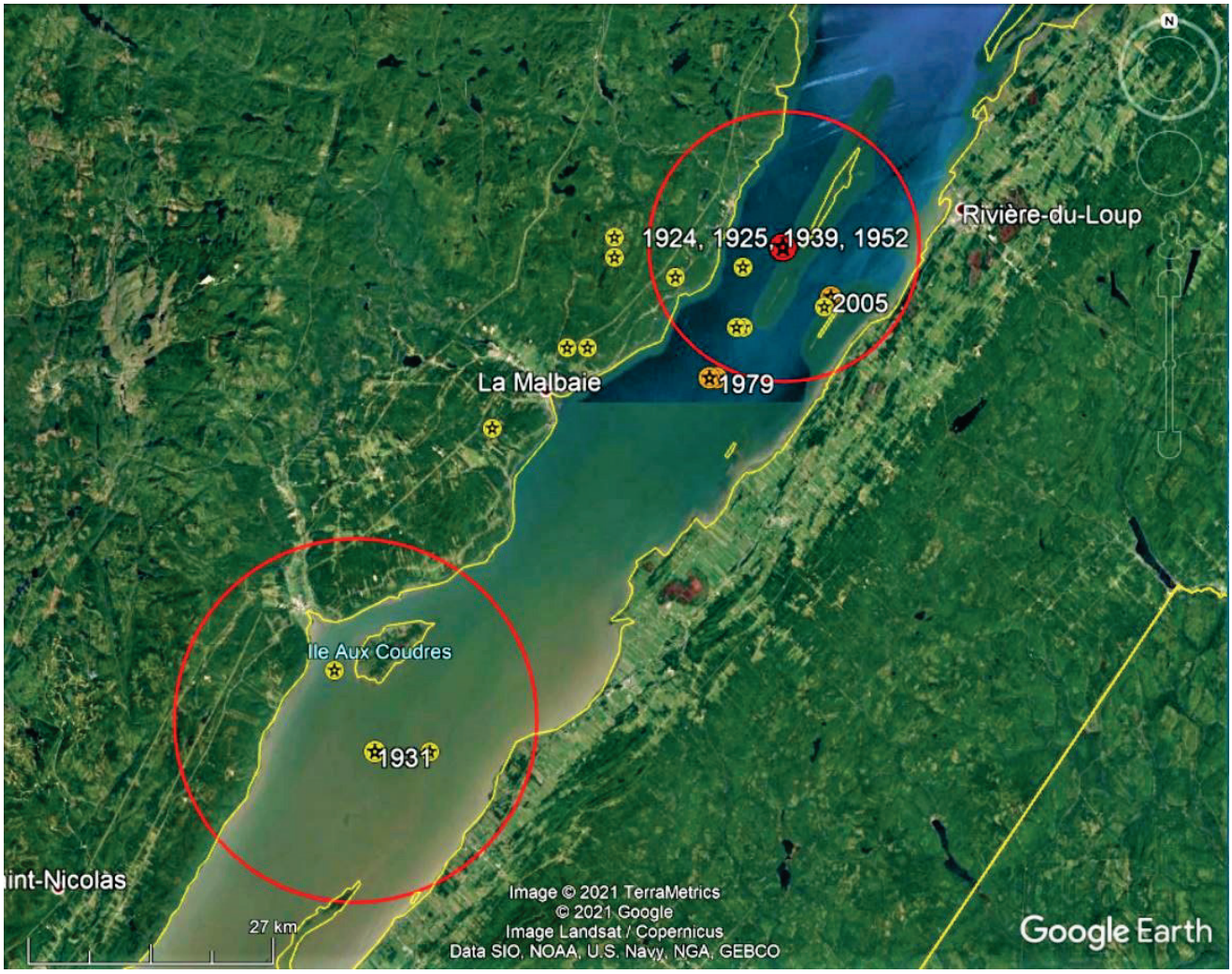


Figure 3. Location map of the epicentres of the six earthquakes studied in this report, that of the 1925 earthquake and those of the magnitude 4.0 and larger earthquakes of the period 1978 to 2020. The colours of the epicentres refer to their m_bL_g or **M** (for our seven larger events) magnitudes: 4.0 to 4.49: yellow; 4.5 to 4.99: orange; and **M** 5 and above: red. The two circles are from Stevens (1980) and represent where epicentres of the period 1924-1978 concentrated (near Ile-aux-Lièvres at the NE and Ile-aux-Coudres at the SW; see Figure 2).

The moderate CSZ earthquakes

The following sections describe the seven moderate earthquakes. For each one, the sources of the macroseismic information are given. The newspaper accounts were obtained from local libraries (special thanks to our colleague Alexandra Lewis), or scanned either from online resources (such as the Bibliothèque et Archives nationales du Québec[1]
or from the scrapbooks of the Dominion Observatory (Lamontagne and Szadurski, 2021). For each earthquake, the scanned accounts are found in the subfolders "newspapers". Although it is out of chronological order, the 1902 earthquake is described last as its interpretation depends on knowledge of the other earthquakes.

The September 30, 1924, M 5.2 earthquake (NE source area of the CSZ)

The September 30, 1924 occurred in the NE area of the CSZ (Figure 3) and its **M** is 5.2 (event no. 40 of Bent, 2009). It occurred at 3:54 am local time when most people were in bed. Consequently, most people who felt it had to be awakened by the vibrations, which explains that most felt reports are MMI IV or more. It was felt over a large area that includes most of the St. Lawrence River valley of Quebec and Ottawa (Ontario) and Fredericton (New Brunswick). It was also sporadically felt it in the northeast United States. Figure 4 shows the macroseismic map of Gouin (2001). Because its epicentre lies in the same area where the March 1st 1925 **M** 6.2 Charlevoix earthquake occurred six months later, it is possible that the 1924 earthquake may have been a foreshock to the much larger 1925 earthquake.

The lists below provides the newspapers that included felt information. While most were available to Gouin (2001), some additional ones were found providing felt information from two additional localities and more detailed information in Ottawa, ON. Felt information exists for a total of 24 Canadian localities and 24 US communities (from NOAA). It is unknown how the earthquake was felt in the largest nearby community, Rivière-du-Loup, as mentioned in Gouin (2001). The reason is simple: the newpaper "La Gazette des campagnes" was not published in

[1] https://numerique.banq.qc.ca

1924 and a local newspaper ‘Le Journal de Fraserville’ ceased publication in 1913.

Figure 5 shows the new macroseismic map. In Canada, the maximum MMI was V which generally corresponds to the fall of small objects. Since we do not have the detailed macroseismic information from American communities, many MMI V, including some at more than 500 km epicentral distances, were probably rated differently than in Canada where the fall or displacement of small objects corresponds to MMI V.

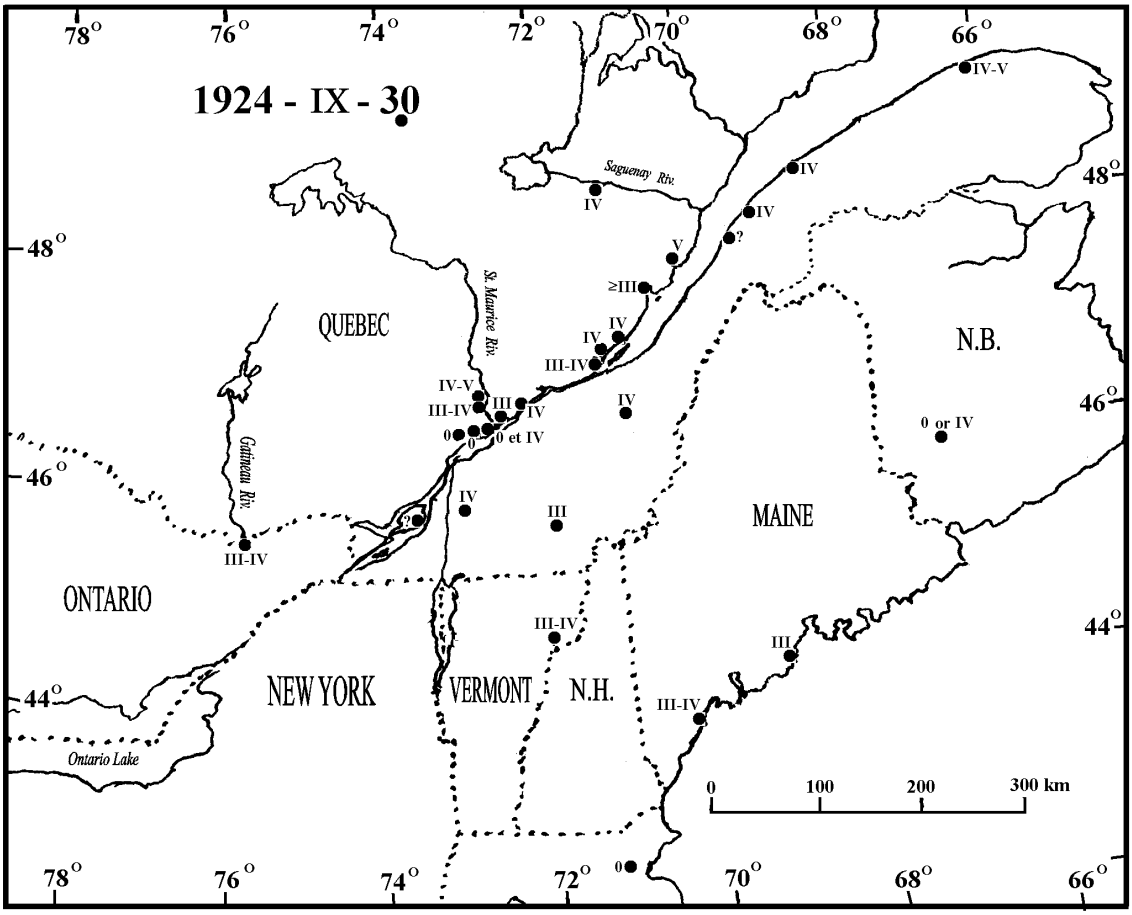


Figure 4. Municipalities where the September 30, 1924, earthquake was felt (intensities on the MMI scale, Gouin 2001).

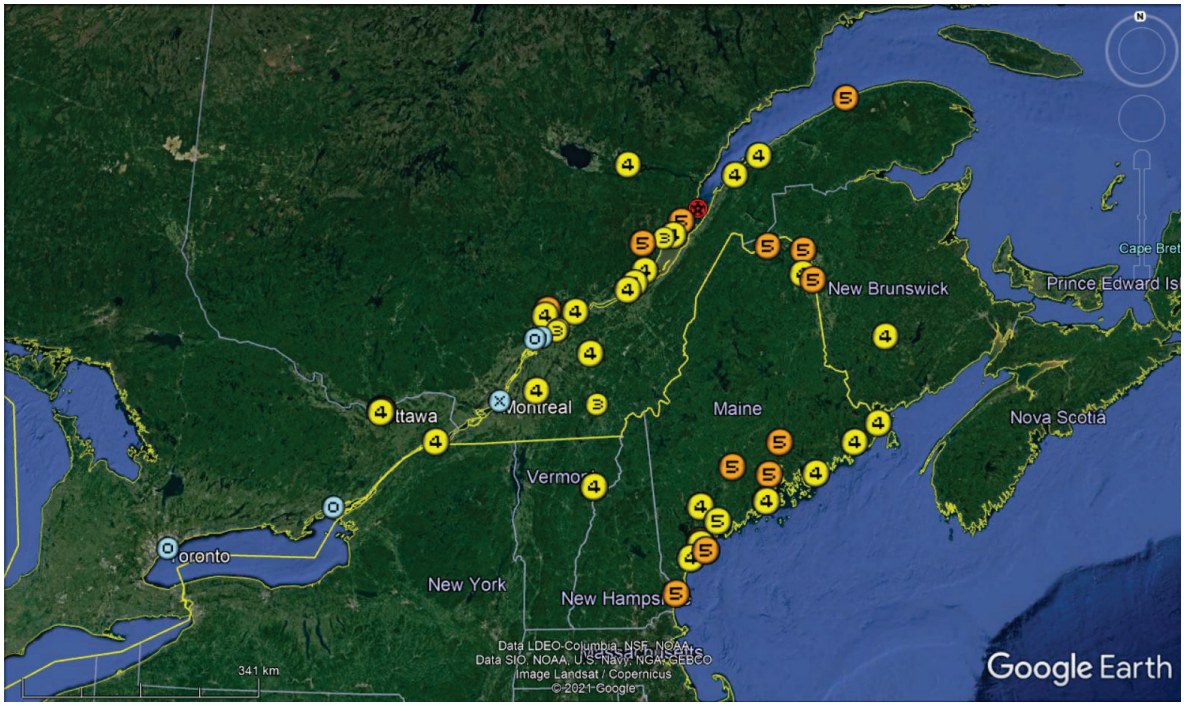


Figure 5. For the September 30th, 1924, Charlevoix earthquake, static image of Google Earth view generated from the kml file that shows the distribution of felt reports on the MMI scale. Numbers refer to the MMI level, (0) means not felt; (X), no report.

List of newspapers used by Gouin (2001). The copies of the newspapers included in this OF are in bold.

***19240930 The Citizen*, Ottawa**

***19240930 Le Soleil*, Québec**

http://numerique.banq.qc.ca/patrimoine/details/52327/3450779

***19240930 Le Nouvelliste*, Trois-Rivières**

http://numerique.banq.qc.ca/patrimoine/details/52327/3204611

***19240930 La Patrie*, Montréal**

***19240930 Le Droit*, Ottawa**

***19240930 The Globe*, Toronto**

***19240930 La Patrie*, Montréal**

***19241001 The Globe*, Toronto**

***19241002 Le Progrès du Saguenay*, Chicoutimi**

http://numerique.banq.qc.ca/patrimoine/details/52327/2616294

19241003 Le Progrès du Golfe, Rimouski

Additional newspapers found with clippings included in the folder: 1924/newspapers:

19241002 L'Union des Cantons de L'Est: journal politique, industriel, littéraire et agricole http://numerique.banq.qc.ca/patrimoine/details/52327/2685599

19240930 La Tribune
http://numerique.banq.qc.ca/patrimoine/details/52327/3505614

19240930 Sherbrooke Daily Record
http://numerique.banq.qc.ca/patrimoine/details/52327/3092525

19240930 La Presse
http://numerique.banq.qc.ca/patrimoine/details/52327/3100762

19240930 Le Devoir
http://numerique.banq.qc.ca/patrimoine/details/52327/2801989

19240930 L'Action Catholique : organe de l'Action sociale catholiquehttp://numerique.banq.qc.ca/patrimoine/details/52327/3516427

19240930 The Ottawa Citizen

19240930 Le Droit
https://numerique.banq.qc.ca/patrimoine/details/52327/4148065?docpos=16

19240930 Daily British Whig, Kingston, ON (Describes impact in Sherbrooke and Vallée-Jonction, nothing on local impact).

19241002 Standard Freeholder, Cornwall, ON

The following newspapers did not mention the earthquake:

19241002 L'Étoile du Nord (Joliette)

19241002 La Gazette du Nord (Abitibi)

19241002 Le Colon (Roberval)

19240930 Le Canada (Montréal)

19240930 Le Bien Public (Trois-Rivières)

19241004 Pembroke Observer

The January 08, 1931, magnitude M 4.9 earthquake (SW source area of the CSZ)

The magnitude **M** 4.9 earthquake occurred on January 7th, 1931 at 19:13 (7:13 p.m.) local time and is Event no. 61 of Bent (2009). The relocation by Stevens (1980) puts its epicentre in the SW circle of larger earthquakes (near Baie-Saint-Paul). Consequently, this earthquake is not located near the epicentre of the 1925 earthquake which occurred in the NE corner of the CSZ. As described below, it was preceded by a foreshock with similar location on 25 December 1930. The 1931 earthquake was felt most strongly near the epicentre, most notably in Baie-Saint-Paul (north shore of the St. Lawrence River) and Rivière-Ouelle (south shore of the St. Lawrence River). In these places, newspapers reported no serious damage but that pendulum clocks were stopped, books fell from shelves and picture frames moved (MMI V). According to the newspaper accounts, it had a strong psychosocial impact on local inhabitants who probably remembered the earthquake sequence of the February 28, 1925 **M** 6.2 earthquake. Surprisingly, it was also felt at the MMI V level in municipalities of the north shore of the St. Lawrence River up to Quebec City, and then in Trois-Rivières, Montreal (Westmount) and Ottawa (at 550 km distance). The spreadsheet provides the details.

In terms of the magnitude of the main shock, this event has a **M** of 4.9 (Bent, 2009). This value was estimated by EPRI based on instrumental M_L (exact details unknown but it appears to be based on m_b magnitudes and their own regional magnitude (5.0; A. Bent, pers. comm. 2021). This M_L magnitude was also listed in Smith (1966) who refer to Gutenberg and Richter (1954) as the source.

Based on Smith (1966), we deduce that intensity questionnaires were not sent to postmasters, and an isoseismal map was never drawn. Our macroseismic map is shown in Figure 6.

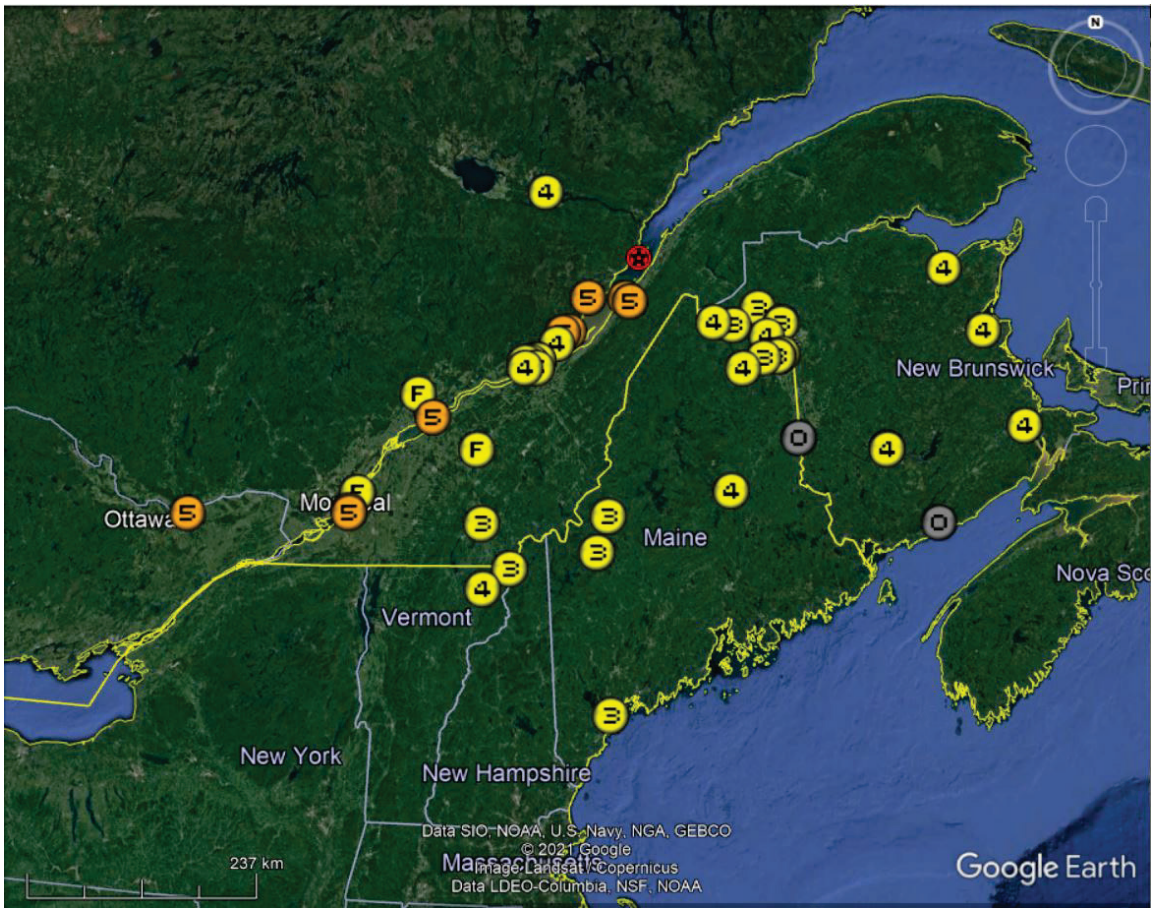


Figure 6. Static image of Google Earth view showing distribution of felt reports for the 1931 Charlevoix earthquake and generated from the kml file. Numbers refer to the MMI level, (0) means not felt.

Interestingly, this moderate earthquake was preceded by a magnitude 4.6 (M_L) foreshock (**M** 4.2; Halchuk et al., 2015) on Dec. 25, 1930 at 17:07 local time which was also felt over a wide sector of the province of Quebec, most strongly in the Baie-St-Paul area (MMI V; no damage) but also over a large area from Chicoutimi to the north and Montreal to the south (Smith, 1966) and in Madawaska, NB (newspaper account). A separate sheet with the macroseismic information of the foreshock is included and the felt report locations are shown in Figure 7. Smith (1966) describes the impact of the foreshock as follows:

> 1930 DECEMBER 25. 22:07:34. M = 4.6. 47°38'N ±19', 70°10'W±18'.
> Near La Malbaie, Que. Felt over a wide sector of the province of Quebec, including

Chicoutimi to the north and Montreal to the west, but most strongly in the Baie-St-Paul area. It may be regarded as a foreshock of a more severe earthquake that occurred at the same location on January 8, 1931.

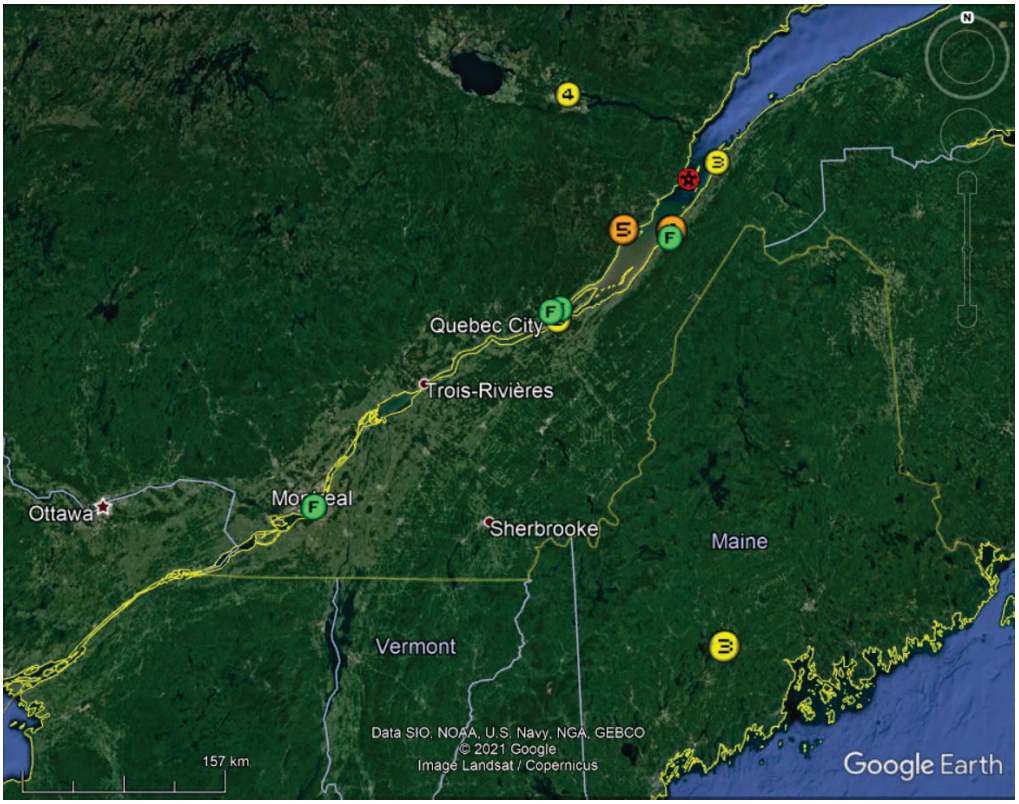


Figure 7. Static image of Google Earth view showing distribution of felt reports for the Dec. 25, 1930 foreshock generated from the kml file. Numbers refer to the MMI level, (F) means felt, no details.

An earthquake of magnitude M_L 3.4 was recorded on January 24th, 1931(Smith, 1966). According to Stevens (1980), its epicentre was in the NE portion of the CSZ, indicating that it was not an aftershock of the January 8th earthquake (see Figure 3).

List of newspapers consulted (Note: all are available in the folder 1931/newspapers; in bold, newspapers with useful macroseismic information). The newspaper accounts were obtained using the online resources as well as the scrapbooks of the Dominion Observatory (Lamontagne and

Szaduski, 2021).

- **Le Soleil, Québec 19301226 (foreshock); 19310108**
- **Le Madawaska, Madawaska, NB 19301226 (foreshock); 19310108**
- L'Action Catholique, Québec 19310108
- **Le Progrès du Saguenay, Chicoutimi 19310108**
- La Gazette du Nord, Amos 19310108
- **Le Bien Public, Trois-Rivières 19310108**
- **Le Nouvelliste, Trois-Rivières 19310108**
- **La Patrie, Montréal 19310108**
- **Montreal Gazette, Montreal 19310108**
- **Montreal Star, 19310108**
- **La Presse, Montréal, 19301226 (foreshock); 19310108**
- Le Canada, Montréal 19310108
- Le Devoir, Montréal 19310108
- **La Tribune, Sherbrooke 19310108**
- **Sherbrooke Daily Record 19310108**
- Le Droit, Ottawa 19310108
- **Ottawa Citizen, Ottawa 19310108**
- **Peterborough Evening Examiner 19310108 (Nothing local; Canadian Press Report)**
- **The Globe, Toronto 19310108 (Nothing local; Canadian Press Report)**
- **Daily Gleaner, Fredericton 19310108 (nothing local, report on seismograph in Halifax)**
- **US: Boston Globe, Boston, MA 1931-01-08.**

No mention of the earthquake in these newspapers:

- Le Clairon de St-Hyacinthe 8 janvier;
- Le Colon de Roberval 8 et 15 janvier;
- Écho du Saint-Maurice 8 et 15 janvier 1931 : not available;
- L'Étoile du Nord, Joliette 8 janvier 1931;
- Le Peuple, Montmagny; 9 janvier 1931,

- Le Progrès du Golfe, Rimouski; 9 janvier 1931,
- L'Évangéline, 8 janvier 1931; Moncton, Nouveau-Brunswick;
- Pembroke Observer: nothing in January 9, 1931 issue.
- Cornwall Freeholder: nothing in editions of January 10, 1931 and January 14, 1931.

The US data from the NOAA database are listed in the USA sheet. Strangely, in the NOAA database, the epicentre for this earthquake was incorrect: it is listed as latitude 50.° N and 74.° W with the same date and time and approximate magnitude (5.6). We deduced that the latitude and longitude that are listed in the database are in error but that the felt information applies to the Charlevoix earthquake. We notified NOAA but believe that there is little chance that the entries will be updated as the database is not maintained anymore. According to Smith (1966), the US data come from the Annual publication of the U.S. Coast and Geodetic Survey, 1928-1959 and were prepared by F. Newmann.

Smith (1966) describes its impact as follows:

> *1931 JANUARY 8. 0:13:37. M=5.4 (G3). 47°38'N±19', 70°10'W±18'.*
> *Near La Malbaie, Que.*
> *Felt most strongly in the Baie-St-Paul and La Malbaie areas. A clock in a convent at Riviere-Ouelle was stopped.*
> *Books were shaken from the shelves of the Technical College library in Quebec City.*
> *A vase containing flowers was topped* (sic: toppled) *over at Westmount, Que.*
> *Houses and window panes rattled in Ottawa, Ont.*
> *The shock was felt at Island Pond, Vt., and at Caribou, Van Buren and Madawaska etc., in northern Maine, as well as at Edmundston, N.B.*

The October 19, 1939, M 5.3 earthquake (NE source area of the CSZ)

The October 19, 1939, earthquake occurred at 6:53 a.m. (local time) when most people were awake. The original epicentre position (47.8°N ± 0.17, 70.0°W ± 0.3) was relocated by Stevens (1980) to be in the NE portion of the CSZ (47.8, -69.8). **M** is rated at 5.2 and m_b(Lg) at 5.6 (Ebel, 1986; and event no 37 of Bent, 2009).

Concerning the macroseismic data, Smith (1966) writes: "Only 28 filled questionnaires were available and in numerous cases several came from the same locality." These original questionnaires are considered lost. Smith's isoseismal map is reproduced as Figure 8.

Smith (1966) add: "A few reports from newspapers (S2: Note: the scrapbook) were also used." The Observatory scrapbook only contained reports from the Ottawa Journal and the Ottawa Citizen (copies of the clippings are included in folder 1939/newspapers).

Based on this macroseismic information and the abstract of Innes (1940), Smith (1966) described this events as follows:

> *"1939 OCTOBER 19. 11:53:58. M=5.8 (G3). VI.*
> *47°48'N ± 10', 70°00'W ± 18'. About 12 miles northeast of La Malbaie and 22 miles west of Riviere-du-Loup, Que.*
> • *The shock was felt from Lake Erie eastward to Moncton, N.B., and from the Lake St. John area of Quebec southward to Connecticut.*
> • *Considering the size of the area over which the tremors were felt, damage in the epicentral region was relatively small.*
> • *Chimneys were damaged at Riviere-Ouelle and La Malbaie. At the latter place some brick walls were cracked and minor damage to machinery occurred.*
> • *Small ground fissures were reported from the Tadoussac area.*
> • *An isoseismal map is shown…*(our Figure 8).
> • *The United States section is adapted from United States Earthquakes, 1939 (U1).*
> • *The data on which the Canadian part is based are insufficient. Only 28 filled questionnaires were available and in numerous cases several came from the same locality.*

- *A few reports from newspapers (S2) were also used."*

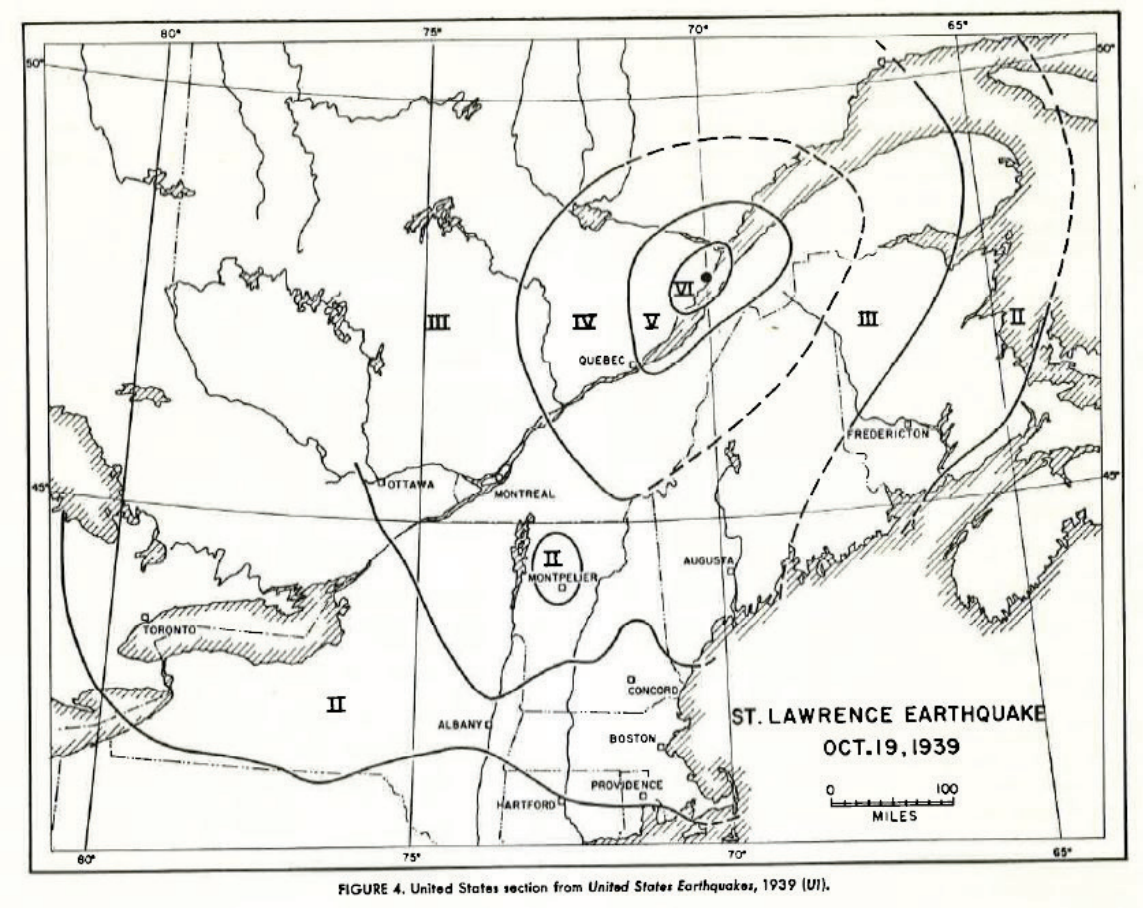


FIGURE 4. United States section from *United States Earthquakes, 1939* (U1).

Figure 8. Isoseismal map of the 19 October 1939 Charlevoix earthquake on the MMI scale (Smith, 1966). Isoseismals are drawn as solid lines when well defined by data and dashed when approximate.

The earthquake had a considerable impact over a large region (figures 9 and 10). A Canadian Press article reports a one inch-wide (2.5 cm) and 200 foot-long (60 m) crevasse. The article appeared in the newspapers Le Soleil and in The Montreal Gazette of October 21, 1939. The way the article is written gives the impression that crevasses were also reported 50-60 miles (90-100 km) north of Tadoussac in isolated lumber camps. The French and English versions differ: thin fissures are reported in the walls in Tadoussac in Le Soleil, whereas the English version mentions fissures 'in the district'.

Damage was reported in La Malbaie: chimneys and walls were cracked according to the newspapers Le Soleil and The Montreal Gazette. We suspect that the chimney damage in Rivière-Ouelle reported

by Smith (1966) must have been reported in the questionnaires because no newspaper mentions it. In St-Urbain, houses were fairly strongly shaken with many fallen chimneys and locals reported it to be as violent as during the 1925 M 6.2 earthquake. In Rivière-du-Loup, the closest town to the epicentre, about 20 chimneys were damaged, moved or fell; many windows, show windows and showcases were broken; a church vault was damaged and plaster fell from the ceiling; children in church panicked, faintings were reported, shelves were partly emptied, causing thousands of dollars of damage. No injuries were reported.

Outside the CSZ, the earthquake had limited impact: some displaced and fallen knickknacks were reported in Quebec City and crooked picture frames in St-Hyacinthe (MMI V). Surprisingly, however, this earthquake was also strongly felt in Ottawa, some 520 km away, where macroseismic information suggests a maximum intensity of MMI V (picture frames moved, furniture shifted). Additional description of this earthquake in Ottawa can be found in Lamontagne et al. (2008) and Lamontagne (2010). Elsewhere, MMIs never exceeded MMI IV.

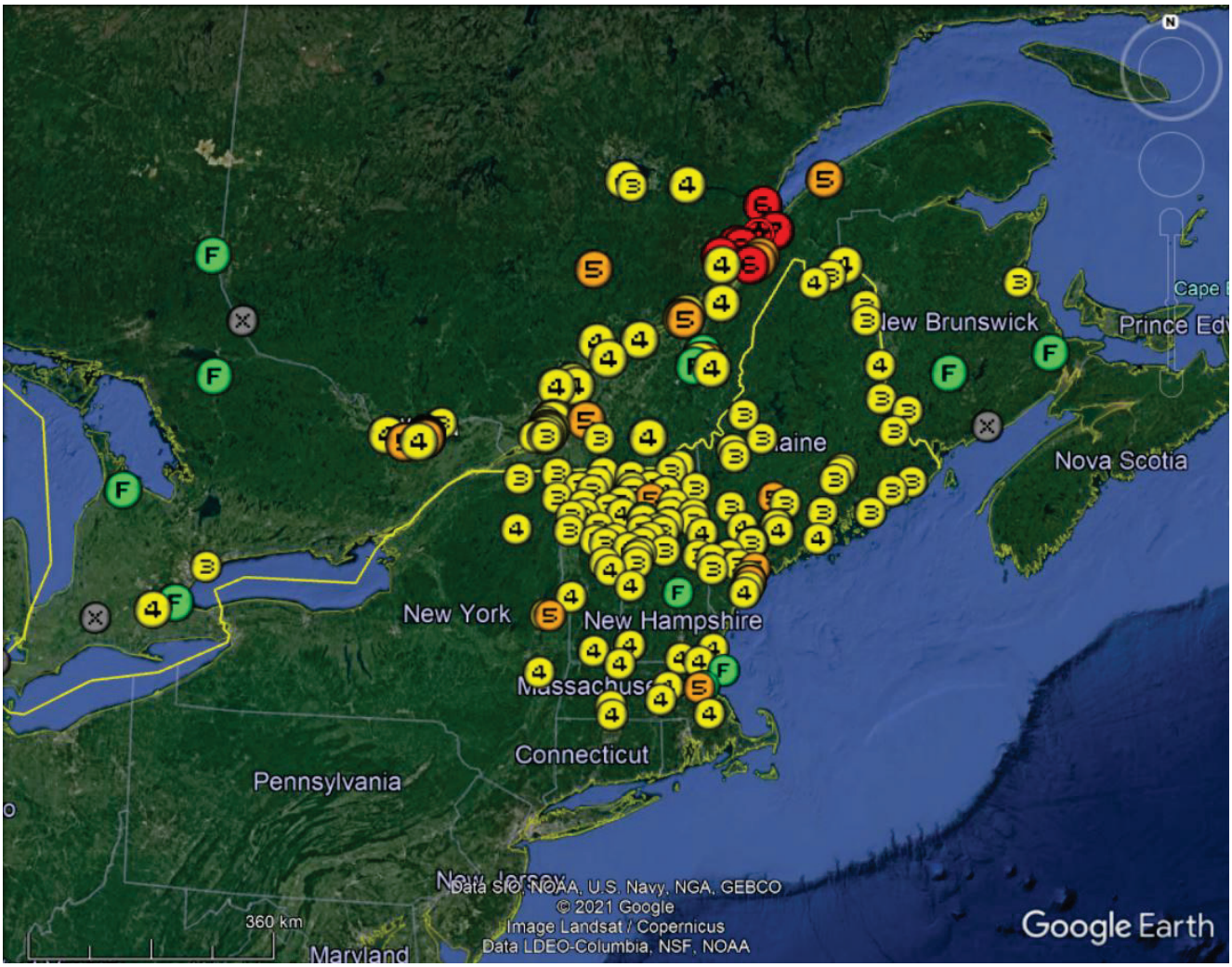


Figure 9. Static image of Google Earth view showing distribution of felt reports for the **M** 5.3 October 19, 1939 earthquake and generated from the kml file. Numbers refer to the MMI level; (F) means felt, no details; (X) means no report.

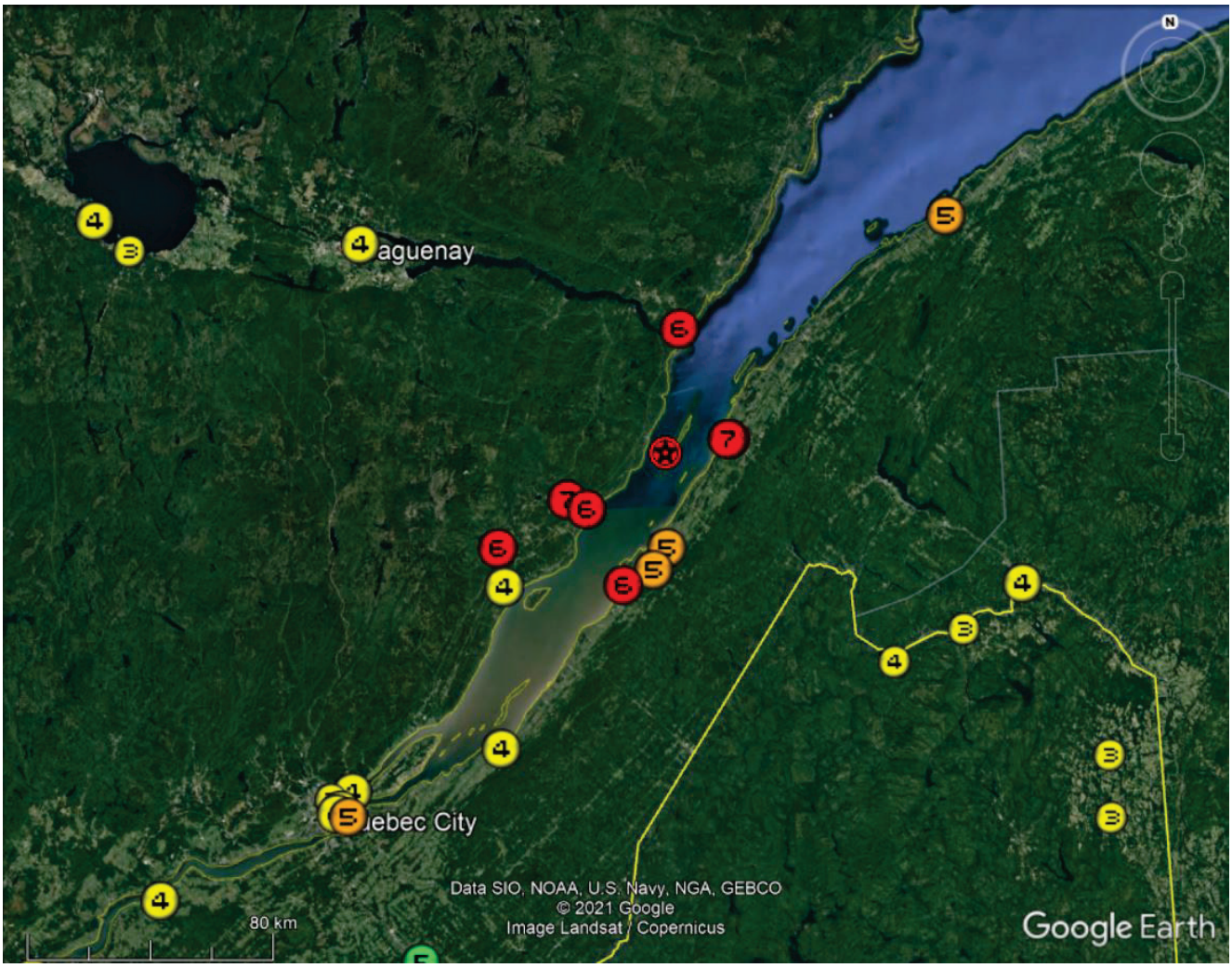


Figure 10. Static image of Google Earth view showing distribution of felt reports for regions surrounding the epicentre of the October 19, 1939 earthquake and generated from the kml file. Numbers refer to the MMI level; (F) means felt, no details.

List of newspapers consulted (all available in folder 1939/newspapers)

19391019 Le St-Laurent, Rivière-du-Loup

19391019 Le Soleil, Québec (1st et 2nd edition)

19391019 L'Action Catholique, Québec

19391019 Le Progrès du Saguenay, Chicoutimi (Saguenay)

19391019 Le Devoir, Montréal

19391019 La Patrie, Montréal

19391020 Le Progrès du Golfe, Rimouski
19391019 Montreal Gazette

19391019 Le Madawaska, Edmundston, NB
19391025 Campbellton Graphic, Campbellton, NB
19391025 Campbellton Tribune, Campbellton, NB

19391019 Le Droit, Ottawa, ON
19391019 Ottawa Journal, ON
19391019 Ottawa Citizen, ON
19391019 Globe and Mail, Toronto, ON
19391019 Peterborough Examiner, ON
19391019 Windsor Star, Windsor, ON

19391020 La Patrie, Montréal, QC
19391021 Le Soleil, Québec, QC

The October 14, 1952, M 4.5 earthquake (NE source area of the CSZ)

The October 14, 1952, Charlevoix earthquake was felt in many communities of the St. Lawrence estuary and neighbouring regions. On both shores of the St. Lawrence River, some minor damage, such as fallen objects (MMI V), were reported. Because of the minor damage, this earthquake was included in the list of significant earthquakes of Canada (Lamontagne et al., 2017; event no. 109 of the list of Bent, 2009). The epicentre of this earthquake was relocated near Ile-aux-Lièvres by Stevens (1980).

The original description by Smith (1966) is as follows:

> *"1952 OCTOBER 14. 22:03:42. ML=5.6. 48°01'±5', 69°47'W ± 5'. On the north shore of the St. Lawrence River about 10 miles south of Tadoussac, Que., and about 20 miles ″note: (32 km)″northwest of Rivière-du-Loup, Que. The origin time and coordinates given were*

calculated by Hodgson (1950) from the first-arrival time data of eight seismograph stations. The complexity of the seismic traces suggested a double shock, but this could not be definitely established. The tremors were felt generally in an area along both sides of the St. Lawrence River, from Trois-Rivières to Cap-Chat and extending northward to Lake St. John and southward into Maine and New Brunswick. A maximum intensity of V occurred in the Rivière-du-Loup area, where dishes were jarred from shelves.

Questionnaires distributed in Canada produced more than 300 replies that the shock was felt. A similar canvass of adjacent parts of the United States was conducted through the courtesy of the United States Coast and Geodetic Survey. The results are shown as isoseismals in Figure 5 (Note: our Figure 11)*, which has been adapted from Hodgson (H21). The limits of perceptibility were poorly defined, as indicated by broken lines."*

Unlike the October 19, 1939, M 5.3 earthquake, it was not felt in Ottawa, Toronto or in eastern NB, in agreement with its lower magnitude (**M** 4.5). The USGS data that we added makes us wonder what data were used by Smith (1966) to draw the isoseismals south of the Canada-US border.

Images of these newspapers are found in the folder 1952/newspaper:

1. **L'Action Catholique : organe de l'Action sociale catholique, 15 octobre 1952; Quebec City; http://numerique.banq.qc.ca/resultats#0000082235f19521015fp3575349**
2. **Le Soleil, 15 octobre 1952; Québec City;**
3. **Le Progrès du Saguenay, 16 octobre 1952; Saguenay (Chicoutimi);**
4. **Le Progrès du Golfe, 19521017; Rimouski**
5. **Le Canada, 15 octobre 1952; Montréal;**
6. **Le Devoir, 15 octobre 1952; Montreal; http://numerique.banq.qc.ca/patrimoine/details/52327/2782156**
7. **Montreal Gazette, 15 October 1952; Montreal;**
8. **Le Droit, 15 octobre 1952: http://numerique.banq.qc.ca/patrimoine/details/52327/4060188; Ottawa**
9. **The Evening Ottawa Citizen, 15 October 1952; Ottawa;**
10. **Daily Gleaner, Fredericton, NB, 15 Oct. 1952;**

There was no mention of the earthquake in:

- Gazette des campagnes : journal du cultivateur et du colon, 16 octobre 1952, jeudi 16 octobre 1952;
- L'Écho du St-Maurice, 16 octobre 1952, jeudi 16 octobre 1952 (Shawinigan, [ca 1915]-1971);
- Le Canada français, 16 octobre 1952;
- Le Clairon, Saint-Hyacinthe; 17 octobre 1952,
- Le Nouvelliste, 15 octobre 1952; Trois-Rivières.
- Sherbroke Daily Record, 15 October 1952; Sherbrooke.

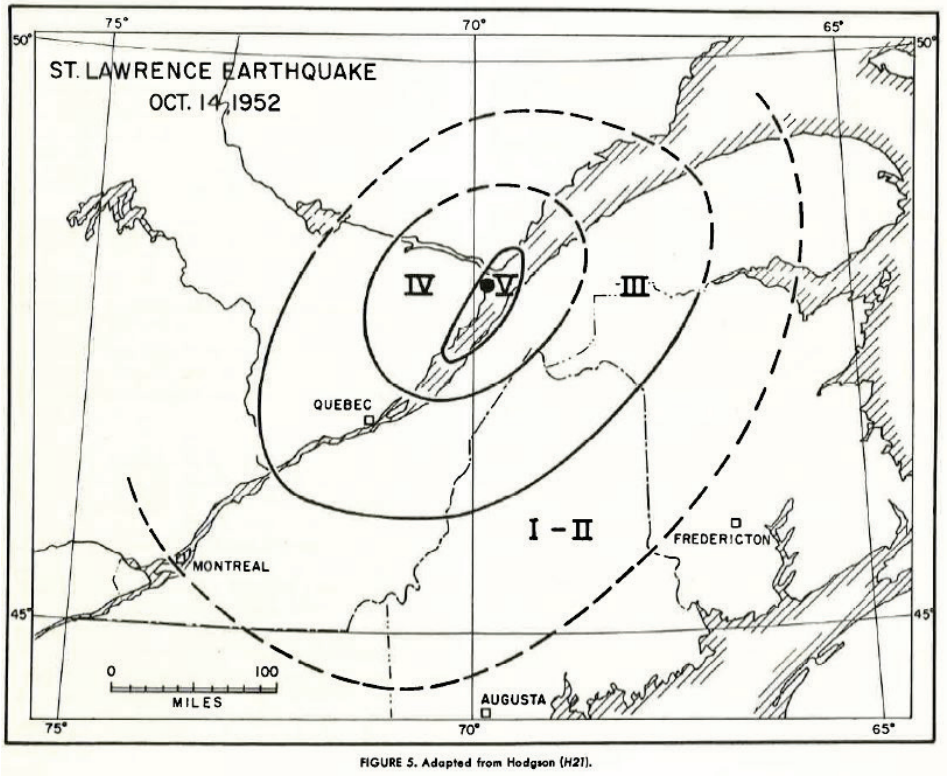


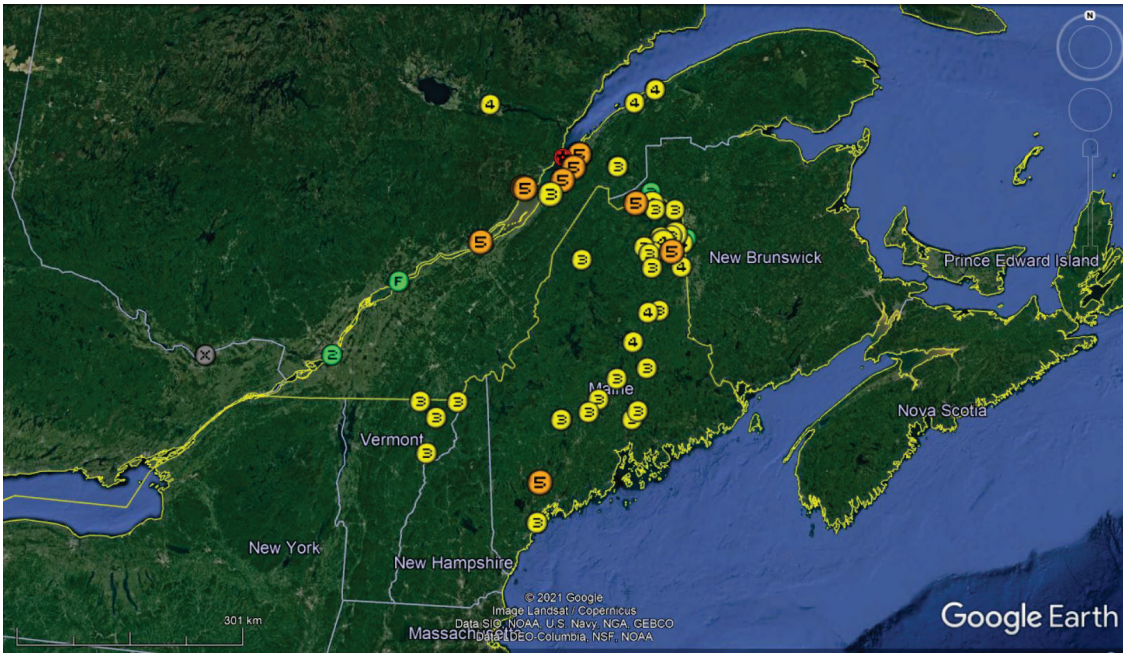
Figure 11. Isoseismal map on the MMI scale of the October 14, 1952, earthquake (Smith, 1966; based on unpublished documents of E.A. Hodgson). Isoseismals are drawn as solid lines when well defined by data and dashed when approximate.

The postmasters of the region where the earthquake was felt were canvassed by a questionnaire and more than 300 replies were received (Smith, 1966). Unfortunately, these questionnaires

cannot be found. For this reason, this OF contains all available information on this earthquake, mainly the descriptions found in newspapers.

Most MMIs were concentrated in the Charlevoix and Kamouraska regions (Figure 12). The only other MMI V in Canada was in the lower elevation parts of Quebec City.

A)



B)

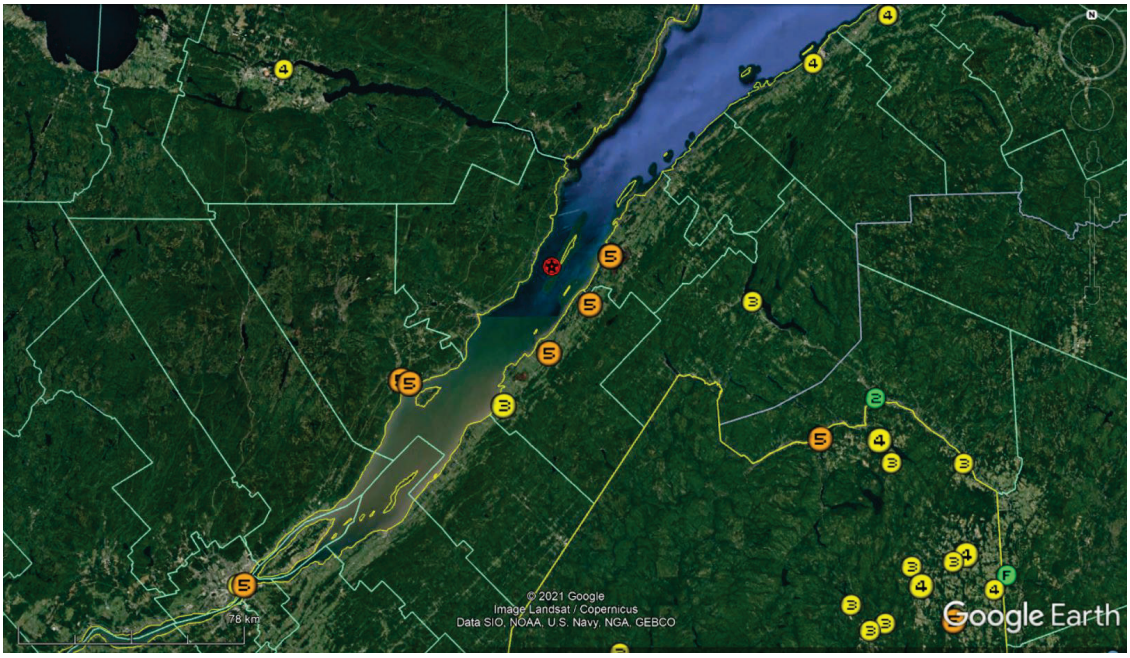


Figure 12. Static images of Google Earth view showing distribution of felt reports for the **M** 4.5 October 14, 1952 earthquake and generated from the kml file. A: all data; B) epicentral region. Numbers refer to the MMI level; (F) means felt, no details.

The August 19, 1979, M 4.8 earthquake (NE source area of the CSZ)

The August 19, 1979, **M** 4.8 earthquake occurred at 18:49 local time (22:49 U.T.). It was rated as $m_b(L_g)$ 5.0 (Hasegawa and Wetmiller, 1980) and **M** 4.8 (Event 78 of Bent, 2009). It was the first time that the main shock of a moderate earthquake and its aftershocks were recorded by the Charlevoix seven-station local microseismic seismograph network (Hasegawa and Wetmiller, 1980). Previous events of the 20th century had only been recorded at regional distances. An isoseismal map was published (Hasegawa and Wetmiller, 1980) along with the following explanations.

> *"Felt reports of the 1979 earthquake were collected in a mailed questionnaire survey supplemented by personal interviews with the residents of the epicentral area. Modified Mercalli (MM) intensities are assigned to each felt report and the results are displayed in Fig. 2* (Note: our Figure 13). *The data allow intensity contours of MM III, IV and V to be reasonably well defined only on the south shore of the St. Lawrence River. On the north shore the poor distribution of data because of the lack of population permits only a tentative assignment of the MM IV and V contours.*
>
> …
>
> *Maximum intensity of this earthquake is MM V at several communities on both the north and south shores. Three damaged chimneys were reported, all located on the north shore, but, in each case, the damage appears to be an isolated incident. Reported chimney damage was not accompanied by other effects such as spilled liquids or broken dishware which would indicate an MM VI level. Communities beyond 200 km were not systematically surveyed so that the total felt area cannot be estimated with any confidence, but the area within the MM IV contour as shown is about 2 x 10^4 km^2. This is approximately one half the area for a $m_b(L_g)$ 5.0 earthquake predicted by Street and Turcotte (1977) but is within the scatter used to define their relationship."*

We intended to gather all macroseismic information on this earthquake. Unfortunately, the original felt report questionnaires and the digital file that led to the creation of the isoseismal map are lost. Consequently, the only remaining information of this survey is the isoseismal map of

Figure 13. The second source of information is the newspaper accounts (described below).

To extract the macroseismic information from the isoseismal map, our GSC colleague Azadeh Ashoori Pareshkoohi georeferenced the map and added the locations of towns and cities (Figure 14). From this, the MMIs of the map could be correlated to the locations of towns and cities indicated as numbers. Sometimes the correlation was clear and unambiguous: in this case, Column R (Basis for MMI (English)) states: "After isoseismal map of Hasegawa and Wetmiller (1980)". In some cases, two or more towns were close to the MMI of the map and the authors chose the most likely location and column R states: "Best estimated location after isoseismal map of Hasegawa and Wetmiller (1980)". All results can be found in the spreadsheet.

A number of newspaper articles were also found (see list below). Since Hasegawa and Wetmiller (1980) do not mention newspapers, we suspect that they did not make use of that information. Based on the newspaper reports, the damage appears to be concentrated in the town of Saint-Siméon, at 18 km epicentral distance. There, there were accounts of damaged chimneys, damaged walls, general fright and power outage. We found that the account of the Quebec City newspaper “Le Soleil” of 21 August, 1979, is the most complete. The text below is a translation of the original text also found in the spreadsheet. We added in bold the excerpts with macroseismic information and our interpreted MMI rating in **red**). Note: contrary to the report below, the local time of the earthquake was 6:49 p.m..

> *“SAINT SIMEON - Some were crying. Others cried. Some simply stood still. Most people, on the other hand, all found themselves outside, by instinct, without knowing why.* **(MMI VII)** *There was even one woman who turned it into indigestion.*
> *The panic that gripped a good part of the population of Saint-Siméon, in Charlevoix, at 5:49 p.m. (sic) on Sunday, was of course caused by the earthquake that shook part of eastern Quebec, but also by the power outage that occurred at the same time.*
> …
> *As was to be expected, some damage was noted by residents of Saint-Siméon. Yesterday,* ***some cracked walls, broken chimney heads, cracked plaster, severed pipes and one or two cracked beams***. **(MMI VII)**

In Mr. Bertrand Therrien's house, a four inch by 10 inch ***support beam cracked*** *over four feet long in his basement. The* ***plumbing*** *in his washroom was also* ***severed****.*

In the home of Mr. Charles Foster, a Saint-Siméon municipal councillor, the ***chimney was shaken and remained bent*** *towards the house. The* ***roof collapsed*** *slightly.*
Just opposite, at Mr. René Tremblay's house, ***the chimney head fell*** **(MMI VIII)** ***and a stone panelled wall cracked.*** **(MMI VII)**

Panic

But it is especially the fear, the fear, the panic which marked the telluric tremor of Sunday evening. "If it had taken another minute, I think I would have gone crazy," said Ms. Adrienne Guérin, an employee of the restaurant Chez Côté, owned by Mayor Lucien Côté.
"I just froze. It was panic. People were screaming. There were about ten employees in the kitchen. Lina (an employee) jumped on the shoulders of one of her uncles. My sister-in-law had indigestion. At first I thought it was thunder," she said.
Another employee, Benoit Côté, described the tremor "as if it was a 'van' passing by the house. "It was rolling," he said. **(MMI IV)**
For Mr Clermont Savard, it was like a tractor hitting the corner of her house. Like the others, Mrs. Savard got off the second floor of her residence and quickly went outside.
Mr. William Harvey, 82, heard the dishes rattle in the dishwasher **(MMI IV)** *along with a muffled rumble. "It was shaking. At first I thought it was thunder," he said.*
*Mr. Bertrand Guérin made a jump like everyone else. "****The knick-knacks were falling*** **(MMI VI)** *into my trailer. The dishes were ringing in the cupboards', he said.*
Mr. Bertrand Therrien, whose house was slightly damaged. **(MMI VI)***, saw like swell or waves on his floor.*
Some public buildings, such as the Manoir Richelieu in Pointe-au-Pic, emptied out in the time it took to say so. **(MMI VI-VII)**. ***People fishing on quiet lakes saw waves forming****.* **(MMI VII)**
Users of the Saint-Siméon-Rivière-du-Loup ferry told how they felt a shock on the St. Lawrence River as if the ship had hit an obstacle."

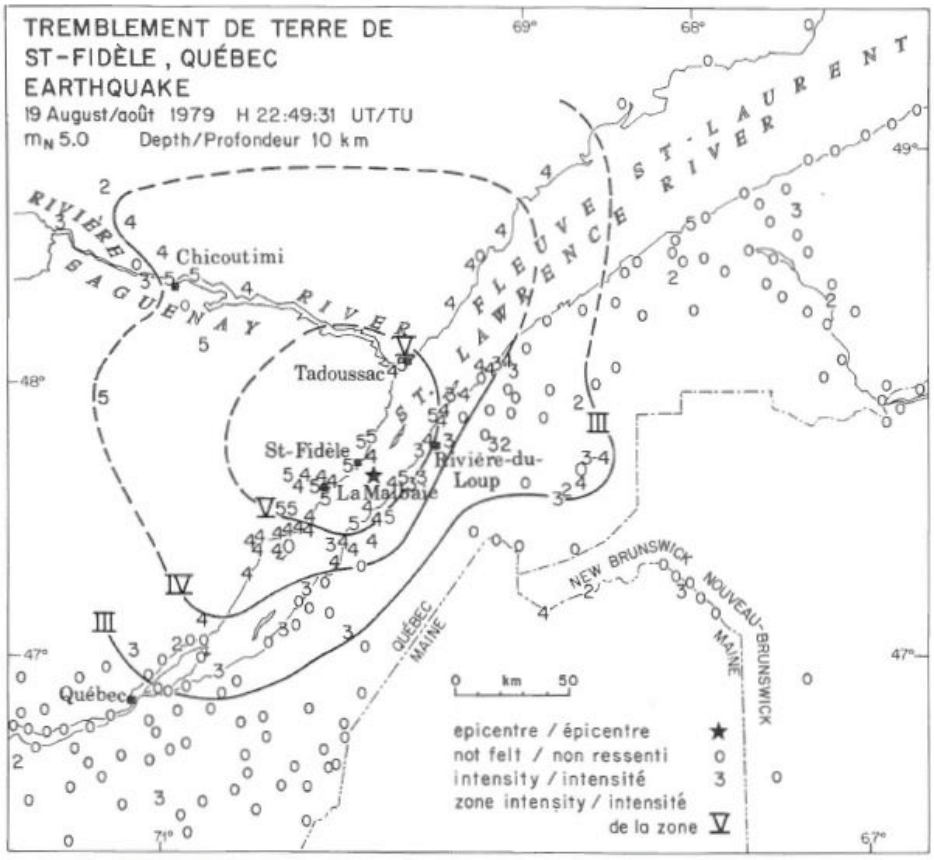


Figure 13: Isoseismal map of the earthquake (Hasegawa and Wetmiller, 1980). Isoseismals are drawn as solid lines when well defined by data and dashed when approximate.

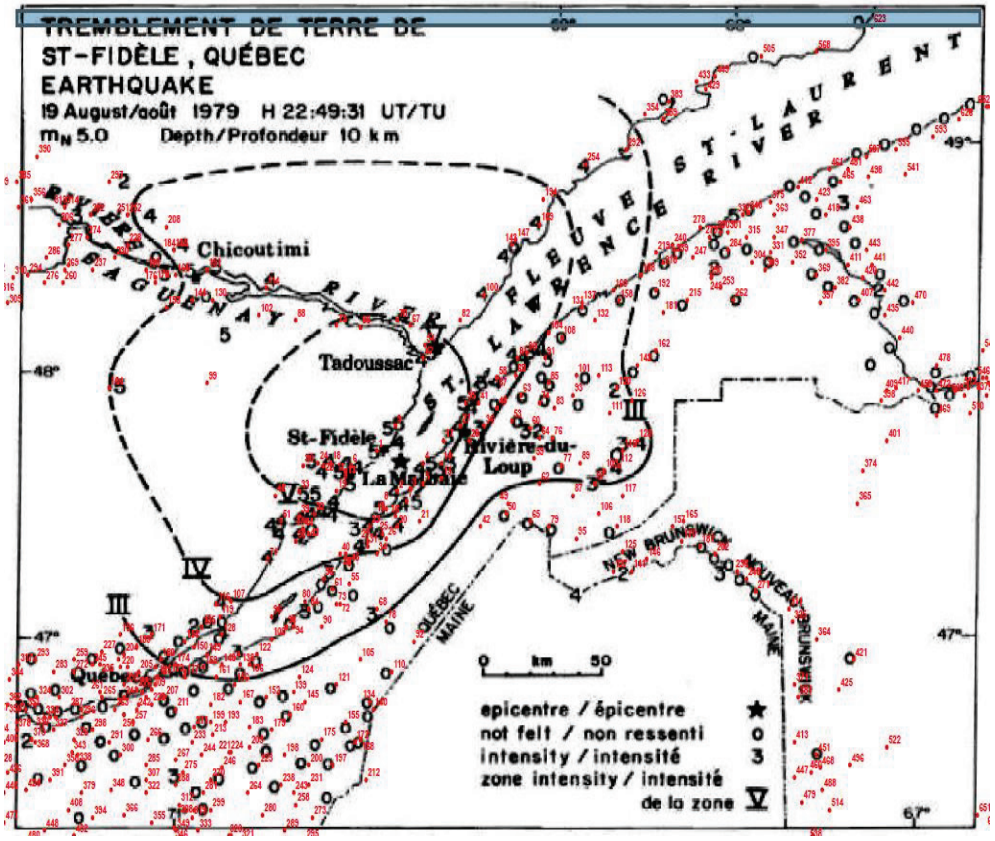
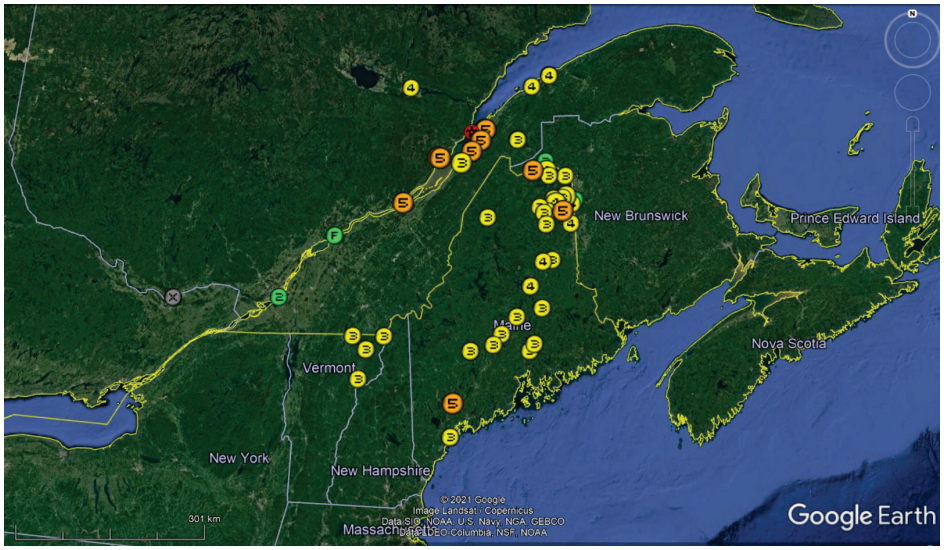


Figure 14. Georeferenced map over which are plotted the locations of towns and cities. Numbers in red are associated with locations of municipalities.

Some other municipalities were as close as or even closer to the epicentre as Saint-Siméon, but no damage was reported there. One of them, St-Fidèle is actually closer to the epicentre than Saint-Siméon is and had no damage (MMI V according to Hasagawa and Wetmiller, 1980). At La Malbaie, one of the two local regional centres of Charlevoix, at the same epicentral distance as Saint-Siméon, no damage was reported (Le Soleil, 20 August 1979). One possible explanation for the anomalous damage and impact in Saint-Siméon might be the near-field focusing of seismic waves, which will be discussed below. Interestingly, the shock was felt on board of the St-Siméon to Rivière-du-Loup ferry (implying that they were close to the epicentre of the main shock) and ripples were seen on nearby lakes.

The near-field impact that reached MMI VII is high compared with the relatively small felt area.

A)



B)

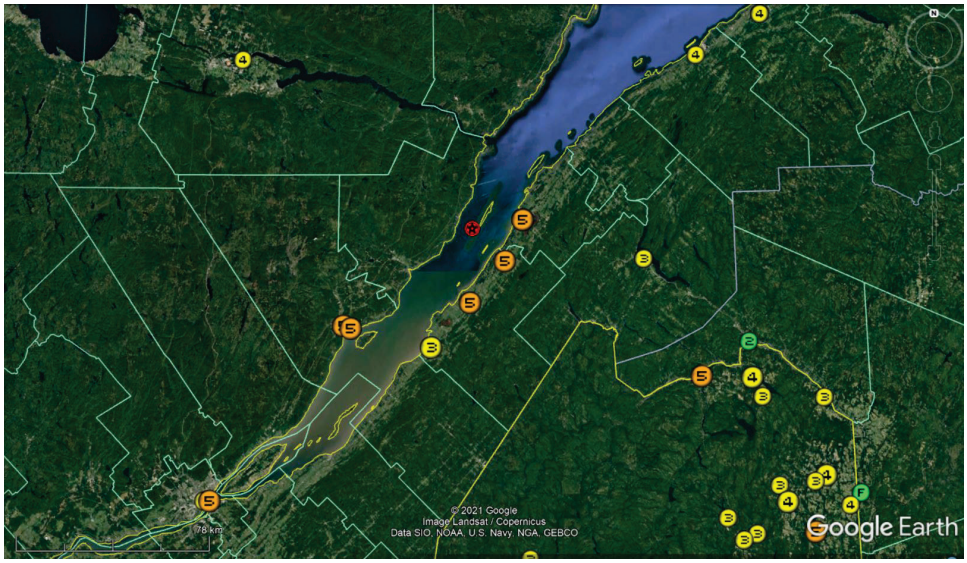


Figure 15. Static images of Google Earth view showing distribution of felt reports for the **M** 4.8 August 19, 1979 earthquake and generated from the kml file. A: all data; B) epicentral region.

Street and Turcotte (1977) have defined a relation between the felt area over which MMI IV was reached and the $m_b(L_g)$ magnitude of the main shock. As mentioned by Hasegawa and Wetmiller (1980), the felt area at level MMI IV or higher (20,000 km^2) is smaller than that predicted for an

earthquake of magnitude $m_b(L_g)$ 5.0 (it corresponds to $m_b(L_g)$ 4.54). Our estimate is somewhat larger at about 38,556 km^2 since we included all MMI data (Figure 16). This corresponds to an m_bL_g of 4.9 according to the formula of *Street and Turcotte (1977)*

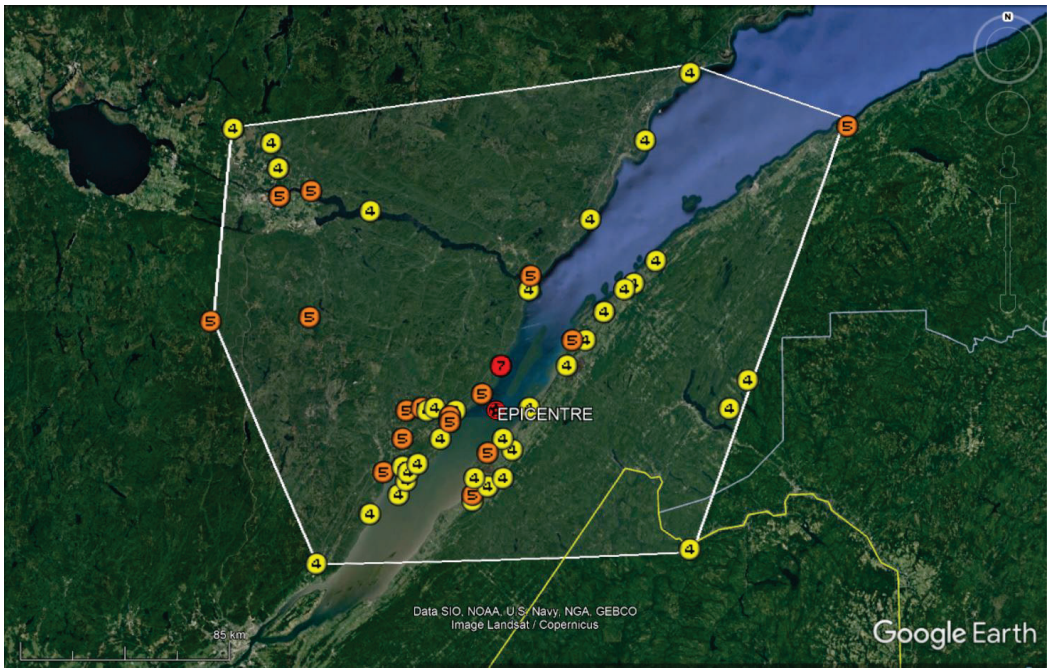


Figure 16: Polygon that contains all MMI IV or higher.

List of newspaper articles for the 19 August 1979 earthquake (copies available in folder 1979/newspapers)

La Presse, 20 août 1979, p. A3 c6;
The Sherbrooke Record, Aug. 20, 1979 p.2 c1-2;
Le Madawaska, 22 août 1979;
Plein Jour sur Charlevoix, 29 août 1979; p. 3 c 4-6;
Le Soleil, 20 août 1979, Cahier A; p. A2 c2;
http://numerique.banq.qc.ca/patrimoine/details/52327/2725741

Nothing mentioned in Le Nouvelliste, Trois-Rivières;

Only two US data points were found in the NOAA intensity database.

The March 6, 2005, M 4.7 earthquake (NE source area of the CSZ; referred to as the Rivière-du-Loup earthquake)

The March 6, 2005, **M** 4.7 (m_N 5.4) earthquake occurred at 06:17 U.T. (01:17 a.m. local time; Assatourian and Atkinson, 2010). The hypocenter was located about 20 km southwest of Rivière-du-Loup at a focal depth of 13 km. No major damage was reported but it was felt strongly in the regions of Charlevoix (north shore of the St. Lawrence River), Kamouraska (south shore), Saguenay and Quebec City, and as far away as Toronto (ON), Fredericton (NB), and Boston, (MA). At station A16 (at about 40 km distance), a peak ground acceleration (PGA) of about 3% g was recorded (Lin and Adams, 2010). These authors showed that the peak ground motions and the response spectra of the Rivière-du-Loup earthquake records are significantly smaller than those predicted by the ground motion relations used for eastern Canada.

For this earthquake, the felt reports were gathered in two ways (Halchuk, 2021). One was the USGS Did-You-Feel-It (DYFI) internet questionnaire which gathered felt reports from the US and from Canada. The other means was through the GSC web interface, which at the time, was not using the DYFI questionnaire. Instead, people were asked to provide answers in words to

specific questions similar to the traditional mail-in questionnaires. At the time it was thought that such an approach would provide more representative answers to felt effects. In order to speed up the processing of the 1500 filled-out questionnaires, GSC seismologist R.J. Wetmiller designed an algorithm that looked for specific words or expressions (in both French and English) that corresponded to specific MMI levels. The interpreted MMIs were plotted and displayed on the GSC web site (Figures 17A and B).

We have reviewed the original data and their interpretation. The original summary file had a total of 2519 reports. After re-examination of many felt reports and deletion of duplicate and void reports, the total number was reduced to 2400. The first author examined the text of all interpreted MMIs VII, VI, most Vs, many IVs and most responses from the Kamouraska, Charlevoix, Saguenay and Quebec City regions (see Appendix Epicentral-region.docx). Most MM IIIs and lower were not re-examined.

In the spreadsheet, the correct spelling of the municipalities were added. As described in Halchuk (2021), coordinates are those of the municipality not of the postal code of the responder, except in the Island of Montreal. The revised isoseismal map is shown in figures 18 and 19.

To assure anonymity of the responders, the personal information (email addresses, names, addresses) have been removed in the spreadsheet. The original line numbers of the response file of Halchuk, (2021) were kept for each entry in the spreadsheet for future research.

The macroseismic effects that were most common and their ratings are as follows.

MMI III: noise reported without rattling (with rattling: MMI IV).

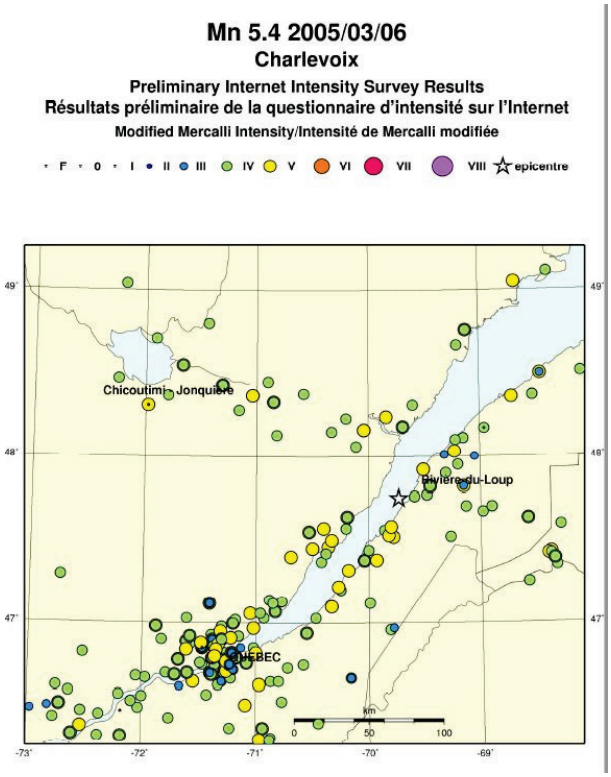
MMI IV: Awakened few; Vibration like that due to the passing of heavy or heavily loaded trucks; Rattling of dishes, windows, doors; glassware and crockery clink and clash; Creaking of walls, frame; Hanging objects swung. If something fell or was displaced; it was rated as MMI V. We did not use the distinction awakened all or few as this best applies to communities, not to families.

MMI V: Awakened many, or most; Buildings trembled throughout; Overturned vases, small or unstable objects, in many instances, with occasional fall; Knocked pictures against walls, or swung them out of place; moved small objects. Many reports mentioned in French "objets bougaient" which we assume meant that objects were vibrating (MM IV) without being displaced at the end (MMI V).

MMI VI: There were only six individual cases of MMI VI (a few cases of cracked plaster in walls or chimneys; picture frames fell; the "awakened all" at the family level was not considered characteristic).

The newspapers were also examined. A total of nine newspapers from the province of Quebec were found (see list below). There were no impact information in the newspaper reports that was not already known from the intensity questionnaires.

17A)



17B)

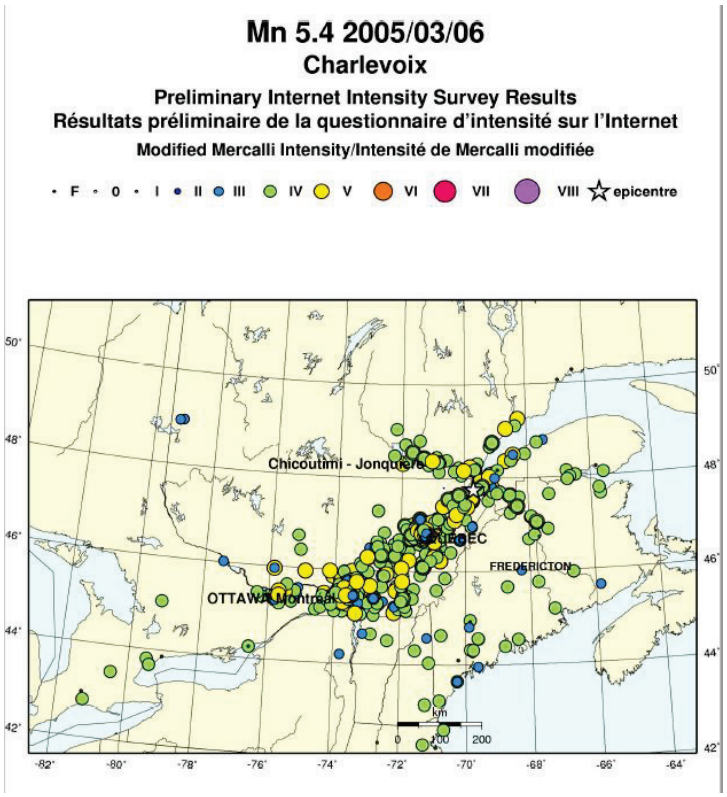


Figure 17. Original local (A) and regional (B) isoseismal maps of the March 6, 2005, **M** 4.7 (m_N 5.4) earthquake as displayed on the earthquake Canada web site. The data shown were the original interpreted MMIs from R.J. Wetmiller and reported in Halchuk (2021).

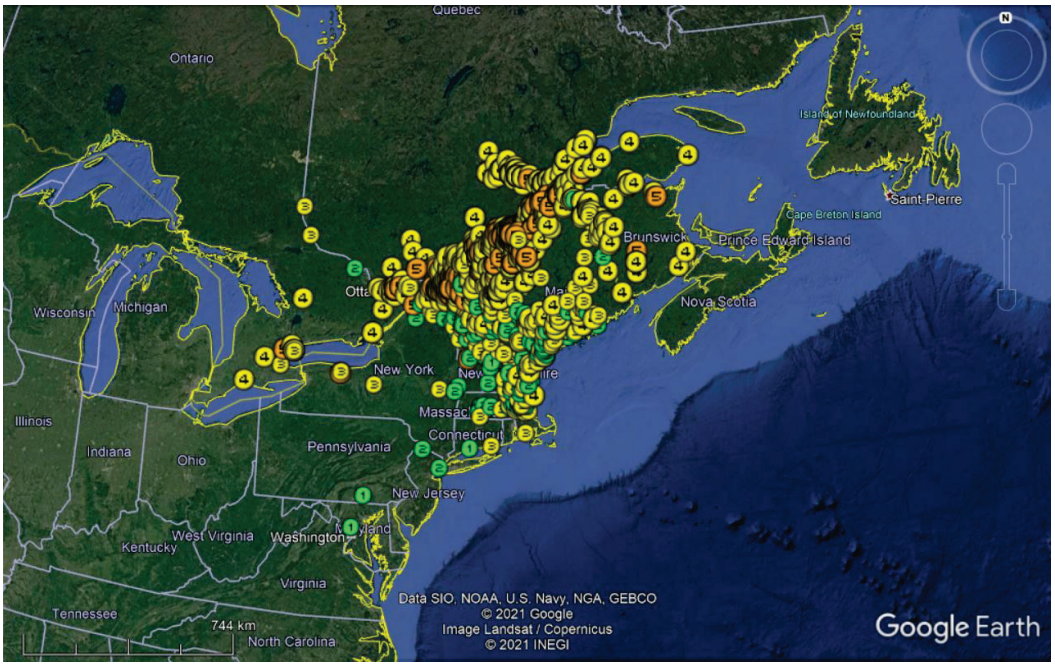


Figure 18. Static image of Google Earth view showing distribution of felt reports of the March 6, 2005, **M** 4.7 earthquake collected by the GSC and the USGS included in this OF and generated from the kml file. Most individual felt reports from any particular municipality have been assigned the same coordinates based on the generic location of their municipality. Numbers refer to the MMI level; (F) means felt, no details; (X) means no report. Readers are encouraged to use the kmz file for clarity.

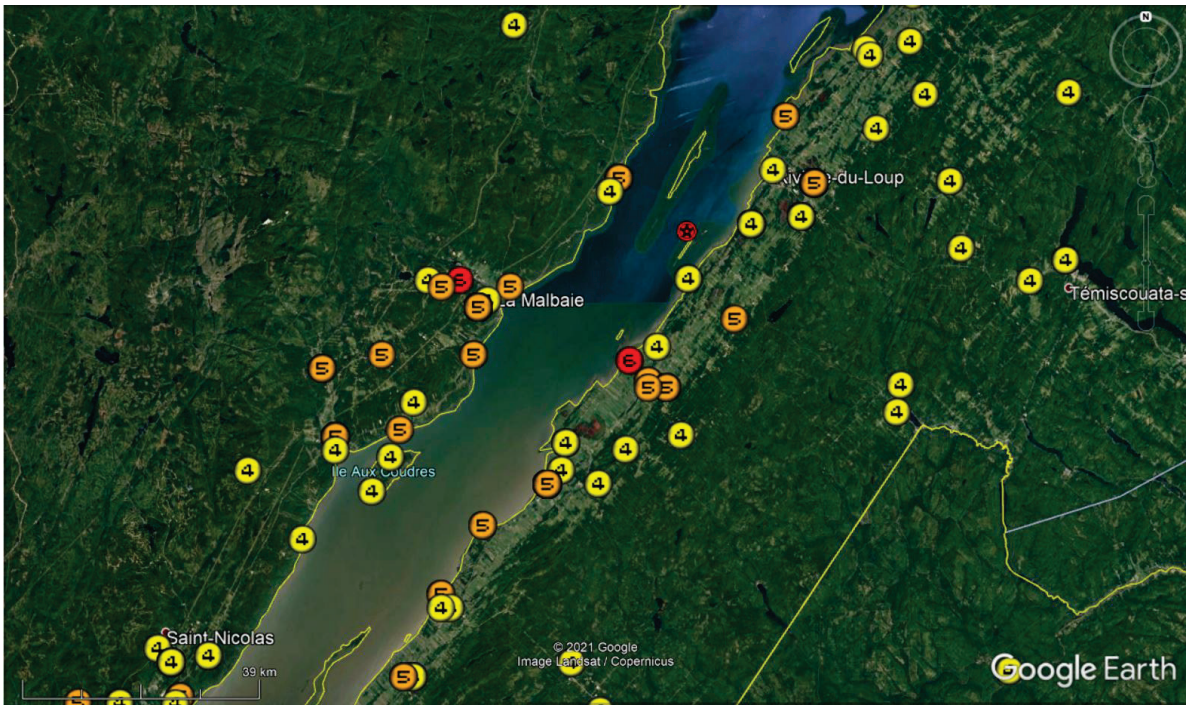


Figure 19. Static image of Google Earth view of the regions surrounding the epicentre (red star) of the March 6, 2005, **M** 4.7 earthquake showing the distribution of GSC and USGS MMI reports IV, V and VI. Most individual felt reports from any particular municipality have been assigned the same coordinates based on the generic location of their municipality.

Newspaper articles for the 6 March 2005 earthquake (copies available in folder 2005/newspapers)

1.Le Soleil (Québec) 20050606, 20050307

2.La Voix de l'Est (Rivière-du-Loup) 20050606

3.Le Quotidien (Saguenay) 20050606

4.La Presse (Montréal) 20050607

5.Le Devoir (Montréal) 20050607 (AFP and Reuters)

6.L'Écho de Frontenac (Lac Mégantic) 20050613

7.La Tribune (Sherbrooke) 20050607 (Presse canadienne)

8.Le Droit (Gatineau) 20050607 (same as Le Soleil)

9.Le Nouvelliste (Trois-Rivières) 20050607 (same as Le Soleil)

A few errors were found in the USGS data: Saint-Augustin was Saint-Augustin-de-Desmaures near Quebec City, not the one in the lower Quebec North Shore region. There were 3 reports (MMI III) from Saint-Bruno. Since there are three municipalities named Saint-Bruno in Quebec (St-Bruno-de-Kamouraska, in the epicentral region, Saint-Bruno, near Alma, Lac Saint-Jean, and St-Bruno-de-Montarville, near Montreal), and that there was no other means of identifying the correct one, we decided to remove all three St-Bruno entries.

The February 3, 1902, M 4.5 earthquake (near Rivière-du-Loup)

On February 3, 1902 at around 7:30 a.m., an earthquake was felt strongly in Rivière-du-Loup and Charlevoix and noticeably over most of the St. Lawrence valley of Quebec. Based on Laflamme (1907)[b], Smith (1966) described the event as a MMI II earthquake "Felt at Quebec City, Que" which later on was taken as a weak earthquake with its epicentre in Quebec City. Rated as a minor earthquake, the 1902 earthquake was not included as one of the 150 largest events in Canada (Bent, 2009) and did not appear in the Seismic Hazard Earthquake Epicentre File (SHEEF; Halchuk et al., 2015). In light of the revised estimate of **M** 4.5, this updated earthquake should be corrected in the National Earthquake Database and added to SHEEF.

Gouin (2001) provided a detailed review of the earthquake's impact based on ten newspaper articles. He documented the impact in 20 localities and drafted a macroseismic map (Figure 20). Gouin (2001) rated the magnitude as m_bL_g 4.5 based on the felt area's relation of Nuttli and Zollweg (1974).

Since this earthquake occurred before the advent of modern seismographs capable of recording moderate earthquakes, its probable epicentre is somewhere in the CSZ. Gouin (2001) assigned the epicentre to the centre of maximum intensity at about 48.0°N and 69.5°W which is about 20 km north from Rivière-du-Loup where the maximum intensity was reported (MMI V; small objects fell). Gouin's epicentre would locate the epicentre slightly outside the CSZ zone of concentrated activity. For this reason, we propose an epicentre at 47.8°N and 69.6°W, two round numbers at a position very close to Rivière-du-Loup, on the NE circle of larger earthquakes of Stevens(1980) and at the limit of the concentrated zone of earthquake activity. Readers are reminded that this epicentre is very approximate. These coordinates are used in the spreadsheet to calculate epicentral distances.

[b] Verbatim : « 1902. - 3 février, vers 7 heures du matin, faible ... à Québec. »

Thanks to the digital archives of Quebec newspapers[c] (REF), we found felt reports not referred to by Gouin (2001). These additional reports describe the impacts in Charlevoix county, Rivière-Ouelle, Sherbrooke and Trois-Rivières. One of these reports is from Baie-St-Paul, home of the weekly newspaper "L'Écho de Charlevoix". It describes the event as "a violent shock" in Charlevoix county, without any "incident". It was also reported felt in Rivière-Ouelle (without details). The earthquake was only midly felt in Sherbrooke and Trois-Rivières. The newspapers are listed below.

Altogether, felt reports from 26 localities were gathered with details listed in the Excel file. Felt report evidence supports an epicentre in the CSZ, possibly near Rivière-du-Loup where the only cases of fallen objects were reported. The earthquake was also mildly felt in northeastern New Brunswick (Madawaska region but not in the rest of New Brunswick. The earthquake is not mentioned in Burke (2007). In Quebec City, some reports mention that the shaking was stronger in the upper town, whereas others mentioned it was in the lower town (St-Roch parish). There are no entries in the NOAA database of earthquakes. The locations with felt reports are plotted in Figure 21.

Newspapers report two possible foreshocks: one between midnight and 1 o'clock in Quebec City (newspaper "Le Soleil", 3 Feb. 1902) and one at 4 a.m. in Rivière-du-Loup (newspaper "La Patrie", 4 Feb. 1902). These foreshocks are doubtful since none was mentioned in other reports from the epicentral region. The noise and shaking misinterpreted as an earthquake were possibly caused by the strong winds associated with a violent snowstorm mentioned in numerous newspaper accounts. No aftershock is reported, including from the Charlevoix newspaper that was published four days after the main shock.

Numerous newspapers did not mention the earthquake (List 2). For these municipalities generally at more than 300 km epicentral distance, it can be assumed that the ground motions were too weak to be felt or worth mentioning.

A few newspapers shared the report that an earthquake was felt at Betsiamites (named Bersimis at the time) and its surrounding region in the evening of the preceding Friday (31 January 1902; The Sherbrooke Examiner, Feb. 3, 1902) or Saturday morning (La Presse, Feb. 3, 1902). Local people were scared; many ran outside; it had a one minute duration; but no '*considerable*' damage was reported. Apparently, it was not felt in any other municipality. This event should not be confused with the earthquake of Monday February 3rd at 7:30 a.m.

[c] https://numerique.banq.qc.ca

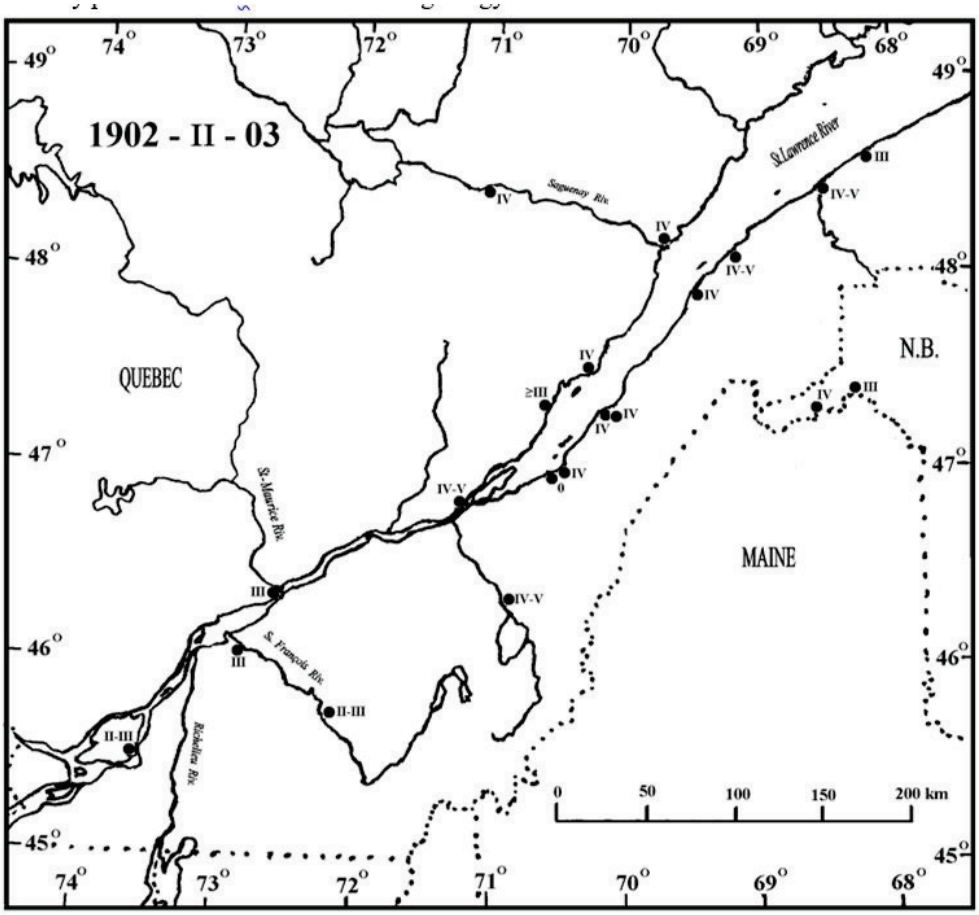


Figure 46: Distribution map of the sites having felt the effects of the earthquake of February 3, 1902. Full circles (●) indicate the sites and the Roman numerals the intensities inferred from newspapers.

Figure 20: Macroseismic map of the 19020203 CSZ earthquake (from Gouin, 2001).

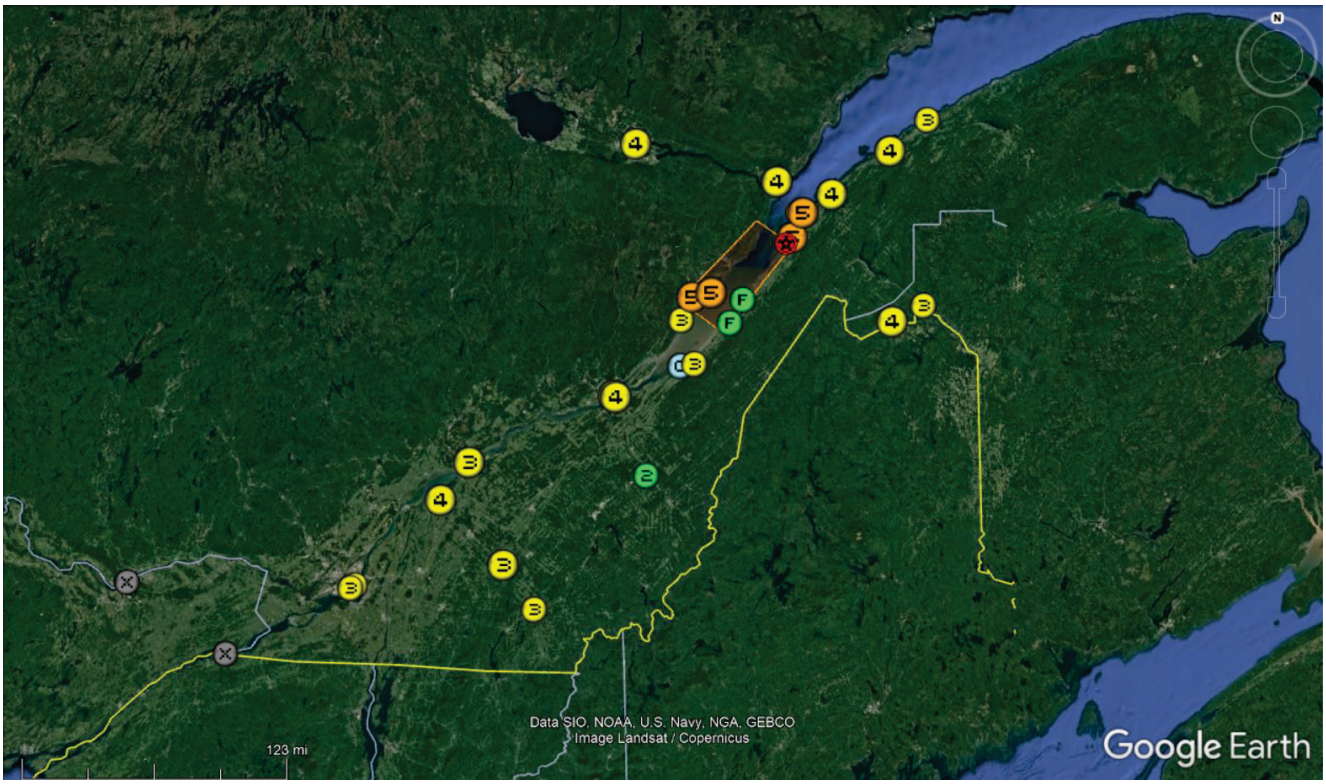


Figure 21. **S**tatic image of Google Earth view generated from the kml file for the February 3, 1902, Charlevoix earthquake, that shows the distribution of felt reports on the MMI scale. Numbers refer to the MMI level, (X), no report. Red star: our epicentre; Gouin(2001) epicentre is located north of our epicentre, under the orange circle 5.

The moment magnitude based on intensity observations (**M_I**) can be estimated by comparing the impact with that of other moderate CSZ earthquakes (Table 2). We interpret the impact and the maximum felt distance of the 1902 earthquake as that of a **M_I** 4.5 event. Assuming that **M_I** is similar to **M, M_I** 4.5 corresponds approximately to m_bL_g 4.9 (Bent, 2011), somewhat larger than m_bL_g 4.5 proposed by Gouin (2001). Although its magnitude is lower than the assumed detection threshold for the CSZ (**M** 4.8 since 1880), we recommend that this CSZ earthquake be included in the SHEEF catalog and the Canadian earthquake database.

Newspaper sources for the 1902 earthquake: from Gouin (2001) and this work (*):

19020203 : Le Soleil, Québec.

19020203 : Quebec Daily Mercury.

19020203 : La Presse, Montréal.

19020203 : La Patrie, Montréal.

*19020203 : The Sherbrooke Examiner

19020204: The Ottawa Citizen : one paragraph about felt impact in Quebec City: no mention of Ottawa.

19020204 : Le Soleil, Québec.

19020204 : La Presse, Montréal.

19020204 : La Patrie, Montréal.

19020204 : The Gazette, Montréal.

19020204 : The Montreal Daily Star, Montréal.

19020204 : Le Trifluvien, Trois-Rivières.

*19020204 : Le Courrier de St-Hyacinthe, St-Hyacinthe.

*19020204 : Le Progrès de l'Est

*19020204 : The Quebec Chronicle

19020206 : Le Moniteur Acadien, Shédiac (not available).

19020206 : Le Progrès du Saguenay, Chicoutimi (5, 1 2).

19020206 : L'étoile du Nord, Joliette*

19020206 : L'Écho de Charlevoix, Baie-St-Paul*

No mention of the 1902 earthquake in these newspapers:

19020204 : Le Sorelois, Sorel

19020204 : Cornwall Standard, Cornwall, ON (4 Feb. 1902 and following days);

19020206 : L'Avenir du Nord, Saint-Jérôme

19020207 : Le Canada français, Montréal

19020206 : L'Union des Cantons de L'Est : journal politique, industriel, littéraire et agricole, Sherbrooke

19020206 : The Equity, Shawville

19020206 : Le Courrier de St-Hyacinthe, Saint-Hyacinthe

19020207 : La Gazette de Berthier, Berthier

19020207 : Le Courrier de Saint-Jean : organe du district d'Iberville, Saint-Jean-d'Iberville

19020206 : Fort Fairfield Review, Maine.

Earthquake	Moment Magnitude (**M**)	Charlevoix or Rivière-du-Loup	Quebec City	Montreal	Ottawa	Atlantic Seabord of Maine
December 25, 1930 (foreshock)	4.2	No details	Felt	Felt	No	No
February 3, 1902	4.5 (interpreted)	V (Small objects fell)	IV-V	II-III	No	No
October 14, 1952	4.5	V (Small objects fell)	V	II	No	II
March 6, 2005	4.7	V (Small objects fell)	V	IV	III	IV
August 19, 1979	4.8	VII Broken chimneys	V	II	No	No
January 08, 1931	4.9	V	IV	V	V	III
September 30, 1924	5.2	No details	IV	IV (region)	IV	IV
October 19, 1939	5.3	Many chimneys damaged	IV	IV	IV	III

Table 2: Impact at selected locations for moderate CSZ earthquakes discussed in this report.

Discussion of the seven moderate earthquakes

Many changes occurred in the reporting of felt earthquakes during the time period 1924-2005. Based mainly on newspaper accounts at first, it became more systematic with the mail-in questionnaires later. Unfortunately, as described above, all filled questionnaires are lost for the events that we considered in this OF. The internet opened a new era with massive amounts of felt reports being collected. The DYFI methodology was only partially applied for the 2005 earthquake. How the DYFI results compares with the traditional GSC evaluation is to be

examined. For the MMI IV and V, it appears that the DYFI puts more emphasis on the comments such as strongly felt, whereas our interpretation looks for specific impacts such as fallen or displaced objects. Our impression is that the large number of DYFI reports averages the local MMI which ends up being lower than the MMI from newspaper reports. On the other hand, newspaper reports may be missing some local impact that would probably gets reported in the DYFI web page (although possibly lost in the averaging process).

The macroseismic maps for these moderate earthquakes reveal some tendencies for the dispersion of ground vibrations. Felt areas are not symmetrical: there appears to be strong attenuation towards the northeast (Quebec North Shore; Gaspe Peninsula, and the Maritimes) and the north and northwest in the direction of the Lac St-Jean and Abitibi regions. The ground motions appear to be less attenuated in the south and southeast towards Maine and New Hampshire. This anisotropic attenuation should be considered in modeling MMIs for these regions.

On this topic, Hasegawa in Wetmiller (1980) wrote:

> *The isoseismal contours in Figure 2 (Note; our Figure 13) indicate rather different rates of intensity fall-off with distance on adjacent sides of the St. Lawrence River. For instance, the distance to the MM IV contour on the south shore varies from about 30 to 80 km while on the north shore it varies from about 90 to 150 km. This feature is common to many earthquakes in eastern Canada (e.g. see Figs. 4, 5 and 6 of Smith, 1966). The closer spacing of isoseismal contours to the southeast is considered to be due primarily to the presence of numerous structural lineaments in the Paleozoic rocks that border the southeastern shore of the St. Lawrence River rather than to the different absorption characteristics of different rock types. The Lg phase, which is the primary contributor to most reported felt sensations from Eastern Canada earthquakes, is absorbed and scattered to a greater degree by these northeast - southwest trending lineaments than by the comparatively less (laterally) structurally complex lineaments and faults in the crust (Precambrian rocks) along the northwest shore of the St. Lawrence River. Structural lineaments that are likely contributors to this anomalous absorption to the southeast are the gravity-slide nappe zones (see Sikander and Pittion, 1978), geosynclines, geanticlines and faults (see Hubbert (sic: Hubert), 1973) and possibly stratigraphic and structural contrasts (see Williams, 1979).*

Out of the seven moderate earthquakes, only one was preceded by a felt foreshock: the 1931 **M** 4.9 was preceded by 15 days by a **M** 4.2 event. On the other hand, the 1924 **M** 5.2 earthquake could have been a foreshock to the 1925 **M** 6.2 earthquake that happened 7 months after. Often after a moderate earthquake, the question of it being a foreshock of a bigger one is often raised. In the case of the CSZ, it can be shown to be the exception rather than the rule. The reports about possible foreshocks for the 1902 earthquake are not credible.

Data and results

A Microsoft Excel spreadsheet contains the basic information on the felt reports. It lists the MMI ratings interpreted by the first author for Canada.

Fields of the Table

Using the Microsoft Excel spreadsheet, a series of tables were created, one for each earthquake. 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 could 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 the 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: QC: Quebec; NB: New Brunswick; NS: Nova Scotia; PE: Prince Edward Island; 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.
15. Longitude (°W): Longitude of the community where the earthquake was felt; taken from the original felt reports or, more rarely, obtained from GoogleEarth.
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 epicentral coordinates listed in Lamontagne et al. (2007), i.e. Latitude 44.96°N and Longitude 74.77°W as listed in the final tab sheet of the spreadsheet.
17. Final Numeric MMI: Based on the felt report, interpreted intensity on the Modified Mercalli Intensity 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. We did not use this field in this report.
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 files

To ease the consulting of the data and put them in a geographic context, each earthquake has one or more kml files which can be viewed using the GoogleEarth software (available for free download at https://www.google.com/earth/) .

A static image of the Google Earth display is shown for each earthquake.

Conclusions

This Open File Report provides the available macroseismic information for six moderate earthquakes of the Charlevoix Seismic Zone. These earthquakes and their magnitude **M** are: 1) September 30, 1924, **M** 5.2; 2) January 08, 1931, **M** 4.9; 3) October 19, 1939, **M** 5.3; 4) October 14, 1952, **M** 4.5; 5) August 19, 1979, **M** 4.8; 6) March 6, 2005, **M** 4.7. For each locality where the earthquakes were felt, macroseismic information is given and interpreted on the Modified Mercalli Intensity Scale. The macroseismic information from localities in Canada and in the US (from NOAA) are tabulated in Microsoft Excel spreadsheets. Most newspaper clippings that have macroseismic information are included. The Open File also provides GoogleEarth kmz files that allow the felt information reports to be viewed in a spatial tool.

Gathering the macroseismic information for these seven earthquakes presented different challenges. Only the 2005 earthquake had felt-information questionnaires, but their format was very time-consuming to analyze. For the others, we had newspaper accounts that provided some macroseismic information. For the 1979 earthquake, we georeferenced the felt information from an isoseismal map.

We are confident that this Open File includes all available information on how these earthquakes were felt. We hope that it will be useful for research on this earthquake as well as on other intraplate earthquakes.

Acknowledgments

We thank Ms. Alexandra Lewis of the Departmental Library for obtaining many newspaper clippings. We thank our GSC colleague Azadeh Ashoori Pareshkoohi who made the study of the 1979 earthquake possible by georeferencing its isoseismal map. We thank our colleague Dr Mareike Adams for her review of this Open File.

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Appendix I: 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.