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M. Lamontagne[1], K.B.S. Burke[2], and L. Olson[1]

[1]Geological Survey of Canada, 601 Booth Street, Ottawa, Ontario
[2]Department of Earth Sciences, University of New Brunswick, 2 Bailey Drive, Fredericton, New Brunswick

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Felt reports and impact of the November 25, 1988, magnitude 5.9 Saguenay, Quebec, earthquake sequence

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Abstract

The November 25, 1988, moment magnitude 5.9 (M_w) Saguenay earthquake is one of the largest eastern Canadian earthquakes of the 20th century. It was preceded by a magnitude (M_N) 4.7 foreshock and followed by very few aftershocks considering the magnitude of the main shock. The largest aftershock was a magnitude (M_N) 4.3 event. This Open File (OF) Report presents a variety of documents (including original and interpreted felt information, images, newspaper clippings, various engineering reports on the damage, mass movements). This OF updates the report of Cajka and Drysdale (1994) with additional material, including descriptions of the foreshock and largest aftershock. Most of the felt report information come from replies of a questionnaire sent to postmasters in more than 2000 localities in Canada and in the United States. Images of the original felt reports from Canada are included. The OF also includes information gathered in damage assessments and newspaper accounts. For each locality, the interpreted information is presented in a digital table. The fields include the name, latitude and longitude of the municipality and the interpreted intensity on the Modified Mercalli Intensity (MMI) scale (most of which are the interpretations of Cajka and Drysdale, 1996). When available or significant, excerpts of the felt reports are added. This OF Report also includes images from contemporary newspapers that describe the impact. In addition, information contained in post-earthquake reports are discussed together with pictures of damage and mass movements. Finally, a GoogleEarth kmz file is added for viewing the felt information reports within a spatial tool.

Résumé

Le tremblement de terre du Saguenay du 25 novembre 1988, d'une magnitude de 5,9 (M_w), est l'un des plus grands tremblements de terre de l'est du Canada du 20e siècle. Il a été précédé d'un précurseur de magnitude (M_N) 4,7 et suivi de très peu de répliques compte tenu de la magnitude du choc principal. La réplique la plus importante a été un événement de magnitude (MN) 4,3. Ce

dossier public (DP) présente une variété de documents (y compris des informations macroséismiques originales et interprétées, des images, des coupures de journaux, divers rapports techniques sur les dégâts, des mouvements de masse). Ce Dossier public met à jour le rapport de Cajka et Drysdale (1994) avec des documents supplémentaires, y compris des descriptions du précurseur et de la plus grande réplique. La plupart des informations des informations macroséismiques proviennent des réponses à un questionnaire envoyé aux maîtres de poste dans plus de 2000 localités au Canada et aux États-Unis. Des images des rapports originaux au Canada sont incluses. Le DP comprend également des informations recueillies dans les évaluations des dommages et les comptes rendus des journaux. Pour chaque localité, les informations interprétées sont présentées dans un tableau numérique. Les champs comprennent le nom, la latitude et la longitude de la municipalité et l'intensité interprétée sur l'échelle d'Intensité de Mercalli Modifiée (MMI) (principalement les interprétations de Cajka et Drysdale, 1996). Lorsqu'ils sont disponibles ou significatifs, des extraits des rapports macroséismiques sont ajoutés. Ce rapport OF comprend également des images de journaux contemporains qui décrivent l'impact. En outre, les informations contenues dans les rapports post-séisme sont discutées avec des images des dommages et des mouvements de masse. Enfin, un fichier kmz GoogleEarth est ajouté pour la visualisation des rapports d'information macroséismique dans un outil spatial.

Introduction

The November 25, 1988, magnitude 5.9 (Mw) Saguenay earthquake was the largest event to take place in Eastern North America since the M 6.2 Temiscaming earthquake of 1935. Its epicenter was located in the Laurentide Fauna Reserve of Quebec, about 35 km to the south of the city of Chicoutimi (now a ward of the City of Saguenay) and 150 km north of Quebec City. It occurred at 18:46 local time (23:46 Universal Time, UT) and caught millions of people by surprise in eastern Canada and in the northeastern United States. The earthquake, its sequence of aftershocks, and their seismotectonic interpretations have been described in various papers (North et al., 1989; Du Berger et al., 1992; Ma et al., 2018). This event has provided a unique set of strong motion data for seismic hazard estimation in eastern North America. Prior to these recordings, ground motions were estimated from intensities from early 20th century earthquakes. This earthquake was special in many respects: it occurred in a relatively aseismic region at the mid to lower crust levels (29 km depth); it contained a large component of high-frequency seismic waves; and it was followed by very few aftershocks, considering the size of the main shock. It is noteworthy that the focal depth of the main shock (29 km)

is deeper than 95 % of all the other earthquakes in eastern Canada. Partly due to its mid-crustal depth, correlating its occurrence with a specific geological fault remains difficult (Ma et al., 2018). It should be noted that the moment magnitude M_W 5.9 is the preferred magnitude for the main shock but other magnitudes were calculated: m_b 5.9, m_{bLg} 6.5, M_S 5.8.

The main objectives of this Open File Report (OF) are:

1) To provide tables with the available felt reports for the main shock, as well as for the foreshock and the largest aftershock.
2) To provide the interpreted intensities on the MMI scale for these earthquakes.
3) To include the text and the scans of the original newspaper accounts and reports when available and free of copyrights.
4) To provide all available pictures of damage and related descriptions.
5) To provide some photographs of field work to document the field instruments and their deployments.
6) To include the available engineering reports on the damage.
7) To include the available geotechnical information on mass movements.
8) To include newspaper accounts that describe how the earthquakes were felt.

Felt reports

This OF builds on a previous GSC OF Report by Cajka and Drysdale (1996) and adds more complete and detailed information. Immediately following the event, the Geological Survey of Canada sent more than 2000 macroseismic questionnaires to postmasters in Quebec, Ontario, and Canada's Atlantic provinces to determine local intensities. The methodology and the description and interpretation of the felt information are described in Cajka and Drysdale (1996). The response rate was estimated to be about 75 %, a figure considered high for broadly-based mail surveys. The Canadian data were combined with similar data collected and interpreted by Carl Stover of the National Earthquake Information Center (NEIC) in the United States. In total, 1924 communities in Canada and the United States were assigned an intensity value by Cajka and Drysdale (1996) based on the MMI scale. Appendix I provides the details of the MMI scale. The collected data were used to produce a series of isoseismal maps (Fig. 1).

In this OF report, the first author re-examined the original accounts for the MMIs V to VIII. When discrepancies were found between the new interpretation and the original work of Cajka and Drysdale (1996), an explanation was added in the spreadsheet and cells that were changed are highlighted in yellow.

The macroseismic information from Canadian and US postmasters was complemented with additional materials from other collaborators and from newspapers. In most cases, the data in the original compilation by Cajka and Drysdale (1996) were kept. For the Province of New Brunswick, the second author, Dr Ken Burke of the University of New Brunswick, collected and analysed the felt reports and collected newspaper articles related to the earthquake: his original report can be found in the directory "Saguenay_other-felt-information". Another source of information was Professor Pierre Cauchy, who was at the time professor of the CEGEP Ahuntsic in Montreal. He compiled more than 437 felt reports from his College students who resided on the Island of Montreal (his report and map are found in the same directory). Finally, local felt information for Ithaca, N.Y. is found in Cladouhos et al., (1989).

Newspapers accounts provided some additional felt information including descriptions and pictures of damage. At the time of the earthquake, the first author collected numerous newspapers from the Province of Quebec. All of these newspaper clippings, plus many others, have been scanned and attached to this report (directory "Newspapers"). This OF Report also includes more detailed and site-specific macroseismic information that had been already published in two reports: Quebec City (Lamontagne, 2007) and Ottawa (Lamontagne, 2008). Additional damage information came from the damage assessment reports as described below. Finally, readers interested in TV and audio reports around the time of the earthquake can find on the Internet a number of videos of damage and felt reports on various platforms.

Damage information

In addition to newspaper reports, a number of post-earthquake surveys documented the damage from the earthquake and are included within the "Technical-Reports" directory. These are: EQE (1988); Ministère des transports du Québec (MTQ, unpublished; directory MTQ); Mitchell et al (1989); Hydro-Québec (Pierre, 1989); and Veillette and Allard (1989). There are also a number of reports that describe the damage from varied sources (Lefebvre et al. (1990); Tuttle et al.,

(1990); Boivin (1992); Paultre et al. (1993); Bruneau and Lamontagne (1994); and Tinawi(1998). The original reports, when free of copyrights, were included in this OF. The damage information they contain was extracted and included in the "of_8803_intensities" spreadsheet. Whenever possible, the location of the damage occurrence was obtained using GoogleEarth with an estimated uncertainty. We believe that the damage information in this OF is more complete than in Cajka and Drysdale (1996) because it includes site-specific information, the sources and associated pictures.

In general, the damage was interpreted to be as much due to the geological materials on which the structure was constructed as to the initial strength of the ground shaking (Mitchell et al., 1989). Hydro-Québec suffered some significant damage at some of their transformer stations in locations where topographical and/or soil conditions made the ground shaking particularly strong (Pierre, 1989).

Following the earthquake, the Ministère de la Sécurité publique du Québec (Public Safety Department of Quebec), sponsored a compensation program for the owners of damaged houses and apartment buildings. Paultre et al. (1993) reported on the results of the statistical analysis of 1927 files of reported damages to buildings submitted under the compensation program. They also consulted other government files, concerning public buildings. Most damage was caused in the Saguenay-Lac St-Jean and Quebec City regions. The total repair cost of damage to buildings reached $44 million, excluding for damage to Hydro-Québec installations (about $7 million), to major industrial facilities (about $1.5 million), and to roads, bridges, and railways. Total damages due to the main shock exceeded $50 millions. In the late 1990's, the first author attempted to access the original damage reports on paper but that was no longer possible. At time of writing, we are uncertain about the fate of these documents. The papers by Boivin (1992) and Paultre et al. (1993) remain the only references to these reports.

Boivin (1992) detailed the regions and municipalities where most of the damage was reported. Over the years, some municipalities have amalgamated. Table 1 lists the ten municipalities that had the largest number of damage claims, based on the 1988 and 2019 boundaries. Two regions stood out with the majority of damage claims: Saguenay-Lac-St-Jean (607) and Quebec City (657; Boivin, 1992). In the intensity database, damage reports were assigned MMI VII for each municipality with 10 or more cases of damage, based on Table 1 of Boivin (1992). Similarly, the number of damage reports for these municipalities were added to our database as MMI VII entries.

Rank	Municipality (1988)	Number of damage reports	Municipality (2019)	Total Number of damage reports
1	Chicoutimi *1	131	Saguenay (*1) (Chicoutimi, La Baie, Jonquière, Laterrière)	299
2	Quebec City*2	106	Quebec City (*2) (Quebec City, Charlesbourg, Beauport,	172
3	La Baie *1	85	Alma	46
4	Jonquière *1	68	Dolbeau	26
5	Alma	46	Ferland-et-Boilleau	24
6	Charlesbourg*2	45	Shannon	22
7	Dolbeau	26	Baie-St-Paul *3 (Baie-St-Paul, Baie St-Paul paroisse)	38
8	Ferland-et-Boilleau	24	Mashteuiatsh	20
9	Shannon	22	St-Félicien	18
10	Baie-St-Paul	21	Clermont	16

Table 1: The 10 municipalities that had the highest number of damage claims in 1989; those numbers based on today's municipal boundaries (based on Boivin, 1992).

Summary of findings

The total felt area exceeded 3 million square kilometres and approached that of the magnitude 6.7 (mbLg; Mw 6.2) 1925 Charlevoix-Kamouraska earthquake (Figure 1; Cajka and Drysdale, 1996). For the Saguenay earthquake, the areas registering intensity IV and greater areas was consistent with the instrumental magnitude of 6.5, based on the high frequency Lg waves. The Saguenay earthquake produced unexpectedly large amounts of high frequency seismic energy, as evidenced by the value

$m_b(L_g)$ 6.5, the intensity data, and the high accelerations observed at distances ranging from 40 to 800 km (Munro and Weichert, 1989).

The Saguenay earthquake was felt to maximum intensity MMI VIII in the Chicoutimi- Jonquière-La Baie area (now all part of the City of Saguenay; Figures 2 and 3). It caused some level of damage hundreds of km away, mostly where unconsolidated deposits amplified ground motions (as far as Montreal some 350 km away). It was distinctly felt by most people within 500 km, felt by many within 1000 km and perceptible by some, under special circumstances, beyond 1000 km**.**

Many people were badly frightened, partly because of an almost general power blackout, partly due to the strength of shaking, and possibly from the lack of previous earthquake experience. There were a few minor injuries but no direct casualties, except for a few cases of heart attack. There were numerous reports of articles being thrown from shelves in the epicentral area (MMI V+), but serious damage was limited. Isolated cases of property damage in the Saguenay region and parts of Quebec City and Montréal, consisted primarily of cracked or partially collapsed unreinforced masonry walls (MMI VIII).

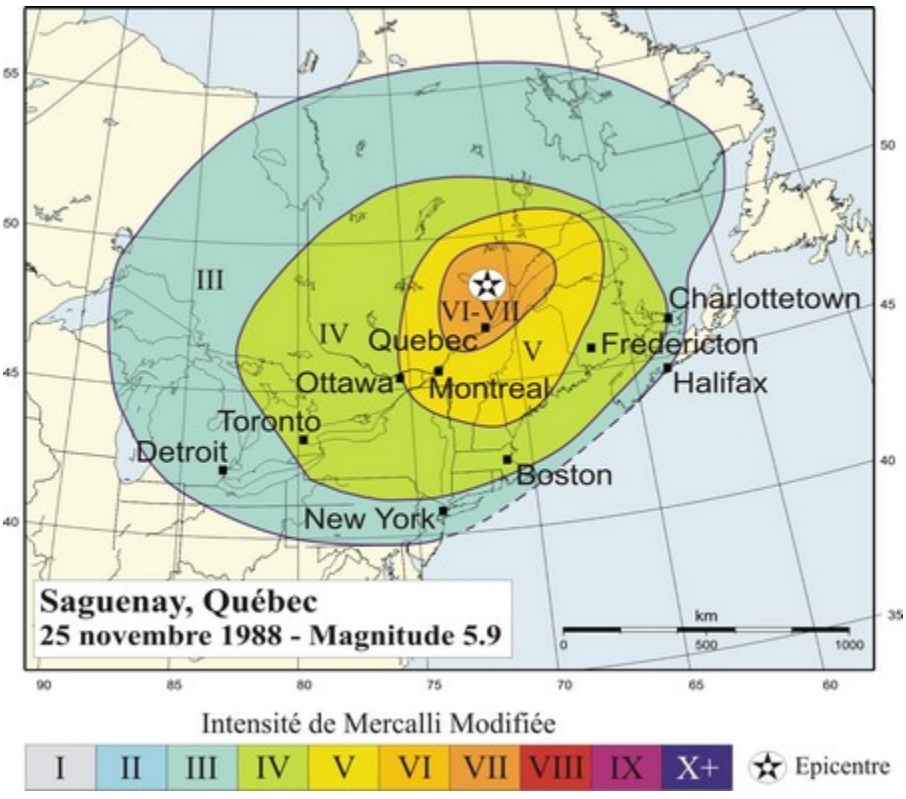

Figure 1: Isoseismal map for the November 25 1988 main shock (Cajka and Drysdale, 1996).

Foreshock and Aftershocks

The Saguenay event was preceded 62 hours earlier by a foreshock (m_N 4.6). It occurred in the early morning hours (04:11 a.m. local time) and woke up many residents in the Saguenay and Quebec City regions. In the felt report questionnaires for the main shock, many mention the foreshock. A separate tab within the intensities spreadsheet is included contains the foreshock reports. The foreshock spurred the GSC to deploy field equipment in the epicentral area and they were operational for some 24 hours before the main shock. The permanent network and the field stations did not detect any small magnitude activity prior to the mainshock.

The Saguenay main shock was followed by over 85 aftershocks within a year after the main shock of which only two have been larger than magnitude 3. The largest aftershock had a magnitude of 4.1 (M_N) and occurred about 4 hours after the main shock (10:38 p.m. local time). Many felt reports for the main shock mention its occurrence. Many others, on the other hand, are deemed false: as they come from localities that are too distant to be credible or at specific times when no aftershock occurred possibly heightened sensitivity to movements of some people after the main shock. A separate tab within the spreadsheet includes the aftershock reports.

The aftershock activity was monitored by the temporary field stations for two weeks after the main shock (we include some pictures of the survey). Once the GSC terminated the field survey, Reynald Du Berger of the Université du Québec à Chicoutimi (UQAC) continued the near-field monitoring with portable seismographs for months afterwards. A few weeks after the main shock, two permanent GSC seismograph stations were installed: one short-period vertical instrument to the southwest of the activity with signal telemetered to Ottawa (Lac Daran, DAQ; at a Hydro-Quebec telecommunication tower) and one analogue station located to the east of the epicentral region near La Baie (station named Chicoutimi, CIQ). During that period, the detection threshold is estimated to have been slightly lower than m_N 1.0. An interesting characteristic of the earthquake period is that the aftershock activity became almost absent a few hours after the main shock. This could possibly be due to the mid-crustal depth of the main shock that may have prevented the triggering of nearby faults and fractures.

Open File

This OF Report includes a spreadsheet with the felt and damage information from more than 2000 Canadian localities. The information includes much of the work of Cajka and Drysdale (1996) by plus additional details. For each locality, available felt information is provided as comments in a table. Images of the original felt report questionnaires are also included (directory Felt-Reports). Most felt reports were interpreted on the Modified Mercalli intensity (MMI) scale by Cajka and Drysdale (1996). The first author revisited some MMI V to VII entries and added comments and references when supplementary details existed. When available, we also provide information about specific buildings or impacts. In addition, the scans of the original newspapers are included when available. This OF also provides a GoogleEarth kmz file that allows the felt information reports to be viewed within this geospatial tool.

Fields of the Table

Using the spreadsheet, a table was created that includes close to 2100 entries (rows). The columns are the same as published in Lamontagne and Burke (2018). Rows have a different colour 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).
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

    The currently-accepted epicentre for the 1988 earthquake is Latitude 48.12°N and Longitude 71.18°W as listed in the final 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. Most MMIs were determined by Cajka and Drysdale (1996). If they were changed, the reason for modification and the author of modification were given.
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 rarely used this field for this OF.
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.
26. Original text: Text from a newspaper when available.

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 available at: https://www.google.com/earth/download/ge/

A static image of the Google Earth display is shown as Figures 2 and 3.

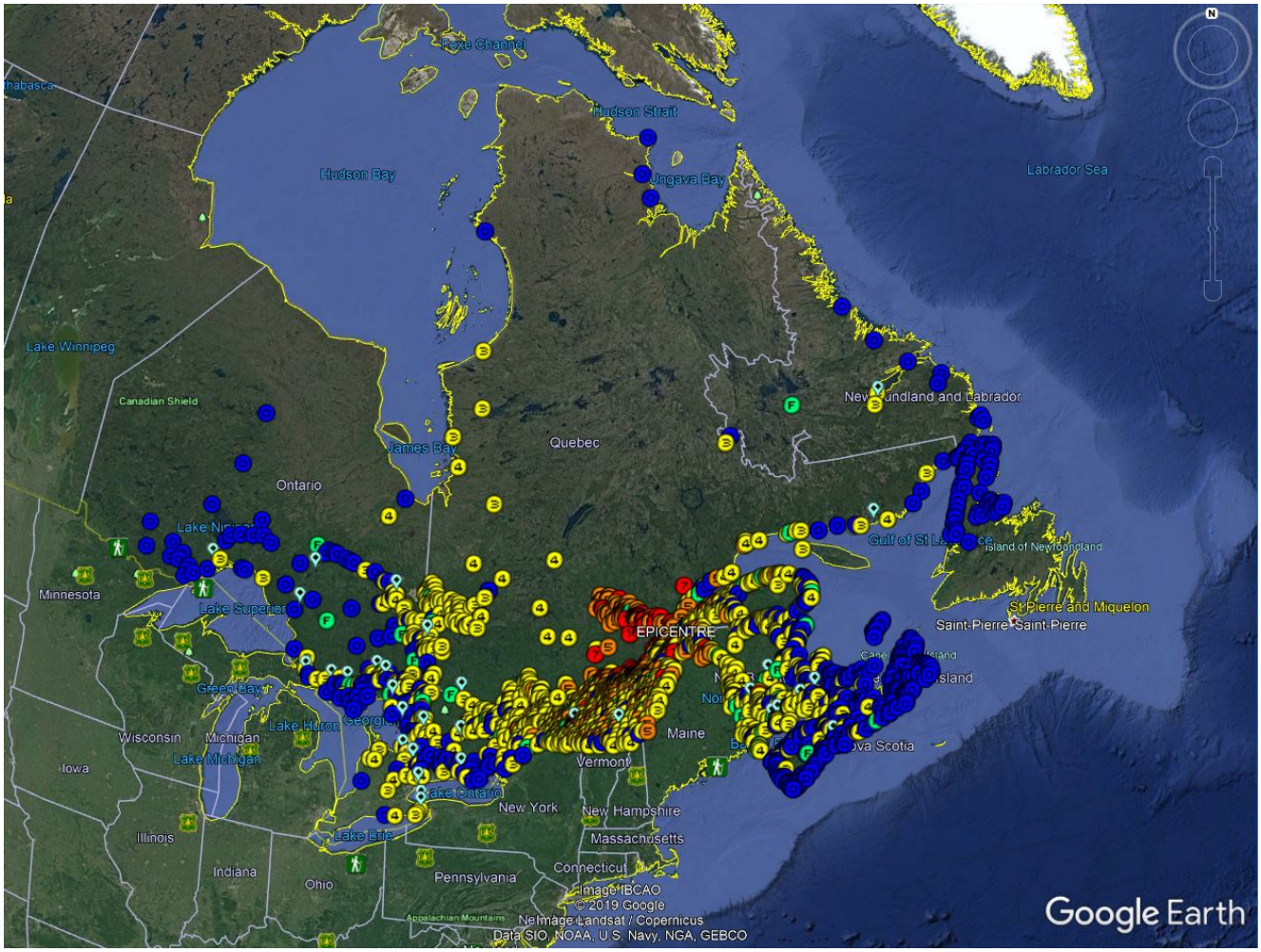

Figure 2. Static image of Google Earth view showing distribution of felt reports included in this OF and generated from the kml file.

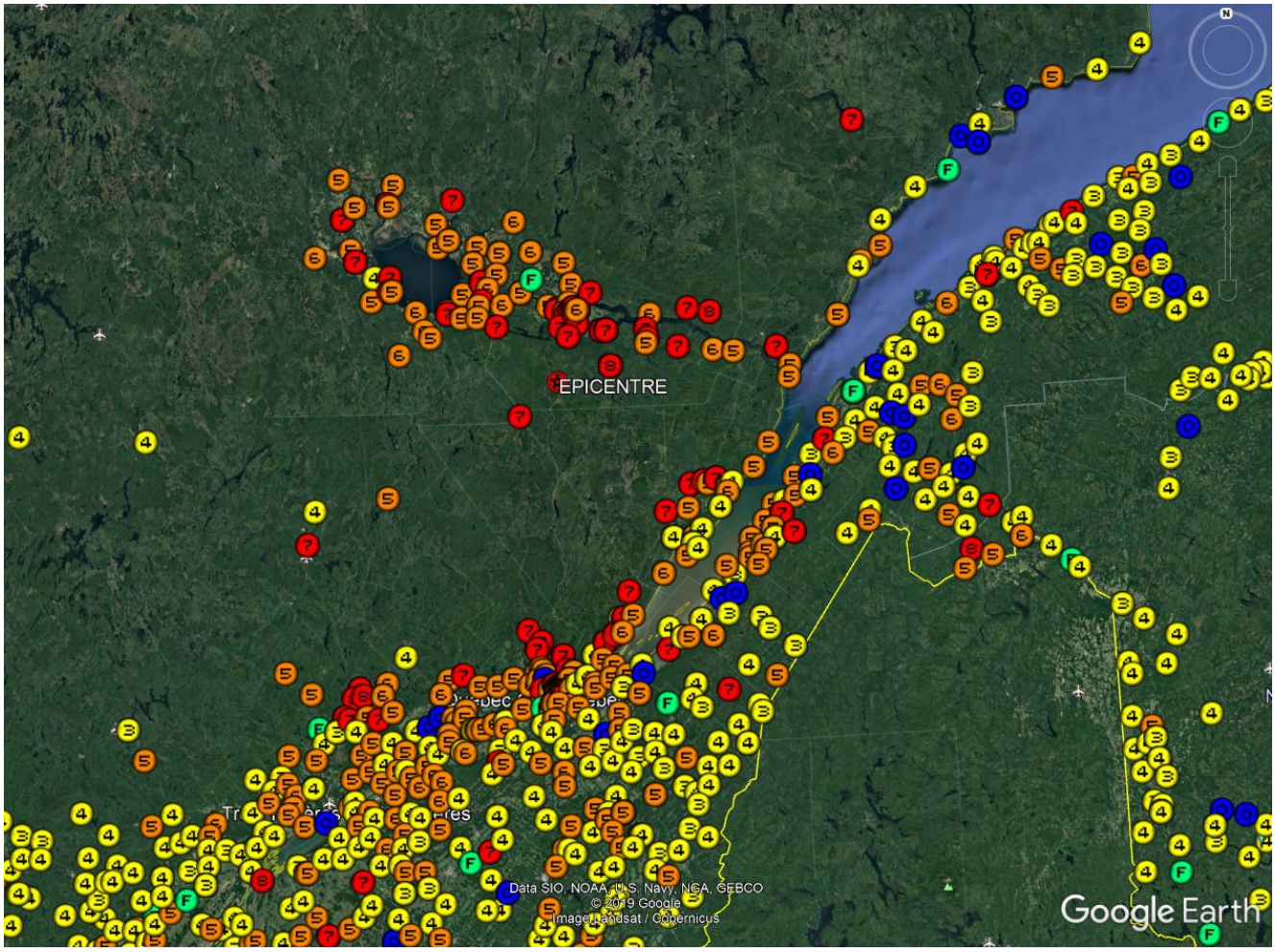

Figure 3. Static image of Google Earth view showing distribution of felt reports in the region surrounding the epicenter included in this OF and generated from the kml file.

Conclusions and recommendations

A new digital repository of felt reports for the November 25, 1988 magnitude 5.9 Saguenay earthquake now exists. Due to the additional details on damage, the inclusion of the original felt reports and the pictures of damage, we are confident that this OF includes all available information on the impact of this earthquake in Canada and the US. It provides considerably more information than the original OF Report of Cajka and Drysdale (1994). We hope that it will be useful for research on this earthquake as well as on other intraplate earthquakes.

Acknowledgments

We recognize the important work done by our former GSC colleagues Mary Cajka and Janet Drysdale who published their interpretations in Cajka and Drysdale (1996). We thank our GSC colleague Alison Bird for reviewing the OF. We also thank Heather Crow, the project leader, for supporting this activity and our NRCan colleagues Elizabeth Burgoyne and Michael Szadurski for scanning the original felt reports. Finally, we thank Professors Tinawi, Mitchell, Paultre, Lefebvre, Dr Allen, and Mr Pierre for their permissions to reproduce their reports and photographs.

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Appendix I: Modified Mercalli Intensity Scale (as published by 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.