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2018

Canada

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2018

Permanent link: https://doi.org/10.4095/306961

This publication is available for free download through GEOSCAN (http://geoscan.nrcan.gc.ca/).

Recommended citation
Lamontagne, M. and Burke, K.B.S., 2018. The 1929 magnitude 7.2 Grand Banks earthquake: felt reports from the dominions of Canada and Newfoundland and islands of Saint-Pierre and Miquelon, France, France; Geological Survey of Canada, Open File 8353, 1 .zip file. https://doi.org/10.4095/306961

Publications in this series have not been edited; they are released as submitted by the authors.

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Abstract

The 18 November 1929 Magnitude (**M**) 7.2 earthquake is the largest historical earthquake of eastern Canada. The earthquake was felt over most of Newfoundland and Labrador, at St-Pierre and Miquelon, in the Maritimes, eastern Quebec and New England. In this Open File Report, we include scans of the original felt information questionnaires that were received by the Dominion Observatory shortly after the earthquake occurred and other felt information from Canada, the Dominion of Newfoundland and St-Pierre and Miquelon. For each locality, the felt information is rated on the Modified Mercalli intensity (MMI) scale and tabulated in a Microsoft Excel sheet. Some 155 MMI reports are listed. This Open File is a pilot project that aims at evaluating the level of effort required to have all similar macroseismic information of Canadian earthquakes included in an intensity database. A total of about four weeks of work was necessary to produce this Open File Report.

Introduction

The 18 November 1929 Grand Banks earthquake is the largest historical earthquake of eastern Canada. Its calculated Moment Magnitude (**M**) is 7.2 (Bent, 1995). At the time of the earthquake, Newfoundland was still the Dominion of Newfoundland. It was only in 1949 that Newfoundland and Labrador joined the Canadian Confederation. This explains that the title may seems a bit strange to a 21st century reader: "Felt reports from the Dominion of Newfoundland and Canada…', but it is a historical fact: Newfoundland and Canada were two different countries in 1929. We also included the felt reports from eastern Canada and one felt report from the archipelago of St-Pierre and Miquelon (France).

Due to its magnitude and the devastating tsunami that followed, the 1929 Grand Banks

earthquake is considered a significant Canadian earthquake (Lamontagne et al., 2007). The earthquake epicentre is located on the Laurentian Slope, south of Newfoundland, approximately at latitude 44.69°N and 56.00°W. The earthquake was felt over most of Newfoundland and Labrador, the Maritimes, eastern Quebec and New England. On land, damage due to earthquake vibrations was limited to Cape Breton Island where chimneys were overthrown or cracked, loose objects and stores were dislodged from shelves and cupboards and where some highways were blocked by minor landslides (Doxsee, 1948). One chimney also fell in Fredericton, New Brunswick (Burke, 2009).

The earthquake is mainly remembered by its associated large ocean wave (tsunami) that was induced by a massive submarine slump (landslide). The tsunami killed 28 people when it struck the Burin Peninsula of southern Newfoundland (Ruffman and Hann, 2006). Total property losses were estimated at more than $1 million in 1929 dollars (estimated as nearly $20 million 2017 dollars; Bank of Canada, 2017). More details on this earthquake and tsunami can be found at http://www.earthquakescanada.nrcan.gc.ca/historic-historique/events/19291118-en.php .

As was the tradition after any widely felt earthquake in Canada, the Dominion Observatory in Ottawa sent macroseismic effect questionnaires to postmasters located in an area larger than the suspected region . Questionnaires were sent to Newfoundland and eastern Canada, i.e. in the Maritime Provinces, Quebec and the eastern part of Ontario (Doxsee, 1948). Questionnaires were also sent in the United States by the United States Coast and Geodetic Survey (Doxsee, 1928), and the results can be found in Bakun et al. (2002).

Shortly after, an isoseismal map was drafted using the Canadian and American felt reports rated on the Rossi-Forel scale (Doxsee, 1948; Figures 1 and 2). In the 1990's, the Canadian felt reports were re-analyzed by A.E. Stevens of the Geological Survey of Canada using the Modified Mercalli Scale of 1931 (see Appendix). Together with the US felt reports, a new isoseismal map was published (Figure 3).

In 2016, the first author looked into creating an intensity database for Canadian earthquakes. To help estimate the amount of work required for the project, it was decided to use the isoseismal information of the 1929 Grand Banks earthquake as a pilot-test for other widely felt earthquakes.

The three main objectives of this project were:

1) To scan the original felt reports that currently exist only on paper.
2) To convert the information of these reports into intensities on the Modified Mercalli scale and making them available in a digital table;
3) To evaluate the time and effort required to do this type of work for future work on historical earthquakes.

We hope that eventually, all available Canadian felt reports currently on paper will be digitized and information be made available.

Data and results

First, the original felt reports for Newfoundland and Canada were photocopied. The unusual size of the original reports on paper by today's standards did not allow direct scanning. The photocopies were scanned, rotated and saved as pdf files. Each file was renamed according to the province and place name where the felt report came from. When the felt description was on two pages or if multiple reports were received from the same locality, the pdf were named with the locality plus a number (1, 2, 3, etc). Exceptionally, newspaper clippings and various written accounts were also scanned. The file folder "felt-reports" contains all scanned documents.

A Microsoft Excel spreadsheet contains the basic information on the felt reports (attached). For reference, we added the MMI ratings of A.E. Stevens (listed in Bakun, 2002) and those of Burke (2009). For Cape Breton Island, a MMI VIII included in the reports by Ann Stevens was deleted: we could not associate it with a specific felt report. We assumed that the rating was interpreted from other felt reports from the area. For the MMI values of IV and higher, we extracted the element of intensity that could help assess the appropriate level on the MMI scale.

Fields of the Table

Using the Microsoft Excel spreadsheet, a table was created that includes some 155 entries (rows).

Some of columns may not appear very useful for the 1929 isoseismals; however, they were defined as general as possible to be used in a future database of intensity information. 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 eventually 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; NL: Newfoundland and Labrador; NS: Nova Scotia; ON: Ontario; PE: Prince Edward Island; QC: Quebec.
12. Country: Only Canadian localities and the St-Pierre and Miquelon entry (France) were included.
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): Epicentral distance in km between the earthquake source 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 1929 earthquake is Latitude 44.69 and longitude -56.00 as it appears in the second sheet of the Excel file.

17. Final Numeric MMI: Based on the felt report, interpreted Intensity on the Modified Mercalli Scale of 1931. Although MMI is defined using Roman numerals, we decided to convert them to arabic numerals for ease of use.
18. Basis for MMI (English): Aspects of the felt report in English (if available) that were used to rate the MMI (in Arabic numerals).
19. Basis for MMI (French): Aspects of the felt report in French (if available) that were used to rate the MMI (in Arabic numerals).
20. Source of felt report: 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 (ex: 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 (ex: MMI 3-4; in Arabic numerals).
24. Interpreter: Author that made the interpretation.
25. Additional notes: Comments of interest on the felt report or its publication.

GoogleEarth file

To ease the consulting of the data and put them in a geographic context, a kmz file is added and can be viewed using the GoogleEarth software that can be downloaded at: https://www.google.com/earth/download/ge/

A static image of the Google Earth display is shown as Figure 4.

Conclusions and recommendations

A new digital repository of felt reports from the Dominion of Newfoundland and Canada for the 1929 Magnitude 7.2 Grand Banks earthquake was created. We are confident that this Open File includes all available information on how this earthquake was felt in eastern Canada. It could be amended if new information is uncovered. We hope that it will be useful for research on this earthquake as well as on other intraplate earthquakes.

The scanning and production of a digital database of intensities is time consuming. We estimate that a minimum of four weeks of work (about 150 hours) were necessary for the scanning, and data entry of the information. Although some of the basic work can be done by non-specialists, a seismologist must verify the end-products and interpreted information (and re-interpret it at times). The process is time consuming but necessary to preserve the wealth of information on historical earthquakes.

Acknowledgments

We thank our colleagues Stephen Halchuk for providing comments and copies of figures 2 and 3, and Dr. John Adams for his comments and valuable materials that he shared with us. We also thank Heather Crow, the project leader, for supporting this activity.

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Appendix 1: 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.

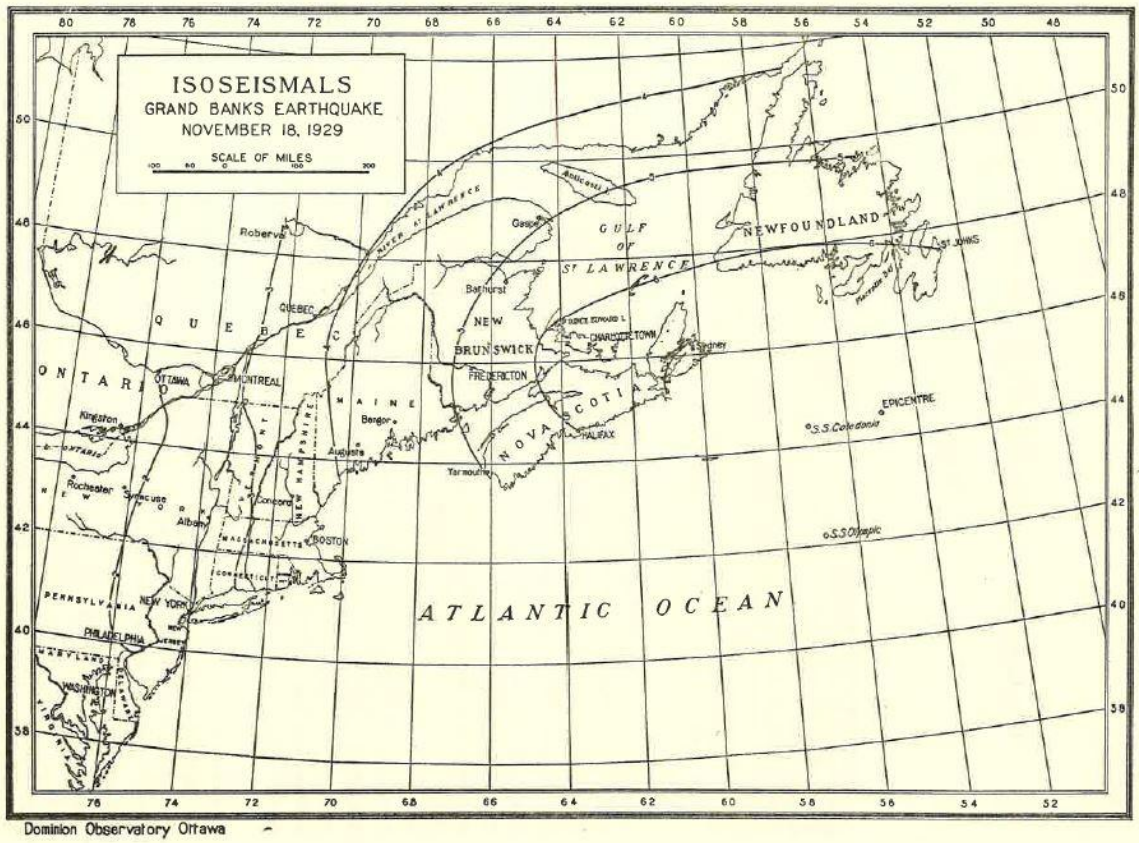
- Landslides considerable from river banks and steep coasts.
- Shifted sand and mud horizontally on beaches and flat land.
- Changed level of water in wells.
- Threw water on banks of canals, lakes, rivers, etc.
- Damage serious to dams, dikes, embankments.
- Severe to well-built wooden structures and 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.



Isoseismal Map. Figure 1.

Figure 1. Original isoseismal map on the Rossi-Forel scale (Doxsee, 1948). As shown in Figure 2, starting from the epicentre, the isoseismal lines represent RF 7, 6, 5, 4, 3 and 0.

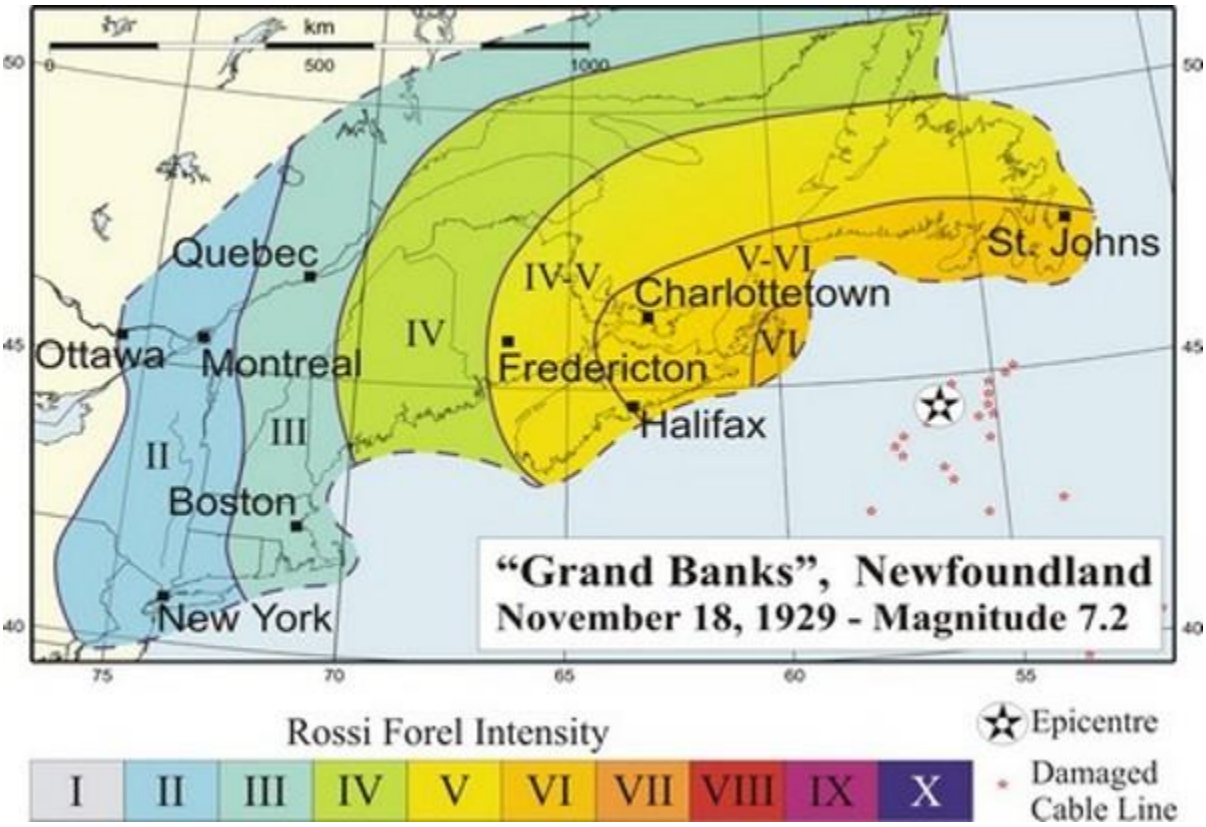


Figure 2. Coloured version of the isoseismal map that used the Rossi-Forel scale (S. Halchuk, unpubl. after Doxsee, 1948) (www.earthquakescanada.ca)

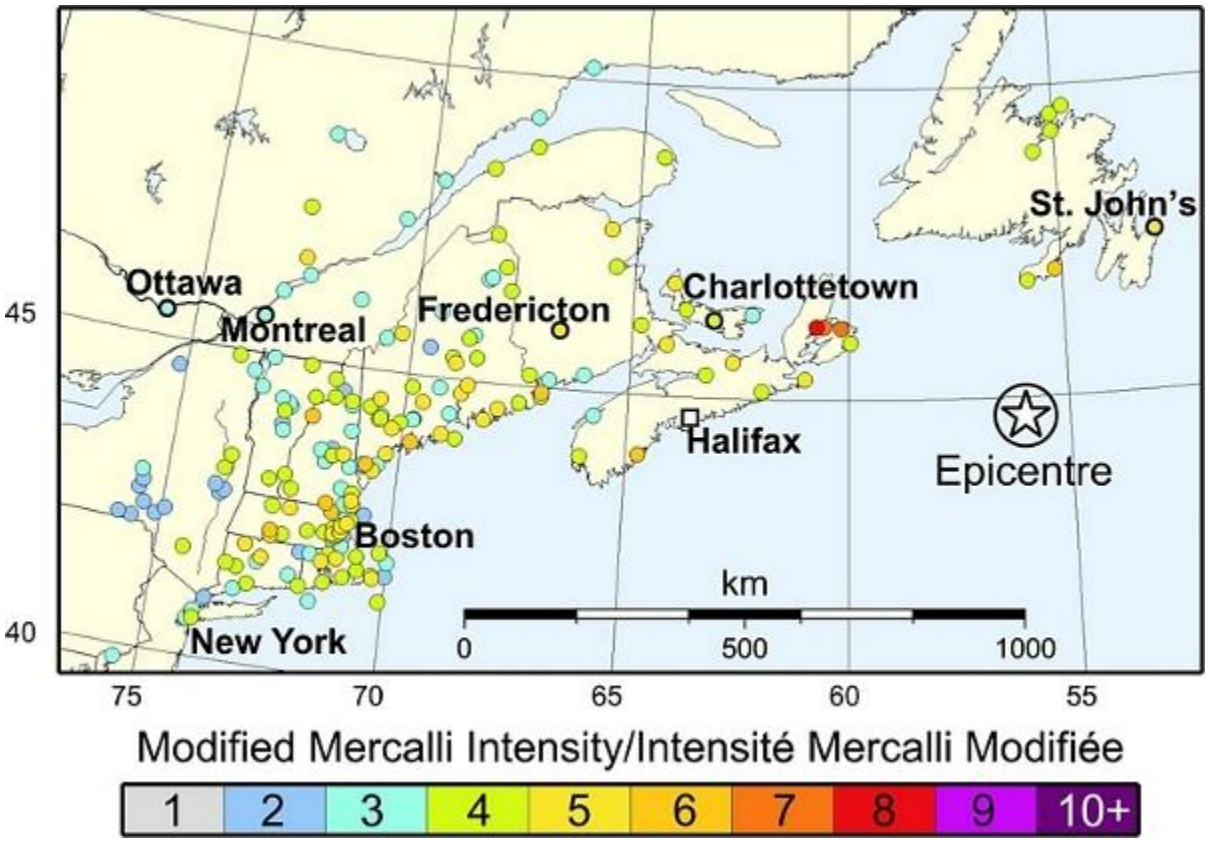


Figure 3. Map of the revised Modified Mercalli intensities for the 1929 Magnitude 7.2 Grand Banks earthquake (Halchuk, personal communication; based on the isoseismal information in Bakun et al., 2002; www.earthquakescanada.ca).

Figure 4. Static image of Google Earth view showing distribution of felt reports included in this Open File and generated from the kmz file.