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Canada

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Felt reports for the December 25, 1989, Moment Magnitude 6.2 Ungava, Quebec, earthquake

M. Lamontagne

Abstract

The December 25, 1989, Moment Magnitude 6.2 Ungava, Quebec, earthquake is one of the largest northern Canadian earthquakes of the 20th century. It occurred in the middle of the Ungava peninsula of Quebec and caused the first documented earthquake surface rupture in Canada east of the Rockies. This Open File Report includes the macroseismic information on this earthquake, including felt report questionnaires. For each locality, the interpreted information is presented in a digital table. The fields include the name, latitude and longitude of the municipality, a short description of the felt effect and the interpreted intensity on the Modified Mercalli Intensity (MMI) scale. Finally, a GoogleEarth kmz file is added for viewing the felt information reports within a spatial tool.

Résumé

Le tremblement de terre du 25 décembre 1989, d'une magnitude de 6,2 dans l'Ungava, au Québec, est l'un des plus grands tremblements de terre du nord du Canada au 20e siècle. Il s'est produit au milieu de la péninsule d'Ungava, au Québec, et a provoqué la première rupture de la surface sismique documentée au Canada, à l'est des Rocheuses. Ce dossier public comprend les informations macroséismiques sur ce tremblement de terre, y compris des questionnaires sur comment le séisme a été ressenti localement. 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, une brève description de l'effet ressenti et l'intensité interprétée sur l'échelle d'intensité de Mercalli modifiée (IMC). Enfin, un fichier kmz GoogleEarth est ajouté pour la visualisation des rapports d'informations macroséismiques dans un outil géospatial.

Introduction

The December 25, 1989, Ungava earthquake occurred at 09:24 local time (14:24 UTC) and its epicenter was located in the middle of the Ungava Peninsula in northern Quebec (latitude 60.12°N, longitude 73.6°W; Adams et al., 1990). The moment magnitude (**M**) was 6.2 (Bent, 1994) with other magnitudes being: 6.3 m_B; 6.1 m_N; m_b 6.2 (NEIC); M_S 6.3. It was the first earthquake in eastern North America known to be associated with a surface fault rupture. Descriptions of the geological context and the near-field effects such as the fault ruptures, the liquefaction and slope failures can be found in Adams et al., (1991a; 1991b; 1992) and Lamontagne and Graham (1993). The epicentral region is uninhabited and its impact there was only of geological nature. People in nine communities, all beyond 200 km epicentral distance, reported feeling the earthquake.

The mainshock was preceded by a magnitude m_{bLg} 5.1 foreshock ten hours earlier. Five earthquakes of magnitude 3 or greater were recorded between the m_{bLg} 5.1 foreshock and the mainshock. In the two weeks following the mainshock, at least eight magnitude 3 or greater aftershocks occurred, the largest being magnitude 4.4 (Wetmiller et al., 1991). Although some earthquakes were recorded sporadically, including an earthquake swarm in 2013, they were all less than m_{bLg} 4. None of these events were reported as being felt.

This Open File Report (OF) documents the 1989 Ungava main shock and has the following objectives:

1) To describe how the macroseismic information was obtained and interpreted.
2) To provide tables with the available felt reports for the main shock.
3) To provide the interpreted intensities on the MMI scale for this earthquake.

Felt reports

Following the event, the Geological Survey of Canada sent macroseismic questionnaires to 100 postmasters in northern Quebec, Nunavut (part of the Northwest Territories at the time) and Labrador (NL) to determine local intensities (Drysdale et al.,1990; Wetmiller et al.,1991; 1992).

About 100 communities as far away as 1400 km were canvassed by the intensity questionnaires but only 70 reports were returned (Wetmiller et al., 1992). Only two questionnaires mentioned that the earthquake was felt locally. The original reports are included in the /Questionnaires .

Although no newspapers were published in the surrounding communities, some other sources of information were obtained. A radio reporter from the Canadian Broadcasting Corporation (CBC) in Kuujjuaq, Qc, gathered information from a number of communities (file: Kuujjuaq-CBC-Letter.pdf in the folder Questionnaires).

This information plus that collected with the questionnaire was used to produce an isoseismal map (Drysdale et al., 1990; Fig. 1).

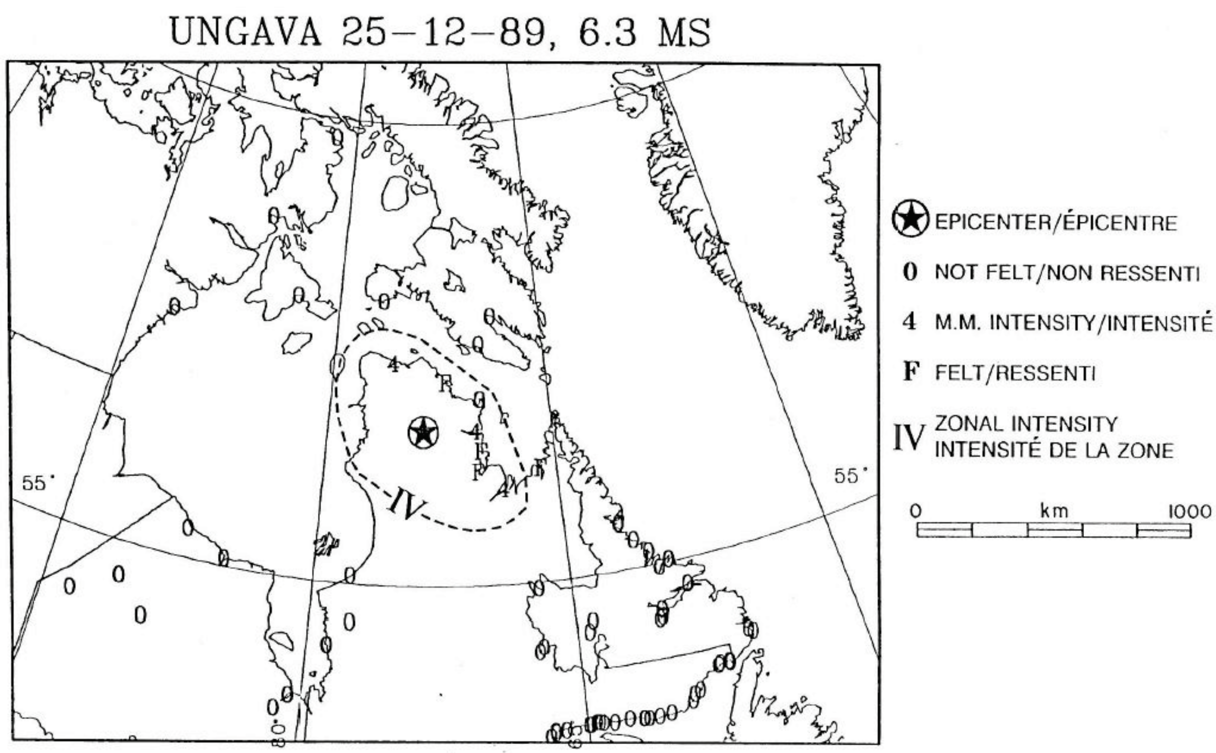

Figure 1: Isoseismal map for the main shock (Drysdale et al., 1990). This map can be compared with the GoogleEarth Map of Figure 2.

In 2020, the author contacted a Facebook group in Nunavik, which provided four additional felt reports, but only one from a community not previously covered (Inukjuak). Altogether, we know that the earthquake was felt in ten communities, all located within 500 km epicentral distance (figures 2 and 3).

Summary of findings

The earthquake was felt in a total of ten communities (Table 1). The furthest municipality where the earthquake was felt is Kangiqsualujjuaq (former Port Nouveau Quebec) at about 460 km epicentral distance. Felt reports indicate a maximum intensity on the Modified Mercalli Intensity (MMI) scale of only IV (noticed but relatively light shaking; swinging of suspended plants; no objects fell). See Appendix I for a description of the 12 levels of the MMI scale.

Municipality	**Epicentral distance (km)**	**MMI**
Kangiqsujuaq (Maricourt)	187	F
Kangirsuk	199	IV
Povungnituk	204	No report
Aupaluk	236	IV
Quaqtaq (Koartac)	240	III-IV
Salluit	258	IV
Tasiujaq	261	F
Akulivik	263	IV
Inukjuak	316	IV *New report
Ivujivik	343	No report
Kuujjuaq	372	IV
Kangiqsualujjuaq	461	F

Table 1: Communities where the earthquake was reported felt. It was possibly felt in Povungnituk and Ivujivik but we do not have any report from those municipalities.

Using a 500 km radius, the corresponding felt area is 785,400 km^2. If we use the Nuttli and Zollweg's formula (1974) defined for eastern North American $m_b \leq 6.0$ earthquakes, such felt area translates into a magnitude m_b 5.1. Obviously, the felt area is much smaller than that expected for an eastern Canadian earthquake of magnitude larger than 6.

$$mb = 2.65 + 0.098f + 0.054f^2 \text{ where f is } \log_{10} (\text{felt area in km}^2)$$

$$\text{using } \log_{10}(\text{felt area}) = 5.895$$

$$= 2.65 + 0.578 + 1.87 = 5.09$$

This small felt area was also noticed in other Canadian Arctic earthquakes (Bent et al., 2018). The author believes that this cannot be due entirely to the sparse distribution of communities. Possible explanations are the crustal structure that may differ from the average eastern Canadian crust and the tectonic boundaries between the epicentre and communities on Baffin Island.

Open File Data Sets

This OF Report includes the spreadsheet 1989-Ungava.xlsx with the information on how the earthquake was felt from nine communities. For each locality, available felt information is provided as comments in a table. Felt reports are interpreted on the Modified Mercalli intensity (MMI) scale, with most originally by Janet Drysdale (now retired) of the Geological Survey of Canada. The highest value was MMI IV, which corresponds to a distinct shock, but without any fallen object or damage. We also lists communities where the questionnaire was not returned and those where the earthquake was not reported felt.

To ease the consulting of the data and put them in a geographic context, 1989_Ungava.kmz file is added and can be viewed using the GoogleEarth software available at: https://www.google.com/earth/download/ge/

Static images of the Google Earth display are shown as Figures 2 and 3.

Fields of the Table

Using the spreadsheet, a table was created that includes 95 entries (rows). The columns are the same as published in Lamontagne and Burke (2018). Rows have a different colour for each province and territory 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 1989 earthquake is Latitude 60.12°N and Longitude 73.6°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.

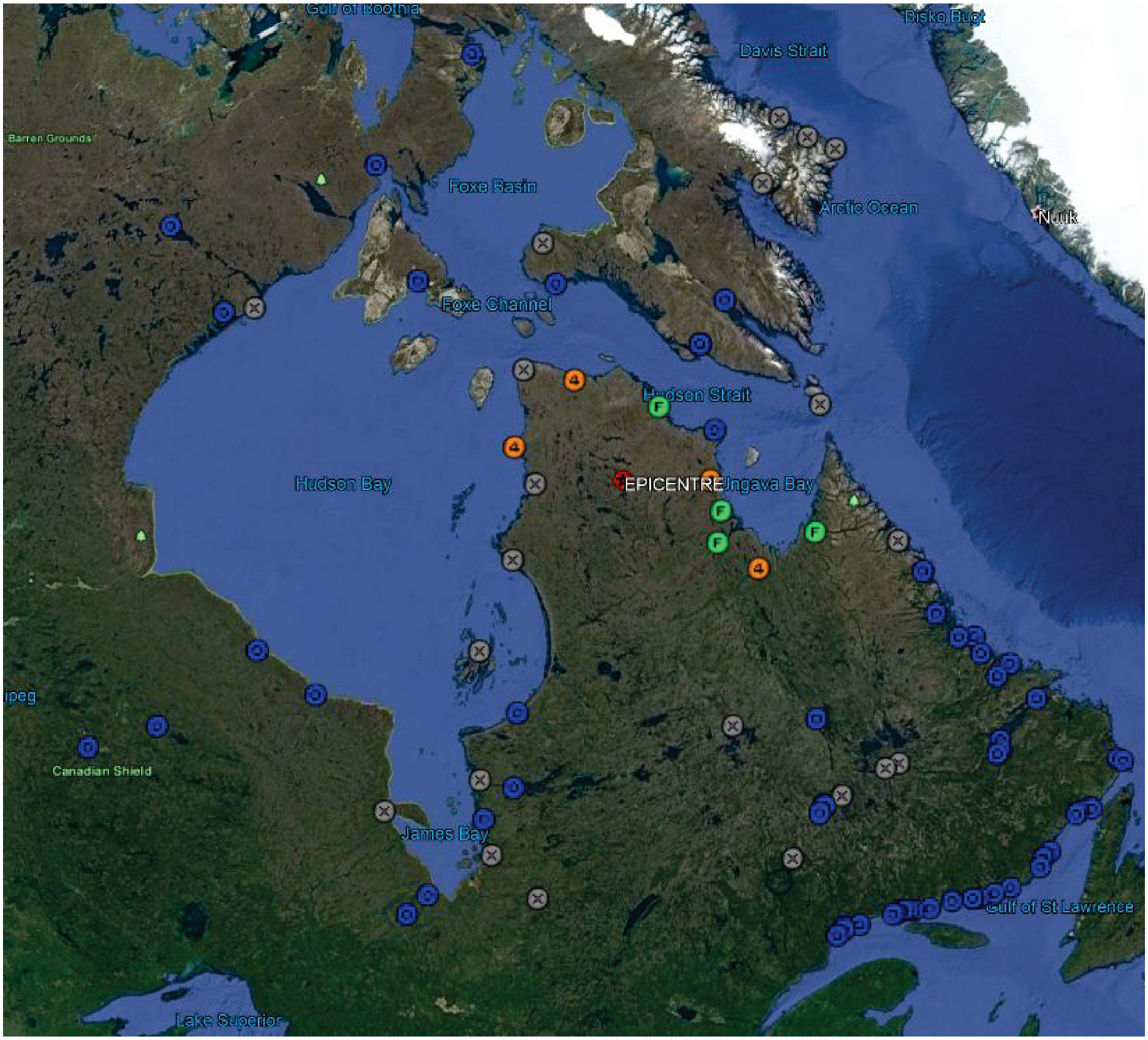

Figure 2. Static image of Google Earth view showing distribution of felt reports included in this OF and generated from the kml file (F=Felt; 4 = MMI IV; 0= not felt; X = questionnaire not returned).

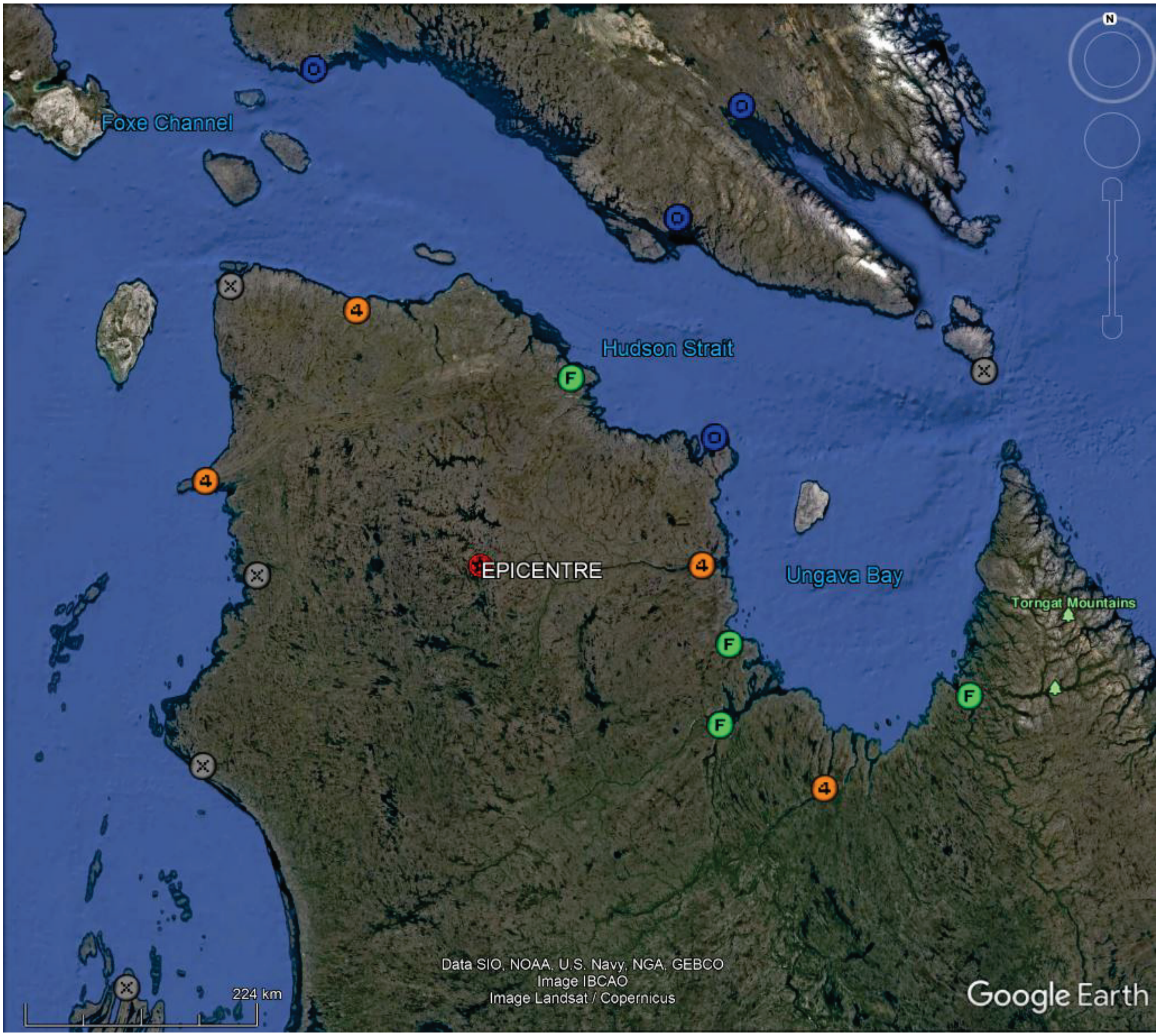

Figure 3. Static image of Google Earth view showing the region where people felt the earthquake included in this OF and generated from the kml file. (F=Felt; 4 = MMI IV; 0= not felt; X = questionnaire not returned).

Conclusions and recommendations

A digital repository of felt reports for the December 25, 1989 Ungava earthquake now exists. As reported in previous publications, the felt area is considerably less than for an eastern North American earthquake with similar magnitude. The shallow focus of the hypocentre may be one factor that increased the attenuation of the seismic waves. We hope that this OF will be useful for research on this earthquake as well as on other intraplate earthquakes.

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References

Adams, J., Wetmiller, R.J., Hasegawa, H.S., Drysdale, J.A., 1991a. The first surface faulting from a historical intraplate earthquake in North America. Nature (London). 352; 6336, Pages 617-619. https://doi.org/10.1038/352617a0

Adams, J., Wetmiller, R.J., Drysdale, J., Hasegawa, H.S., 1991b. The First Surface Rupture from an Earthquake in eastern North America. *in* Current Research, Part C, Canadian Shield / Recherches En Cours, Partie C, Bouclier Canadien., Geological Survey of Canada., Geological Survey of Canada, Paper no. 91-1C, 1991 p. 9-15, https://doi.org/10.4095/132555 (Open Access)

Adams, J., Percival, J A., Wetmiller, R.J., Drysdale, J.A., Robertson, P.B. 1992. Geological controls on the 1989 Ungava surface rupture: a preliminary interpretation. *in* Current Research, Part C, Canadian Shield / Recherches En Cours, Partie C, Bouclier Canadien., Geological Survey of Canada., Geological Survey of Canada, Paper no. 92-1C, p. 147-155, https://doi.org/10.4095/132858 (Open Access).

Bent, Allison. L. 1994. The 1989 (M_S 6.3) Ungava, Quebec earthquake; a complex intraplate event. Bulletin of the Seismological Society of America. 84; 4, 1075-1088.

Bent, A., Kolaj, M., Ackerley, N., Adams, J., Halchuk, S. 2018. The 2017 Barrow Strait, Arctic Canada, Earthquake Sequence and Contemporaneous Regional Seismicity. Seismological Research Letters, 89 (5): 1977–1988.

Drysdale, J.A., Horner, R.B., Kolinsky, R. and Lamontagne, M. 1990. Canadian Earthquakes--National Summary - October-December 1989. Energy, Mines and Resources Canada.

Lamontagne, M., Graham, D.F. 1994. Remote sensing looks at an intraplate earthquake surface rupture. Eos, Transactions of the American Geophysical Union vol. 74, no. 32, p. 353, 357, https://doi.org/10.1029/93eo00487

Lamontagne, M; 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. Geological Survey of Canada, Open File 8353, 2018, 164 pages, https://doi.org/10.4095/306961

Lamontagne, M., Halchuk, S., Cassidy, J.F. and Rogers, G.C. 2018. Significant Canadian Earthquakes 1600-2017. Open File 8285, 2018, 37 pages, (https://doi.org/10.4095/311183. https://geoscan.nrcan.gc.ca/starweb/geoscan/servlet.starweb?path=geoscan/fulle.web&search1=R=311183; last accessed 15 July, 2019).

Nuttli, O.W., and J.E. Zollweg (1974). The relations between felt area and magnitude for Central United States earthquakes, Bull. Seism. Soc. Am., **64:** 73-85.

Wetmiller, R.J., Lyons, J.A., Shannon, W.E., Munro, P.S., Thomas, J.T., Andrew, M.D., Lapointe, S.P., Lamontagne, M., Wong, C., Anglin, F.M., Adams, J., Cajka, M.G., McNeil, W., Drysdale, J.A. 1991. Eastern canadian seismic studies, July 1989 to June 1990, Geological Survey of Canada, Open File 2369, 46 pages, https://doi.org/10.4095/131698 (Open Access)

Wetmiller, R.J., Lyons, J.A., Shannon, W.E., Munro, P.S., Thomas, J.T., Andrew, M.D., Lapointe, S.P., Lamontagne, M., Wong, C., Anglin, F.M., Adams, J., Cajka, M.G., McNeil, W., Drysdale, J.A. 1992. Canadian Seismic Agreement: Annual Report, July 1989-June 1990. NUREG/CR-4753 Vol. 5. (Access to document; last accessed 2 November 2020).

Wood, H.O. and Neumann, F. (1931). Modified Mercalli Intensity Scale of 1931. Bulletin of the Seismological Society of America, **21**, p 277-283.

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.