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A Moment Magnitude Catalog for the 150 Largest Eastern Canadian Earthquakes

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Abstract

Moment magnitude, M_W, which can be related to the physical properties of a fault rupture and which, unlike other magnitude scales, does not saturate for the largest earthquakes is generally the preferred magnitude scale to use in evaluating seismic hazard. It is, however, not routinely calculated for earthquakes of magnitude less than 5.0 and difficult to determine precisely for pre-instrumental earthquakes. In this study, M_W is determined for 150 of the largest earthquakes in eastern Canada. For many of these earthquakes, M_W had been previously determined in other studies and those values are adopted here unless there is a compelling reason not to use them. For the remaining earthquakes, M_W was determined by conversion from another magnitude scale or from intensity data. Seven earthquakes were dropped from the original list as it was determined that they were either smaller than previously thought or non-events. One event, which had been buried in the coda of a larger one and not noted at the time of its occurrence, was added to the list.

Introduction

There are many magnitude scales used to measure earthquake size. Although it is common practice to say that there is one magnitude for any given earthquake, the reality is that the calculated magnitude is often dependent upon which scale is used. While there may be legitimate reasons to prefer one scale over another for a particular earthquake or application, it is desirable (if not imperative) that the same scale be used for all earthquakes when using magnitudes to determine seismic hazard. Generally speaking, the moment magnitude scale, M_W, is preferred as it can be related to the physical properties of the fault rupture. It also has the advantage of not saturating at very high magnitudes.

In eastern Canada as well as many other regions M_W is not routinely calculated as part of the standard earthquake analysis procedure and thus must be obtained by other means. For large earthquakes with good broadband or long-period data, it is a relatively straightforward procedure to determine M_W. For smaller earthquakes, pre-instrumental earthquakes and any earthquakes with poor records or only short-period records it can be more difficult. M_W must generally be obtained by converting another magnitude or by estimating it from the felt reports, both of which increase the uncertainty associated with the final value assigned.

The largest earthquakes in any region are those most likely to cause damage and are therefore of most concern. Thus, in an effort to procure M_W's for a given region it makes sense to start with the largest earthquakes. In this study M_W's are derived for the 150 largest eastern Canadian earthquakes (see Table) that satisfy the geographic limits and completeness periods used in seismic hazard calculations for eastern Canada. It should be noted that this list may not strictly represent the largest 150 earthquakes, as the original search used the preferred database magnitude, most often m_N or M_L, as a criterion and some earthquakes that may not have made the cut may have M_W's larger than some of the events near the bottom of the list. Additionally, some earthquakes larger than some of those evaluated may have been removed from the list because they did not satisfy the completeness criteria. Despite these caveats, it is unlikely that any of the very largest earthquakes have been missed.

Selection Criteria

This project was originally intended to cover the "top 100" eastern Canadian earthquakes. A cursory search of the Canadian earthquake database (National Earthquake Database, 2008), hereafter referred to as NEDB, indicated that the lower magnitude threshold would be somewhere between magnitude 5.0 and 5.5. Events of magnitude 5.0 or greater regardless of the preferred magnitude scale were extracted from the NEDB using the geographic coordinates corresponding to those used in the hazard calculations for eastern Canada (latitude 38º-90ºN and 45º-110º W; S. Halchuk, personal communication). These boundaries encompass parts of the northeastern and north-central United States and western Greenland as well as many offshore regions. Any events that did not satisfy the completeness criteria were removed from the list. The completeness periods (S. Halchuk, personal communication) for magnitude 6.0 and greater are 1660 along the St. Lawrence River, 1850 elsewhere in southeastern Canada and 1930 for northern Canada. For magnitude 5.0 and greater the corresponding years are 1880 for the south and 1950 for the north. For the time periods considered complete for magnitude 6.0, all events of magnitude 5.7 and greater were retained to allow for uncertainties in the magnitudes and variations between magnitude scales. The epicenters of the selected earthquakes are shown in Figure 1.

The edited list contained 149 earthquakes (Table 1), of which 98 were of magnitude 5.1 or greater on at least one magnitude scale. For completeness, the events which were excluded from this study because they did not pass the magnitude completeness period are listed in Table 2. Table 2 is an unedited, non-annotated list of the earthquake solutions exactly as they were extracted from the NEDB. The majority of the deleted events occurred prior to 1900 and had estimated magnitudes of 5.0. There are a few northern events from the 1930s that would have been instrumentally recorded but which did not pass the magnitude completeness test. Also note that although the locations are given relative to communities in Canada, many of these events occurred in the United States.

In the comments section of Table 1 there are several references to the JD database. This term is used to refer to the body of work resulting from the re-evaluation of post-1940 eastern Canadian earthquakes by J. Adams, J. Drysdale, R. Wetmiller and a large number of students. For the purposes of the current study, the most important outcome of their work is that m_N was determined for many events for which only an M_L had been previously available. Because m_N is considered a more appropriate magnitude for eastern Canada, these JD magnitudes were preferred over the NEDB M_L magnitudes for conversion to M_W. It should also be noted that the JD magnitudes have been incorporated into the data set used for seismic hazard calculations in Canada. Also note that several events would not have passed the initial selection criteria had the NEDB adopted the JD magnitudes.

Only three of the earthquakes of interest (#10, #20, #42 in Table 1) had M_W listed as the preferred magnitude. An attempt was made to derive M_w for all of the earthquakes on the list. The task was made considerably easier in that the M_w's for many of these events had been previously published (Johnston *et al.*, 1994, hereafter referred to as EPRI) in an exhaustive study of earthquakes in stable continental regions. Unless there were compelling reasons not to, EPRI magnitudes were used for all events for which they were available. A brief note in the comments section of the Table indicates EPRI's primary reason for the magnitude assignment.

For the remaining events, M_w's determined by detailed source studies or moment tensor inversions were preferred and used when available. Conversions from other instrumentally derived magnitudes were the second choice, with preference given to teleseismic magnitudes (M_s, m_b), which are considerably less sensitive to depth (assuming the earthquake occurred within the crust) and local variations in structure and attenuation and for which the conversion relations should therefore be more reliable. When both were available, the unified magnitude, M_U, defined in the EPRI report as a weighted average of M_s and m_b with M_S having twice the weight, was used. Regional instrumental magnitudes (m_N, M_L) were used when none of the aforementioned was available, giving preference to m_N, which was developed to be used in eastern North America. Felt information (area and/or maximum intensity) was used when there were no instrumental magnitude data. In all cases the conversions were made using the equations derived in the EPRI report. Although all earthquakes in this study had a magnitude of at least 5.0 on at least one magnitude scale, when converted to M_w only fifty-eight had a magnitude greater than or equal to 5.0. Figure 2 shows the distribution of events by magnitude based on the NEDB preferred magnitudes and the M_W's from this study. The large number of NEDB magnitude 5.0 events suggests that it was used as a default magnitude for earthquakes whose magnitude was not well constrained. Figure 3 plots the NEDB magnitude against M_W. For earthquakes above magnitude 6.0 there is a good correlation between the NEDB magnitudes (mostly M_S and M_L) and M_W. At lower magnitudes there is much more scatter but it should be noted that M_W was sometime determined from a magnitude other than the preferred NEDB value and type.

Moment Magnitude Catalog

In Table 1 the events studied are listed in descending order based on M_W. Origin times (Universal Time) and epicenters are those found in the NEDB unless stated otherwise. Note that there is always some uncertainty associated with the epicenter and that it is generally larger for pre-instrumental earthquakes. Thus, distances from specific locations should be taken as approximations only. Origin times of 00:00:00 generally indicate that this parameter is unknown. Events of equal M_W are arranged in ascending chronological order. Column 5 lists whatever the NEDB considers to be the preferred magnitude with the magnitude type noted. M_W and its source follow the descriptive location information. Minor issues regarding an earthquake are noted as comments only in the final column of Table 1. An asterisk indicates that the earthquake is discussed in more depth in the following section. Note that many of the earthquakes listed as being in the Northwest Territories (NT) are geographically located in what is now the territory of Nunavut (NU) because their epicenters were in areas that were in the Northwest Territories at the time the earthquakes occurred. Earthquakes occurring since the creation of the new territory (1 April 1999) are designated as Nunavut or Northwest Territories based on the current boundaries. The primary source regions affected are Baffin Bay, Baffin Island and the Wager Bay region.

Discussion

Of the six events that have an M_W of 6.5 or greater, four were instrumentally recorded. The two largest, the 1929 Grand Banks and 1933 Baffin Bay earthquakes, were the subjects of detailed source studies (Bent, 1995, 2002) that determined focal mechanism, moment, magnitude and depth. The 1934 and 1945 Baffin Bay earthquakes both had instrumental M_S values that EPRI used to convert to M_W. The remaining two, the 1663 and 1870 Charlevoix earthquakes, were pre-instrumental with M_W's estimated primarily from felt data. The uncertainty attached to these two M_W's is thus greater than for the other four, although it is doubtful that the values can be further refined and they are clearly among the largest earthquakes on the list.

Seven events (#144-150) were removed from the list. They are shown at the bottom of Table 1 with no M_W associated with them. Six of these occurred in or near the United States and were perhaps not given adequate attention when initially added to the Canadian database. The other was a Canadian earthquake that occurred in 1910.

According to Gouin (2001) the 1910 Charlevoix region earthquake (#144) was probably a very small event that was felt in St-Pascal on 25 February 1910 and was possibly only a rumor. He lists several local newspapers not reporting the event, which would have been extremely unusual had it been truly an earthquake with a magnitude of around 5. He also notes that it does not appear in catalogs of earthquakes felt in New England during that time period, and that the original reference (Mather et al, 1927), relies on secondary sources and only mentions it in the Appendix. It appears that Smith (1962) took their comments about how widespread it was allegedly felt at face value and then calculated an epicenter and magnitude.

The only evidence for event #145 (1915, offshore) is that a ship at sea felt a strong shock (Smith, 1962). Given the date and location, it is possible that a moderate sized earthquake would not have been instrumentally recorded. An offshore earthquake with a magnitude of about 5 would probably not have been felt on land. However, given the properties of wave propagation in water, an earthquake strong enough to be felt at sea should have been large enough to have been recorded at teleseismic distances. Thus, this event is being dropped from the list.

Events #146 and #149 that occurred in Pennsylvania in February 1954 were probably related to subsidence of an underground coal mine. The United States Geological Survey (2008, hereafter referred to as the USGS) notes that the events were felt strongly and caused damage in Wilkes-Barre. It appears that the M_L's of 5.7 and 5.0 assigned to these earthquakes by Smith (1962) and reported in the NEDB were based on the maximum intensity and ignored the fact the earthquakes were not felt outside of the epicentral area and not instrumentally recorded, both of which would have been unusual for large earthquakes occurring at that location in the 1950s. The USGS does not assign magnitudes to either of these events.

Two other Pennsylvania earthquakes were removed from the list also based on information obtained from the USGS, which has a descriptive on-line history of earthquakes in Pennsylvania at
http://earthquake.usgs.gov/regional/states/pennsylvania/history.php .

Event #147 (May 1908) was a small earthquake near Allentown. While it was responsible for damage to a few chimneys the total felt area was less than 150 km^2. The database magnitude appears to stem from the peak intensity only. The January 1954 (#148) earthquake near Reading also appears to be much smaller than the database magnitude. This earthquake was felt and caused some minor damage locally but there are no instrumental magnitudes for it, again not normal for a large earthquake in that region during the 1950s.

Event #150 that occurred in Massachusetts in 1963 was an actual earthquake but should not appear on the list of largest earthquakes. Weston Observatory as reported by the USGS gives an M_L of 3.2 for this event.

One event (#51) was added to the list. This earthquake did not show up in the original search of the NEDB. Because its onset overlapped with the coda of an earlier event (#15) it had not been identified at the time of its occurrence. Both events are aftershocks of the 1929 Grand Banks earthquake (#2). The "new" event was found as part of a later study on the Grand Banks region. Its magnitude was calculated by scaling its amplitudes to the 1929 mainshock at common stations (J. Adams, personal communication).

There are several additional events that require some degree of discussion with respect to magnitude and/or other source parameters. They are discussed in the order in which they appear in the Table. Note that many of these events were near the bottom of the Table with an NEDB magnitude of 5.0.

EPRI had assigned an M_W of 6.7 to event #3 (1663, Charlevoix) based on maximum intensity. Subsequent work suggests that the earthquake may have been larger. The comments that follow come from Ebel (2009 and additional personal communication). There are two separate lines of evidence for the larger magnitude. The first comes from the size of the Charlevoix Seismic Zone, which is approximately 70 km in length. Assuming this is the length of the aftershock zone and applying the relations of Wells and Coppersmith (1994) the moment magnitude is between 7.1 and 7.5 depending on the choice of relations used. There are two damage reports for this earthquake from the Boston area- a damaged chimney and a cracked brick wall. Converting intensity to ground motion results in an acceleration of 0.03g at 0.3 sec. Using standard attenuation relations the ground motion suggests a moment magnitude of at least 7.0 and if the epicenter was at the end of the seismic zone closest to Boston and larger if the earthquake occurred elsewhere in the zone with the best estimate being in the 7.3-7.5 range. Ebel (2009) also notes that some of the aftershocks of this earthquake were felt in Boston, suggesting that they were of magnitude 6.0 or greater. Aftershocks of this size would most typically occur if the mainshock magnitude was greater than 7.0 but they do not require the mainshock to be that large. On the other hand, Tuttle and Atkinson (2009) use paleoseismological studies, particularly evidence or lack thereof for liquefaction, to argue that no earthquakes greater than magnitude 7.0 have occurred in the Charlevoix seismic zone but did qualify their conclusions by saying that the 1663 earthquake could have been as large as magnitude 7.0 if the epicenter was at the extreme northeast end of the seismic zone (M. Tuttle, 2009 Seismological Society of America annual meeting). While a lack of paleoseismic evidence is not absolute proof that the magnitude was less than 7.0, the fact that such evidence was looked for and not found should be taken into consideration. Further discussions of the damage associated with the 1663 earthquake, with emphasis on Quebec, may also be found in Gouin (2001) and Lamontagne (2009). I have assigned a moment magnitude of 7.0 to this earthquake but note that the uncertainty is high with the best estimate for probable values ranging from 6.7 to 7.5. While this paper was in revision, a series of historical documents (Tony Sewell, several written communications) was uncovered documenting that the 1663 earthquake had been felt in New York, then New Amsterdam. Closer examination of these documents in the future may help reduce the uncertainty associated with the magnitude but, in any case, provide evidence that the event was felt at locations more distant than Boston.

During November and December 1972 a swarm occurred in the Byam Martin Channel region of the Queen Elizabeth Islands. Four of the swarm earthquakes are included in Table 1 (#9, #17, #19, #21). There is a poor correlation in relative ranking between M_W and m_N. The M_w values adopted in this study are those preferred by EPRI. A closer investigation shows that they adopted the values of Hasegawa (1977) based on instrumental data. Because the earthquakes occurred over a short time period there should not have been any major differences, such as method or station distribution, affecting the way m_N was calculated. Thus the reason for the difference is unclear. Although the earthquake epicenters are on continental crust and m_N should therefore be an appropriate magnitude scale, it may be that the attenuation relation for southern Canada is not appropriate for this reason. It should also be noted that there is a much better correlation between M_W and M_S.

Based on a re-evaluation of felt reports, Burke (2004) suggested that the epicenter of event #29 (1869, New Brunswick) should be moved north and east to 46.5ºN, 66.5ºW. He, however, retained the NEDB magnitude.

The ISS located event #35 off the east coast of Newfoundland using six stations, only one of which was in Canada. Adams and Wahlström (1995) relocated the event using several Canadian stations, including the closest one at Halifax. Their work moves the event to Baffin Island (70ºN, 75ºW). They also calculated an M_S of 5.1, which was applied to the EPRI conversion formula to give an M_W of 5.3.

The magnitude of event #46 (1967, Colorado) is not in question as it was recorded instrumentally. However, no event appears in the USGS database for the date and time listed (22:09, 26 November) but there is an event at the same location 7 hours later (5:09, 27 November), suggesting that the time in the NEDB is local time and not UT. Neither this event nor the one discussed in the next paragraph appear in the EPRI report but these omissions are probably due to their locations, which were likely not considered part of the stable North American craton, rather than because of their magnitudes.

The magnitude of event #75 (1897, Wyoming) may be overestimated but it is difficult to refine it further given that it occurred in the pre-instrumental era in a sparsely populated state. The USGS does not attach a magnitude to this event but they do corroborate its occurrence. The event was felt strongly in Casper, Wyoming. For lack of additional information, the original magnitude estimated from felt information (maximum intensity) was retained and converted to M_W. Given its location, this event should not have a large impact on Canadian seismic hazard calculations. The origin time of 00:00 in the NEDB indicates that it was unknown. The USGS provides an origin time of 13:30.

EPRI classifies event #83 in the Northwest Territories as a non-event using the argument that it does not appear in any global databases or in the database of Canadian epicenters they had received. However, this earthquake does appear in both the NEDB and ISC databases. Further investigation found that it was mentioned in the Canadian earthquake bulletin for 1961 (Seismological Service of Canada, 1962) along with arrival time and amplitude data. The original hand-written notes summarizing the data used and solution obtained were also examined. A search of global data found no teleseisms with which this earthquake might have been confused. Thus, it was retained in this study and a standard conversion from the instrumental M_L was applied.

The USGS reports that event #91 (1883, Michigan) was felt over a wide area, suggesting that the M_L 5.0 assigned to it may not be inappropriate. The magnitude was retained and converted to M_W for lack of further information. Note that the USGS does not assign a magnitude to this pre-instrumental earthquake.

Events #93 and #94 are both aftershocks of event #10, the 1925 Charlevoix earthquake. Both were reported felt in Quebec City. Using recent events for comparison, this suggests that m_N for each was in the 4.5-5.0 range. Again the database M_L 5.0 was not recomputed for lack of information required to refine it.

Event #98 (1940, Illinois) appears to have the wrong date attached to it. The USGS shows nothing at this time but has an event at the same location and date in 1939. This study assumes that the date was, in fact, 1939 and then adopts the USGS felt area magnitude of 4.6.

Finally event #100 (1952, Labrador Sea) also has considerable uncertainty attached to the magnitude. The database magnitude of 5.0 was retained for lack of additional information and noting that it occurred in a remote area that even in 1950s not well instrumented and therefore would have to have been large enough to be recorded at relatively large distances for its occurrence to be noted. It was one of many Labrador Sea events re-evaluated by Adams and Simmons (1991) who retained the original magnitude but slightly shifted the epicenter from 57.0º N, 57.0º W to 57.01º N, 57.73º W. This event is listed in the ISC catalog but with no magnitude.

Uncertainties associated with M_W are not included in Table 1. For those earthquakes where M_W was calculated from waveform data, the uncertainties are readily available from the primary sources. Uncertainties for other instrumental magnitudes are for the most part available or can be calculated from the information in the databases or publications in which they appear. Typical instrumental uncertainties, regardless of magnitude type, are of the order of 0.1-0.3 magnitude units but can be higher. However, the uncertainty in M_W for these earthquakes must take into account both the uncertainty in the original magnitude as well of that of the conversion equation. For magnitudes derived from felt area the uncertainty is the most difficult to calculate as it is often difficult to quantify the uncertainty in the felt area. In addition to that, the uncertainty in the felt-area-to-magnitude conversion must be considered and may be further complicated if the conversion was first to another magnitude type and then to M_W. Magnitudes derived solely from maximum intensity may often have huge uncertainties associated with them, as is shown by several of the earthquakes removed from the initial list used in this study. The uncertainty is almost assuredly asymmetric. That is, that the magnitude is far more likely to be overestimated than underestimated. Additionally this uncertainty is very difficult to quantify.

Conclusions

Moment magnitudes (M_W) were calculated for the 150 largest eastern Canadian earthquakes that pass the completeness test used for hazard calculations. These earthquakes are the most important ones for understanding the seismic hazard of the region. Moment magnitude is generally considered to the preferred magnitude scale for quantifying earthquake size as it can be related to the physical properties of the fault rupture and does not saturate at high magnitudes. However, it is not at present a routinely calculated magnitude in eastern Canada. This study represents the completion of the first step of a more ambitious project to determine reliable moment magnitudes for all eastern Canadian earthquakes used in hazard calculations.

Six earthquakes were removed from the list as it was clear that their magnitudes were considerably smaller than previously believed. Their database entries should be updated to reflect this. However, except in one case (event #150), there is considerable uncertainty as to the appropriate magnitude value. Several other earthquakes near the bottom of the list probably should not be considered among the top 150 and would not have been evaluated had the NEDB adopted the JD magnitudes.

During the course of the magnitude evaluations it was discovered that the dates and origin times of some earthquakes listed in the NEDB were incorrect and it is recommended that the database entries be corrected. Additionally, when a parameter is unknown leaving the field blank rather than assigning a value of “0” would leave less room for misinterpretation as zero is a physically possible value for many parameters, including magnitude and origin time. It should be noted that some progress has been made on the issue of “0” while this paper was in review.

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References

Adams, J. and D. G. Simmons (1991). Relocation of earthquakes in the Labrador Sea and Southern Labrador, *Geological Survey of Canada Open File 2326*, 103 pp.

Adams, J. and R. Wahlström (1995). Revised seismicity of the Grand Banks and offshore Newfoundland, *Geological Survey of Canada Open File 3043*, 58 pp.

Bent, A. L. (1992). A re-examination of the 1925 Charlevoix, Québec, earthquake, *Bulletin of the Seismological Society of America*, **82**, 2097-2113.

Bent, A. L. (1994). The 1989 (M_S 6.3) Ungava, Quebec, Earthquake: A complex intraplate event, *Bulletin of the Seismological Society of America*, **84**, 1075-1088.

Bent, A. L. (1995). A complex double-couple source mechanism for the M_S 7.2 1929 Grand Banks earthquake, *Bulletin of the Seismological Society of America*, **85**, 1003-1020.

Bent, A. L. (1996a). An improved source mechanism for the 1935 Timiskaming, Quebec earthquake from regional waveforms, *Pure and Applied Geophysics*, **146**, 5-20.

Bent, A. L. (1996b). Source parameters of the damaging Cornwall-Massena earthquake of 1944 from regional waveforms, *Bulletin of the Seismological Society of America*, **86**, 489-497.

Bent, A. L. (2002). The 1933 M_S=7.3 Baffin Bay earthquake: strike-slip faulting along the northeastern Canadian passive margin, *Geophysical Journal International*, **150**, 724-736.

Bent, A. L. and H. S. Hasegawa (1992). Earthquakes along the northwestern boundary of the Labrador Sea, *Seismological Research Letters*, **63**, 587-602.

Bent, A. L. and J. F. Cassidy (1993). The January 1992 Franklin Lake, Northwest Territories, earthquake sequence, *Bulletin of the Seismological Society of America*, **83**, 398-415.

Bent, A. L., M. Lamontagne, J. Adams, C. R. D. Woodgold, S. Halchuk, J. Drysdale, R. J. Wetmiller, S. Ma and J.-B. Dastous (2002). The Kipawa, Québec "Millennium" earthquake, *Seismological Research Letters*, **73**, 285-297.

Burke, K. B. S. (2004). Historical seismicity in the Central Highlands, Passamaquoddy Bay, and Moncton regions of New Brunswick, Canada, 1817-1961, *Seismological Research Letters*, **75**, 419-431.

Ebel, J. E. (2009). On the magnitude of the 1663 Charlevoix, Quebec earthquake, *Seismological Research Letters*, **80**, 343.

EPRI (1994). See Johnston *et al.* (1994).

Global CMT Project (2008). On-line database, http://www.globalcmt.org

Gouin, P. (2001). *Tremblements de terre historiques au Québec : de 1534 à mars 1925, identifiés et interprétés à partir des textes originaux contemporains/ Historical earthquakes felt in Quebec : from 1534 to March 1925 as revealed by the local contemporary literature*, Montreal, Guérin, 1491 pp.

Hasegawa, H. S. (1977). Focal parameters of four Sverdrup Basin, Arctic Canada earthquakes in November and December 1972, *Canadian Journal of Earth Sciences*, **14**, 2481-2494.

International Seismological Centre (2008). On-line bulletin, http://www.isc.ac.uk, International Seismological Centre, Thatcham, UK.

Johnston, A. C., K. J. Coppersmith, L. R. Kanter and C. A. Cornell (1994). *The Earthquakes of Stable Continental Regions Volumes 1, 2 and 4: Assessment of Large Earthquake Potential,* TR-102261-V1, 5 volume proprietary report prepared for Electric Power Research Institute, Palo Alto, California.

Lamontagne, M. (2009). Description and analysis of earthquake damage in the Quebec City region between 1608 and 2008, *Seismological Research Letters*, **80**, 514-524.

Lamontagne, M., H. S. Hasegawa, D. A. Forsyth, G. G. R. Buchbinder and M. Cajka (1994). The Mont-Laurier, Québec, earthquake of 19 October 1990 and its seismotectonic environment, *Bulletin of the Seismological Society of America*, **84**, 1506-1522.

Lamontagne, M., A. L. Bent, C. R. D. Woodgold, S. Ma and V. Peci (2004). The 16 March 1999 m_N 5.1 Côte-Nord earthquake: the largest earthquake ever recorded in the Lower St. Lawrence Seismic Zone, Canada, *Seismological Research Letters*, **75**, 299-316.

Mather, K. F., H. Godfrey and K. Hampson (1927). The record of earthquakes felt by man in New England, manuscript of paper presented at the Eastern Section of the Seismological Society of America, May 1927.

National Earthquake Database (2008). Digital database, http://www.seismo.nrcan.gc.ca, Geological Survey of Canada, Ottawa, Ontario.

North, R. G., R. J. Wetmiller, J. Adams, F. M. Anglin. H. S. Hasegawa, M. Lamontagne, R. Du Berger, L. Seeber and J. Armbruster (1989). Preliminary results from the November 25, 1988 Saguenay (Quebec) earthquake, *Seismological Research Letters*, **60**, 89-93.

Seismological Service of Canada (1962). 1961-1 (Concluded) Seismological Bulletin October-December 1961, *Seismological Series of the Dominion Observatory*, 185-261.

Smith, W. E. T. (1962). Earthquakes of eastern Canada and adjacent areas, 1534-1927; *Publications of the Dominion Observatory*, **26-5**.

Tuttle, M. P. and G. M. Atkinson (2009). Contributions of paleoseismology to estimates of maximum earthquake magnitude, *Seismological Research Letters*, **80**, 338.

United States Geological Survey (2008). On-line database, http://neic.usgs.gov , United States Geological Survey, Golden, Colorado.

Wells, D. L. and K. J. Coppersmith (1994). New empirical relations among magnitude, rupture length, rupture area, and surface displacement, *Bulletin of the Seismological Society of America*, **84**, 974-1002.

Note: URL's for all on-line references were correct at the time of writing

Table 1
Top 150 Earthquakes

Event	dd-mm-yyyy	hh:mm:ss	deg N	deg W	mag	Location	Mw	Source	Comments
1	20-11-1933	23:21:32	73.00	70.75	7.3Ms	241 km E of Pond Inlet, NT (Baffin Bay)	7.4	B02	
2	18-11-1929	20:32:00	44.50	56.30	7.2ML	offshore- Laurentian Channel (“Grand Banks”)	7.1	B95	
3	05-02-1663	17:30:00	47.60	70.10	7.0ML	7 km SE of La Malbaie, QC	7.0*	B09*	based on E09, T09; see text
4	20-10-1870	16:30:00	47.40	70.50	6.5ML	6 km S of Baie-Saint-Paul, QC	6.6	EPRI	from felt area
5	31-08-1934	05:02:45	73.00	71.00	6.5Ms	233 km E of Pond Inlet, NT (Baffin Bay)	6.5	EPRI	from instrumental Ms
6	01-01-1945	01:20:42	73.00	70.00	6.5Ms	265 km E of Pond Inlet, NT (Baffin Bay)	6.5	EPRI	from instrumental Ms
7	02-05-1957	03:55:33	72.31	67.52	6.3Ms	Baffin Bay, off Cape Hunter, Baffin Island	6.4	EPRI	from instrumental ML
8	16-09-1732	16:00:00	45.50	73.60	5.8mN	Montreal, QC	6.3	EPRI	average of multiple isoseismal contours
9	27-12-1972	22:59:26	76.80	106.49	5.4mN	340 km E of Mould Bay, NT	6.3*	EPRI	from instrumental moment
10	01-03-1925	02:19:20	47.80	69.80	6.2Mw	20 km W of Riviere-du-Loup, QC	6.2	NEDB	instrumental Mw from B92
11	25-12-1989	14:24:32	60.12	73.60	6.3Ms	Ungava, Northern Quebec	6.2	B94	
12	17-10-1860	11:15:00	47.50	70.10	6.0ML	13 km W of Saint-Denis, QC	6.1	EPRI	from felt area
13	01-11-1935	06:03:40	46.78	79.07	6.2ML	7 km N of Temiscaming, QC	6.1	B96b	
14	04-09-1963	13:32:12	71.40	73.30	6.4Ms	203 km NW of Clyde River, NT	6.1	EPRI	from instrumental moment
15	18-11-1929	23:01:48	44.50	56.30	6.0ML	Laurentian Channel; aftershock of event #2	6.0	Ms-Mw	Ms 5.9 from scaled records
16	10-07-1947	10:48:45	73.00	71.00	6.0Ms	233 km E of Pond Inlet, NT	6.0	EPRI	from instrumental Ms
17	21-11-1972	10:06:27	76.58	106.02	5.7mN	352 km E of Mould Bay, NT	6.0*	EPRI	from instrumental moment
18	19-11-1929	02:01:28	44.50	56.30	5.8ML	Laurentian Channel; aftershock of event #2	5.9	Ms-Mw	Ms 5.8 from scaled records
19	19-11-1972	17:33:44	76.55	106.33	5.6mN	343 km E of Mould Bay, NT	5.9*	EPRI	from instrumental moment
20	25-11-1988	23:46:04	48.12	71.18	5.9Mw	34 km SW of La Baie, QC	5.9	NEDB	instrumental Mw from N89
21	28-12-1972	14:36:05	76.80	106.16	5.1mN	349 km E of Mould Bay, NT	5.9*	EPRI	from instrumental moment
22	05-09-1944	04:38:45	44.97	74.90	5.6ML	15 km SW of Cornwall, ON	5.8	B96a	
23	21-03-1904	06:04:00	45.00	67.20	5.9mN	14 km SW of Saint Andrews, NB	5.7	EPRI	average of multiple isoseismal contours
24	16-05-1909	04:15:00	49.00	104.00	5.5mN	75 km S of Weyburn, SK	5.7	EPRI	average of multiple isoseismal contours
25	24-12-1940	13:43:44	43.80	71.30	5.0ML	New Hampshire	5.6	EPRI	from instrumental moment
26	07-12-1971	12:04:18	55.09	54.51	5.6ML	offshore; 690 km N of Grand Falls, NL	5.6	EPRI	from instrumental moment
27	09-01-1982	12:53:52	47.00	66.60	5.7mb	Miramichi, NB	5.6	EPRI	from instrumental moment
28	06-12-1791	20:00:00	47.40	70.50	6.0ML	6 km S of Baie-Saint-Paul, QC	5.5	EPRI	from felt area
29	22-10-1869	10:45:00	45.00	67.20	5.7mN	14 km SW of Saint Andrews, NB	5.5	EPRI	*average of multiple isoseismal contours
30	12-11-1976	14:47:19	72.30	70.43	5.6mN	217 km N of Clyde River, NT	5.5	EPRI	from instrumental Ms and mb
31	04-01-1992	00:56:56	66.73	94.60	5.0mb	219 km S of Gjoa Haven, NT	5.5	BC93	
32	18-04-1935	22:15:28	70.50	73.00	5.6Ms	165 km W of Clyde River, NT	5.4	EPRI	from non-ISC/NEIS instrumental Ms
33	20-12-1940	07:27:26	43.80	71.30	5.0ML	New Hampshire	5.4	EPRI	from instrumental moment
34	13-12-1987	21:05:04	74.40	92.96	5.4mb	67 km SE of Resolute, NT	5.4	EPRI	from instrumental moment
35	26-07-1922	06:31:08	50.00	50.00	5.3ML	272 km NE of Bonavista, NL	5.3	Ms-Mw*	see text and Adams&Wahlstrom(1995)
36	13-12-1929	11:19:15	44.50	56.30	5.0Ms	Laurentian Channel; aftershock of event #2	5.3	Ms-Mw	Ms from scaled records
37	19-10-1939	11:53:58	47.80	69.80	5.6mN	20 km W of Riviere-du-Loup, QC	5.3	EPRI	from instrumental moment
38	22-04-1951	12:36:16	76.00	73.00	5.7ML	269 km E of Grise Fiord, NT	5.3	EPRI	from instrumental ML
39	26-05-1909	14:42:00	42.50	89.00	5.7ML	Wisconsin-Illinois border	5.2	EPRI	from felt area
40	30-09-1924	08:52:30	47.80	69.80	5.5mN	20 km W of Riviere-du-Loup, QC	5.2	EPRI	from instrumental mb

41	14-08-2001	19:35:38	76.63	107.22	5.6mN	Byam Martin Channel, NU	5.2	GCMT	
42	18-04-2008	09:36:57	38.45	87.89	5.2Mw	S 7 km NNE of Bellmont, IL.	5.2	NEDB	instrumental Mw from USGS
43	27-11-1893	16:50:00	45.50	73.30	5.7ML	11 km SW of Beloeil, QC	5.1	EPRI	from felt area
44	10-02-1914	18:31:00	46.00	75.00	5.5ML	32 km N of Saint-Andre-Avellin, QC	5.1	EPRI	from felt area
45	09-03-1937	05:45:00	40.60	84.00	5.5ML	Ohio	5.1	EPRI	from non-ISC/NEIS instrumental mb, Ms
46	26-11-1967	22:09:00	40.00	104.70	5.0ML	Colorado	5.1	mb-mW*	local time? USCGS mb 5.2
47	06-10-1975	22:21:41	44.71	57.07	5.7ML	offshore; 291 km SE of New Waterford, NS	5.1	EPRI	from instrumental moment
48	27-07-1980	18:52:21	38.17	83.91	5.1mb	Near Sharpsburg, Kentucky	5.1	EPRI	from instrumental moment
49	24-08-1981	11:20:33	61.32	59.29	5.5ML	300 km E of Resolution Island, NT	5.1	Mu-Mw	Ms 4.7, mb 4.7 (mean ISC and NEIS)
50	20-04-2002	10:50:47	44.53	73.73	5.5mN	Plattsburgh, NY	5.1	GCMT	
51	18-11-1929	23:06:33	44.68	56.00	4.9mN	Laurentian Channel; Aftershock of event #2	5.0	Ms-Mw*	new event; scaled Ms
52	14-01-1943	21:32:38	45.25	69.60	5.0ML	107 km E of Lac-Megantic, QC	5.0	mN-Mw	JD mN 5.3
53	08-03-1975	05:20:34	79.82	94.07	5.2ML	160 km W of Eureka, NT	5.0	EPRI	from instrumental Ms and mb
54	27-06-1979	08:50:35	70.03	96.48	5.0mN	127 km NW of Spence Bay, NT	5.0	EPRI	from instrumental moment
55	11-01-1982	21:41:08	47.00	66.60	5.4mb	Miramichi, NB	5.0	EPRI	from instrumental moment
56	16-03-1989	04:17:29	60.06	70.06	5.7mN	6 km NW of Kangirsuk, QC	5.0	BH92	
57	25-12-1989	04:25:50	60.12	73.60	5.1mN	Ungava Peninsula, Northern Quebec	5.0	EPRI	from instrumental Ms and mb
58	06-12-1997	08:06:47	64.84	88.19	5.7mN	Wager Bay region, NT	5.0	BCMT	
59	09-04-1917	20:52:00	38.10	90.60	5.0ML	Missouri	4.9	EPRI	average of multiple isoseismal contours
60	12-08-1929	11:24:48	42.87	78.35	5.5ML	48 km E of Fort Erie, ON	4.9	EPRI	from instrumental moment
61	08-01-1931	00:13:36	47.30	70.40	5.4ML	14 km NW of Saint-Jean-Port-Joli, QC	4.9	EPRI	from instrumental ML
62	02-03-1937	14:48:00	40.70	84.00	5.3ML	Ohio	4.9	EPRI	from non ISC/NEIS instrumental mb
63	28-08-1954	15:23:01	45.17	56.87	5.2ML	offshore; 277 km SE of New Waterford, NS	4.9	mL-mb-Mw	JD ML 5.3
64	16-10-1954	06:45:00	44.83	56.80	5.3ML	offshore; 301 km SE of New Waterford, NS	4.9	EPRI	from instrumental ML
65	04-02-1958	08:06:43	57.90	53.50	5.1ML	Labrador Sea	4.9	ML-mb-MW	JD ML 5.3
66	09-01-1982	16:36:44	47.00	66.60	5.1mb	Miramichi, NB	4.9	EPRI	from instrumental moment
67	31-03-1982	21:02:20	47.00	66.60	5.0mb	Miramichi, NB	4.9	EPRI	from instrumental mb
68	07-10-1983	10:18:47	43.94	74.25	5.1mb	127 km S of Cornwall, ON	4.9	EPRI	from instrumental moment
69	31-01-1986	16:46:43	41.70	81.18	5.0mb	Painsville, Ohio (Near Cleveland)	4.9	EPRI	from instrumental moment
70	06-11-1997	02:34:33	46.80	71.42	5.1mN	Quebec City Region	4.9	BCMT	
71	09-09-1816	00:00:00	45.50	73.60	5.7ML	Montreal, QC	4.8	EPRI	from maximum intensity
72	08-05-1831	00:00:00	47.30	70.50	5.7ML	17 km S of Baie-Saint-Paul, QC	4.8	EPRI	from maximum intensity
73	10-08-1884	19:07:00	40.60	74.00	5.6ML	New York	4.8	EPRI	average of multiple isoseismal contours
74	19-09-1884	14:14:00	40.70	84.10	5.0ML	Ohio	4.8	USGSFA	
75	14-11-1897	00:00:00	42.90	106.30	5.3ML	Wyoming	4.8	ML-mb-Mw*	Felt; time 1330
76	28-03-1964	04:09:00	42.90	101.60	5.7ML	Nebraska	4.8	EPRI	from non ISC/NEIS instrumental mb
77	30-06-1975	18:48:55	71.44	71.19	5.2mN	147 km NW of Clyde River, NT	4.8	EPRI	from instrumental Ms and mb
78	19-08-1979	22:49:30	47.67	69.90	5.0mN	Charlevoix Seismic Zone, QC	4.8	EPRI	from instrumental moment
79	29-07-1999	12:50:56	60.90	58.02	5.3ML	Labrador Sea Seismic Zone	4.8	Mu-Mw	ISC mb 4.7 Ms 4.1
80	27-09-1909	09:45:00	39.00	87.70	5.7ML	Indiana-Illinois border	4.7	EPRI	average of multiple isoseismal contours
81	02-01-1912	16:21:00	41.50	88.50	5.0ML	Illinois	4.7	USGSFA	
82	14-05-1958	17:41:21	46.97	76.55	5.0ML	79 km NW of Maniwaki, QC	4.7	EPRI	from instrumental mb and ML
83	25-12-1961	19:58:29	63.90	89.30	5.1ML	119 km NE of Chesterfield Inlet, NT	4.7	ML-mb-Mw*	
84	08-03-1963	00:14:16	76.60	94.33	5.7ML	213 km N of Resolute, NT	4.7	mN-Mw	JD mN 5.0
85	02-10-1971	30:19:28	64.20	86.67	5.1mN	171 km W of Coral Harbour, NT	4.7	EPRI	from instrumental moment
86	21-11-1981	18:25:18	79.52	108.12	5.3ML	442 km W of Eureka, NT	4.7	EPRI	from instrumental mb and Ms

87	01-01-2000	11:22:58	46.84	78.93	5.2mN	Temiscamingue Region, QC	4.7	BL02	
88	22-01-2001	18:17:40	65.96	53.06	5.2ML	Western Greenland.	4.7	Mu-Mw	ISC mb 4.7 Ms 3.8
89	06-03-2005	06:17:49	47.75	69.73	5.4mN	Charlevoix Seismic Zone, QC	4.7	BCMT	
90	18-06-1875	00:00:00	40.20	84.00	5.7ML	Ohio	4.6	EPRI	average of multiple isoseismal contours
91	04-02-1883	05:00:00	42.30	85.60	5.0ML	Michigan	4.6	ML-mb-Mw*	Felt over wide area
92	23-03-1897	00:00:00	45.50	73.60	5.0ML	Montreal, QC	4.6	EPRI	from felt area
93	01-03-1925	04:30:42	47.80	69.80	5.0ML	20 km W of Riviere-du-Loup, QC	4.6	ML-mb-Mw	mN 4.5-5; felt in QCQ
94	21-03-1925	015:22:04	47.80	69.80	5.0ML	20 km W of Riviere-du-Loup, QC	4.6	ML-mb-Mw	see above event
95	01-06-1927	012:23:00	40.30	74.00	5.0ML	New Jersey	4.6	FA-Mw	felt area from USGS
96	01-12-1928	00:00:00	50.00	81.50	5.0ML	90 km S of Moose River, ON	4.6	ML-mb-Mw	>=mN 4.5 based on felt reports
97	20-09-1931	23:05:00	40.20	84.30	5.7ML	Ohio	4.6	EPRI	from felt area
98	23-11-1940	21:15:00	38.20	90.10	5.0ML	Illinois	4.6	USGSFA*; 1939?- see text	
99	27-06-1951	13:17:50	45.00	57.00	5.0ML	offshore; 278 km SE of New Waterford, NS	4.6	EPRI	from instrumental ML
100	20-10-1952	01:04:35	57.00	57.00	5.0ML	Labrador Sea	4.6	ML-mb-MW*	see text
101	23-03-1957	19:42:56	70.60	65.00	5.9ML	133 km E of Clyde River, NT (Baffin Bay)	4.6	mN-mW	JD mN 4.9
102	06-09-1960	21:24:26	64.70	86.40	5.5ML	168 km NW of Coral Harbour, NT	4.6	mN-Mw	JD mN 4.9
103	26-10-1962	10:29:20	60.80	57.50	5.0ML	403 km E of Resolution Island, NT	4.6	ML-mb-Mw	instrumental ML
104	21-01-1972	14:43:39	71.84	74.96	5.1mN	140 km SE of Pond Inlet, NT (Baffin Bay)	4.6	EPRI	from instrumental moment
105	04-01-1981	14:46:58	76.10	66.60	5.0mN	Northwestern Greenland	4.6	mb-Mw	ISC mb 4.6
106	18-06-2002	17:37:17	38.10	87.70	5.1mN	Kentucky-Indiana border	4.6	USGS	
107	03-05-2008	18:23:06	75.25	62.17	5.1ML	Western Greenland.	4.6	mb-Mw	USGS mb 4.6
108	01-03-1935	11:00:00	40.30	96.20	5.0ML	Nebraska	4.5	EPRI	from non-ISC/NEIS MS and mb
109	14-10-1952	22:03:42	47.80	69.80	5.2ML	21 km W of Riviere-du-Loup, QC	4.5	EPRI	from instrumental mN, mb and ML
110	30-01-1959	05:17:32	61.00	78.50	5.9ML	28 km NW of Akulivik, QC	4.5	EPRI	from instrumental mN
111	30-09-1972	22:51:30	79.88	107.72	5.0ML	424 km W of Eureka, NT	4.5	EPRI	from instrumental mb
112	12-02-1983	18:19:08	60.91	59.55	5.0ML	291 km E of Resolution Island, NT	4.5	mb-Mw	ISC mb 4.4
113	19-10-1990	07:01:57	46.47	75.59	5.0mN	11 km SW of Mont-Laurier, QC	4.5	LH94	
114	21-01-1998	08:39:21	59.09	54.74	5.1ML	Labrador Sea Seismic Zone.	4.5	Mu-Mw	ISC mb 4.0 Ms 3.5
115	25-09-1998	19:52:54	41.52	80.53	5.4mN	Ohio-Pennsylvania border	4.5	USGS	
116	16-03-1999	12:50:48	49.61	66.34	5.1MN	65 km S of Sept-Iles, QC	4.5	LB04	
117	09-06-1998	00:34:44	80.93	90.94	5.3ML	Northern Ellesmere Island, NT	4.4	Mu-Mw	ISC mb 4.2 Ms 3.3
118	19-07-1909	04:34:00	40.20	90.00	5.7ML	Illinois	4.3	EPRI	from felt area
119	03-09-1917	21:30:00	46.30	94.50	5.0ML	Minnesota	4.3	USGSFA	
120	30-07-1934	07:20:00	42.70	103.00	5.0ML	Nebraska	4.3	USGSFA	
121	23-06-1944	06:37:53	49.42	67.75	5.1ML	37 km NE of Baie-Comeau, QC	4.3	mN-Mw	JD mN 4.6
122	24-07-1991	18:10:04	60.91	58.71	5.0ML	Labrador Sea	4.3	mb-Mw	ISC mb 4.2
123	26-08-2004	23:11:37	64.76	86.28	5.0mN	Wager Bay region NU	4.3	BCMT	
124	27-07-1905	00:20:00	47.30	88.40	5.6ML	140 km SE of Thunder Bay, ON (Michigan)	4.2	EPRI	from felt area
125	21-07-1957	08:53:31	68.90	59.40	5.7ML	244 km NE of Broughton Island, NT(Baffin Bay)	4.2	mN-Mw	JD mN 4.5
126	31-12-1961	10:36:00	44.40	100.50	5.0ML	South Dakota	4.2	USGSFA	
127	01-09-1895	00:00:00	40.70	74.80	5.0ML	New York	4.1	USGSFA	
128	18-03-1926	21:00:00	43.20	72.00	5.0ML	New Hampshire	4.1	ML-mb-Mw	USGS ML 4.1
129	23-07-1946	00:45:00	44.30	98.40	5.0ML	South Dakota	4.1	USGSFA	
130	20-06-1952	09:38:00	39.70	82.10	5.0ML	Ohio	4.1	USGSFA	
131	12-01-1988	00:42:40	72.91	70.23	5.0ML	258 km E of Pond Inlet, NT (Baffin Bay)	4.1	mb-Mw	ISC mb 3.8
132	12-11-1934	08:45:00	41.50	90.50	5.0ML	619 km W of Amherstburg, ON	4.0	USGSFA	

133	08-06-1941	20:21:39	52.40	75.30	5.0ML	65 km NE of Baie-James, QC	4.0	EPRI	from instrumental mbLg
134	05-06-1956	07:45:16	56.80	58.90	5.1ML	Labrador Sea	4.0	mN-Mw	JD mN 4.3
135	26-06-1966	06:00:00	44.30	103.40	5.0ML	South Dakota	4.0	mb-Mw	USGS mb 4.1
136	05-11-1926	15:53:00	39.10	82.10	5.3ML	Ohio	3.8	USGSFA	
137	09-01-1958	21:14:38	65.50	80.00	5.0ML	138 km W of Nuvukjuak, NT	3.8	mN-Mw	JD mN 4.0
138	28-01-1959	23:14:57	62.50	76.00	5.0ML	36 km NW of Salluit, QC	3.8	mN-Mw	JD mN 3.9
139	21-10-1959	07:46:17	65.00	87.00	5.3ML	175 km S of Repulse Bay, NT	3.8	mN-Mw	JD mN 4.0
140	22-03-1966	22:10:03	64.75	88.00	5.1ML	215 km SW of Repulse Bay, NT	3.8	mN-Mw	JD mN 4.0
141	10-05-1906	00:27:00	43.00	101.30	5.3ML	South Dakota-Nebraska border	3.7	USGSFA	
142	25-06-1943	04:25:24	48.50	105.00	5.0ML	Montana	3.7	mN-Mw	USGS mN 4.0
143	13-02-1964	19:46:42	40.40	78.20	5.2ML	Pennsylvania	3.5	EPRI	from instrumental mbLg
144	00-02-1910	00:00:00	48.00	70.00	5.0ML	40 km NW of Riviere-du-Loup, QC		G01*	see text and Gouin (2001)
145	22-01-1915	00:00:00	41.00	60.00	5.0ML	offshore; 499 km SE of Lake Echo, NS		B09*	see text
146	21-02-1954	20:00:00	41.20	75.90	5.7ML	Pennsylvania		B09*	mine collapse; see text
147	31-05-1908	17:42:00	40.60	75.50	5.0ML	Pennsylvania		B09*	too small; see text
148	07-01-1954	07:25:00	40.30	76.00	5.0ML	Pennsylvania		B09*	too small; see text
149	24-02-1954	03:55:00	41.20	75.90	5.0ML	Pennsylvania		B09*	mining event; related to #146
150	30-10-1963	17:37:00	42.70	70.80	5.0ML	Massachusetts		B09*	too small; ML(Weston) 3.2

Sources:

B92- Bent, 1992
B94- Bent, 1994
B95- Bent, 1995
B96a- Bent, 1996a
B96b- Bent, 1996b
B02- Bent, 2002
B09- Bent, this study
BH92- Bent and Hasegawa, 1992
BC93- Bent and Cassidy, 1993
BL02- Bent et al., 2002
BCMT- Bent, unpublished moment tensor solution
E09- Ebel, personal communication 2009
EPRI- Johnston et al., 1994
FA-Mw- conversion from felt area to Mw using equations from EPRI report
G01- Gouin, 2001
GCMT- Global CMT Project, 2008
ISC- International Seismological Centre, 2008
JD- JD database; see notes in text
LH94- Lamontagne et al., 1994
LB04- Lamontagne et al., 2004
Mx-Mw- conversion from Mx to Mw using equations found in EPRI report
N89- North et al., 1989
NEDB- National Earthquake Database, 2008
T09- Tuttle and Atkinson, 2009
USGS- United States Geological Survey, 2008
USGSFA- USGS, 2008, estimated from felt area
* -see additional discussion in text

Table 2
Events Excluded: Did Not Meet Magnitude Completeness Criteria

1568/00/00	00:00:00	41.50N	72.50W	0.0	5.7ML	GSC	404 km S from Bedford, QC
1574/00/00	00:00:00	41.60N	72.50W	0.0	5.7ML	GSC	393 km S from Bedford, QC
1584/00/00	00:00:00	41.60N	72.60W	0.0	5.7ML	GSC	392 km S from Bedford, QC
1592/00/00	00:00:00	41.50N	72.60W	0.0	5.7ML	GSC	403 km S from Bedford, QC
1638/06/11	20:00:00	42.50N	69.00W	0.0	6.3ML	GSC	277 km SW from Yarmouth, NS
1661/02/10	12:00:00	45.50N	73.00W	0.0	5.7ML	GSC	9 km N from Saint-Cesaire, QC
1663/02/06	15:00:00	47.60N	70.10W	0.0	5.0ML	GSC	7 km SE from La Malbaie, QC
1665/02/24	00:00:00	47.80N	70.00W	0.0	5.5ML	GSC	20 km NE from La Malbaie, QC
1668/04/13	13:00:00	47.10N	70.50W	0.0	5.0ML	GSC	14 km N from Montmagny, QC
1727/11/09	00:00:00	42.80N	70.80W	0.0	7.0ML	GSC	272 km S from Coaticook, QC
1727/12/28	00:00:00	42.80N	70.80W	0.0	5.0ML	GSC	272 km S from Coaticook, QC
1728/01/04	00:00:00	42.80N	70.80W	0.0	5.0ML	GSC	272 km S from Coaticook, QC
1728/02/10	00:00:00	42.80N	70.80W	0.0	5.0ML	GSC	272 km S from Coaticook, QC
1737/12/18	00:00:00	40.80N	74.00W	0.0	5.7ML	GSC	431 km SE from Gananoque, ON
1744/06/14	15:00:00	42.60N	70.00W	0.0	6.4ML	GSC	317 km SE from Coaticook, QC
1744/06/14	22:00:00	42.60N	70.00W	0.0	5.0ML	GSC	317 km SE from Coaticook, QC
1755/11/18	09:12:00	41.50N	67.00W	0.0	7.0ML	GSC	269 km S from Yarmouth, NS
1755/11/23	01:27:00	41.50N	67.00W	0.0	5.0ML	GSC	269 km S from Yarmouth, NS
1761/03/12	07:15:00	42.50N	71.00W	0.0	5.0ML	GSC	300 km S from Coaticook, QC
1766/02/02	00:00:00	42.00N	68.00W	0.0	5.0ML	GSC	255 km SW from Yarmouth, NS
1783/11/29	00:00:00	41.00N	74.50W	0.0	5.0ML	GSC	395 km S from Gananoque, ON
1785/01/02	12:15:00	40.00N	67.00W	0.0	5.7ML	GSC	432 km S from Yarmouth, NS
1791/05/16	13:00:00	41.50N	72.40W	0.0	6.4ML	GSC	405 km S from Bedford, QC
1791/05/18	00:00:00	41.50N	72.40W	0.0	6.4ML	GSC	405 km S from Bedford, QC
1800/12/25	00:00:00	41.90N	71.10W	0.0	5.0ML	GSC	364 km S from Coaticook, QC
1810/11/09	00:00:00	42.80N	70.50W	0.0	5.0ML	GSC	280 km S from Coaticook, QC
1816/09/16	00:00:00	45.50N	73.60W	0.0	5.0ML	GSC	0 km N from Montreal, QC
1817/10/05	16:45:00	42.50N	71.20W	0.0	5.7ML	GSC	297 km S from Coaticook, QC
1831/07/14	00:00:00	47.60N	70.10W	0.0	5.0ML	GSC	7 km SE from La Malbaie, QC
1842/11/09	00:00:00	46.00N	73.20W	0.0	5.0ML	GSC	8 km SW from Sorel, QC
1845/10/26	00:00:00	42.50N	73.70W	0.0	5.0ML	GSC	282 km SE from Brockville, ON
1847/08/08	15:00:00	42.00N	71.00W	0.0	5.0ML	GSC	354 km S from Coaticook, QC
1855/02/06	00:00:00	42.00N	74.00W	0.0	5.0ML	GSC	314 km SE from Gananoque, ON
1855/02/08	11:30:00	46.00N	64.50W	0.0	5.2MN	GSC	13 km NW from Sackville, NB
1857/10/23	20:15:00	43.20N	78.60W	0.0	5.0ML	GSC	38 km E from Niagara-on-the-Lake, ON
1861/07/12	00:00:00	45.40N	75.40W	0.0	5.0ML	GSC	17 km N from Russell, ON
1864/04/20	18:15:00	46.90N	71.20W	0.0	5.0ML	GSC	10 km N from Quebec, QC
1867/12/18	03:00:00	44.65N	75.15W	0.0	5.0ML	GSC	26 km SE from Iroquois, ON
1872/01/09	00:00:00	47.50N	70.50W	0.0	5.0ML	GSC	6 km N from Baie-Saint-Paul, QC
1877/11/04	00:00:00	45.20N	73.90W	0.0	5.0ML	GSC	19 km E from Salaberry-de-Valleyfield,
1877/11/15	11:45:00	41.00N	97.00W	0.0	5.6ML	GSC	892 km S from Fort Frances, ON
1933/12/19	17:48:20	75.00N	72.00W	0.0	5.6MS	GSC	284 km SE from Craig Harbour, NU
1934/02/24	00:49:03	73.50N	71.50W	0.0	5.6MS	GSC	229 km NE from Pond Inlet, NU
1934/06/15	06:34:25	61.50N	59.00W	0.0	5.6MS	GSC	315 km E from Resolution Island, NU
1935/08/22	20:30:52	73.25N	71.50W	0.0	5.6MS	GSC	221 km E from Pond Inlet, NU

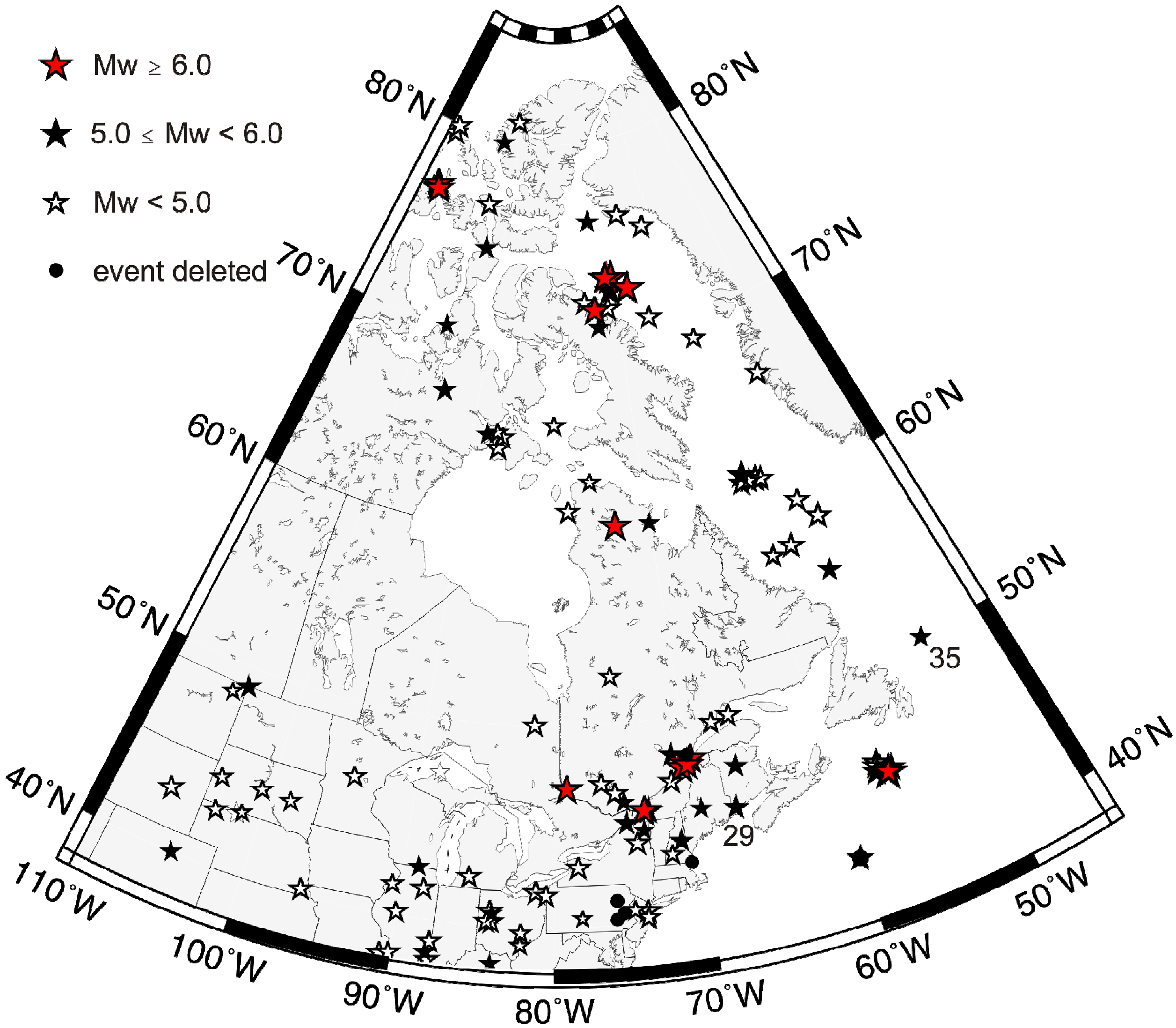

Figure 1: Map showing earthquakes evaluated in this study. Solid stars represent earthquakes of M_W 5.0 and greater; open stars represent earthquakes of M_W less than 5.0; circles indicate those events that have been removed from the "Top 150" list, the reasons for which are discussed in the text. Symbol size is scaled to magnitude. Note that at this scale, some symbols plot directly on top of each other. Earthquakes are plotted at the epicenters listed in the NEDB. A number beside an earthquake symbol is the number associated with that earthquake in the Table and indicates that the epicenter appears to be significantly incorrect. Readers should consult the text for details.

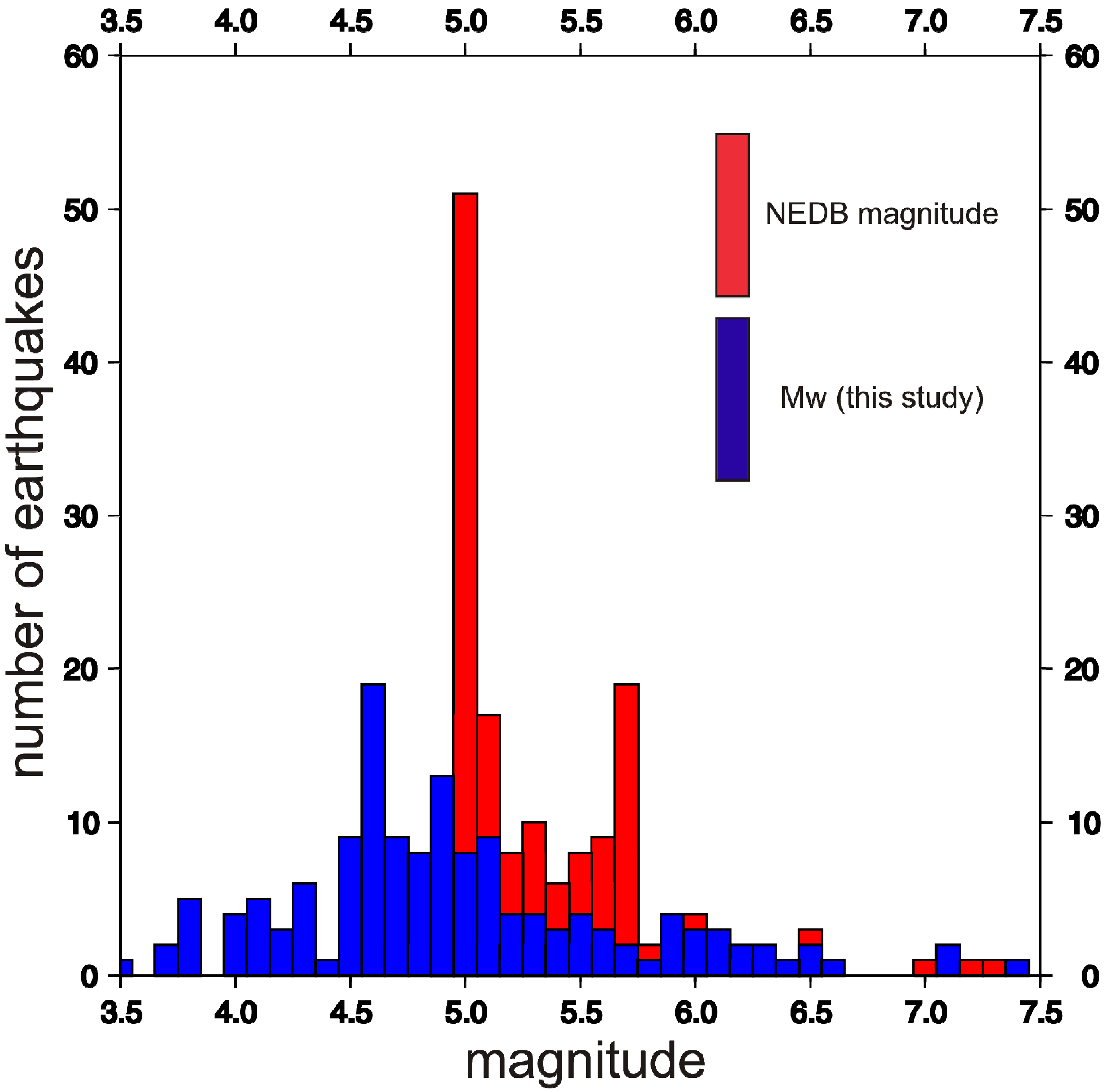

Figure 2. Distribution of events by magnitude. The red bars represent the original NEDB magnitudes and the blue bars the M_W's obtained in this study. Note that 5.0 was the NEDB cut off magnitude and that in no case are the red bars obscured by the blue ones.

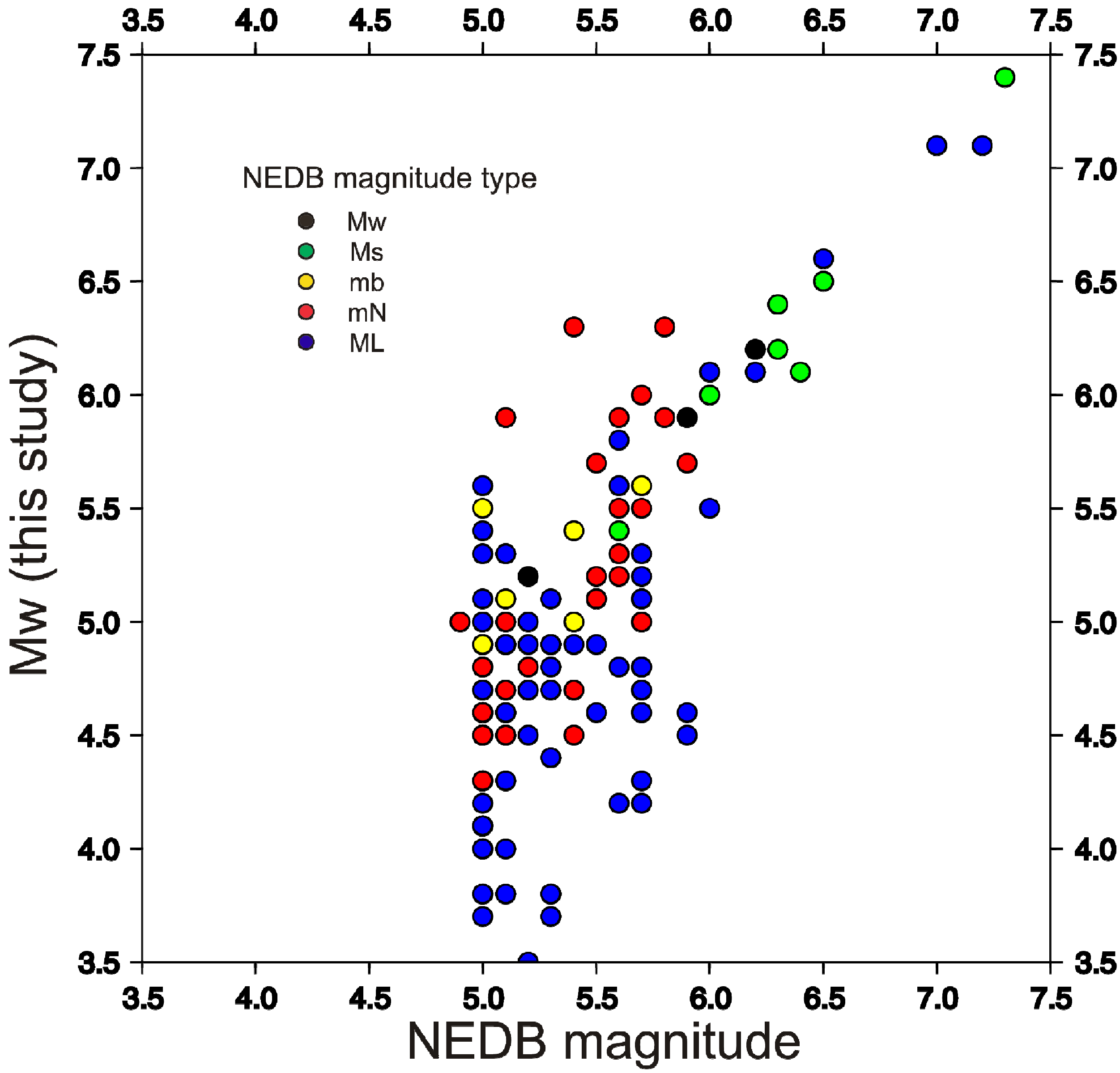

Figure 3. Original NEDB magnitude plotted against the M_W preferred by this study. Note that there are some events plotted at the same points and that the NEDB magnitude was not always the one used to determine M_W. The points are color coded by NEDB magnitude type.