THE SAGUENAY, QUÉBEC, CANADA, EARTHQUAKE OF 25 NOVEMBER 1988

This EERI Newsletter Special Insert on the Saguenay earthquake has been compiled from information received from several sources, namely: in Canada - the Geological Survey of Canada, Ottawa (Anne E. Stevens, R.J. Wetmiller, M. Lamontagne, P.S. Munro, R.G. North, Janet A. Drysdale, Mary G. Cajka, F.A. Anglin and J.A. Adams), Université du Québec at Chicoutimi (R. Du Berger), McGill University (D. Mitchell), École Polytechnique, Montréal (R. Tinawi), National Research Council of Canada (T. Law), Pacific Geoscience Centre, Sidney, B.C. (D. Weichert); in the United States - National Center for Earthquake Engineering Research (P. Friberg, R. Busby, D. Lentrichia, D. Johnson, K. Jacob and D. Simpson) and EQE Engineering Inc. (H. Johnson, C. Scawthorn, R. Augustine, J-P Conoscente, S. Swan). Their reports are acknowledged and referenced. Some limited editing has been performed by G. Brady, and there may be some duplication. Funding for the Special Inserts is provided by the NSF Learning from Earthquakes Project at EERI.

Main Facts

25 November 1988, 18:46 Eastern Standard Time

48.12° North, 71.18° West

29 km depth

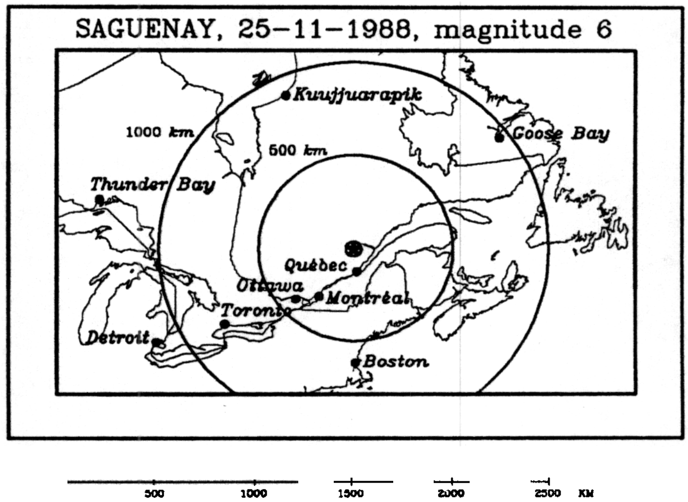
magnitude 6

epicentral intensity M.M.VII

hypocenter in Canadian Shield

aftershock zone 35 km NS x 35 km EW x 15 km

active zone unrelated to mapped geologic structures



Interesting Features

1. 35 km south of the cities of Chicoutimi and Jonquière, Québec (joint population 123,000); 100 km northwest of the Charlevoix-Kamouraska earthquake zone; no previously known significant earthquake activity in the Saguenay region.
2. Widely felt, as expected for an earthquake of this magnitude.

   Felt strongly by most people within about 500 km, felt by many within 1000 km, perceptible by some persons in special circumstances beyond 1000 km *(see map above)*; damage near epicenter, some isolated examples of damage up to 350 km, no major structural damage anywhere; no deaths directly attributable to the earthquake, a few minor injuries.
3. Largest earthquake in eastern North America since 1935.

   01 November 1935, magnitude 6.2, near Témiscaming, Québec, 300 km NW of Ottawa *(see map above)*.
4. Twice as deep within the earth's crust as most of the eastern Canadian earthquakes previously studied; aftershock depths range from 15 to 30 km.
5. Aftershocks, relatively few and small, probably due to lower crustal depth.

   During first three weeks, 70 aftershocks recorded with magnitudes all less than 3.0, except for one magnitude 4.1 aftershock on 25 November at 22:38 E.S.T.; subsequent aftershock rate about two per month; up to late April 1989, only one additional aftershock greater than magnitude 3.0 (19 January, 16:36 E.S.T., magnitude 3.6); local monitoring continuing with detection threshold about magnitude 0.
6. Foreshock on 23 November 1988, 04:11 E.S.T., magnitude 4.7, felt widely in Québec; no foreshocks in the 30 hours preceding the main shock; any earthquake of magnitude greater than 1.0 in this period could have been detected.
7. New engineering design data for eastern North America recorded at eleven sites in Québec *(see page 4)*.

   First strong ground motion records from a large earthquake in eastern North America; maximum accelerations on bedrock were 0.156g, horizontal, and 0.102g, vertical, recorded near Chicoutimi at epicentral distances of 64 km and 43 km, respectively.

DAMAGE DUE TO THE 25 NOVEMBER 1988 SAGUENAY, QUÉBEC, CANADA EARTHQUAKE

An earthquake of magnitude 6.0 occurred in the Saguenay region of the province of Québec on Friday 25 November 1988 at 18:46 Eastern Standard Time. Despite its size, no loss of life was directly attributed to the earthquake and no major structural damage was observed. Much of the damage observed in towns in the epicentral region and at larger distances (up to 350 km) was due in whole or in part to soft subsoil conditions or to poor performance of unreinforced masonry. This EERI engineering report presents a sample of damage to public buildings in four communities. Investigations in these and other communities are continuing for private buildings, industrial facilities and lifelines (e.g. pulp-and-paper mills, aluminum smelters, hydro-electric power generation and transmission facilities).

Canadian Site-Visit Team

The site-visit team sponsored by the Canadian National Committee on Earthquake Engineering consisted of Denis Mitchell (structural engineer, McGill University, Montréal), René Tinawi (structural engineer, École Polytechnique, Université de Montréal, Montréal) and Tim Law (geotechnical engineer, Institute for Research in Construction, National Research Council of Canada, Ottawa). They arrived in Chicoutimi, Québec, on Sunday 27 November, less than 48 hours after the main earthquake, and concentrated investigations on public facilities (schools, hospitals and emergency facilities). Site visits were also made to Québec City, Ste-Anne-de-Beaupré and Montréal. Inspections made by other engineers for private industries and government agencies, particularly in the Saguenay–Lac-St-Jean region, will be released later.

Public Schools

A number of public schools in Chicoutimi and La Baie, about 35 km north of the epicenter, were closed for several days due to damage to the unreinforced masonry partition walls. Since the earthquake occurred at 18:46 local time, these schools were virtually empty, and no injuries were reported. Severe shear cracks occurred in many of the masonry walls.

Residual displacements of about 12 mm (0.5 in.) were observed at the expansion joints in Dominique Racine Secondary School in Chicoutimi. This school also displayed many examples of unreinforced masonry blocks that had toppled from the top of the walls and fell through the ceiling panels, as shown in Figure 1. Similar problems occurred in the secondary school in the town of La Baie. Severe cracking of unreinforced masonry walls also occurred in the two-storey Georges Vanier Primary School in La Baie. This damage to the unreinforced masonry walls was accentuated by a poor structural system.

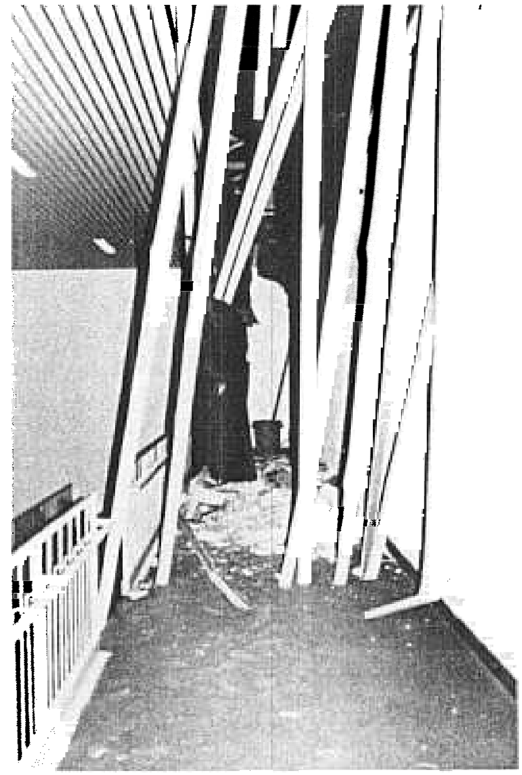


Figure 1: Debris from fallen masonry blocks in Dominique Racine Secondary School, Chicoutimi (Québec).

Hospitals

Only minor damage occurred to the hospitals in the epicentral region. However, significant non-structural damage occurred to two hospitals in Québec City, about 150 km south of the epicenter. Although a maximum horizontal acceleration of 5%g (0.05g) was recorded on bedrock in Québec City, it is believed that considerable amplification of this ground motion occurred in "Lower Town" due to thick alluvial deposits from the Rivière St-Charlès. The two hospitals were both located in this area.

Two masonry chimneys collapsed on two wings of the Saint-François-d'Assise Hospital, Québec City. Plaster walls were severely damaged, particularly in the stairwells of one of the older wings. The emergency generating system functioned without any problems during the two-hour power outage. One of the elevator counterweights had been derailed from its guides during the earthquake, which led to a shear failure in a reinforced concrete beam when the elevator was put back into service, two hours after the earthquake. The separate seven-storey Notre-Dame Pavilion of this same hospital complex consisted of a steel frame with a brick masonry cladding. Figure 2 shows the diagonal shear cracking that occurred between the window openings in the wall at the ground floor level.

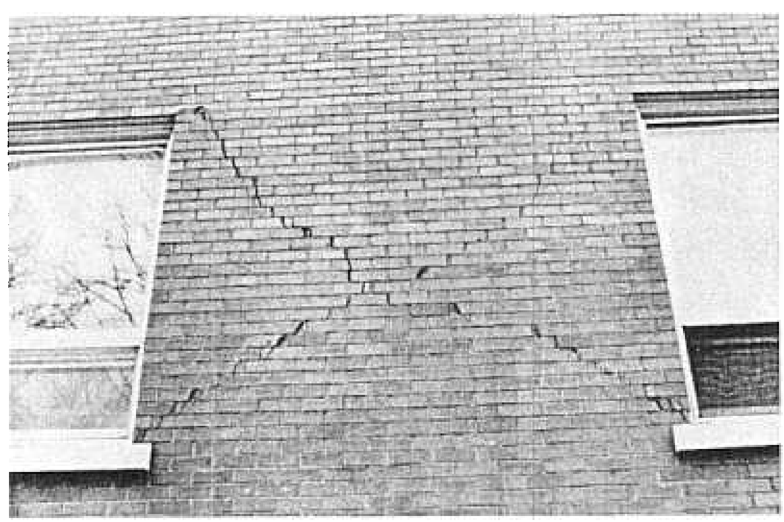


Figure 2: Diagonal cracks in brick wall of Notre-Dame Pavilion, Saint-François-d'Assise Hospital, Québec City (Québec).

Government Buildings

The Sagamie Pavilion in Chicoutimi, which houses a number of provincial government agencies, consists of two major wings. Differential movement between these two wings caused severe cracking in the connecting corridor. Severe cracking also occurred in an unreinforced masonry wall of the stairwell in the newer wing, due to flexural failure about its weak axis.

In La Baie, non-structural minor damage due to cracking of masonry infills occurred in the Police and Fire Station. This facility remained fully operational after the earthquake, even during the three-hour power outage.

Although very little damage was reported in Montréal, about 340 km southwest of the epicenter, the City Hall in Montréal East experienced severe damage to the masonry cladding (see Figure 3). This structure is located near the bank of the St. Lawrence River on 17 m (56 ft.) of clay. It is important to realize that the structure had had a history of settlement problems and had experienced, prior to the earthquake, differential settlements of over 90 mm (3.5 in.) causing cracking of the masonry cladding and interior walls.

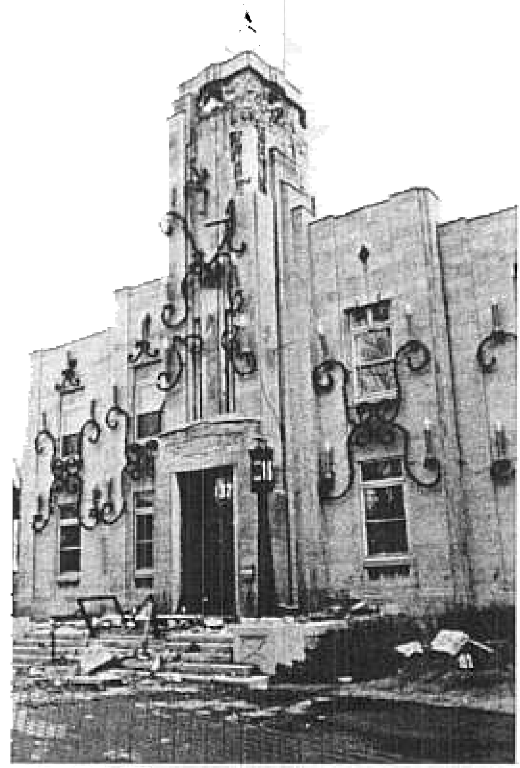


Figure 3: Loss of masonry cladding from clock tower of Montréal East City Hall

Churches

The nine-storey bell tower of the Christ-Roi Church in Chicoutimi suffered cracking to the exterior and interior masonry. The structural system consisted of steel framing with tension-only cross-bracing. The cross-bracing showed signs of buckling and one cross-brace on the sixth storey was found to have been omitted during construction. The nave of the church sustained damage to the marble decorative wall panels and a number of prisms fell from the crystal chandeliers.

The Maison Provinciale des Filles de Ste-Marie-de-la-Présentation, a religious residence in La Baie, experienced cracking of the unreinforced masonry infilled walls of this two-storey reinforced concrete frame structure. In the chapel, one small masonry wall collapsed behind the altar. This wall was unreinforced, was improperly connected to the backing wall, and had the decorative masonry blocks stacked in their upright position. Failure of this wall occurred about its weak plane, which coincided with the azimuth to the epicenter.

Embankment Failures

At least six highway embankment failures and several natural slope landslides were reported. Figure 4 shows a highway embankment failure on Route 138, just east of Ste-Anne-de-Beaupré (about 120 km south of the epicenter). The embankment consisted of medium to fine sand, with a total height of 24 m (78 ft.) and a slope of 1.5 horizontal to 1.0 vertical. It is believed that liquefaction played an important role in this embankment failure. The slope failure took place over a stretch of about 60 m (200 ft.).

Canadian National reported two slides of railway embankments with the larger occurring north of Hervey Junction (about 170 km southwest of the epicenter). This slide occurred in a 15 m (50 ft.) high embankment, consisting of fine to medium sand with a slope of 1.5 horizontal to 1.0 vertical. The railway track was left suspended over a length of about 90 m (300 ft.), and the line was closed for one week in order to repair the embankment.

Figure 4: Overall view of embankment failure (60 m long) near Ste-Anne-de-Beaupré (Québec).

Follow-up Work and Open-File Report

Follow-up work includes studies on damage to industrial facilities, response of dams, occurrence of liquefaction, causes and extent of electrical power failures, distribution and amount of damage, assessment of repairs, and studies on the stability of embankments and natural slopes. More information can be obtained from: Mitchell, D., Tinawi, R. and Law, T., *The 1988 Saguenay Earthquake – A Site-Visit Report*, Geological Survey of Canada Open-File Report No. 1999, February 1989, 97 pages. This report may be ordered from Ashley Reproductions Inc., 386 Bank Street, Ottawa, Canada K2P 1Y4; telephone 613-235-2115; price $16.50 (CAN $) plus shipping and handling costs.

CANADIAN STRONG-MOTION DATA FOR SAGUENAY, QUÉBEC, EARTHQUAKE, 25 NOVEMBER 1988

The eastern Canadian strong-motion seismograph network, maintained by the federal government, is designed to measure free-field ground motion, not structural or soil response. Most of the 19 accelerographs are located along or near the St. Lawrence River in Québec to monitor the active Charlevoix–Kamouraska seismic zone *(see Figure 5)*. In addition, Hydro-Québec has installed accelerograph arrays on three of its large dams (Manic-3, Manic-5 and Outardes-2) on the Manicouagan and Outardes Rivers in northeastern Québec. All instruments are analogue SMA-1s.

Accelerographs at 15 of the 22 sites triggered on the main shock of 25 November 1988. No stations triggered on either the foreshock of 23 November nor on any of the aftershocks. During the field project, five additional SMA-1s were installed in the epicentral region. To mid-April 1989, none of these have triggered on an aftershock, although they lie within 20 km epicentral distance of the active area.

In Figure 5, different symbols denote triggered and untriggered sites; the triggered sites are labelled with their maximum horizontal acceleration in *g* (Munro and Weichert, 1989). Three of the untriggered sites are labelled by name. At the Hydro-Québec sites *(upper right corner)* peak free-field accelerations were less than 0.01g. All 13 stations within 200 km epicentral distance triggered, with one exception, as noted on Figure 5. One instrument malfunctioned after triggering. Seven of the 10 triggered bedrock sites were free-field sites. The remaining three accelerographs were sited on a concrete basement floor slab on bedrock in a one- or three-storey building.

Examples of ground motion and pseudo-velocity response spectra are presented in Figures 6 and 7 for St-André, Québec, the site exhibiting the largest horizontal bedrock acceleration *(plotted as 0.156 in Figure 5)*. None of the accelerograms at any of the sites shows strong spikes. Digital strong-motion data recorded at U.S. sites are described later in this EERI Special Report.

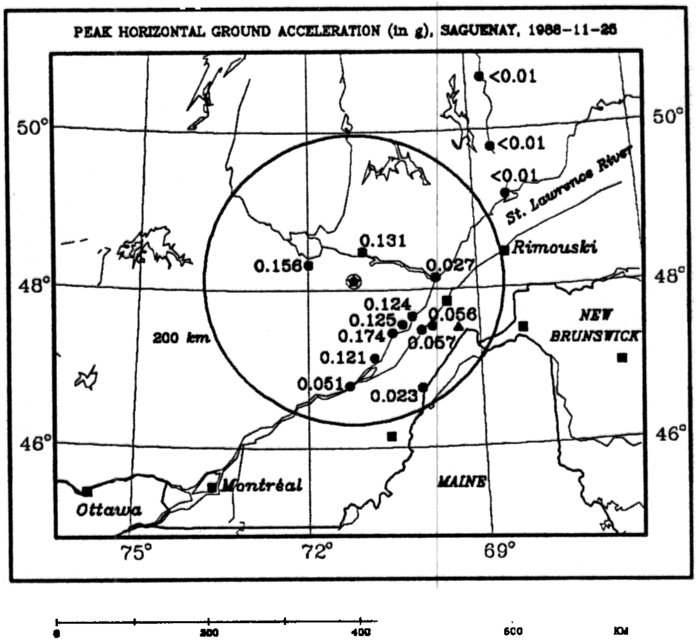


Figure 5: Maximum horizontal acceleration (in g), from Table 2 of Munro and Weichert (1989). All instruments on bedrock, except Baie-St-Paul on alluvium (0.174 on map). Symbols: encircled star – epicenter; solid circles – triggered; solid square – not triggered; solid triangle – triggered but equipment malfunctioned; large circle has a radius of 200 km.

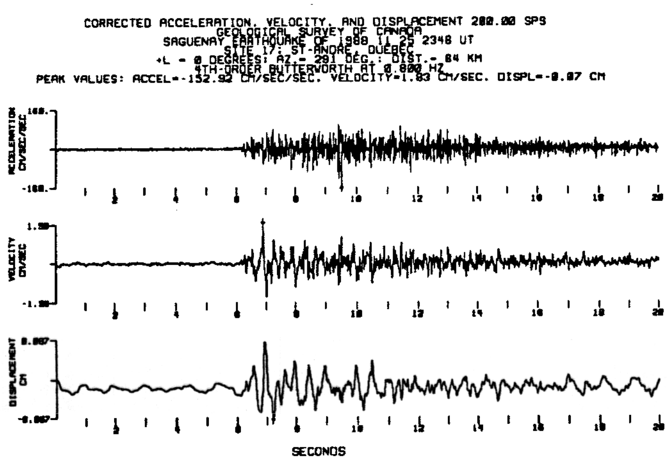


Figure 6: Corrected acceleration, velocity and displacement of north-south horizontal component at St-André (Québec); azimuth from epicenter is 291 degrees, epicentral distance is 64 km.

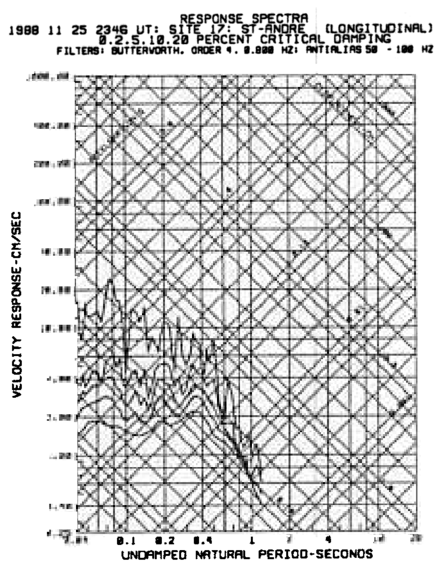


Figure 7: Pseudo-velocity response spectra for north-south horizontal component at St-André (Québec) for 0, 2, 5, 10 and 20% damping; azimuth from epicenter is 291 degrees, epicentral distance is 64 km.

More information can be obtained from: Munro, P.S. and Weichert, D., *The Saguenay Earthquake of November 25, 1988 – Processed Strong-Motion Records*, Geological Survey of Canada Open-File Report No. 1996, February 1989, 150 pages. This report may be ordered from Ashley Reproductions Inc., 386 Bank Street, Ottawa, Canada K2P 1Y4; telephone 613-235-2115; price $24.00 (CAN $) plus shipping and handling costs.

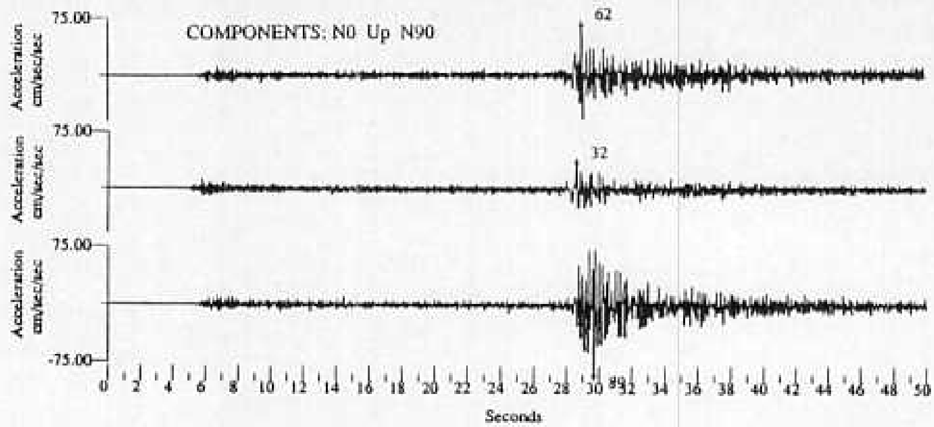
Digitized Canadian data may be ordered from P.S. Munro, Geological Survey of Canada, Geophysics Division, 613-995-4669.

Lamont-Doherty

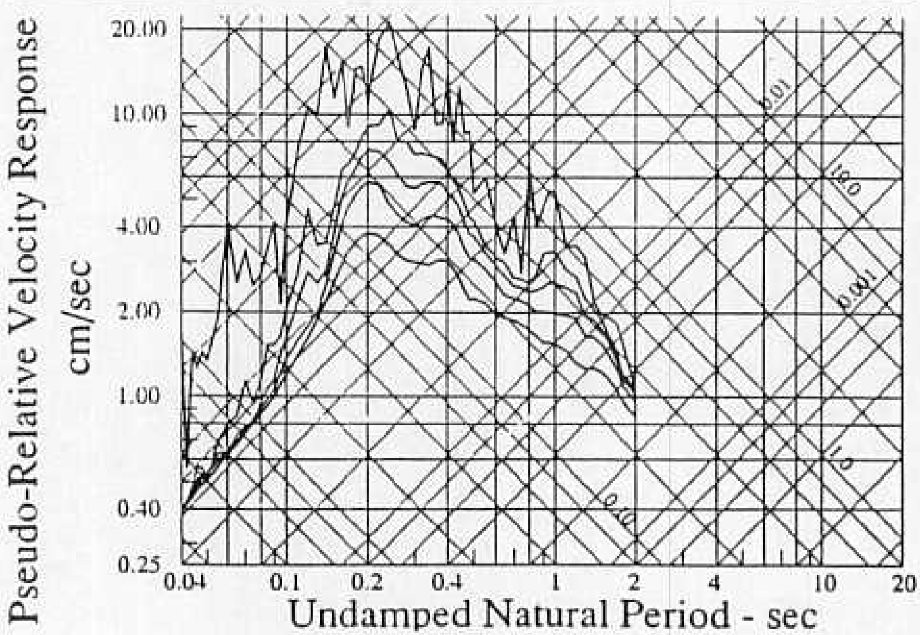
The following has been extracted from the report "The M=6 Saguenay earthquake of November 25, 1988, in the province of Quebec, Canada: preliminary NCEER strong-motion data report" prepared by F. Friberg, R. Busby, D. Lentrichia, D. Johnson, K. Jacob and D. Simpson; Lamont-Doherty Geological Observatory of Columbia University, Palisades, NY 10964, December 1, 1988.

From the Introduction -- The earthquake caused some damage in the sparsely populated region, caused power outages more regionally, and was widely felt in eastern Canada and over a wide area in the northeastern U.S. from Maine to Boston, New York City and Washington D.C. along the Atlantic coast, and inland as far as Ohio and Michigan. It is the first severe earthquake in eastern North America to occur since the National Center of Earthquake Engineering Research (NCEER) installed a number of digital strong-motion stations in portions of the northeastern and central U.S.

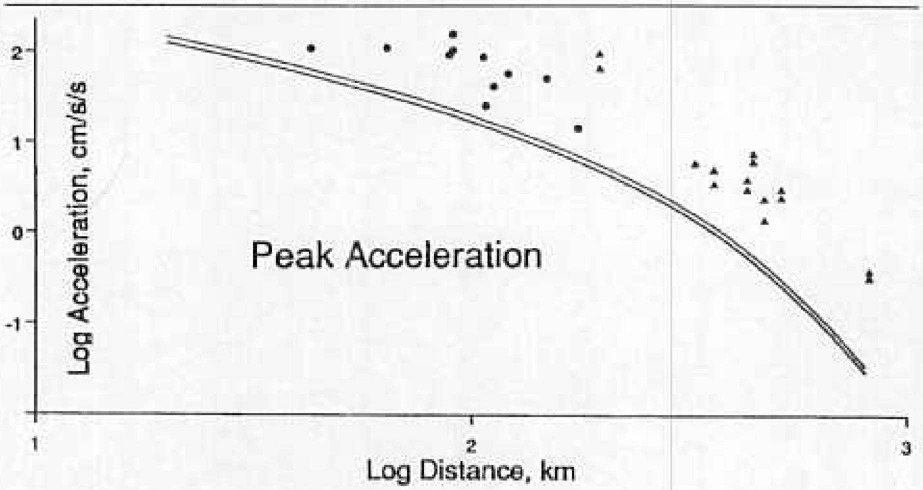
L-DGO functions as NCEER's ground motion core-facility. During 1988, digitally recording strong-motion instruments were installed by L-DGO personnel under its NCEER mission and with combined funding by NSF and the State of New York. Station installation occurred throughout the summer and fall of 1988; in fact the station nearest to this earthquake became operative only about one week prior to the Saguenay earthquake. Hence this earthquake provided the first real opportunity to test the performance of the strong-motion stations. It allowed a test of its novel communications capability to retrieve the digital data by phone from the instruments within hours of the event. The earthquake also provided an opportunity to test the readiness of the NCEER ground motion core-facility to process the data quickly, at least in a preliminary fashion.



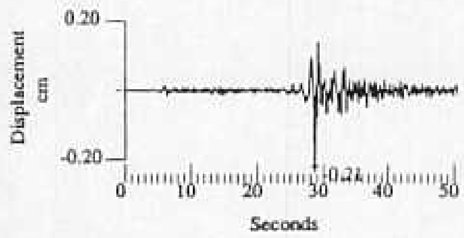
First 50 sec of the 214 sec Dickey record, at an epicentral distance of 198 km. Components N0, Up, N90.



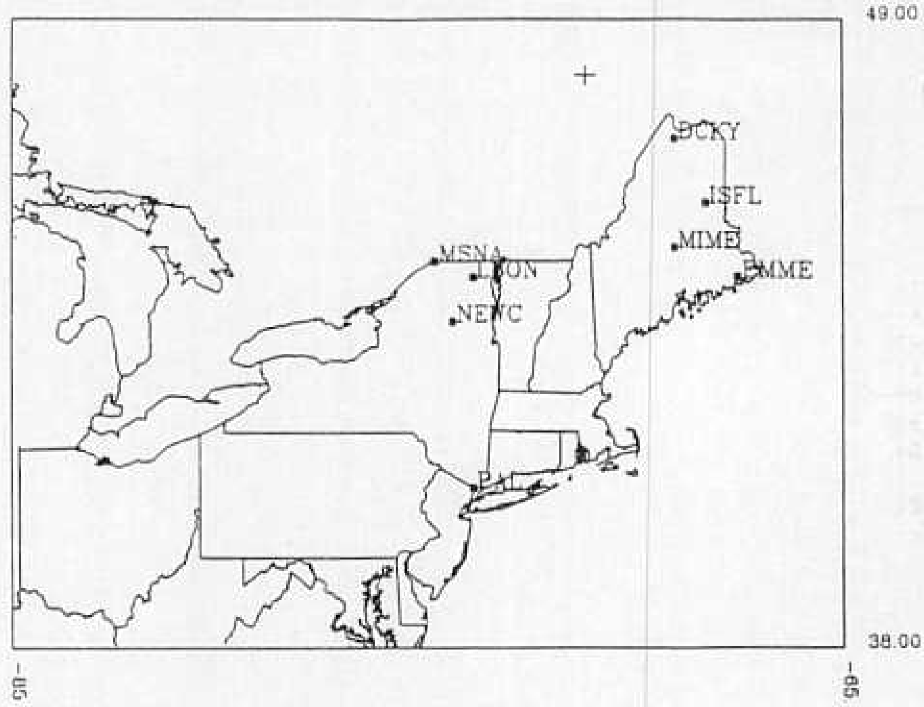
Response spectrum of the N0 component of the Dickey record.



Peak horizontal accelerations from CGS data (circles) and NCEER (triangles). Western US acceleration data are typically represented by Joyner and Boore (for M=6.3 and 6.0) but not to distances as far as shown here.



First 50 sec of the integrated displacement of the N0 component of the Dickey record, filtered with a long period limit of 2 sec.



NCEER station locations, with preliminary epicenter.

Data -- The strong-motion data for the Saguenay earthquake and its fore-shock are presented in the report in a preliminary form. All of the data processing and plotting was done using the Sun Agram strong-motion processing software package converted at Lamont (see Friberg and Liu, 1989, or Converse, 1984). The data consists of nine three-component digital accelerograms recorded at eight NCEER SSA-1 stations. Station coordinates and orientations are given in Table 1.

Main shock accelerograms -- Eight of the accelerograms are from the main-shock for the Saguenay earthquake. Each record was sampled at 200 samples per second for each component of acceleration at variable resolutions.

No instrument corrections have been made since the accelerometers record accelerations truthfully for frequencies up to about 30 Hz, and with only little distortion to higher frequencies close to the natural frequency of the sensor at 50 Hz. Moreover, these highest frequencies have low signal amplitudes.

Table 1

Station Code	Location	Total Sensitivty	Orientation	Peak Acceleration (cm/sec/sec)
DCKY	Dickey, ME	+/- 0.25 g	N0	61.95
			Up	23.07
			N90	89.42
ISFL	Island Falls, ME	+/- 0.125 g	N177	5.29
			Up	3.93
			N267	5.41
MIME	Milo, ME	+/- 0.5 g	N326	3.12
			Up	3.59
			N56	4.51
LYON	Lyon Mtn., NY	+/- 0.5 g	N55	2.73
			Up	3.90
			N325	3.50
MSNA	Massena, NY	+/- 0.5 g	N245	5.49
			Up	2.51
			N335	6.81
EMME	Machias, ME	+/- 0.5 g	N335	1.22
			Up	1.75
			N65	2.11
NEWC	Newcomb, NY	+/- 0.5 g	N15	2.17
			Up	1.70
			N105	2.72
PAL	Palisades, NY	+/- 0.125 g	N0	0.29
			Up	0.37
			N90	0.34

References

Converse, April, AGRAM: a Series of Computer Programs for Processing Digitized Strong-Motion Accelerograms, Version 2.0 United States Geological Survey Open-File Report 84-525, 1984.

Friberg, Paul & Liu, Lynn, The Sun Version of Agram Strong-motion Processing Programs: An Instruction Manual, NCEER Technical Report 89-XXXX, in preparation, 1989.

EQE Engineering

The following is excerpted from the EQE Engineering report entitled "The Saguenay, Quebec earthquake of November 25, 1988 -- a preliminary summary," December 5, 1988, EQE Engineering, 595 Market 18th and 21st floors, San Francisco, CA 94105. Price, $5.00.

From the Abstract -- Damage in the centers of population and industry along the Saguenay River was generally moderate, due apparently to the epicentral distance of 30-40 kilometers, and the location of the towns on solid rock. Sporadic damage was observed at locations over 100 kilometers from the epicenter, mostly near the City of Quebec.

The information contained in this report was compiled by Harry Johnson, Charles Scawthorn, Richard Augustine, Jean-Paul Conoscente, and Sam Swan, of EQE Engineering Inc.

Background. Minor sporadic damage occurred in the populated areas along the Saguenay River east of Lac-Saint-Jean, and also in the city of Quebec about 170 kilometers south of the epicenter. Motion was felt as far away as New York City, Washington D.C., Buffalo, and Detroit, illustrating the gradual attenuation typical of eastern earthquakes. Minor injuries were reported in the Chicoutimi and Quebec area, as well as at least two fatalities from heart attacks.

EQE dispatched a team of engineers to the Saguenay/Lac-Saint-Jean area nearest the epicenter on Sunday, November 27, for a general reconnaissance of earthquake effects. The EQE team was able to contact seismologists sent to the area from the Canadian Geological Survey (CGS), and from Columbia University's Lamont Doherty Geological Observatory, who provided valuable assistance, as did engineers from the provincial utility Hydro Quebec, the local municipal agencies, and the local news media.

The initial concern of the local government focused primarily on the reaction of the populace, rather than direct damage from the earthquake. The Saguenay/Lac-Saint-Jean region has not been a focus of historic earthquakes, and the experience is totally unfamiliar to the local population. Many of the injuries treated by hospitals were caused by panic rather than earthquake damage. A large portion of the populace was reported suffering from sleeplessness and anxiety in the days following the shock.

Initially, damage appeared modest. However, in subsequent days estimates of losses from the earthquake have increased to over $7 million, and are likely to be much higher when losses outside the epicentral area are fully accounted.

Geological Setting. The region of Saguenay/Lac-Saint-Jean is principally rock, with a general lack of overlaying soft soil deposits of significant depth. The lack of overlaying soft soil to amplify the motion of rock may account for the modest level of damage observed in the populated areas nearest the epicenter. The few pockets of soft soil in the Saguenay/Lac-Saint-Jean area experienced sporadic settlement, with subsequent damage to structures and roadways. Damage at far-field locations to the north, to the southeast along the Saint Lawrence, and in the area of Quebec appear to have occurred in soft soil regions.

Power Outages. The earthquake caused a power blackout over a large portion of the Hydro Quebec system, including service to the Saguenay/Lac-Saint-Jean region, and to sections of the City of Quebec and Montreal. Service was lost to about 250,000 customers in Southern Quebec Province. Little if any damage was reported to substations or transmission lines in the power system. The outages appear to have been caused by protective relay actuation, a common occurrence even in moderate earthquakes. Momentary electrical faults caused by swaying transmission lines, or splashing of oil within substation transformers will often cause relays to actuate, opening switchyard circuit breakers and disconnecting sections of the power grid.

Hydro Quebec reported only minimal damage to substations in the Saguenay/Lac-Saint-Jean area. However, substation switchyard damage was reported in the hydroelectric generating regions further to the north. Details are pending inspections by officials from the utility.

Power was restored to essentially all of the Hydro Quebec service area within about 3 hours of the earthquake.

Effects on Industry. The Alcan aluminum smelting operations reported minimal direct damage from the earthquake. Press releases from Alcan mentioned minor leaks in water, fuel gas, pneumatic air, and steam lines. The Alcan plant in the town of Arvida reported cracking in concrete columns of one structure, requiring shutdown of overhead bridge cranes operating above. Necessary repairs on the columns were expected to take one or two days.

Power was lost to the smelting operations for up to 3-1/2 hours following the earthquake. Extended power outages present potential problems to smelting furnaces; surprisingly there seemed to be no source of backup power. Reports, however, indicated no serious damage to the furnaces.

Far-field Effects. Sporadic damage was reported at distances ranging from 100 to 200 kilometers in different directions from the epicenter.

Near the town of Beaupre (epicentral distance 120 kilometers south), a landslide of some 4,000 cubic meters of soil separated from the shoulder of a roadcut on Route 138. A similar slide dislodged from the embankment supporting a rail line near La Tuque (epicentral distance 140 kilometers southwest).

Substations serving the Hydro Quebec power plants near the Saint Lawrence River some 200 kilometers to the north were reported to have sustained switchyard damage totaling $900,000. The substations were constructed in the early 1950s and apparently were equipped with tall ceramic components which are susceptible to earthquake damage.

Discussion. An earthquake the size of the magnitude 6.0 Saguenay event represents a rare occurrence for the eastern United States and Canada, a "once in a lifetime" opportunity for the engineering and geotechnical community. This appears to be the first eastern earthquake of its size in which a significant amount of strong-motion data will be available, thanks to the strong-motion instrument system maintained by the Canadian Geologic Survey, and the far-field system maintained by Lamont Observatory.

The moderate amount of damage caused by the earthquake is generally attributed to the lack of man-made structures in the immediate epicentral area, and the fact that the closest populated areas along the Saguenay River are mostly founded on rock. In comparison, the magnitude 5.9 earthquake in Los Angeles in October, 1987 caused similar effects (Intensity VI) at epicentral distances of 30 - 40 kilometers, in communities in the San Fernando Valley, or in Orange County. The observed effects of the Saguenay earthquake appear to comply with the magnitude, and the geology and epicentral distance of the Saguenay River industrial area.

Abstracts at SSA, Victoria

Contributors to this insert on the M6.0 Saguenay, Quebec earthquake of November 25, 1988 are listed on the first page. Many are coauthors of abstracts of presentations at a special session of the Seismological Society of America annual meeting in Victoria, British Columbia, Canada during April 19-21, 1989. Other researchers also made presentations at this meeting. There follows the complete list of titles and authors at the Saguenay earthquake session. The full abstracts are published in Seismological Research Letters, volume 60, number 1, January-March 1989, a copy of which is available from, and remittance of $4.00 made payable to, Waverly Person, Treasurer, Eastern Section, S.S.A., USGS, NEIS, Stop 967, Box 25046, Denver Federal Center, Denver, CO 80225. Requests for subscriptions to the ESSSA may be made to the SSA office, Suite 201, Plaza Professional Building, El Cerrito, CA 94530. Phone, (415) 525-5474. For further research results concerning this earthquake, keep track of the following authors' work.

FIELD STUDIES OF THE M6.0 SAGUENAY, QUEBEC EARTHQUAKE OF NOVEMBER 25, 1988 AND ITS FORESHOCK AND AFTERSHOCKS, by Wetmiller, R.J., Lamontagne, M., Munro, P. Geophysics Division, Geological Survey of Canada, Ottawa, Canada K1A 0Y3; Asudeh, I. Lithospheric and Canadian Shield Division, Geological Survey of Canada, Ottawa, Canada K1A 0Y3; Du Berger, R. Universite du Quebec a Chicoutimi, Chicoutimi, Quebec G7H 2B1; Such, R., Busby, R., Seeber, L. and Armbruster, J.G. Lamont-Doherty Geological Observatory, Palisades, New York 10964, USA.

FOCAL MECHANISMS AND AFTERSHOCK DISTRIBUTION OF THE 1988 SAGUENAY, QUEBEC EARTHQUAKE SEQUENCE, by Wetmiller, R.J., Adams. J., Anglin, F.A., Lamontagne, M. and Drysdale, J. Geophysics Division, Geological Survey of Canada, 1 Observatory Crescent, Ottawa K1A 0Y3, Canada.

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