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Résumé de l'article

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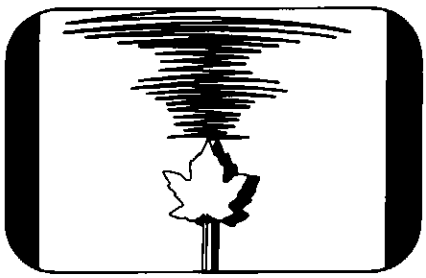

Some Twentieth-Century Canadian Earthquakes

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Summary
Six contemporary earthquakes have been chosen to illustrate typical effects of past earthquakes in southern Canada - 1925, 1929, 1944, 1973 in eastern Canada; 1909 in central Canada; 1946 in western Canada. In the epicentral region brick chimneys of frame houses have broken at the roof line or have lost bricks from the top. Damage has been greater in structures not located on rocky ground or not well designed, constructed or maintained. Twenty-eight persons drowned following two earthquakes. The effects of future earthquakes may differ in nature and extent from those experienced in the past, particularly if such events are centred near urban areas.

Sommaire
Six tremblements de terre contemporains ont été choisis pour présenter les résultats typiques des séismes déjà survenus dans le sud du Canada, à savoir ceux de 1925, 1929, 1944, 1973 dans l'est du Canada; 1909 dans le Canada central; 1946 dans l'ouest du Canada. Tout près de l'épicentre les cheminées de brique ont été sectionnées à la ligne du toit des maisons de bois; quelques fois des briques sont simplement tombées du haut des cheminées. Les dommages ont été plus élevés dans les bâtiments situés sur un sol non rocheux et dans les structures mal conçue, mal construites ou mal entretenues. Vingt-huit personnes sont mortes noyées à la suite de deux de ces tremblements de terre. La nature et l'étendue des effets des tremblements de terre à venir peuvent être différentes de celles du passé, tout particulièrement si de tels séismes se situaient près des agglomérations urbaines.

Introduction
Canadians are accustomed to hearing about damaging earthquakes in other countries, but few realize that such shocks have taken place in Canada. Thirty years have passed since the last significant property damage from earthquakes centered in either eastern or western Canada. Fortunately, none of our damaging earthquakes has caused widespread destruction and death. However, since the turn of the century several "million dollar" earthquakes have occurred in Canada, 28 persons have perished and numerous homes have experienced damage to chimneys and glassware.

Four of the damaging earthquakes of the twentieth century in southern Canada are featured in this article, along with two earthquakes that caused only slight damage. Three of the earthquakes were major shocks - i.e., with magnitude about 7; three were moderate, with magnitude about 5 to 5½. The present review includes some of the more interesting aspects of each earthquake. Detailed scientific reports are listed in the reference section. (In the text the local date of each earthquake is used. For earthquakes occurring in the evening, the Greenwich Mean Time date is one day later.)

The six earthquakes described are not intended to be representative of relative earthquake activity or relative earthquake risk across southern Canada. Damage resulting from future earthquakes may not necessarily be similar to that already experienced. This article simply summarizes what has been observed following six recent earthquakes in the past 70 years.

St. Lawrence Earthquake—1925
The largest earthquake in the St. Lawrence Valley in this century occurred on the evening of February 28, 1925, near La Malbaie, 120 km downriver from Quebec City. The earthquake was reported felt to 1400 km from the epicentre, including all of southern Québec, southern Ontario, the Maritime Provinces and the adjacent United States as far south as New Jersey and as far west as Michigan. The earthquake was recorded instrumentally nearly worldwide, on seismographs as far away as in the Soviet Union, Egypt and Argentina. In 1925 most seismographs were rather insensitive by today's standards and only major earthquakes could be widely recorded.

Despite the size of the earthquake no one was killed or injured, although some were certainly badly frightened. Damage near the epicentre was confined to a narrow belt about 35 km long on both shores of the St. Lawrence River. Within this belt damage was greater in buildings located on deep soil, and much less, often insignificant, in those standing on rocky ground. Limited but significant damage occurred also in Québec City, Trois-Rivières and Shawanigan Falls (epicentral distance 240 km) to structures that had been poorly designed, constructed or maintained or that were located on clay slopes, deep fill or alluvium.

Figure 1 shows the west transept wall of the stone church at Rivière-Ouelle within about 20 km of the epicentre. Stones near the top of the wall have been jarred loose and thrown down. The church was severely damaged. The organ pipes were projected upward and outward and fell into the auditorium clear of the choir loft. The great stone chimney crashed through the roof. In the churchyard monuments were overturned or rotated. The church building was 53 years old, in good repair but stood on deep alluvial soil.

Nearly every chimney for several miles around Rivière-Ouelle was thrown down. Most of the houses were of frame construction and the chimneys of brick. In other villages there were fallen chimneys, broken windows, cracked plaster, and broken dishes. During field investigations in the epicentral region, cracks were observed in the frozen ground in several localities but no fractures were reported in rock.

Earthquake 1909
Earthquakes on the Prairies have been considered to be exceedingly rare. The occurrence of a minor earthquake in southern Saskatchewan in July 1972 renewed interest in a larger earthquake in 1909, which American earthquake

Figure 1
Feb. 28, 1925. West transept wall of the stone church at Rivière-Ouelle, Québec. Note damage near the roof and diagonal crack following mortar joints between stones. (Fig. 4 in Hodgson, 1925).

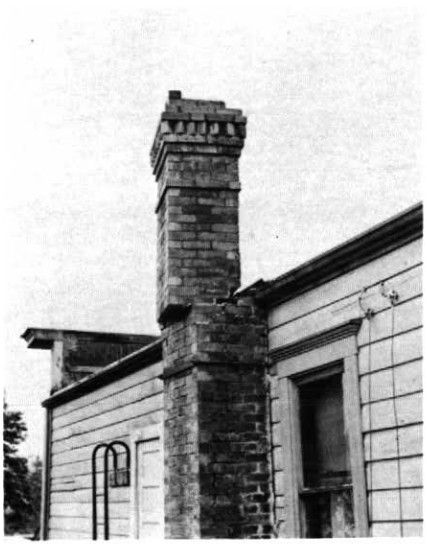

Figure 2
June 23, 1946. Chimney damage at Port Alberni, B.C. The house was not built on rock. (Fig. 19 in Hodson, 1946).

catalogues had placed in Canada south of Regina, but which Canadian catalogues had virtually ignored, believing the event to have happened somewhat farther west in the United States.

On the evening of May 15, 1909, an earthquake was felt from western Manitoba to southeastern Alberta and southward into Montana and the Dakotas, to distances of 550 km from the epicentre. Damage was confined to broken articles that had fallen from shelves in several localities. It is still not possible to decide whether the earthquake occurred in southern Saskatchewan, northwestern North Dakota or northeastern Montana, as there are too few instrumental recordings (it was recorded at Ottawa). However, the earthquake was definitely near the International Border and moderate in size - magnitude about 5½. No shock of a similar size has occurred on the Prairies since then.

Vancouver Island—1946

In British Columbia there have been a number of large and major earthquakes, some of which have been damaging. One of the chief differences between earthquakes west and east of the Rockies in North America is the distance to which they are felt. An earthquake in the west is felt to only one-third or one-quarter of the distance as an earthquake of the same size in the east.

On June 23, 1946, a major earthquake occurred about halfway up the east coast of Vancouver Island. It was about the same size as the 1925 St. Lawrence earthquake, was recorded worldwide, but was felt to only about 500 km in comparison to 1400 km for the 1925 eastern event.

The 1946 earthquake was the most damaging earthquake in British Columbia to date (1976). Its epicentre was not offshore west of Vancouver Island, where most west coast earthquakes originate, but in the Strait of Georgia between Courtenay and Campbell River. Most of the serious damage occurred along a 110-km section of the east coast of the Island. Ground cracks and land slumps along roads, shorelines and in fields were observed as well as some rock slides, but no surface faulting was noted. Broken chimneys, damaged goods in stores, broken dishes and windows were reported.

Figure 2 is a photograph taken in Port Alberni, about 55 km south of the epicentre. The chimney was broken at the roof line and rotated. Most of the chimneys affected in Port Alberni were buildings located on low-lying land. Houses built on rock were little damaged.

Chimney damage has been the most common type of damage in all Canadian earthquakes that have caused damage. In many cases houses were built on poor soil, which amplified vibrations, or chimneys were old or in need of repair. Thus chimney damage is not a direct measure of the size of an earthquake. One must endeavour to determine the probable condition of the chimney before the shock and the type of material beneath the building - whether soil or rock. If such information is not available, then the approximate proportion of damaged chimneys within a community may indicate whether the damage was due chiefly to the strength of the earthquake, or to soil amplification or some prior defects in the chimneys. This is an important consideration when reading descriptions of early earthquakes for which there were no instrumental recordings. An estimate of the size of such earthquakes must be based on a careful evaluation of reports of damage.

Chimney damage sometimes induces other damage. Figure 3b shows the interior of a schoolroom in Courtenay about 25 km south of the epicentre of the 1946 earthquake. Fortunately, the shock occurred about 10 a.m. local time on a Sunday morning when the classroom was empty. Damage here was caused when the large school chimney fell through the roof. In Courtenay about 25 per cent of the chimneys were damaged, mostly in the central part of town. Windows and bottles were cracked in some stores.

Only one person died in this earthquake of 1946. A man fell out of a boat near shore when it was tipped by a wave created by the subsidence of the side of a small spit. He drowned before he could be rescued. In several places residents suffered minor injuries from broken glass.

Woburn—1973

The most recent earthquake damage to date (1976) in southeastern Canada ocurred on the evening of June 14, 1973,

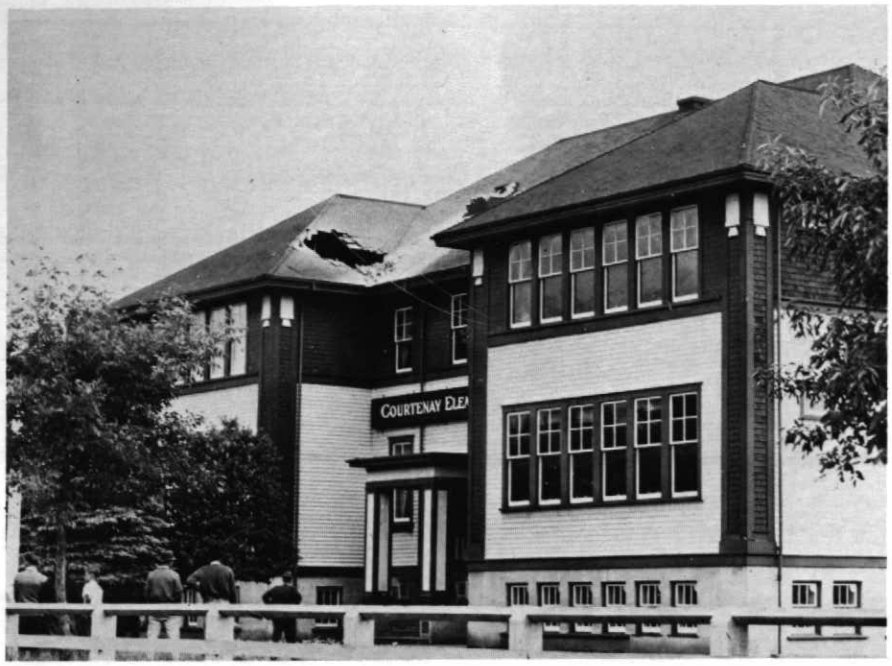

Figure 3
June 23, 1946. Elementary School, Courtenay, B.C. The chimney, located above the front entrance, fell sideways through the roof into a classroom. (Figs. 16 and 15, respectively, in Hodgson, 1946).

in the town of Woburn on the Québec-Maine border about 80 km east of Sherbrooke. This moderate earthquake felt to about 300 km was somewhat smaller than the 1909 Prairie earthquake. The epicentre was located within about 20 km of Woburn. Several chimneys had bricks dislodged from the the top, as shown in Figure 4, although many chimneys in Woburn were left undamaged. Articles on shelves in two general stores were thrown to the floor and broken. But the total damage was relatively unimportant.

Cornwall-Massena—1944

The most significant recent earthquake damage in eastern Canada occurred in the upper St. Lawrence Valley late on Labour Day evening on September 4, 1944. The estimate of damage was about one million dollars each in Cornwall, Ontario, and Massena, New York, made up almost entirely of minor items such as house chimneys, plate glass windows, cracked and fallen plaster, and store goods fallen from shelves. No building collapsed and no one was injured.

The chimneys of 90 per cent of the 3000 homes and buildings in Cornwall were either cracked or knocked down at the roof level, the latter costing an average of $200 each for repair. The walls of some old brick buildings with poor mortar were cracked and several bulged outwards. A few poorly-braced high brick parapets were thrown down. In general, damage was greatest in those parts of the two communities located on deposits of sand and clay. Little damage occurred in the northeast section of Cornwall located on firmer ground.

The earthquake was centred between Cornwall and Massena, within about 10 km of each. In size it was comparable to the 1909 Prairie earthquake, and considerably smaller than the 1925 St. Lawrence earthquake. It was well recorded only by seismograph stations in North America. The earthquake was felt to distances of nearly 800 km. It dislodged a large block of masonry from

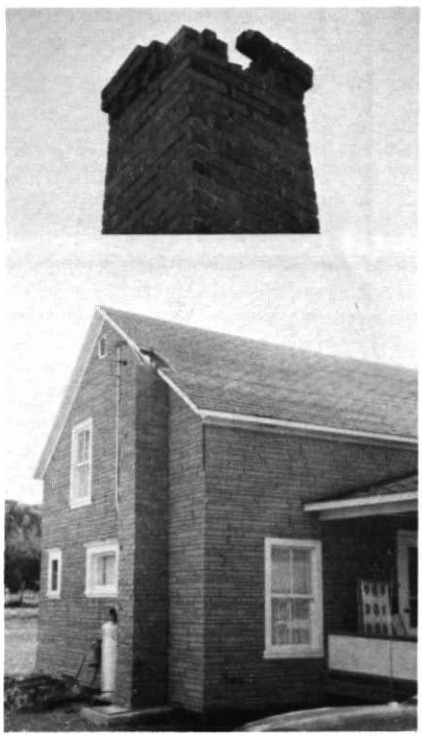

Figure 4
June 14, 1973. Chimney damage at Woburn, Québec. Most chimneys in the town were undamaged. (Fig. 3 in Wetmiller, 1975).

a tall church spire in Hamilton, 400 km to the southwest, although the shock was felt strongly there.

The newspaper photograph in Figure 5 shows the gymnasium in the Cornwall Collegiate and Vocation School, the latter valued at $300,000. Earthquake damage was estimated at $12,000, about four per cent of the total value. The photograph suggests that the gymnasium roof may have collapsed due to the earthquake shaking, but this was not the case.

The top two metres of the 35-metre central section of the west and east walls of the adjacent school collapsed outward. These brick coping walls extended above the second floor and surrounded the flat roof. Bricks dislodged from the east wall fell down on to the single-storey gymnasium below and broke through its thin timber roof, carrying a large part of the roof with them. Failure of the top of the walls occurred because it was not well secured to the main roof framing. The north and south walls were properly anchored and were not damaged.

Grand Banks—1929

The most serious loss of life in earthquakes in Canada resulted from the Grand Banks earthquake of Nov 18, 1929 - actually long before Newfoundland became part of Canada in the political sense. This was another major earthquake, similar in size to the St. Lawrence earthquake of 1925 and the Vancouver Island earthquake of 1946, and also recorded worldwide. It was reported felt as far west as Montreal and the New England States, about 1400 km from the epicentre.

The earthquake took place about 5 p.m. on a Monday afternoon. There was no damage in St. John's except for a few dishes. The newspaper of Tuesday did not treat the earthquake as an extraordinary news item. It was not until Thursday that the earthquake made the headlines, when it first became apparent that it had not been simply a minor tremor near St. John's. Shortly before the earthquake on Monday afternoon an early winter storm had knocked out communications between St. John's and the south coast. On Thursday a ship, which had put into a south shore port on a routine visit, discovered the tragedy and wired the news to St. John's.

The south coast of the Burin Peninsula was about 250 km north of the earthquake epicentre. Severe shaking was felt in the south coast fishing villages about 5 p.m. But after the initial excitement had subsided, the residents returned to their homes. Then about 7:30 p.m., 2½ hours later, a 5-metre tsunami struck the south coast. Its height here was due in part to the combination of high tide and a heavy gale at sea. The tsunami swept away buildings along the waterfront, including the people inside them. Some were rescued when their homes came back in on the next wave. Some were saved when neighbours went out in boats to rescue them before the houses sank. A total of 27 persons from several villages were drowned.

Extensive property damage was experienced along a 65-km stretch of the south coast with fishing gear as well as buildings either swept away or damaged. Property damage was estimated to exceed one million dollars. In addition, turbidity currents resulting from landslides on the continental shelf and slope broke 12 trans-Atlantic cables at distances up to 600 km from the epicentre. Some chimney damage and minor landslides occurred on Cape Breton Island.

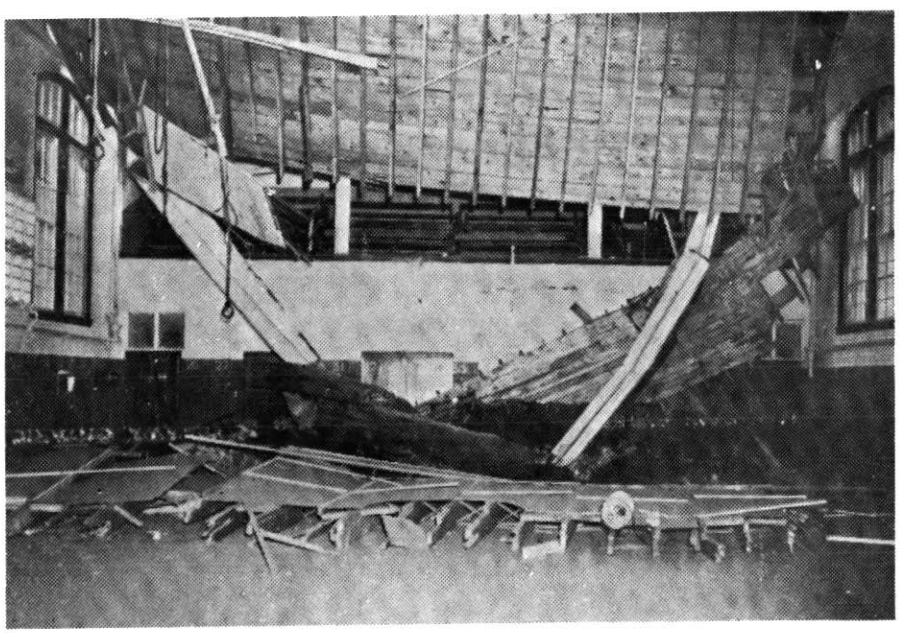

Figure 5
Sept. 4, 1944. High school gymnasium, Cornwall, Ontario. Bricks fell through the gymnasium roof, bringing down part of the roof. (Newspaper photograph).

Conclusions

Significant earthquake damage has occurred in Canada in the present century, as illustrated by the earthquakes in eastern, central and western Canada discussed above. The major earthquakes of 1925 and 1946 were located more than 100 km from the nearest urban areas, Quebec City and Vancouver respectively, which lessened their potential for extensive damage and injuries. All the 28 deaths resulted from drownings and not from partial or complete building collapse. In many cases, serious building damage was due to defects in the building or to enhancement of ground vibrations by thick deposits of clay or sand.

Thus damage in future earthquakes could be minimized if more attention were paid to proper earthquake-resistant design and construction followed by adequate maintenance. While many new buildings in recent years do satisfy the earthquake loading requirements of the National Building Code, little has been done to reinforce older structures. Buildings - new or old - may experience significant damage in future earthquakes in Canada wherever they are found in a comparable condition to those in the earthquakes of 1925, 1944, or 1946. Deaths and injuries could be greater if some of the future earthquakes occur when large buildings such as schools are occupied and/or if these earthquakes occur closer to

densely populated areas.

A look at our earthquake history should remind us that earthquake risks are real in Canada but that significant earthquake damage is not inevitable, if proper precautions are taken now.

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