Investigation of Earthquakes in Burlington, Ontario

by

R.J. Wetmiller

Seismological Service of Canada

Internal Report # 80-5

Division of Seismology
and Geothermal Studies
Earth Physics Branch
Energy, Mines & Resources Canada

May 1980

Introduction

This report presents a summary of the investigation of earthquakes in the city of Burlington, Ontario by officials of the Earth Physics Branch, Department of Energy, Mines & Resources, Ottawa. There have been fourteen tremors reported felt in the city from June, 1975 to April, 1980. Some of these tremors can be identified as small earthquakes on the records of nearby seismograph stations, but most have not been recorded on any seismograph station and are only identified by the felt reports. There has been increasing concern expressed by residents of Burlington over the origin of the unexplained tremors in the city. If all the tremors are earthquakes, what are the implications for seismic risk in the city of Burlington? If some are not earthquakes, what source has been causing the non-earthquake tremors?

On December 13, 1979 officials of the Earth Physics Branch installed a seismograph in the city of Burlington. This was done at the invitation of the Mayor and with co-operation of the civic officials in an effort to clear up the mystery of the unexplained tremors. The seismograph operated until April 30, 1980 and recorded two of the disturbances. The information obtained from the seismograph allows a re-evaluation of all the tremors to be made.

Seismic History of the Burlington Region

The area around the southwestern end of Lake Ontario lies within Zone 2 of the 1970 Canadian Seismic Zoning Map (Fig. 1). The city of Burlington is included in this zone. Generally, a Zone 2 rating implies a moderate level of earthquake activity. Felt tremors may be expected to occur from time to time in this zone while smaller events not capable of being felt will occur more frequently. Large magnitude destructive earthquakes are not expected to

occur and intermediate magnitude events capable of causing widespread but minor damage to buildings are expected only infrequently i.e. a few times per century. To date no earthquake has caused damage in Canada in this region, although several potentially damaging events in the magnitude range 4.0 - 5.0 have occurred without damage (Fig. 2). Two earthquakes have caused damage in adjacent New York State. The most notable of these was the August 12, 1929 earthquake near Attica, New York which caused widespread chimney damage in Attica.

The distribution of all known earthquakes in the region is shown in Fig. 2. No part of this area in Canada has been particularly susceptible to earthquake activity. The known earthquake activity is scattered around the western end of Lake Ontario without showing a strong tendency to repeat at specific sites. The area of New York State near Attica does appear to have such a tendency, however. Earthquake reports go back to 1840 for this map but,rely exclusively on felt reports until 1965 and are not complete for magnitudes less than 3 before this time. The area was settled in the late 1700's so even large earthquakes before about 1750 could easily have gone undocumented. The largest known earthquake is the 1929 event near Attica which had a magnitude of 5.8. The largest event in Canada occurred near Welland, Ontario with magnitude of about 5.0 in 1873. It was widely felt but apparently caused no damage. The largest earthquakes in the past two decades have been a magnitude 4.7 event in New York State east of Buffalo in 1966 and the magnitude 3.0 event at Burlington, Ontario in June, 1975.

History of the Burlington Tremors

The June, 1975 earthquake was widely felt in the city of Burlington but caused no damage. The felt area comprised a few miles along the lakeshore from the Appleby Line in east Burlington to the Bronté Road in Oakville (Fig. 3). Residents felt a strong but brief tremor and some reported a loud noise like a sonic boom. The tremor was recorded on 7 seismograph stations in Canada and New York and an analysis of these stations' records showed that the earthquake had been a magnitude 3.0 event and had indeed originated from the area of the city.

The epicentre of the June, 1975 earthquake cannot be precisely calculated because none of the seismographs were very close to it. The closest station was about 80 km away. The calculated location for the epicentre is about 10 km north and west of the felt area and is probably in error. Similarly, a smaller earthquake felt in the city on March 05, 1978, has been located about 20 km north and east of the felt area (Fig. 2). The data used for the calculation of the epicentre of this event is very poor and its epicentre is probably very close to the epicentres of the two more recent events on Fig. 2.

The June tremor is the first Burlington tremor documented. Some residents of the city claim that such tremors have occurred many times before June, 1975, but no dates and times have ever been documented. The on-going seismic monitoring of the western Lake Ontario region has not identified any earthquakes in Burlington prior to June, 1975. It seems reasonable to assume that a tremor as large or larger than the June, 1975, tremor could not have gone undocumented since the area was densely populated. In

general, however, there does not exist a reliable basis to judge how long small tremors have been occurring in Burlington.

Table 1 gives a history of all the Burlington tremors that have been reported to the Earth Physics Branch. The tremors of January and February, 1978, were reported only during the investigation of the March, 1978 earthquake. Some very small tremors may have gone unreported in the time between the June, 1975 and March, 1978 tremors, but it seems reasonable to assume that none would have been as large as the March, 1978 tremor. The felt reports have come from newspapers and radio stations in Burlington or nearby Hamilton that wished to confirm if a tremor felt in Burlington was in fact an earthquake. The effects reported for each of the tremors have been remarkably similar: a brief strong shaking often accompanied by a loud noise. The area affected by the tremors has varied in size but always included parts of the same few miles of east Burlington along the lakeshore from the Appleby Line to the Oakville border. For the stronger tremors the effects have spread beyond this area but they have always included it.

The fact that many of the disturbances were not recorded by nearby seismograph stations caused speculation that they were not earthquakes but, instead, some kind of local air-borne sonic boom. The effects of sonic booms are very similar to the effects of earthquakes at short distances, namely a strong brief vibration accompanied by a loud noise. Two possible causes of sonic booms in Burlington, military aircraft and activity at oil refineries on the Oakville-Burlington boundary, have been investigated without finding any connection to the disturbances. The Noise Pollution

Branch of the Ontario Ministry of the Environment has monitored the noise emissions from the oil refineries at various times in connection with the Burlington tremors. The office of the Director Air Regulations and Traffic Services of the Department of National Defense in Ottawa has investigated possible overflights by supersonic aircraft, both Canadian and American, for a number of the Burlington tremors.

The smallest earthquake at Burlington that could be detected at the permanent seismograph stations existing since 1975 is about magnitude 2.0 to 2.5. Earthquakes with magnitudes smaller than this would not be recorded at the seismograph stations. In addition, the Earth Physics Branch opened a seismograph station at Effingham, Ontario near St. Catherines in July, 1979. This station, which is the closest permanent seismograph to Burlington at about 60 km distance, lowered the detection level for earthquakes in Burlington to below magnitude 2.0.

Earthquakes with magnitudes less than 2.0 are rarely reported felt. They are strong enough to be felt over a few kms if they are shallow and if there are people in the immediate vicinity of the event. Thus, in the case of the Burlington disturbances, an earthquake with magnitude less than 2.0 could cause a tremor felt by the residents of the city if the earthquake occurred at shallow depth right below the residential area. In such a case, the earthquake would not be detected by any of the existing seismograph stations.

On December 4, 1979 a tremor occurred in Burlington which was poorly recorded on the Effingham station but not on other more distant stations.

The record suggested that an earthquake with magnitude less than 2.0 had occurred in Burlington but was not conclusive. It was therefore decided to install a temporary seismograph station in Burlington within the area being affected by the tremors in order to determine conclusively whether or not earthquakes were causing the disturbances.

Burlington Seismograph, BUO

A regional modular seismograph was installed on December 13, 1979 at the home of Mr. W. O'Connell, Ward 8 Alderman for the city of Burlington, at 215 Appleby Line in the area being disturbed by the tremors. The seismometer was placed on a patio stone in the backyard of the home and the recorder was set up in the utility room in the basement. The seismograph was set at peak magnification of about 8×10^4 at 10 Hz making it capable of recording any nearby events above magnitude 0.5. Mr. O'Connell and two Burlington firemen, Mr. J. Pocha and Mr. D. Gale were trained to operate the system. Routine operation of the station was carried out by the firemen and liaison with the Earth Physics Branch was via the office of the Burlington Fire Chief, Mr. W. Corp. The co-operation of all people concerned with the operation of the seismograph was excellent and is to be commended. The seismograph, code name BUO, proved to be a valuable monitor of the low level seismic activity in the city of Burlington.

Burlington Earthquakes of February 28 and March 14

Two felt tremors occurred while the Burlington seismograph was in operation. These were on February 28th at 20:24 EST and March 14th, 1980 at 05:57 EST. Both tremors were felt by residents of the east end of

Burlington in a manner that was typical of the previous disturbances. The March tremor was noticed by fewer people than the February tremor probably because the March tremor occurred in the early morning. Both events were well recorded by the seismograph and can be confidently identified as small earthquakes of approximately the same size, about magnitude 1.5 on the Richter magnitude scale. A copy of their records is shown in Fig. 4.

The similar nature of the records suggests that both events occurred at the same location. The exact location of the earthquakes cannot be calculated from a single station's record. Records from at least three stations are required to do an earthquake location. However, a maximum radial distance to the source can be estimated from the BUO record. The fault break which caused the two tremors appears to be within a few kms of the seismograph and possibly within one km. An area of radius 2 km is shown on Fig. 3. It includes all the residential area of east Burlington and extends into Lake Ontario. The source of the March and February tremors, and probably all the other Burlington tremors, almost certainly lies within this area at a depth of no more than 2 kms.

For the purposes of cataloguing these two earthquakes in the Earth Physics Branch data files the following basic parameters have been assumed.

Date 1980	Time EST	Latitude ^{o}N	Longitude ^{o}W	Depth Km	Magnitude M_L
Feb. 28	19:24:31	46.36	79.75	1	1.5
Mar. 14	05:57:04	46.36	79.75	1	1.5

These parameters are consistent with the records of the two events on BUO. The epicentral co-ordinates are those of the seismograph station and may be

in error by 2 kms but this is a smaller uncertainty than a conventional instrumental earthquake location would give in this area.

The February 28th tremor was followed by a sequence of smaller events interpreted as aftershocks. They were all much smaller than the February 28th event. Table 2 gives a list of fourteen aftershocks that could be conclusively identified from the Burlington records; none of the aftershocks were reported felt. A similar series of aftershocks did not occur after the March 14th event. The reason for this difference in behaviour is unknown.

The seismograph has recorded no other earthquake disturbances in the Burlington area. Except for the two felt tremors and the aftershock sequence following the first, no on-going low level seismic activity was detected in Burlington during the period from December 13, 1979 to April 30, 1980. The seismograph was nevertheless a sensitive monitor of seismic activity and did record a number of earthquakes occurring outside Burlington during this same period. One of these was the magnitude 2.5 earthquake felt in Hamilton on January 21, 1980.

Possible Causes

The most likely cause for all the Burlington felt tremors is earthquake activity. The tremors of February 28th and March 14th are conclusively identified as earthquakes by their seismograph records, and the similarity of how those two disturbances were felt in Burlington with how the previous 11 were felt suggests that all were of the same cause. However, the possibility that one or two of the tremors that were felt but not recorded

were caused by non-earthquake activity cannot be discounted. In addition, the similarity of the felt reports and their distribution suggest that all the tremors occurred at or very near the same location. In particular, the locations of the earthquakes of June, 1975 and March, 1978 that have been calculated on the basis of seismograph information to be outside the felt area of the tremors are in error and should be revised to be at the location of the two most recent tremors. This revision is consistent with the accuracies of the instrumental solutions which are not better than 10 and 20 kms for the June, 1975 and March 1978 events, respectively.

The fact that fourteen earthquakes in the past five years have occurred in the same small area is unusual considering the known seismic activity in the surrounding region. Although our knowledge of the distribution of small magnitude activity is admittedly limited, no area on Fig. 2 seems to be particularly subject to repeated earthquake occurrences. The only exception is the area near Attica, New York where there have been a number of larger earthquakes in this century. It is beyond the scope of this report to detail the many studies that have been made of the earthquake activity near Attica. In general, it is believed that the earthquakes are related to a major deep seated crustal fault zone and that the relatively frequent seismic activity on that structure is confined to the Attica area. Certainly the seismic activity at Burlington has been much smaller in magnitude than at Attica and is not linked to any known major crustal break.

Some minor geological features have been identified in the Burlington area by geologists, which may provide an explanation for the earthquake activity. These features are described in a paper by White et al. (1973).

These authors describe seventeen examples of deformation of the near surface rocks in the Toronto-Hamilton area. The deformational features are either folds or faults and are attributed to the effect of high horizontal stress in the rock. One such feature has been identified in the Burlington area, a low fold in the parking lot of CIP Containers Ltd. in Burlington. Such features are good evidence of on-going deformation in this region but they have not been related to seismic activity. Indeed, there are documented cases where they have occurred very slowly over the space of a few hours without the release of any seismic energy. Nevertheless, it is plausible that such deformation could occur instantaneously with the release of seismic energy in the form of an earthquake.

Conclusions

1. The disturbances felt by the residents of Burlington on February 28th and March 14th, 1980 were small earthquakes. Both earthquakes had a magnitude of about 1.5 on the Richter Scale and were located under Burlington or an adjacent area of Lake Ontario.

2. It is concluded that the previous tremors for which no seismograph record could be found were also caused by earthquakes. No evidence for another source of any of the disturbances has been found. All fourteen earthquakes felt since June, 1975 occurred at or very near the same location. The published locations for the earthquakes of June, 1975 and March, 1978 are in error and should be revised. No information is available for tremors in Burlington before June, 1975.

3. The recent frequent earthquake activity at Burlington is not typical of seismic activity in the region, and is not, in general, comparable to earthquake activity at Attica, New York. The Burlington earthquakes may be related to near surface deformational features identified in the area, but the relationship, if any, of these features and the seismic activity to a possible damaging earthquake in Burlington in the future is not known. The general region of western Lake Ontario has shown a potential for earthquakes over magnitude 5, but no earthquake of this magnitude has occurred in the Burlington city area for at least 200 years.

Acknowledgements

The information on felt reports was supplied by many reporters of newspapers and radio stations in the Burlington - Hamilton area. Mr. M. Patton of the Burlington Post, in particular, supplied much valuable information on how and where the recent tremors were felt. Noise emissions from the two oil refineries on the Burlington - Oakville border were investigated by Mr. L. Kende of the Ontario Ministry of the Environment. Possible flights of supersonic aircraft near Burlington were investigated by Major J. Ritzell of the National Defence Headquarters. Mr. G. Girouard of the Earth Physics Branch assisted in the installation of the seismograph in Burlington.

References

White, O.L., P.F. Karrow and J.R. Macdonald, 1973. Residual stress relief phenomena in southern Ontario, in Proceedings of the 9th Canadian Rock Mechanics Symposium, pp. 323-346.

TABLE 1

BURLINGTON TREMORS

	Date	Time Local	Remarks
1.	1975 June 30	16:15	M3.0 earthquake
2.	1978 Jan. 09	08:37	No record
3.	1978 Jan. 21	08:18	No record
4.	1978 Feb. 02	09:59	No record
5.	1978 Mar. 05	18:21	M2.1 earthquake
6.	1979 Nar, 16	08:50	No record
7.	1979 Aug. 24	13:15	No record
8.	1979 Aug. 30	11:00	No record
9.	1979 Sept. 23	13:00	No record
10.	1979 Sept. 24	10:00	No record
11.	1979 Sept. 25	06:09	No record
12.	1979 Dec. 03	20:55	M<2.0 earthquake
13.	1980 Feb. 28	19:24	M1.5 earthquake
14.	1980 Mar. 14	05:57	M1.5 earthquake

TABLE 2

EARTHQUAKES RECORDED BY BUO
(Dec.13, 1979 to Apr.30, 1980)

	Date 1980	Time EST	Amplitude[1] mm	Magnitude M_L
1.	Feb. 28	19:24	74 (estimated)	1.5
2.	Feb. 28	23:04	15	0.8
3.	Feb. 29	01.30	8	0.5
4.	Feb. 29	04:52	7	0.5
5.	Feb. 29	06:05	18	0.9
6.	Feb. 29	06:41	13	0.8
7.	Feb. 29	07:13	5	0.3
8.	Feb. 29	14:56	18	0.9
9.	Feb. 29	19:59	9	0.6
10.	Feb. 29	20:42	9	0.6
11.	Mar. 01	20:48	20	0.9
12.	Mar. 01	21:12	8	0.5
13.	Mar. 02	03:18	5	0.3
14.	Mar. 02	06:25	13	0.8
15.	Mar. 03	01:23	6	0.3
16.	Mar. 14	05:57	62	1.5

1 peak to peak maximum amplitude on the BUO record

Figure 1. The 1970 Canadian Seismic Zoning Map. The Burlington area lies in the small area of Zone 2 at the western end of Lake Ontario.

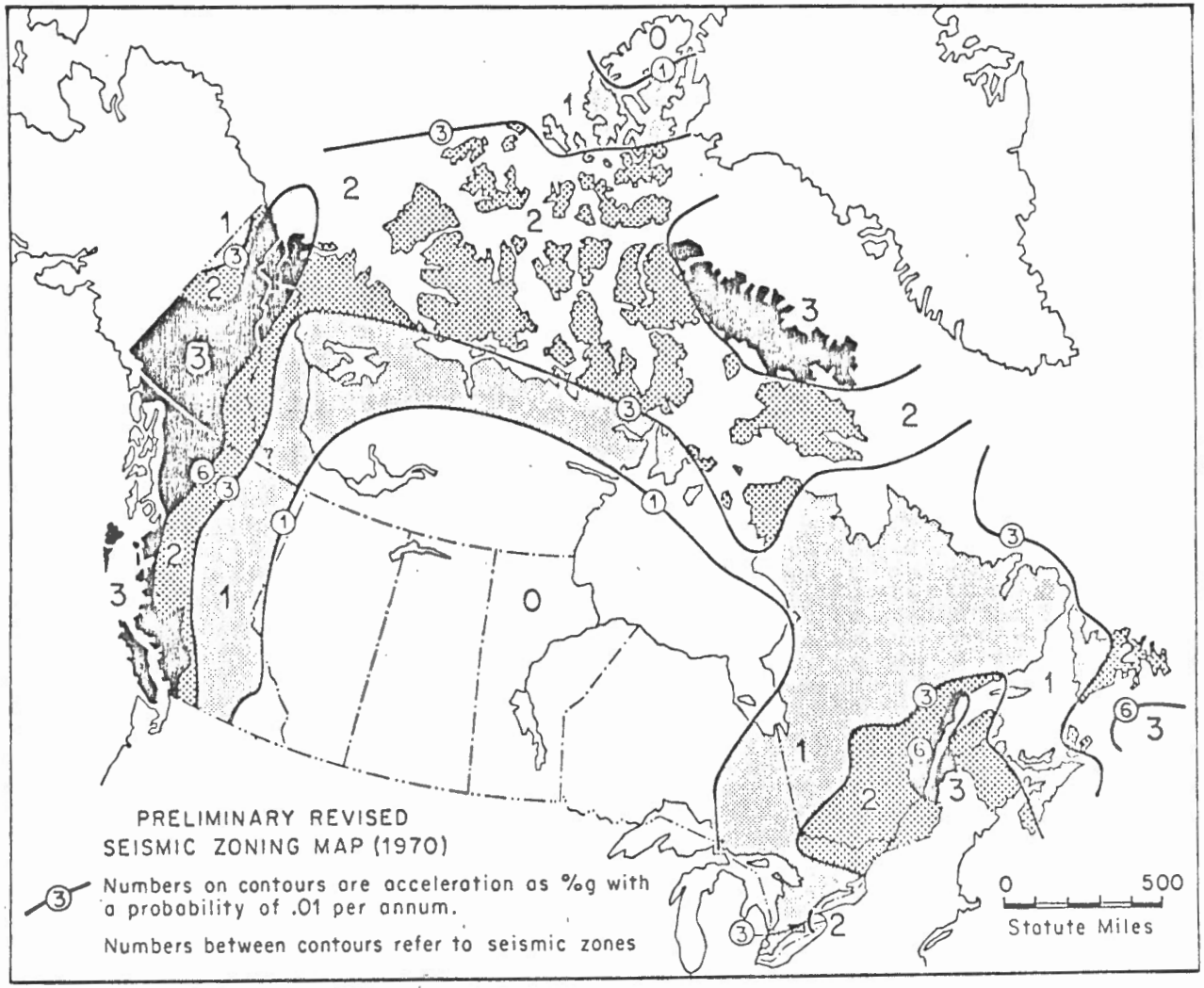
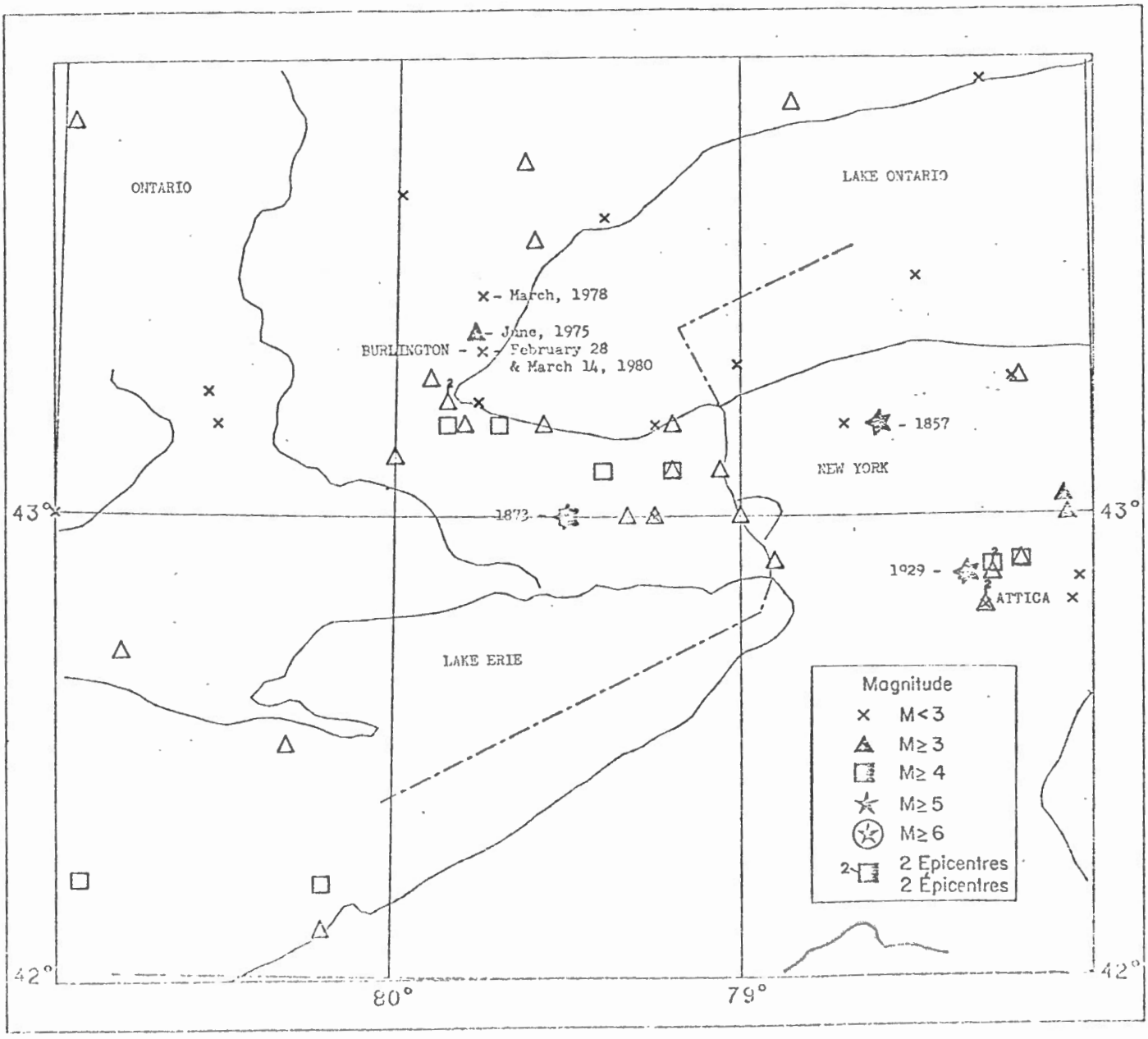


Figure 2. All known earthquakes up to August, 1979. Some small events in the Burlington area up to March, 1980 have also been plotted. Open symbols are less reliable locations.



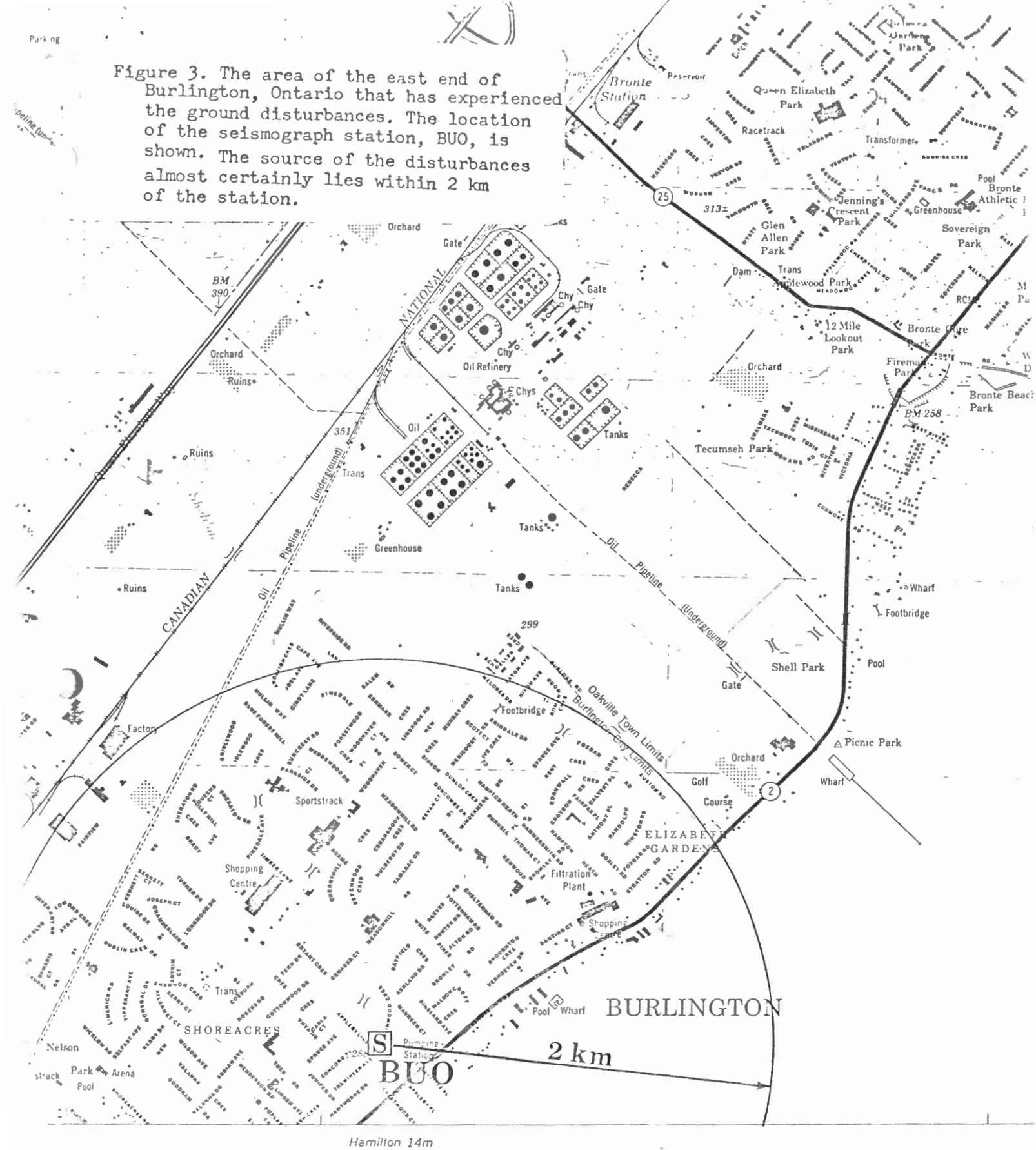


Figure 3. The area of the east end of Burlington, Ontario that has experienced the ground disturbances. The location of the seismograph station, BUO, is shown. The source of the disturbances almost certainly lies within 2 km of the station.

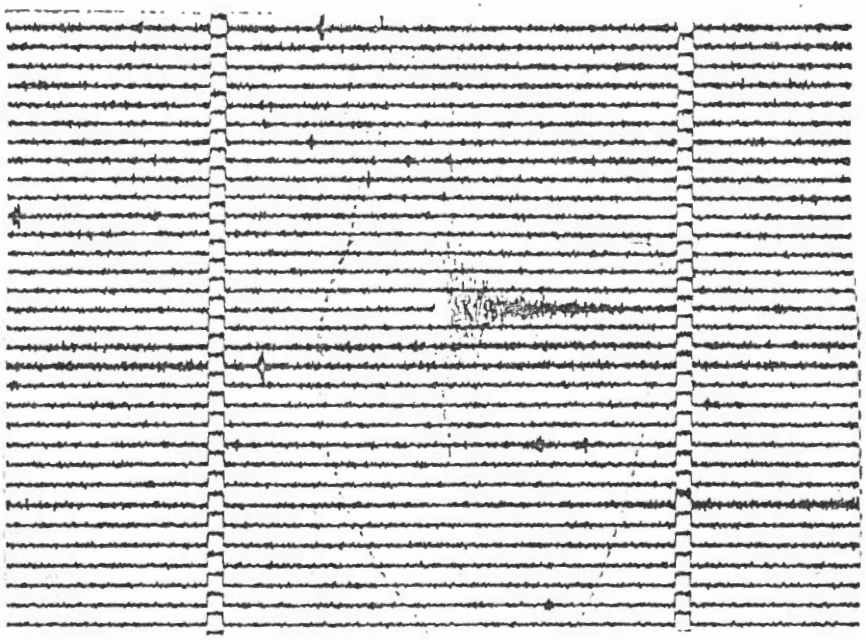
SCALE 1:25,000 ÉCHELLE

Elevations in Feet above Mean Sea Level
Transverse Mercator Projection
North American Datum 1927

Élévations en pieds au-dessus du niveau moyen de la mer
Projection transverse de Mercator
Référence des données nord-américaines de 1927

Figure 4. Portions of the BUO seismograph records of February 28th and March 14th showing the disturbances that were felt in the city on those days.

A: February 28 at 19:24



B: March 14 at 05:57