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Seismograms for historic Canadian earthquakes: The 1 March 1925 Charlevoix-Kamouraska, Quebec earthquake

Allison L. Bent

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SEISMOGRAMS FOR HISTORIC CANADIAN EARTHQUAKES: THE 1 MARCH 1925 CHARLEVOIX-KAMOURASKA, QUEBEC EARTHQUAKE

Allison L. Bent
Geophysics Division
Geological Survey of Canada
1 Observatory Cres.
Ottawa, Ont. K1A 0Y3

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ABSTRACT

For those who are interested in studying historic earthquakes, collecting the data often proves to be the most difficult and most time consuming aspect of the project. For the large 1925 Charlevoix-Kamouraska (Quebec) earthquake, records from 20 regional and teleseismic seismograph stations have been assembled by past and present seismologists at the Geological Survey of Canada in Ottawa. This paper catalogs the data set, and briefly describes the seismograms in the collection to assist those who may study this earthquake in the near or distant future. Many of the body waves have been digitized for a waveform analysis study; these data files may be obtained from the GSC.

RÉSUMÉ

Ceux qui s'intéressent à l'étude des tremblements de terre historiques trouvent souvent que collectioner les données est l'aspect du projet le plus difficile et qui exige beaucoup de temps. Une collection des données du grand tremblement de terre de Charlevoix-Kamouraska (Québec) de 1925 qui comprend des séismogrammes enregistrés aux 20 stations séismologiques régionales et télésismiques était ramassée par des séismologues au passé et au présent de la Commission géologique du Canada (CGC). Cet article-ci énumère ces données et aussi fournit une déscription brève des séismogrammes de la collection pour ceux qui pourraient étudier ce tremblement de terre à l'avenir proche ou lointain. Le plupart des ondes de volume ont été chiffré pour une analyse des formes des ondes, et on peut obtenir ces fichiers de données de la CGC.

INTRODUCTION

The Charlevoix-Kamouraska seismic zone of southeastern Quebec (Figures. 1, 2), which lies near many of the heavily populated regions of eastern Canada and New England, has produced at least four earthquakes of magnitude 6 or greater since the region was settled in the 1600s and, in all likelihood, will be the site of a large earthquake sometime in the future. Of the large past earthquakes, only the 1 March 1925 (28 February, local time) earthquake was recent enough to have been recorded instrumentally. Since 1925, there have been no earthquakes of magnitude greater than 5.5 in the Zone. Thus, the data set for this earthquake is unique for this region.

Seismograms of early instrumental earthquakes (like their modern counterparts) can be important tools for understanding seismic sources and seismotectonics (for example see *Kanamori,* 1988). In seismically active regions with no large recent (since 1963) earthquakes the early instrumental records become even more important. Unfortunately, assembling a data set large enough for an in-depth study of an older earthquake is often more difficult than the study itself. While the establishment of the World Data Centers [*Glover et al.,* 1985] has somewhat facilitated this task, frequently the seismograms are still scattered around the globe. If a seismograph station has been in continuous operation over a long period of time, records can often be obtained directly from that station. However, many historical seismograph stations are no longer in operation, and tracking down the archive for their records can be particularly time consuming. Occasionally, however, a reasonably complete data set may be found for an earthquake of interest. The 1925 Charlevoix-Kamouraska earthquake (sometimes referred to as the St. Lawrence, La Malbaie, or Charlevoix earthquake) is one of these cases.

After the 1925 earthquake, E. A. Hodgson of the Dominion Observatory (now part of the Geological Survey of Canada (GSC)) in Ottawa collected worldwide seismograms for the earthquake, and analyzed them using the rather limited tools available at the time. Unfortunately, these records later "disappeared" and more recent attempts to use modern waveform analysis techniques to study the 1925 earthquake were hampered by a lack of data (for example, *Ebel et al.*, 1986). During the spring of 1991 while the Seismology Building at the GSC was undergoing renovations, the data collection reappeared. The results of a predominantly body wave analysis of these records may be found in *Bent* [1992] and will not be repeated here. The main goal of this report is to summarize the data set for those present or future researchers who may be interested in this earthquake. For those who are interested in more details about the 1925 earthquake the two studies cited above as well as that of *Hodgson* [1950] should be consulted. Descriptions of Charlevoix-Kamouraska seismicity and seismotectonics include the works of *Stevens* [1980], *Anglin and Buchbinder* [1981], *Anglin* [1984], *Lamontagne* [1987], *Adams et al.* [1989], and *Wetmiller and Adams* [1990].

SEISMOGRAM COLLECTION

The GSC seismogram collection for the 1925 Charlevoix-Kamouraska earthquake consists of records from 20 stations. While this collection is by no means complete (83 stations reported arrival times to the International Seismological Summary), it does provide reasonably good azimuthal coverage of the earthquake, and contains at least one record from every quadrant (Figure 3) although some regions are better covered than others. Most of the seismograms are photographic copies of the originals, but there are also some original records and some that are on microfiche. Records from 3 stations were added later and were not part of the "misplaced" collection (these are indicated below). The available records and instrument constants are summarized in Table 1. A brief description of each of the seismograms can be found in the seismogram section below and some examples are shown in Figure 4.

Seven of the 20 stations in Table 1 were at regional or P_{nl} distances ($<$ 1400 km) with respect to the epicenter, 11 were at true teleseismic distances ($> 32^{o}$) and the remaining 2 were at intermediate or upper mantle triplication distances. The majority of the instruments had natural periods in the 6–15 second range, although there are some exceptions.

The instrument parameters were obtained from a number of sources. Parameters provided by the seismograph stations at the time of the earthquake are assumed to be the most reliable and were used whenever available. Station bulletins were the second choice for instrument parameters. Instrument parameters listed in *Charlier and van Gils* [1953] were provided by the stations, but are not always from the time period of this earthquake (although they do note the dates of the calibrations). *Ebel et al.* [1986] and *Street and Turcotte* [1977] also list some instrument parameters. Their origins are not noted but these authors may be able to provide the sources. *Kanamori* [1988] lists only the average parameters for each instrument type and was therefore used only when no other source was available and was not used to provide the magnifications. No obvious problems with the instrument parameters were noted by *Bent* [1992] or *Ebel et al.* [1986], but small deviations from the expected period and damping, and magnification problems of less than a factor of 2 would not necessarily be obvious.

SUMMARY OF SEISMOGRAMS

This section provides a brief description of the available seismograms. Unless stated otherwise, the records are copies. Hereafter, the abbreviation B92 will used to refer to the *Bent* [1992] paper.

Berkeley: All phases are very small, but most can be identified.

Bidston: Everything well recorded.

Cheltenham: Everything well recorded.

Chicago: Records have some faint sections, but clear P waves.

De Bilt: This record was not in the original collection. A copy of the vertical component was obtained from J. Ebel. All phases were well recorded. DBN has a good archive and the original record probably still exists. The noted polarity is consistent with the final source mechanism of B92. The author has used this station in several studies of historical earthquakes and found it to be reliable.

Fordham: Good body wave recordings, but sections of surface waves are faint.

Georgetown: Everything well recorded.

Halifax: In general the body and surface waves are well recorded although some surface waves appear to be clipped. The minute marks are very hard to find, and there are some blotches on the record.

Harvard: Body waves well recorded. Beginning of surface waves well recorded, but a large section is off-scale.

Honolulu: Very noisy. Can get a maximum amplitude but nothing else.

New Orleans: Generally well recorded. A small section of the north-south record appears to be clipped. This is an original record.

Ottawa: The Bosch instrument has good P_{nl} recordings, but sections of the surface waves are faint. The Milne-Shaw records have faint sections, although this is less of a problem on the north-south component than on the east-west.

Pulkovo: This station was not in the original collection. Microfiche copies were obtained from the World Data Center in Moscow, where the originals presumably reside. All phases well recorded.

Sitka: Good surface waves. Body waves may be there, but very small.

Stonyhurst: Everything well recorded.

Toronto: The north-south record is more or less complete. The east-west component has a faint section from roughly 2-10 minutes after the first arrival.

Tucson: Clear surface waves. No body waves.

Uccle: Everything well recorded. Marked polarities are consistent with the final source mechanism of B92.

Uppsala: Records not available in Ottawa. The waveforms used in the B92 analysis were digitized from the paper by *Ebel et al.* [1986].

Victoria: In general well recorded. North-south component is very clear. Sections of east-west record are faint but can probably be recovered.

DIGITIZED RECORDS

The body waves of many of the seismograms discussed herein were digitized to facilitate their analysis [*Bent*, 1992]. A floppy disc containing these digitized records may be purchased from the GSC. While every effort was made to digitize the seismograms as accurately as possible, any potential users of these data should bear in mind that some personal bias is always involved in hand digitizing, and that these records, digitized for a specific study, may not contain phases or sections of the record required for other types of analysis.

The seismograms were digitized at a rate of 1 point per 0.25 mm using a digitizing tablet with a 0.025 mm resolution. To improve the resolution most of the records were enlarged to 2 to 4 times the original size before digitizing. After digitizing, the instrument magnification (but not the complete instrument response) was removed, and the records were corrected for curvature and skew (although this was generally not a problem). If the original seismogram was plotted from right to left, the digitized version has been reversed, as noted in Table 2. In most cases, the polarities were not indicated on the seismograms, but if the polarities were marked, this is also noted in Table 2. The original orientation (top to bottom) has been retained for all digitized records. In most cases, the length of the digitized record is from 1 to 2 minutes.

The digitized records are in ASCII format and consist of 4 lines of header followed by x-y pairs of data, where x is the time in seconds and y is the amplitude in cm. The records are generally not equally spaced in time, but may easily be converted by any simple interpolation method. The data points are unformatted with one pair per line. The names of the data files are in the format STN.COMP.PHASE where STN is the station code from Table 1, COMP is the component (z, ns or ew) and PHASE is the phase (usually one of p, pnl, or s). If more than one instrument type was digitized for a single station, there will be a fourth field in the file name indicating to which instrument the record corresponds. Appendix A contains a sample annotated data file.

The digitized records are summarized in Table 2 and shown in Figure 5. An available record was not digitized when the body waves were not considered of sufficiently good quality for a waveform study. This most commonly occurred when the body waves were too small to be seen. Other common reasons for not digitizing a record were that all or part of it was off-scale, that it was too faint, or that the minute marks could not be found.

If the P waves were well-recorded on the vertical component, the horizontal components were not always digitized. The reverse is true for S waves. However, if only one horizontal component was available, the record was generally not digitized unless the station was close to being naturally rotated.

Table 2 also lists the start times for the digitized records (the data files themselves all begin with $t_0 = 0$). The absolute start times and time corrections are also indicated in the header of the digitized files. These times have been read directly from the seismograms and do not include the clock corrections. If the clock corrections are known, however, they have also been included in a separate column and in the header. Unless it was impractical or impossible, the digitizing was started at a minute mark. The beginning of the minute mark was used unless indicated otherwise. For anyone undertaking an analysis where absolute timing is essential, it may be worth checking the appropriate station bulletins to ascertain whether the minute starts at the beginning or end of the minute mark. If both horizontal components were digitized, the digitized records begin at the same absolute time.

ACQUISITION OF DIGITIZED RECORDS

The digitized seismograms may be purchased from the GSC for a nominal fee. The data files will be distributed on a high-density floppy disk and are intended for a single user only. A data order form and sole use agreement may be found in Appendix B.

Acknowledgements: Constructive reviews were provided by John Adams and Anne Stevens. Records not in the original collection were supplied by J. Ebel, N. A. Sergeyeva and O. E. Starovoit.

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Table 1
Available Seismograms

Station	Δ (deg)	Az. (deg)	Instr.(*)	Comps	τ(*) (sec)	ε(*)	V(*)	Source(†)
Berkeley (BKS)	38	273	W	Z,N,E	6	10	80	S
Bidston (BID)	42	57	MS	N	12	20	150	S
Cheltenham (CHE)	10	207	BO	N,E	15	2	10	S,ST
Chicago (CHI)	13	248	MS	N,E	12	20	150	S
De Bilt (DBN)	47	55	G**	Z	12		740	S
				N,E	25		310	S
Fordham (FOR)	8	198	MS	N	12	20	250	S
Georgetown (GEO)	10	209	W	N,E	8	5	115	ST
Halifax (HAL)	6	122	M	E	10	2	120	K
Harvard (HRV)	6	183	BO	N	15	4	?	C,K
				E	10	4	?	C,K
Honolulu (HON)	73	281	MS	E	12	20	150	S
New Orleans (NOL)	23	223	W	Z,N,E	7	5	80	ST
Ottawa (OTT)	4	233	B	N	5.3	2	120	ST
				E	6	15	120	ST
			MS	N,E	12	20	250	S
Pulkovo (PUL)	55	37	G**	Z	15		1428	S
				E	14		1928	S
Sitka (SIT)	39	307	BO	N	17.1	1	10	S,ST
				E	18.8	1	10	S,ST
Stonyhurst (STO)	42	57	MS	E	12	20	150	S
Toronto (TNT)	7	236	MS	N,E	12	20	150	S

Tucson (TUC)	34	257	BO	E	17	1	10	S
Uccle (UCC)	47	58	G**	N,E	24.5		840	S
Uppsala (UPP)	49	40	W	N,E	8.7	3.5	190	E
Victoria (VIC)	34	290	MS	N,E	12	20	250	S

* τ is the pendulum period; ϵ is the damping ratio; V is the static magnification for mechanical instruments and the maximum magnification for electromagnetic instruments

B = Bosch; BO = Bosch-Omori; G = Galitzin; M = Mainka; MS = Milne-Shaw; W = Wiechert

† Source of calibration data: S = station (either from record or station bulletin); C = Charlier and van Gils [1953]; E = Ebel *et al.*[1986]; K= Kanamori [1988]; ST = Street and Turcotte [1977]; if more than 1 source is listed, not all parameters were available from the first source

** for Galitzin instruments it is assumed that the pendulum and galvanometer periods are equivalent, and that the damping constant is 1.0

This Table originally appeared in *Bent* [1992].

Table 2
Summary of Digitized Records

file name	t_o*	length (sec)	t_{corr} (sec)	comments
bid.ns.p	2:26	112.4		
bid.ns.s	2:33	116.7		
bks.z.p	2:26	59.9		
chi.ew.p	2:21	175.3	-11	
chi.ns.p	2:21	176.8	-11	
dbn.z.p	2:27	62.8		up positive
for.ns.pnl	2:20	98.0		
geo.ew.pnl	2:21	114.0	-2	
geo.ns.pnl	2:21	110.7	-2	
hrv.ew.pnl	2:19	105.6		not corrected for gain
hrv.ns.pnl	2:19	139.2		not corrected for gain
nol.ew.s	2:29	106.9		
nol.ns.p	2:25	60.1		
nol.ns.s	2:29	97.9		
nol.z.p	2:25	63.3		
ott.ns.pnl	2:20	69.9	0.0	Bosch record digitized
pul.z.p	2:37	60.5	9 (min?)	original right to left timing makes more sense if clock correction is in minutes (not indicated whether min. or sec.)
sto.ew.p	2:26	113.1	-4	
sto.ew.s	2:33	108.5	-4	
tnt.ns.pnl	2:20	141.3	0.5	
ucc.ew.p	2:27	85.5	-3	west positive
ucc.ew.s	2:34	54.2	-3	west positive
ucc.ns.p	2:27	89.8	-3	north positive
ucc.ns.s	2:34	64.0	-3	north positive
vic.ew.p	2:25	121.4	0.0	
vic.ns.s	2:31	121.2	0.0	

* time (UT) at which digitized record begins

Appendix A
Sample Digitized File

```
bid.ns.p
  89    4.44215E-04
0226    0
   150.000  0.  0.
0.0000E+00    0.0000E+00
0.1154E+01   -0.6198E-04
0.2308E+01   -0.5165E-04
0.3692E+01   -0.4132E-04
0.5423E+01   -0.4132E-04
0.6923E+01   -0.6198E-04
0.8885E+01   -0.8264E-04
0.1050E+02   -0.5165E-04
0.1212E+02   -0.3099E-04
0.1385E+02   -0.5165E-04
0.1558E+02   -0.9298E-04
0.1719E+02   -0.8264E-04
0.1927E+02   -0.8264E-04
0.2042E+02   -0.1033E-03
0.2181E+02   -0.9298E-04
0.2354E+02   -0.7231E-04
          •
          •
          •
```

explanation of header

line 1: id (usually same as file name)

line 2: number of data points; maximum amplitude in cm (not corrected for instrument magnification)

line 3: absolute start time (UT and doesn't include clock correction); clock correction in seconds (NOTE: 0.0 implies clock correction of 0 seconds, 0 implies unknown)

line 4: instrument magnification (1 implies unknown); radius of curvature in cm; skew angle

remaining lines: data points (x in seconds, y in cm)

Appendix B
Data Order Form for 1925 Charlevoix Digital Data Set and Statement of Sole Use

To obtain digital data files, please complete the form below and send cheque or money order for $50.00 Canadian funds or $40.00 U.S. funds (all taxes included) payable to the "Receiver General for Canada" to:

Seismology Program
Geophysics Division, GSC
1 Observatory Cres.
Ottawa, Ontario
Canada K1A 0Y3
Attention: Allison Bent

The digital data supplied is under crown copyright. It is supplied on the understanding that it is for the sole use of the purchaser and not to be redistributed in any digital form to third parties. In acknowledging receipt of the data, the purchaser undertakes to abide by the foregoing legal requirements implicit in the purchase.

____

Company Name

____

Purchaser's Name and Title

____

Signature

____

Date

____

____

____

Mailing Address

FIGURE CAPTIONS

Figure 1. The location of the Charlevoix-Kamouraska seismic zone (black oval) with respect to some larger urban centers in eastern North America. The concentric circles are drawn at distances of 250, 500 and 1000 km from the 1925 epicenter.

Figure 2. Map of the Charlevoix-Kamouraska zone, showing the epicenter of the 1925 earthquake (large asterisk) and all recorded earthquakes (small squares) of magnitude ≥ 2.0 that occurred between 1983 and 1991. The epicenter of the large 1988 Saguenay earthquake, which occurred outside the seismic zone, is also shown. Note that due to the instrument distribution, earthquakes of magnitude 2.0 are not easily detected outside of the seismic zone.

Figure 3. Seismograph stations (triangles) from which seismograms are available for the 1925 Charlevoix-Kamouraska earthquake. The solid lines indicate the great circle paths from station to epicenter.

Figure 4. Some examples of seismograms for the 1925 earthquake. a) EW record from Stonyhurst, England clearly shows both body and surface waves. Reduced to page size. b) NS record from Fordham, New York. P_{nl} waves are clearly recorded, but surface waves are faint and possibly off-scale. At approximately original scale. c) EW record from Tucson, Arizona shows clear surface waves, but body waves are too small to be seen. At approximately original scale. An example of the Ottawa record can be found in *Hodgson* [1950].

Figure 5. Digitized seismograms for the 1925 earthquake. Labels refer to station, component and phase. Note that the horizontal components have not been rotated.

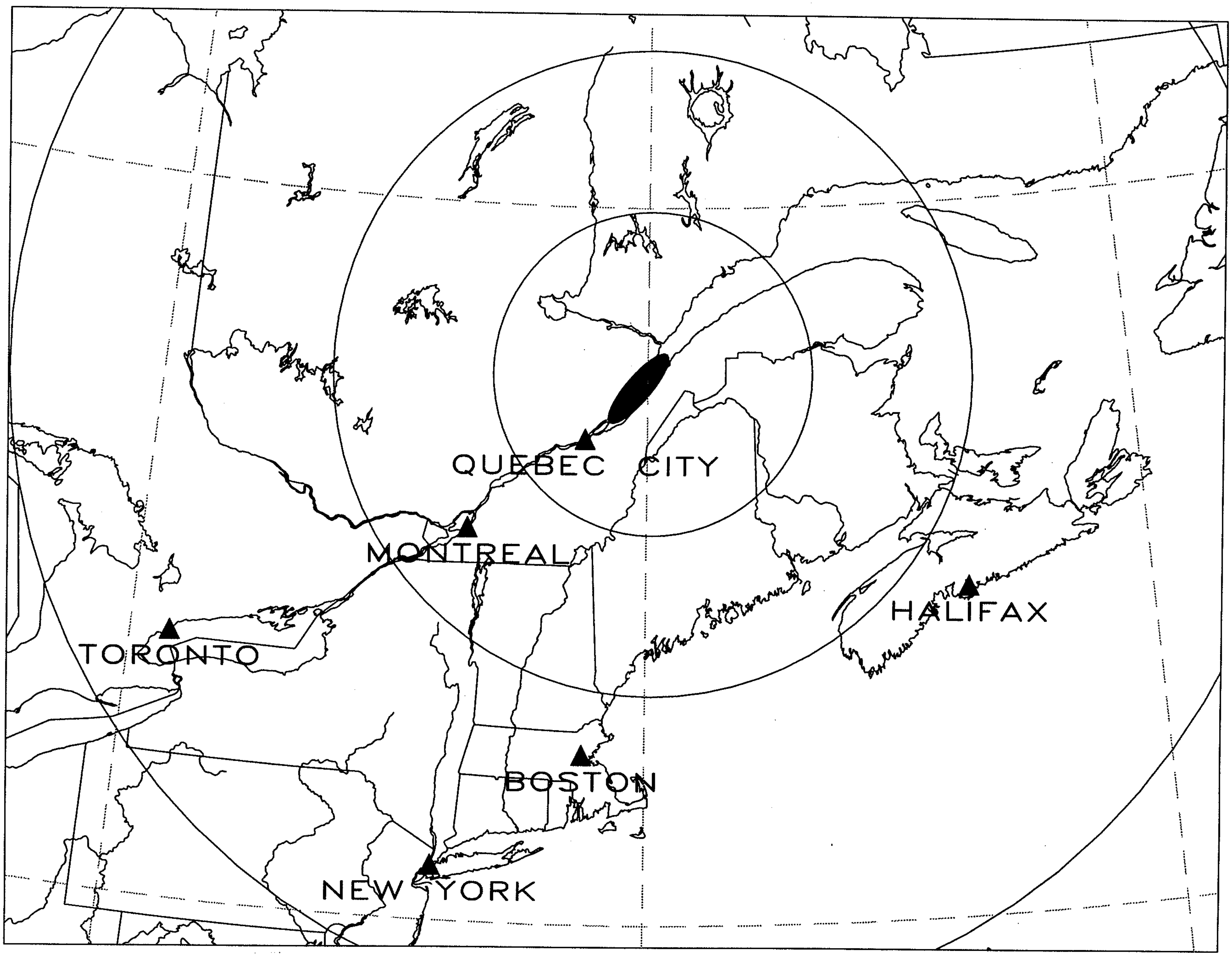

Figure 1

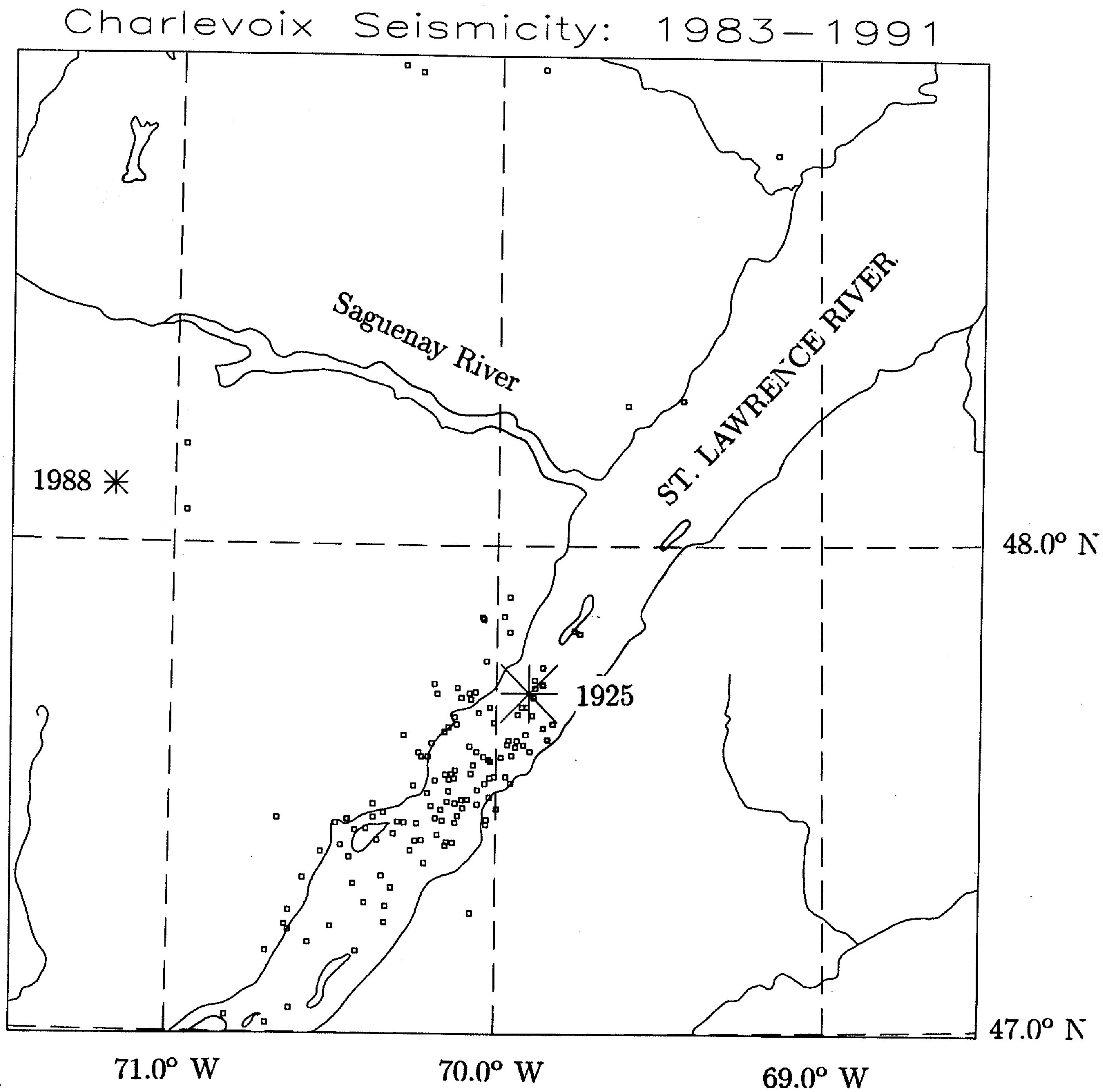
Charlevoix Seismicity: 1983–1991
Saguenay River
ST. LAWRENCE RIVER
1988
1925
48.0° N
47.0° N
71.0° W
70.0° W
69.0° W

Figure 2

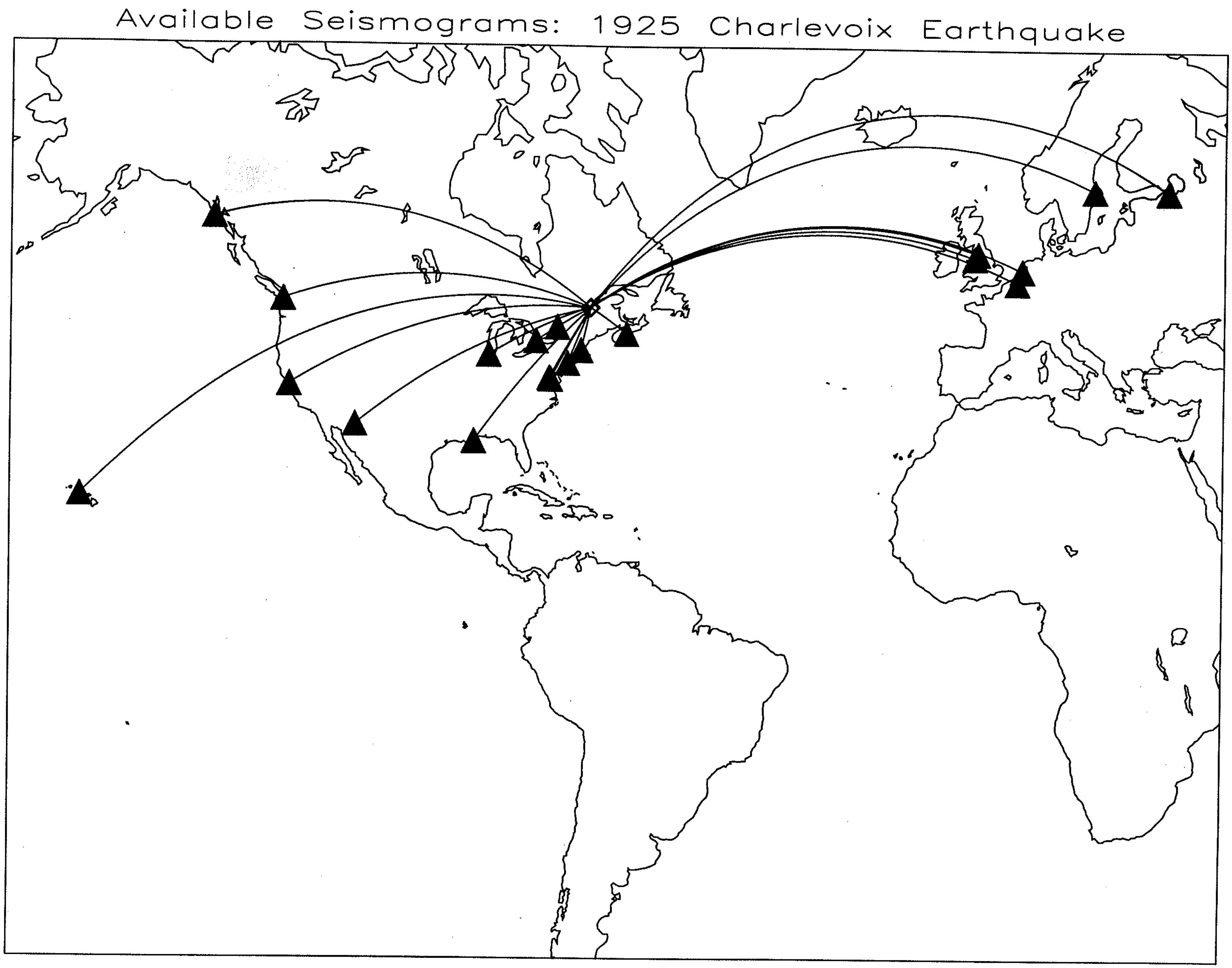

Figure 3

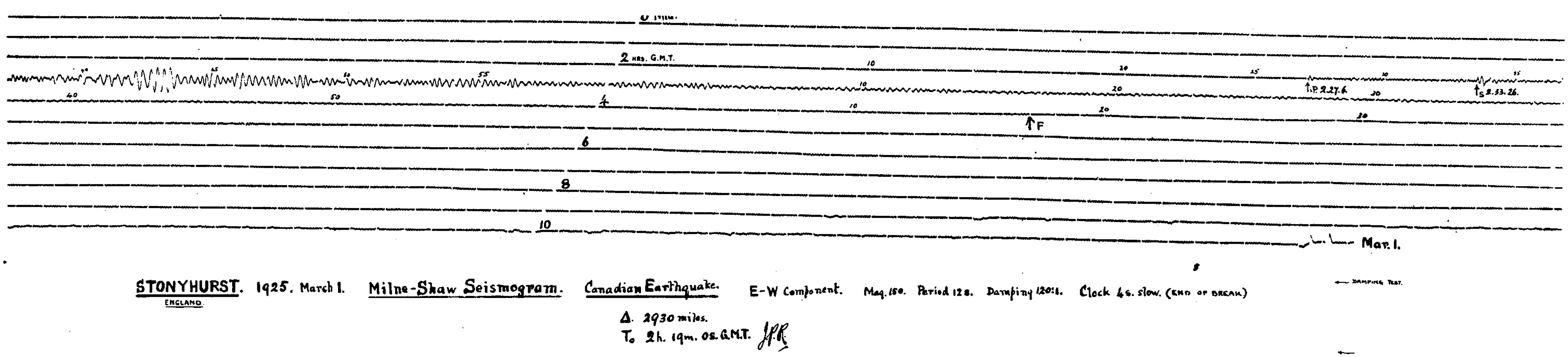
STONYHURST. 1925. March 1.
ENGLAND
Milne-Shaw Seismogram.
Canadian Earthquake.
E-W Component.
Mag. 150. Period 12 s. Damping 120:1.
Clock 4s. slow. (END OF BREAK)
Δ. 2930 miles.
T₀ 2h. 19m. 05. G.M.T.
2 HRS. G.M.T.
↑F
Mar. 1.
DAMPING TEST.

Figure 4a

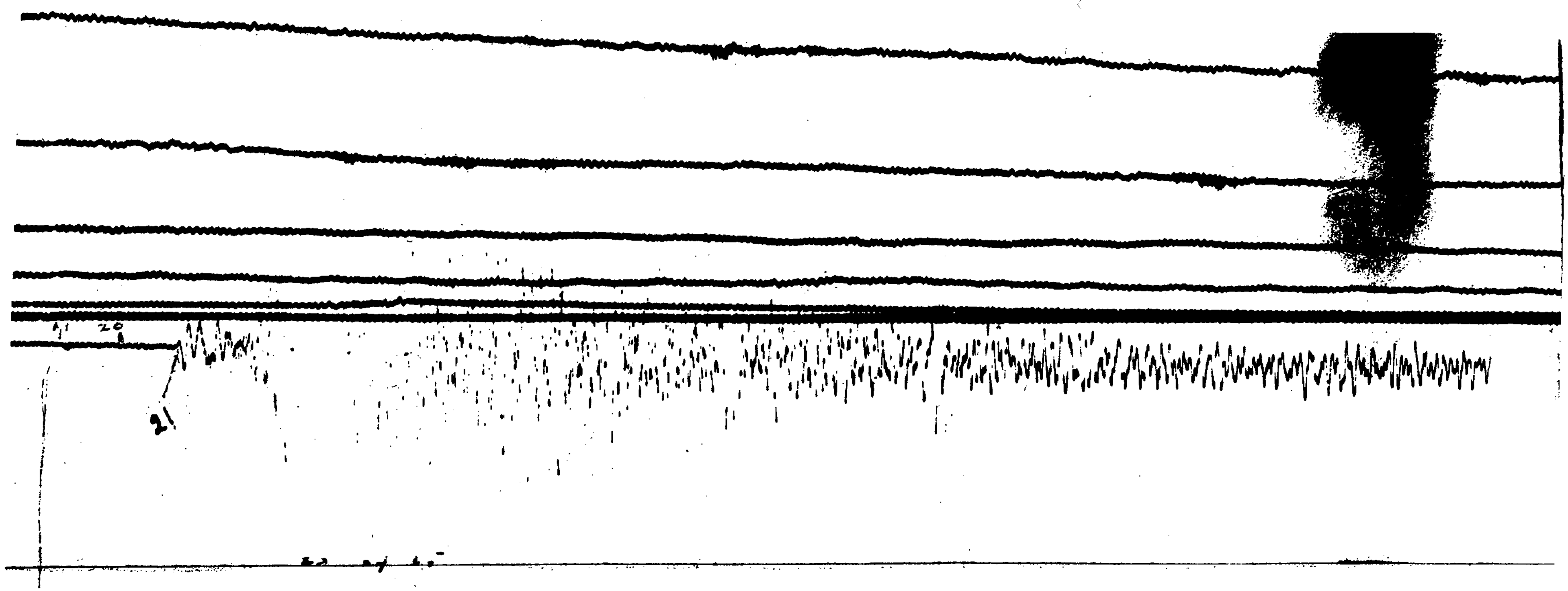

Figure 4b

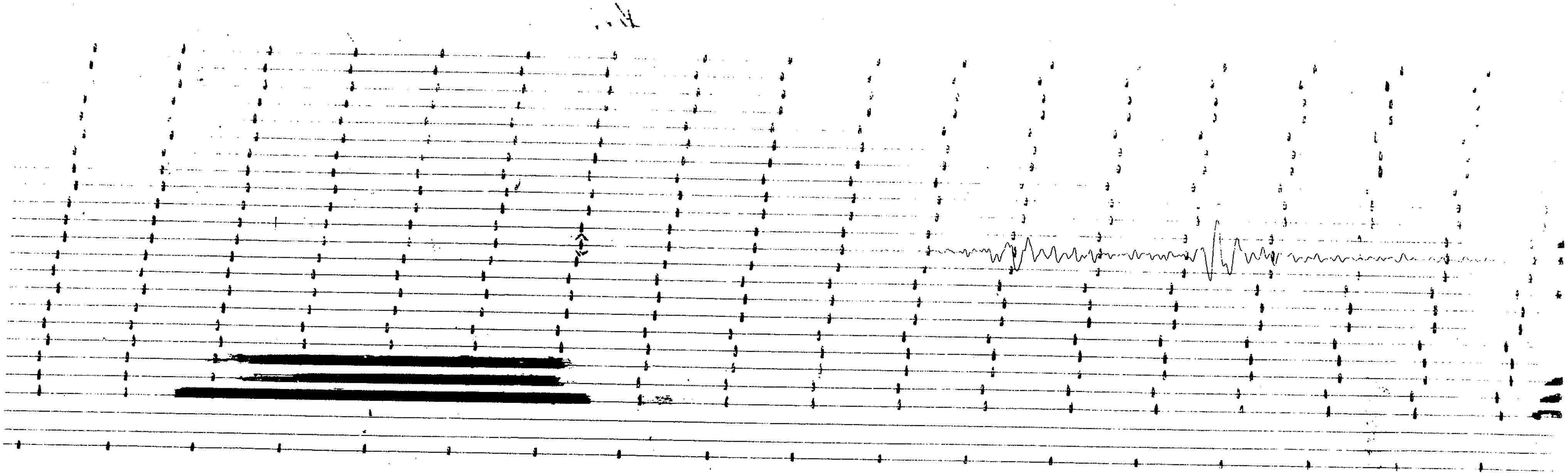

Figure 4c

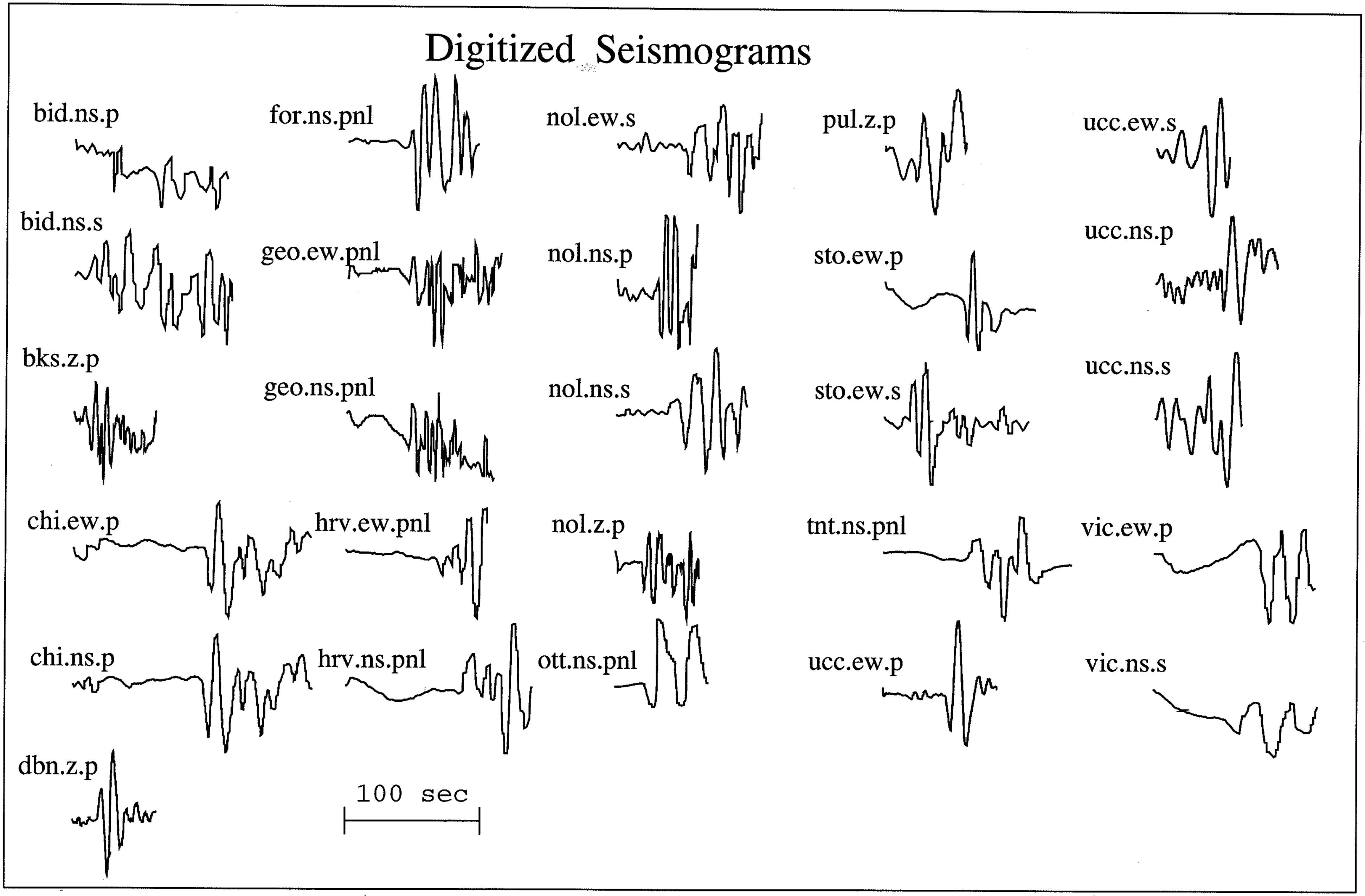
Digitized Seismograms
bid.ns.p
bid.ns.s
bks.z.p
chi.ew.p
chi.ns.p
dbn.z.p
for.ns.pnl
geo.ew.pnl
geo.ns.pnl
hrv.ew.pnl
hrv.ns.pnl
100 sec
nol.ew.s
nol.ns.p
nol.ns.s
nol.z.p
ott.ns.pnl
pul.z.p
sto.ew.p
sto.ew.s
tnt.ns.pnl
ucc.ew.p
ucc.ew.s
ucc.ns.p
ucc.ns.s
vic.ew.p
vic.ns.s

Figure 5