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Seismograms for historic Canadian earthquakes: the 18 November 1929 Grand Banks earthquake

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SEISMOGRAMS FOR HISTORIC CANADIAN EARTHQUAKES: THE 18 NOVEMBER 1929 GRAND BANKS EARTHQUAKE

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ABSTRACT

For those who are interested in studying historical earthquakes, collecting the data often proves to be the most difficult and most time consuming aspect of the project. For the 1929 (M_S 7.2) Grand Banks earthquake, records from 46 seismograph stations have been assembled by past and present seismologists at the Geological Survey of Canada (GSC) 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 and some of the surface 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 tremblement de terre de Grand Banks (M_S 7.2) de 1929 qui comprend des séismogrammes enregistrés aux 46 stations séismologiques était ramassée par des séismologues au passé et au présent de la Commission géologique du Canada (CGC) à Ottawa. 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 et lointain. Le plupart des ondes de volume et quelques ondes de surface ont été chiffré pour une analyse des formes des ondes, et on peut obtenir ces fichiers de données de la CGC.

INTRODUCTION

The 18 November 1929 M_S 7.2 Grand Banks earthquake is the largest instrumentally recorded and only fatal earthquake to have occurred in southeastern Canada. The earthquake resulted in a tsunami, which caused 27 deaths and considerable property damage mostly in southern Newfoundland, and in a large scale submarine landslide and turbidity current, which caused numerous breaks to several trans-Atlantic telephone cables. More thorough discussions of the tsunami and landslide can be found in many papers, including *Doxsee* [1948], *Piper and Aksu* [1987], *Piper et al.,* [1988] and *Hughes Clarke* [1990]. Source properties of the earthquake are discussed by *Hasegawa and Kanamori* [1987], who believed the event to be a submarine landslide, and by *Bent* [1994], who concluded that the event was an earthquake which subsequently triggered the landslide.

Earthquakes occurring in the source region of the 1929 earthquake (Fig. 1) have potential consequences for the coastal regions of Nova Scotia and Newfoundland as well as for offshore hydrocarbon exploration facilities. Of the four earthquakes [*Adams*, 1986] of magnitude 5 or greater (excluding aftershocks of the 1929 earthquake) that occurred in this region, only one was recent enough to have been recorded by a modern standardized seismograph network (1975, M5.2). Thus, we cannot obtain an adequate understanding of the seismic hazard and tsunami potential for this region from recent earthquakes alone. The 1929 earthquake, which is the largest and best recorded of the early instrumental earthquakes, may help improve our understanding of this problem.

Seismograms of early instrumental earthquakes can be important tools for understanding seismic sources and seismotectonics (for example, see *Kanamori*, 1988), particularly in regions which have not been subjected to large recent earthquakes but which have been seismically active in the past. Often, however, one of the more challenging aspects of studying early instrumental earthquakes is assembling a data set large enough to make the analysis worthwhile. While the existence 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, it is often possible to obtain early instrumental records directly from that station. However, many historical seismograph stations are no longer in operation, and tracking down their records can be particularly time consuming. An additional problem that often occurs for the largest and most interesting earthquakes is that the seismograms have been permanently borrowed or have otherwise disappeared from their various archives. Occasionally, however, a reasonably intact data set may be found for an earthquake of interest. The 1929 Grand Banks earthquake represents one of these cases.

Shortly after the 1929 earthquake, a collection of seismograms was assembled by seismologists at the Dominion Observatory (now part of the Geological Survey of Canada, GSC) in Ottawa. The data set has recently been augmented to include records from the former Soviet Union, Sweden, Alaska, and California. In most cases, the station operators included a list of the instrument constants with the seismograms so we do not have to rely on secondary sources for the instrument parameters as is often the case when studying early instrumental earthquakes. The purpose of this paper is to provide a summary of the records that are known to be available for this earthquake, and also to catalog those seismograms or sections of seismograms that have been digitized.

DATA SET

The GSC data set for the Grand Banks earthquake consists of records from 46 stations and contains at least one record from every quadrant (Fig. 2) although some regions are covered much more densely than others. Most of the seismograms in this collection are photographic copies of the originals. The available records and instrument constants are summarized in Table 1. A brief description of each of the seismograms can be found in the following section of this paper, and some examples of the seismograms are shown in Figure 3.

Of the 46 stations in Table 1, one was at a regional or P_{nl} distance (< 1400 km) with respect to the epicenter, 37 were at true teleseismic distances ($> 32°$) and the remaining 8 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 longer and shorter period instruments.

SUMMARY OF SEISMOGRAMS

Brief qualitative descriptions of the seismograms in the collection are provided below. The source and format of the data are also noted. Seismograms listed as being part of the original collection were collected by E. Hodgson of the Dominion Observatory in the months immediately following the earthquake. A complete list of components and instrument parameters can be found in Table 1.

Abisko: Everything appears to be recorded, but some sections are difficult to read due to overlap. Some surface waves may be off-scale. Photocopy obtained from archive in Uppsala.

Alma-Ata: Very faint but some surface waves visible. North-south is extremely faint. These records were microfiche copies, and the originals may be clearer. Obtained from World Data Center B in Moscow.

Ann Arbor: Everything well recorded. Photographic copy. Part of original collection.

Barcelona: Everything well recorded, but body waves (especially P) are very small. Photographic copy. Part of original collection.

Böhmen: Everything well recorded on north-south (Mainka). East-west (Belar) record has surface waves only and they are small. Photographic copy. Part of original collection.

Bombay: Good surface waves. Some body waves. Photographic copy. Part of original collection.

Buffalo: Everything well recorded. Surface waves on north-south record have significant curvature. Photographic copy. Part of original collection.

Chicago: Everything recorded. Some sections of S and Lg(?) are faint but all peaks seem to be recorded and on-scale. Photographic copy. Part of original collection.

Copenhagen: Body and surface waves visible and on-scale for all records. The

Wood-Anderson record is noisier than the others. Photographic copy. Part of original collection.

Ebro (Tortosa): Everything well recorded on Mainkas. Surface waves only on Milne. Photographic copy. Part of original collection.

Fordham: Most phases well recorded, but a section of the surface wave record is off-scale. Photographic copy. Part of original collection.

Granada (Cartuja): Everything well recorded on horizontals. On the vertical record, some surface waves are faint and/or off-scale. Photographic copy. Part of original collection.

Graz: Everything well recorded although some sections of north-south record are difficult to read due to uneven paper coloring, which is similar to the ink color. Photographic copy. Part of original collection.

Helgoland: Everything well recorded. Photographic copy. Part of original collection.

Helwan: Everything well recorded. Photographic copy. Part of original collection.

Kew: Everything recorded. Sections of surface wave records are faint and possibly off-scale. Surface waves clearest on north-south component. Photographic copy. Part of original collection.

Kobe: Very small. Some surface waves recorded. Photographic copy. Part of original collection.

Kodaikanal: Surface waves recorded. Difficult to find minute marks. Photographic copy. Part of original collection.

La Paz: Everything well recorded. Possible instrument problem on east-west record especially noticeable near S waves, which may be caused by instrument drift or friction between pen and paper. Photographic copy. Part of original collection.

Lund: Generally well recorded. Some sections difficult to read due to uneven paper coloring. Some surface waves appear clipped. Components are marked I and II, not north-south and east-west. Comparisons with Wiechert records at Copenhagen and Uppsala suggest I is probably north-south and II east-west. Photographic copy obtained from Uppsala.

Manila: Good surface waves. Body waves very small but visible. Photographic copy. Part of original collection.

Melbourne: Good surface waves. Body waves small but visible. Photographic copy. Part of original collection.

Mt. Hamilton: Surface waves well recorded but occasionally obscured by blotches on record. These are microfilm records; originals may be clearer but blotched areas probably still difficult to read. Obtained from World Data Center A in Golden.

Ottawa: Generally well recorded by Wiechert although there are a few off-scale sections. Much of the Bosch records are either faint or off-scale. Original record and part of original collection.

Oxford: Everything recorded. Some faint sections, but can be recovered. Photographic copy. Part of original collection.

Perth: Good surface waves. Body waves visible but close to noise level. Photographic copy. Part of original collection.

Potsdam: Everything well recorded. Minute marks very hard to find but time scale in mm/min is noted on record. Photographic copy. Part of original collection.

Pulkovo: Everything recorded. Sections of surface waves are faint but probably recoverable. Surface waves large so some lines overlap. Long-period record. Photographic copy from original collection, and microfiche copy from World Data Center B.

Rio de Janeiro: S and surface waves well recorded. P recorded but very small. Photographic copy. Part of original collection.

Scoresby Sund: Horizontal components very noisy. Body waves recorded on vertical component, but the instrument appears to "die" early in the surface wave train. Photographic copy. Part of original collection.

Seven Falls: Earthquake begins at top of page on Wood-Anderson, so much of record is off-scale. Milne-Shaw has only coda of surface waves. Photographic copy. Part of original collection.

Simferopol: Most of record is very faint. S waves small but easily identified. P wave faint but most of it can probably be recovered. Some surface waves. Microfiche copy from World Data Center B in Moscow.

Sitka: Surface waves well recorded although there are a few blotched areas. Some body waves visible but very small. Microfilm copy from World Data Center A in Golden.

St. Louis: Everything recorded. Some surface waves faint and possibly off-scale. Record is a copy, and original may be clearer. Photocopy from St. Louis University archives.

Stonyhurst: Everything recorded. Faint sections of surface waves can be recovered. Photographic copy. Part of original collection.

Sucre: Everything well recorded. Photographic copy. Part of original collection.

Sverdlovsk: Very good P wave recording. S small but can be identified. There are gaps (very faint sections) in the surface waves. Long-period record. Minute marks hard to find. Microfiche copy from World Data Center B in Moscow.

Sydney: Surface waves only. Minute marks hard to find but hour marks are clear. Photographic copy. Part of original collection.

Tblisi (Tiflis): Both body and surface waves were recorded. Long-period records. There are some faint sections. On the vertical component, almost everything could be recovered. Larger gaps exist for the horizontal components. These are microfiche records, and it is possible that the originals are clearer. Obtained from World Data Center B in Moscow.

Tokyo: Surface waves only. Photographic copy. Part of original collection.

Toronto: Mostly well recorded. A few sections of very faint surface waves that can possibly be recovered by a patient person with good eyesight. Photographic copy. Part of original collection.

Tucson: In general, everything is well recorded. There is a 2 minute section of the surface wave record that is very faint. Photographic copy. Part of original collection.

Tyosi (Chosi): Very small but some surface waves recorded. Photographic copy. Part of original collection.

Uccle: Wiecherts have everything on scale. Galtizins have very clear records, but some of the surface waves are off-scale. Overlapping lines. Photographic copy. Part of original collection.

Uppsala: Everything well recorded. Photographic copy. Part of original collection.

Wellington: Surface waves well recorded. Body waves also recorded but some lost due to page change. Photographic copy. Part of original collection.

DIGITIZED RECORDS

The body and surface waves of many of the seismograms discussed above were digitized to facilitate their analysis [*Bent*, 1994]. These digitized records, shown in Figures 4-7, can be purchased from the GSC. While every effort was made to digitize the seismograms as accurately as possible, any potential users of this data should bear in mind that there is always some personal bias involved in hand digitizing, and that these records were digitized for a specific study and may not contain phases or sections of the record required for other types of analyses.

Most of the seismograms were digitized at a rate of 1 point per 0.25 mm using a digitizing tablet with a 0.025 mm resolution. In some cases, such as high frequency large amplitude waves or very faint records where only the peaks were well recorded the waveforms were digitized at unequal intervals on a point by point basis, with the highest point density where the seismogram is rapidly changing (for example, near local maxima and minima, and saddle points). The digitizer resolution is the same for these records as for the others although the point separation tended to be larger. To improve the resolution, any small records were enlarged before digitizing. Any gaps caused by a page or line change were filled zeros. Except at Wellington, where there is a six minute gap caused by a page change, the duration of these gaps is less than 30 seconds. After digitizing, the Seismic Analysis Code (SAC) interpolation routine [*Tull,* 1989] was used to create equally spaced files with 1 sample per second. If necessary, the data were also detrended and corrected for curvature and skew. The instrument responses were not removed.

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 (absolute time corrected for clock error if known) and y is the amplitude in cm. 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, s, bod, srf, or all). A phase designation of "bod" indicates that both the P and S waves and possibly other body wave phases are contained in the record, "srf" indicates surface waves, and "all" indicates that both body and surface waves are included. Some records labeled p or s may contain multiply reflected phases, such as PP or SS. If more than one instrument was digitized for a single station, there will be a fourth field in the file name indicating which instrument the record corresponds to. Appendix A contains a sample annotated data file.

The digitized records are summarized in Table 2. If an available record was not digitized, it generally indicates that it was not of sufficient quality to be used in a waveform analysis. Common reasons for not digitizing records were that the phases of interest were either too small or too large (off-scale), that the record was faint, that the minute marks or other time indications could not be found, or that several lines of signal overlapped such that they were almost impossible to separate. Occasionally a good quality record was not digitized if there was a better or more useful seismogram at a nearby station. For example, if a vertical P wave was available from any station, the horizontal P waves at the same station were not always digitized.

Table 2 also lists the start times for the digitized records as well as the length of record digitized. Known clock corrections provided by the stations are listed in Table 3. If any are thought to be in error, this is noted. There could be additional errors in the clock corrections at stations not modeled by previous researchers.

Additionally, sign errors would not necessarily have been detected if the clock corrections were small (a few seconds). The start times in Table 2 have been read directly from the seismograms and do not include the clock corrections. Start time information and clock corrections are also included in the file headers. The clock corrections are those provided by the station operators, not those assumed by later researchers. In the header, clock corrections of 0.0 imply that the assumed clock correction is 0.0 seconds; clock corrections of 0 indicate that the correction is unknown.

Unless it was impractical or impossible, the digitizing was started at a minute mark. It was assumed that the minute began at the beginning of the minute mark. If absolute timing is essential to any users of this data, it may be worth checking the appropriate station bulletins to determine whether this assumption is valid. In all cases where the station operator noted this information, the minute did start at the beginning of the minute mark. However, *Stevens* [1980] notes that until the end of 1960, the end of the minute mark signalled the beginning of the minute at all Canadian stations.

If both horizontal components were digitized, the digitized records start at the same absolute time, except at Wellington, where the earthquake occurred during a page change, and at Rio de Janeiro where they were inadvertantly started a minute apart. Also note that the minute marks could not be found on the Potsdam record, and that the time in the digitized files for this station is measured from the first point digitized, not in absolute time.

All the digitized records are in their original orientations with respect to polarity. Table 3 summarizes the polarities marked on the original records as well as some assumptions made by later researchers.

INTERPRETATION OF SEISMOGRAMS

While the previous sections are concerned primarily with cataloguing the seismogram collection and summarizing additional information provided by the station operators, this section will summarize many of the assumptions and interpretations of the data set made by subsequent researchers. More details on the magnitudes calculated and discussed by *Bent* [1994] will also be provided.

Table 3 summarizes the instrument clock corrections and polarities. Those which came from a source other than the station operators and those assumed to be in error are flagged. *Bent* [1994] assumed the polarities at RDJ by matching the P wave first motions to those at LPB and SUC. With those polarity assumptions, the SH and SV waves at all three stations were also consistent. The polarity at HLW was assumed by matching the P wave first motion to nearby European stations. The same is true for SVE and TBL. At a number of additional stations, it was not clear whether the polarities had been marked on the records by the original station operators or by a later researcher. For these stations, the first motions obtained by *Bent* [1994] are in agreement with those of *Hasegawa and Kanamori* [1987]. Summaries of the first motions used by these authors may be found in their papers and will not be repeated here. The only questionable marked polarity was MEL, where *Bent* [1994] found that all phases fit the CMT solution better if the polarity was reversed (but this station was not used in her final inversion).

In a CMT inversion of part of the data set by *Bent* [1994] some of the clock corrections were suspected of being in error. In many cases, it appeared that only the sign was in error (using the convention that the clock correction is subtracted from the time read from the record). In other cases a clock error was suspected (based on noticeable differences between the expected and observed arrival times) but could not be completely resolved, usually because the phases in question were emergent or because the station was near a triplication. Clock errors of a few seconds would not have been within the resolving capabilities of the study. The clock corrections at stations not used in the CMT inversion were not checked for reliability. All questionable clock corrections are flagged in Table 3.

Magnitudes for the 1929 earthquake have been calculated by several researchers and are in general agreement. Those who calculated the magnitudes from measurements of the seismograms generally break them down on a station by station basis (*Bent, 1994; Hasegawa and Kanamori, 1987; Street and Turcotte, 1977*) in their papers, although they do not necessarily include the components and periods from which the magnitudes were calculated. Table 4 summarizes the periods and components used by *Bent* [1994] to determine M_S and m_B . M_W was determined by fitting part or all of the waveforms (which are shown in the paper) and not by direct measurements of the seismograms or by an assumed relation to another magnitude scale, and is therefore not be included in Table 4.

ACQUISITION OF DIGITIZED SEISMOGRAMS

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.

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Table 1

Seismograms for 1929 Grand Banks Earthquake

Station	Δ	Az.	Instr(*)	Comps	τ*	ε*	V*	Source(†)
Abisko (ABI)	44	31	G	Z,N,E	11.9	-	1100	Wo
Alma-Ata (AAA)	83	33	N	N,E	3.0	8.8	360	S
Ann Arbor (AAM)	20	273	W	N,E				
Barcelona (FBR)	42	73	M	N	10	25	78	S,Wo
				E	10	19	65	S,Wo
Böhmen (BOH)	45	58	M	N	9.4	40	100	S
			Be	E	12	∞	110	S
Bombay (BOM)	101	49	MS	N	12	20	250	S
Buffalo (BFF)	16	272	W	N	3.7	5	80	S
				E	4.8	5	80	S
Chicago (CHI)	23	274	MS	N,E	12	20	150	S
Copenhagen (COP)	43	50	W	Z	5.8	4.1	160	S
				N	9.8	4.6	220	S
				E	9.6	4.5	195	S
			WA	N	11	aper		S
			MS	E	12	20	300	S
Ebro/Tortosa (EBR)	41	75	MS	N	20	10	7	S
			M	N	14.8	2.3	194	S
				E	7.5	2	100	S
Fordham (FOR)	14	260	W	N,E			45	B
Granada/ Cartuja (CRT)	40	82	Blm	Z	6			C
			Ber	N	5.4	4	760	S
				E	4		590	S
Graz (GRA)	48	60	W	N	10	4.5	164	S
				E	9.9	4.3	181	S
Helgoland (HLG)	41	53	W	N	11.6	3.9	126	S
				E	12.5	5.3	153	S
Helwan (HLW)	68	69	MS	E	12	20	250	Wi
Kew (KEW)	37	59	G	Z	12.9	-	308	S,B
				N	25.5	-	280	S,E
				E	24.7	-	280	S,E
Kobe (KOB)	100	351	W	NE	5	2.2	90	S
				NW	3	1.8	94	S

Kodaikanal (KOD)	111	50	Mi	E	16	1	10	S
La Paz (LPB)	62	193	Bi	E	12	3	300	S
				N	14	3	180	S
Lund (LUN)	44	50	W	N,E	9	3.5	190	S
Manila (MAN)	121	3	W	N	7.82	4.7	156	S
				E	7.85	5.5	155	S
Melbourne (MEL)	162	290	MS	E	12	20	250	S
Mt. Hamilton (MHC)	49	286	W	N,E			80	S
Ottawa (OTT)	14	280	W	Z	6	7	160	B
			B	N	5.3	2	120	B
				E	6	15	120	B
Oxford (OXD)	36	59	MS	N,E	12	20	250	S
Perth (PER)	152	29	MS	N	12	20	250	S
Potsdam (POT)	45	54	W	N	9.8	4	250	S
				E	6.0	2.5	330	S
Pulkovo (PUL)	51	40	G	Z	14.0	-	1428	S
				N	14.8	-	1587	S
				E	13.9	-	1392	S
Rio de Janeiro (RDJ)	68	167	MS	N,E	12	20	250	S
Scoresby Sund (SCO)	31	22	GW	Z	10	-	600	S
				N	12.4	-	770	S
				E	11.9	-	750	S
Seven Falls (SFA)	11	288	WA	E	1		2500	C
			MS	E	12	20	250	B
Simferopol (SIM)	60	55	N	N	2.0	90	400	S,C
Sitka (SIT)	49	315	BO	N	17	1	10	S,ST
St. Louis (SLM)	26	269	WA	N	10.2	1	400	B
				E	9.5	1	360	B
Stonyhurst (STO)	35	55	MS	E	12	20	150	S
Sucre (SUC)	64	190	Bi	N	12	2	300	S
Sverdlovsk (SVE)	66	33	G	E	25.0	-	2048	S
Sydney (SYD)	156	289	MS	E	19			S
Tblisi/Tiflis	69	52	G	Z	12.3	-	1156	S

lpb.ew.srf	2103	952	
man.ew.all	2049	4975	
man.ns.all	2049	4959	
mel.ew.all	2052	7112	
ott.ew.p	2034	180	
ott.ns.p	2034	221	
ott.z.p	2034	181	
per.ns.all	2050	6958	
pot.ew.bod	P-60	669	no minute marks but
pot.ns.bod	P-60	712	absolute time scale noted
pul.ew.p	2040	225	
pul.ns.p	2040	261	
pul.z.p	2040	101	
rdj.ew.all	2040	4732	
rdj.ns.all	2041	5007	
sco.z.p	2038	81	
sco.z.s	2043	169	
sto.ew.p	2040	183	
sto.ew.s	2045	374	
suc.ns.all	2041	2885	
sve.ew.p	2042	94	
tbl.z.p	2041	1515	
tnt.ew.p	2034	296	
tnt.ns.p	2034	294	
tuc.ew.bod	2038	991	
ucc.ew.p.g	2039	260	
ucc.ew.s.g	2043	174	
ucc.ns.p.g	2039	291	
ucc.ns.s.g	2043	215	
ucc.z.p.w	2039	118	
upp.ew.all	2038	2058	
upp.ns.all	2038	1896	
wel.ew.all	2052	7080	starts after PKP
wel.ns.all	2049	6896	some gaps due to page change (filled with 0's)

(TBL)				N	12.4	-	1402	S
				E	12.4	-	1511	S
Tokyo (TOK)	99	347	BO	N,E	4.5		120	S
Toronto (TNT)	17	275	MS	N,E	12.0	20.	150	S
Tucson (TUC)	44	273	WA	E	10	28.7	435	S
Tyosi/Chosi	99	346	W	N	3.7	4	76	S
(CHO)				E	6.3	7	91	S
Uccle (UCC)	40	59	G	N	25	-	860	S
				E	25		820	S
			W	Z,E	4.8	2.8	150	S
Uppsala (UPP)	45	43	W	N,E	8.7	3.5	190	S
Wellington	143	258	MS	N	10.15	25	150	S
(WEL)				E	10	19	150	S

* B = Bosch, BO = Bosch-Omori, Be = Belar, Ber = Berchmans, Bi = Bifilaire, Blm = Belamino, G = Galitzin GW = Galitzin-Wilip, M = Mainka, MS = Milne-Shaw, Mi = Milne, N = Nikiforov, W = Wiechert, WA = Wood-Anderson;

for electromagnetic instruments, such as the Galitzin, it is assumed that the pendulum and galvanometer periods are equal and that the damping constant for each is 1.0

τ is the pendulum period (assumed same as galvanometer period for electromagnetic instruments unless otherwise indicated); ϵ is the damping ratio; V is the static magnification for mechanical instruments and the maximum magnification for electromagnetic instruments

† S = station (record), B = station bulletin, C = Charlier and Van Gils [1953], E = Ebel *et al.* [1986], ST = Street and Turcotte [1977], Wi = Wilson [1940], Wo = Wood [1921]

Table 2
Summary of Digitized Records

stn.comp.ph	t_0 (UT)	length (sec)	comments
aam.ew.p	2035	103	
aam.ew.s	2039	69	
aam.ew.srf	2039	640	includes S
aam.ns.p	2035	122	
aam.ns.s	2039	91	
aam.ns.srf	2039	587	includes S
bff.ew.p	2035	232	
bff.ns.p	2035	211	
boh.ns.p	2040	102	
boh.ns.s	2047	105	
bom.ns.all	2044	5231	
chi.ew.all	2035	386	
chi.ns.all	2035	430	
cop.ew.all	2037	3869	Wiechert digitized
cop.ns.all	2037	3789	originals right to left
cop.z.all	2037	3040	on all components
crt.ew.srf	2048	1207	
crt.ns.srf	2048	1198	
ebr.ew.all	2038	1656	
ebr.ns.all	2038	3410	
fbr.ew.p	2040	123	
fbr.ew.s	2046	118	
fbr.ew.ss	2049	121	
for.ew.p	2034	249	
for.ns.p	2034	145	original right to left (NS only)
gra.ew.all	2038	2474	original right to left
gra.ns.all	2038	2485	original right to left
hlg.ew.bod	2039	556	
hlg.ns.bod	2039	583	
hlw.ew.all	2041	5326	
kew.ew.bod	2037	784	beginning of P during line
kew.ns.bod	2037	818	change-gap filled with 0's
kew.z.bod	2038	821	
lpb.ew.p	2042	152	
lpb.ew.s	2050	275	problem with instr. (see text)

Table 3
Summary of Clock Corrections and Polarities

Stn	t_{corr}* (sec)	Direction Positive Z	N-S	E-W
AAM			N	W
ABI	-1.1	C	N	E
BFF	1.5		N	E
BOH	-24.2		S	W
BOM			N†	
CHI	-17(–)		S	E
CHO	-66.2		S	E
COP(MS)	27.2			E
COP(WA)	-17		S	
COP(W)	27(–)	D†	S†	W†
CRT	42	C†	N†	E†
EBR(MS)	-1.2(-5)		N	
EBR(M)	-1.2(-5)		S	
FBR	15		S	W
GRA	-3(OK)			
HLG	-4.0,-7.6		N	W
HLW	(OK)			E(B)
KEW	-12(–)	C	N	E
KOB	163.0			
KOD	-0.9			E
LPB	0.0		N	E
MAN	0.5(OK)		N	E
MEL	-0.3(?)			E(–,B)
MHC	-11			
OXD	-10.7,-8			
PER	< .1(?)		S	
POT			S	W
PUL	-18			
RDJ	(OK)		N(B)	E(B)
SCO		C†	N†	E†
SIT			S	
SLM	1.4		N†	W†
STO	-72			W

SUC	-53(–)		S	
SVE	55			E(B)
SYD				E
TBL	37(47)	C(B)		
TNT	1.2		S	W
TOK	9		N	E
TUC	(OK)			W
UCC(G)	-7.2		N	W
UCC(W)	-7.2	C		W
UPP	-13.1(OK)		S	W
WEL	15(?)†		N†	E†

* if two values are given, the first was determined before the earthquake and the second after; if an individual station is marked by (–), the sign of the time correction was assumed to be in error by *Bent* [1994] using the convention that the correction is subtracted from the measured time; (?) implies error in clock correction suspected but not resolved; (n) indicates preferred clock correction of n sec; (OK) indicates clock correction appears to be accurate; no comment indicates that the clock correction was not checked; if a comment is included where no correction is given, the comment refers to a correction of 0.0 sec.

† unclear whether noted at time of earthquake by station operator or added by later researcher; in the case of SLM the polarities came from a station bulletin.

polarities marked with a (B) were assumed by *Bent* [1994] as discussed in the text, and those marked by (–) appear to be in error.

Table 4
Summary of Magnitude Data

Station	Comp*	Period	M_S	Comp*	Period	m_B
BFF				PH	7.4	7.3
BOH	N	20.0	6.7	PN	4.8	7.1
				SN	12.0	6.9
BOM	N	15.0	7.2	PN	7.1	7.3
				SN	7.5	7.2
CHI				PH	9.4	7.1
				SH	11.3	7.5
COP	H	17.4	7.1	PZ	6.7	7.3
				PH	6.9	6.9
				SH	11.5	7.2
CRT	H	20.0	7.2	PH	4.4	7.3
				SH	4.4	7.3
EBR	H	18.8	7.2	PH	5.5	7.1
				SH	8.9	6.9
FBR	H	18.9	6.8	PH	6.6	6.9
				SH	12.2	7.3
GRA	H	18.2	7.6	PH	7.5	7.3
				SH	10.7	7.0
HLG	H	16.2	7.2	PH	9.2	6.8
				SH	11.5	7.0
HLW	E	18.9	7.1	PE	7.5	7.4
				SE	15.0	7.4
KEW				PZ	8.0	7.3
				PH	15.0	7.4
				SH	16.0	7.0
LPB	H	16.9	7.1	PH	4.9	7.5
				SN	12.5	7.0
LUN	H	18.0	7.6			
MAN	H	21.2	7.0			
MEL	E	18.9	7.2			
OTT				PZ	5.0	7.0
PER	N	22.5	7.4			
POT	H	16.4	6.7	PH	4.7	7.5
				SH	9.4	7.2

PUL				PZ	10.0	6.9
RDJ	H	19.5	7.2	PH	9.6	7.2
				SH	11.3	7.3
SIT	N	15.0	7.6			
STO	E	16.5	7.1	PE	5.6	7.0
				SE	18.9	7.0
SUC	N	17.6	6.6			
SVE				PE	16.2	6.8
				SE	12.8	6.5
TBL				PZ	13.8	6.7
				PH	12.0	6.8
TNT				PH	5.1	6.7
TOK	N	18.0	7.1			
TUC	E	15.0	7.3	PE	6.8	6.9
				SE	8.2	7.0
UCC	E	17.2	7.6	PZ	3.2	7.0
				SH	17.0	7.1
UPP	H	16.0	6.8	PH	6.0	7.1
mean			7.2 ±0.3			7.1 ±0.2

* H implies both horizontal components were measured; for m_B the phase (P or S) is also included in the component list.

Appendix A
Sample Digitized File

test.dig

440 1.0232

203900.00 -0.2

59.858 17.627

203900.20 0.000000e+00

203901.20 1.111111e-01

203902.20 2.444444e-01

203903.20 1.002233e-01

203904.20 -1.234567e-01

•

•

•

explanation of header:

1st line: id

2nd line: number of data points; ymax in cm (not corrected for gain)

3rd line: uncorrected start time (UT) as hhmmss.ss; clock correction in sec

4th line: station latitude and longitude (north and east positive)

remaining lines: x-y pairs; x in time (after clock correction); y in cm not corrected for gain

Appendix B
Data Order Form for 1929 Grand Banks 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 $100.00 Canadian funds (plus PST and GST; Canadian adresses only; includes shipping) or $100.00 U.S. funds (non-Canadian addresses; all taxes and shipping 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. Seismicity in the region of the 1929 Grand Banks earthquake. All located earthquakes from the Canadian epicenter database of magnitude 2.0 or higher between 1900 and 1993 are shown, with the symbol size scaled to magnitude. 29.1 and 29.2,3 refer to the subevent mechanisms for the 1929 earthquake determined by *Bent* [1994]. 75 refers to the 1975 Laurentian Channel earthquake (mechanism by *Hasegawa and Herrmann* [1989]). NFZ is the Newfoundland Fracture Zone. For reference, the 200 m and 2000 m bathymetry contours are shown.

Figure 2. Seismograph stations (triangles) from which seismograms are available for the 1929 Grand Banks earthquake. Great circle paths between the stations and epicenter are indicated by solid lines.

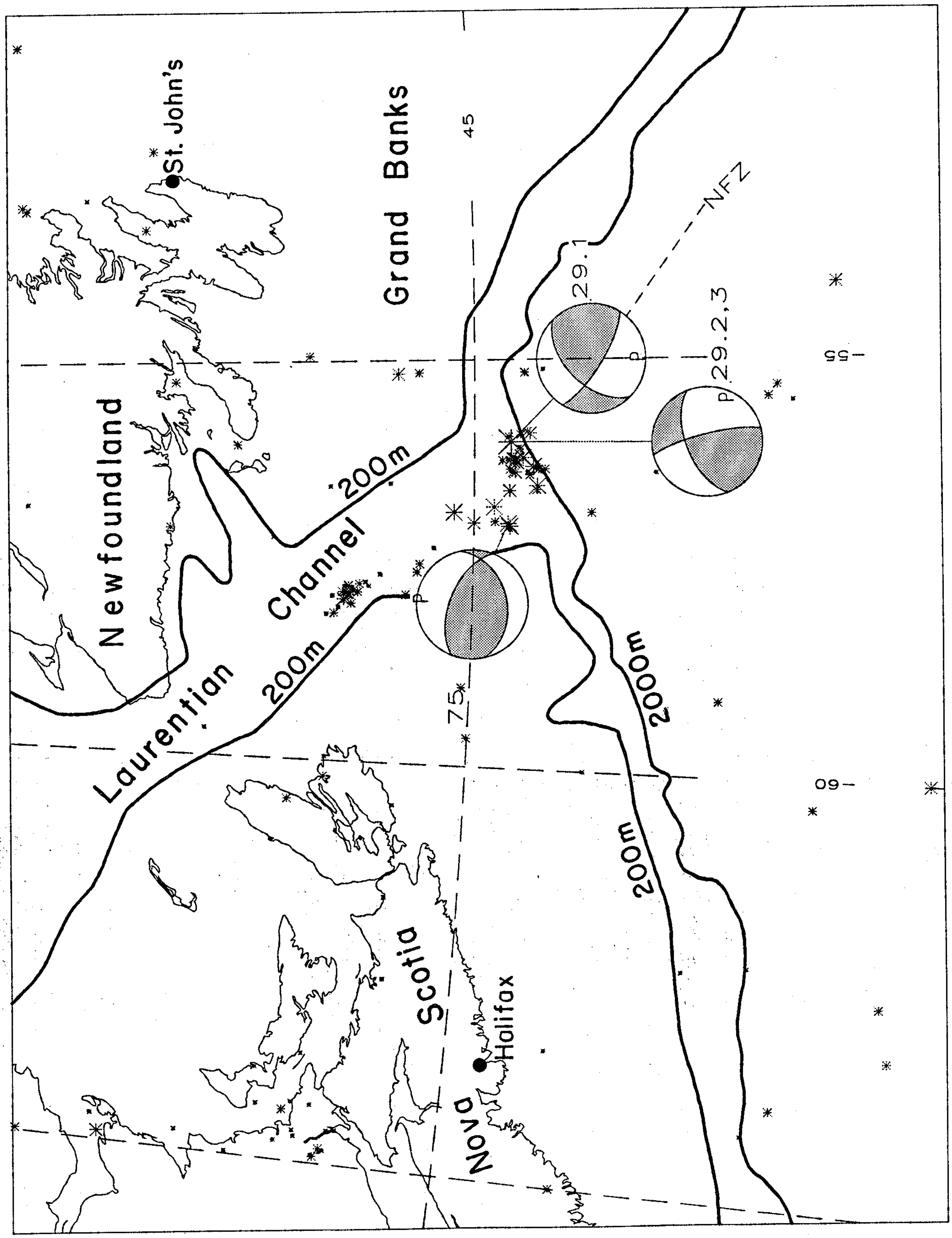
Figure 3. Some examples of seismograms for the 1929 earthquake. All have been photographically reduced to fit the page. a) Horizontal Milne-Shaw records from Chicago show clear body waves; surface waves are recorded and on scale, but very faint. b) North-south Milne-Shaw record from Rio de Janeiro shows both body and surface waves. c) East-west Milne-Shaw record from Helwan (Egypt) shows well recorded body and surface waves.

Figure 4. Digitized seismograms where the length of record digitized is less than 300 seconds. The labels correspond to the file names in Table 2.

Figure 5. As for Fig. 4 but where length of record digitized is between 300 and 1000 seconds.

Figure 6. As for Fig. 4 but where length of record digitized is between 1000 and 4000 seconds.

Figure 7. As for Fig. 4 but where length of record digitized is greater than 4000 seconds.

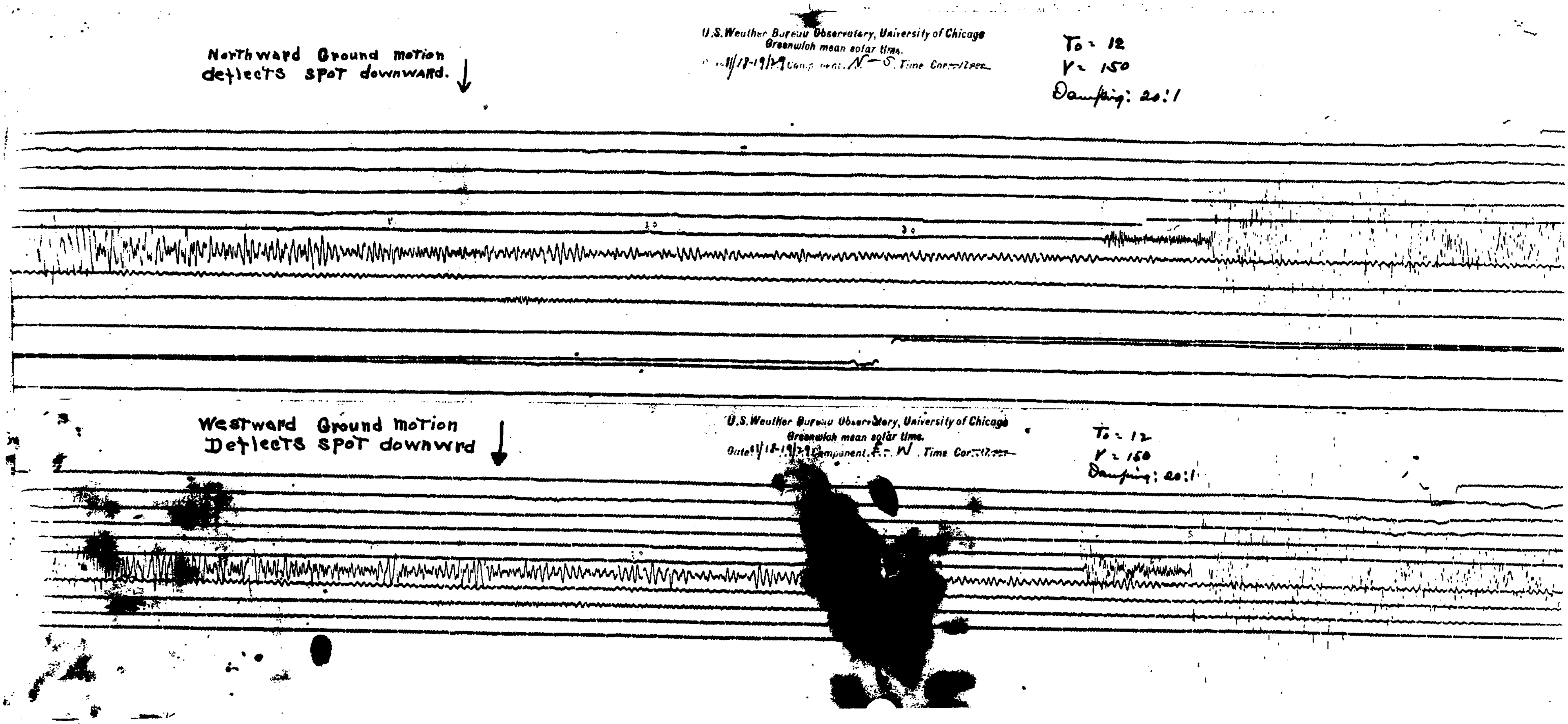


Newfoundland
St. John's
Grand Banks
Laurentian
Channel
200m
200m
200m
2000m
Nova
Scotia
Halifax
NFZ
29.1
29.2,3
P
45
55
60
75

Fig. 1

Available Seismograms: 1929 Grand Banks Earthquake

FIG. 2



Northward Ground motion deflects spot downward.
U.S. Weather Bureau Observatory, University of Chicago
Greenwich mean solar time.
To = 12
V = 150
Damping: 20:1
Westward Ground motion Deflects spot downwrd
U.S. Weather Bureau Observatory, University of Chicago
Greenwich mean solar time.
To = 12
V = 150
Damping: 20:1

Fig. 3a

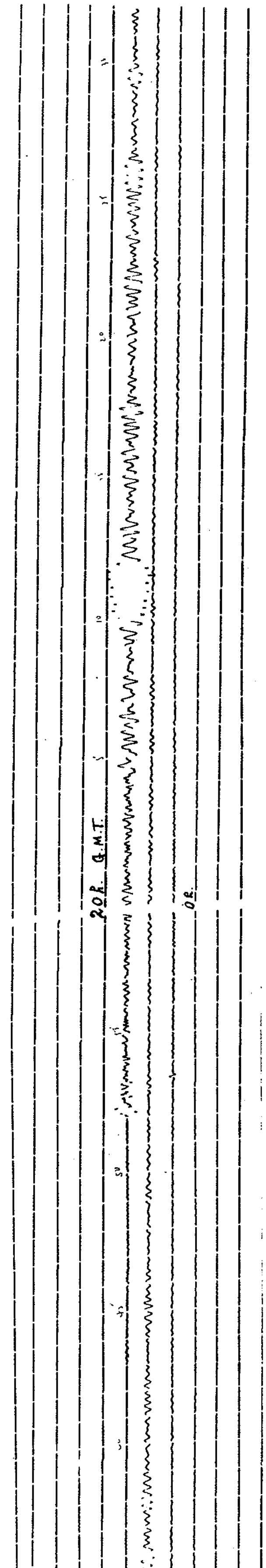


FIG. 3b

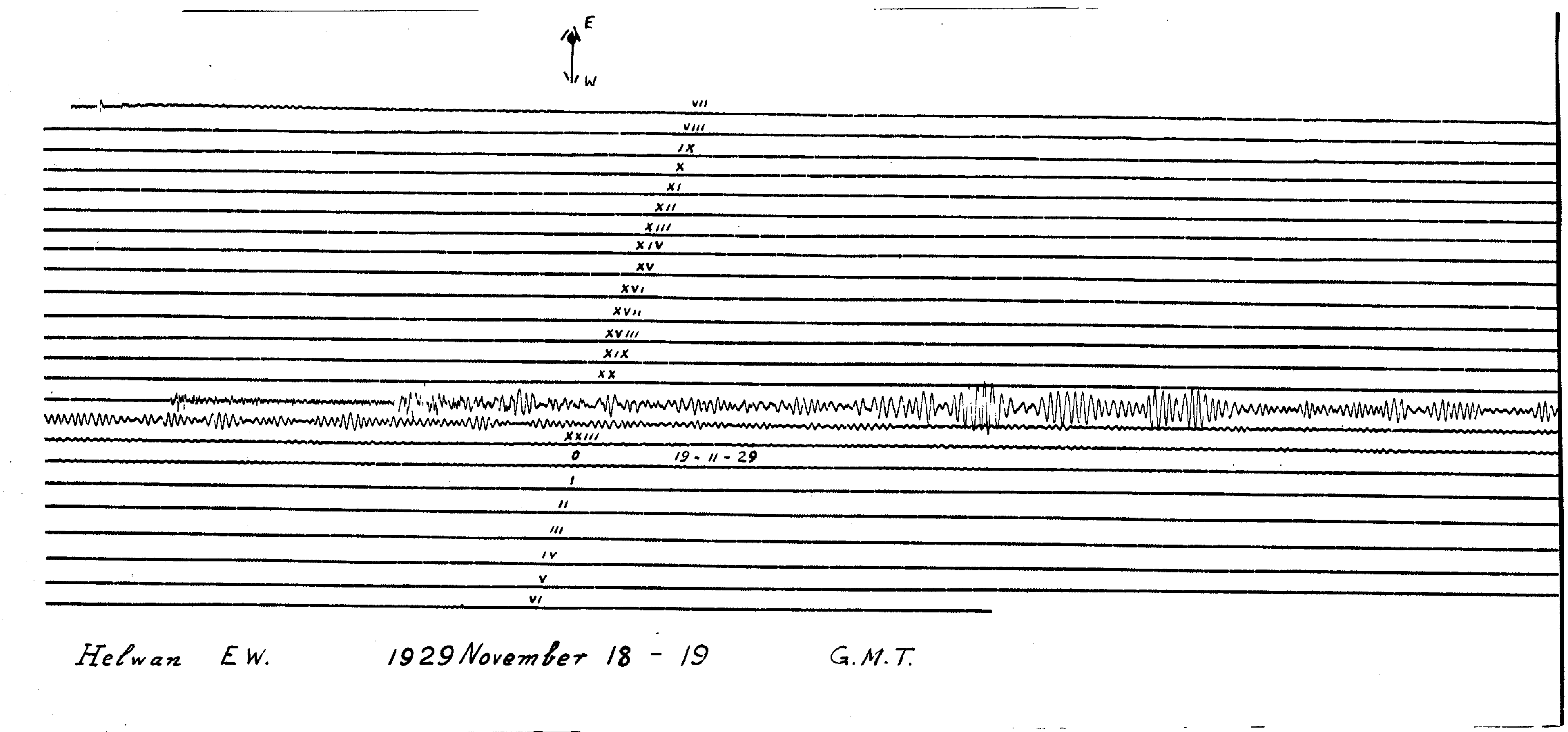

E
W
VII
VIII
IX
X
XI
XII
XIII
XIV
XV
XVI
XVII
XVIII
XIX
XX
XXIII
0
19 - 11 - 29
I
II
III
IV
V
VI
Helwan E.W. 1929 November 18 - 19 G.M.T.

FIG. 3C

Digitized Records (<300 s)

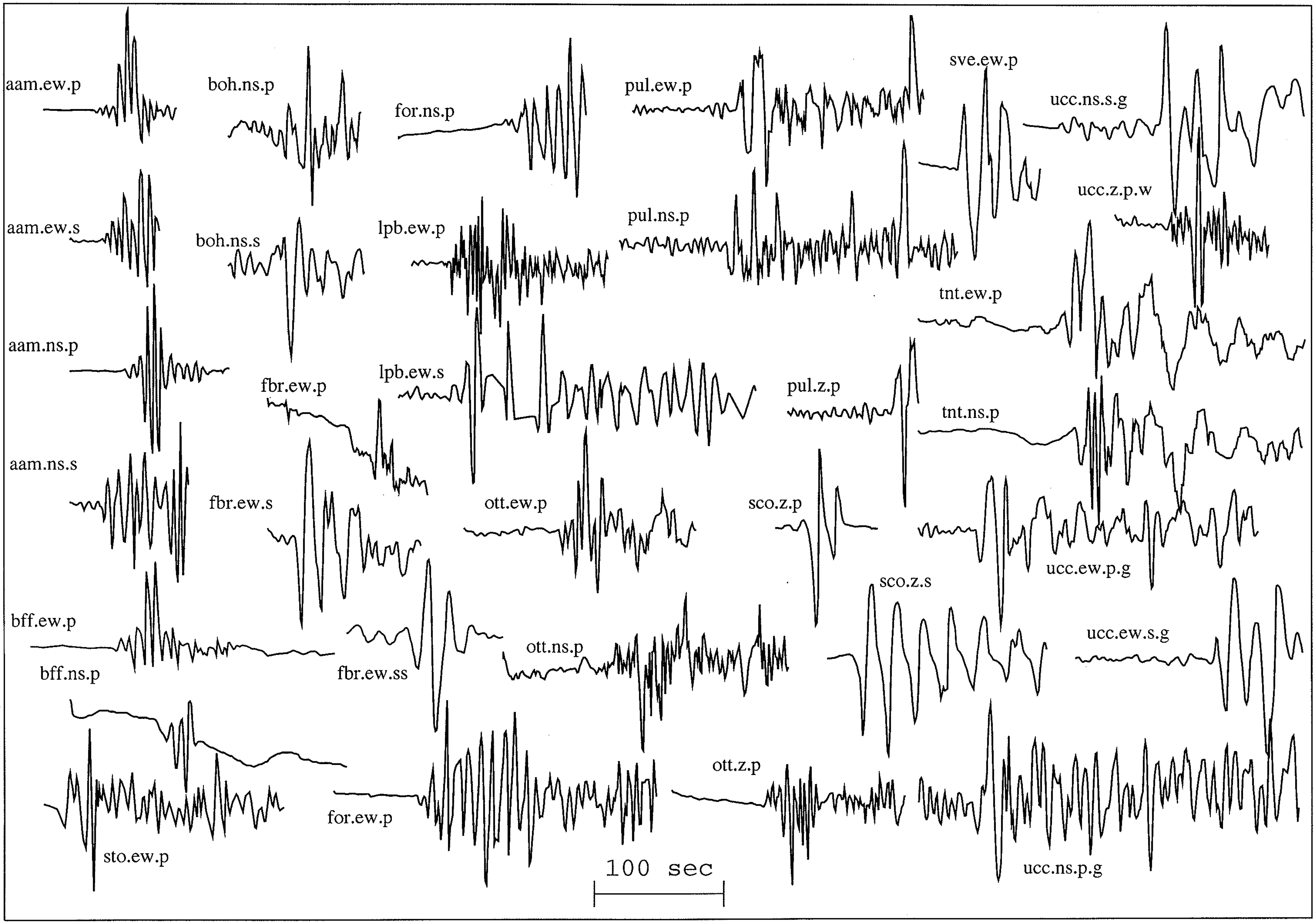


FIG. 4

Digitized Records (300-1000 s)

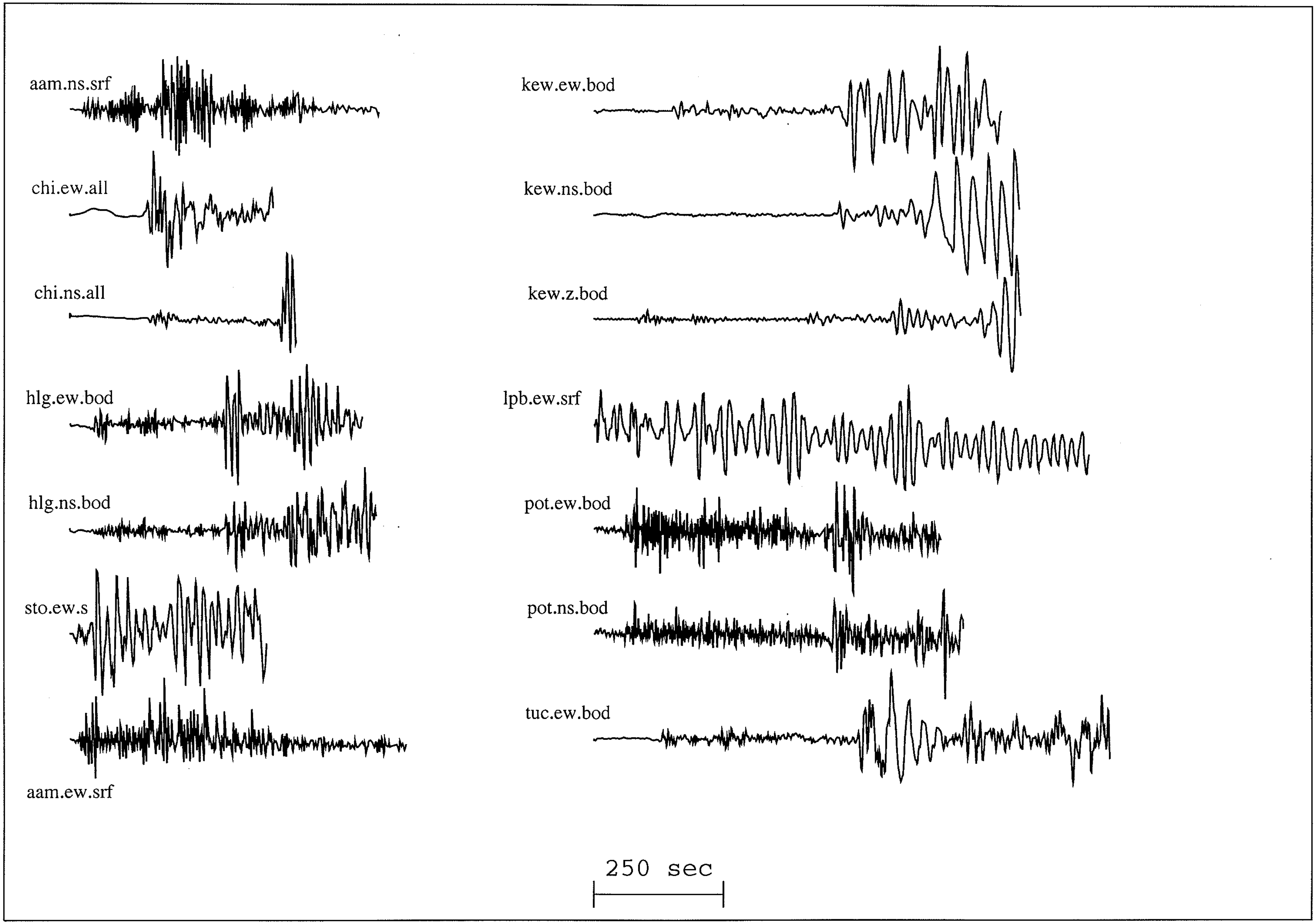


FIG. 5

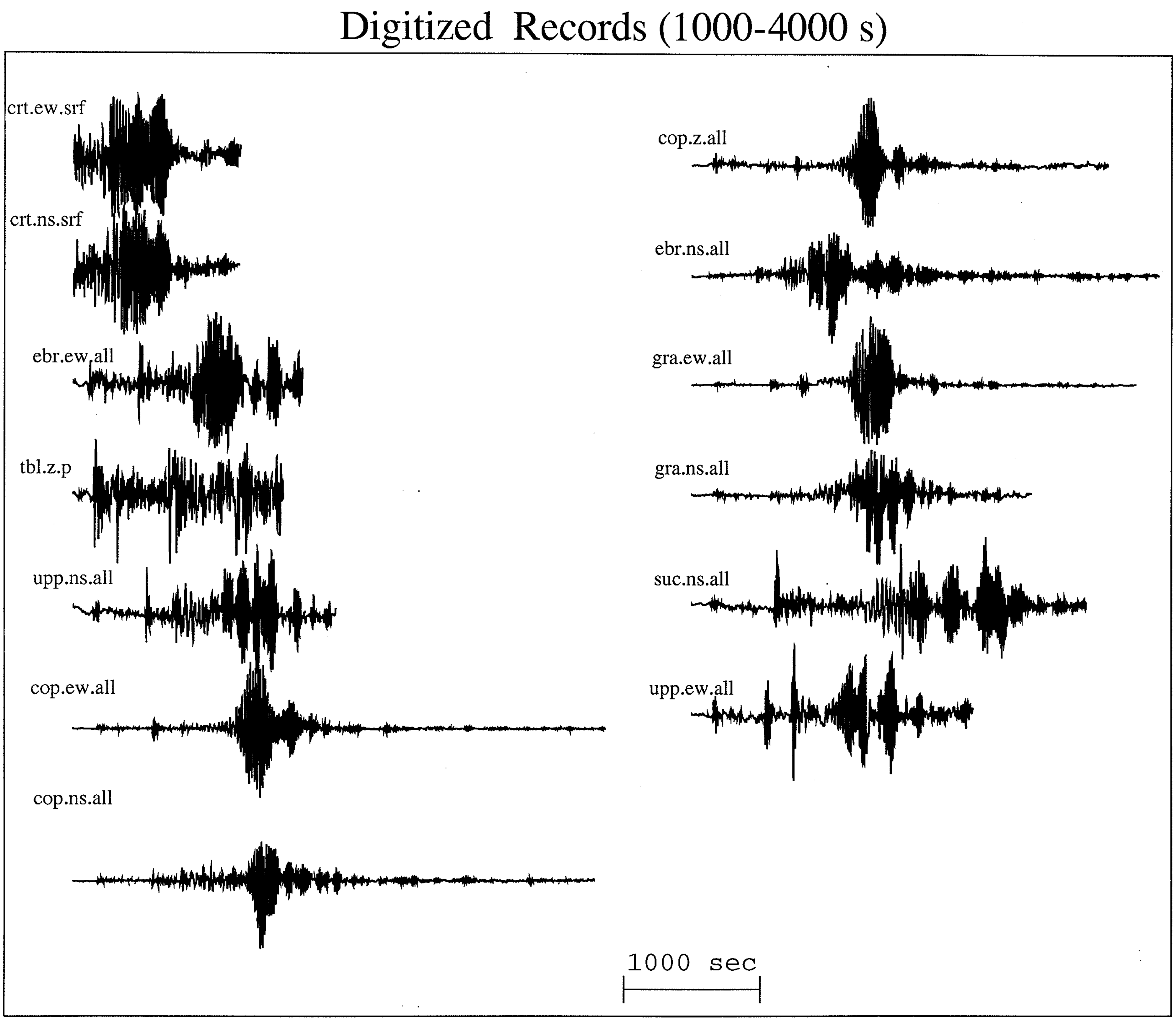

Digitized Records (1000-4000 s)
crt.ew.srf
crt.ns.srf
ebr.ew.all
tbl.z.p
upp.ns.all
cop.ew.all
cop.ns.all
cop.z.all
ebr.ns.all
gra.ew.all
gra.ns.all
suc.ns.all
upp.ew.all
1000 sec

FIG. 6

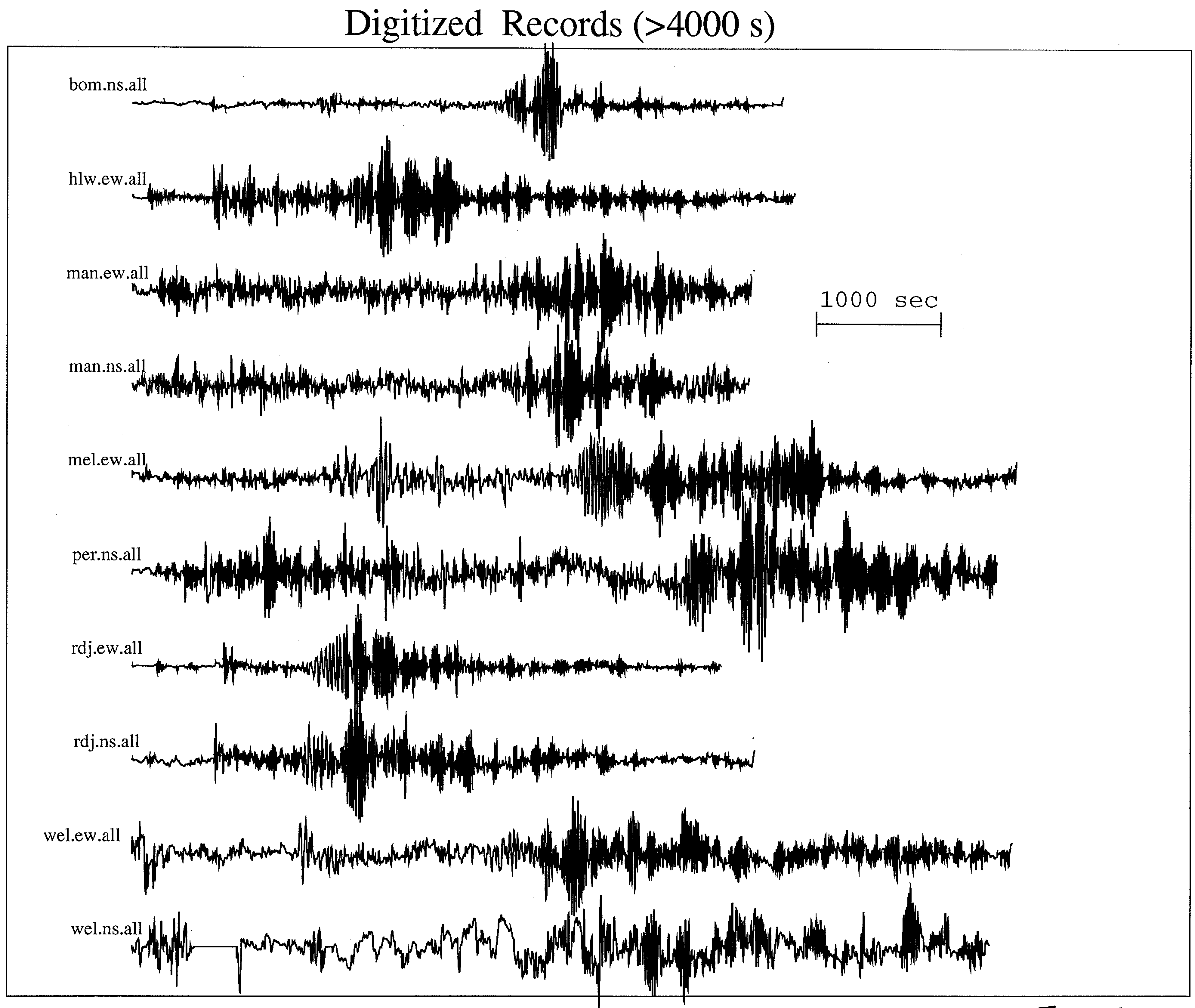

Digitized Records (>4000 s)
bom.ns.all
hlw.ew.all
man.ew.all
man.ns.all
mel.ew.all
per.ns.all
rdj.ew.all
rdj.ns.all
wel.ew.all
wel.ns.all
1000 sec

FIG. 7