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Seismograms for historic Canadian earthquakes: the 29 May 1940 Richardson Mountains, Yukon earthquake

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SEISMOGRAMS FOR HISTORIC CANADIAN EARTHQUAKES: THE 29 MAY 1940 RICHARDSON MOUNTAINS, YUKON EARTHQUAKE

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ABSTRACT

This paper is one in a series of reports designed to catalog the Geological Survey of Canada's (GSC) collection of seismograms for historical Canadian earthquakes. The data set has been assembled by past and present seismologists at the GSC. The seismogram collection for the May 1940 Richardson Mountains earthquake consists of 89 records from 34 seismograph stations. Of these, 58 seismograms from 19 stations have been digitized. To assist those who may study this earthquake in the future, this report describes the seismograms in the collection and indicates which record segments have been digitized. The digital data files may be obtained from the GSC. We also summarize magnitude calculations and first motion polarities for all stations utilized in the detailed study of this earthquake by *Cassidy and Bent*, [1993].

RÉSUMÉ

Cet article-ci est une partie d'un série de rapports qui énumère la collection de séismogrammes pour les tremblements de terre historiques et canadiens qui existe à la Commission géologique du Canada (CGC). Des données furent amassées par plusieurs générations de séismologues de la CGC. Des données du tremblement de terre des montagnes Richardson de mai 1940 comprend 59 séismogrammes enregistrés à 34 stations séismologiques dont 58 séismogrammes de 19 stations ont été chiffrés. Cet article fournit une description brève des séismogrammes de la collection pour ceux intéressés par l'étude de ce tremblement de terre dans un avenir proche ou lointain, et aussi indique quels séismogrammes ont été chiffrés. On peut obtenir ces fichiers de données de la CGC. Aussi on inclut les calculs de magnitude et les premières motions pour toutes les séismogrammes que nous avons utilisées dans étude détaillée de *Cassidy et Bent*, [1993].

INTRODUCTION

The 29 May 1940 M_S 6.2 earthquake (66.87°N, 135.33°W) is one of the largest events known to have occurred in the northern Yukon Territory (Fig. 1). It was followed, seven days later, by a M_S 6.5 earthquake. Although this region (the boundary of the Canadian Cordillera and the stable continental craton) continues to be seismically active, there have been no large (M > 5.5) earthquakes here since 1940. To constrain the source parameters of these events, and to better understand the seismotectonics of this region (and, by analogy, to better understand the earthquake potential of the more populated southern Canadian Cordillera) we have collected historical seismograms of these earthquakes from numerous seismograph stations worldwide. By applying modern analyses methods we can obtain important new information from seismograms long after the earthquake occurred.

Historical earthquakes are often overlooked however, because of the difficulty in obtaining either seismograms or adequate information concerning the instrument responses. The principal intentions of this paper are to catalog the Geological Survey of Canada's (GSC) seismogram collection for the May 1940 Yukon earthquake, to provide a record of those seismograms that have been digitized by the GSC, and to provide as much information as possible concerning the instrument responses for the seismograms in the collection. In addition, we summarize the magnitude calculations and first motion data that were used in the detailed analysis of this earthquake by *Cassidy and Bent* (1993). In a companion report, *Bent and Cassidy* (1995) summarize the data, and analysis of the 5 June 1940 Yukon earthquake.

DATA SET

The GSC data set for the 29 May 1940 (01 57 51 U.T.) earthquake consists of 89 records from 34 seismograph stations covering all quadrants (Fig. 2). Most of the seismograms in this collection are paper copies of the originals. Of these records, 58 from 19 stations were digitized and are presented in this publication. The stations and instrument constants are summarized in Table 1. Most of the seismograms were collected by the authors by requesting data from either the current station operators or from the World Data Center A. A brief description of each of the seismograms can be found in the following section of this paper, and some examples of the original seismograms are shown in Figure 3.

SUMMARY OF SEISMOGRAMS

Brief qualitative descriptions of the seismograms are provided below. The format and origin of the data are also noted. A complete list of components and instrument parameters can be found in Table 1 and a list of digitized records in Table 2.

ABU: Z, N-S, and E-W seismograms. Small surface waves, body waves not visible. Photocopies obtained from the Abuyama Seismological Observatory, Japan.

BAK: Z, N-S, and E-W seismograms. Good surface waves, nice S-wave, but the P-wave is not clear. Microfiche copies obtained from the World Data Centre B in Moscow.

BRK: Z, N-S, and E-W seismograms. Good surface and body waves. The P-wave is off the edge of the photocopied vertical component seismogram. Paper copies obtained from the Berkeley Seismograph station, Berkeley, California.

BUD: N-S, and E-W seismograms. Very small surface waves; body waves not visible. Records not used. Paper copies obtained from Budapest, Hungary.

CHR: Z, N-S, and E-W seismograms. Very small surface waves; body waves not visible. Paper copies obtained from Christchurch, New Zealand.

CLL: Z, and E-W seismograms. Nice P-waves visible. Paper copies obtained from Collm, Germany.

COL: N-S and E-W seismograms. Only the first 30 seconds of the P-wave is visible on the N-S component, and only the first 60 seconds is visible on the E-W component. The remainder of the waveform is too faint to be useful. Microfiche obtained from the World Data Centre A.

EBR: N-S seismogram. Only faint surface waves are visible. Paper copies were obtained from the Ebro seismic observatory, Spain.

HAI: Z, N-S, and E-W seismograms. Small surface waves and P-waves are visible. Paper copies were obtained from the California Institute of Technology Seismological Laboratory (CIT), Pasadena, California.

HAL: N-S, and E-W seismograms. Nice surface waves (but relatively short-period), S-wave visible, the P-wave is too small. Original seismograms were obtained from the Canadian Seismogram Archives.

HAM: Z, N-S, and E-W seismograms. Nice surface waves, and body waves. Paper copies were obtained from Hamburg, Germany.

HLW: Z, N-S, and E-W seismograms. Small surface waves, very nice P-wave, small S-wave. Paper copies were obtained from Helwan, Egypt.

HON: N-S, and E-W seismograms. Nice surface waves, small S-wave, but the P-wave is not visible. Microfiche copies were obtained from the World Data Centre A.

IRK: Z, N-S, and E-W seismograms. Nice surface waves (although faint in places), and body waves. Microfiche copies were obtained from the World Data Centre B in Moscow.

JEN: N-S seismogram. Small surface waves and body waves. Paper copies were obtained from Jena, Germany.

KEW: Z, N-S, and E-W seismograms. Nice surface waves and S-waves. P-waves are too small. Paper copies were obtained from the British Geological Survey.

LJC: Z, N-S, and E-W seismograms. Small surface waves and P-waves. Paper copies were obtained from the California Institute of Technology Seismological Laboratory, Pasadena.

LPZ: Z seismogram. Nice surface waves; body waves not visible. Paper copies were obtained from La Paz, Bolivia.

LUN: N-S, E-W seismograms. Small surface waves; body waves not visible. Photographic copies were obtained from Uppsala, Sweden.

OTT: Z, N-S, and E-W seismograms. Nice surface waves (although some portions are faint and a peak is missing on the E-W component). Very clear S-wave. The P-wave is not observed on the horizontal components, and is faint on the Z component. The original seismograms were obtained from the Canadian Seismogram Archives.

PAS: A variety of Z, N-S, and E-W seismograms were obtained. Very nice surface waves and body waves were recorded. Paper copies were obtained from the California Institute of Technology Seismological Laboratory.

POT: N-S, E-W seismograms. Small surface waves, body waves. Paper copies were obtained from Potsdam, Germany.

PUL: Z, N-S, and E-W seismograms. Very nice surface waves and body waves. Microfiche copies were obtained from the World Data Centre B in Moscow.

RVR: Z, N-S, and E-W seismograms. Small surface waves. Very nice P-wave. Paper copies were obtained from the California Institute of Technology Seismological Laboratory.

SAS: N-S, and E-W seismograms. Nice surface waves (although the E-W record is faint and clipped). Nice body waves. The original seismograms were obtained from the Canadian Seismogram Archives.

SHF: N-S seismogram. Nice surface waves, but short period. The P-wave is small. The original seismograms were obtained from the Canadian Seismogram Archives.

SJP: E-W seismogram. Nice surface waves, and S-wave, but the P-wave is not visible. Microfiche copies were obtained from the World Data Centre A.

SVE: Z, N-S, and E-W seismograms. Nice surface waves (although faint in places), and very nice P-wave and S-wave. Microfiche copies were obtained from the World Data Centre B in Moscow.

TIF: Z, N-S, and E-W seismograms. Very nice surface waves and body waves. Microfiche copies were obtained from the World Data Centre B in Moscow.

TIN: Z, N-S, and E-W seismograms. Small surface waves, very small P-wave. Paper copies were obtained from the California Institute of Technology Seismological Laboratory.

UCC: Z, N-S, and E-W seismograms. Very nice surface and body waves. Paper copies were obtained from Uccle, Belgium.

UPP: N-S, E-W seismograms. Nice surface waves and body waves. Photographic copies were obtained from Uppsala, Sweden.

WES: Z, N-S, E-W seismograms. Nice surface waves and body waves. Short-period records were too faint and clipped to be useful (with the exception of the initial portion of the P-wave on the horizontal components). Very nice body waves on the long-period components, but only the initial portion of the surface wave train was on-scale and readable. Photographic copies were obtained from Weston Observatory.

DIGITIZED RECORDS

Many of the seismograms discussed above were digitized to facilitate their analysis [*Cassidy and Bent*, 1993]. These digitized records, shown in Figures 4-6, 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.

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, any small records were enlarged (by photocopier) before digitizing. If necessary, the data were detrended and corrected for curvature and skew. The surface waves and long-period waveforms were resampled to 1 Hz, and the short-period waveforms were resampled to 10 Hz. 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 (relative to the first point digitized) and y is the amplitude in cm (not corrected for instrument magnification). If a record was enlarged before digitizing, the amplitude has been corrected to the original scale. 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 (lpz, lpn or lpe for long-period data, and spz, spn, spe for short-period data) and PHASE is the phase (for example, P, S, or SURF). 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 considered of sufficient quality to be used in a waveform analysis. The most common reasons for not digitizing a record were that the phases of interest were either too small to digitize accurately or they were faint, or off-scale.

Table 2 also lists the start times for the digitized records (not including clock corrections) as well as the length of record digitized. For many of the body waves, the start time is not given. However, in most cases, the digitizing was started at the beginning of a minute mark immediately preceding the phase of interest. *Stevens* [1980] notes that until the end of 1960, the end of the minute mark signaled the beginning of the minute at all Canadian stations. If absolute timing is essential to any users of this data, it may be worth checking the appropriate station bulletins for the arrival times of the body waves. If both horizontal components were digitized, the digitized records start at the same absolute time. Known clock corrections provided by the stations are listed in Table 3.

All the digitized records are in their original orientations with respect to polarity. The horizontal records have not been rotated into their radial and tangential components. 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 some of the assumptions and interpretations (including detailed magnitude calculations, and first motion polarities) of the data set.

Table 3 summarizes the instrument clock corrections and polarities obtained from the original seismograms, the seismographic stations, or bulletins. Any instrument polarities assumed by *Cassidy and Bent* [1993] are also noted. Note that the clock corrections have not been verified, as *Cassidy and Bent* [1993] did not require or utilize this information in their study. Table 4 summarizes the magnitude calculations - the periods and components used to compute M_S (the surface-wave magnitude given by *Vanek et al.*, 1962) and m_b (the broadband body-wave magnitude defined by *Gutenberg and Richter*, 1956). Both vertical and horizontal components were used in the magnitude determinations, with vector addition being applied to form total horizontal amplitudes (H) from the north-south (N) and the east-west (E) components. Stations for which only one horizontal component was used in the calculations are indicated in Table 4. First-motion polarities are provided in Table 5, and the P-wave arrival times at the 45 stations used to locate this earthquake (for details, see *Cassidy and Bent*, 1993) are given in Table 6.

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 or by e-mail 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

Stations and Instrument Constants for the May 1940, Yukon Earthquake

Station	Instr*	Comps	Ts	hs	Tg	hg	σ^2	V_{max}	Source(†)
ABU	W	N, E	10.0	4.9	—	—	—	170	S
	W	Z	4.7	4.9	—	—	—	150	S
BAK	G	N, E	25.0	1	25.0	1.0	0.02	440	S
	G	Z	12.4	1	12.8	1.0	0.08	540	S
BRK	G-W	N, E	12.0	1	12.0	1	0	1300	S
	G-W	Z	12.0	1	12.0	1	0	780	S
BUD	W	N, E	9.1	5.0	—	—	—	190	S
CHR	G	N, E	24.0	1	24.0	1	-0.06	390	S
	G	Z	12.8	1	12.9	1	-0.04	390	S
CLL	B	Z, E	1.0	1	0.2 ?	1	0	~50,000	S
COL	M-R	N, E	12.0	~10	—	—	—	140	USCGS
EBR	M	N	15.4	1.75	—	—	—	227	S (1943)
HAI	W-A	N, E	0.8	65	—	—	—	2800	CVG
	B	Z	1.0	1	0.2	1	0	10000	CVG
HAL	B	N, E	5.0	20	—	—	—	125	S
HAM	W	N	9.7	3.5	—	—	—	210	S
	W	E	10.1	3.5	—	—	—	220	S
	W	Z	5.9	5.0	—	—	—	230	S
HLW	M-S	N, E	12.0	20	—	—	—	250	S
	G-W	Z	11.0	1	11.0	1	0	1000	S
HON	M-S	N, E	12.0	~20	—	—	—	150	USCGS
IRK	G	N, E	12.1	1.0	12.3	1.0	0.04	1100	S
	G	Z	12.1	1.0	12.4	1.0	0.07	850	S
JEN	W	N	2.1	6.9	—	—	—	2200	S
KEW	G	N, E	8.1	1	24.4	1	0.0	200	S
	G	Z	12.3	1	14.2	1	0.01	300	S
LJC	W-A	N, E	0.8	65	—	—	—	2800	CVG
	B	Z	1.0	1	0.2	1	0	3000	CVG
LPZ	G-W	Z	11.74	1	10.0	1	0.02	1300	S
LUN	W	N, E	9.1	3.7	—	—	—	188	S
OTT	M-S	N, E	12.0	20.0	—	—	—	300	S
PAS	B	N, E, Z	1.0	1	90.0	1	0	2000	S
	B	N, E, Z	1.0	1	0.2	1	0	30000	S
	Str	N	—	—	70.0	1.0	0	200	S
	W-A	E	0.8	65	—	—	—	2800	S
	W-A	E	6.0	65	—	—	—	800	S

POT	W	N	8.0	3.5	—	—	—	200	S
	W	E	9.0	4.0	—	—	—	200	S
PUL	G	N, E	13.0	1	13.0	1.0	0.0	1100	S
	G	Z	13.1	1	12.9	1.0	0.1	700	S
RVR	W-A	N,E	0.8	65	—	—	—	2800	CVG
	B	Z	1.0	1	0.2	1	0	30000	CVG
SAS	M	N, E	9.2	5	—	—	—	60	S
SHF	W-A	N	1.0	15	—	—	—	2000	S
SJP	We	E	10.2	1	15.0	1	0	~1200	USCGS
SVE	G	N, E	25.0	1	25.0	1	0	1500	S
	G	Z	13.0	1	13.0	1	0	2100	S
TIF	G	N, E	12.0	1	12.3	1.0	0.01	1200	S
	G	Z	12.4	1	12.3	1.0	0.0	3400	S
TIN	W-A	N,E	0.8	65	—	—	—	2800	CVG
	B	Z	1	1.0	0.2	1	0	30000	CVG
UCC	G	N, E	24.5	1	24.2	1	0.07	850	S
	G-W	Z	10.0	1	10.1	1	0.0	290	S
UPP	W	N, E	9.1	3.7	—	—	—	188	S
WES	B	N, E, Z	1.0	1	90.0	1	0	3000	S
	B	N, E, Z	1.0	1	0.5	1	0	50000	S

Instrument types are as follows:

B = Benioff | B-O = Bosch Omori | G= Galitzin

G-W = Galitzin-Wilip | M = Milne | M-R = McComb-Romberg

M-S = Milne-Shaw | Str = Strainmeter | W = Weichert

W-A = Wood-Anderson | We = Wenner

The instrument parameters are as follows:

Ts, Tg = seismometer and galvonometer periods (in seconds)

hs, hg = seismometer and galvonometer damping

σ^2 = coupling coefficient, V_{max} = maximum magnification

Note that integer values for hs, hg and σ^2 denote *assumed* values.

† For mechanical instruments V_{max} is the static magnification.

Sources are as follows:

S = Information provided by the station, CVG = *Charlier and Van Gils* [1953]

USCGS = United States Coast and Geodetic Survey Bulletin, January 1940

TABLE 2
SUMMARY OF DIGITIZED SEISMOGRAMS

Stn.Comp.Phase	T_0	length (sec)
bak.lpe.s	1209	100
bak.lpn.s	1209	100
bak.lpe.surf	1898	674
bak.lpn.surf	1898	674
brk.lpe.p	—	—
brk.lpn.p	—	—
brk.lpe.s	—	—
brk.lpn.s	—	—
cll.spz.p	—	—
col.lpe.pnl	—	—
ham.lpz.p	549	68
ham.lpe.s	1029	74
ham.lpn.s	1029	74
hlw.lpz.p	729	56
hon.lpe.s	—	—
hon.lpn.s	—	—
irk.lpe.s	—	—
irk.lpn.s	—	—
kew.lpe.s	1029	80
kew.lpn.s	1029	80
ott.lpe.s	—	—
ott.lpn.s	—	—
ott.lpe.surf	734	720
ott.lpn.surf	734	720
pas.spz.p	—	—
pas.lpz.p	—	—
pas.lpe.surf	849	522
pas.lpn.surf	849	522
pas.70strn.surf	—	—
pot.lpe.s	—	—
pot.lpn.s	—	—
pul.lpz.p	489	56
pul.lpe.s	489	76
pul.lpn.s	489	61

rvr.spz.p	—	—
sjp.lpe.s	—	—
sve.lpz.p	—	—
sve.lpe.s	—	—
sve.lpn.s	—	—
sve.lpe.surf	1368	810
sve.lpn.surf	1368	810
tif.lpz.p	—	—
tif.lpe.s	—	—
tif.lpn.s	—	—
ucc.lpz.p	549	80
ucc.lpe.s	—	—
ucc.lpn.s	—	—
ucc.lpz.surf	1455	1080
ucc.lpe.surf	1455	1080
ucc.lpn.surf	1455	1080
wes.spz.p	—	—
wes.spe.p	—	—
wes.spn.p	—	—
wes.lpz.p	—	—
wes.lpe.s	—	—
wes.lpn.s	—	—
wes.lpe.surf	854	460
wes.lpn.surf	854	480

T_0 denotes the start time of the digitized record relative to the origin time of the earthquake (01 57 51 UT), and 'length' denotes the length of the digitized record.

TABLE 3
CLOCK CORRECTIONS AND INSTRUMENT POLARITIES

STN	t_{corr}* (sec)	Direction Z	Positive N-S	E-W
BAK			N†	E†
BRK		C†	N†	E†
CLL		D		W
COL	-1.6, -0.7		S	W
HAM		C†	N†	E†
HON	-0.7,-0.5		N	E
HLW		C†		
IRK		C†	N†	E†
JEN			N†	
KEW			N†	E†
OTT		C	N	E
PAS		C	N	E
POT		C†	N†	E†
PUL		C†	N†	E†
RIV		C	N	E
SJP	+1.3, +2.8		N	E
SVE		C†	N†	E†
TIF	-27.0	C†	N†	E†
TIN		C	N	E
UCC	-1.4	C	N	E
UPP			S	W
WES	-26.1, -25.2	C	N	E

* if two time corrections are given, they indicate measurements made before and after (within 24 hrs) the earthquake

† assumed by *Cassidy and Bent* [1993]

TABLE 4
Summary of Magnitude Calculations

Station	Δ (o)	Az. (o)	Comp*	Period (sec)	M_S	Comp*	Period (sec)	m_B
ABE†	52	30	H	15	6.2	–	–	–
ABU	58	284	Z	20	6.0	–	–	–
	58	284	H	20	5.9	–	–	–
BAK	73	356	H	20	6.8	PH	7.2	6.5
	73	356				SH	11	6.8
BRK	30	159	Z	18	5.8	PZ	5.0	6.6
	30	159	H	19	6.5	PH	6	6.4
	30	159				PPZ	9	6.5
	30	159				SH	10	6.0
CHR	117	220	Z	20	6.1			
CLL	60	22	Z			PZ	0.9	6.0
COL	5	257	H			PH	4.0	6.2
CRT†	70	39	Z	22	6.2	PZ	7.0	6.0
	70	39	Z			PPZ	7.0	6.1
EBR	68	35	N	15	5.6			
HAI	32	153	H	17	6.7	PH	1.3	6.4
	32	153	Z			PZ	1.2	6.4
HAL	43	84	H			SH	5.7	6.2
HAM	57	24	Z	16	6.1	PZ	3.9	6.3
	57	24	H	16	6.1	SH	7.5	6.1
HLW	83	11	Z			PZ	5.6	6.2
	83	11	H	21	5.8	PH	5.6	6.6
HON	48	209	H	18	6.2	SH	8.3	6.2
IRK	53	318	H	19	5.9	PH	4.0	6.5
	83	11	H			SH	11.5	5.8
JEN	60	23	N	17	6.1	PH	1.0	6.6
KEW	57	31	Z	18	5.9			
	57	31	H	19	6.3	SH	9.2	6.2
LJC	36	153	Z			PZ	1.6	6.8
	36	153	H	18	6.6	PH	2.1	6.6
LPZ	96	117	Z	20	6.4			
LUN	55	21	H	18	5.9			
OTT	38	94	H			SH	8.5	6.4

PAS	34	154	Z			PZ	0.8	6.9
	34	154	H			PH	1.0	6.8
	34	154	Z	22	6.5	PZ	2.6	6.9
	34	154	H	18	6.9	PH	3.0	6.8
	34	154	H			SH	9.0	6.3
	34	154	Z	20	6.0			
	34	154	H	17	6.6	PH	2.7	6.7
POT	59	22	H	19	6.2	PH	4.0	6.6
	59	22	H			SH	7.5	6.0
PUL	53	9	Z	18	5.7	PZ	7.8	6.1
	53	9	Z			PPZ	4.7	6.1
	53	9	H	18	5.8	PH	9.4	6.3
	53	9	H			PPH	4.7	6.2
	53	9	H			SH	10.0	6.3
REN†	29	154	H			SH	10.0	7.6
RIV	31	153	Z			PZ	1.5	6.5
	31	153	H	15	6.7	PH	2.3	6.4
SAS	20	121	H			PH	4.1	6.6
	20	121	H			SH	5.7	6.7
SHF	38	90	N			PH	1.0	6.4
SJP	65	101	E	18	6.5	SH	6.9	6.3
SVE	56	350	Z	21	6.0	PZ	6.5	5.8
	56	350	H	21	5.9	SH	15.0	6.0
TIF	72	0	Z	21	5.5	PZ	7.8	5.6
	72	0	H	21	6.1	SH	9.0	6.2
TIN	31	153	Z			PZ	1.5	6.5
	31	153	H	15	6.7	PH	2.3	6.4
UCC	59	29	Z	20	6.2	PZ	7.0	6.4
	59	29	H	19	6.3			
UPP	52	17	H	18	5.7	PH	4.0	6.4
	52	17	H			SH	6.1	5.9
WES	42	92	Z			PZ	2.0	6.0
	42	92	H			PH	2.4	6.0
	42	92	H			SH	11.5	6.4

† denotes calculations based on amplitudes and periods from station bulletins

* 'Z' indicates that the vertical component was used in the calculation, 'H' indicates that both horizontal components were used, 'N' indicates that only the N-S component was used, and 'E' indicates that only the E-W component was used.

TABLE 5
Summary of First Motion Data

Station	Δ (∘)	Az. (∘)	Comp	First motion	Comments
BUC	68	14		D	emer. (from bulletin)
BZM	25	135		C	emer. (from bulletin)
CRT	70	40	Z	C	imp. (from bulletin)
CLL	**60**	**22**	**Z**	**D**	**imp.**
COL	**5**	**257**	**N, E**	**D**	**imp.**
DBN	58	28		C	im. (from bulletin)
HAM	57	24	Z	D	emer.
HLW	83	11	Z	D	emer.
KSA	80	8		D	imp. (from bulletin)
OTT	38	94	Z	C	emer.
PAS	**34**	**154**	**Z, N, E**	**C**	**imp.**
POT	59	23		C	imp. (from bulletin)
PUL	53	9	Z	D	emer.
ROM	69	26		D	imp. (from bulletin)
RVR	**34**	**154**	**Z**	**C**	**imp.**
SCO	36	32		D	imp. (from bulletin)
STU	62	26		C	imp. (from bulletin)
SVE	56	349	Z	D	
TIF	72	0	Z	D	emer.
UCC	59	30		D	imp. (from bulletin)
WAR	60	17		D	emer. (from bulletin)
WES	**42**	**93**	**Z, N, E**	**C**	**imp.**
UCC	**59**	**29**	**Z**	**D**	

boldface is used to denote those stations for which the instrument polarity was indicated on the seismograms.

'from bulletin' indicates first motions taken from the May 1940 International Seismological Society (ISS) bulletin.

'imp.' denotes impulsive first motion

'emer.' denotes emergent first motion

TABLE 6
Summary of P-arrival Time Data Used

Station	Δ (∘)	Az. (∘)	P-time (hh mm ss)	Corr. (sec)	Res. (sec)	Source
COL	5	255	01 59 12	−2.1	+1.7	Seismo.
SIT	10	180	02 00 10	−0.9	−1.0	ISS
VIC	19	156	02 02 17	+1.3	−0.2	Bull.
SPO	21	145	02 02 36	+1.3	−2.0	ISS
BUT	24	139	02 03 06	+1.3	−0.3	ISS
BZM	25	137	02 03 12	+1.3	−1.1	ISS
UKI	29	160	02 03 49	+1.3	+1.6	ISS
SLC	29	142	02 03 53	+1.3	+0.2	ISS
HAI	32	153	02 04 22	+1.3	+1.4	Seismo.
MWC	34	154	02 04 29	+1.3	−1.7	ISS
CHI	36	110	02 04 51	−1.6	+2.5	ISS
TUC	38	144	02 05 04	+1.3	−1.2	ISS
FLO	38	115	02 05 04	−1.6	+0.8	ISS
SLM	38	115	02 05 05	−1.6	+0.2	ISS
ABE	51	31	02 06 54	−0.1	−0.4	ISS
UPP	52	17	02 06 59	−0.1	+0.7	ISS
EDI	52	32	02 07 02	−0.1	+0.7	ISS
IRK	53	318	02 07 05	+0.5	−1.3	ISS
PUL	53	9	02 07 07	−0.1	−0.3	ISS
COP	55	21	02 07 23	−0.1	−0.2	ISS
SVE	56	350	02 07 27	+0.5	−1.4	ISS
HAM	57	24	02 07 35	−0.1	−0.7	Seismo.
KEW	57	32	02 07 35	−0.1	−0.9	ISS
DBN	58	28	02 07 41	−0.1	+1.7	ISS
MOS	58	5	02 07 37	−0.1	−1.8	ISS
POT	59	29	02 07 46	−0.1	−0.5	ISS
UCC	60	22	02 07 46	−0.1	−0.9	Seismo.
CLL	60	24	02 07 52	−0.1	−1.6	Seismo.
JEN	60	24	02 07 53	−0.1	−1.6	ISS
WAR	60	17	02 07 53	−0.1	−1.5	ISS
PAR	60	31	02 08 01	+0.9	+3.5	ISS
STU	62	26	02 08 06	+0.9	+0.3	Bull.
BAS	62	27	02 08 13	+0.9	+0.7	ISS
NEU	63	28	02 08 15	+0.9	−0.0	ISS

ZUR	63	27	02 08 14	+0.9	−0.6	ISS
CFF	63	31	02 08 18	+0.9	+0.1	ISS
CHU	63	26	02 08 19	+0.9	−0.1	ISS
AAA	67	335	02 08 45	+0.5	−0.3	ISS
RMP	69	25	02 08 51	+0.9	−2.9	ISS
SFS	70	42	02 09 03	+0.9	+2.5	ISS
TAS	70	341	02 09 05	+0.5	+0.7	ISS
ALG	72	34	02 09 14	+0.9	+1.7	ISS
SAM	72	342	02 09 16	+0.5	+0.1	ISS
KSA	79	7	02 09 56	−0.1	+0.5	ISS
HLW	83	12	02 10 18	−0.1	+3.0	ISS

'Corr.' indicates the path correction that is subtracted from the given arrival-time at this station. These values were computed using a well-located 'calibration event' - as described in *Cassidy and Bent* (1993).

'Res.' denotes the travel-time residual

'Seismo.' indicates arrival times read from seismograms by the authors

'Bull.' indicates times taken from station bulletins

'ISS' indicates times taken from the May 1940 International Seismological Society (ISS) bulletin.

APPENDIX A
Sample Digitized File

test.dig

440 1.0232

30.0 1.00

1.0 0.0 0.0

0.0 1.111111e-01

1.0 2.444444e-01

2.0 1.002233e-01

3.0 -1.234567e-01

•

•

•

explanation of header:

1^{st} line: id

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

3^{rd} line: horizontal and vertical scales (for plotting purposes only)

4^{th} line: enlargement factor (if greater than 1, record was enlarged before digitizing; amplitudes have been corrected for this) radius of curvature in cm; skew angle

remaining lines: x-y pairs; x is time in sec relative to first point digitized; y is amplitude in cm (not corrected for instrument magnification)

APPENDIX B
Data Order Form for 1940 Richardson Mountains Digital Data Set and Statement of Sole Use

To obtain digital data files, please complete the form below and either:

A) send cheque or money order for $40.00 Canadian funds (plus PST and GST; Canadian addresses only; shipping included) or $40.00 U.S. funds (all taxes and shipping included; non-Canadian addresses) payable to the "Receiver General for Canada" to:

Seismology Program, Geological Survey of Canada
1 Observatory Cres., Ottawa, Ont. K1A 0Y3
Attention: Allison Bent

B) fax this form to (613) 992-8836 and enclose standard information for credit card billing or e-mail information to bent@seismo.emr.ca

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

____

((Option B) Credit card name, number and expiry date)

FIGURE CAPTIONS

Figure 1. Location of the May 1940 M=6.5 earthquake and the seismicity and main structural features of the northern Canadian Cordillera (inset shows the map area). The shaded region represents the Cordillera, the white area is the interior platform and craton. Heavy lines denote the major faults. The N-S trending strike-slip Richardson fault array lies along the eastern flank of the Richardson Mountains, and S to SW dipping thrust faults lie within the Mackenzie Mountain fold and thrust belt. Earthquake magnitudes are scaled to the circle size. Solid triangles indicate the felt locations for the 1940 Yukon earthquakes, open triangles denote those communities where the earthquakes were not felt.

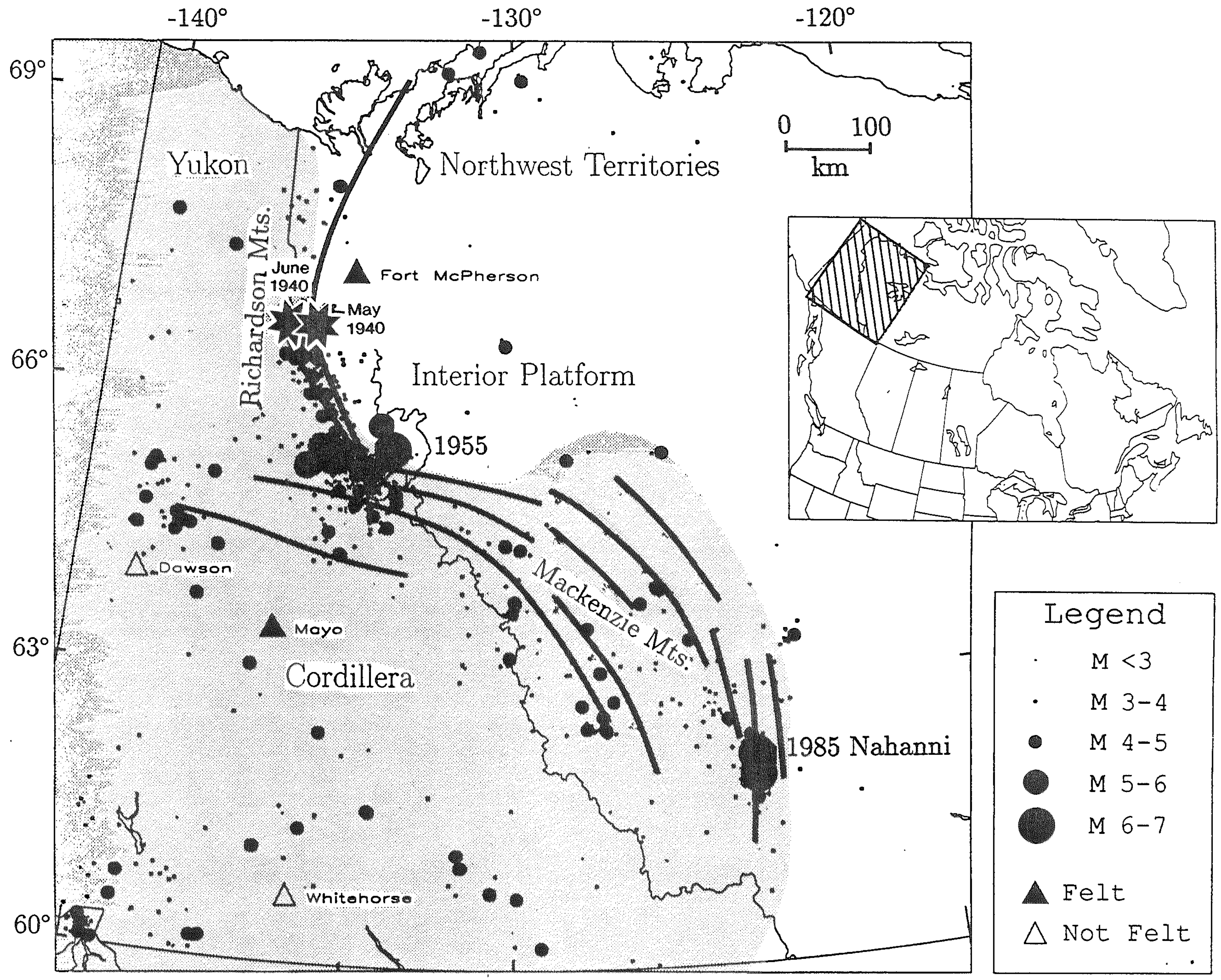
Figure 2. Seismograph stations (open triangles) for which seismograms were collected for the May 1940 Yukon earthquake. Filled triangles represent those stations for which we have digitized some or all of the available seismograms. Lines denote the great circle paths from the earthquake to the recording stations - note the excellent azimuthal coverage.

Figure 3. Some examples of seismograms for the May 29 1940 Yukon earthquake. All have been photographically reduced to fit on the page. a) Uccle, Belgium (UCC) N-S and E-W long-period seismograms. This station is 59° (6600 km) from the earthquake, at an azimuth of 29°. b) Pasadena, California (PAS) N-S and E-W long-period (1-90) seismograms. This station is 34° (3800 km) from the earthquake, at an azimuth of 154°.

Figure 4. Digitized seismograms - P-waves. The labels correspond to the file names given in Table 2.

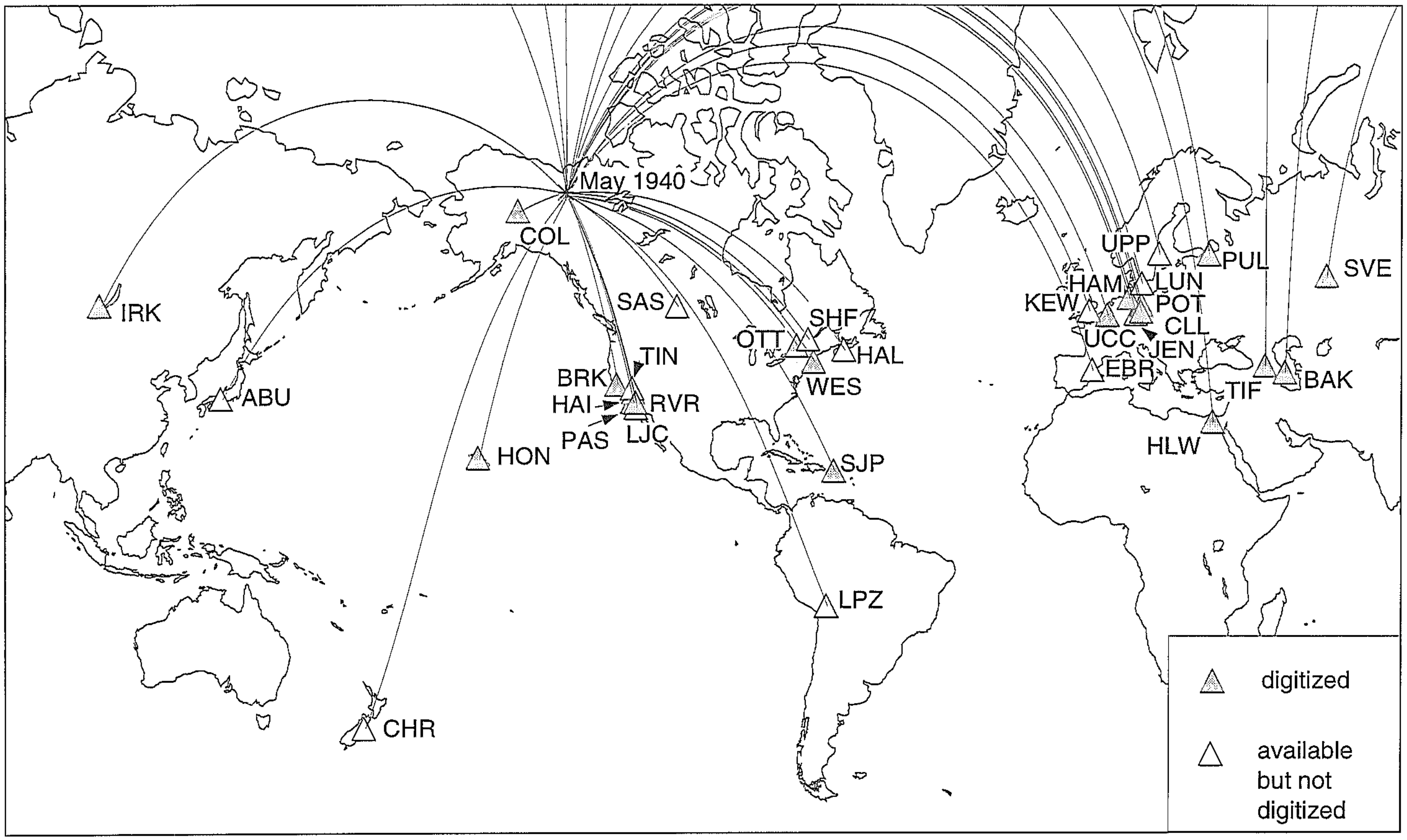
Figure 5. Digitized seismograms - S-waves. The labels correspond to the file names given in Table 2.

Figure 6. Digitized seismograms - surface-waves. The labels correspond to the file names given in Table 2.



-140°
-130°
-120°
69°
66°
63°
60°
0 100
km
Yukon
Northwest Territories
Richardson Mts.
June 1940
May 1940
Fort McPherson
Interior Platform
1955
Dawson
Mayo
Cordillera
Mackenzie Mts.
1985 Nahanni
Whitehorse
Legend
M <3
M 3-4
M 4-5
M 5-6
M 6-7
Felt
Not Felt

FIG 1



May 1940
IRK
ABU
CHR
COL
HON
SAS
BRK
HAI
PAS
TIN
RVR
LJC
OTT
SHF
HAL
WES
SJP
LPZ
UPP
PUL
HAM
LUN
KEW
POT
UCC
CLL
JEN
EBR
TIF
BAK
SVE
HLW
digitized
available but not digitized

Figure 2

Fig. 3a

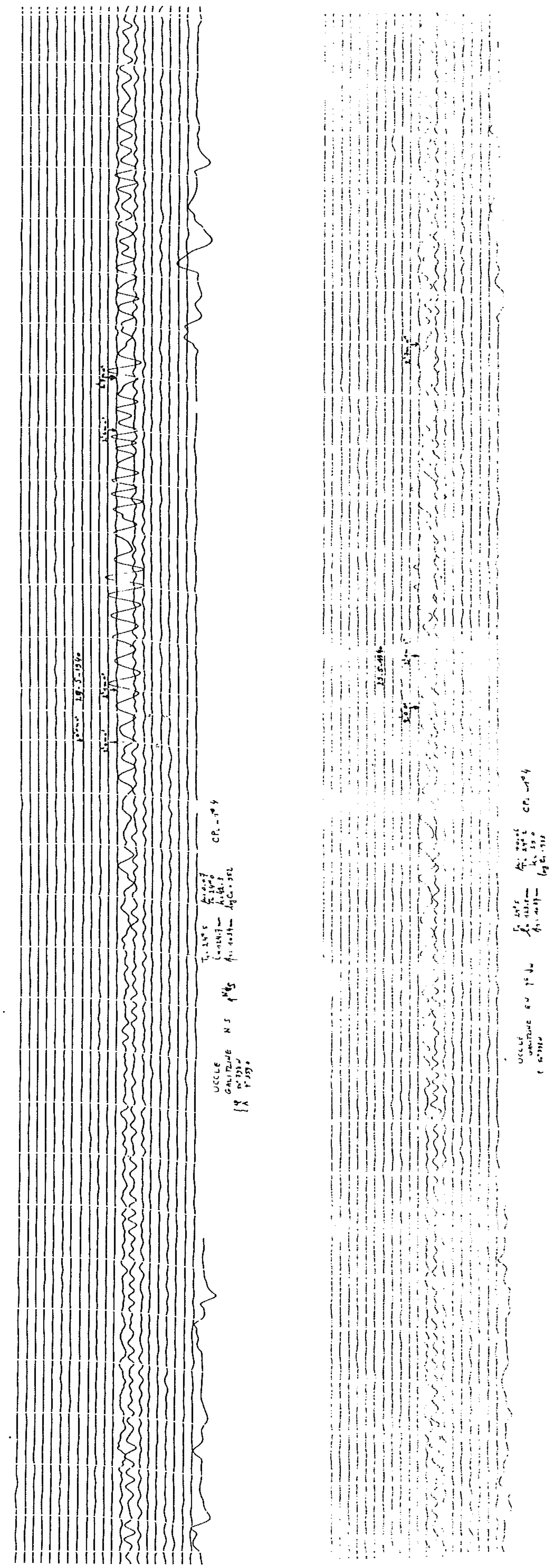
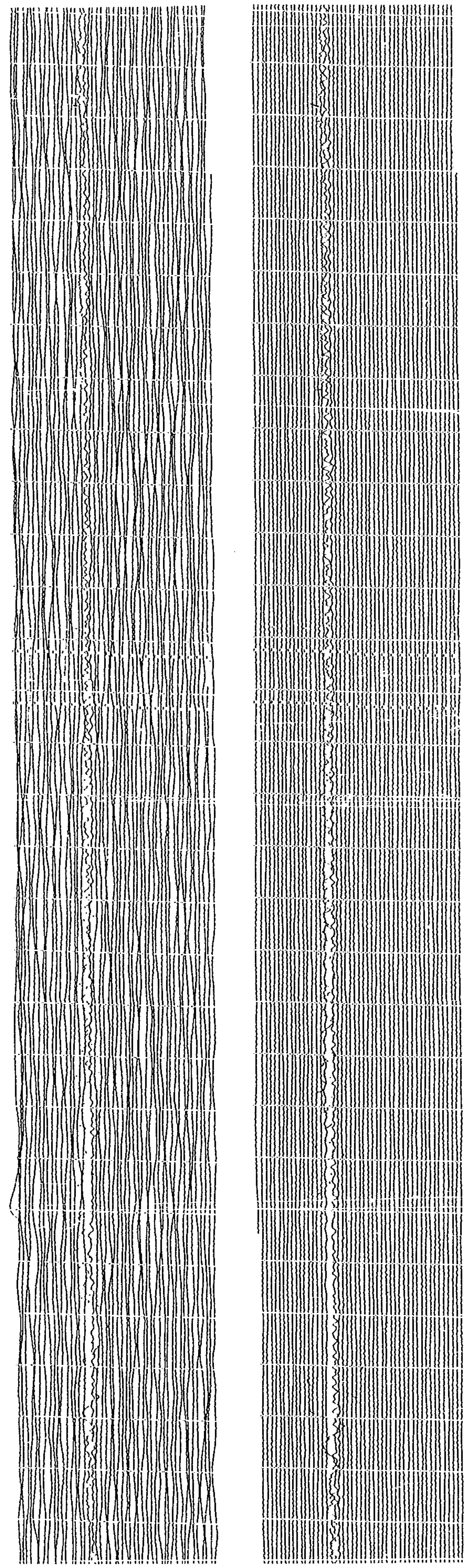


Fig. 3b



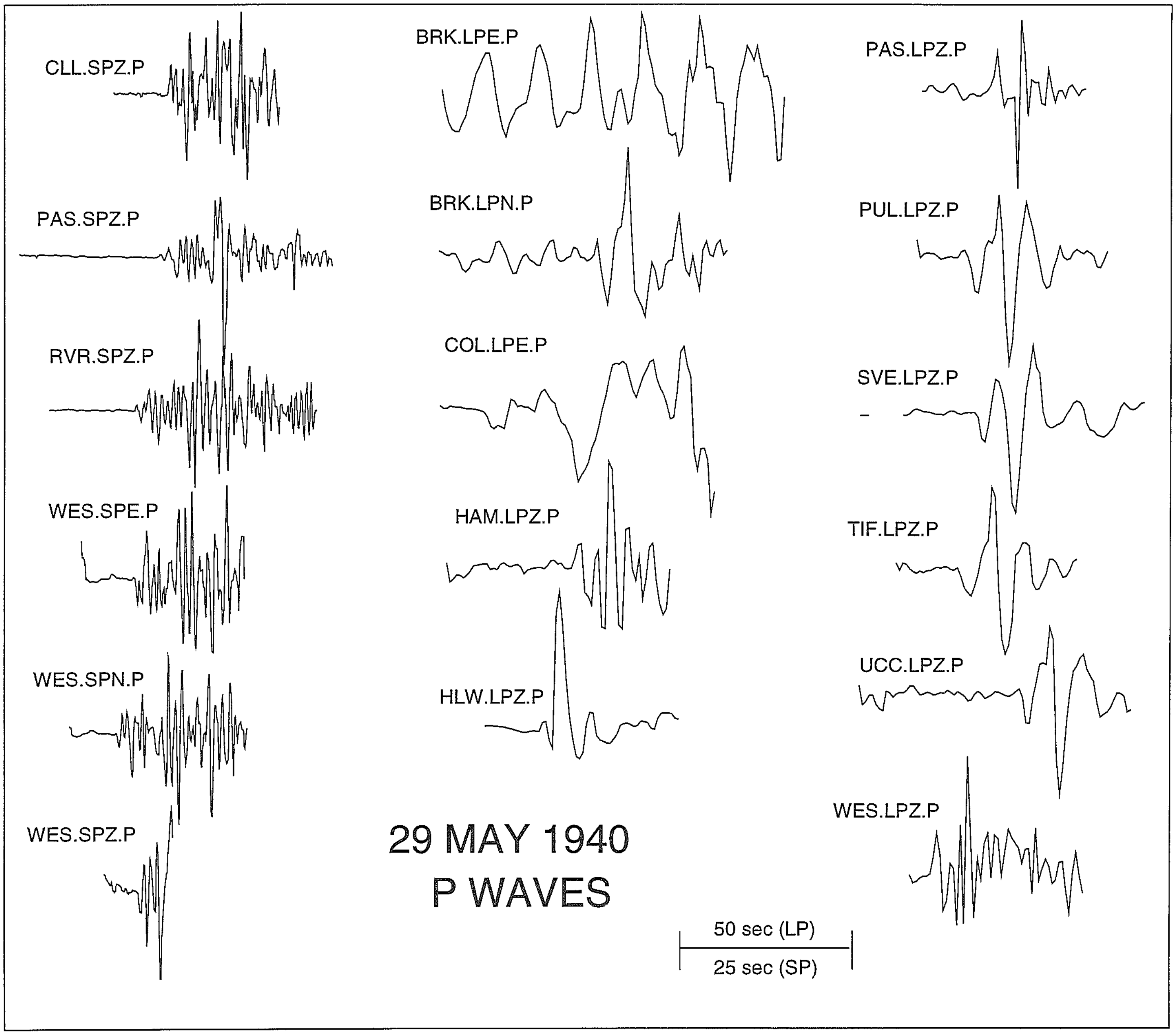

CLL.SPZ.P
PAS.SPZ.P
RVR.SPZ.P
WES.SPE.P
WES.SPN.P
WES.SPZ.P
BRK.LPE.P
BRK.LPN.P
COL.LPE.P
HAM.LPZ.P
HLW.LPZ.P
29 MAY 1940
P WAVES
50 sec (LP)
25 sec (SP)
PAS.LPZ.P
PUL.LPZ.P
SVE.LPZ.P
TIF.LPZ.P
UCC.LPZ.P
WES.LPZ.P

Figure 4

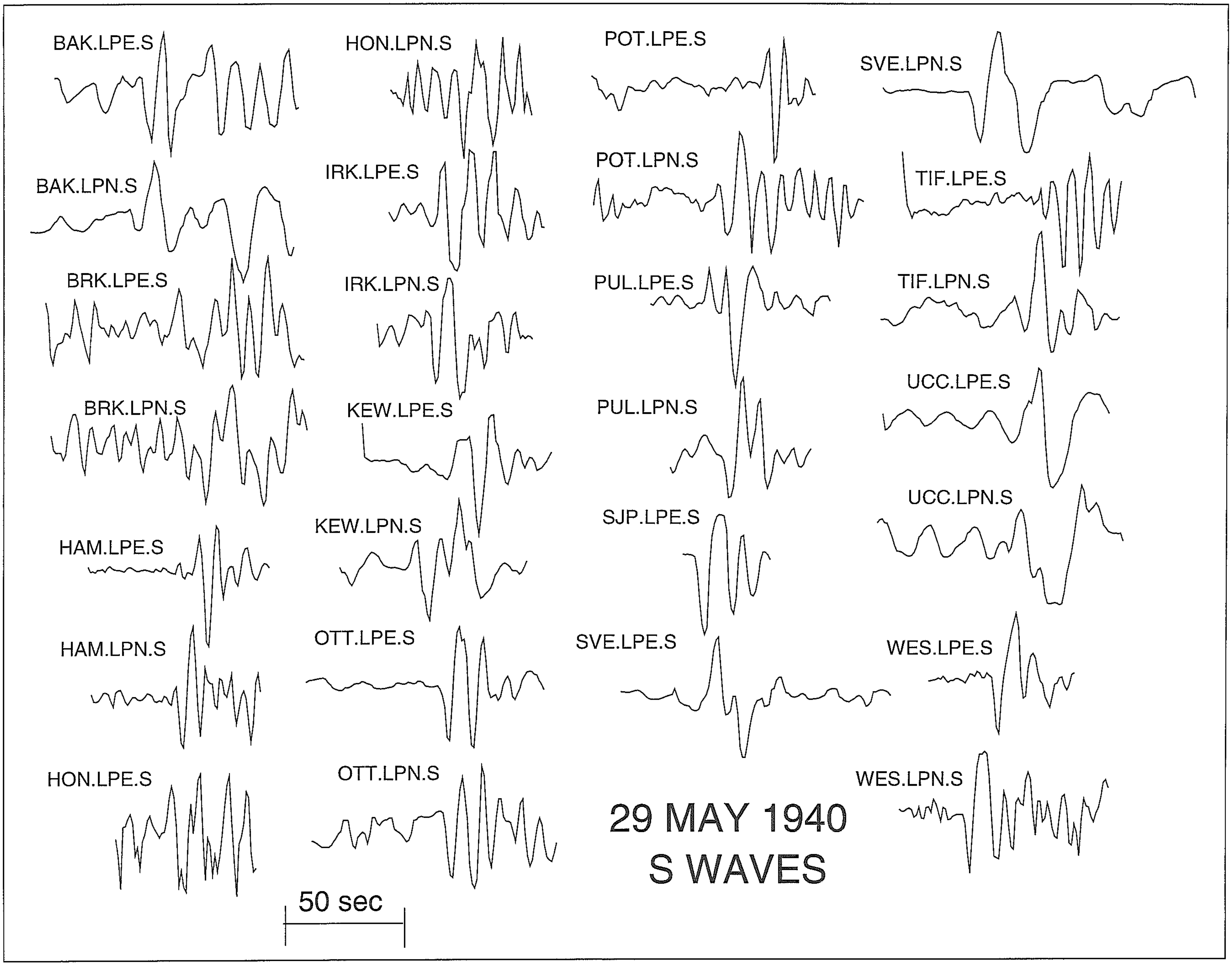

BAK.LPE.S
HON.LPN.S
POT.LPE.S
SVE.LPN.S
BAK.LPN.S
IRK.LPE.S
POT.LPN.S
TIF.LPE.S
BRK.LPE.S
IRK.LPN.S
PUL.LPE.S
TIF.LPN.S
UCC.LPE.S
BRK.LPN.S
KEW.LPE.S
PUL.LPN.S
UCC.LPN.S
HAM.LPE.S
KEW.LPN.S
SJP.LPE.S
HAM.LPN.S
OTT.LPE.S
SVE.LPE.S
WES.LPE.S
HON.LPE.S
OTT.LPN.S
WES.LPN.S
29 MAY 1940
S WAVES
50 sec

Figure 5

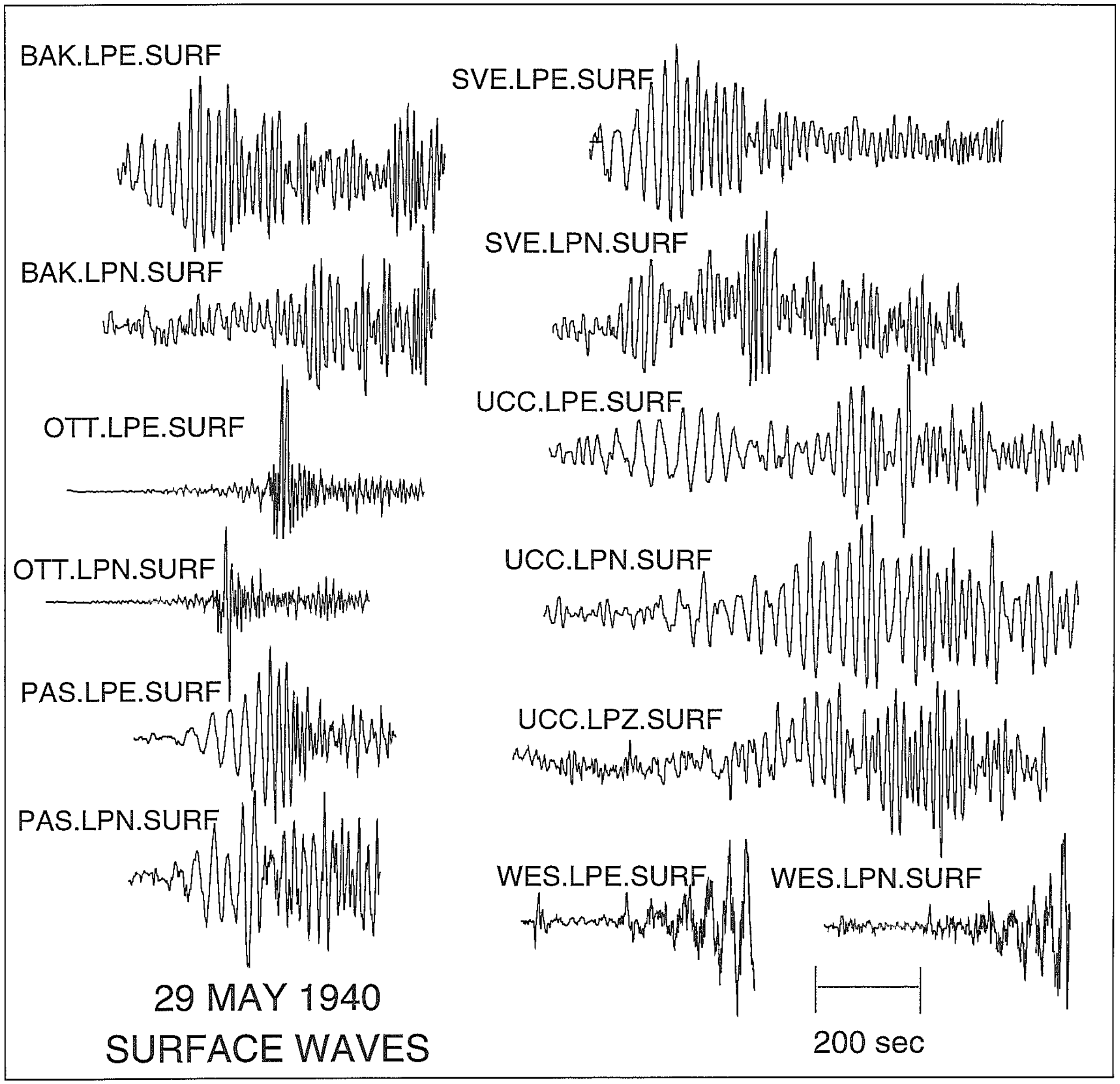

BAK.LPE.SURF
BAK.LPN.SURF
OTT.LPE.SURF
OTT.LPN.SURF
PAS.LPE.SURF
PAS.LPN.SURF
29 MAY 1940
SURFACE WAVES
SVE.LPE.SURF
SVE.LPN.SURF
UCC.LPE.SURF
UCC.LPN.SURF
UCC.LPZ.SURF
WES.LPE.SURF
WES.LPN.SURF
200 sec

Figure 6