Strong Motions from Nearby Seismometer Records of the Val-des-Bois, Québec, Earthquake of June 23, 2010

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Note: This Canadian Hazard Information Service Internal Report is a preliminary version of a report that will be issued as a GSC Open File once revisions are completed and the report has undergone internal review; the preliminary report is issued to provide researchers quick access to the GSC's data in advance of the release of the Open File.

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ABSTRACT

This report presents preliminary information for the strong ground motions recorded by nearby seismometers during the moment magnitude (M_w) of 5.0 June 23rd 2010 Val-des-Bois earthquake.

RÉSUMÉ

Ce rapport présente l'information préliminaire des données des mouvements forts enregistrées par des proches sismomètres lors du séisme de magnitude moment (Mw) 5.0 du 23 juin 2010 de Val-des-Bois.

INTRODUCTION

Currently, Geological Survey of Canada (GSC) is operating two ground motion monitoring networks in eastern Canada, i.e. weak-motion network, and strong-motion network. Different instruments are employed in these two networks. Etna and Internet-accelerometer (IA) are the instruments used in the strong-motion network, while seismometer is used in the weak-motion network. It should be mentioned that the Etna and the IA instruments record acceleration, while seismometers record **velocity**.

The Val-des-Bois earthquake which occurred on June 23, 2010 was the biggest recent earthquake in eastern Canada. The epicenter of the earthquake was at latitude of 45.90, and longitude of 75.50. The moment magnitude (M_w) of the earthquake was 5.0. The depth of the source was 22.4 km. During this event, the instruments (Etna, IA, seismometer) in both the strong-motion network and the weak-motion network were triggered, and a large number of records from this earthquake were collected by GSC.

The records obtained by the Etna and IA instruments from the strong-motion network were released by GSC in 48 hours after the earthquake. The preliminary report describing these records, including the digital data for the records, was posted on Earthquakes Canada website at http://earthquakescanada.nrcan.gc.ca/index-eng.php (Lin and Adams 2010).

This report presents the records obtained by nearby seismometers from the weak-motion network. Note that the seismometer in Montreal (MNT) was temporarily removed for building renovations, so there is no MNT seismometer record of this earthquake. In total, 24 components recorded at 11 stations are considered in this report (Table 1). In terms of the soil conditions, 7 stations are on bedrock, and 4 stations are on soil. The records were obtained at epicentral distances from about 20 km to 160 km. For completeness, the digital files for the data of the records are also included in this report. It is useful to mention that the records obtained by seismometers at distances larger than 160 km are not included in this report because the peak ground accelerations of those records are very small.

Waveforms of all the records are shown in Appendix A. Detailed explanations for use the digital files are given in Appendix B along with the raw data for the ground motions.

AVAILABLE RECORDS OBTAINED BY SEISMOMETERS FROM VAL-DES-BOIS EARTHQUAKE OF JUNE 23, 2010

Station Information

A large number of records obtained by seismometers of the GSC weak-motion network have been recovered since the occurrence of the Val-des-Bois earthquake. In total 24 components recorded at distances of up to 160 km are included in this report. The deployment of these stations is illustrated in Fig. 1. Detailed information for the stations

is given in Table 1. The records were obtained at 11 stations, 8 of which are located in Ontario and the remaining 3 stations (i.e. GAC, GRQ, and TRQ) are in Québec. As seen in Table 1, seven stations are on rock and the other four stations are on soil. The shear wave velocity at the top 30 meters (Vs30) for station OTT, GRQ, and WBO are given in Beresnev and Atkinson (1997). The Vs30 values for the other stations are not yet available.

Characteristics of Seismometers

For the purpose of the data processing it is important to know the characteristics of the instruments. Since the records presented in this report were obtained by seismometers, the main characteristics of the seismometer instrument are as follows:

- Data type: the data recorded by seismometer are **velocities.**
- Number of components recorded: Each record consists of one vertical component (V) for the short period instruments using S-13 seismometers, or three components of earthquake ground motions, i.e., two perpendicular horizontal components (N-S and E-W) and one vertical component (V) for the instruments using Guralp CMG-3 seismometers.
- Channel code: The channel codes for the recorded components are related to the type of the seismometer. For the vertical seismometer (i.e. corner period shorter than 10 s), the channel code is EHZ, while for the broadband seismometer (i.e. corner period longer than 10 s), the channel code for the N-S, E-W, and V component is HHN, HHE, and HHZ, respectively.
- Sampling rate: the sampling rate of the seismometer is 100 samples per second (i.e., the time interval of the recorded data is 0.01 s) for the records presented in this report..
- Units: the data recorded by seismometer are in units of counts. The calibration factor to convert counts to SI units, such as m/s^2, is different for different stations.

Available Data

As mentioned earlier, 24 components of seismometer records obtained during the Val-des-Bois earthquake of June 23, 2010 are included in this report. The information for the records along with the peak ground accelerations (PGA) for each of the components considered is shown in Table 2. Among the recorded components included in this report, the seismograms of 7 components were found to be clipped (i.e. component EHZ at station GAC, components HHN, HHZ, and HHE at station ORHO, and components EHZ, HHZ, and HHE at station OTT). In addition, the record for the EHZ component at station GRQ is of only partial value because of the currently assigned gain of its digitizer appears to be wrong by four orders of magnitude. For completeness, however, all 24 components (including the clipped components) are presented in this report in order to provide a complete documentation for the seismometer records obtained during this earthquake.

For illustration, the clipped seismogram for the EHZ component at station GAC is shown in Fig. 2(a). The waveform shown includes the S-wave arrival and subsequent strong shaking; the P-wave arrival is off the record to the lefthand side. Note that the trace in Fig. 2(a) represents the velocity in units of counts, as recorded by the seismometer (see section "Characteristics of Seismometers"). It is seen in Fig. 2(a) that the seismogram is strongly clipped between the 30th and the 31st second marks and a few peaks may clip slightly as late as 32.3 seconds. The time shown on the horizontal axis is the relative time corresponding to the event start time (20100623.174120 UTC) shown in the upper left corner of the graph. The event start time was used for extracting the records from the GSC database. Since structural engineers normally require accelerations, the velocity data were converted to accelerations (see the next section regarding the conversion to acceleration). The acceleration waveform in Fig. 2(b) is obtained by converting the velocity waveform shown in Fig. 2(a). Note that while the clipping is not immediately evident in the acceleration trace (Fig. 2(b)), the acceleration data between the 30th and the 32.3st second marks are not completely correct, and that the acceleration record is approximately zero when the velocity record is clipped.

Since the largest accelerations may be near the zero-crossing of the velocity waveforms, it is possible that the peaks of the GAC acceleration record might still be usable. However, we note that the peak acceleration on GAC is 0.45 m/s^2. This seems a little low, given that this station is less than half the distance from the epicentre than OTT, for which the strong motion Etna recorder gave 0.3 m/s^2 (Lin and Adams, 2010). We note also that the ORHO velocity record is clipped (Figure 3), but still gives peak acceleration values of 1 m/s^2 or 10% g.

Acceleration waveforms

As mentioned above, structural engineers commonly use accelerations rather than velocities. Since the records from the seismometers are velocities, they need to be converted to accelerations. For the purpose of this report, all 24 components (including the clipped components) were converted to **accelerations** by using SAC software (1989) in the time-domain. The conversion was conducted by considering two-point differentiation, which is the default option in SAC.

The acceleration waveforms of all 24 components considered in this report are given in Appendix A. The clipped records are indicated in "red" in the figure captions (also in Table 2). It is highly recommended that structural engineers do not use the clipped records in time-history analyses of structures.

SUMMARY

This report presents the ground motion records from the Val-des-Bois earthquake of June 23, 2010 obtained by seismometers of the weak-motion monitoring network operated by Geological Survey of Canada. The records considered in this report were obtained at epicentral distances ranging from about 20 km to about 160 km. In total, 24 ground motions components are included in this report.

SOURCE FOR VELOCITY WAVEFORM DATA

The ground motion records for earthquake events since 1975 from the Geological Survey of Canada's seismometers can be downloaded through autodrm at http://earthquakescanada.nrcan.gc.ca/stndon/AutoDRM/index-eng.php Please note that the online data are velocities in the units of counts. The seismometer records from the Val-des-Bois event at **all** stations (about 100 in total) will also available through the link at: http://earthquakescanada.nrcan.gc.ca/stndon/NWFA-ANFO/eve/index-eng.php in the near future.

REFERENCES

Lin, L. and Adams, J. 2010. Strong Motion Records of the Val-des-Bois, Québec, Earthquake of June 23, 2010. Canadian Hazard Information Service Internal Report 2010-1.1, 20 pages plus digital Appendix; version 1 posted on the web on 20100625.

Beresnev, I.A., and Atkinson, G.M. 1997. Shear-wave velocity survey of seismographic sites in Eastern Canada: calibration of empirical regression method of estimating site response. Seismological Research Letters, Vol. 68, Issue 6, 981-987.

SAC. 1989. Seismic Analysis Code, Lawrence Livermore National Laboratory, University of California, Livermore, CA.

Table 1. List of seismometer stations with the records included in this report from the Val-des-Bois earthquake (source depth = 22.4 km).

No.	Station Code	Station Name	Coordinates		Elevation (m)	Soil Condition	Vs30 (m/s)	Epicentral Distance (km)	Hypocentral Distance (km)	Azimuth (degree)
1	GAC	Glen Almond, Québec	45.7033 N	75.4783 W	62	Rock		21.9	31.3	175.6
2	ORHO	Orleans, Ottawa, Ontario	45.4563 N	75.5367 W	51	Soil		49.4	54.2	183.3
3	ORIO	Orleans, Ottawa, Ontario	45.4515 N	75.5111 W	74	Rock		49.9	54.7	181.0
4	ALFO	Alfred, Ontario	45.6283 N	74.8842 W		Till ??		56.5	60.8	122.1
5	OTT	Ottawa, Ontario	45.3942 N	75.7167 W	77	Rock	1914	58.7	62.8	196.8
6	TRQ	Mont-Tremblant, Québec	46.2175 N	74.5514 W	864	Rock		81.3	84.3	63.9
7	GRQ	Grand-Remous, Québec	46.6067 N	75.8600 W	290	Rock	1889	83.3	86.3	340.7
8	WBO	Williamsburg, Ontario	45.0003 N	75.2750 W	85	Rock	1734	100.1	102.6	177.4
9	PEMO	Pembroke, Ontario	45.6773 N	77.2466 W	180	Soil		137.7	139.5	260.3
10	CRLO	Chalk River, Ontario	46.0375 N	77.3801 W	168	Rock		146.1	147.8	276.7
11	PLVO	Plevna, Ontario	45.0396 N	77.0754 W		Rock		155.7	157.3	232.7

Table 2. List of PGA from nearby seismometer records of the Val-des-Bois earthquake (source depth = 22.4 km).

No.	Station Code	Component Code	Comment	Epicentral Distance (km)	Hypocentral Distance (km)	PGA (m/s^2)	Soil Condition
1	GAC	**EHZ**	**Clipped**	21.9	31.3	**0.454**	Rock
2	ORHO	**HHN**	**Clipped**	49.4	54.2	**1.054**	Soil
		HHZ	**Clipped**			**0.945**	
		HHE	**Clipped**			**1.068**	
3	ORIO	HHN		49.9	54.7	0.434	Rock
		HHZ				0.151	
		HHE				0.435	
4	ALFO	HHN		56.5	60.8	0.169	Till??
		HHZ				0.081	
		HHE				0.117	
5	OTT	**EHZ**	**Clipped**	58.7	62.8	**0.192**	Rock
		HHN				0.220	
		HHZ	**Clipped**			**0.186**	
		HHE	**Clipped**			**0.278**	
6	TRQ	EHZ		81.3	84.3	0.070	Rock
7	GRQ	**EHZ**	**Wrong gain**	83.3	86.3		Rock
8	WBO	EHZ		100.1	86.3	0.032	Till
9	PEMO	HHN		137.7	139.5	0.216	Soil
		HHZ				0.008	
		HHE				0.145	
10	CRLO	EHZ		146.1	147.8	0.061	Rock
11	PLVO	HHN		155.7	157.3	0.077	Rock
		HHZ				0.066	
		HHE				0.091	

Note red values indicate accelerations taken from clipped records, and may not be reliable.

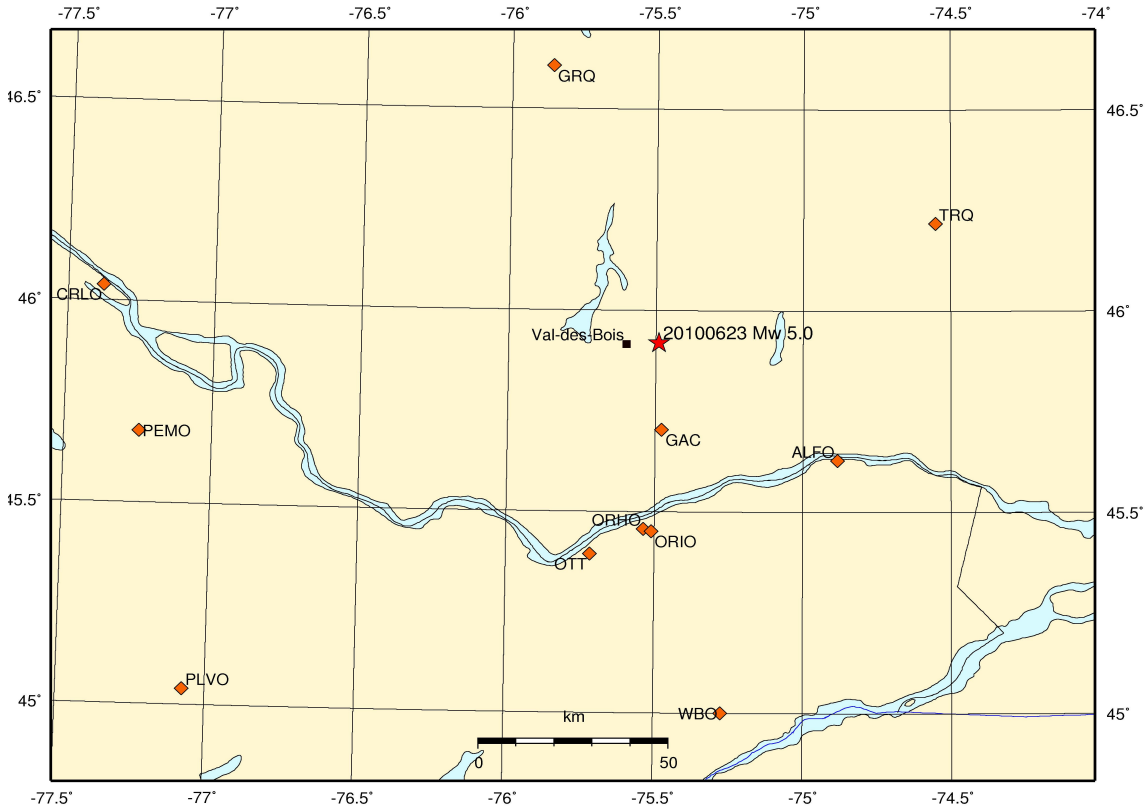


Figure 1. Locations of nearby stations where seismometers records were obtained during the Val-des-Bois earthquake.

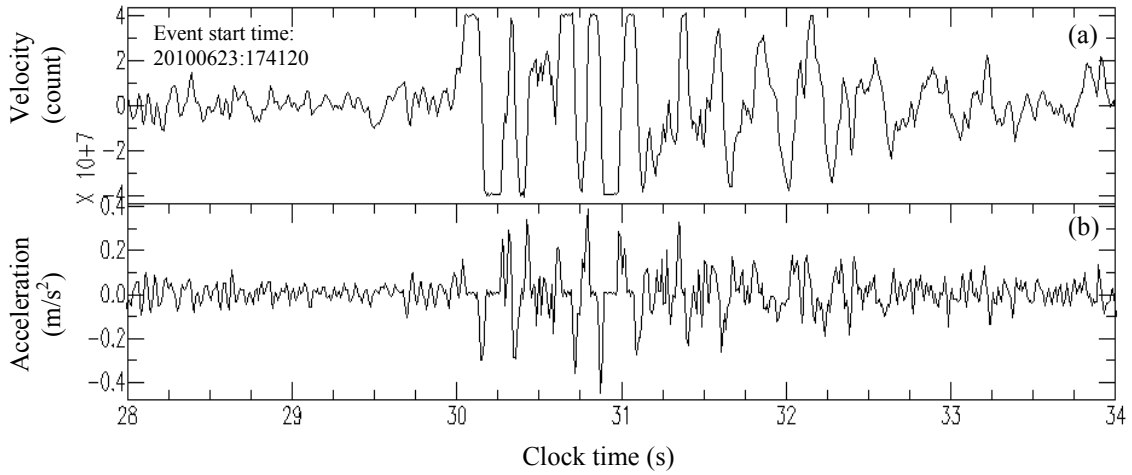


Figure 2. Illustration of clipped velocity waveform recorded by the GAC seismometer and the converted acceleration waveform. The waveform shown includes the S-wave arrival and subsequent strong shaking; the P-wave arrival is off the record to the left hand side. Note that the acceleration record is approximately zero when the velocity record is clipped.

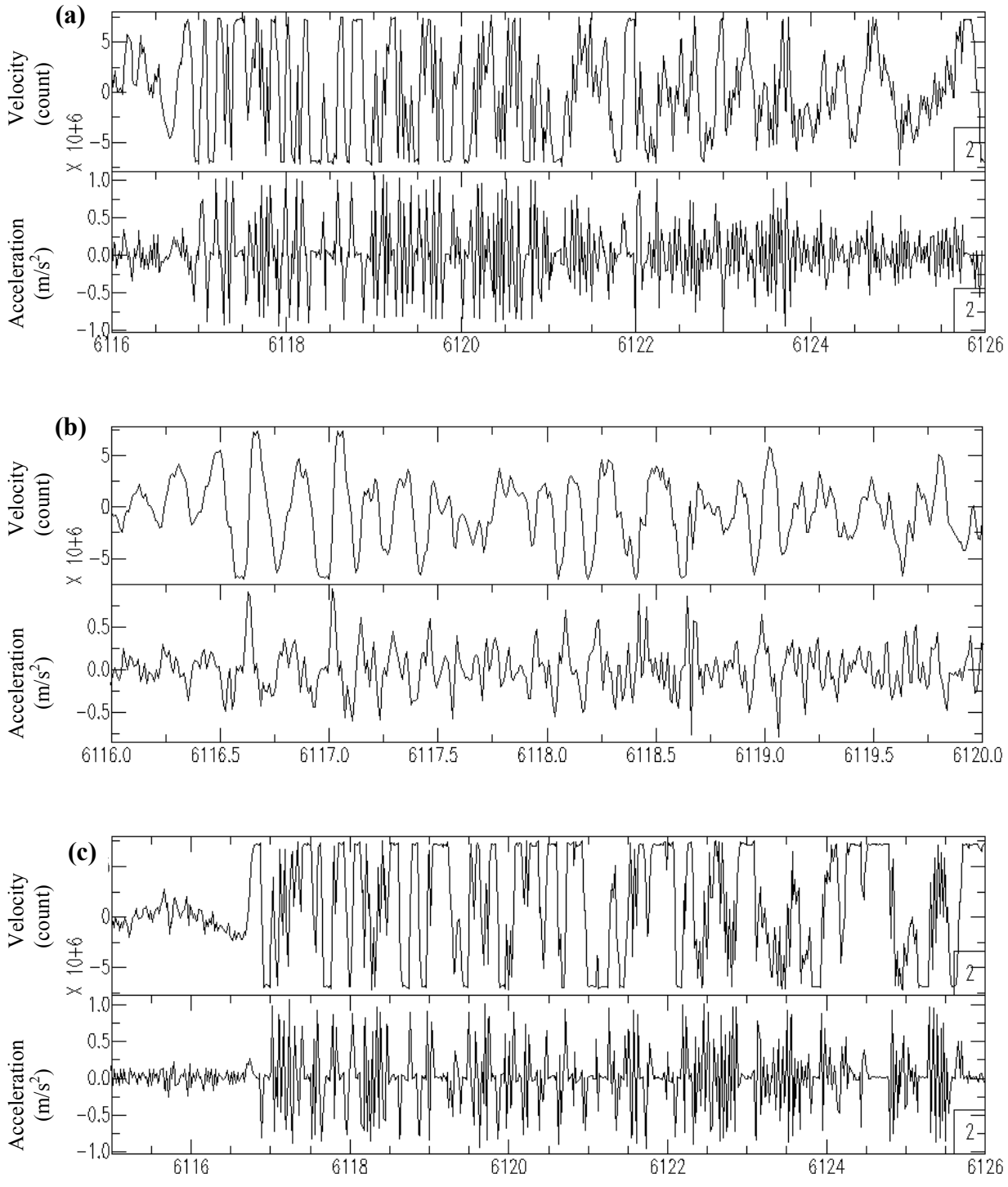


Figure 3. Illustration of clipped velocity waveforms recorded by the ORHO seismometer and the converted acceleration waveforms with the event start time of 20100623:160000, a) HHN component, b) HHZ component, c) HHE component.

APPENDIX A

ACCELERATION WAVEFORMS
(Units in m/s^2)

Station GAC, EHZ, clipped record

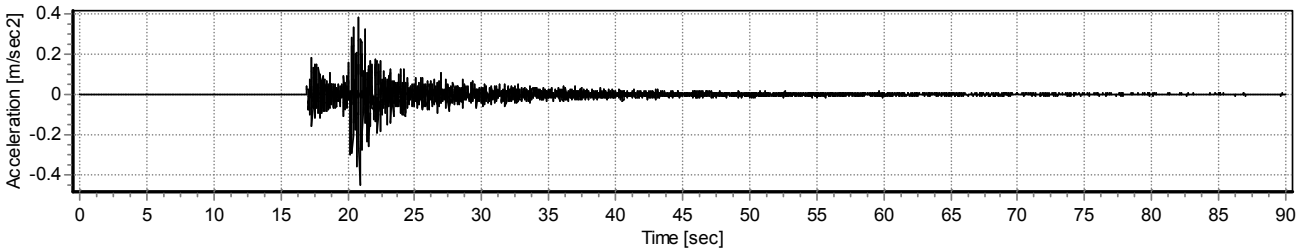
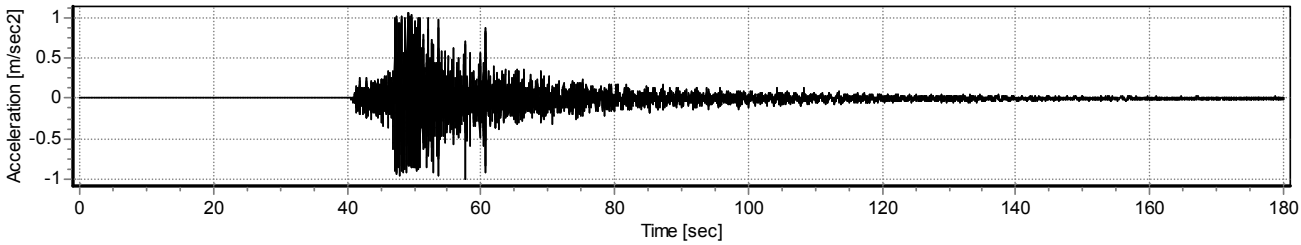


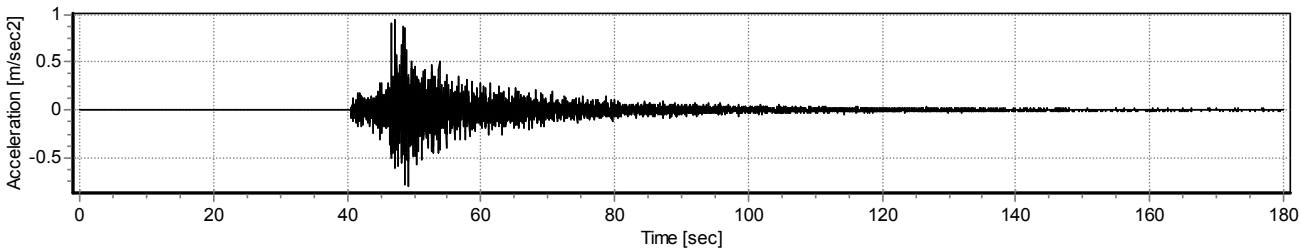
Figure A1. Acceleration waveform for EHZ component recorded by seismometer at station GAC.

Station ORHO

HHN, clipped record



HHZ, clipped record



HHE, clipped record

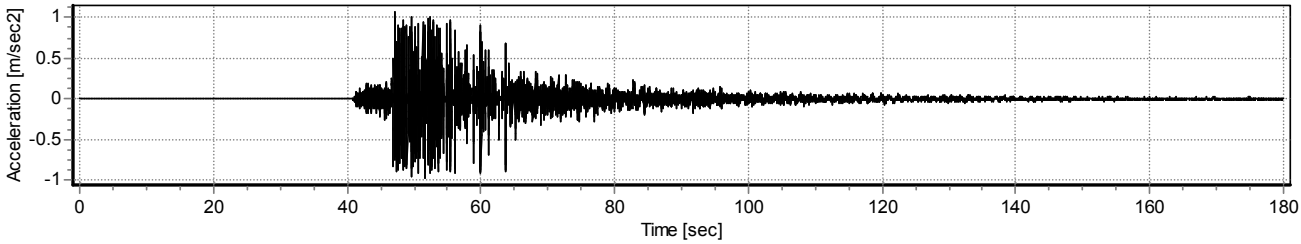
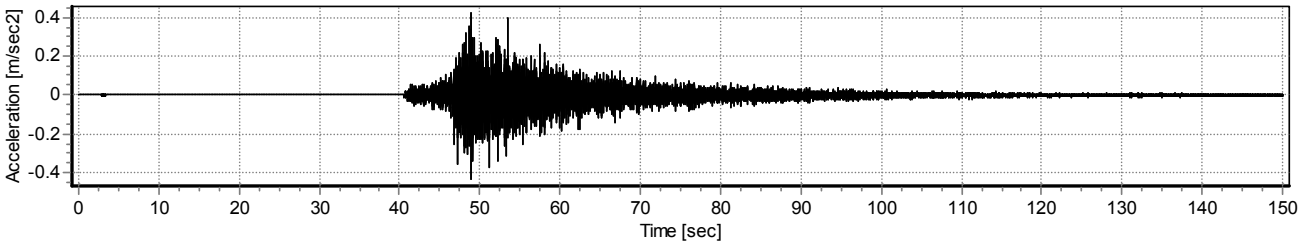


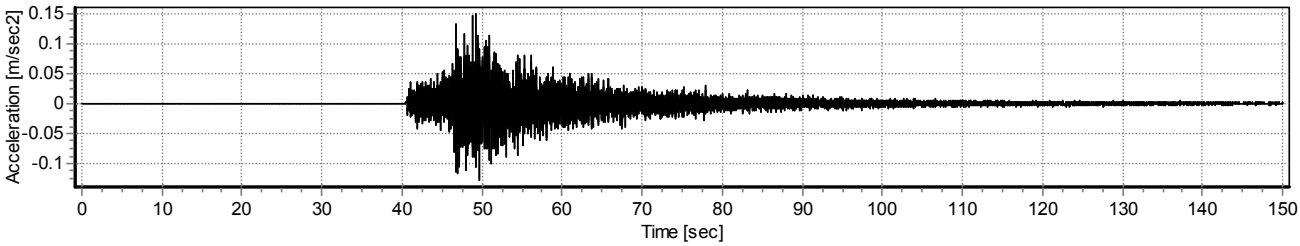
Figure A2. Acceleration waveforms for HHN, HHZ, and HHE components recorded by seismometer at station ORHO.

Station ORIO

HHN



HHZ



HHE

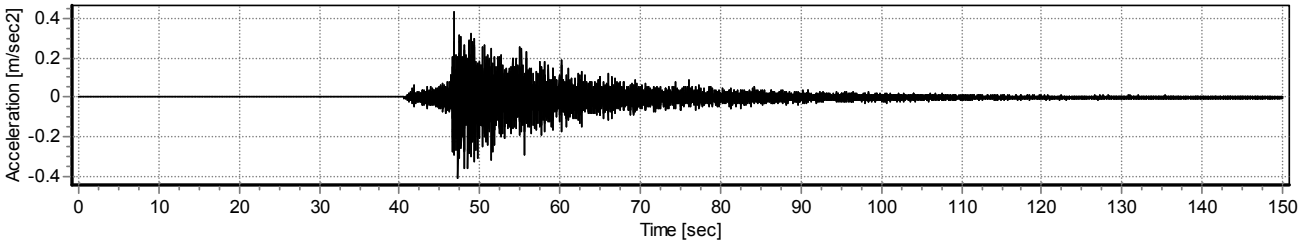
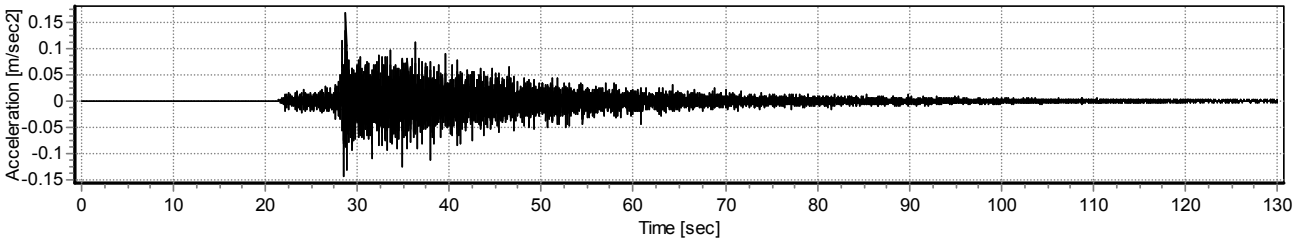


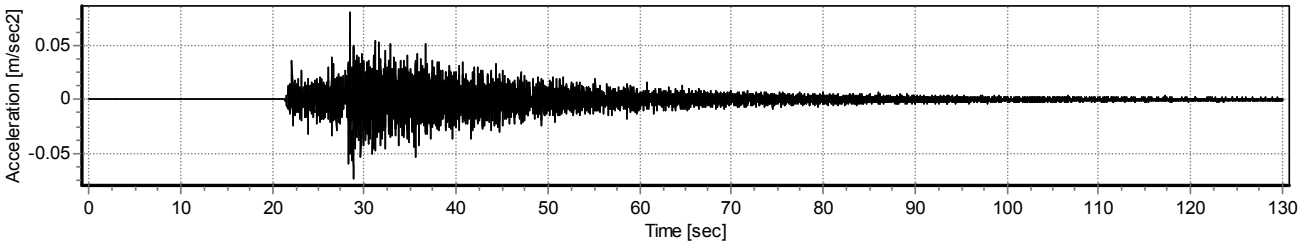
Figure A3. Acceleration waveforms for HHN, HHZ, and HHE components recorded by seismometer at station ORIO.

Station ALFO

HHN



HHZ



HHE

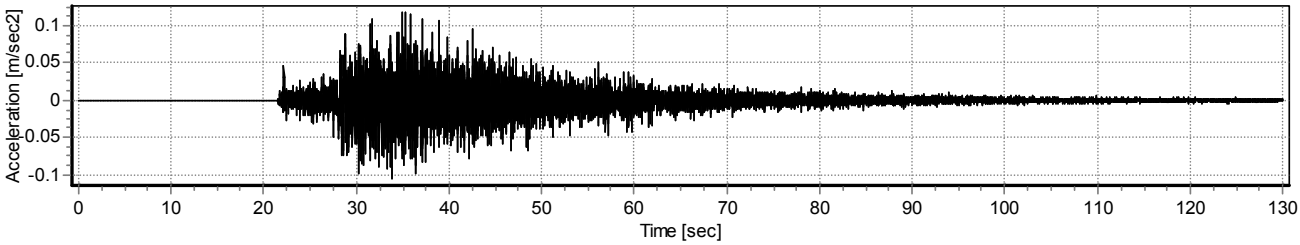
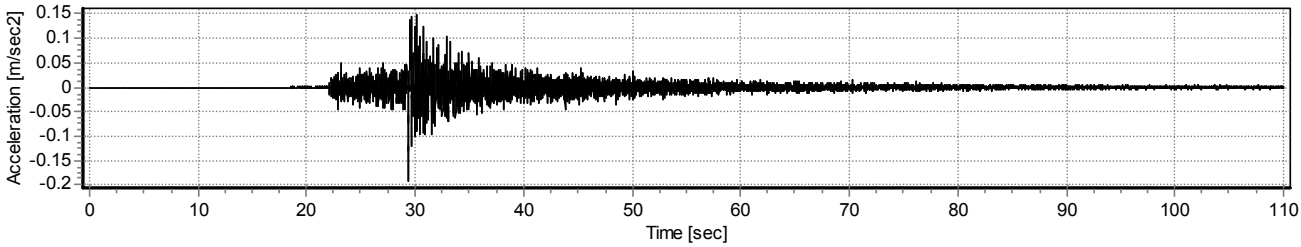


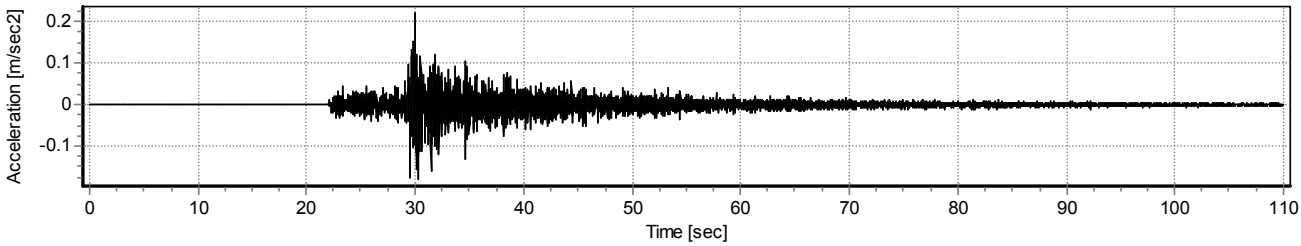
Figure A4. Acceleration waveforms for HHN, HHZ, and HHE components recorded by seismometer at station ALFO.

Station OTT

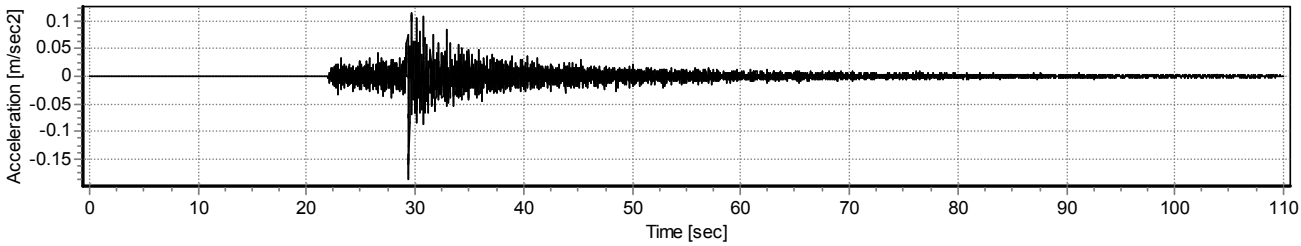
EHZ, clipped record



HHN



HHZ, clipped record



HHE, clipped record

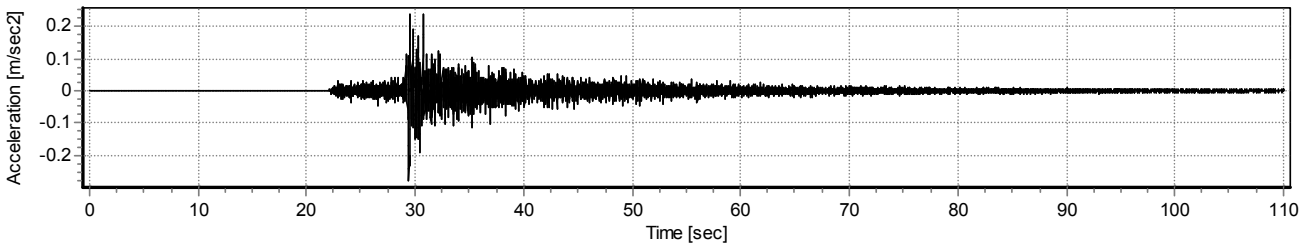


Figure A5. Acceleration waveforms of EHZ, HHN, HHZ, and HHE components recorded by seismometer at station OTT.

Station TRQ, EHZ

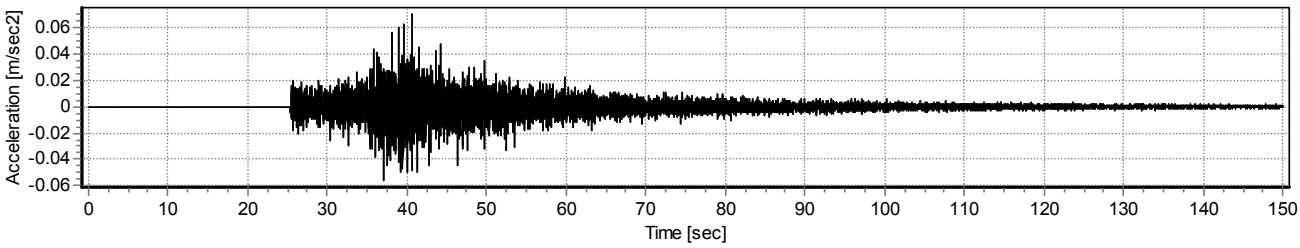


Figure A6. Acceleration waveform for EHZ component recorded by seismometer at station TRQ.

Station GRQ, EHZ wrong gain

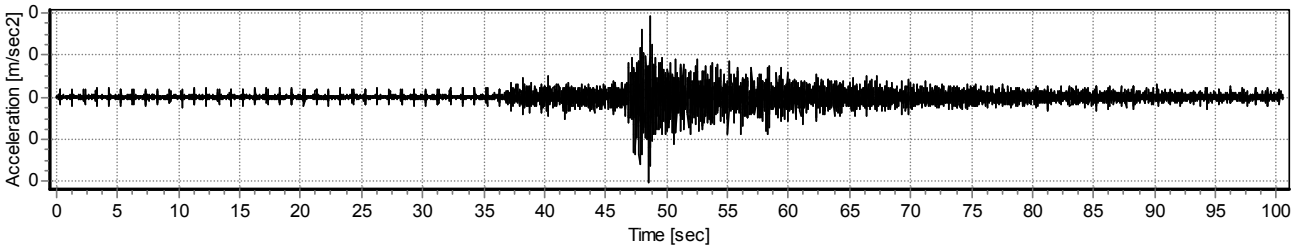


Figure A7. Acceleration waveform for EHZ component recorded by seismometer at station GRQ.

Note: Since the instrument was found to have wrong gain, please do not consider this record for further use.

Station WBO, EHZ

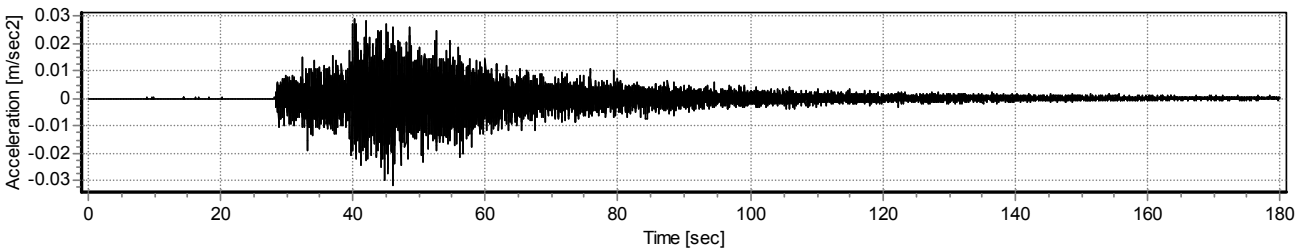
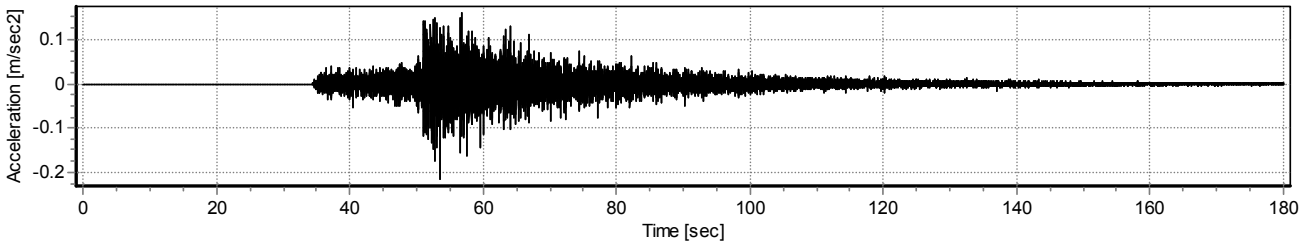


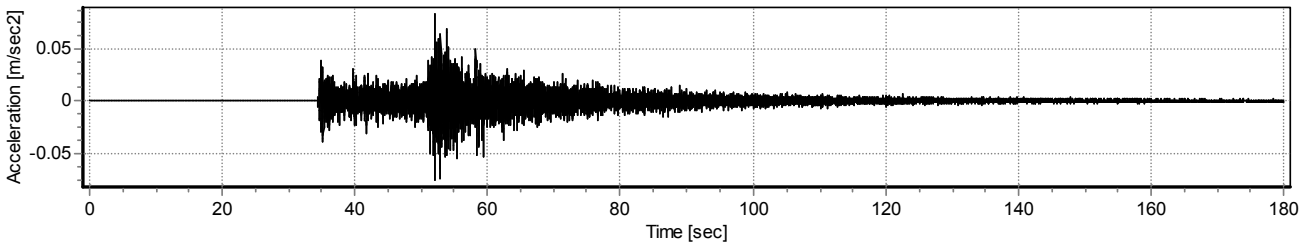
Figure A8. Acceleration waveform for EHZ component recorded by seismometer at station WBO.

Station PEMO

HHN



HHZ



HHE

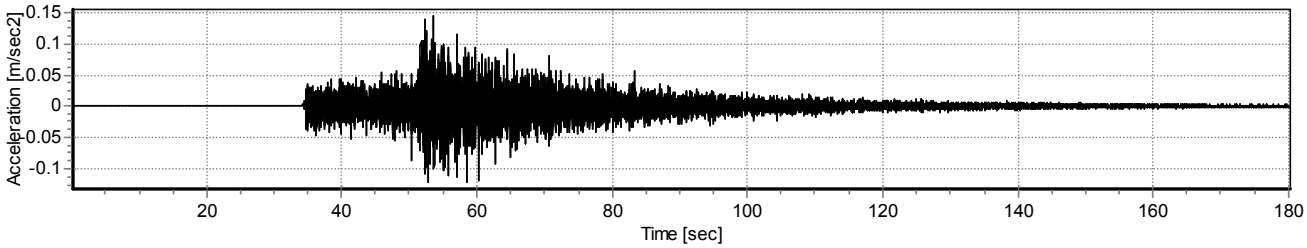


Figure A9. Acceleration waveforms for HHN, HHZ, and HHE components recorded by seismometer at station PEMO.

Station CRLO

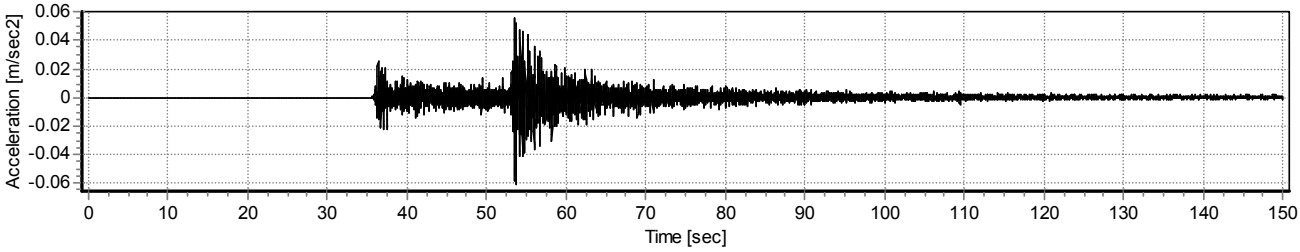
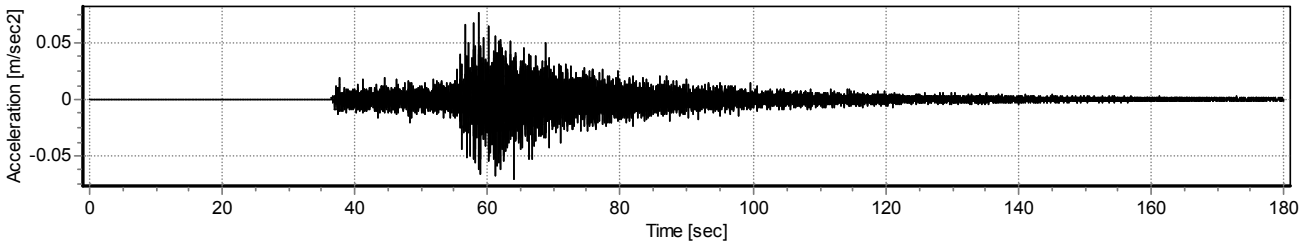


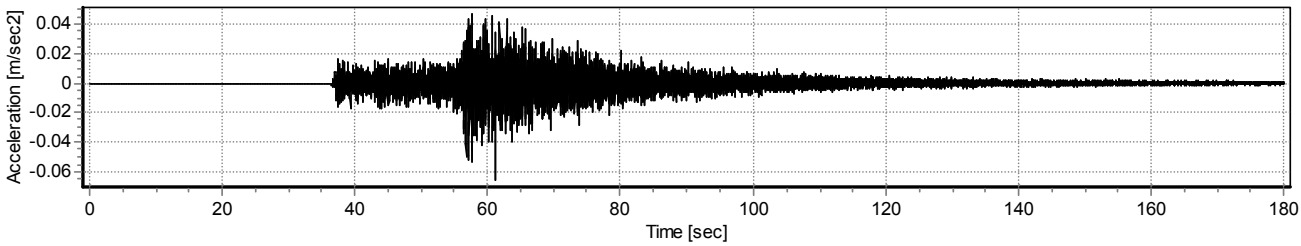
Figure A10. Acceleration waveform for EHZ component recorded by seismometer at station CRLO.

Station PLVO

HHN



HHZ



HHE

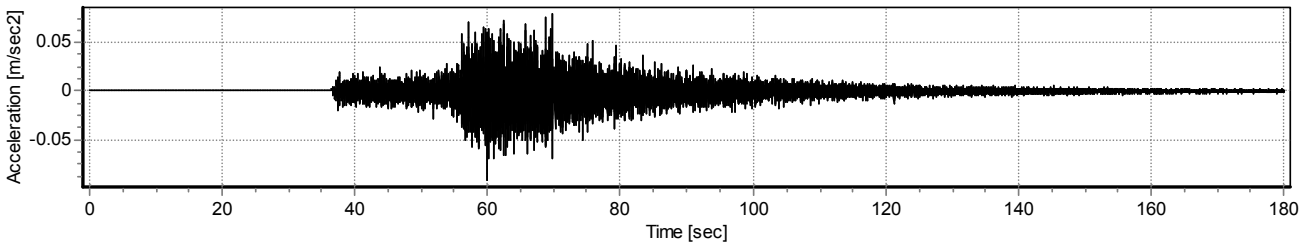


Figure A11. Acceleration waveforms for HHN, HHZ, and HHE components recorded by seismometer at station PLVO.

APPENDIX B:
EXPLANATION OF DIGITAL FILES

1. The released data along with this report are raw data, i.e. no filtering was conducted on the data.
2. The data were recorded by seismometers.
3. The data in the digital files are **accelerations**, in the units of m/s^2. The time interval for the data point is 0.01 s.
4. The record is given in a separate folder according to station code as given in Table 1 and Table 2.
5. If there is more than one component is available for a given station, then the data for each of the components are saved in subfolders by the component code shown in Table 1 and Table 2.
6. The data are given in ASCII format and SAC format.