# Strong Motion Records of the Val-des-Bois, Québec, Earthquake of June 23, 2010


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## ABSTRACT

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



## RÉSUMÉ

Ce rapport présente les analyses préliminaires des données accélérométriques enregistrées lors du séisme de magnitude moment (Mw) 5.0 du 23 juin 2010 de Val-des-Bois.

# INTRODUCTION

Records of ground motions due to earthquakes are very important for seismologists and structural engineers. They are essential for understanding the regional seismicity, the development of attenuation relations for earthquake ground motions, and for investigation of the behavior of structures subjected to ground motions.

This report presents the ground motion data recorded by Etna and IA instruments during the Val-des-Bois earthquake, which occurred on June 23, 2010 in Québec. The epicentre 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, and it occurred at a depth of 16 km. It was the biggest recent earthquake in eastern Canada, produced the some of the strongest shaking ever felt in Ottawa, was felt widely in Ontario and Québec, and was also felt into the US as far as Kentucky.

The records considered in this report were obtained by two types of instrument, Etna and Internet-accelerometer (IA). In total 39 components of ground motions were have been recovered so far from 4 Etna stations and 9 IA stations. The records were obtained at epicentral distances ranging from 50 km to 160 km. In terms of the soil condition, two records (i.e. 6 components) were obtained on bedrock (station OTT and station OT012, which are however located on the same instrument pier); while the other 11 records (i.e. 33 components) were obtained on various soil conditions.

Limited processing of the recorded data was done, which consisted of transferring the recorded data in units of acceleration, and removing the initial offset (i.e. the shift of the records from zero value). No detailed processing (including base line correction and filtering) has been done yet because of the very limited time since acquiring the records. For the purpose of using the data by researchers and practitioners, digital files of the data are released with this report.

Waveforms of all the records are illustrated in Appendix A. Detailed explanations on how to use the digital data files are given in the Appendix B. It is highly recommended that the user should read Appendix B before using the digital files.

It should be noted that this report should be considered as a preliminary report. A more detailed report containing the processed data (i.e. additional GSC records, corrected accelerograms, velocity and displacement time histories), response spectra for the accelerograms, and Fourier amplitude spectra, will be published soon. Moreover, it should be mentioned that all the records contained in this report were obtained by Geological Survey of Canada (GSC). Additional records from other sources, for example, Public Works and Government Services Canada, Hydro-Quebec and perhaps others, may be included in the final report. Also, a report containing additional strong motion data from the aftershocks will be published separately.

# AVAILABLE RECORDS FROM VAL-DES-BOIS EARTHQUAKE OF JUNE 23, 2010 (GSC-OWNED)

## Station Information

Records from Val-des-Bois earthquake were recovered from four Etna stations and nine IA stations. The deployment of the recording stations is shown on Figure 1. An additional GSC Etna at Blackburn (OTBB) did not work, and two Carleton University Etnas had been temporarily removed and so did not provide records. As seen in the figure, all four the Etna stations are located in Ottawa, and are designated OTT, OTGH, OTNM, OTRS. In terms of the nine IA stations, five are located in Ottawa (OT002, OT004, OT006, OT008, and OT012) while the other four are located in Montreal (MO001, MO002, MO003, and MO004).

Table 1 and Table 2 list the information for the stations such as station code, installation date, coordinates of stations, instrument housing (i.e. on free field or in basement of buildings), and soil conditions for Etna stations and IA stations respectively. As shown in the table, most of the instruments are installed in basements of buildings. Regarding the soil conditions, only Etna station OTT and IA station OT012 are on bedrock (on the same pier), while all the other instruments are on soil of various quality. Incomplete information will be updated in future versions of this report.

## Instrument Characteristics

For the purpose of the data processing it is important to know the characteristics of the instruments. Since the records from the Val-des-Bois earthquake are obtained by Etna and IA instruments, the characteristics of these two types of the instruments are summarized below.

### *Etna instrument*

The main characteristics of the Etna instrument are as follows:

- Data type: the data recorded by Etna are accelerations.
- Number of components recorded: Each record consists of three components of earthquake ground motions, i.e., two perpendicular horizontal components and one vertical component (V, designated Channel 2). Note that the recorded horizontal components by Etna are oriented in North-South (N-S, designated Channel 1) and in East-West (E-W, designated Channel 3) directions.
- Sampling rate: the sampling rate of the Etna instrument is 200 samples per second (i.e., the time interval of the recorded data is 0.005 s).
- Units: the data recorded by Etna are in units of Volts, note that 1.25Volt=1g.

### *IA instrument*

The main characteristics of the IA instrument are as follows:

- Data type: the data recorded by IA are accelerations.
- Number of components recorded: IA records three components of ground motions, i.e., two perpendicular horizontal components (N-S and E-W), and one vertical component (V).
- Sample rate: the sample rate used in IA is 100 per second, i.e., the time interval of the recorded data is 0.01 s.
- Units: the raw data recorded by IA are in the units of Counts. The conversion factor from count to acceleration in g is different for different components and different stations.

### Available GSC Data

As mentioned earlier, 13 records are available from the main shock of the Val-des-Bois earthquake of June 23, 2010, four of which were obtained by Etna instruments and nine by IA instruments. Since each record consists of three components (i.e., two horizontal perpendicular components and one vertical component) as described above, in total 39 components are available from this earthquake. Note that all these are GSC records, i.e., they were obtained by the instruments of the earthquake monitoring network operated by GSC.

The records are listed in Table 3. It is seen in the table that Re1 to Re4 are Etna records while Re5 to Re13 are IA records. As shown in the table, the records were obtained at epicentral distances between 47 km and 158 km (hypocentral distances between 59 km and 159 km. Records Re1 and Re9 were obtained on bedrock, and all other records were obtained on soil, i.e., alluvium, clay, silt or sand.

## PRELIMINARY RESULTS

### Peak ground motions

The peak ground accelerations (PGA) of the records are shown in Table 4. It can be seen in the table that the maximum PGA value of the records obtained on bedrock is about 3% g. The maximum PGA value of the records obtained on the soft soil is about 7% g, which indicates significant effects of the soft soil on the ground motions. The minimum PGA value for the records is about 0.3% corresponding to the data obtained at the stations located in Montreal. Such small PGA values recorded in Montreal were not surprising since the stations are quite far from the epicentre of the event (about 160 km, see Table 3) compared with the data collected in Ottawa, which is about 50 km from the epicentre.

**Response spectra**

Since the Val-des-Bois earthquake is a quite large event for eastern Canada, it is useful to compare the response spectra for the records with the design spectra prescribed by the National Building Code of Canada (NBCC 2005). For illustration, the response spectra of the horizontal components of record Re9 are shown in Figure 2 (both linear- and log-scale versions of the same data are shown); this record was selected since it was recorded on bedrock (see Table 3). The design spectra for Ottawa, for soil class A (hard rock) and soil class C (very dense soil and soft rock) are included in the figure. Note that the design spectra correspond to probability of exceedance of 2% in 50 years. It is seen from the figure that the design spectra are well above the computed spectra, i.e. the soil class A spectrum by a factor of about 5 and the soil class C spectrum by a factor of about 6.5 for periods below 0.2 s.

## SUMMARY

This preliminary report describes the ground motion records from the Val-des-Bois earthquake of June 23, 2010. In total 39 ground motions components were recorded during this earthquake by the instruments of the GSC ground motion monitoring network. Among the recorded components, six components (Re1 and Re9) were obtained on bedrock while all the other components were obtained on soft soil such as alluvium, clay and silt.

Because of the very limited time, only the main characteristics of the motions have been presented in this report. More detailed information will be included in the final report which will be released in near future.

Table 1. List of Etna stations with available records from the Val-des-Bois earthquake.

| No. | Station Code | Installation Date | Station Name | Coordinates | Elevation (m) | Instrument Housing | Soil Condition |
|---|---|---|---|---|---|---|---|
| 1 | OTT | 2002/02/27 | Ottawa, Ontario | 45.3942 N 75.7167 W | 77 | Underground seismic vault | Bedrock |
| 2 | OTGH | 2001/12/18 | Ottawa, Ontario | 45.4014 N 75.6969 W | 74 | Basement, 4-storey masonry building, Glebe High School | Thin soil |
| 3 | OTNM | 2003/06/11 | Ottawa, Ontario | 45.4121 N 75.6891 W | 72 | Basement, 4-storey mansory/steel building, Canadian Museum of Nature | Soil |
| 4 | OTRS | 2002/05/15 | Orleans, Ontario | 45.4603 N 75.4962 W | 90 | Basement, 2-storey wood building | Soil |

Table 2. List of IA stations with available records from the Val-des-Bois earthquake.

| No. | Station Code | Installation Date | Station Name | Coordinates | Elevation(m) | Instrument Housing | Soil Condition | Thickness(m) |
|---|---|---|---|---|---|---|---|---|
| 1 | OT002 | 2005/03/24 | Ottawa, Ontario | 45.4742 N 75.5019 W | 84 | Basement, 2-storey wood house | Clay | |
| 2 | OT004 | 2005/03/24 | Ottawa, Ontario | 45.3644 N 75.7746 W | 78 | Basement, 2-storey wood house | Clay or Till | |
| 3 | OT006 | 2006/03/03 | Ottawa, Ontario | 45.4292 N 75.6500 W | 68 | Basement, 1-story wood house | | |
| 4 | OT008 | 2005/06/29 | Ottawa, Ontario | 45.3496 N 75.6418 W | 80 | Basement, 2-storey wood house | Sand | |
| 5 | OT012 | 2001/09/24 | Ottawa, Ontario | 45.3942 N 75.7167 W | 77 | Underground seismic vault | Bedrock | |
| 6 | MO001 | 2009/10/01 | Montreal, Québec | 45.5099 N 73.5534 W | 61 | | Clay | 5 |
| 7 | MO002 | 2009/10/01 | Montreal, Québec | 45.4962 N 73.5533 W | 26 | | Sand | 20 |
| 8 | MO003 | 2009/10/01 | Montreal, Québec | 45.5430 N 73.5714 W | 52 | | Remblais | 10 |
| 9 | MO004 | 2009/10/01 | Montreal, Québec | 45.5125 N 73.5841 W | 84 | | Bedrock ? | |

Note: blank fields will be supplied in later versions.

Table 3. List of the records from the Val-des-Bois earthquake (hypocentral depth = 16 km).

| Record ID | Station Code | Recording Instrument | Station Coordinates | | Epicentral Distance (km) | Hypocentral Distance (km) | Azimuth (degree) | Soil Condition |
|---|---|---|---|---|---|---|---|---|
| Re1 | OTT | Etna | 45.3942 N | 75.7167 W | 58.7 | 60.8 | 196.8 | Bedrock |
| Re2 | OTGH | Etna | 45.4014 N | 75.6969 W | 57.5 | 59.7 | 195.5 | Thin soil |
| Re3 | OTNM | Etna | 45.4121 N | 75.6891 W | 56.2 | 58.4 | 195.2 | Soil |
| Re4 | OTRS | Etna | 45.4603 N | 75.4962 W | 48.9 | 51.5 | 179.7 | Soil |
| Re5 | OT002 | IA | 45.4742 N | 75.5019 W | 47.3 | 49.9 | 180.2 | Clay |
| Re6 | OT004 | IA | 45.3644 N | 75.7746 W | 63.3 | 65.3 | 199.8 | Clay or Till |
| Re7 | OT006 | IA | 45.4292 N | 75.6500 W | 53.6 | 55.9 | 192.6 | |
| Re8 | OT008 | IA | 45.3496 N | 75.6418 W | 62.2 | 64.2 | 190.3 | Sand |
| Re9 | OT012 | IA | 45.3942 N | 75.7167 W | 58.7 | 60.8 | 196.8 | Bedrock |
| Re10 | MO001 | IA | 45.5099 N | 73.5534 W | 157.2 | 158.0 | 105.3 | |
| Re11 | MO002 | IA | 45.4962 N | 73.5533 W | 157.7 | 158.5 | 105.8 | |
| Re12 | MO003 | IA | 45.5430 N | 73.5714 W | 154.9 | 155.7 | 104.2 | |
| Re13 | MO004 | IA | 45.5125 N | 73.5841 W | 154.9 | 155.7 | 105.5 | |

Table 4. List of PGA values of the records from the Val-des-Bois earthquake (units = g).

| Record ID | Station Code | Recording Instrument | N-S component | V component | E-W component | Soil Condition |
|---|---|---|---|---|---|---|
| Re1 | OTT | Etna | 0.03 | 0.03 | 0.03* | Bedrock |
| Re2 | OTGH | Etna | 0.04 | 0.02 | 0.06 | Thin soil |
| Re3 | OTNM | Etna | 0.04 | 0.08 | 0.08 | Soil |
| Re4 | OTRS | Etna | 0.06 | 0.06 | 0.06 | Soil |
| Re5 | OT002 | IA | 0.05 | 0.05 | 0.07 | Clay |
| Re6 | OT004 | IA | 0.05 | 0.06 | 0.06 | Clay or Till |
| Re7 | OT006 | IA | 0.04 | 0.03 | 0.06 | |
| Re8 | OT008 | IA | 0.06 | 0.04 | 0.06 | Sand |
| Re9 | OT012 | IA | 0.03 | 0.03 | 0.03 | Bedrock |
| Re10 | MO001 | IA | 0.008 | 0.009 | 0.007 | |
| Re11 | MO002 | IA | 0.008 | 0.004 | 0.005 | |
| Re12 | MO003 | IA | 0.005 | 0.003 | 0.004 | |
| Re13 | MO004 | IA | 0.003 | 0.003 | 0.003 | |

* The number in red gives the maximum PGA for horizontal components.

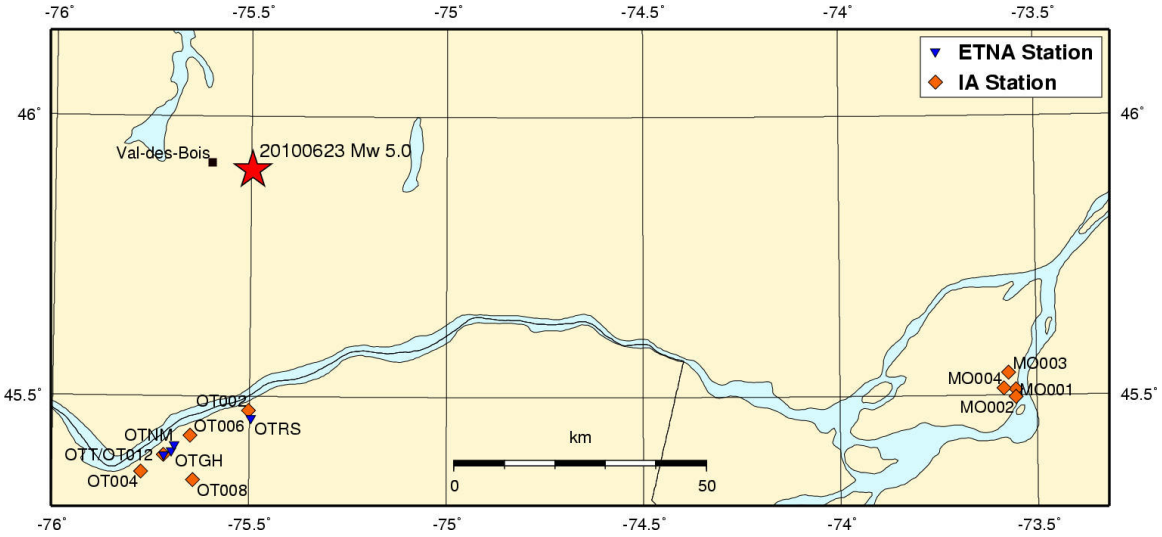


Figure 1. The locations of the stations with recovered records from the Val-des-Bois earthquake.

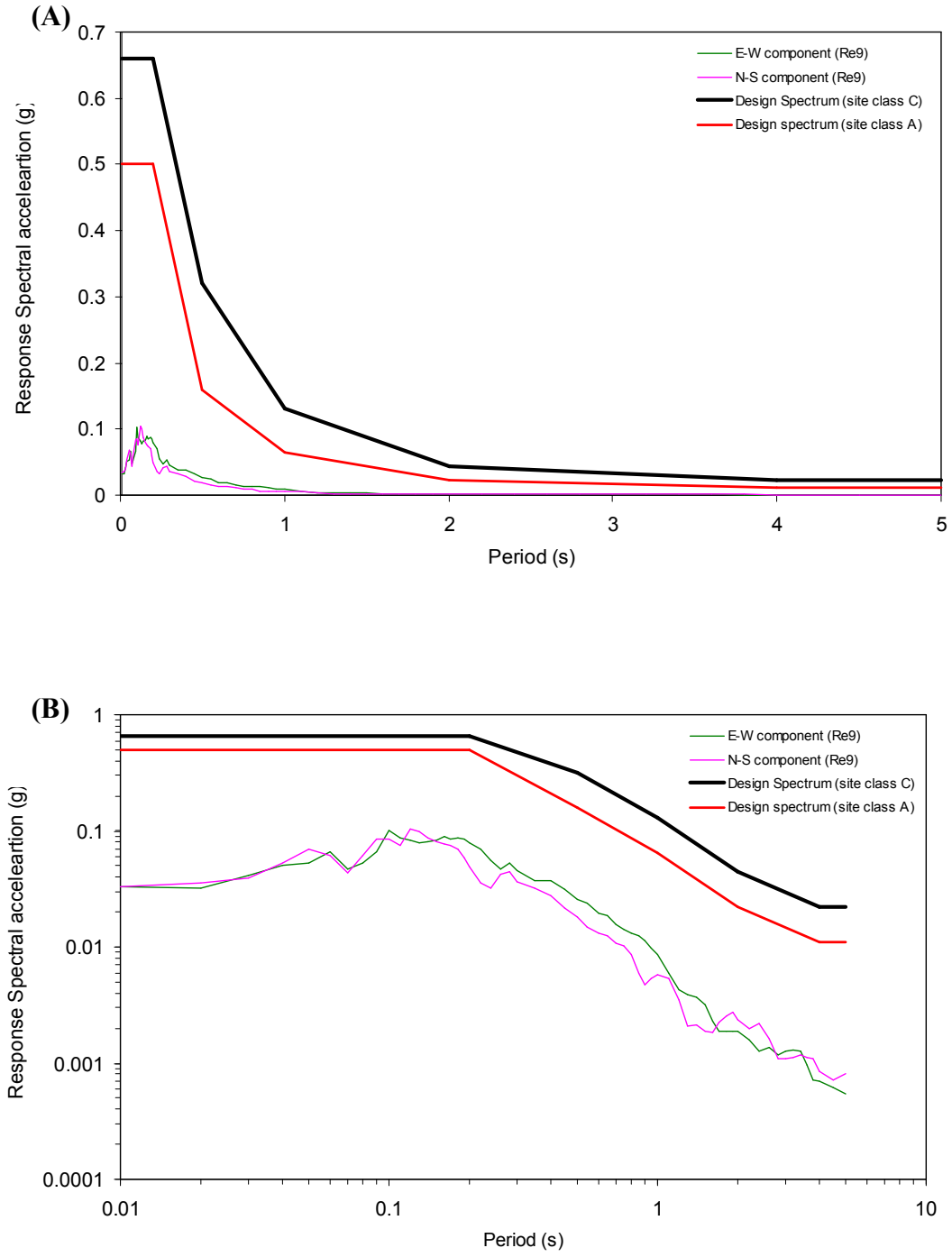


Figure 2. Comparison of the response spectra recorded at OTT on rock (record Re9) with the design spectra for Site Class A and C at Ottawa, according to National Building Code of Canada 2005, shown on (A) linear scale, (B) log-log scale.

# APPENDIX A: ACCELERATION WAVEFORMS (UNIT: g)

## Re1 (station OTT)

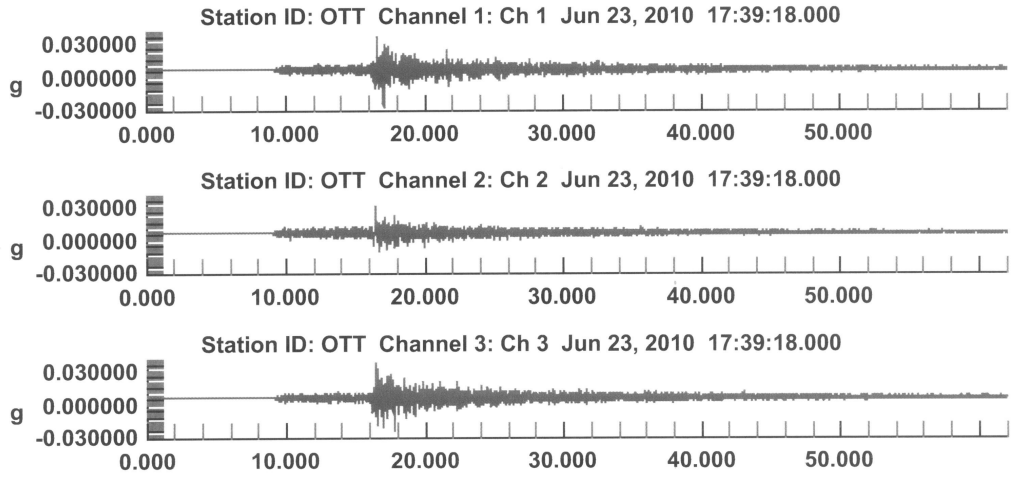


Figure 1. Acceleration waveforms for the N-S component, Vertical component, and E-W component for record Re1.

# Re2 (station OTGH)

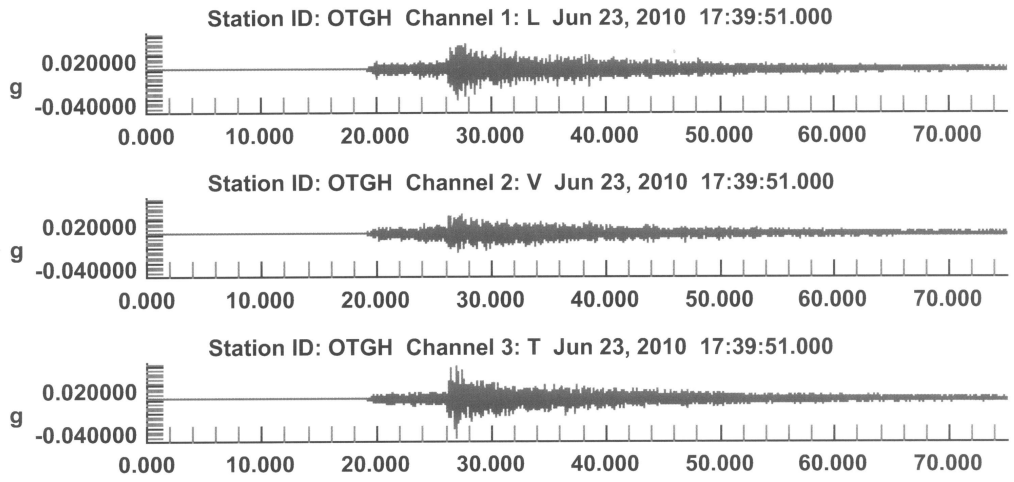


Figure 2. Acceleration waveforms for the N-S component, Vertical component, and E-W component for record Re2.

# Re3 (station OTNM)

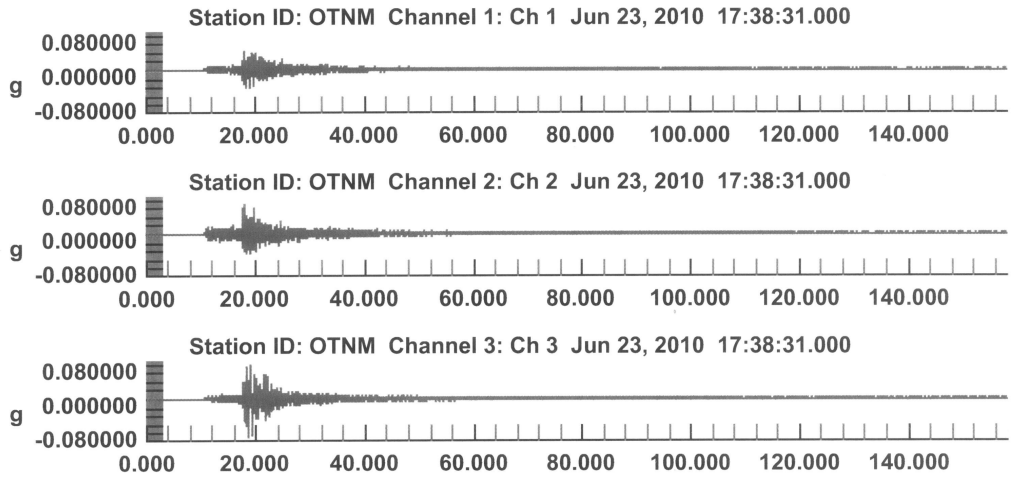


Figure 3. Acceleration waveforms for the N-S component, Vertical component, and E-W component for record Re3.

# Re4 (station OTRS)

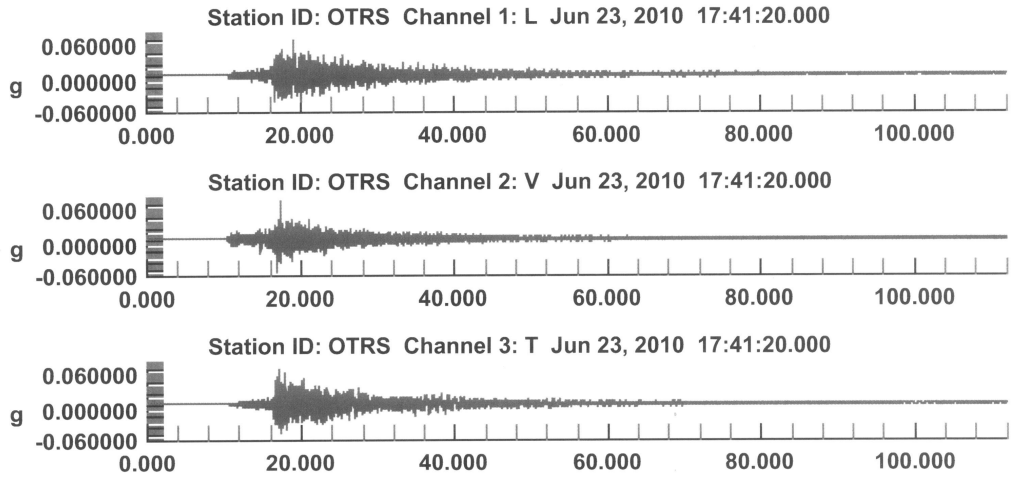


Figure 4. Acceleration waveforms for the N-S component, Vertical component, and E-W component for record Re4.

## Re5 (station OT002)

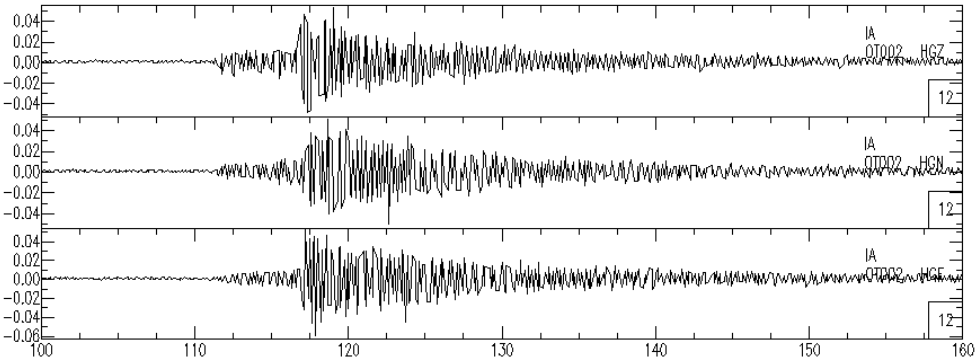


Figure 5. Acceleration waveforms for the Vertical component, N-S component, and E-W component for record Re5.

## Re6 (station OT004)

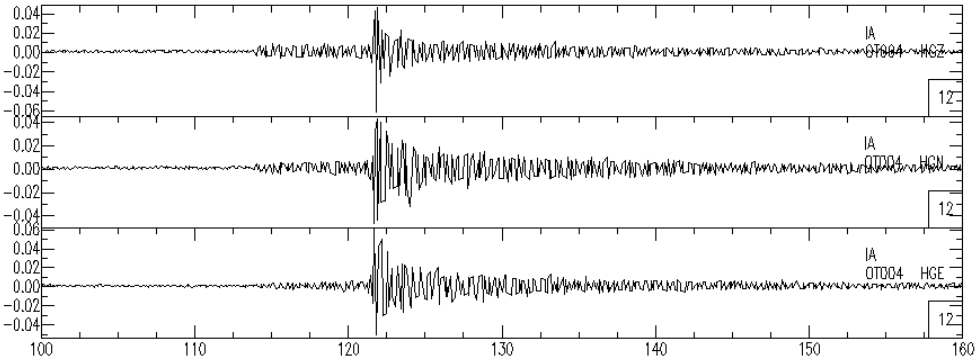


Figure 6. Acceleration waveforms for the Vertical component, N-S component, and E-W component for record Re6.

## Re7 (station OT006)

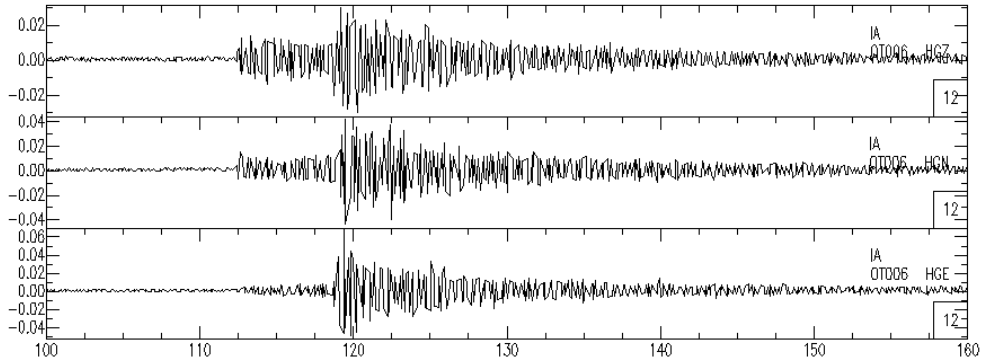


Figure 7. Acceleration waveforms for the Vertical component, N-S component, and E-W component for record Re7.

## Re8 (station OT008)

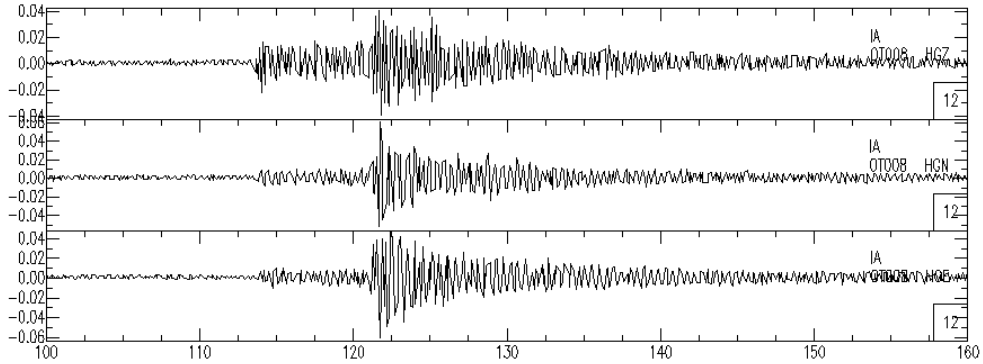


Figure 8. Acceleration waveforms for the Vertical component, N-S component, and E-W component for record Re8.

## Re9 (station OT012)

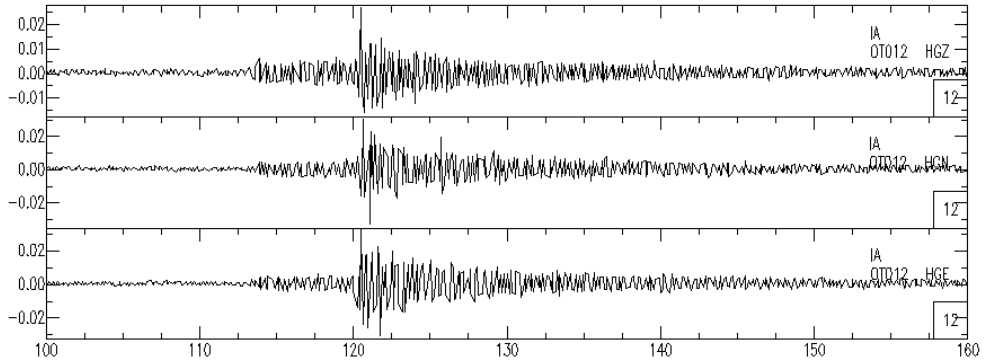


Figure 9. Acceleration waveforms for the Vertical component, N-S component, and E-W component for record Re9.

## Re10 (station MO001)

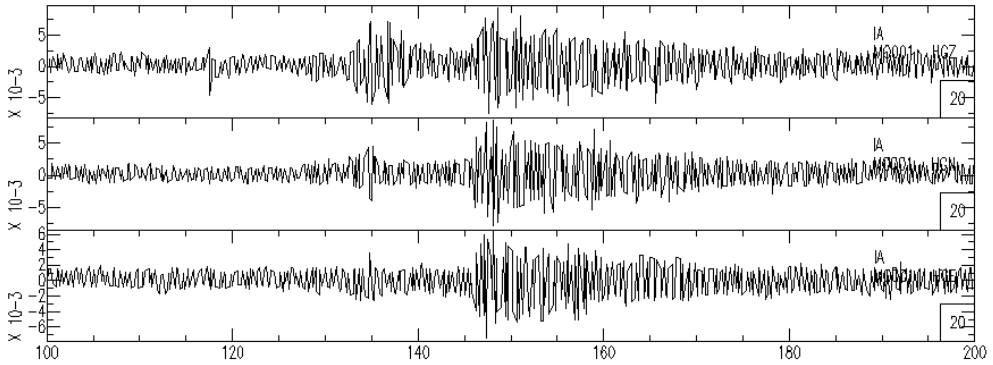


Figure 10. Acceleration waveforms for the Vertical component, N-S component, and E-W component for record Re10.

## Re11 (station MO002)

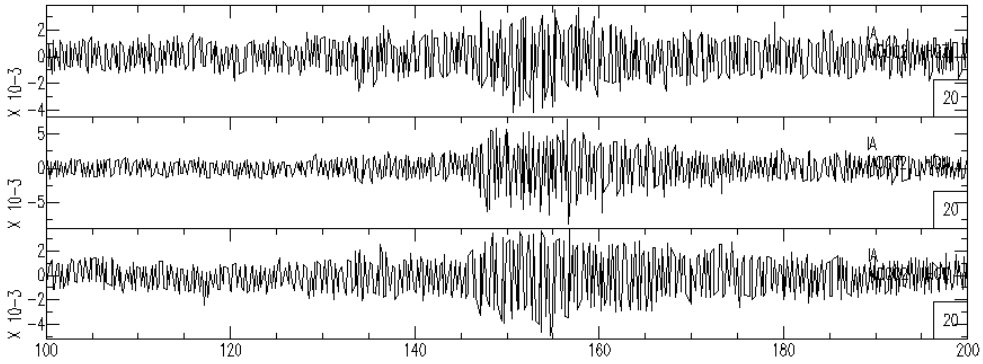


Figure 11. Acceleration waveforms for the Vertical component, N-S component, and E-W component for record Re11.

## Re12 (station MO003)

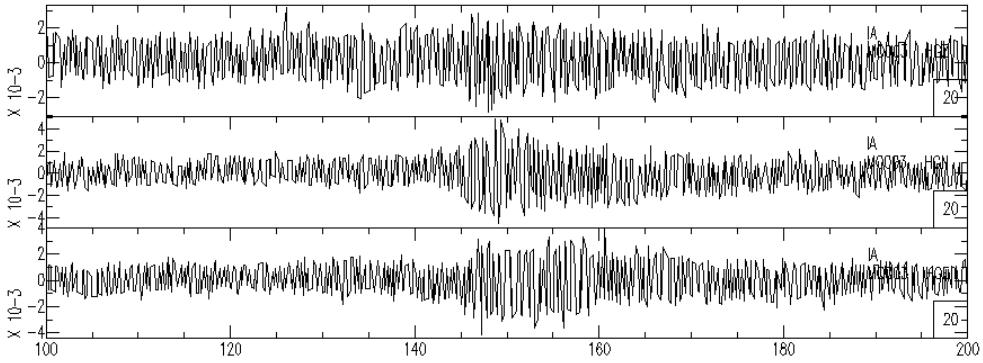


Figure 12. Acceleration waveforms for the Vertical component, N-S component, and E-W component for record Re12.

# Re13 (station MO004)

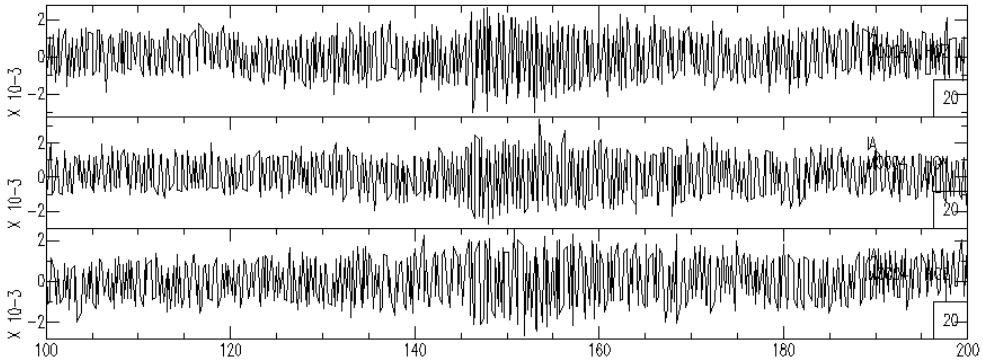


Figure 13. Acceleration waveforms for the Vertical component, N-S component, and E-W component for record Re13.

# APPENDIX B:
# EXPLANATION OF DIGITAL FILES

1. The released data along with this preliminary report are raw data.
2. The record is given in a separate folder according to the Record ID as given in Table 3 and Table 4.
3. **For the Etna data** (records Re1, Re2, Re3, and Re4)
    - There are two subfolders under each of the main folders which are called EVT FILE and ASCII Files.
    - The .EVT file in the folder of the EVT FILE is the original data file generated by Etna instrument automatically when it starts to record ground motions.
    - The ASCII files in the folder of ASCII FILES gives the data in ASCII format converted from the corresponding .evt file. The ASCII file with the extension of .001 gives the data for the N-S component, .002 file gives the data for the Vertical component, and .003 file gives the data for the E-W component.
    - The units for the Etna data in both folders are Volts, 1.25Volt=1g.
    - The sample rate for the data is 200 samples/second.
4. **For the IA data** (records Re5 to Re13)
    - There are also three subfolders under each of the main folders. They are called HGE, HGN, and HGZ which provides the data for E-W component, N-S component, and Vertical component respectively.
    - Under the folder of HGE, HGN, and HGZ, there are two subfolders called SAC FILE and ASCII FILE.
    - The file in the folder of SAC FILE provides the data in SAC format. This format is mainly used by seismologists.
    - The file in the folder of ASCII FILE gives the data in ASCII format.
    - The units for the IA data are g.
    - The sample rate for the data is 100 samples/second.