Leo Brady Seismic Network Legacy Data

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1. INTRODUCTION

For several years, Sandia National Laboratories (SNL) has been digitizing legacy magnetic tapes containing analog seismic waveforms from historical U.S. underground nuclear explosive tests at the Nevada Test Site (NTS) recorded by the Leo Brady Seismic Network (LBSN). This process involves three steps:

1. Digitizing the tapes into a raw binary form
2. Recovery of waveforms from the digitized tapes
3. Calibration of recovered waveforms

Because these tapes are very old and slowly physically decaying, with some dating back more than 60 years, a digitize-first-and-calibrate-later approach has been taken in order to give priority to the preservation of these data, with the expectation that mass waveform recovery/calibration can occur at some later date. Further information on this recovery process may be found in Young & Abbott (2020).

2. FILE/FOLDER SUMMARY

This package contains 1,297 newly digitized and recovered seismic waveforms of historical U.S. underground nuclear explosive tests recorded by the LBSN, the first such release of these data. Calibrated short-period data, and uncalibrated wideband and long-period data, are included from the following events:

1966-02-24	REX	1968-03-14	POMMARD	1969-10-29	CALABASH
1967-01-19	NASH	1968-04-26	BOXCAR	1970-03-06	CYATHUS
1967-05-26	KNICKERBOCKER	1968-12-08	SCHOONER	1970-04-21	SNUBBER
1967-06-29	UMBER	1968-12-19	BENHAM	1970-12-17	CARPETBAG
1967-09-21	MARVEL	1969-09-10	RULISON	1971-07-08	MINIATA
1968-01-18	HUPMOBILE	1969-10-29	CRUET	1972-09-26	DELPHINIUM
1968-01-26	CABRIOLET	1969-10-29	POD		

These events were chosen at random, with no specific priority, among tapes for events which had already been digitized though the waveforms were not yet recovered or calibrated, from U.S. underground nuclear explosive tests with publicly disclosed explosive yields. All event metadata, such as name and date, has been copied from the DOE/NV-209 (Rev. 16) document (Nevada Field Office, 2015). Any discrepancy between that document and these data should be assumed to be inadvertent, with DOE/NV-209 metadata taking precedence.

The events are organized into the following file/folder structure, using BOXCAR as an example:

```
1968-04-26.6819.Boxcar
├── 6819_seismic_activity_report.pdf
├── Ampex_6819-1
│   └── miniseeds
│       ├── LB.LDS.05.RSP.mseed
│       ├── LB.LDS.01.TSP.mseed
│       ├── LB.LDS.05.VSP.mseed
┆       ┆
│       ├── RESP.LB.LDS.05.RSP
│       ├── RESP.LB.LDS.01.TSP
│       └── RESP.LB.LDS.05.VSP
├── Ampex_6819-2
│   └── miniseeds
│       ├── LB.DAC.01.RSP.mseed
│       ├── LB.DAC.01.TSP.mseed
│       ├── LB.DAC.01.VSP.mseed
┆       ┆
┆       ├── RESP.LB.DAC.01.RSP
┆       ├── RESP.LB.DAC.01.TSP
┆       └── RESP.LB.DAC.01.VSP
```

3. NAMING CONVENTIONS

At the top level, the event folders are named following a format of `yyyy-mm-dd.YYXX.event_name`, where `yyyy`, `mm`, and `dd` indicate the year, month, and day of the event, and `YYXX` is a historical event ID used internally at SNL until the end of testing in 1992; `YY` indicates the two-digit year, and `XX` indicates the Nth event recorded by SNL in that year. BOXCAR has event ID 6819, indicating it was the 19th event recorded by SNL in 1968.

Inside of each event folder there is a PDF file of the "seismic activity report", which are scans of the field notes originally taken for that particular event. These field notes contain information related to frequency modulation and multiplexing of various instrument channels onto each tape track, as well as other miscellaneous notes such as information about instrument calibration, tape start/stop times, and sometimes the rough first-arrival time of event seismic signals.

Within the event folders you will also find "`Ampex_YYXX`" folders. LBSN data were always recorded onto one or two Ampex tapes. In the early 1960s, Crown-type tapes were also sparingly used, but at this time waveform recovery has only been completed for Ampex-type tapes. Within these Ampex folders are miniSEED files and, where available, RESP instrument response files corresponding to some of the miniSEED files. The miniSEED and RESP files adhere to the SEED standard (Ahern et al., 2012) and can be read with standard seismology software packages such as ObsPy (Beyreuther et al., 2010).

The naming and metadata convention for the miniSEED files is:

```
network.station.location.channel.mseed
```

The *network* name for all data is "LB", which stands for "Leo Brady." The *station* names follow the format below:

Table 3-1. Seismic Station Metadata

Code	Station	Latitude	Longitude	Elevation (m)
BMN	Boulder City, NV	35.980833	-114.833889	780
DAC	Darwin, CA	36.276944	-117.593611	1581
TPH	Tonopah, NV	38.075000	-117.222500	1907
NLS	Nelson, NV	35.712222	-114.843333	1059
BMN	Battle Mountain, NV	40.431389	-117.221667	1517
ELY	Ely, NV	39.131667	-114.892222	2302
LDS	Leeds, UT	37.242500	-113.351389	1088

Location and *channel* names adhere as closely as possible to the instrument names provided in the *seismic activity logs*. For example, very common instrument names within the historical LBSN data include: VSP×1 VSP÷5, and VSP÷25; as well as HWB-1, HWB-2, HWB-3, and HWB-4. The VSP and HWB acronyms stand for "vertical short-period" and "horizontal wideband", respectively. For short-period stations, the numbers represent attenuator/gain settings. Each seismic instrument usually recorded into multiple channels with different gain/attenuation settings to prevent clipping. The 1, 2, 3, and 4 suffixes on the HWB channels are just sequential numbers for ID purposes, but those channels also each had different gain/attenuation settings. For further information on this system, see Young and Abbott (2020). A list of all unique channel names is given below:

Table 3-2. Channel Names

Code	Instrument Type	Code	Instrument Type
VSP	Vertical Short-period	VLP	Vertical Long-period
RSP	Radial Short-period	NLP	North-South Long-period
TSP	Tangential Short-period	ELP	East-West Long-period
VWB	Vertical Wideband	AR	Accelerometer Radial
RWB	Radial Wideband	AT	Accelerometer Transverse
TWB	Tangential Wideband	AV	Accelerometer Vertical
HWB	Horizontal Wideband (assumed to be radial)		

4. CALIBRATION AND DATA QUALITY

Though waveforms for all channels have been recovered and exported to miniSEED files, not all short-period channels have associated RESP files. Instead, RESP files have been written only for the most suitable channels. For example, data from the ×1 channels are very frequently badly clipped, and the signal-to-noise on the ÷25 channels is usually quite poor. In most cases, the ÷5 channel provides the best signal without clipping. In some cases where there are no clear "best" channel, RESP files for multiple location codes for the same instrument have been created. These gain and attenuator settings have been taken into account in the RESP instrument response files.

Quality of the waveforms varies from very good to very poor. Nevertheless, these are the best available data from these very old seismic events. A few samples are shown below for demonstrative purposes. Note that the time axis is typically given in U.S. Pacific Time (UTC –8 or –7, depending on observance of Daylight Savings Time).

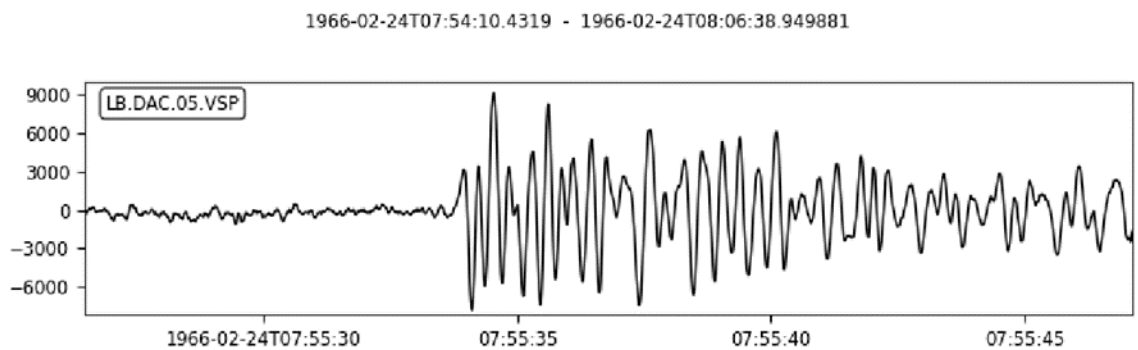

Figure 4-1. REX event (1966)

Sample of the VSP÷5 channel recorded at Darwin, CA of the REX event (1966). Data quality is generally good.

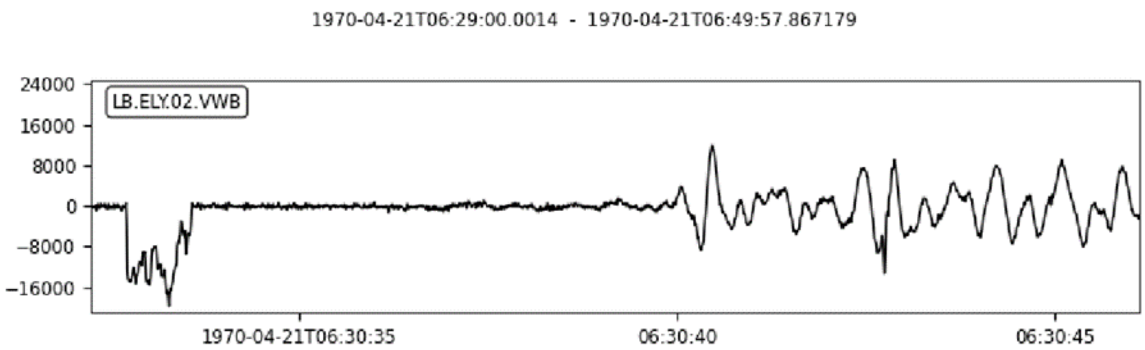

Figure 4-2. SNUBBER event (1970)

Sample of the VWB-2 channel recorded at Ely, NV of the SNUBBER event (1970). There is noticeable tape drop-out before first-arriving seismic energy and also a noise spike at approximately 06:30:43.

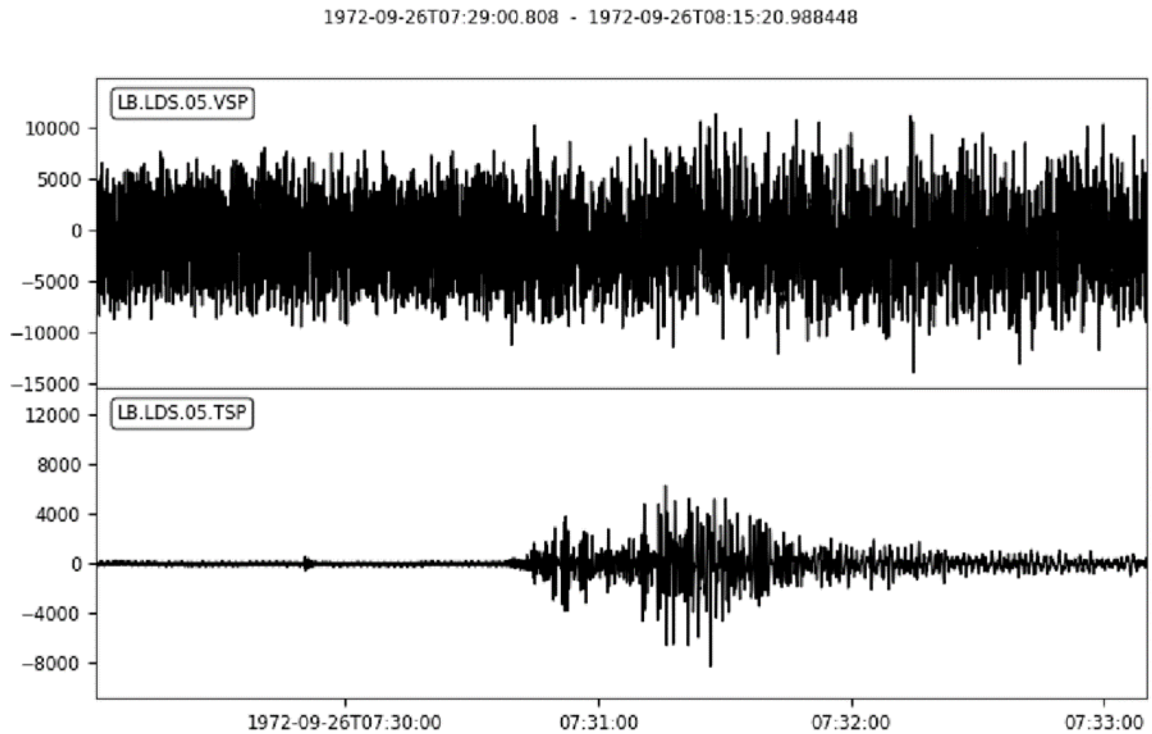

Figure 4-3. DELPHINIUM event (1972)

Sample of the VSP÷5 and TSP÷5 channels recorded at Leeds, UT of the DELPHINIUM event (1972). The waveform was well-recorded on the TSP channel, but the VSP channel is extremely noisy.

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