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## THE 1988-89 PASSCAL BASIN AND RANGE PASSIVE-SOURCE SEISMIC EXPERIMENT
## PART I: Large Aperture Array Data

Prepared by
Thomas J. Owens, University of South Carolina
George E. Randall, University of Nevada-Reno

for the
Project Science Team

## PASSCAL Data Report 90-001

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# Data Report

# for

# The 1988-89 PASSCAL Basin and Range

# Passive-Source Seismic Experiment

# Part I: Large Aperture Array Data


*submitted by*

*Thomas J. Owens, University of South Carolina*

*George E. Randall, University of Nevada-Reno*

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***** PASSCAL DATA REPORT #90-001 *****


ABSTRACT


This report describes the data from the 1988-89 PASSCAL Basin and Range Passive Source Seismic Experiment, collected by the triggered large aperture array consisting of 7 prototype PASSCAL recorders with 3-component intermediate period seismometers. A total of 214 seismic events with known locations, and many smaller local events without locations are included in this data distribution. Data formats, auxiliary information, calibration information, and organization of the distribution data tape are discussed.

## 1. Introduction

The 1988-89 PASSCAL Basin and Range Passive Source Seismic Experiment consisted of two deployments. The Large Aperture Array of 7 PASSCAL data recorders was deployed from August 17, 1988 until April 29, 1989. The Large Aperture Array used 3-component mid-period sensors, and each site operated independently in a triggered mode. A Small Aperture Array, consisting of the Lawrence Livermore National Laboratory (LLNL) Configurable Seismic Monitoring System (CSMS), was deployed from August 1988 through October 1988. The Small Aperture Array used 3-component short-period sensors, and operated in a continuous recording mode with digital telemetry to a central recording site.

The study area was in the region of the Stillwater Range in Nevada (see Figures 1 and 2), and was chosen to coincide with the center of the crossing refraction profiles of the 1986 PASSCAL Basin and Range Lithospheric Experiment. This location was chosen so that a comparison of lithospheric modeling techniques, principally receiver function modeling, and refraction and reflection modeling, could be compared in a coincident study area.

The experiment team consisted of a field crew, and project scientists. The field crew, Randy Kuehnel and Thom Morin, deserve a great deal of credit for the success of the field operation. Their consistent dedication and effort made both array deployments operate as smoothly as possible, and aided greatly in the preliminary data processing. The project scientists consisted of T.J. Owens, D. McNamara (University of Missouri, now at University of South Carolina), G.E. Randall, K.F. Priestley (both at University of Nevada-Reno), and G. Zandt (at the LLNL Insitute for Geophysics and Planetary Physics).

The instrumentation for the Large Aperture Array consisted of 7 prototype PASSCAL data recorders, with 3-component mid-period (Kinemetrics SV-1 and SH-1) seismometers. Sites were constructed with separate insulated buried vaults for recorders and seismometers, and were powered with batteries recharged with solar panels. Most sites (SUN,NYC,GRN,SHP,CHB,ADR) were placed in locations either directly on or slightly above hardrock. The other sites (FNC,ANT) were chosen based on spatial constraints only. Brief site descriptions are given in Appendix A. Johnson (1977) provides a more detailed summary of the geology of this region. Site locations are given in Table 1.

This was the first major experiment to make use of the PASSCAL recorder, and the recording parameters varied often for test purposes. Typically, each recorder operated in a triggered mode, with some units occasionally operating with an additional low sample rate continuous data stream. The triggered data streams were recorded with sampling rates typically of 20 samples per second, although occasionally 50 and 100 samples per second were recorded. The triggers were STA (Short-term average) to LTA (Long-term average) ratios with the LTA window of 100 seconds, and the STA window 6 seconds. The STA/LTA ratio was initially 2.5, but was increased to 2.8 which successfully lowered the false trigger rate during the winter months and preserved the data triggering. The triggered data streams typically had pre-event buffers of 30 seconds and an overall record length of 150 seconds. Most of the recording was done in 16 bit mode, although some data was recorded with the 32 bit mode.

During the course of the experiment GOES clocks were used at the sites. Clock lock problems existed early in the project but were fixed by mid-December. Table 2 summarizes the dates when GOES clocks were added to each site. Prior to these dates, clocks were set manually to GMT during service visits if clock lock appeared to be a problem. Therefore, data recorded prior to the dates in Table 2 are suitable for single station studies, but are not reliable enough for detailed array analysis. In addition, from Julian Day 097 to 109 and from Days 114 - 119, the clock antenna at Chocolate Butte was uprooted by cattle and therefore the clock was not locked in these time periods. A similar problem occurred twice at Anderson Ranch somewhere between Days 080 and 119. It was temporarily corrected once on Day 094, but users are warned to be wary of the timing at Anderson Ranch during this period.

The instrumentation for the Small Aperture Array consisted of the LLNL CSMS system, with 13 continuously recorded digitally telemetered stations. One station was co-located with a station from the large aperture array (FNC), and operated with mid-period (Kinemetrics SV-1 and SH-1) seismometers. The remaining 12 stations used short period (Geotech S-13) 3 component seismometers. Time information was derived from an OMEGA clock at the central recording site, and rebroadcast to synchronize the field sites. The field sites used digital telemetry via radio links to pass the 100 sample per second data to the central recording site, where data was continuously recorded onto either optical disk or 8 mm tape for later demultiplexing and analysis.

This data report summarizes the data available from the Large Aperture Array. The data from the Small

Aperture Array is not yet ready for distribution and will be summarized in Part II of this report at a later date. The standard distribution tape for this experiment is trace data for located seismic events. Supplementary raw data for unlocated events is also available to interested researchers.

## 2. Description of Data Distribution

The Large-Aperture Array data has been provided to IRIS in three subsets, each of which is a UNIX file structure. The contents of the subsets is described below. The entire data distribution totals just over 207 Mbytes in size.

All of the trace data in this data distribution is in SAC format. SAC is an acronym for "Seismic Analysis Code", a general purpose software package for the manipulation of seismic data developed at Lawrence Livermore National Laboratory (LLNL). It is available through IRIS or LLNL. In this data distribution, we have separated out seismic events from spurious or culturally-induced triggers. Due to our limited duration recording window, we also eliminated triggers due to teleseismic surface waves that occasionally triggered the stations. After this initial culling of the data, we searched the Quick Determination of Epicenters (QDE) listings obtained through the toll-free modem number of the National Earthquake Information Center (NEIC). Local and regional events not found in the QDEs were often found in the Nevada Regional Catalog distributed by the Seismological Laboratory of the University of Nevada-Reno.

We were able to identify most seismic triggers using this method, however many smaller local events or mine blasts could not be assigned a location from either catalog. These were retained and are distributed in two subsets as part of the "Raw Data Distribution" described below. All events with known locations were assigned an event number and trace data from these events make up the third, and primary, subset of this distribution. This data is termed the "Numbered Event Data" and is described in the next section.

### 2.1. Numbered Event Data

A total of 214 separate seismic events with known locations make up the numbered event data. These events are listed in Table 3. Our numbering scheme was as follows:

| | |
|---|---|
| 001-299 | P-wave triggers |
| 701-999 | Teleseismic S-wave Triggers |
| 301-599 | Other Teleseismic Body Wave Triggers |

In the cases of an S-wave trigger, the event number assigned was the P-wave trigger number plus 700 and for the other teleseismic triggers, the event numbers assigned were the P-wave trigger number plus 300. For example the Fiji Island event of 4/16/89 triggered some sites on the P-wave, PP-wave, and S-wave. These were assigned event numbers 181, 481, and 881 respectively.

The numbered event trace data is distributed using the following file naming convention:

*EX.EVT.STA.C*

where *EX* is the 2-letter experiment identification code. In this case, the code used was "*lv*" for Lovelock, the nearest town to the array, was used; *EVT* is the assigned event number, column 1 in Table 3; *STA* is the 3-letter station abbreviation, column 1 in Table 1; *C* is the component identifier, *z* for Vertical component (positive up), *n* for North component (positive north), or *e* for East component (positive east).

The trace data amplitudes are given in units of microvolts. The event and station latitude, longitude, and depth or elevation as well as the proper component orientations have been entered into the proper SAC header fields. The numbered event data distribution is organized in the following UNIX directory structure:

| Directory Name | Size (Mb) | Description of Contents |
|---|---|---|
| NV8889_LAA/ | 72.9 | Main Directory |
| ./calb | 8.9 | Calibration Traces |
| ./tele | 22.1 | Teleseismic events |
| ./others | 21.5 | Local and Regional Events |
| ./tele.std | 19.3 | Standardized teleseismic data |
| ./general_info | 0.1 | all non-trace data files |
| ./data_report | 1.0 | text and figures of this report |

### 2.1.1. Teleseismic Data

The geographic distribution of teleseismic data is shown in Figure 3. A typical event that triggered for both P- and S-waves is plotted in Figure 4a and b. The NV8889_LAA/tele.std directory contains the teleseismic traces standardized to a sampling rate of 20 samples/sec and a record length of 150 sec. In tele.std, the mean of each trace has been removed and a Hanning taper applied to the first and last 7.5 sec of each trace. Also, for each event, the traces at all stations recording the event have been synchronized to a common reference time to allow for more accurate array analysis. Some low signal-to-noise ratio traces and events with other quality control problems have been discarded from this directory. This directory contains the data used in the research portion of this study. The NV8889_LAA/tele directory contains teleseismic events saved at their original sampling rate and record length. Some data in NV8889_LAA/tele may be found to suffer from the Picket Fence sampling problem described in the next section.

### 2.1.2. Local/Regional Data

The NV8889_LAA/others directory contains all of the trace data for non-teleseismic events recorded by the Large-Aperture Array. Figures 5 and 6 show typical regional and local events. Each trace has the original sampling rate and record length. Since we have not used this data in our research to date, we have not made thorough attempts to cull low signal-to-noise ratio events or other events with data quality problems from this data set. One correctable data quality problem that occurred with some regularity during the experiment was that the PASSCAL data logger occasionally became hung in a mode where it stored a constant of 10 digital counts between every other data point. In these cases, users need only to remove these points from the data trace. The resulting record is half the normal length, but the actual data has not been corrupted. In SAC, the "decimate 2 filter off" function fixes this problem, if users redefine the sampling interval to the original value after decimation. This problem became known as the "Picket Fence" mode. It was eventually corrected via hardware/software upgrades.

### 2.2. Calibration

The Kinemetrics SV-1 and SH-1 seismometers were carefully calibrated in the laboratory prior to deployment. The SV-1/SH-1 sensors are moving-coil electromagnetic seismometers with a nominal natural period of 5 seconds. Damping resistors were added to the seismometer circuit to obtain a nominal damping of 0.7 critical. After the initial installation and debugging period, a routine calibration procedure was established and applied at each site during the service visits. Each calibration was assigned a number and the file named in the same manner as in Section 2.1, except that the experiment identifier is "lvc" to distinguish it as a calibration pulse from the Lovelock data set.

Our calibration procedure used a battery, cable, and resistor network to inject a step of current equally into the calibration coils of all three seismometers simultaneously. The current was equal for each of the three coils, but unknown, so true amplitude calibration is not available. Kinemetrics documentation lists a nominal calibration coil force constant of 0.12 Newtons/ampere for the SV-1 and 0.08 Newtons/ampere for the SH-1. We obtained the effective mass of 1.36 Kg for the SV-1 and 1.1 kg for the SH-1 from Kinemetrics by phone. The tabulated observed relative amplitudes in Table 4 should be corrected by multiplication by 1.213 ([1.1/0.08]/[1.36/0.12]) to account for the different coils and effective masses of the SV-1 and SH-1 seismometers, which accelerate the SV-1 more than the SH-1 for the same calibration current.

Calibration pulses were repeated manually for sufficient duration to fill at least one trigger window (150 seconds), and provided multiple calibration pulses per calibration file. A single calibration pulse was cut from each calibration file for analysis. An unpublished code of D.B. Harris of LLNL was used to fit synthetic calibration pulses to the observed pulses. The code uses a grid search followed by a conjugate gradient least squares optimization to find a best fit to the observed calibration pulse's free period, fraction of critical damping, amplitude, and bias. Tabulated calibration information consists of free period, fraction of critical damping, and observed amplitude relative to the vertical for each horizontal component. Some calibrations are not reported because the station had excessive noise which degraded the parameter estimation. A few calibrations were discarded because we identified instrumental or recording problems with the calibration. The calibration information for each available calibration is given in Table 4. The parameters did not normally vary significantly at each site unless a seismometer was changed.

The calibration data is provided in SAC format in the NV8889-LAA/calb directory. It is sorted into station subdirectories, e.g. all of the Anderson Ranch calibrations are in NV8889_LAA/calb/ADR. Some calibration traces in these directories suffer from the Picket Fence problem described in Section 2.1.2 of this report.

### 3. Raw Data Distribution

Since events for which no catalogued location exists may still be of interest to other researchers, we have included supplementary data distributions of our raw data. Two subsets are available: 1988 data and 1989 data. The 1988 subset totals 95 Mb and the 1989 data totals 40 Mb. The data is organized in day directories as follows:

| | |
|---|---|
| RXXX/events | Seismic event traces |
| RXXX/calb | Calibration traces |
| RXXX/inst | Potential instrument problems |

where *XXX* is the Julian Day. If no triggers of a certain type occurred on a given day, that subdirectory will not exist. If all three subdirectories are empty, the *RXXX* directory will not exist. Within each subdirectory, the

The data in the *RXXX* subdirectories give amplitudes in counts. To convert counts to volts, use the formula:

$$V = \frac{counts*S*DGF}{PAG}$$

where *PAG* is the preamp gain, *DGF* is the Damping Gain Factor required due to the manner in which damping resistance was added to the seismometer circuit, and the scale factor *S* is given by

$$S = \frac{3.75}{32768} \qquad \text{(for 16 bit data)}$$

and

$$S = \frac{3.75}{32768^2} \qquad \text{(for 32 bit data)}$$

**4. Data Report Format**

We have included in the directory NV8889_LAA/data_report a complete version of the text in UNIX troff format and the figures in PostScript format. On our Sun Microsystems workstations, the data report may be printed using:

```
eqn nv8889_laa.txt | tbl | ptroff -ms
```

The Figures may be printed on a PostScript printer using:

```
lpr figure*.ps
```

trace data naming convention is:

*sHR.MN.SC.UNIT.DS.C*

where *HR* is the hour of the first data point in the trace, *MN* is the minute of the first data point, *SC* is the second of the first data point, *UNIT* is the PASSCAL recorder serial number, *DS* is the Data Stream that recorded the trace, and *C* is the Channel number, either 1, 2, or 3.

Each subdirectory also contains a tab-delimited file (called event.lst, calb.lst, inst.lst respectively) consisting of 4 fields: Field 1 - Channel 1 trace filename; Field 2 - trigger type indicator; Field 3 - Event number, if applicable, null field otherwise; Field 4 - Pertinent comments by the field crew. Field 2 may include: tele - teleseismic event; loco - local event; regi - regional event; nuke - known underground nuclear explosion; calb - calibration trigger; inst - potential instrument problem; eqke - general undifferentiated seismic event. Some traces in the Raw Data Distribution may suffer from the Picket Fence sampling problem described in Section 2.1.2.

For convenience, all of the event.lst files have been combined into two files, eventlists.1988 and eventlists.1989, in the directory NV8889_LAA/general_info distributed with the numbered event data. In addition, we have included files calblists.1988 and calblists.1989 in this directory to allow correlation of calibration triggers with the numbered calibrations distributed with the numbered event distribution. Also in the general_info directory are database files containing information by site that will allow users to correlate instrument serial numbers to a specific site. A sample entry is:

```
STATION NO: 07    STATION NAME: Anderson Ranch        AKA: adr
STATION LATITUDE: 39.972    LONGITUDE: -118.094    ELEVATION: 1520.000
CHANGES:

DATE: 09/28/88    TIME: 22:00
INSTRUMENT TYPE: ref    SERIAL #: 0027
STATUS: u    LTA: 100.    STA: 6.    STA/LTA: 2.8
PRE-EVENT MEMORY: 30.    EVENT RECORD LENGTH: 150.    DATA FORMAT: 32
COMMENTS: No GOES clock; usual 20 Hz, 3 channel trigger but no 1 Hz co
         ntinuous stream.
CHANNEL 01:    COMPONENT: z    SERIAL #: sv-170    +-DIRECTION: u
               PRE-AMP GAIN: 512    DAMP GAIN FACTOR: 1.00
CHANNEL 02:    COMPONENT: n    SERIAL #: sh-252    +-DIRECTION: n
               PRE-AMP GAIN: 512    DAMP GAIN FACTOR: 1.00
CHANNEL 03:    COMPONENT: e    SERIAL #: sh-260    +-DIRECTION: e
               PRE-AMP GAIN: 512    DAMP GAIN FACTOR: 1.00
```

## 5. Acknowledgements

This project could not have been completed without the expertise, enthusiasm, and endless efforts of Jim Fowler, PASSCAL Project Engineer. Technical, logistical and administrative assistance by Tim Ahern, Richard Boaz, Diane DePolo, Wally Nicks, Glen Offield, Sally Owens, Bill Prothero, and Austin Wilson was valuable. This project was supported by IRIS grants to the University of Missouri-Columbia, the University of South Carolina, and the University of Nevada-Reno. T.J. Owens was also supported by the UMC Research Council during the Fall of 1988.

## 6. References

Johnson, M., Geology and mineral deposits of Pershing County, Nevada, Bulletin 89, Nev. Bur. Mines & Geology, 1977.

## 7. Data Distribution

The Data referenced in this report may be obtained through:

IRIS Data Management Center
8701 Mopac Blvd., Suite 205
Austin, TX 78759
Telephone: (512) 471-0403, 0404, or 0405

## 8. Appendix A - Large Aperture Array Site Descriptions

ADR. Located on the western flank of the Stillwater Range on basalt and andesite flow units of Pliocene age.

CHB. Located in the Buena Vista Hills in an area underlain by a gabbroic complex of Jurassic age.

FNC. Located on the eastern side of the Buena Vista Valley on a westward dipping alluvial fan of Quaternary age. This deposit is characterized by poorly sorted, unconsolidated sands, silts and gravels derived from the adjacent Stillwater Range. Bedrock was estimated to be at a depth of less than 30 meters.

GRN. Located in the northeastern portion of the array on the western flanks of the Stillwater Range along vertical pinnacles of highly weathered and fractured, Late Oligocene to Late Miocene, rhyolite. Local rhyolite accumulations occur as thick flows and shallow intrusives associated with plug domes.

NYC. Located on the western slope of the Stillwater Range on highly mylonitized phyllite of the upper Triassic Auld Lang Syne Group.

SHP. Located on the eastern slope of the Humbolt Range, on a plug of Tertiary basalt. Some seismometer instability due to frost heaving and lack of insulation occurred. This was the only site that was not buried completely.

SUN. Located along the eastern slope of the Humbolt Range in a mine that penetrated into thickly bedded upper Triassic limestone and dolomite of the Dun Glenn formation.

ANT. This site was chosen because the array needed a central site to increase wavenumber resolution across the array. We found that the data were of poor quality due to higher frequency reverberations within the thick Quaternary alluvium of the Buena Vista Valley floor. The site was removed in November of 1988 because of low data quality.

TABLE 1

Large Aperture Array
Station Locations

| Station ID | Latitude (Deg. N) | Longitude (Deg. W) | Elevation (meters) | Station Name |
|---|---|---|---|---|
| ADR | 39.972 | 118.094 | 1520.0 | Anderson Ranch |
| ANT | 40.113 | 117.974 | 1241.7 | Antelope |
| CHB | 40.032 | 118.133 | 1347.0 | Chocolate Butte |
| FNC | 40.096 | 117.885 | 1487.0 | Fencemaker Flat |
| GRN | 40.218 | 117.878 | 1317.0 | Granite Hills |
| NYC | 40.051 | 118.007 | 1475.0 | New York Canyon |
| SHP | 40.217 | 118.058 | 1341.0 | Shiprock |
| SUN | 40.139 | 118.099 | 1335.0 | Sunnyside |

TABLE 2

Large Aperture Array
Installation Date of Upgraded GOES Clock

| Station ID | Date |
|---|---|
| ADR | 12/13/88 |
| ANT | |
| CHB | 01/12/89 |
| FNC | 12/03/88 |
| GRN | 12/03/88 |
| NYC | 12/03/88 |
| SHP | 12/20/88 |
| SUN | 12/06/88 |

TABLE 3

Event Locations

| Evt ID | Date | Origin Time | Latitude (Deg) | Longitude (Deg) | Depth (Km) | Mb | Region |
|---|---|---|---|---|---|---|---|
| 001 | 08/17/88 | 015911.1 | 7.658S | 107.264E | 58 | 6.0 | JAVA. |
| 002 | 08/17/88 | 113452.4 | 26.912S | 70.855W | 39 | 5.6 | NEAR COAST OF NORTHERN CHILE |
| 003 | 08/17/88 | 123813.7 | 27.208S | 70.812W | 37 | 5.3 | NEAR COAST OF NORTHERN CHILE |
| 007 | 08/17/88 | 170000.0 | 37.297N | 116.307W | 0 | 5.4 | SOUTHERN NEVADA. "KEARSARGE" |
| 004 | 08/20/88 | 230910.3 | 26.663N | 86.620E | 70 | 6.5 | NEPAL-INDIA BORDER REGION. |
| 005 | 08/21/88 | 111548.8 | 23.293N | 108.346W | 10 | 4.9 | GULF OF CALIFORNIA |
| 006 | 08/21/88 | 135143.4 | 42.795S | 85.877W | 10 | 5.8 | WEST CHILE RISE |
| 008 | 08/26/88 | 215323.1 | 38.810N | 118.069W | 20 | | Near Lovelock, NV |
| 009 | 08/27/88 | 012517.7 | 11.303N | 141.455E | 33 | 5.2 | WEST CAROLINE ISLANDS |
| 010 | 08/27/88 | 163017.6 | 15.838S | 172.144W | 33 | 6.0 | SAMOA ISLANDS REGION |
| 011 | 08/30/88 | 122824.9 | 37.540N | 118.353W | 5 | | CALIFORNIA-NEVADA BORDER REGION. |
| 012 | 08/30/88 | 180000.1 | 37.086N | 116.069W | 0 | 5.0 | SOUTHERN NEVADA. "BULLFROG" |
| 013 | 08/30/88 | 190345.0 | 37.086N | 116.069W | 0 | | BULLFROG COLLAPSE? OT/Location estimated |
| 014 | 08/31/88 | 164516.0 | 31.789N | 115.796W | 5 | 4.9 | BAJA CALIFORNIA. ML 5.1 (PAS). |
| 015 | 09/01/88 | 165252.3 | 17.065N | 99.265W | 33 | 5.0 | GUERRERO, MEXICO |
| 016 | 09/02/88 | 102748.5 | 54.030N | 161.491E | 47 | 5.1 | NEAR EAST COAST OF KAMCHATKA |
| 017 | 09/05/88 | 061318.7 | 18.532N | 70.391W | 33 | 5.5 | DOMINICAN REPUBLIC REGION. |
| 018 | 09/07/88 | 115325.4 | 30.336N | 137.364E | 499 | 6.0 | SOUTH OF HONSHU, JAPAN |
| 718 | 09/07/88 | 115325.4 | 30.336N | 137.364E | 499 | 6.0 | SOUTH OF HONSHU, JAPAN *** S-WAVE |
| 019 | 09/13/88 | 005845.9 | 29.806N | 138.364E | 447 | 5.8 | SOUTH OF HONSHU, JAPAN |
| 020 | 09/14/88 | 035957.4 | 49.801N | 78.791E | 0 | 6.1 | EASTERN KAZAKH SSR |
| 021 | 09/14/88 | 221407.6 | 23.387S | 67.945W | 124 | 5.8 | CHILE-ARGENTINA BORDER REGION |
| 022 | 09/15/88 | 184803.2 | 1.404S | 77.896W | 189 | 5.8 | ECUADOR. |
| 722 | 09/15/88 | 184803.2 | 1.404S | 77.896W | 189 | 5.8 | ECUADOR. *** S-wave |
| 023 | 09/16/88 | 000652.9 | 22.952S | 175.413W | 33 | 4.9 | TONGA ISLANDS REGION |
| 024 | 09/16/88 | 021614.9 | 20.362S | 178.364W | 500 | 5.2 | FIJI ISLANDS REGION |
| 025 | 09/16/88 | 024535.8 | 20.170S | 177.770W | 500 | 4.7 | FIJI ISLANDS REGION |
| 026 | 09/16/88 | 062729.0 | 17.785S | 169.065E | 33 | 4.9 | VANUATU ISLANDS |
| 027 | 09/17/88 | 062014.6 | 29.900N | 114.100W | 10 | 4.4 | BAJA, CA from NEIC via phone |
| 028 | 09/17/88 | 152353.7 | 44.910N | 152.945E | 43 | 5.3 | KURIL ISLANDS REGION |
| 029 | 09/19/88 | 025630.7 | 38.432N | 118.320W | 5 | 4.5 | CALIFORNIA-NEVADA BORDER REGION. |
| 030 | 09/19/88 | 032215.8 | 38.461N | 118.341W | 5 | | CALIFORNIA-NEVADA BORDER REGION. |
| 031 | 09/19/88 | 114619.8 | 38.450N | 118.349W | 7 | 2.5 | Hawthorne, NV aftershock |
| 032 | 09/19/88 | 185837.7 | 23.003S | 175.508W | 33 | 5.4 | TONGA ISLANDS REGION |
| 033 | 09/19/88 | 210145.8 | 38.478N | 118.111W | 5 | | CALIFORNIA-NEVADA BORDER REGION. |
| 034 | 09/20/88 | 001609.1 | 38.937N | 118.063W | 5 | | CALIFORNIA-NEVADA BORDER REGION. |
| 035 | 09/21/88 | 095851.8 | 46.129N | 152.142E | 38 | 5.9 | KURIL ISLANDS |
| 036 | 09/21/88 | 144334.9 | 41.790N | 118.847W | 22 | 2.8 | Local near Denio, NV. |
| 037 | 09/21/88 | 182955.7 | 38.460N | 118.340W | 9 | 3.2 | Local near Hawthorne, NV |
| 038 | 09/21/88 | 235926.7 | 16.073S | 173.481W | 33 | 5.5 | TONGA ISLANDS |
| 039 | 09/22/88 | 105255.0 | 38.462N | 118.340W | 12 | 3.0 | Local near Hawthorne, NV |
| 040 | 09/22/88 | 222836.3 | 23.030N | 167.860W | 10 | 5.5 | HAWAII REGION |
| 041 | 09/23/88 | 154855.6 | 38.957N | 118.171W | 0 | 3.5 | California/Nevada border |
| 117 | 09/24/88 | 043759.8 | 38.459N | 118.343W | 0 | 2.3 | California/Nevada border |
| 042 | 09/26/88 | 082321.4 | 35.402N | 140.864E | 45 | 5.9 | NEAR E COAST OF HONSHU, JAPAN |
| 043 | 09/28/88 | 143847.9 | 38.462N | 118.353W | 11 | 2.3 | California/Nevada border |
| 044 | 09/28/88 | 164810.0 | 38.898N | 117.830W | 14 | 2.5 | North of Hawtorne Nevada |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 092 | 11/07/88 | 035002.8 | 22.179S | 175.008E | 33 | 5.6 | SOUTH OF FIJI ISLANDS |
| 093 | 11/09/88 | 201459.7 | 36.987N | 116.009W | 5 | | CALIFORNIA-NEVADA BORDER REGION |
| 094 | 11/10/88 | 050800.1 | 37.357N | 121.868W | 5 | 4.7 | CENTRAL CALIFORNIA |
| 096 | 11/20/88 | 053926.8 | 33.461N | 118.145W | 5 | 5.1 | SOUTHERN CALIFORNIA. |
| 796 | 11/20/88 | 053926.8 | 33.461N | 118.145W | 5 | 5.1 | SOUTHERN CALIFORNIA. *** S-wave |
| 097 | 11/21/88 | 230131.69 | 40.257N | 118.162W | 0 | 1.7 | Local mine blast |
| 098 | 11/22/88 | 075739.2 | 37.396N | 118.515W | 5 | | CALIFORNIA-NEVADA BORDER REGION |
| 099 | 11/22/88 | 145445.76 | 39.358N | 118.466W | 0 | 2.4 | Local mine blast |
| 100 | 11/23/88 | 201122.6 | 38.568N | 117.738W | 5 | | 11 NEVADA. ML 2.8 (NEIC) |
| 101 | 11/25/88 | 234602.9 | 48.124N | 71.246W | 20 | 5.9 | SOUTHERN QUEBEC |
| 102 | 12/03/88 | 113825.0 | 34.151N | 118.139W | 10 | 4.5 | SOUTHERN CALIFORNIA |
| 103 | 12/04/88 | 123358.9 | 39.319N | 118.162W | 0 | 3.0 | Near Fallon Nevada |
| 104 | 12/05/88 | 160531.4 | 15.320S | 173.400W | 33 | 6.1 | TONGA ISLANDS |
| 105 | 12/07/88 | 074124.2 | 40.949N | 44.293E | 10 | 6.2 | TURKEY-USSR BORDER REGION |
| 106 | 12/07/88 | 074544.2 | 41.056N | 44.481E | 10 | 5.8 | WESTERN CAUCASUS |
| 107 | 12/07/88 | 225359.58 | 41.085N | 119.120W | 0 | 2.6 | West of Winnemucca NV. |
| 108 | 12/08/88 | 121720.00 | 40.246N | 117.751W | 0 | 2.1 | Local mine blast |
| 109 | 12/08/88 | 125859.8 | 6.876N | 82.827W | 10 | 5.7 | SOUTH OF PANAMA |
| 809 | 12/08/88 | 125859.8 | 6.876N | 82.827W | 10 | 5.7 | SOUTH OF PANAMA *** S-wave |
| 110 | 12/09/88 | 190909.64 | 38.090N | 118.861W | 0 | 2.9 | Local mine blast |
| 111 | 12/10/88 | 203000.0 | 37.199N | 116.209W | 0 | 5.1 | SOUTHERN NEVADA."MISTY ECHO" |
| 112 | 12/13/88 | 040138.9 | 71.067N | 7.775W | 10 | 5.7 | JAN MAYEN ISLAND REGION |
| 114 | 12/16/88 | 055303.5 | 33.984N | 116.695W | 5 | 4.9 | SOUTHERN CALIFORNIA |
| 115 | 12/16/88 | 095717.4 | 29.670S | 178.000W | 33 | 6.2 | KERMADEC ISLANDS |
| 116 | 12/30/88 | 174136.95 | 37.532N | 118.403W | 0 | 3.0 | Local mine blast |
| 118 | 12/24/88 | 042657.5 | 23.386S | 66.392W | 223 | 5.9 | JuJuy Province, Argentina |
| 119 | 01/02/89 | 015210.4 | 18.326S | 174.548W | 122 | 6.0 | TONGA ISLANDS |
| 819 | 01/02/89 | 015210.4 | 18.326S | 174.548W | 122 | 6.0 | TONGA ISLANDS S-wave |
| 120 | 01/03/89 | 044111.2 | 29.526N | 131.454E | 33 | 5.7 | RYUKYU ISLANDS REGION |
| 121 | 01/09/89 | 050821.0 | 36.311N | 115.115W | 5 | | CALIFORNIA-NEVADA BORDER REGION. |
| 122 | 01/09/89 | 134237.2 | 46.794N | 153.733E | 33 | 5.9 | KURIL ISLANDS |
| 822 | 01/09/89 | 134237.2 | 46.794N | 153.733E | 33 | 5.9 | KURIL ISLANDS, S-wave |
| 123 | 01/11/89 | 122332.1 | 44.577N | 129.723W | 10 | 4.7 | OFF COAST OF OREGON |
| 124 | 01/11/89 | 155202.5 | 44.554N | 129.653W | 10 | 4.7 | OFF COAST OF OREGON |
| 125 | 01/12/89 | 194740.5 | 46.694N | 153.981E | 33 | 5.6 | KURIL ISLANDS |
| 126 | 01/13/89 | 180156.2 | 46.497N | 153.662E | 33 | 5.6 | KURIL ISLANDS |
| 127 | 01/14/89 | 231326.43 | 39.716N | 117.339W | 0 | | Local mine blast |
| 128 | 01/19/89 | 065328.0 | 33.922N | 118.629W | 10 | 5.2 | SOUTHERN CALIFORNIA. |
| 129 | 01/20/89 | 121041.56 | 39.288N | 119.672W | 0 | | Local Mine Blast |
| 130 | 01/22/89 | 222018.8 | 41.742N | 144.359E | 33 | 6.0 | HOKKAIDO, JAPAN REGION. |
| 131 | 01/25/89 | 093056.93 | 38.459N | 118.328W | 0 | | Local Mine Blast |
| 132 | 01/27/89 | 083451.9 | 56.188N | 164.440E | 33 | 5.8 | KOMANDORSKY ISLANDS REGION |
| 133 | 01/30/89 | 040621.0 | 38.900N | 111.600W | 10 | 5.4 | UTAH |
| 134 | 01/31/89 | 173925.3 | 22.292N | 107.179W | 10 | 5.2 | OFF COAST OF CENTRAL MEXICO |
| 135 | 02/04/89 | 192411.2 | 5.929N | 82.808W | 33 | 5.8 | SOUTH OF PANAMA |
| 136 | 02/07/89 | 040300.5 | 21.852S | 66.931W | 179 | 5.4 | SOUTHERN BOLIVIA |
| 137 | 02/10/89 | 111526.7 | 3.03N | 126.92E | 33 | 6.0 | TALAUD ISLANDS. |
| 437 | 02/10/89 | 111526.7 | 3.0300N | 126.920E | 33 | 6.0 | TALAUD ISLANDS. |
| 138 | 02/10/89 | 200559.2 | 37.064N | 115.976W | 0 | 5.1 | SOUTHERN NEVADA. |
| 162 | 02/10/89 | | 37.064N | 115.976W | 0 | | Collapse from Evt 138 explosion? |
| 139 | 02/13/89 | 145124.4 | 57.460N | 33.107W | 10 | 5.2 | NORTH ATLANTIC OCEAN |
| 140 | 02/13/89 | 151447.4 | 57.409N | 33.279W | 10 | 5.2 | NORTH ATLANTIC OCEAN |
| 141 | 02/14/89 | 062026.9 | 10.434S | 161.283E | 78 | 6.1 | SOLOMON ISLANDS |
| 841 | 02/14/89 | 062026.9 | 10.434S | 161.283E | 78 | 6.1 | SOLOMON ISLANDS *** S-wave |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 142 | 02/14/89 | 154353.7 | 35.067N | 119.145W | 10 | | CENTRAL CALIFORNIA. |
| 143 | 02/15/89 | 053136.3 | 39.273N | 117.331W | 5 | | NEVADA. |
| 144 | 02/16/89 | 215037.8 | 45.327N | 151.785E | 95 | 5.7 | KURIL ISLANDS |
| 210 | 02/17/89 | 012316.2 | 39.312N | 117.428W | 0 | 2.6 | Regional |
| 145 | 02/18/89 | 071704.0 | 34.017N | 117.733W | 6 | | SOUTHERN CALIFORNIA. |
| 211 | 02/18/89 | 140245.0 | 39.226N | 117.333W | 10 | 3.3 | Nevada Regional |
| 197 | 02/19/89 | 120041.9 | 39.309N | 115.939W | 10 | 3.4 | Nevada Regional |
| 198 | 02/20/89 | 073211.3 | 39.244N | 117.375W | 10 | 2.4 | Nevada Regional |
| 199 | 02/22/89 | 092859.0 | 39.256N | 117.401W | 4 | 2.9 | Nevada Regional |
| 200 | 02/22/89 | 094944.6 | 39.230N | 117.338W | 0 | 3.5 | Nevada Regional |
| 146 | 02/22/89 | 102541.4 | 56.217N | 153.629W | 7 | 5.7 | KODIAK ISLAND REGION |
| 147 | 02/24/89 | 161500.0 | 37.128N | 116.122W | 0 | 4.4 | SOUTHERN NEVADA."KAWICH," |
| 148 | 02/25/89 | 112637.7 | 29.759S | 177.918W | 47 | 6.4 | KERMADEC ISLANDS |
| 848 | 02/25/89 | 112637.7 | 29.759S | 177.918W | 47 | 6.4 | KERMADEC ISLANDS *** S-wave |
| 149 | 02/27/89 | 151307.0 | 38.915N | 111.674W | 10 | 3.4 | UTAH. |
| 150 | 02/28/89 | 130157.9 | 23.086S | 61.585W | 575 | 5.5 | PARAGUAY |
| 151 | 03/01/89 | 024202.2 | 43.769N | 148.985E | 44 | 5.7 | KURIL ISLANDS REGION |
| 152 | 03/02/89 | 071345.6 | 18.413N | 68.676W | 129 | 5.4 | MONA PASSAGE. |
| 153 | 03/06/89 | 143942.0 | 35.800N | 140.400E | 33 | 5.7 | NEAR EAST COAST OF HONSHU, JAPAN |
| 154 | 03/06/89 | 221646.0 | 33.000N | 115.600W | 10 | 4.4 | SOUTHERN CALIFORNIA |
| 463 | 03/09/89 | 023700.5 | 13.743S | 34.298E | 33 | 5.7 | MALAWI Triggered on PKP |
| 155 | 03/09/89 | 140500.0 | 37.143N | 116.067W | 0 | 5.0 | SOUTHERN NEVADA "INGOT," |
| 464 | 03/10/89 | 214946.1 | 13.781S | 34.226E | 33 | 6.1 | MALAWI Triggered on PKP |
| 156 | 03/11/89 | 050454.3 | 17.723S | 174.798W | 175 | 6.3 | TONGA ISLANDS |
| 856 | 03/11/89 | 050454.3 | 17.723S | 174.798W | 175 | 6.3 | TONGA ISLANDS *** S-wave |
| 157 | 03/11/89 | 122145.0 | 37.881N | 116.018W | 5 | | SOUTHERN NEVADA |
| 201 | 03/12/89 | 133133.4 | 40.285N | 117.766W | 7 | 2.5 | Nevada Regional |
| 202 | 03/12/89 | 225659.9 | 39.860N | 119.381W | 3 | 2.2 | Nevada Regional |
| 158 | 03/15/89 | 233410.7 | 38.376N | 119.353W | 5 | | CALIFORNIA-NEVADA BORDER REGION |
| 203 | 03/15/89 | 234207.8 | 38.404N | 119.404W | 7 | 3.4 | Nevada Regional |
| 159 | 03/16/89 | 093400.5 | 29.992S | 178.119W | 57 | 5.7 | KERMADEC ISLANDS |
| 160 | 03/17/89 | 193306.9 | 34.350S | 178.650W | 44 | 5.9 | SOUTH OF KERMADEC ISLANDS |
| 204 | 03/19/89 | 031918.8 | 39.356N | 120.003W | 9 | 2.5 | Nevada Regional |
| 161 | 03/20/89 | 010633.1 | 59.927N | 153.718W | 127 | 5.0 | SOUTHERN ALASKA. |
| 205 | 03/25/89 | 073529.7 | 39.924N | 117.837W | 6 | 2.6 | Nevada Regional |
| 206 | 03/25/89 | 133530.2 | 39.236N | 117.373W | 0 | 2.7 | Nevada Regional |
| 165 | 03/26/89 | 180336.3 | 38.752N | 122.595W | 5 | | N CALIF |
| 214 | 03/30/89 | 203929.6 | 19.371S | 176.052W | 229 | 5.5 | FIJI ISL REGION |
| 166 | 04/03/89 | 174631.3 | 37.350N | 121.868W | 5 | 4.5 | CENTRAL CALIFORNIA |
| 167 | 04/05/89 | 234748.3 | 21.135S | 69.211W | 114 | 5.8 | NORTHERN CHILE |
| 867 | 04/06/89 | 234748.3 | 21.135S | 69.211W | 114 | 5.8 | NORTHERN CHILE S-wave |
| 168 | 04/06/89 | 080540.0 | 19.602S | 169.467E | 33 | 6.3 | VANUATU ISLANDS |
| 868 | 04/06/89 | 080540.0 | 19.602S | 169.467E | 33 | 6.3 | VANUATU ISLANDS S-wave |
| 169 | 04/07/89 | 133211.6 | 51.337N | 30.008W | 10 | 5.1 | NORTH ATLANTIC RIDGE |
| 170 | 04/07/89 | 200728.2 | 33.540N | 118.006W | 5 | 4.5 | SOUTHERN CALIFORNIA |
| 171 | 04/08/89 | 012220.5 | 57.251N | 143.615W | 10 | 4.9 | GULF OF ALASKA |
| 172 | 04/08/89 | 030601.4 | 15.680S | 173.004W | 33 | 5.5 | TONGA ISLANDS |
| 173 | 04/09/89 | 050750.3 | 51.533N | 178.440W | 32 | 5.2 | ANDREANOF ISLANDS, ALEUTIAN IS |
| 174 | 04/11/89 | 035638.8 | 49.387N | 159.259E | 33 | 6.3 | KURIL ISLANDS REGION |
| 874 | 04/11/89 | 035638.8 | 49.387N | 159.259E | 33 | 6.3 | KURIL ISLANDS REGION S-wave |
| 175 | 04/13/89 | 004311.2 | 39.488S | 75.081W | 33 | 5.9 | OFF COAST OF CENTRAL CHILE |
| 875 | 04/13/89 | 004311.2 | 39.488S | 75.081W | 33 | 5.9 | OFF COAST OF CENTRAL CHILE S-wave |
| 176 | 04/14/89 | 125209.2 | 19.200N | 144.860E | 33 | 5.8 | MARIANA ISLANDS |
| 177 | 04/14/89 | 130247.8 | 18.052S | 178.423W | 571 | 5.4 | FIJI ISLANDS REGION |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 877 | 04/14/89 | 130247.8 | 18.052S | 178.423W | 571 | 5.4 | FIJI ISLANDS REGION S-wave |
| 207 | 04/15/89 | 061407.4 | 38.155N | 117.864W | 10 | 2.9 | Local mine blast |
| 178 | 04/15/89 | 142641.6 | 8.430N | 61.070W | 25 | 5.8 | VENEZUELA. Felt in southern |
| 179 | 04/15/89 | 203411.5 | 30.021N | 99.321E | 33 | 6.2 | SICHUAN PROVINCE, CHINA |
| 479 | 04/15/89 | 203411.5 | 30.021N | 99.321E | 33 | 6.2 | SICHUAN PROVINCE, CHINA *** PP Phase |
| 180 | 04/16/89 | 105116.6 | 4.735N | 32.671W | 10 | 5.4 | CENTRAL MID-ATLANTIC RIDGE |
| 181 | 04/16/89 | 194814.9 | 20.989S | 179.034W | 611 | 5.6 | FIJI ISLANDS REGION |
| 881 | 04/16/89 | 194814.9 | 20.989S | 179.034W | 611 | 5.6 | FIJI ISLANDS REGION S-wave |
| 481 | 04/16/89 | 194814.9 | 20.989S | 179.034W | 611 | 5.6 | FIJI ISLANDS REGION *** PP phase |
| 182 | 04/18/89 | 123353.6 | 23.718S | 179.914E | 536 | 5.8 | SOUTH OF FIJI ISLANDS |
| 882 | 04/18/89 | 123353.6 | 23.718S | 179.914E | 536 | 5.8 | SOUTH OF FIJI ISLANDS S-wave |
| 196 | 04/19/89 | 000822.9 | 31.323S | 177.906W | 33 | 5.8 | KERMADEC ISLANDS REGION |
| 183 | 04/19/89 | 144856.0 | 17.859N | 105.303W | 10 | 5.1 | OFF COAST OF JALISCO, MEXICO |
| 184 | 04/19/89 | 223929.0 | 37.263N | 115.100W | 5 | | SOUTHERN NEVADA |
| 185 | 04/20/89 | 080851.5 | 9.170S | 79.034W | 64 | 5.7 | OFF COAST OF NORTHERN PERU |
| 186 | 04/20/89 | 124552.7 | 38.489N | 117.831W | 5 | 4.3 | NEVADA |
| 187 | 04/20/89 | 225954.9 | 57.123N | 121.950E | 33 | 6.0 | EASTERN USSR |
| 887 | 04/20/89 | 225954.9 | 57.123N | 121.950E | 33 | 6.0 | EASTERN USSR S-wave |
| 188 | 04/22/89 | 151545.4 | 38.165N | 117.805W | 5 | | NEV. ML 3.2 |
| 189 | 04/22/89 | 152312.9 | 38.162N | 117.806W | 5 | | NEV. ML 2.9 |
| 190 | 04/23/89 | 192110.0 | 66.918N | 156.241W | 33 | 5.7 | ALASKA |
| 191 | 04/25/89 | 021324.5 | 30.042N | 99.477E | 33 | 6.1 | SICHUAN PROV CHINA |
| 491 | 04/25/89 | 021324.4 | 30.042N | 99.477E | 33 | 6.1 | SICHUAN PROV CHINA *** PP phase |
| 192 | 04/25/89 | 142901.1 | 16.874N | 99.411W | 23 | 6.4 | NEAR COAST OF GUERRERO, MEX. |
| 193 | 04/25/89 | 171837.9 | 35.890N | 140.414E | 71 | 5.4 | NEAR E COAST OF HONSHU, JAPAN. |
| 194 | 04/27/89 | 022005.8 | 30.694N | 140.734E | 93 | 6.0 | S OF HONSHU, JAPAN. |
| 894 | 04/27/89 | 022005.8 | 30.694N | 140.734E | 93 | 6.0 | S OF HONSHU, JAPAN. S-wave |
| 208 | 04/26/89 | 204316.2 | 38.517N | 119.268W | 10 | 2.8 | Local mine Blast |
| 209 | 04/26/89 | 210108.7 | 38.514N | 119.271W | 13 | 2.6 | Local Mine Blast |
| 212 | 04/28/89 | 074816.0 | 13.100N | 89.700W | 33 | | El Salvador |
| 213 | 04/28/89 | 023425.0 | 17.800N | 105.200W | 33 | | Jalisco, Mexico |

TABLE 4

Large Aperture Array
Seismometer Calibration Parameters

| | | Vertical Component | | East Component | | | North Component | | |
|---|---|---|---|---|---|---|---|---|---|
| Sta Cal ID | Date | Free Period (sec) | Fraction Critical Damping | Free Period (sec) | Fraction Critical Damping | Relative Ampl. | Free Period (sec) | Fraction Critical Damping | Relative Ampl. |
| ADR 003 | 10/18/88 | 4.92 | 0.71 | 4.23 | 0.64 | 0.606 | 4.23 | 0.66 | 0.586 |
| ADR 011 | 10/25/88 | 4.91 | 0.71 | 4.20 | 0.63 | 0.593 | 4.23 | 0.64 | 0.572 |
| ADR 018 | 11/02/88 | 4.91 | 0.71 | 4.23 | 0.63 | 0.595 | 4.21 | 0.63 | 0.566 |
| ADR 042 | 11/17/88 | 4.99 | 0.71 | 4.15 | 0.61 | 0.598 | 4.14 | 0.63 | 0.574 |
| ADR 043 | 11/17/88 | 5.00 | 0.71 | 4.16 | 0.59 | 0.587 | 4.14 | 0.62 | 0.577 |
| ADR 058 | 12/02/88 | 5.01 | 0.75 | 4.23 | 0.60 | 0.567 | 3.99 | 0.63 | 0.587 |
| ADR 074 | 12/06/88 | 4.85 | 0.71 | 4.08 | 0.62 | 0.577 | 4.08 | 0.63 | 0.565 |
| ADR 075 | 12/13/88 | 5.09 | 0.70 | 4.06 | 0.61 | 0.619 | 3.98 | 0.61 | 0.616 |
| ADR 093 | 01/04/89 | 5.00 | 0.71 | 3.98 | 0.60 | 0.595 | 3.92 | 0.62 | 0.593 |
| ADR 094 | 01/04/89 | 5.00 | 0.71 | 3.98 | 0.60 | 0.594 | 3.92 | 0.62 | 0.592 |
| ADR 105 | 01/13/89 | 5.08 | 0.70 | 4.12 | 0.58 | 0.573 | 4.03 | 0.57 | 0.577 |
| ADR 106 | 01/13/89 | 5.08 | 0.70 | 4.12 | 0.58 | 0.574 | 4.06 | 0.55 | 0.551 |
| ADR 109 | 02/07/89 | 5.14 | 0.72 | 4.05 | 0.59 | 0.582 | 3.98 | 0.61 | 0.587 |
| ADR 110 | 02/07/89 | 4.99 | 0.71 | 3.97 | 0.59 | 0.583 | 3.91 | 0.60 | 0.591 |
| ADR 117 | 02/15/89 | 4.91 | 0.72 | 3.99 | 0.56 | 0.541 | 3.92 | 0.59 | 0.543 |
| ADR 130 | 03/01/89 | 5.00 | 0.68 | 4.06 | 0.59 | 0.584 | 4.07 | 0.60 | 0.567 |
| ADR 131 | 03/09/89 | 5.07 | 0.70 | 3.98 | 0.58 | 0.606 | 3.99 | 0.61 | 0.586 |
| ADR 138 | 03/21/89 | 5.08 | 0.71 | 4.07 | 0.59 | 0.587 | 4.07 | 0.60 | 0.575 |
| ADR 146 | 04/04/89 | 4.85 | 0.71 | 3.98 | 0.60 | 0.574 | 3.97 | 0.63 | 0.563 |
| ADR 168 | 04/29/89 | 4.92 | 0.71 | 4.06 | 0.61 | 0.585 | 4.06 | 0.63 | 0.575 |
| ADR 169 | 04/29/89 | 5.00 | 0.69 | 4.14 | 0.60 | 0.578 | 4.14 | 0.61 | 0.555 |
| ANT 016 | 10/26/88 | 5.47 | 0.80 | 4.21 | 0.64 | 0.412 | 4.15 | 0.62 | 0.549 |
| ANT 021 | 11/02/88 | 5.15 | 0.81 | 3.84 | 0.72 | 0.401 | 3.81 | 0.37 | 0.465 |
| ANT 031 | 11/08/88 | 5.61 | 0.76 | 3.82 | 0.69 | 0.549 | 3.69 | 0.66 | 0.654 |
| CHB 004 | 10/18/88 | 4.61 | 0.70 | 4.59 | 0.59 | 0.547 | 4.76 | 0.63 | 0.559 |
| CHB 012 | 10/26/88 | 4.68 | 0.70 | 4.70 | 0.59 | 0.573 | 4.76 | 0.64 | 0.589 |
| CHB 019 | 11/02/88 | 4.60 | 0.72 | 4.47 | 0.61 | 0.589 | 4.61 | 0.64 | 0.577 |
| CHB 025 | 11/08/88 | 4.60 | 0.69 | 4.53 | 0.59 | 0.571 | 4.54 | 0.63 | 0.588 |
| CHB 051 | 11/20/88 | 4.53 | 0.73 | 4.28 | 0.58 | 0.563 | 4.45 | 0.61 | 0.566 |
| CHB 107 | 01/13/89 | 4.54 | 0.68 | 4.14 | 0.57 | 0.611 | 4.06 | 0.53 | 0.553 |
| CHB 132 | 03/09/89 | 4.37 | 0.90 | 4.15 | 0.58 | 0.639 | 4.11 | 0.57 | 0.599 |
| CHB 139 | 03/21/89 | 4.54 | 0.82 | 4.22 | 0.59 | 0.677 | 4.22 | 0.58 | 0.667 |
| CHB 147 | 04/04/89 | 4.76 | 0.81 | 4.29 | 0.60 | 0.713 | 4.21 | 0.58 | 0.711 |
| CHB 148 | 04/04/89 | 4.62 | 0.83 | 4.31 | 0.59 | 0.680 | 4.24 | 0.59 | 0.668 |
| CHB 156 | 04/19/89 | 4.61 | 0.82 | 4.52 | 0.59 | 0.652 | 4.52 | 0.57 | 0.627 |
| CHB 167 | 04/29/89 | 4.60 | 0.81 | 4.37 | 0.60 | 0.684 | 4.44 | 0.58 | 0.648 |
| FNC 032 | 11/08/88 | 5.15 | 0.73 | 4.38 | 0.61 | 0.664 | 4.06 | 0.74 | 0.737 |
| FNC 040 | 11/12/88 | 5.01 | 0.77 | 4.44 | 0.60 | 0.582 | 4.14 | 0.70 | 0.628 |
| FNC 055 | 11/29/88 | 5.00 | 0.73 | 4.27 | 0.58 | 0.640 | 4.14 | 0.69 | 0.633 |
| FNC 061 | 12/03/88 | 4.92 | 0.71 | 4.12 | 0.59 | 0.657 | 4.05 | 0.67 | 0.645 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| FNC 062 | 12/03/88 | 4.92 | 0.72 | 4.15 | 0.62 | 0.672 | 4.05 | 0.63 | 0.627 |
| FNC 067 | 12/06/88 | 5.00 | 0.72 | 4.13 | 0.60 | 0.664 | 4.00 | 0.67 | 0.654 |
| FNC 068 | 12/06/88 | 4.99 | 0.70 | 4.04 | 0.58 | 0.683 | 3.99 | 0.68 | 0.668 |
| FNC 078 | 12/13/88 | 4.91 | 0.75 | 3.99 | 0.59 | 0.669 | 4.13 | 0.63 | 0.577 |
| FNC 079 | 12/13/88 | 5.14 | 0.71 | 4.13 | 0.58 | 0.688 | 4.14 | 0.65 | 0.643 |
| FNC 090 | 12/20/88 | 5.07 | 0.73 | 4.13 | 0.58 | 0.667 | 4.05 | 0.62 | 0.621 |
| FNC 096 | 01/04/89 | 5.07 | 0.76 | 4.05 | 0.59 | 0.658 | 3.91 | 0.67 | 0.663 |
| FNC 100 | 01/13/89 | 5.07 | 0.72 | 4.05 | 0.56 | 0.655 | 3.93 | 0.64 | 0.649 |
| FNC 101 | 01/13/89 | 5.08 | 0.70 | 4.05 | 0.58 | 0.679 | 4.05 | 0.61 | 0.627 |
| FNC 120 | 02/15/89 | 4.99 | 0.71 | 3.98 | 0.57 | 0.654 | 3.88 | 0.66 | 0.656 |
| FNC 126 | 02/23/89 | 4.93 | 0.71 | 4.07 | 0.65 | 0.724 | 3.92 | 0.64 | 0.643 |
| FNC 127 | 03/01/89 | 4.93 | 0.68 | 4.08 | 0.53 | 0.630 | 3.92 | 0.69 | 0.668 |
| FNC 135 | 03/09/89 | 5.06 | 0.67 | 4.19 | 0.55 | 0.649 | 4.13 | 0.63 | 0.644 |
| FNC 144 | 03/21/89 | 4.93 | 0.71 | 4.16 | 0.59 | 0.645 | 4.05 | 0.63 | 0.627 |
| FNC 153 | 04/04/89 | 4.84 | 0.72 | 4.07 | 0.61 | 0.656 | 4.00 | 0.66 | 0.637 |
| GRN 002 | 10/15/88 | 4.76 | 0.71 | 3.82 | 0.54 | 0.452 | 4.45 | 0.61 | 0.466 |
| GRN 009 | 10/19/88 | 4.78 | 0.72 | 3.81 | 0.54 | 0.452 | 4.47 | 0.62 | 0.468 |
| GRN 017 | 10/26/88 | 4.78 | 0.72 | 3.99 | 0.57 | 0.447 | 4.61 | 0.63 | 0.464 |
| GRN 020 | 11/02/88 | 4.69 | 0.71 | 3.77 | 0.57 | 0.463 | 4.30 | 0.62 | 0.490 |
| GRN 033 | 11/08/88 | 4.84 | 0.76 | 3.74 | 0.62 | 0.491 | 4.52 | 0.69 | 0.484 |
| GRN 034 | 11/08/88 | 4.70 | 0.68 | 3.67 | 0.55 | 0.486 | 4.29 | 0.60 | 0.494 |
| GRN 041 | 11/13/88 | 4.62 | 0.64 | 3.69 | 0.54 | 0.461 | 4.30 | 0.59 | 0.472 |
| GRN 044 | 11/17/88 | 4.83 | 0.69 | 3.50 | 0.50 | 0.482 | 4.14 | 0.59 | 0.504 |
| GRN 056 | 11/30/88 | 4.67 | 0.69 | 3.50 | 0.51 | 0.475 | 3.96 | 0.58 | 0.507 |
| GRN 057 | 11/30/88 | 4.71 | 0.64 | 3.45 | 0.50 | 0.476 | 4.03 | 0.57 | 0.505 |
| GRN 064 | 12/03/88 | 4.76 | 0.70 | 3.38 | 0.49 | 0.483 | 4.06 | 0.59 | 0.492 |
| GRN 069 | 12/06/88 | 4.69 | 0.69 | 3.51 | 0.50 | 0.449 | 4.06 | 0.59 | 0.476 |
| GRN 070 | 12/06/88 | 4.91 | 0.68 | 3.37 | 0.53 | 0.526 | 4.07 | 0.57 | 0.510 |
| GRN 076 | 12/13/88 | 4.70 | 0.69 | 3.52 | 0.51 | 0.460 | 3.92 | 0.55 | 0.489 |
| GRN 077 | 12/13/88 | 4.69 | 0.68 | 3.51 | 0.49 | 0.453 | 3.98 | 0.54 | 0.479 |
| GRN 088 | 12/20/88 | 4.83 | 0.71 | 3.43 | 0.51 | 0.484 | 4.13 | 0.58 | 0.484 |
| GRN 089 | 12/20/88 | 4.76 | 0.69 | 3.44 | 0.47 | 0.462 | 4.13 | 0.58 | 0.472 |
| GRN 095 | 01/04/89 | 4.70 | 0.65 | 3.42 | 0.52 | 0.484 | 4.00 | 0.63 | 0.501 |
| GRN 099 | 01/13/89 | 4.77 | 0.73 | 3.29 | 0.48 | 0.463 | 3.84 | 0.57 | 0.498 |
| GRN 113 | 02/07/89 | 4.77 | 0.72 | 3.37 | 0.51 | 0.468 | 3.98 | 0.59 | 0.489 |
| GRN 114 | 02/07/89 | 4.75 | 0.71 | 3.35 | 0.49 | 0.463 | 3.92 | 0.59 | 0.501 |
| GRN 118 | 02/15/89 | 4.68 | 0.72 | 3.28 | 0.49 | 0.459 | 3.92 | 0.59 | 0.493 |
| GRN 119 | 02/15/89 | 4.68 | 0.72 | 3.28 | 0.49 | 0.459 | 3.92 | 0.59 | 0.493 |
| GRN 137 | 03/14/89 | 4.70 | 0.73 | 3.53 | 0.54 | 0.470 | 4.07 | 0.61 | 0.497 |
| GRN 142 | 03/21/89 | 4.78 | 0.72 | 3.52 | 0.50 | 0.454 | 4.20 | 0.59 | 0.467 |
| GRN 143 | 03/21/89 | 4.76 | 0.71 | 3.51 | 0.48 | 0.450 | 4.20 | 0.58 | 0.479 |
| GRN 151 | 04/04/89 | 4.92 | 0.75 | 3.51 | 0.48 | 0.450 | 4.15 | 0.59 | 0.485 |
| GRN 152 | 04/04/89 | 4.62 | 0.75 | 3.44 | 0.51 | 0.450 | 4.13 | 0.61 | 0.461 |
| GRN 158 | 04/19/89 | 4.62 | 0.68 | 3.61 | 0.53 | 0.475 | 4.07 | 0.54 | 0.479 |
| GRN 163 | 04/29/89 | 4.61 | 0.67 | 3.49 | 0.49 | 0.467 | 4.15 | 0.60 | 0.509 |
| NYC 007 | 10/18/88 | 5.48 | 0.75 | 4.47 | 0.64 | 0.627 | 4.39 | 0.63 | 0.669 |
| NYC 015 | 10/26/88 | 5.61 | 0.75 | 4.11 | 0.73 | 0.756 | 4.31 | 0.62 | 0.701 |
| NYC 022 | 11/03/88 | 5.55 | 0.74 | 4.31 | 0.64 | 0.666 | 4.22 | 0.62 | 0.711 |
| NYC 029 | 11/08/88 | 5.70 | 0.72 | 4.31 | 0.61 | 0.676 | 4.13 | 0.63 | 0.759 |
| NYC 030 | 11/08/88 | 5.70 | 0.73 | 4.30 | 0.62 | 0.684 | 4.23 | 0.62 | 0.727 |
| NYC 038 | 11/12/88 | 5.45 | 0.75 | 4.23 | 0.62 | 0.637 | 4.22 | 0.59 | 0.676 |
| NYC 045 | 11/18/88 | 5.85 | 0.72 | 4.28 | 0.61 | 0.699 | 4.07 | 0.59 | 0.756 |
| NYC 046 | 11/18/88 | 5.63 | 0.74 | 4.13 | 0.61 | 0.664 | 4.13 | 0.60 | 0.692 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| NYC 065 | 12/06/88 | 5.60 | 0.75 | 4.06 | 0.59 | 0.657 | 3.91 | 0.59 | 0.701 |
| NYC 066 | 12/06/88 | 5.64 | 0.67 | 4.07 | 0.54 | 0.669 | 3.91 | 0.52 | 0.702 |
| NYC 080 | 12/13/88 | 5.39 | 0.76 | 3.91 | 0.54 | 0.631 | 3.83 | 0.59 | 0.697 |
| NYC 091 | 12/20/88 | 5.38 | 0.76 | 3.92 | 0.58 | 0.643 | 3.75 | 0.58 | 0.689 |
| NYC 092 | 12/20/88 | 5.78 | 0.68 | 4.07 | 0.58 | 0.727 | 3.90 | 0.59 | 0.753 |
| NYC 097 | 01/04/89 | 5.63 | 0.71 | 4.00 | 0.55 | 0.669 | 3.77 | 0.54 | 0.709 |
| NYC 102 | 01/13/89 | 5.31 | 0.75 | 3.90 | 0.55 | 0.621 | 3.68 | 0.52 | 0.663 |
| NYC 121 | 02/15/89 | 5.39 | 0.77 | 3.75 | 0.53 | 0.631 | 3.76 | 0.55 | 0.650 |
| NYC 124 | 02/22/89 | 5.40 | 0.68 | 3.90 | 0.53 | 0.648 | 3.68 | 0.56 | 0.731 |
| NYC 125 | 02/22/89 | 5.78 | 0.80 | 4.14 | 0.59 | 0.645 | 4.08 | 0.59 | 0.665 |
| NYC 145 | 03/21/89 | 5.78 | 0.76 | 4.05 | 0.59 | 0.658 | 3.81 | 0.55 | 0.686 |
| NYC 154 | 04/04/89 | 5.62 | 0.60 | 4.14 | 0.58 | 0.740 | 3.90 | 0.57 | 0.782 |
| NYC 155 | 04/04/89 | 5.63 | 0.60 | 4.14 | 0.58 | 0.736 | 3.90 | 0.57 | 0.777 |
| NYC 160 | 04/19/89 | 5.29 | 0.53 | 4.30 | 0.60 | 0.751 | 4.00 | 0.59 | 0.810 |
| SHP 001 | 10/14/88 | 5.16 | 0.76 | 4.61 | 0.68 | 0.512 | 4.29 | 0.60 | 0.515 |
| SHP 005 | 10/18/88 | 5.08 | 0.78 | 4.70 | 0.64 | 0.478 | 4.39 | 0.60 | 0.482 |
| SHP 013 | 10/26/88 | 5.31 | 0.76 | 4.69 | 0.66 | 0.505 | 4.37 | 0.59 | 0.507 |
| SHP 035 | 11/12/88 | 5.30 | 0.73 | 4.52 | 0.63 | 0.510 | 4.22 | 0.58 | 0.536 |
| SHP 047 | 11/18/88 | 5.15 | 0.73 | 4.38 | 0.63 | 0.510 | 4.15 | 0.59 | 0.524 |
| SHP 048 | 11/18/88 | 5.24 | 0.71 | 4.39 | 0.62 | 0.528 | 4.20 | 0.58 | 0.531 |
| SHP 054 | 11/29/88 | 5.24 | 0.74 | 4.16 | 0.64 | 0.549 | 3.97 | 0.58 | 0.551 |
| SHP 059 | 12/03/88 | 5.25 | 0.73 | 4.23 | 0.66 | 0.559 | 3.99 | 0.55 | 0.520 |
| SHP 071 | 12/06/88 | 5.31 | 0.71 | 4.22 | 0.63 | 0.573 | 3.91 | 0.59 | 0.580 |
| SHP 081 | 12/14/88 | 5.08 | 0.75 | 4.21 | 0.62 | 0.512 | 3.91 | 0.59 | 0.528 |
| SHP 136 | 03/13/89 | 5.08 | 0.72 | 4.38 | 0.63 | 0.540 | 4.00 | 0.55 | 0.523 |
| SHP 140 | 03/21/89 | 5.08 | 0.69 | 4.38 | 0.61 | 0.538 | 4.17 | 0.56 | 0.521 |
| SHP 149 | 04/04/89 | 4.92 | 0.62 | 4.47 | 0.62 | 0.545 | 4.23 | 0.58 | 0.541 |
| SHP 161 | 04/19/89 | 4.61 | 0.54 | 4.68 | 0.67 | 0.585 | 4.38 | 0.56 | 0.544 |
| SHP 165 | 04/29/89 | 4.94 | 0.68 | 4.53 | 0.63 | 0.527 | 4.23 | 0.58 | 0.532 |
| SUN 006 | 10/18/88 | 4.92 | 0.65 | 4.23 | 0.65 | 0.656 | 4.07 | 0.62 | 0.528 |
| SUN 014 | 10/26/88 | 4.93 | 0.65 | 4.23 | 0.64 | 0.653 | 4.08 | 0.63 | 0.531 |
| SUN 023 | 11/03/88 | 5.01 | 0.68 | 4.20 | 0.66 | 0.676 | 3.99 | 0.64 | 0.556 |
| SUN 024 | 11/03/88 | 4.92 | 0.64 | 4.29 | 0.63 | 0.646 | 3.92 | 0.64 | 0.571 |
| SUN 028 | 11/08/88 | 4.68 | 0.72 | 4.15 | 0.70 | 0.616 | 3.84 | 0.68 | 0.544 |
| SUN 036 | 11/12/88 | 4.84 | 0.66 | 4.13 | 0.67 | 0.658 | 3.92 | 0.64 | 0.542 |
| SUN 037 | 11/12/88 | 4.82 | 0.67 | 4.15 | 0.66 | 0.636 | 3.99 | 0.64 | 0.518 |
| SUN 049 | 11/18/88 | 4.93 | 0.64 | 4.07 | 0.65 | 0.666 | 4.07 | 0.65 | 0.666 |
| SUN 050 | 11/18/88 | 4.84 | 0.68 | 4.15 | 0.64 | 0.624 | 4.15 | 0.64 | 0.624 |
| SUN 052 | 11/29/88 | 4.75 | 0.66 | 4.07 | 0.66 | 0.639 | 3.99 | 0.63 | 0.522 |
| SUN 053 | 11/29/88 | 4.92 | 0.65 | 4.13 | 0.63 | 0.650 | 3.91 | 0.61 | 0.543 |
| SUN 060 | 12/03/88 | 4.93 | 0.65 | 4.13 | 0.63 | 0.644 | 3.92 | 0.65 | 0.548 |
| SUN 072 | 12/06/88 | 4.93 | 0.65 | 4.00 | 0.66 | 0.691 | 4.06 | 0.62 | 0.511 |
| SUN 073 | 12/06/88 | 4.82 | 0.63 | 4.07 | 0.65 | 0.651 | 3.92 | 0.63 | 0.551 |
| SUN 082 | 12/14/88 | 4.83 | 0.67 | 4.07 | 0.60 | 0.634 | 3.98 | 0.63 | 0.536 |
| SUN 083 | 12/14/88 | 4.84 | 0.67 | 4.07 | 0.60 | 0.632 | 3.99 | 0.63 | 0.529 |
| SUN 098 | 01/05/89 | 4.99 | 0.63 | 3.91 | 0.61 | 0.696 | 4.04 | 0.58 | 0.499 |
| SUN 103 | 01/13/89 | 5.08 | 0.62 | 4.00 | 0.56 | 0.645 | 3.75 | 0.65 | 0.611 |
| SUN 104 | 01/13/89 | 5.00 | 0.62 | 3.84 | 0.59 | 0.674 | 3.84 | 0.64 | 0.577 |
| SUN 111 | 02/07/89 | 5.01 | 0.65 | 3.68 | 0.57 | 0.678 | 3.90 | 0.61 | 0.536 |
| SUN 112 | 02/07/89 | 4.84 | 0.67 | 3.74 | 0.57 | 0.618 | 3.75 | 0.62 | 0.530 |
| SUN 122 | 02/15/89 | 4.83 | 0.64 | 3.82 | 0.57 | 0.621 | 3.81 | 0.61 | 0.526 |
| SUN 123 | 02/15/89 | 4.85 | 0.66 | 3.84 | 0.57 | 0.617 | 3.82 | 0.60 | 0.529 |
| SUN 128 | 03/01/89 | 4.84 | 0.64 | 3.85 | 0.60 | 0.652 | 3.90 | 0.63 | 0.532 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| SUN 129 | 03/01/89 | 4.78 | 0.66 | 3.92 | 0.59 | 0.613 | 3.91 | 0.60 | 0.515 |
| SUN 133 | 03/09/89 | 5.01 | 0.67 | 4.04 | 0.58 | 0.624 | 3.99 | 0.60 | 0.524 |
| SUN 134 | 03/09/89 | 4.92 | 0.65 | 4.00 | 0.61 | 0.638 | 3.91 | 0.60 | 0.538 |
| SUN 141 | 03/21/89 | 5.06 | 0.63 | 3.84 | 0.63 | 0.727 | 3.75 | 0.64 | 0.603 |
| SUN 150 | 04/04/89 | 4.92 | 0.66 | 3.99 | 0.59 | 0.633 | 3.84 | 0.63 | 0.552 |
| SUN 162 | 04/19/89 | 4.91 | 0.65 | 3.98 | 0.60 | 0.637 | 3.89 | 0.62 | 0.548 |
| SUN 166 | 04/29/89 | 4.94 | 0.65 | 3.89 | 0.59 | 0.646 | 3.92 | 0.64 | 0.550 |

**9. Figure Captions**

Figure 1. Basemap of Nevada. Heavy lines show the locations of the 1986 PASSCAL Basin and Range Active-Source Seismic Experiment. The 1988-89 Passive-Source Experiment was located in an area with a radius of 20 km around the intersection of the 1986 lines.

Figure 2. Expanded map of stations locations. Boxes are the stations of the Large Aperture Array, diamonds are the stations of the Small Aperture Array, and small triangles are the sites of the 1986 Active Source Experiment.

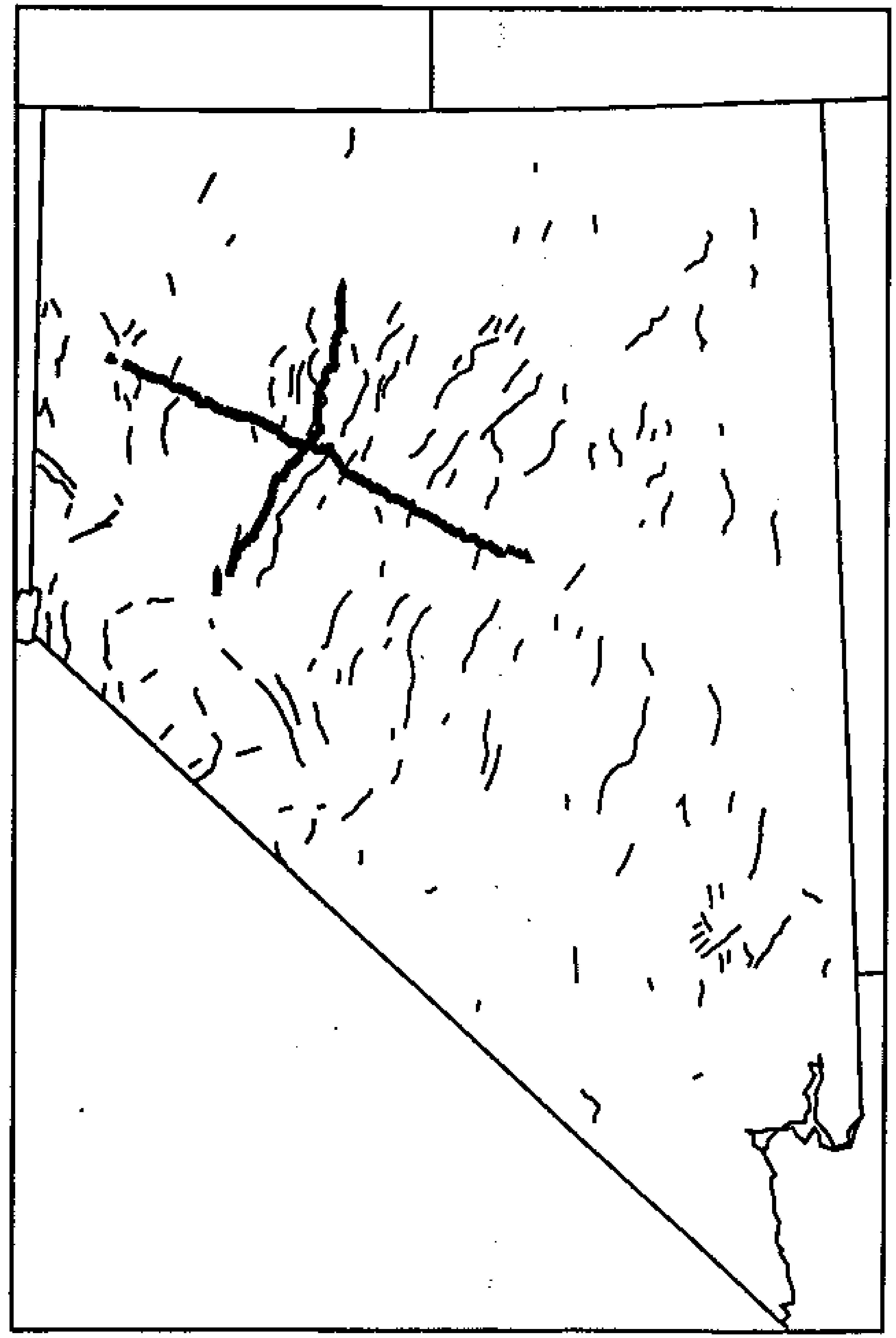
Figure 3. Distribution of Teleseismic Events recorded by the Large Aperture Array. Distance increases radially outward, back azimuth increases clockwise.

Figure 4A. P-wave trigger for Event 156 recorded by the Large Aperture Array.

Figure 4B. S-wave trigger for Event 156 recorded by the Large Aperture Array. Using our numbering scheme, this is event number 856. Trigger occurred 9 minutes, 41 seconds after the P-wave trigger shown in Figure 4A.

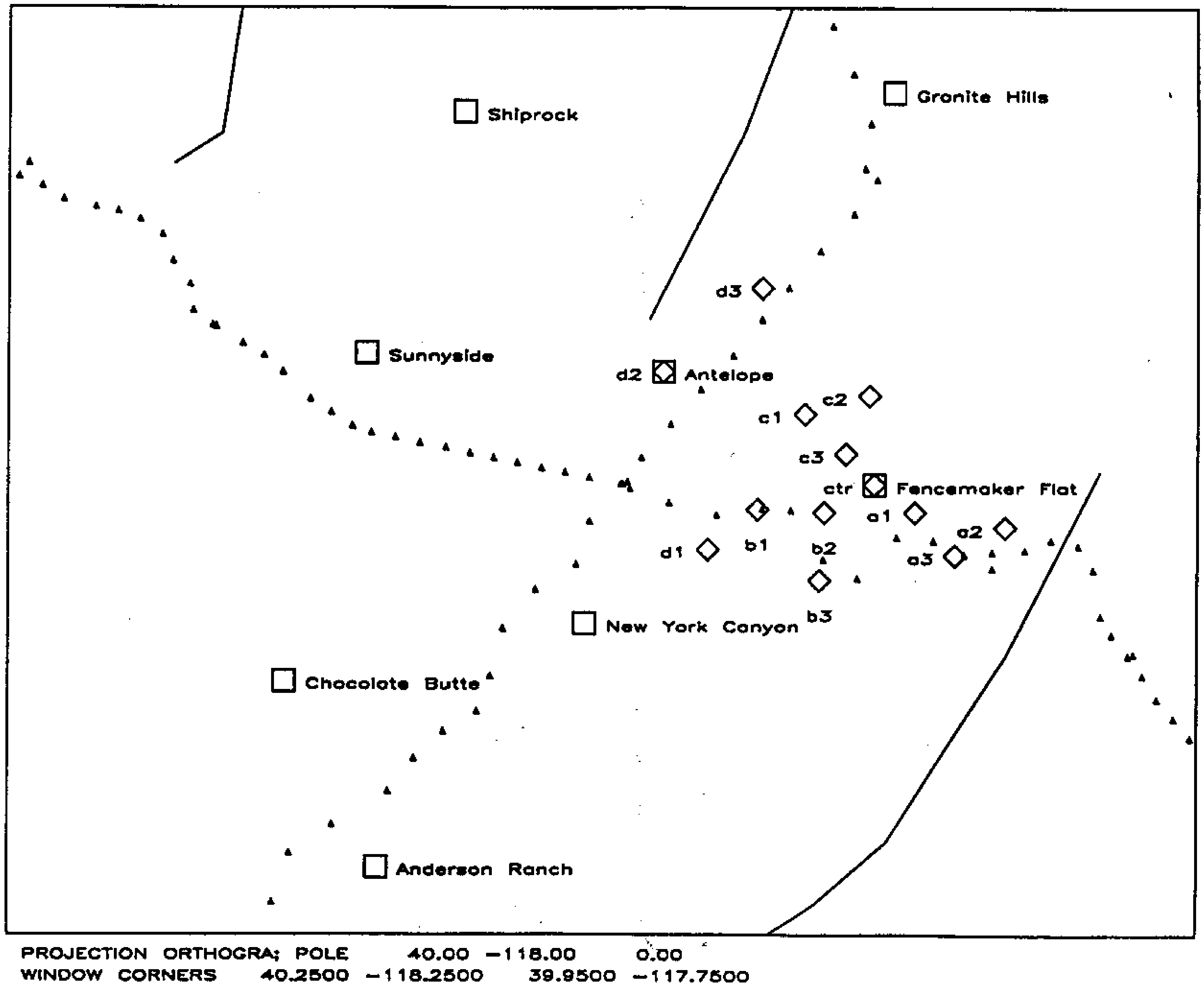
Figure 5. Trigger for Event 155, NTS shot "INGOT", recorded by the Large Aperture Array.

Figure 6. Trigger for Event 208, a Nevada mine blast, recorded by the Large Aperture Array.



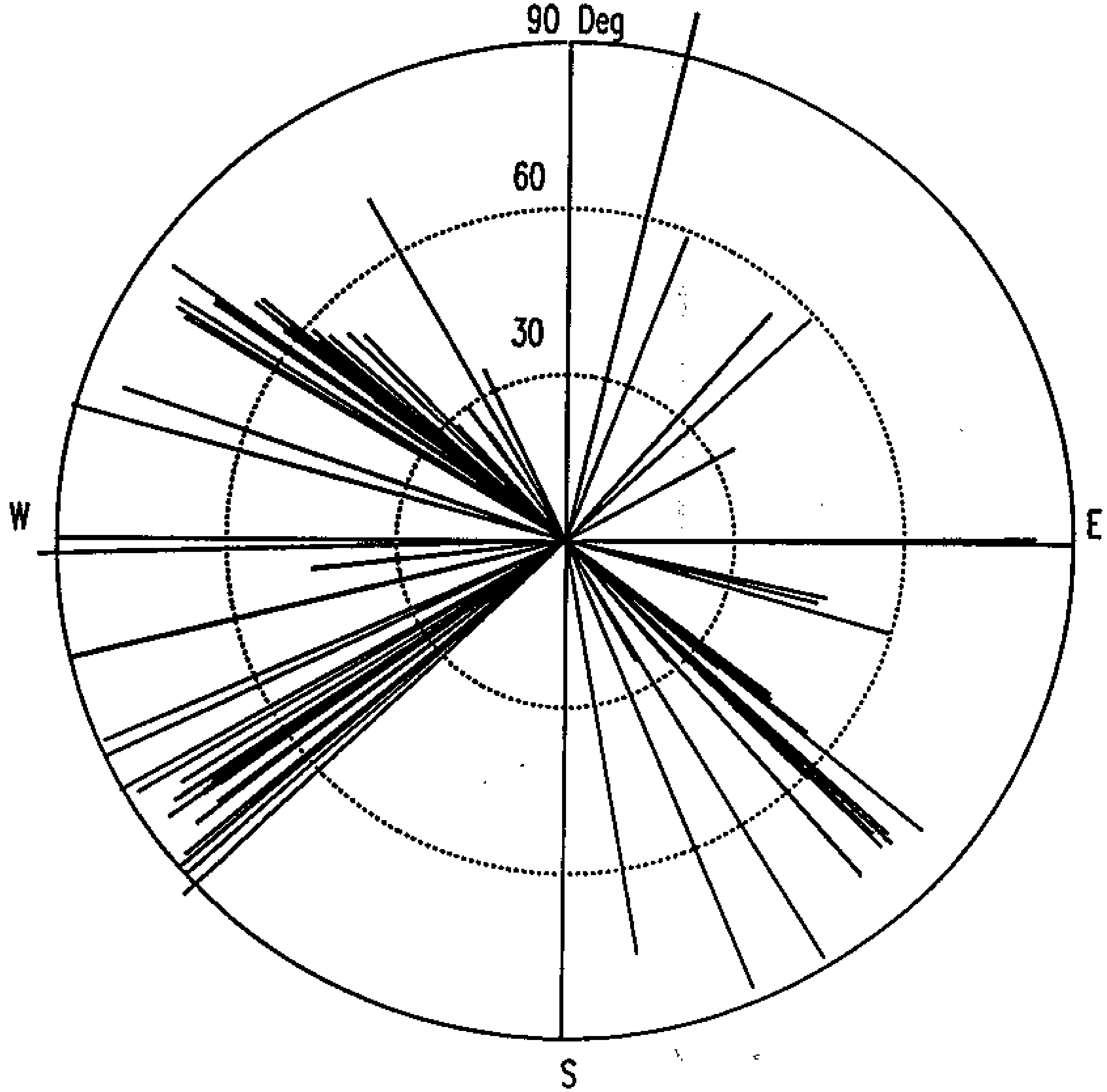
PROJECTION ORTHOGRA; POLE 40.00 −118.00 0.00
WINDOW CORNERS 35.0000 −120.0000 42.5000 −113.5000

Owens and Randall, PDR 90-001, Figure 1

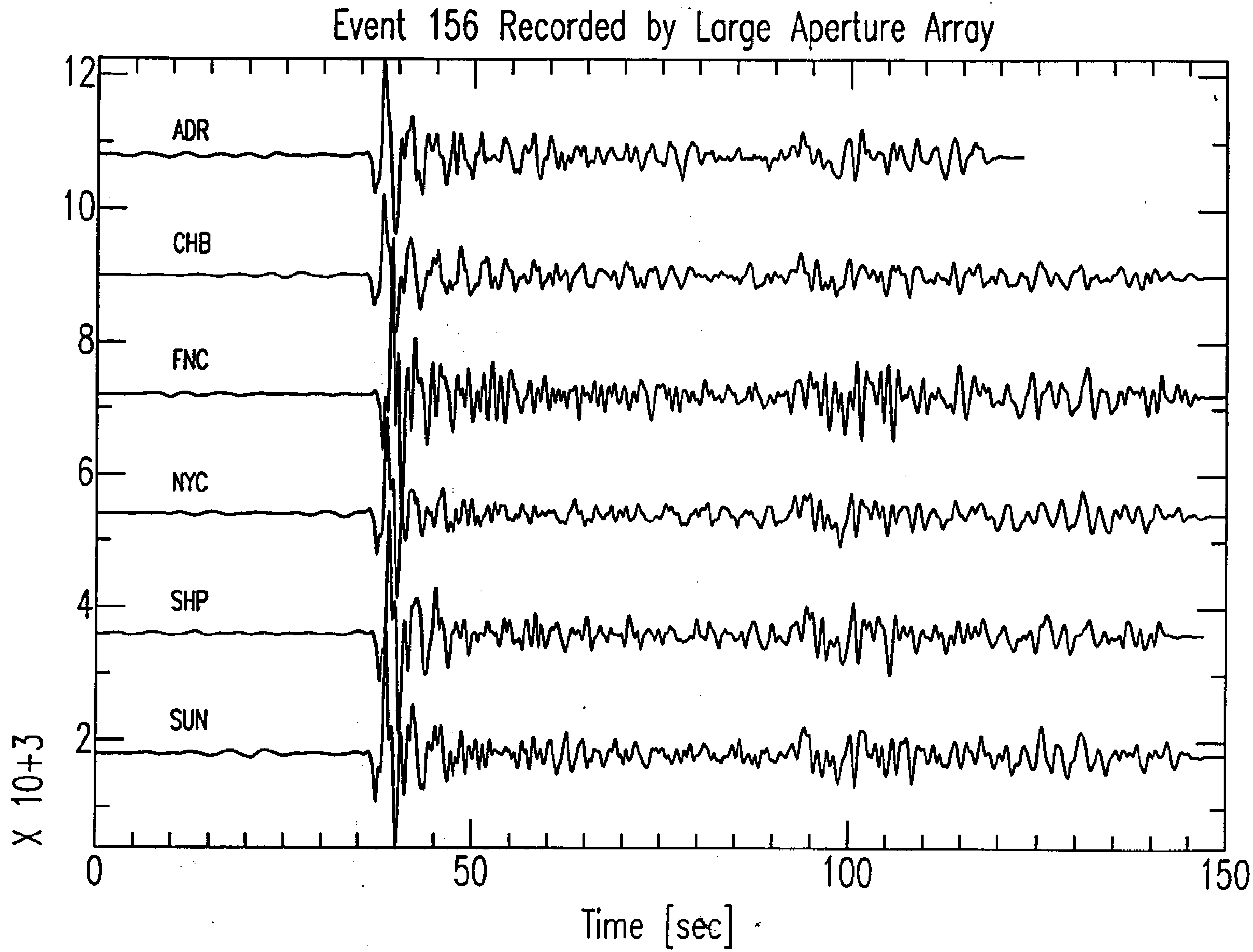



Owens and Randall, PDR 90-001, Figure 2

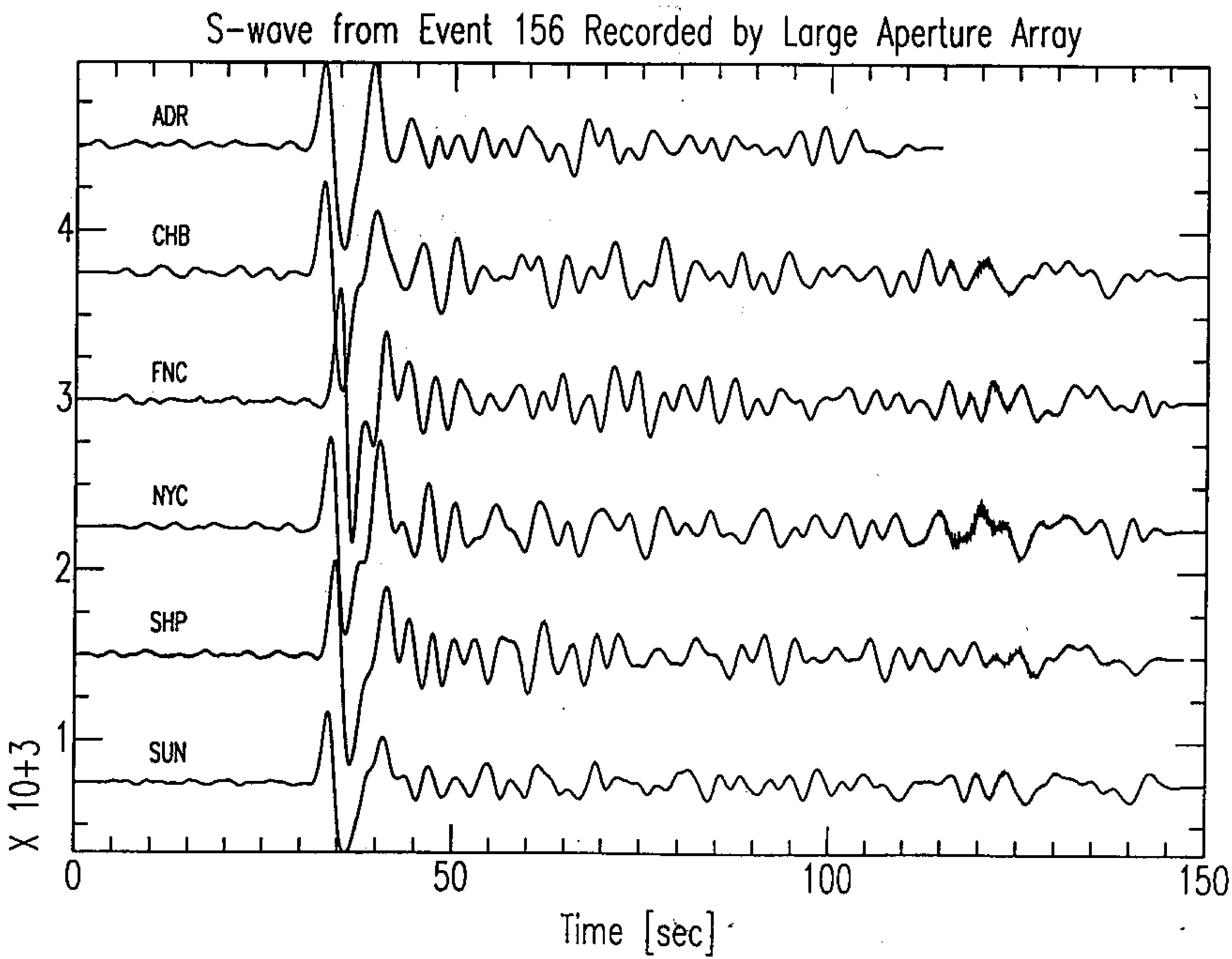
Azimuthal Distribution of Teleseismic Events



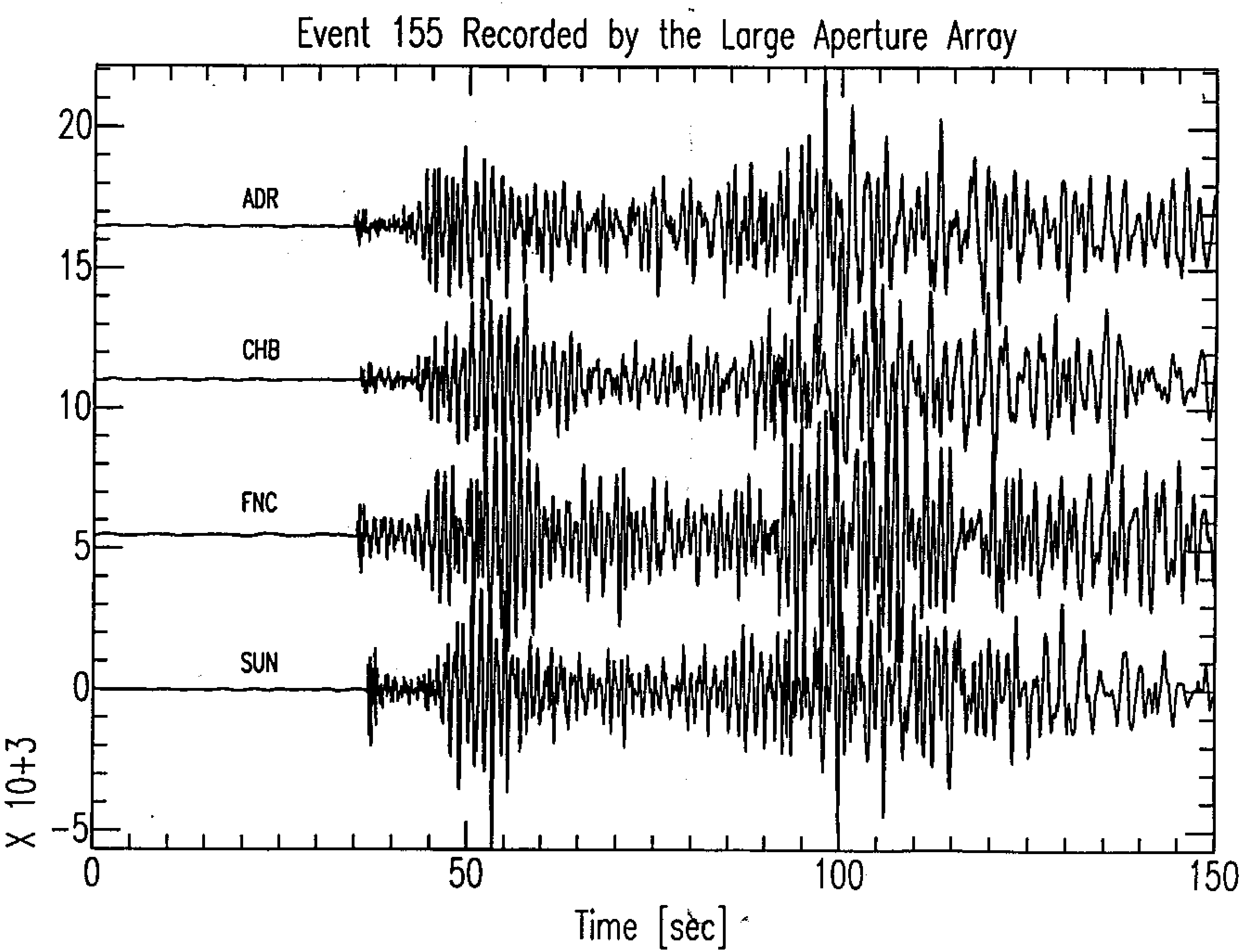

Owens and Randall, PDR 90-001, Figure 3



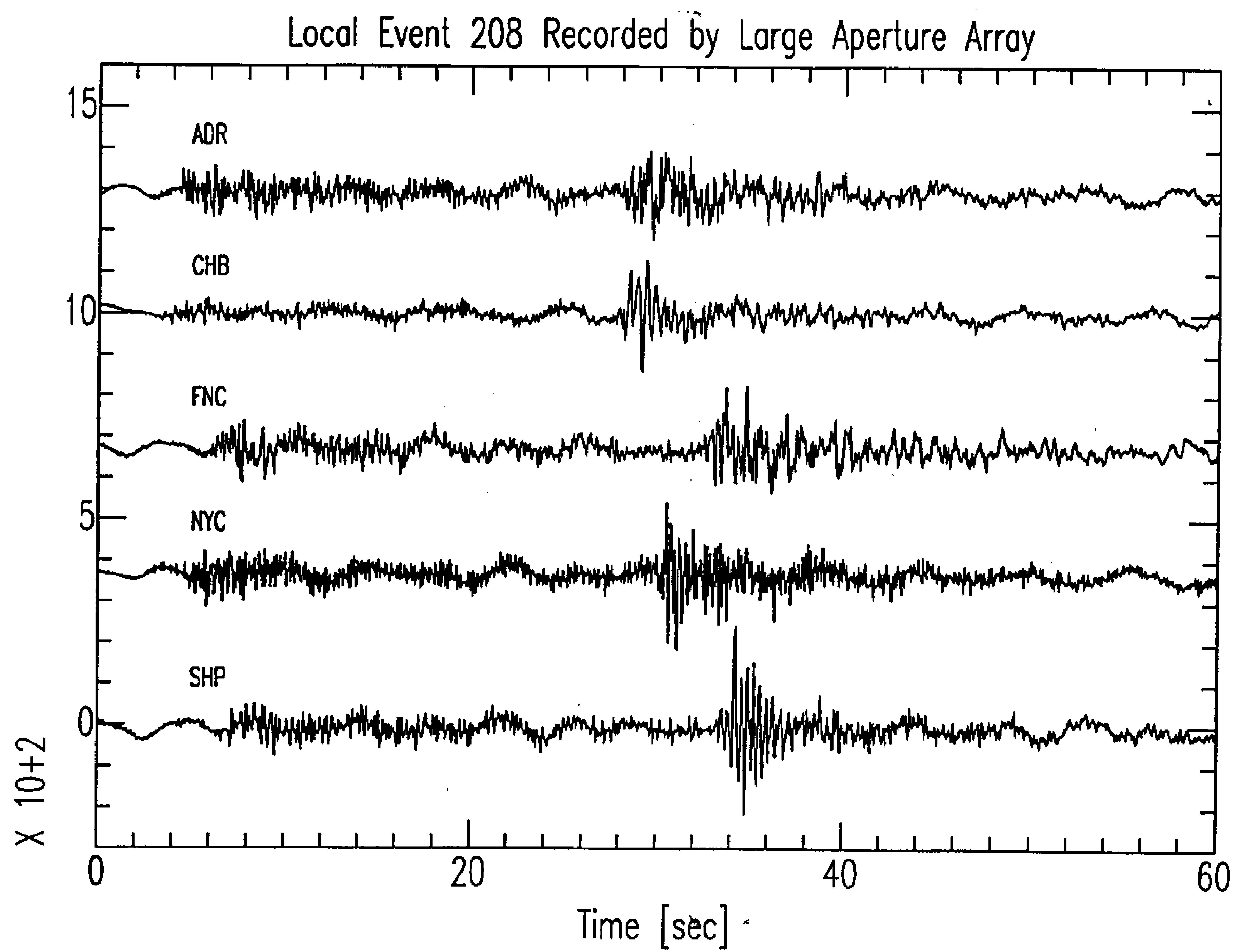

Owens and Randall, PDR 90-001, Figure 4A




Owens and Randall, PDR 90-001, Figure 4B




Owens and Randall, PDR 90-001, Figure 5




Owens and Randall, PDR 90-001, Figure 6