Seismicity in the Vicinity of Yucca Mountain, Nevada, for the Period October 1, 2002, to September 30, 2003

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Abstract

Earthquake activity in the Yucca Mountain from October 1, 2002 through September 30, 2003 (FY03) is assessed and compared with previous activity in the region. FY03 is the first reporting year since the 1992 M 5.6 Little Skull Mountain earthquake with no earthquakes greater than M 3.0 within 65 km of Yucca Mountain. In addition, FY03 includes the fewest number of earthquakes greater than M 2.0 in any reporting year since the LSM event. With 3075 earthquakes in the catalog, FY03 represents the second largest number of earthquakes (second to FY02) since FY96 when digital seismic network operations began. The largest event during FY03 was M 2.78 in eastern NTS and there were only 8 earthquakes greater than M 2.0.

1. Introduction

This report describes the seismicity and earthquake monitoring activities within the Yucca Mountain region from October 1, 2002, through September 30, 2003, based on operation of the Southern Great Basin Digital Seismic Network (SGBDSN). Network practices and earthquake monitoring conducted at the Nevada Seismological Laboratory (NSL) are covered in comprehensive yearly reports (see references). Real-time systems, including regional data telemetry and local data management, provide for the automatic determination of earthquake locations and magnitudes and notification of important earthquakes in the region to UNR staff and DOE management. All waveform and meta-data, including automatic locations, phase arrival information, and analyst reviewed information, are managed through a relational database system allowing quick and reliable evaluation and analysis of ongoing earthquake activity near Yucca Mountain.

2. Data Collection and Processing

2.1 Station Description

As of September 2003 the Southern Great Basin Digital Seismic Network (SGBDSN) included 30 digital seismograph stations. Two stations (ECO and YFT) were installed by Sandia National Laboratories (SNL) but are considered part of the SGBDSN, with all normal QA procedures applied. Some analog stations have been maintained outside the SGBDSN to aid in the characterization of Death Valley area seismicity and in regions not monitored effectively outside of the SGBDSN. (SGBDSN and analog network station locations: DID #012DV.010 and DID #006DV.005). Digital stations ECO and YFT are configured with Geotech GS-13 seismometers and station AL5 in the ESF is configured with a Mark Products L-4. Only S-13 sensors are used in magnitude calculations; no analog station data are used to determine earthquake magnitudes. Ten digital sites are equipped with strong-motion instrumentation. Supplemental 16-bit A/D cards were added to onsite recorders in order to handle the output from RefTek Model 133-05 accelerometers. Data from these strong-motion sites are available in near-real-time and recorded and archived along with all SGBDSN data.

The S-13 seismometers/recorders produce voltage proportional to ground velocity on the flat portion of the velocity response. The nominal corner frequency is at 1.0 Hz, and the damping is a nominal 0.7 critical. Monthly system checks ensure that there is a maximum ±10% deviation for any particular instrument from the nominal response. System check pulses were analyzed to show that none of the instruments drifted outside of this range. Sensors of the analog stations have a similar free period and damping. The SGBDSN S-13 response falls off at

40 Hz due to anti-aliasing filters in the DAS (Digital Acquisition System) units recording at 100 sps.

2.2 Data Collection Method

The field data acquisition systems are described in von Seggern and Smith (1997). During the time period covered by this report, two data streams were in effect at all stations except ECO and YFT: 1) a 20-sps, 3-component, continuous data stream and 2) a 100-sps, 3-component, triggered data stream. Stations ECO and YFT had only the triggered stream. The latter was controlled by an "event" trigger specification with the following parameters:

short-term average (STA) length	0.4 seconds
long-term average (LTA) length	10.0 seconds
STA/LTA trigger threshold	3.5
pre-trigger record length	30 seconds
total record length	150 seconds
channels included in trigger	Z, N, E
threshold exceeded by at least *n* channels	1

A third data stream has been added for the 10 stations equipped with accelerometers. This stream is "cross-triggered" from the 100-sps seismometer stream described above, and the data are also recorded at 100 sps. Raw data are archived in 24-hour files (one per station) that contain all original data packets sent from the field acquisition units. These data are archived on DVD media and submitted to the Records Processing Center (RPC).

On January 1, 2000, a transition to the Antelope seismic processing system was made (von Seggern et al., 2000) for the entire Nevada network. This transition for the NSL network incorporated recording and processing of seismic data from the SGBDSN. The SGBDSN data, directed to files as described above, are also transmitted in near-real-time to the Antelope system where it is then available for review and analysis with the seismic data processing tools of the Antelope system. In automating some seismic network operations through Antelope, additional data processing measures are incorporated in the data flow. We implemented new archival procedures on January 1, 2000, to put the data on 4-mm DAT tapes in Antelope format as a "downstream" dataset. Therefore there are duplicate backups of all seismic data. Depending on the use of the data, retrieval from one or the other (upstream or downstream) of the archived datasets is possible. In addition to storing waveform data, Antelope also stores various parametric data in tables, under the Datascope relational database system (Quinlan, 1998).

2.3 Network Station Downtime

A station-specific method of tracking downtime from the upstream recording was implemented for this fiscal-year report. It is based on querying the Datascope database tables for recorded time intervals for each station. (The Datascope tables are in the daily Antelope directories in the YMP computing system at the NSL. Extraction of recording times from these tables is 'unqualified'.) Figure 1 is a summary of the downtime for each station within the SGBDSN. (The SNL stations ECO and YFT are run in triggered mode only and are not represented here.) Downtime was under 3% for all stations except four: HEL, SCF, STC, and SYM. The least downtime, at station TWP, is approximately 0.7% (Figure 1). The 0.7% can be inferred as the upper bound on network-wide downtime.

2.4 Daily Processing

The daily processing routine was described in von Seggern and Smith (2001) for FY00 and has not changed. The preliminary processing is done within the Antelope system and the preliminary event locations and magnitudes are maintained in the Datascope database (Quinlan, 1998). Waveforms are excerpted for these events and stored online.

The last step in preliminary analysis is for the events to be checked and initialed on record sheets called the “Yucca Mountain Seismic Event Sheet.” These sheets are made by subsetting the Antelope database for events within 65 km of Yucca Mountain (the 65 km radius is referenced to the location of seismograph station RPY in the Yucca Mountain repository area). Events are reviewed according to NSHE (Nevada System of Higher Education) procedure IPR-002 (“Determining the Location of Earthquakes Recorded by the Yucca Mountain Seismic Network”) and initialed by professional staff on the record sheets. In this process events may be relocated and magnitudes recomputed; the revised information is maintained in the database. Also at this time, a review is made on classification of events other than local earthquakes (for instance, blasts).

2.5 Finalizing the Earthquake Catalog

The final locations and magnitudes for the FY03 earthquakes were obtained according to UCCSN procedures IPR-002 and IPR-003 (“Determining the Magnitude of Earthquakes Recorded by the Yucca Mountain Seismic Network”). The location program specified in IPR-002 is HYPOINVERSE, V1.0 (STN 10080-1.0 – operating system Sun Solaris 2.8) (Klein, 1989). The magnitude program specified in IPR-003 is MLCALC, V2.0 (STN 10081-2.0), which was internally developed and implements the local magnitude calculation (ML) of Richter (1935). Non-SGBDSN arrivals may be used in the locations, depending on seismological judgment. This enables the best constraints on event locations near the fringe of the SGBDSN. Only S-13 SGBDSN waveforms are used for final magnitudes, as required by IPR-003.

The preliminary earthquake catalog for FY03, as residing in the Datascope database, contained a total of 3160 earthquakes. The procedure for computing final locations prescribes that the arrival times and preliminary locations be extracted from the Datascope tables and reformatted for input to the program HYPOINVERSE (Klein, 1989); this was done with the program DB2PHS (STN # 10637-1.0 – operating system Sun Solaris 2.8). Phase arrival times were determined with Antelope application DBPICK v. 4.6 (v. 4.6 STN # UCCSN-04-009). The procedure requires that a single velocity model be used for the entire suite of earthquakes; this model specified in IPR-002, and derived from the Hoffman and Mooney (1984) study, has the following structure:

Depth to Top of Layer (km)	P velocity (km/s)
0.0	3.00
1.0	5.85[1]
25.0	6.35
30.0	6.60
35.0	7.80

1. Note that the velocity of the second layer in IPR-002 is given as 5.85 km/s, not 6.00 km/s as in Hoffman and Mooney (1984). This alteration crept into the velocity model and has affected all SGBDSN locations since the start of operations in October 1995. A Non-Conformance Report (NCR # UNR-03-0011) was filed and has been closed. This NCR contains an impact analysis which states that the result of this error on locations is insignificant, and for consistency we continue to use the 5.85 km/s for the second layer in locations.

S-wave velocities are computed from P-wave velocities using a Poisson ratio of 0.25. HYPOINVERSE was run in batch mode. Forty-five events had less than a sufficient number of phases for a location. Also, forty small events were excluded from the catalog because the azimuthal gap was greater than 300 degrees, indicating large uncertainty in the location. Preliminary magnitudes of these forty events were less than ML 0.75 and none were located within 15 km of station RPY in the central repository area.

HYPOINVERSE output format includes uncertainty estimates (+/- one standard deviation) for the horizontal (*erh*) and vertical (*erz*) precision of the hypocenters. These uncertainties are generally greater for *erz* values than for *erh* ones. The uncertainties for the FY03 catalog are comparable to those in prior years.

3. Yucca Mountain Area Seismicity

3.1 FY03 Seismicity

The FY03 earthquake catalog consists of 3,075 earthquakes located within 65 km of Yucca Mountain (Figure 2). There were few notable earthquakes during FY03 and there were no earthquakes larger than M 3. Figure 3 shows the locations of earthquakes larger than M 2.0 in FY03. Since 1992 the LSM aftershock zone has been the most prominent feature of the seismicity of the NTS region (#1, Figure 2). LSM area activity has been covered in numerous yearly seismicity reports (see references; yearly seismicity reports) and in published reports (Harmsen, 1994; Meremonte et. al., 1995; Smith et al., 2001). Summarizing the earthquakes in Figure 2, one feature not observed in previous years (labeled #2) in the LSM region is a north-south striking lineation defined by a number of small magnitude earthquakes that plot on the north side of Rock Valley east of the LSM sequence area. Other features of note in the FY03 activity are a set of northwest and northeast striking short-length alignments of small magnitude earthquakes east of Timber Mountain caldera (#3 Figure 2), two parallel northeast striking alignments of similar length within the topographic expression of Timber Mountain Caldera (#4 Figure 1), and a cluster of activity in northern NTS (#5, Figure 2). These short-length alignments are based on very small earthquakes. Although the lengths of the trends are larger than the epicentral uncertainties for the majority of the earthquakes, it is possible the geometry of the network and the uncertainties in the velocity model may contribute to the observed northeast and northwest alignments. These trends are apparent in the activity since October 1, 1996 (Figure 4).

The largest event during FY03 (M 2.78; March 15, 2003) occurred in the Rock Valley fault zone west of and adjacent to the 1999 Frenchman Flat sequence area at the eastern end of Rock Valley (Figure 2). All earthquake magnitudes from FY96 through FY03 and reported here as 'M' are local Richter (1935) magnitudes, M_L. Earthquakes magnitudes in prior years are derived from coda durations (see references and reports from previous years). Table 1 lists the eight earthquakes greater than M 2.0 during FY03 (Figure 3).

Table 1. Largest Earthquakes of FY03 (from DID 006DV.001)

Origin Time	Latitude	Longitude	Depth	Mag	#p	Gap	near	rms	eh	ez
20030315 0322 58.49	36 43.44	116 00.60	10.94	2.78	35	112	8.3	0.11	0.4	0.7
20030329 0819 29.19	37 01.35	116 06.87	11.21	2.63	33	123	15.7	0.12	0.3	1.0
20030713 2044 25.44	36 50.99	116 05.22	11.55	2.61	31	161	15.8	0.11	0.4	1.3
20030925 2110 28.88	36 37.17	115 57.51	13.15	2.32	33	139	14.3	0.08	0.4	0.7
20030524 1616 26.58	36 42.31	116 18.34	12.63	2.32	42	80	3.3	0.11	0.2	0.5
20030802 2344 24.71	36 54.07	116 42.81	1.32	2.20	30	117	8.1	0.13	0.3	9.9
20030828 2206 56.90	36 50.57	116 16.10	10.96	2.11	16	171	6.2	0.08	0.4	0.5
20030321 1830 50.54	36 41.28	117 06.76	2.93	2.08	37	77	13.0	0.11	0.3	2.9

Origin Time: time of the event in UTC (Coordinated Universal Time)
Latitude: North latitude in decimal minutes
Longitude: West longitude in decimal minutes
Depth: hypocentral depth (km)
Mag: magnitude (ML)
#p: number of phase picks used to locate the event
Gap: location gap (degrees)
near: nearest station, epicentral distance (km)
rms: root-mean-square station travel time residual (sec)
eh: horizontal uncertainty (km)
ez: vertical uncertainty (km)

Figure 4 shows the locations of FY03 earthquakes along with those of the catalog from FY96 through FY02 illustrating the activity since digital network operations began. This allows for comparing regions of activity in FY03 with respect to previous years. In FY03, one event was located within 10 km of seismograph station RPY in the central repository area. Its location parameters are as follows: Origin Time: February 4, 2003, 10:35:55.23 UTC; Latitude: 36

54.40N; Longitude: 116 28.04W; Depth: 9.49 km; Magnitude: -0.33. Figure 5 shows the location of the event relative to Yucca Mountain and seismograph station RPY.

Blasts recognized in the network during FY03 are tabulated in Appendix 1. These are not included in the earthquake catalog but have been recognized as explosion sources by analysts.

3.2 FY03 Focal Mechanisms

Appendix 2 includes first-motion focal mechanism solutions for FY03; 35 mechanisms were determined for FY03 and individual event solutions are tabulated in a modified FPFIT format (Reasenburg and Oppenheimer, 1985). Focal mechanisms were determined with application FPFIT, V1.0 (STN 10083-1.0). Corresponding lower hemisphere graphical representations and first-motion polarities are shown in Appendix 2. Because there were no events greater than M 2.8 during FY03, first motion focal mechanisms are generally poorly constrained; in many cases only two quadrants include first-motion polarities. Therefore, highlighted in Appendix 2 are those solutions judged to be relatively more reliable and better constrained in the set.

3.3 1978-FY03 Seismicity Rate Comparisons

Table 2 lists the numbers of M 2, M 3, and M 4+ earthquakes, and total number of earthquakes, located within 65 km of Yucca Mountain for time periods covering 1978-FY03. Data periods listed in the first two rows of Table 2 (time periods 8/1978 through 09/1993) includes unqualified data and seismicity during these time periods is considered corroborative in developing conclusions based on qualified data (qualified data is listed in Table 2 and includes

FY94-FY03 time periods). This summary is compiled in order to compare activity rates through the history of recent earthquake monitoring and to illustrate the increase and subsequent gradual decline in activity in the region that followed the LSM sequence. FY03 is the only year since the 1992 LSM sequence with no earthquakes larger than M 3. In contrast to earthquake activity throughout the NTS region following the LSM earthquake, from 1978 to prior to the LSM sequence in 1992 there were no earthquakes larger than M 4 recorded within 65 km of Yucca Mountain. Prior to the LSM earthquake, large underground nuclear explosions were detonated in the northern NTS area, and some of the aftershocks of these events may be included in some earthquake catalogs. The second time period in Table 2, 6/28/1992-09/1993, is not directly on a fiscal year boundary in order to bracket the initiation and first year and a half of the LSM sequence. This period includes an M 3.3 foreshock that occurred approximately 14 minutes prior to the M 5.6 LSM mainshock. Earthquake activity for this time period also includes the May 1993 M 4.0 Rock Valley earthquake and its aftershock sequence (Shields et al., 1998). The remaining time periods cover fiscal year boundaries (October 1 through September 30 for relevant years) in order to make rate comparisons. Activity rates have gradually declined over the nearly 12 years since the LSM sequence, illustrated in the numbers of M 3 and M 2 events in progressing years. Two notable earthquake sequences have occurred during the FY96-FY03 period (digital recording era). These are the FY99 M 4.7 Frenchman Flat and FY02 M 4.4 LSM earthquake and their aftershock sequences. In no operating year since the 1992 LSM earthquake have there been fewer earthquakes greater than M 2.0 than in FY03, and in no other reporting year have there been no earthquakes M $\geq$ 3.0. von Seggern and Smith (2001) described the general increase in seismicity throughout the NTS region in the immediate years following the June 28, 1992, M 7.1 Landers and June 29, 1992, M 5.6 LSM earthquakes.

Over the approximately 14 years of seismic monitoring activity prior to the LSM event there were only 8 earthquakes M ≥ 3 (a rate of less than 1 M 3 per year) and no earthquakes M ≥ 4 within 65 km of Yucca Mountain. There is a general decreasing trend in the number of M ≥ 2.0 and greater events since 1992 with FY99 and FY02 numbers reflecting the earthquake sequences noted in those years. Figure 4 shows FY96-02 (dark symbols) and FY03 (red symbols) earthquakes to illustrate FY03 source areas that have and have not been active since FY96 when the digital network became operational.

Although the earthquake catalog is still dominated by LSM aftershock activity, the post-LSM period represents a region-wide decline in M > 2 earthquakes and apparent return to pre-LSM activity rates (Table 2). Therefore, the observed rates of activity over the past several years may be representative of the longer term state of seismicity in the region. The increase in total numbers of earthquakes per-year located within 65 km of seismic station RPY at Yucca Mountain primarily reflect the multiple, offsetting effects of improved detection threshold of the digital network and decreasing rates subsequent to the LSM earthquake. The decline in the rates of earthquakes larger than M 2.0 that has taken place since the 1992 M 5.6 LSM earthquake is based on yearly trends from qualified data (FY94-FY03), as can be seen in Table 2. Trends over time periods 8/1978 through 09/1993 (unqualified data in Table 2) corroborate this conclusion.

Table 2. Earthquake Activity Summary: 1978-FY03

Period of Activity	Earthquakes within 65 km from YM	M ≥ 4.0	M 3.0-3.99	M 2.0-2.99
8/1978-6/28/1992[1]	4601	0	8	223
6/28/1992-09/1993[2]	2270	6[3]	54	449
FY94	1096	1	16	158
FY95	775	0	8	127
FY96	2027	0	4	26

FY97	1925	1[4]	3	16
FY98	2732	0	5	24
FY99	2983	2[5]	9	53
FY00	2313	0	3	9
FY01	2014	0	2	11
FY02	5171	1[6]	2	26
FY03	3075	0	0	8
Totals	30982	11	114	1130

1. Includes earthquake activity prior to the M 5.6 LSM sequence. USGS earthquake catalog for 1978 -1992 is 'unqualified' data and therefore not to be used for quality-affecting work.
2. Includes LSM aftershock sequence from June 28, 1992, through September 30, 1993 ('unqualified data').
3. Includes the M 5.6 LSM mainshock.
4. M 4.1 Groom Lake earthquake.
5. 1999 M 4.7 (mainshock) and M 4.0, Frenchman Flat Sequence.
6. M 4.4; LSM aftershock, 2002.

Data sources; DID#s 012DV.019 (UQ), 012DV.011, 012DV.012, 006,DV.004 and 006DV.001; DTN#'s GS950183117412.001 and GS950383117412.003.

Rows 1 and 2 of this Table (data from 8/1978-09/1993) include unqualified data and these data should not be used for quality-affecting work. Activity during these times periods should only be considered corroborative in supporting conclusions regarding seismicity rates.

4. Summary of FY03 Seismicity

Although FY03 includes the second largest number of events since digital network operations began in FY96, it is the only reporting year since the 1992 LSM earthquake and the only reported year for which qualified data is used (FY94-FY03) with no earthquakes M ≥ 3.0 within 65 of the Yucca Mountain site. Data from 8/1978 through 09/1993 include unqualified data and corroborate this conclusion. For earthquakes larger than M ≥ 2, it is the least seismically active reporting year based on qualified data sets in Table 2 (FY94-FY03). This is also the case considering activity since the LSM sequence in mid-1992 (statement based on corroborative data). FY03 activity is generally consistent with the spatial patterns of seismicity observed during the FY96-FY02 time period (digital recording era; Figure 4). One earthquake of M -0.33, was located within 10 km of Yucca Mountain during FY03. The number of M ≥ 3.0

earthquakes, many of these outside the 1992 LSM aftershock zone, has decreased since the LSM event and the region may be returning to pre-LSM activity levels.

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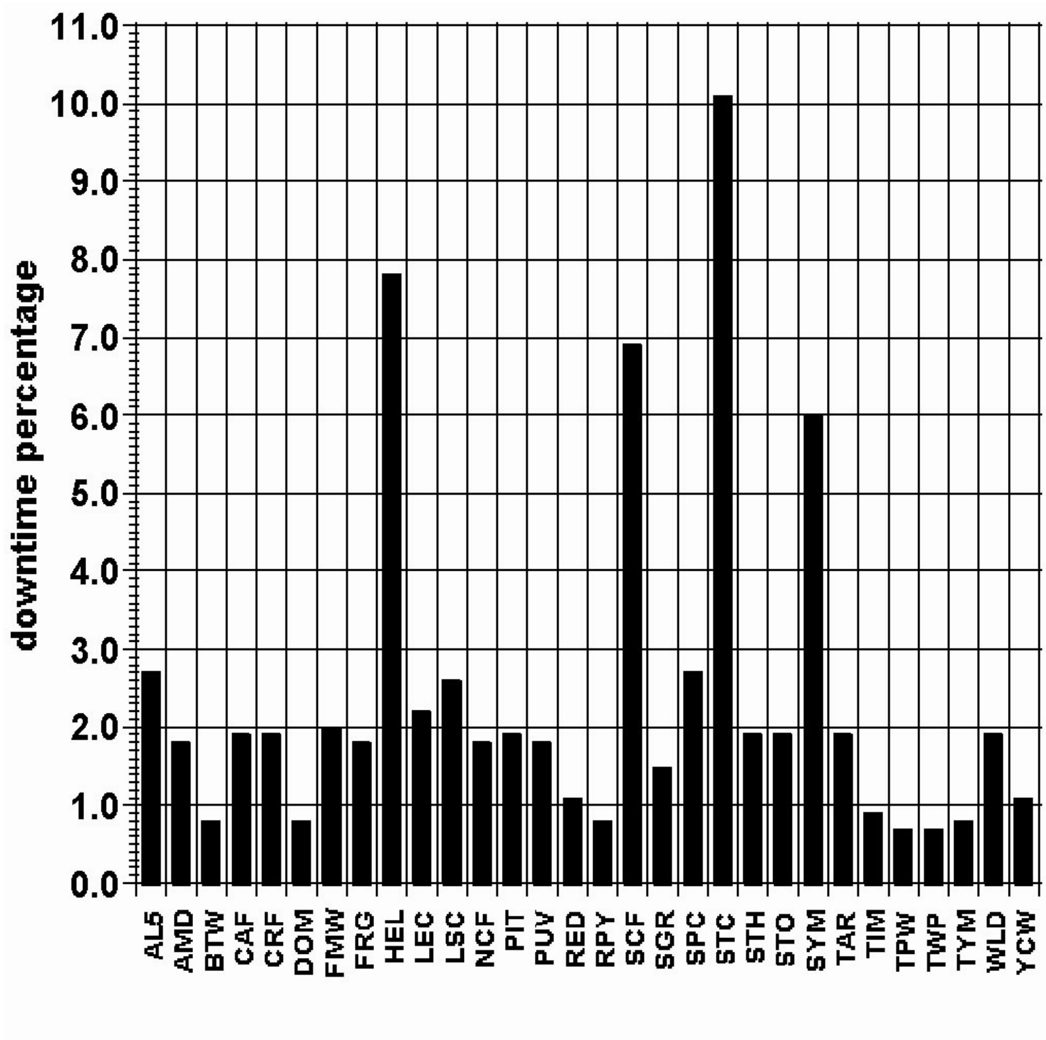

Figure 1. Downtime of individual stations of the SGBDSN for FY03.

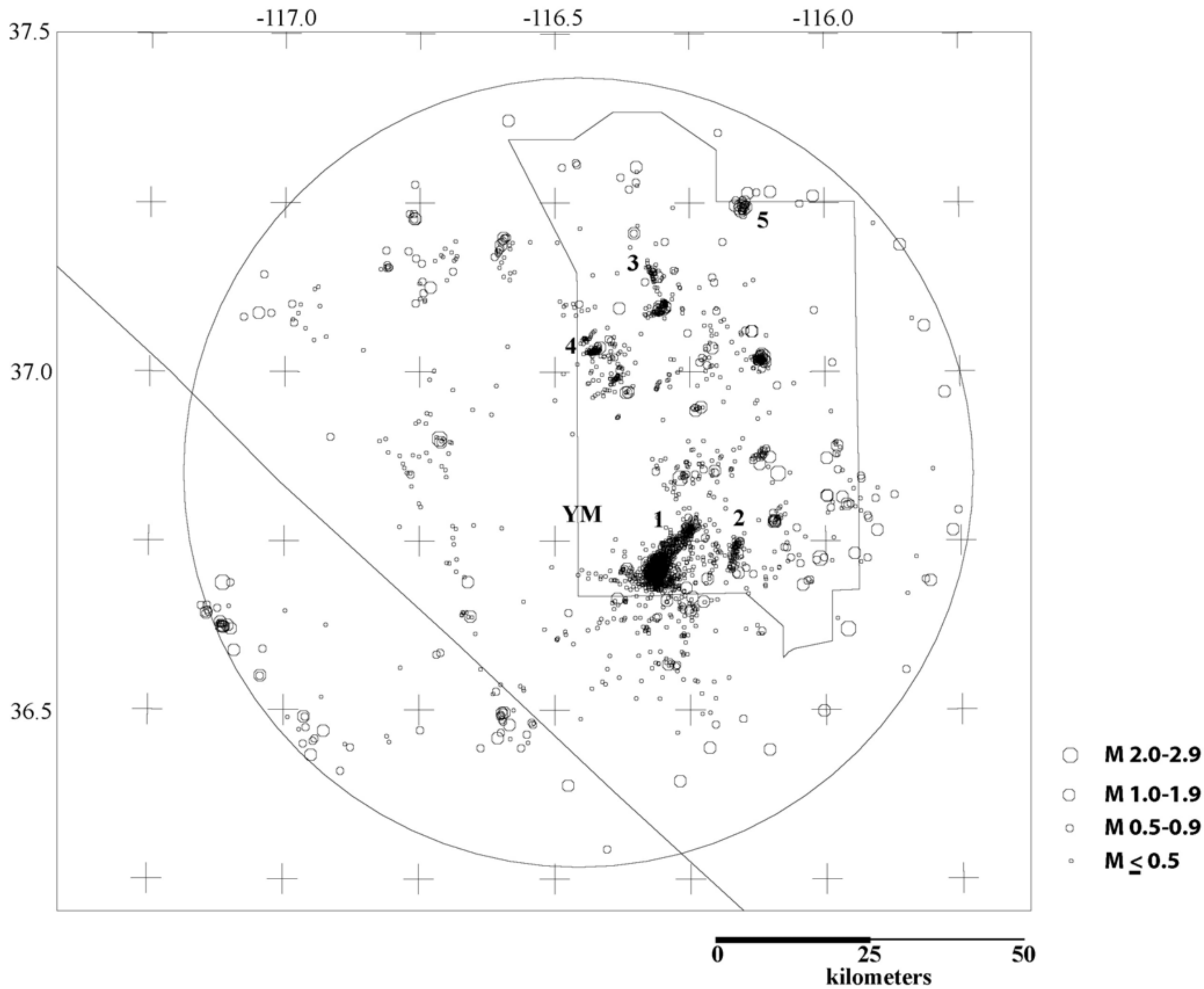

Figure 2. FY03 catalog locations. **YM -** Yucca Mountain. Notable features in the FY03 seismicity; **1** – Little Skull Mountain aftershock zone; **2** – NS striking lineation of seismicity north of Rock Valley and east of Skull Mountain; **3 and 4** – clusters of seismicity along the rim and within the moat structure of the Timber Mountain Caldera, respectively; **5** – cluster of seismicity in northern NTS. (DID 006DV.001.) The circle represents 65 km from seismograph station RPY in the central Yucca Mountain area and is included in figures below

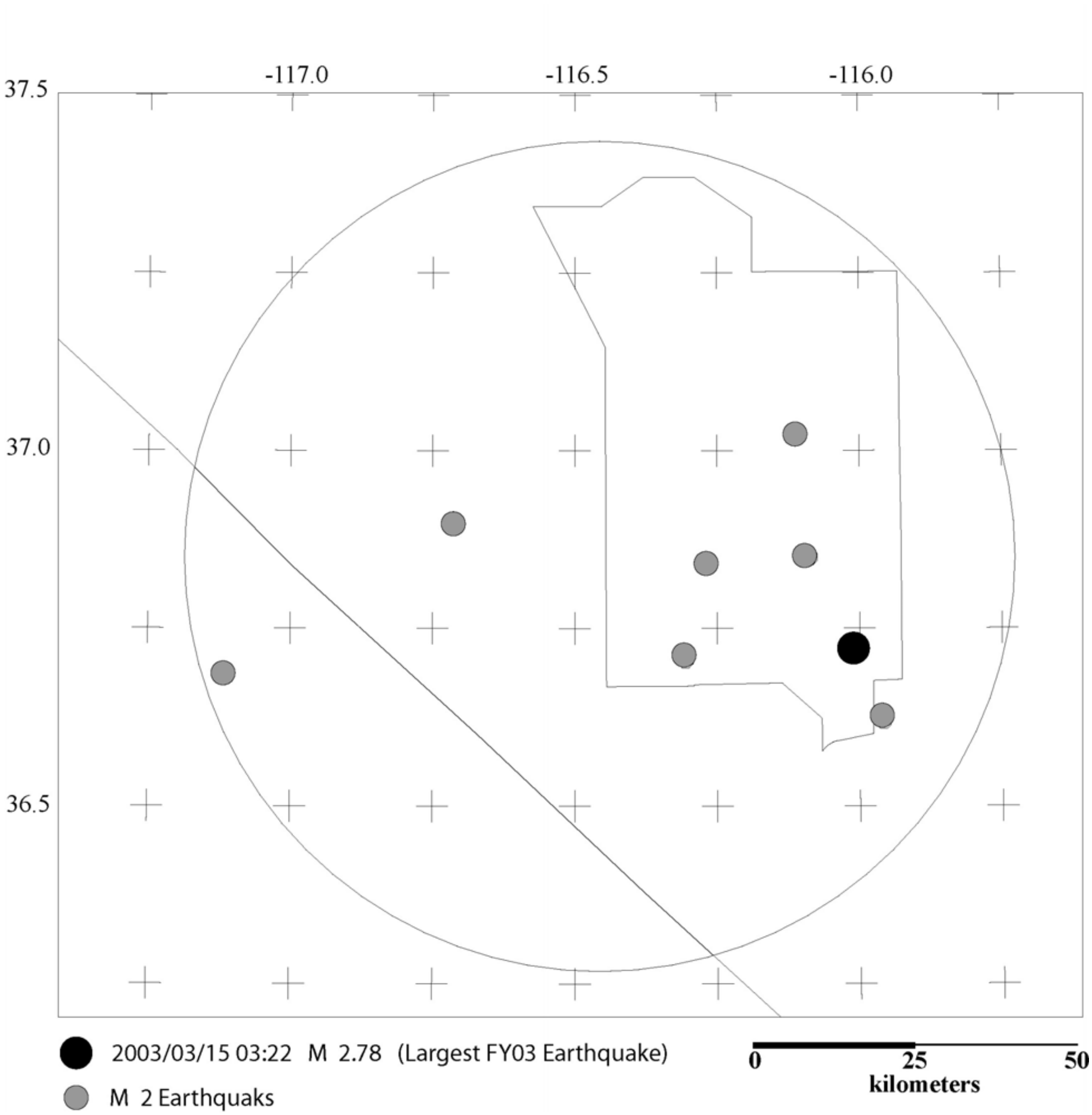

Figure 3. Earthquakes M 2.0 and larger during FY03 (DID 006DV.001).

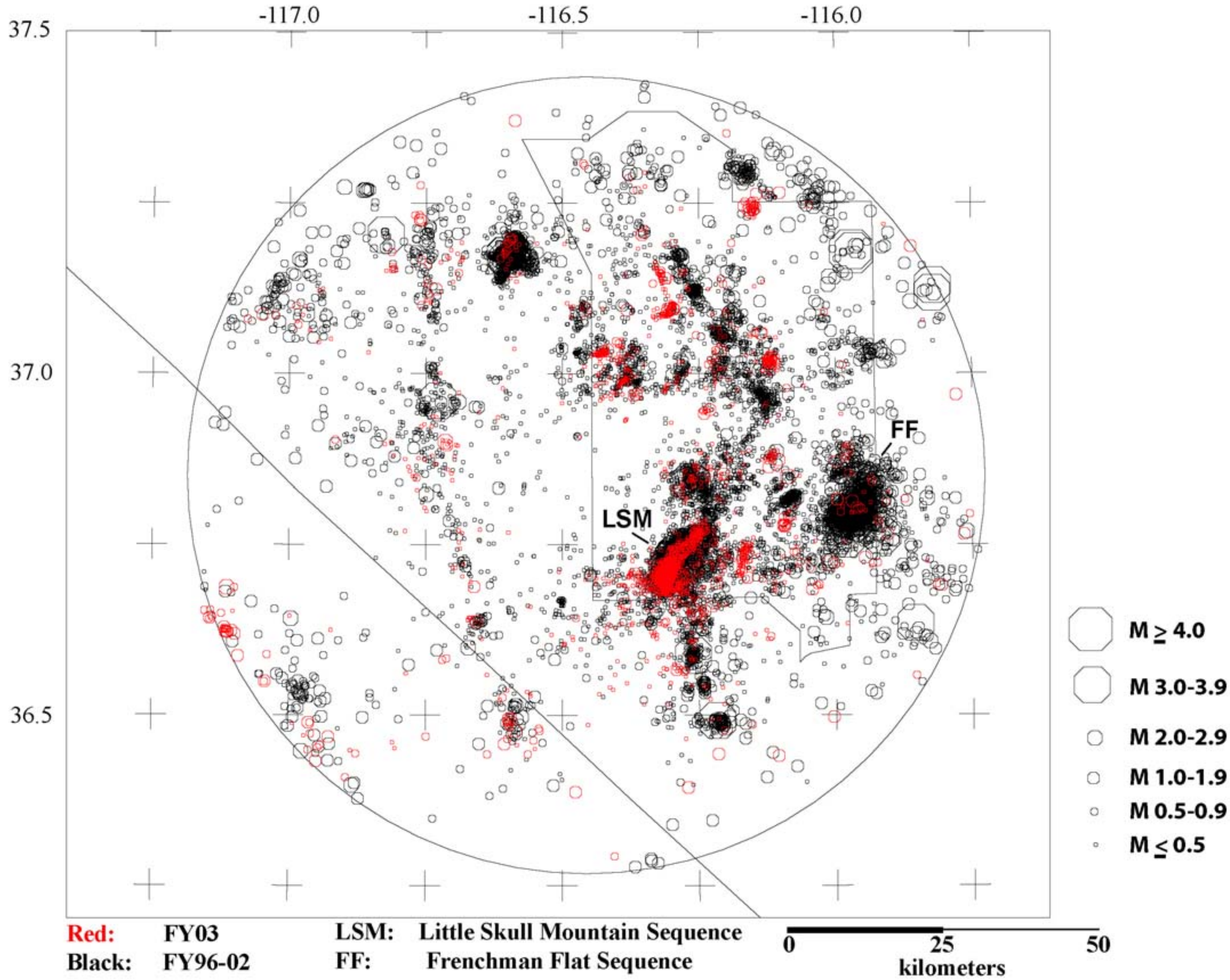

Figure 4. FY96-FY02 (black) and FY03 (red) SGBDSN earthquake locations shown as a function of magnitude (DID 006DV.001 and DID 006DV.004).

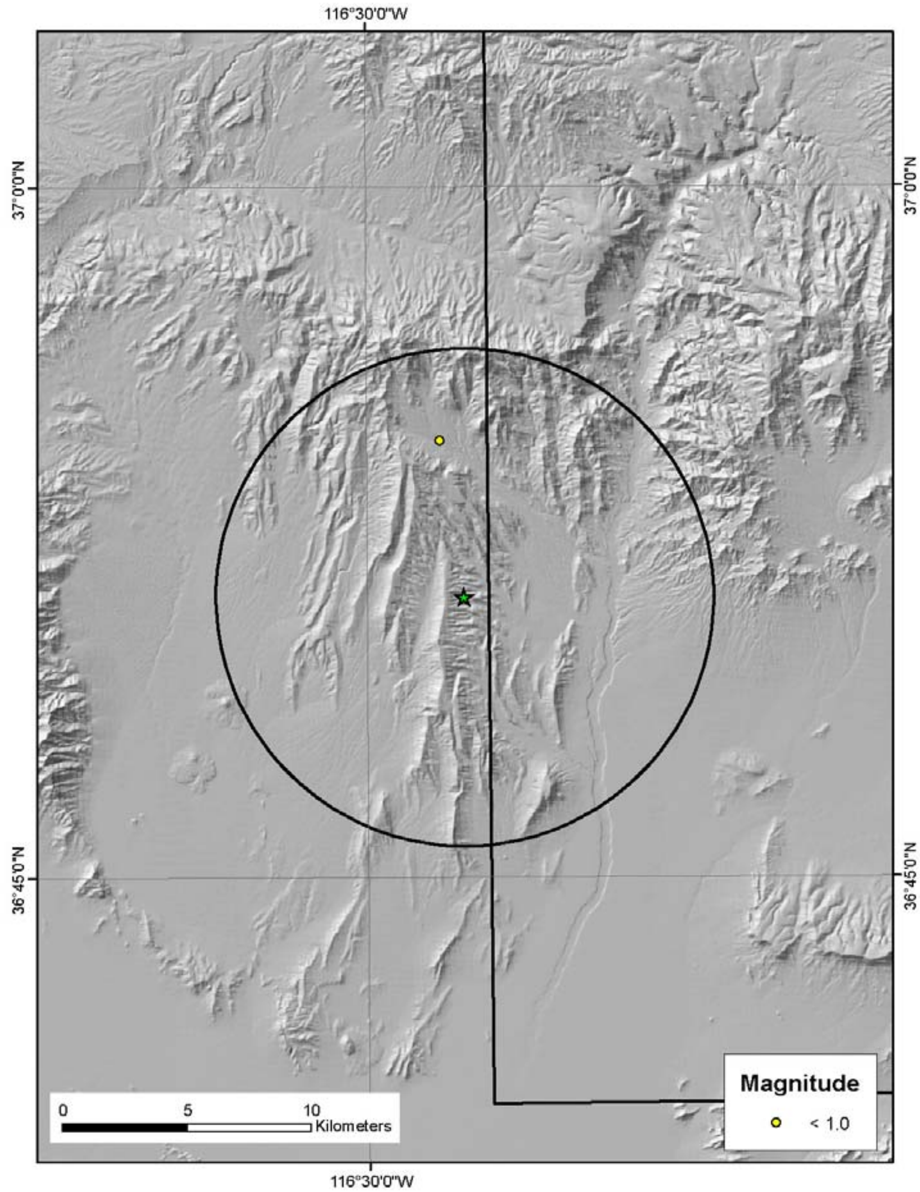

Figure 5. The location of the only event (M -0.33) located within 10 km of station RPY (green star) in the central repository area during FY03 (DID 006DV.001).

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Appendix 1
Events Identified and Located As Blasts in FY03 (006KS.004)

Date	Origin Time	Latitude	Longitude	ML
12/05/2002	15:23:03.86	37.3072	-116.4666	0.82
12/06/2002	16:53:20.15	36.6029	-116.0232	0.32
01/23/2003	19:59:54.00	36.5972	-115.9603	0.98
01/25/2003	19:57:51.22	36.9997	-116.7235	0.28
03/03/2003	17:03:20.94	37.2245	-116.4227	0.41
03/05/2003	08:35:47.37	36.7891	-115.7366	0.60
03/07/2003	00:34:08.53	37.2397	-116.5604	-0.09
03/07/2003	00:59:25.25	37.2937	-116.3916	0.32
03/07/2003	06:06:32.40	37.3106	-116.3661	0.11
03/10/2003	23:31:32.04	36.6265	-115.8604	1.22
03/13/2003	06:30:16.37	37.4142	-116.5774	0.49
03/13/2003	17:17:05.31	36.8634	-116.2939	0.10
04/10/2003	20:00:57.79	37.0746	-115.9845	0.73
05/15/2003	22:09:47.90	37.3913	-116.5857	0.41
06/06/2003	16:24:44.25	37.0125	-116.1722	0.62
06/21/2003	17:41:20.82	36.6018	-115.8515	1.09
07/07/2003	00:25:21.16	36.7915	-116.7285	-0.04
07/26/2003	15:30:47.59	37.0185	-116.1641	0.40
07/26/2003	15:39:56.91	37.0133	-116.1684	0.37
08/08/2003	17:22:23.91	36.9784	-116.7678	0.13
08/15/2003	13:48:52.26	37.3966	-116.4846	0.69
08/16/2003	17:21:12.53	37.0258	-116.1689	0.54
08/21/2003	23:07:18.13	36.9995	-116.7738	-0.14
09/22/2003	19:43:00.73	37.0043	-116.7861	0.14
09/24/2003	23:18:34.86	37.0025	-116.1616	0.00
09/30/2003	19:20:25.44	36.3964	-115.9805	0.91

Date: Calendar date
Origin Time: hour:minute:seconds (UTC)
Latitude: N latitude (decimal degrees)
Longitude: W longitude (decimal degrees)
ML: local magnitude

Appendix-2
FY03 Focal Mechanisms
DID's 006DV.001 (locations) and 006DV.002 (focal mechanisms)

Summary of fpfit focal mechanism solutions modified FPFIT format for table display in column format. Strike, dip, and rake are in Aki and Richards (1980) convention. Location information for each event included in DID 006DV.001.

Origin Time	Mag	#p	Gap	near	rms	eh	ez	str	dp	rk	erft	#fm	s	d	r
20021019 719	1.81	26	117	12.0	0.08	0.3	1.6	255	85	170	0.06	22	15	45	35
20021104 1021	1.40	34	154	10.0	0.09	0.3	0.8	155	70	-40	0.11	16	15	20	10
20021111 428	1.42	36	70	9.0	0.12	0.2	1.1	55	65	140	0.16	27	13	35	55
20021114 537	1.25	43	63	14.0	0.12	0.2	1.6	250	75	160	0.16	17	10	28	15
20021127 1130	1.49	42	139	6.0	0.12	0.3	0.3	0	85	0	0.06	23	10	5	15
20021130 2212	1.56	28	109	4.0	0.09	0.3	0.6	105	55	-100	0.00	21	23	28	40
20021206 1449	1.20	36	88	12.0	0.13	0.3	1.1	70	75	180	0.06	27	10	45	30
20021222 2048	1.12	36	97	4.0	0.10	0.3	0.6	135	25	-100	0.00	22	23	3	50
20030313 1054	1.21	46	132	5.0	0.12	0.3	0.6	355	85	40	0.00	22	15	20	40
20030315 322	2.78	35	112	8.0	0.11	0.4	0.7	230	65	-160	0.00	29	18	45	65
20030316 1723	1.26	43	134	5.0	0.10	0.2	0.6	175	65	20	0.07	18	13	30	30
20030319 2033	1.57	30	126	12.0	0.13	0.3	1.0	130	70	-180	0.03	21	10	38	70
20030320 2012	1.91	27	206	13.0	0.10	0.4	1.7	175	45	-50	0.00	17	45	40	30
20030321 1830	2.08	37	77	13.0	0.11	0.3	2.9	85	50	-100	0.09	24	40	35	45
20030323 726	1.13	40	147	10.0	0.10	0.2	1.7	125	85	-150	0.06	24	3	8	40
20030329 819	2.63	33	123	16.0	0.12	0.3	0.9	110	55	-100	0.07	22	33	25	80
20030329 1844	1.43	29	148	10.0	0.10	0.3	2.3	115	75	-170	0.05	17	5	40	20
20030330 1033	1.80	30	90	7.0	0.09	0.2	0.7	155	70	-30	0.03	25	23	43	60
20030403 1458	1.05	28	100	16.0	0.11	0.3	1.3	150	30	-60	0.08	15	0	0	0
20030419 2026	1.05	22	100	16.0	0.13	0.4	2.8	85	65	-180	0.05	16	5	40	40
20030421 1230	1.10	37	148	10.0	0.10	0.3	1.8	115	65	-140	0.06	20	10	30	40
20030501 927	1.18	31	122	5.0	0.10	0.3	0.8	340	80	-10	0.00	20	8	38	30
20030522 1410	1.09	43	132	15.0	0.14	0.3	0.9	170	45	-60	0.12	20	10	5	10
20030610 1542	1.66	35	125	14.0	0.12	0.3	0.9	210	75	-10	0.13	21	10	45	55
20030617 1152	1.30	25	82	15.0	0.11	0.3	2.0	95	65	-180	0.00	18	8	15	20
20030618 1248	1.59	37	117	5.0	0.11	0.3	0.8	170	75	40	0.00	23	8	10	5
20030715 2158	1.40	31	128	5.0	0.09	0.3	0.8	245	80	-170	0.00	18	20	33	30
20030730 116	1.35	42	127	15.0	0.11	0.3	1.1	170	70	0	0.12	23	8	18	60
20030731 212	1.00	26	105	16.0	0.10	0.4	1.1	105	45	-100	0.19	15	10	10	50
20030801 2300	1.68	45	79	14.0	0.12	0.3	1.1	170	70	-10	0.13	21	8	33	60
20030802 2344	2.20	30	117	8.0	0.13	0.3	9.9	70	90	180	0.00	16	10	63	80
20030803 107	1.05	34	70	8.0	0.14	0.3	2.5	160	90	10	0.00	20	15	53	60
20030814 23	1.49	34	108	4.0	0.09	0.3	0.5	205	50	40	0.06	18	10	13	10
20030902 850	1.05	35	78	8.0	0.12	0.3	0.9	85	55	-160	0.18	20	10	15	30
20030915 618	1.21	29	214	13.0	0.09	0.5	1.3	325	85	0	0.00	22	8	38	35

Origin Time: Year Month Day Hour Minute (Example: 20021019 719)
Mag: magnitude
#p: number of phase picks used in location
Gap: location gap (degrees)
Near: nearest station (km)
Rms: root-mean-square residual of station travel time residual (sec)
Eh: horizontal uncertainty in the location (km)
Ez: vertical uncertainty in the location (km)
Str: strike of one of the fault planes (degrees)

```
Dp: dip of one of the fault planes (degrees)
Rk: rake of one of the fault planes (degrees)
Erft: solution misfit (0=perfect fit)
#fm:  number of p-waves used in the solution
S: maximum half-width of 90% confidence range of strike (degrees)
D: maximum half-width of 90% confidence range of dip (degrees)
R: maximum half-width of 90% confidence range of rake (degrees)
```

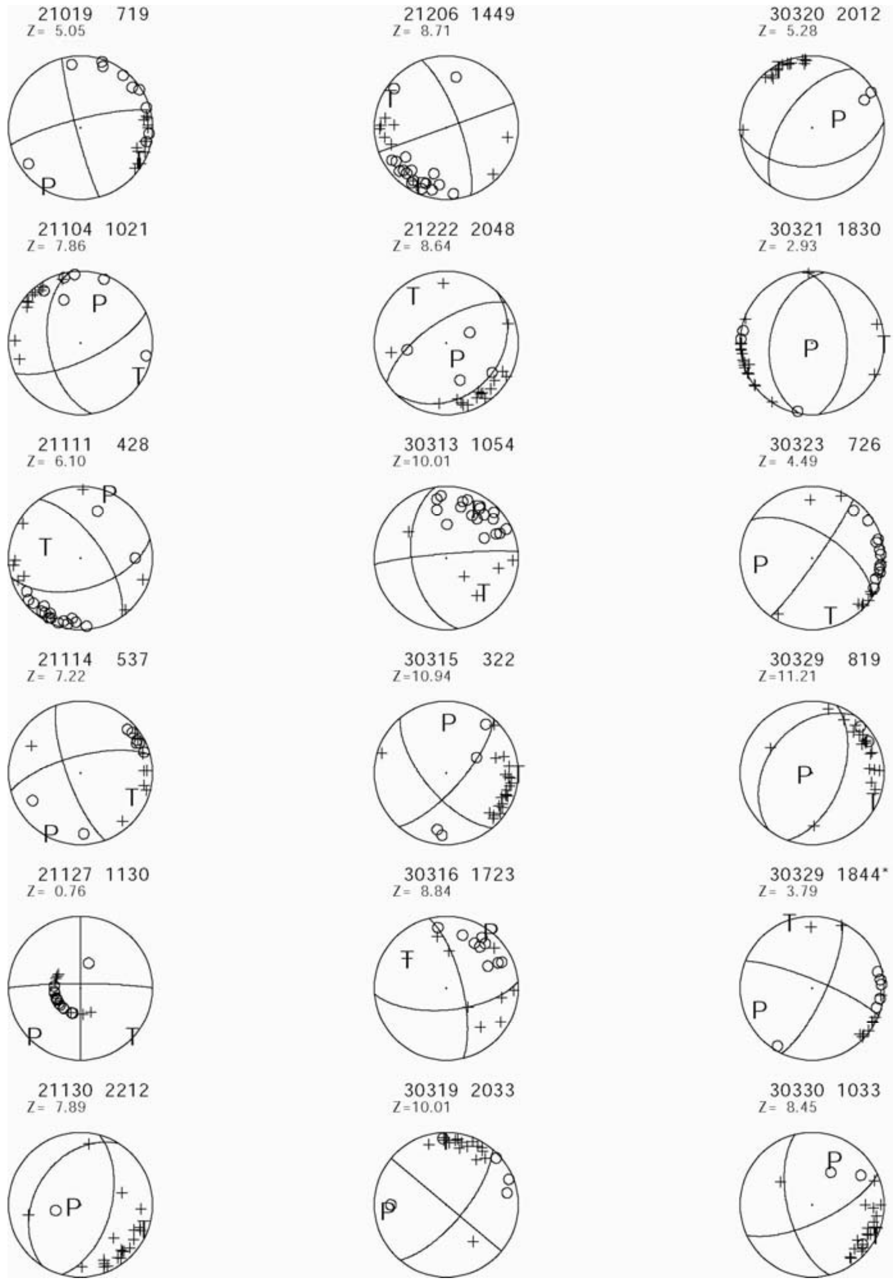

Figure A2-1. FPFIT (Reasenburg and Oppenheimer, 1985) short period P-wave first motion focal mechanism solutions (DID 006DV.002).

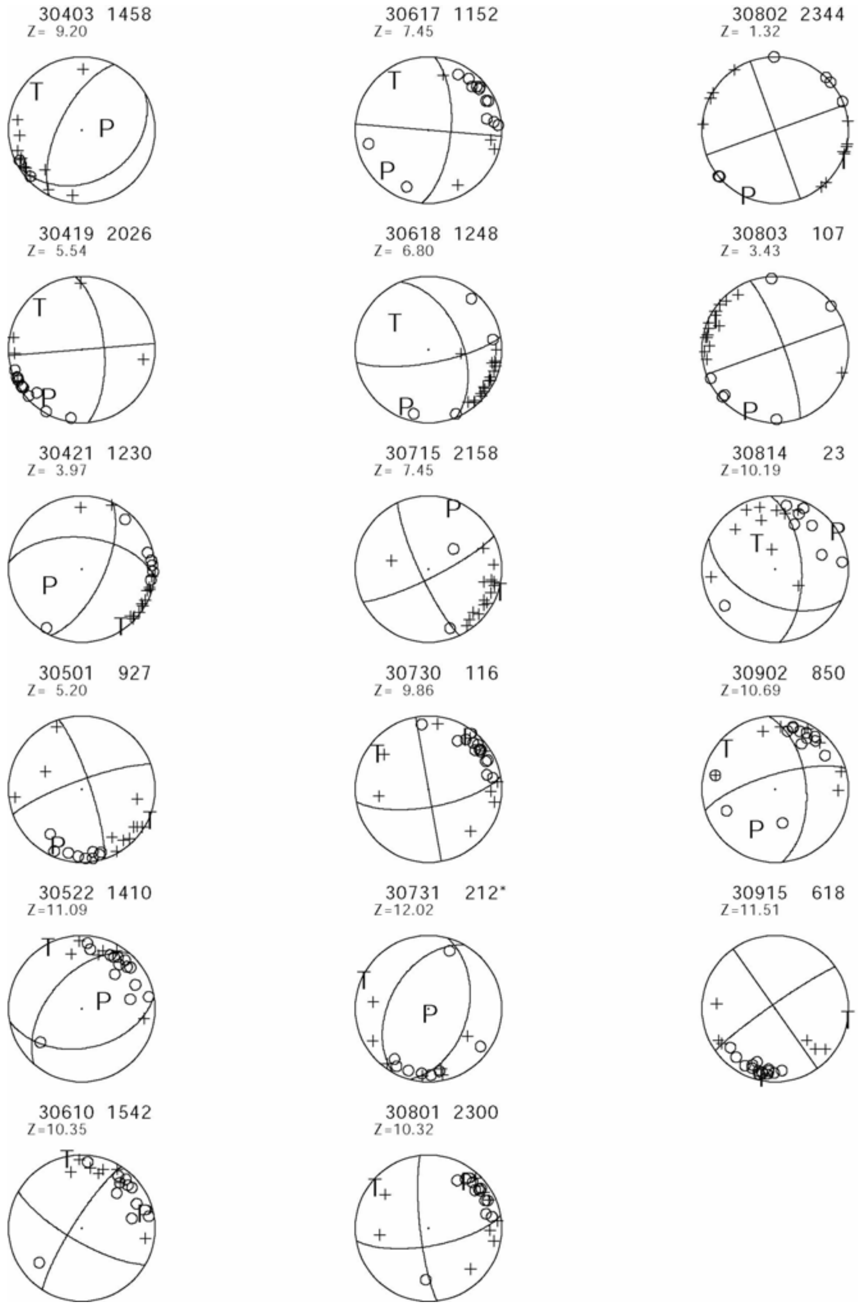

Figure A2-2. FPFIT (Reasenburg and Oppenheimer, 1985) short period P-wave first motion focal mechanism solutions continued (DID 006DV.002).