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Seismicity in the vicinity of Yucca Mountain, Nevada, for the period October 1, 2004 to September 30, 2006

Ken Smith
University of Nevada, Reno, ken@seismo.unr.edu

John G. Anderson
University of Nevada, Reno, jga@seismo.unr.edu

Amy J. Smiecinski
University of Nevada, Las Vegas, smiecins@unlv.nevada.edu

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Originators:

[redacted]

Ken Smith, Nevada Seismological Laboratory

Approvals:

[redacted] 21 Nov 2007

John Anderson, Principal Investigator Date

[redacted] 11-26-07

Amy Smiecinski, QA Manager, NSHE Date

TABLE OF CONTENTS

List of Tables

List of Figures

2. Purpose

This report describes earthquake activity within approximately 65 km of Yucca Mountain site during the October 1, 2004 to September 30, 2006 time period (FY05-06). The FY05-06 earthquake activity will be compared with the historical and more recent period of seismic activity in the Yucca Mountain region. The relationship between the distribution of seismicity and active faults, historical patterns of activity, and rates of earthquakes (number of events and their magnitudes) are important components in the assessment of the seismic hazard for the Yucca Mountain site. Since October 1992 the University of Nevada has compiled a catalog of earthquakes in the Yucca Mountain area. Seismicity reports have identified notable earthquake activity, provided interpretations of the seismotectonics of the region, and documented changes in the character of earthquake activity based on nearly 30 years of site-characterization monitoring. Data from stations in the seismic network in the vicinity of Yucca Mountain is collected and managed at the Nevada Seismological Laboratory (NSL) at the University of Nevada Reno (UNR). Earthquake events are systematically identified and cataloged under Implementing Procedures developed in compliance with the Nevada System of Higher Education (NSHE) Quality Assurance Program. The earthquake catalog for FY05-06 in the Yucca Mountain region submitted to the Yucca Mountain Technical Data Management System (TDMS) forms the basis of this report.

3. Quality Assurance

The Yucca Mountain seismic network is managed under the NSHE Quality Assurance Program under Cooperative Agreement (contract# DE-FC28-04RW12232). Task 6 of the Cooperative Agreement (ORD-FY04-006; Seismic Monitoring) is governed by Scientific Investigation Plan SIP-UNR-027 rev. 0 (referenced “SIP” below). Software used to develop conclusions in this report is referenced in section 9.0. All references to IPR's are associated with the revision numbers listed below. Implementing Procedures (IPR's) for development of the earthquake catalog and seismic network operations include:

1. IPR-001 rev. 5; *Operation of the Yucca Mountain Digital Seismic Network*
2. IPR-002 rev. 4; *Determining the Location of Earthquakes Recorded by the Yucca Mountain Seismic Network*
3. IPR-003 rev. 4; *Determining the Magnitude of Earthquakes Recorded by the Yucca Mountain Seismic Network*

4. Introduction

This report covers seismicity observed within 65 km of Yucca Mountain from October 1, 2004 through September 30, 2006 (FY05-06). NSL now operates 49 real-time digital seismograph stations in the Yucca Mountain area, including borehole and underground systems, and analog seismograph stations in the Death Valley National Park, to characterize seismicity and earthquake ground motions for assessing potential impact to the Yucca Mountain site from earthquakes. Not all of these stations contribute to the regional catalog discussed in this report; numerous strong motion stations (free-field, borehole, and ESF deployed) are also managed under the "SIP" in order to assure on-scale recording of large earthquakes. The network (weak and strong motion stations) provides event magnitude data for earthquake recurrence estimates, activity rates, hypocentral control for identification of active geologic structures and verification of tectonic models, and a ground motion archive. Stations utilized in developing the earthquake catalog are included in DID# 012.DV012.

5. Methods and Materials

5.1 Network Upgrade

Under the "SIP" an upgrade of the regional monitoring network and telemetry systems is underway. The upgrade of the Southern Great Basin Digital Seismic Network (SGBDSN) to Internet Protocol s(IP) impacts some network recording mechanisms but does not impact regional earthquake monitoring. The transition to new systems is conducted without any discontinuity of regional monitoring, although with replacement of dataloggers and communications systems some stations downtimes are encountered. This upgrade has been planned and is being implemented due to the sale of communications frequencies used in Yucca Mountain area earthquake monitoring to private telecommunications interests by the U.S. government. As importantly, Reftek 72A datalogger and data systems (1980s technologies utilizing analog telemetry) are now obsolete and unsupported. Although planned under the current Cooperative Agreement, yearly funding delays and cuts have forced continued reliance on obsolete 72A systems. Changes in data recording processes are discussed in section 4.3 below.

The fundamental components of the upgrade are implementing IP communications to all regional network stations and upgrading existing Reftek 72A to IP-based Reftek RT130 dataloggers (references to 72A and RT130 below will imply these communications protocols, respectively). The upgrade progresses by first implementing the communication infrastructure, by zone or communications node, within the seismic network and then by replacement of end-point data acquisition systems. The 72A systems require an analog communications infrastructure and vendor- dedicated technologies at the data center receive site, and they include bandwidth limitations that impose specific strategies for optimizing regional monitoring and integrating strong motion recording. On the other hand, the IP infrastructure provides sufficient bandwidth to maintain continuous data recording at high-sample rates for velocity and accelerometer data streams, allows capabilities for system redundancy not available under 72A protocols, and enables a wide range of real-time interaction with remote IP devices for more efficient operations. However, until the network is complete, network maintenance will require support for both analog and IP-based communications systems and reliance on some obsolete data acquisition and data management systems.

5.2 Station Description

The regional catalog is developed from seismic stations configured with Geotech S-13 sensors in the NTS area and from analog stations in the Death Valley region. Stations installed in the ESF area (NI5, AL5, and SME) in 2005 and 2006, and their corresponding surface sites (NI5S, AL5S, and SMES), are configured with Mark Products L-4 sensors. Two stations (ECO and YFT configured with Geotech GS-13 sensors) were provided by Sandia National Laboratories (SNL) in the late 1990's and are considered effectively part of the SGBDSN, with all normal QA procedures applied. The ESF area stations configured with Mark Products L-4, 3-component, 1-Hz sensors are not used to determine regional event locations or magnitudes discussed in this report. In routine analysis, phase data from these stations are included, but are weighted such that they are do not impact regional locations. This is done so as not to bias regional locations due to the density of the network at Yucca Mountain itself. Neither the GS-13 nor L-4 seismometers are used in magnitude computations; all regional earthquake magnitudes are developed from S-13 velocity sensors. Also, no analog station data are used to calculate earthquake magnitudes. System check pulses are analyzed to ensure conformance with sensor response tolerances specified in IPR-001. The free period of the S-13 instruments was nominally set to 1.0 s, and the damping coefficient was nominally set to 0.7 (critical damping) in all cases.

5.3 Data Collection Method

The Reftek 72A field data acquisition protocols and recording systems are described in von Seggern and Smith (1997). These systems rely on the analog telemetry system that has been in operation since the early 1990's. For Reftek 72A recording, two data streams are in effect at regional SGBDSN stations: 1) a 20-sps, 3-component, continuous data stream and 2) a 100-sps, 3-component, triggered data stream. ECO and YFT are operated with strictly a triggered mode stream.

These recording parameters were established in 1995 and were dictated by bandwidth limitations in Reftek 72A analog communications protocols. Stream 1 is enabled with a "continuous" trigger specification, which creates contiguous trigger windows of 30 minutes duration each. Stream 2 is 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

Ten of the 72A datalogger stations have been equipped with accelerometers. The 72A 3-component accelerometer stream is "cross-triggered" from the 100-sps velocity sensor stream described above, and the data are also recorded at 100 sps. These are limited to 16-bit data streams as compared to 24-bit data streams allowed under the IP protocols of the network upgrade. Raw data from 72A systems are archived in 24-hour files (one per station) that include all original data packets received from the field acquisition units. These data are submitted to the YMP Records Processing Center (RPC), as in all prior years, as a raw data record.

Seismic waveform and event data are managed under the Antelope seismic processing system (von Seggern et al., 2000). Antelope (a product of Boulder Real-Time Systems, Inc., Boulder, Colorado) is a Commercial-Off-The-Shelf (COTS) seismic data management system. The 2000 transition of the entire NSL network to Antelope-based data management incorporates recording and processing of seismic data from both the SGBDSN and the Nevada statewide network. In addition to storing waveform data, Antelope also manages parametric data in the Datascope relational database (Quinlan, 1998).

Continuous as well as event data are archived on duplicate DVD's as well as on system-wide, Nevada Seismological Laboratory, computer backup media. System-wide backups are stored in an independent secure facility and a DVD duplicate is secured in a fire-rated storage vault.

5.4 Station/Network Uptime

A record of all station data is maintained within the Antelope Datascope tables, and station-specific downtimes can be estimated by querying the Datascope tables for recorded time intervals for each station. (Datascope tables are managed in the daily Antelope directories in the YMP computing system at the NSL.) Downtime for any given station is simply the total span of time minus the total of these time intervals for that station. Figures 1 and 2 show a summary of the downtime for each station within the SGBDSN and Death Valley National Park analog stations for FY05-06. Stations ECO and YFT are run in triggered mode only and so are not represented here. In the winter of FY05 considerable data outage was experienced at stations in the northern NTS due to a power failure at the Shoshone Peak Mountain relay. This was not a routine maintenance issue and could only be rectified by the primary NTS contractor. This impacted stations utilizing the Shoshone Peak and Echo Peak communications link (6 SGBDSN stations) and also the two Sandia stations, YCO and YFT. Also, significant telemetry outages were experienced at some 72A network stations that transmit through the Yucca Mountain communications link due to unexpected interference between the 200 MHz analog radios and the IP bands of the network upgrade in 2006. Data return was reduced from stations FRG, STO, CRF, and TAR. The delay in the network upgrade has not allowed resolution of this issue. Also, snow/ice damage at Rogers Peak relay has impacted the HEL data reception (Hells Gate, Death Valley); HEL issues have not been addressed since new communications will be required under the network upgrade and there is limited access to Rogers Peak. Funding for HEL upgrade was anticipated in FY06. These outages are reflected in the summaries (Figures 1 and 2). Data recovery for Death Valley area stations was 99.8% and 99.9% for FY05 and FY06, respectively. Digital stations with the most complete recording were TYM for FY05 (99.5%) and TWP for FY06 (99.8%), defining the overall network uptime.

5.5 Daily Processing

The daily processing routine is described in von Seggern and Smith (2001), and documented under IPR-001. Under the Antelope recording system, data from 72A and RT130 systems are integrated and visually inspected for earthquake signals. Although real-time event notification processes are reliable enough to confirm most events within the Yucca Mountain region, visual inspection of the continuous data for a representative set of stations provides a complete assessment of earthquake activity. Preliminary event location determination is conducted with Antelope utilities, and preliminary event locations and magnitudes are maintained in Datascope database tables (Quinlan, 1998), all within the NSL secure computing environment. Event waveform data are excerpted for all recognized earthquakes and maintained in a secure online archive at NSL.

The last step in preliminary analysis is the final checking and initialing of event data sheets; these are submitted as records to the RPC. All preliminary event locations for earthquakes within 65 km of Yucca Mountain are reviewed (specifically, within 65 km of station RPY in the Yucca Mountain repository area). In this process events may be relocated and magnitudes recomputed; the revised information is maintained in the Antelope database. This represents the complete preliminary catalog. Also at this time, a review is made on classification of events other than local earthquakes including located blasts (see Appendix 2). The process constitutes as thorough as possible assessment of all earthquakes that can be located within 65 km of Yucca Mountain.

5.6 Finalizing the Earthquake Catalog

The final locations and magnitudes for the FY05 and FY06 earthquakes were obtained according to IPR-002 and IPR-003 ("Determining the Locations of Earthquakes in the Yucca Mountain Seismic Network ", and "Determining the Magnitude of Earthquakes Recorded by the Yucca Mountain Seismic Network", respectively). Location program HYPOINVERSE, V1.0 (STN 10080-1.0) (Klein, 1989), and local earthquake magnitude determination program MLCALC, V3.0 (STN UCCSN-04-014) were used according to IPR-002 and IPR-003, respectively, to develop the earthquake catalog. MLCALC implements the local magnitude (ML) calculation of Richter (1935). All earthquake magnitudes stated in this report (M) are local magnitude (ML). We note that non-SGBDSN arrival times may be used in the locations, depending on seismological judgment. This establishes the most accurate hypocentral locations possible, especially near the boundary of the 65 km circle, with the regional seismic network.

The preliminary earthquake catalog for FY05-06 was initially developed within the Datascope database environment under routine network operations (IPR-001). The procedure for computing final locations prescribes that the arrival times and preliminary locations be extracted from the Datascope tables. The procedure requires that a single velocity model be used for the entire suite of earthquakes. This model is given in IPR-002 rev. 4 is as follows;

Depth (km)	P velocity (km/s)
0.0	3.00
1.0	5.85
25.0	6.35
30.0	6.60
35.0	7.80

HYPOINVERSE was run in batch mode with the above velocity model. A total of 3517 qualified event locations are included in the FY05-06 catalog. Figures 3-5 summarize the depth and magnitude distribution.

6. Assumptions

Seismicity plots that include unqualified data are considered corroborative; no conclusions in this report are based on unqualified data. Conclusions regarding FY05-06 data are based on the qualified FY05-06 catalog. Figures that include catalog data with time-period references in the figure captions are keyed to the qualification status of those particular data sets and time periods in Table 2. Figures that include unqualified catalog data are used to corroborate conclusions based on qualified data.

7. Discussion and Conclusions

7.0 Yucca Mountain/NTS Area Seismicity

7.0.1 Earthquake Catalogs: Historical Perspective

FY05-06 earthquake epicenters within 65 km of Yucca Mountain are shown in Figure 7 (for reference, Figure 6 shows local geographic features), and these will be compared with the historical and more recent periods of site characterization monitoring. Historical earthquakes (prior to Yucca Mountain characterization) have been compiled by Meremonte and Rogers (1987) and are shown in Figure 8. From August 1978 through September 1995 earthquake monitoring was conducted by the USGS, and later (post 10/1/1992) by NSL, with a regional, analog-telemetry seismic network consisting primarily of vertical component low-dynamic range seismographs. The analog network was in place during the Underground Nuclear Explosion (UNE) testing era at NTS (last announced UNE, September 1992) and during the 1992 M 5.6 Little Skull Mountain earthquake (Meremonte et al., 1995; Smith et al., 2001). The analog network did not include strong motion instrumentation; NTS area strong motion monitoring was conducted by Blume and Associates, primarily for UNE programs. August 1978 through September 1995 earthquake activity is shown in Figure 9.

In the early 1990's the Yucca Mountain project committed to implementation and operation of a modern digital seismic network; NSL revamped the entire network recording infrastructure, including telemetry systems, and sited new stations to optimize catalog development and to improve network density and overall signal-to-noise, particularly in the Yucca Mountain area. Digital recording provides on-scale, 3-component, high-dynamic-range waveform data for all but the largest earthquakes. Strong motion instrumentation was installed to provide digital waveform data from the largest earthquakes. The digital network has decreased the magnitude detection threshold by almost

1 magnitude unit within some areas of the network. The change from analog to digital recording and the resulting increased network performance is reflected in the larger number of small earthquakes observed between analog (Figure 9) and digital recording periods (Figures 7 and 10).

The historical catalog (1868 – July 1978; Figure 8) includes large uncertainties in locations and magnitudes, and spatial representation of actual seismicity may not be very accurate. Many earthquakes in the historical catalog have no assigned magnitude and are presumed to be M < 5 prior to 1932; M < 4 between 1932 and 1968, when the California networks began locating events in Nevada; and M < 3 after 1968 when instrumentation relating to the underground nuclear testing program was installed. The 1978-1995 data (analog instrumentation era; Figure 9) have much lower uncertainties in magnitudes and locations; and regional spatial seismicity patterns, also routinely observed since FY96, were established. However, much of the analog-era activity (Figure 9) in the northwest NTS region most likely consists of induced seismic events associated with high-yield underground nuclear tests conducted in the late 1960's and the early 1970's and smaller yield tests through 1992. Apparent northeast trends of seismicity in very northern NTS are coincident with those reported by Hamilton et al. (1972) in a study of UNE triggered seismicity. By the mid-1990's, remnants of UNE triggered activity appears to have subsided (Figures 7 and 10).

The analog recording period includes the 1992 M 5.6 Little Skull Mountain earthquake and its first four years of aftershock activity. This comprises the concentration of seismicity about 20 km SE of Yucca Mountain. Even in the pre-1978 historical catalog (Figure 8), although the location quality is not as good as in the later catalogs, the Little Skull Mountain and eastern Jackass Flat regions show concentrations of seismicity, with magnitudes estimated as M 3 and larger. The distribution of earthquake activity through the digital recording period (Figures 7 and 10) is consistent with that observed during the analog era (Figure 9). Improved monitoring with the digital network has resulted in better defined zones that have had persistent seismicity.

7.0.2 FY05-06 Earthquakes

A total of 3517 earthquakes were located within 65 km of the central repository area in FY05-06 (Figure 7). With 1636 located in FY05 and the 1881 events located in FY06, these two recording periods constitute the fewest events located in any fiscal year since the digital recording began in FY96. The next lowest number of events was in FY97 with 1925 earthquakes located. The largest event in FY05-06 was an M 3.40 earthquake on April 17, 2006 (Origin Time: 20:14:50.96 UTC; 1:14 PM PST; Latitude: 36.7117N; Longitude: 116.0588W; Depth: 6.88 km; Figure 7). This event took place on NTS south of the Rock Valley Fault zone about 10 km NNW of Mercury (this was a reported felt earthquake). This event is west of the 1999 Frenchman Flat earthquake sequence (1999 Frenchman Flat mainshock M 4.7; January 1, 1999). The second largest event in the FY05-06 catalog was an M 2.99 event in north central Yucca Flat, NE NTS, on December 22, 2005 (Origin Time: 21:57:38.37; Latitude: 37.2270N; Longitude:116.0197W; Depth: 8.31 km). The largest event in FY05 was an M 2.61 earthquake in Pahute Mesa, north of the Timber Mountain caldera, on June 28, 2005 (Origin Time: 22:30:19.45 UTC; Latitude: 37.2792N; Longitude: 116.3738W; Depth: 13.64 km). A discussion of the FY05-06 activity rates and magnitude recurrence is included in section 7.4, below.

Figure 7 is labeled with symbols (#'s 1-5) identifying notable earthquake activity in FY05-06. Figure 7 (#1) is the largest event of the time period (reference in paragraph above), and Figure 7 (#2) is the continuing aftershocks of the 1992 M 5.6 Little Skull Mountain earthquake (Meremonte et al., 1995; Smith et al., 2001). The Little Skull Mountain area still contributes the dominant portion of the catalog in terms of numbers of located events. Figure 7 (#3) is an extension of seismicity south from the Little Skull Mountain aftershock zone into the western Specter Range. This trend has included several M 3+ earthquakes since mid-1992 and has been a prominent feature in the seismicity since the Little Skull Mountain earthquake. Figure 7 (#4) includes several M > 1 earthquakes in the Spotted Range northeast of Mercury. Although aftershocks of the 1992 Little Skull Mountain earthquake are prominent in the FY05-06 catalog, aftershock activity in the 1999 M 4.7 Frenchman Flat source area has decreased significantly. Figure 7 (#5) is a swarm of small events in December 2005 in a location that was much less active during FY96 through FY04 (see Figure 8; FY96-04 seismicity). The two largest events were M 1.84 and M 1.82 on December 8, 2005. Areas north and northwest of Beatty (Figure 6) typically include low-magnitude distributed seismicity as can be seen in all seismicity figures. Also, typical of Death Valley activity, there was little to no seismicity along the high-slip rate Furnace Creek Fault Zone; however, northwest lineations of small magnitude earthquakes, and/or clusters of activity are observed at the limit of the 65 km radius from Yucca Mountain near Stovepipe Wells (Figure 6).

7.0.3 Depth Distribution

Figure 4 shows the depth distribution of the FY05-06 catalog; 30% of the earthquakes have hypocentral depths $\geq$ 10 km, but few have depths greater than 15 km. The depth distribution is consistent with earthquake activity reported in previous years.

7.0.4 Earthquake Magnitude Distribution and Detection Threshold

In the FY05-06 catalog there were only five events greater than M 2.5. Figure 5 shows the cumulative magnitude recurrence distribution in 0.25 magnitude bins for FY05-06 earthquake magnitudes. The *b* value in the equation,

$$\log_{10}(N) = a - b\ M_L$$

was determined by the method given in Aki (1965) for the cumulative recurrence distribution shown in Figure 5. The detection threshold from Figure 5, where the curve levels off at low magnitudes, is observed to be about M -0.25. FY05-06 data give a 'b-value' of 0.99, when applying a minimum magnitude of M 0.5, and the log of the exceedance rate at M 0.5 is 3.00. The b-value is consistent with that determined for previous years.

7.0.5 Earthquakes Near Yucca Mountain

Seven earthquakes for FY05-06 were located within 10 km of station RPY in the central Yucca Mountain repository block (Latitude: 36.8515N Longitude: 116.4563W), and the waveforms for these have been reviewed one additional time. These events are listed in Table 1 and shown in Figure 11. The largest of these is M 0.73 on March 25, 2005.

Table 1. Earthquakes Near Yucca Mountain, FY05-06

Origin Time			Latitude		Longitude		Depth	ML	nphs
20041025	0024	45.61	36	49.22	116	23.50	4.86	-0.47	6
20050325	1249	43.96	36	51.73	116	24.29	10.76	0.73	28
20050405	1324	13.37	36	56.37	116	26.11	5.99	-0.08	5
20050430	2354	20.74	36	47.39	116	28.04	9.84	-0.26	17

```
20050907 0534  5.18 36 53.44 116 33.41   7.13  -0.23 11
20060309 1150  8.30 36 48.89 116 31.05   7.41  -0.15 11
20060720 1550 59.56 36 54.96 116 23.39  10.68  -0.61 10
```

Origin Time: Year-Month-Day Hour-Minute Second
Latitude: decimate degrees
Depth: km
ML: Magnitude
Nphs: number of phases used in location

7.0.6 Seismicity Zones

In order to facilitate a discussion of the activity in the NTS area, zones of seismicity are identified and described. Figure 12 shows the recent activity used to describe the seismicity zones shown in Figure 13. Zone boundaries are intended to be general and not discrete, but to be associated with spatial zones of seismicity that can be qualitatively isolated from adjacent distributions. Geologic and structural information is taken into account in constructing the generalized regions.

Seismicity Zones (#'s reference in Figure 13):

1. **Yucca Mountain Block – Bare Mountain Fault:** This area covers the zone of limited seismicity that characterizes Yucca Mountain, Crater Flat basin, and western Jackass Flat. Noted by Gomberg (1991) and through the recent monitoring period, there has been very little seismicity observed at Yucca Mountain and within 10 km of the repository area. This region includes Quaternary faults and background source zones that would have important implications for the ground motion hazard at the repository.
2. **Western Rock Valley Fault – Little Skull Mountain Earthquake – Eastern Amargosa Valley:** The zone includes the 1992 Little Skull Mountain earthquake and its aftershock zone, seismicity in eastern Amargosa Valley that may be associated with the most western portion of the Rock Valley fault zone (Piety, 1996), and a trend of seismicity extending south from the Little Skull Mountain sequence into the western Specter Range.
3. **Western Jackass Flat – Mine Mountain:** This zone includes an M 3.9 earthquake in

northern Jackass Flat in 1998 (von Seggern et al., 2001) and earthquake activity SE of the Calico Hills and SE of the Timber Mountain caldera in west-central NTS.

4. **Central Rock Valley – Caines Springs:** This zone of seismicity located between the 1992 Little Skull Mountain sequence and the 1999 Frenchman Flat earthquake defines the south central NTS region of seismicity along the central portion of the Rock Valley fault zone.
5. **Frenchman Fault – Spotted Range:** The region is defined by the western Rock Valley fault zone and Frenchman Flat and includes the M 4.7 1999 Frenchman Flat earthquake (von Seggern et al., 2001) and its aftershock sequence. This zone also includes seismicity associated with the oroflexural strain fabric of the Spotted Range (Cole and Cashman, 1999) in eastern and southeastern NTS.
6. **Yucca Flat – Northeast NTS:** This zone includes the UNE testing areas of Yucca Flat and Rainer Mesa and concentrations of seismicity in far NE NTS that are on the fringes of the network where earthquake locations are less well constrained.
7. **Northern and Eastern Rim, Timber Mountain Caldera:** This activity appears to be associated with the rim of the Timber Mountain Caldera, or the footwall of what may exist of the possible caldera ring fracture system. Some of this activity may also be considered a continuation of triggered UNE activity. The western extent of this zone is defined primarily by the 2001 Thirsty Mountain sequence (von Seggern and Smith, 2003), a localized source zone that was also included in widespread post-UNE triggered seismicity reported by Hamilton et al. (1972).
8. **Central Timber Mountain Caldera:** This activity is defined within the physiographic expression of Timber Mountain caldera and may be associated with caldera structures.
9. **Northern Pahute Mesa:** Continued activity north of the northern rim of Timber Mountain

caldera may also be remnants of UNE-triggered earthquakes in Pahute Mesa.

10. **N-S Beatty Trend:** Although clearly defined north of Beatty as the western margin of the Timber Mountain and Black Mountain calderas, this zone of persistent seismicity appears to extend north-south for almost 100 km as far south as the southern Funeral Mountains. It also includes a western expression of activity near the Bull Frog Hills, west of Beatty. Whether this north-south alignment of seismicity is a coherent regional structural feature is problematic.

11. **Sarcobatus Flat:** This zone is defined by distributed seismicity within Sarcobatus Flat basin, northeast of Beatty.

12. **Death Valley - Furnace Creek:** The zone includes the relatively high-slip rate faults of the Death Valley region, west of the Funeral and Grapevine Mountain core complex.

7.2 Conclusions

Fiscal years 2005 and 2006 included the two lowest numbers of located earthquakes within 65 km of central Yucca Mountain since digital data recording began in FY96 (October 1, 2005). The largest event in these two years of monitoring was an M 3.40 earthquake about 10 km WNW of Mercury, Nevada on April 17, 2006. The distribution of earthquakes observed (Figure 7) was similar to that observed in previous years of the digital monitoring era. The Little Skull Mountain aftershock zone, as has been the case since the 1992 M 5.6 Little Skull Mountain earthquake, was the dominant source of events for FY05-06. A swarm of earthquakes, primarily on December 7 and 8, 2005, represented a new source region of activity for the digital monitoring era. These events were on the northern rim of Timber Mountain Caldera in southern Pahute Mesa. The largest events in this swarm were M 1.82 and M 1.84. As in previous years, a small number of earthquakes were located within 10 km of station RPY in the central repository area (Table 1, Figure 11). The largest of these was M 0.73 on March 25, 2005, southwest of Yucca Mountain in western Jackass Flat. The distribution of FY05-06 activity was not unusual compared to previous years and activity rates were the lowest observed in over ten years of digital network monitoring.

8. Inputs and References

Data sets used to support and/or corroborate the conclusions in this report are the older earthquake catalogs for the Yucca Mountain region. Older catalogs are unqualified and used to corroborate conclusions based on the FY05-06 earthquake catalog. Geographic locations referred to in the text are included in the base map of Figure 6. The earthquake catalogs cover either calendar years, or more recently, federal fiscal years (i.e., October 1 through September 30 of the following year). Data sets in the figures of this report are described in Table 2 where the qualification status for the relevant seismicity catalog is listed along with figure references. Seismicity figures are labeled with particular time periods, and data for those time periods are listed in Table 2.

Table 2. Data Sources for Earthquake Catalogs

Q Status	ID	Accession Number	Time Period Covered	Included in Table, Figure or Appendix #
UQ	N/A	MOL.19980601.0231	1868 – 7/29/1978	Fig. 8

UQ	012DV.019	MO0307UCC012DV.019	8/3/1978 – 9/30/1992	Figs. 9, 12, 13
Q	012DV.011	MO0208UCC012DV.011	10/1/1992 – 12/31/1992	Figs. 9, 12, 13
Q	N/A	GS950183117412.001	1/1/1993 – 12/31/1993	Figs. 9, 12, 13
Q	N/A	GS950383117412.003	1/1/1994 – 12/31/1994	Figs. 9, 12, 13
Q	012DV.012	MO0208UCC012DV.012	1/1/1995 – 9/30/1995	Figs. 9, 12, 13
Q	006DV.004	MO0404UCC006DV.004	FY1996-2002	Figs. 10, 12, 13
Q	006DV.001	MO0402UCC006DV.001	FY2003	Figs. 10, 12, 13
Q	006DV.011	MO0508UCC006DV.011	FY2004	Figs. 10, 12, 13
Q	006KS.002	This Report	FY2005 – 2006	Table 1, Figs. 3, 4, 5, 7, 11, 12, 13
UQ	006KS.003	This Report	FY2005-2006	Appendix 1

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9.0 Software

The following software, including version numbers and STN numbers, was used to develop the earthquake catalog (Operating system Solaris 8).

Application	**Version**	**STN#**	**Use**
MLCALC	3.0	UCCSN-04-014	earthquake magnitudes
HYPOINVERSE	1.0	10080-1.0-00	earthquake locations

Appendix 1. Events Identified and Located as Blasts, FY05-06 (Unqualified; For information only. Do not use for quality-affecting work).

M	Lat	Lon	Date	Time
-0.16	36.7019	-115.8009	10/06/2004	3:47:20.647
0.51	36.7884	-115.7410	10/07/2004	4:40:09.883
-0.11	37.3203	-116.3623	10/11/2004	23:31:50.139
0.68	36.6037	-116.0050	11/10/2004	20:09:09.717
0.56	37.0333	-116.7504	11/13/2004	19:15:58.460
0.84	36.9977	-116.7533	11/13/2004	21:59:09.447
0.96	36.9969	-116.7695	11/23/2004	16:14:36.778
1.04	36.9958	-116.7761	1/22/2005	18:29:16.631
1.35	37.1167	-116.1466	2/14/2005	19:33:41.868
1.77	37.1585	-116.1036	2/15/2005	5:35:15.592
1.16	36.9911	-116.7749	4/27/2005	18:32:38.101
-0.29	37.3003	-116.5975	7/08/2005	17:11:43.424
0.96	37.0077	-116.7757	7/10/2005	19:14:52.479
0.29	36.8583	-116.2838	8/05/2005	17:16:31.459
0.79	36.9980	-116.7840	12/11/2005	18:57:58.432
1.04	36.7137	-115.9069	1/06/2006	20:54:21.061
0.63	37.0163	-116.7786	1/22/2006	19:08:53.453
1.01	37.0055	-116.7679	2/08/2006	0:03:03.043
0.03	36.9917	-116.8221	2/22/2006	22:23:30.401
0.99	37.0090	-116.7783	3/05/2006	19:40:13.795
0.15	36.8990	-116.7151	3/26/2006	18:04:54.214
0.29	37.0316	-116.1736	4/07/2006	21:24:41.702
0.63	36.9891	-116.7363	6/04/2006	17:59:07.172
1.13	37.0227	-116.7730	6/12/2006	2:43:18.101
0.82	36.5978	-115.9570	6/24/2006	18:06:08.569
0.53	37.2801	-116.4089	7/11/2006	14:08:04.784
0.24	37.0585	-115.9413	7/26/2006	12:43:48.927
0.27	36.4436	-116.1157	7/31/2006	19:44:46.920
0.76	36.8868	-116.0591	8/07/2006	16:13:10.786
0.45	36.8415	-116.2614	8/07/2006	18:05:34.035
-0.03	36.8403	-116.2483	8/09/2006	1:50:51.275
0.28	36.8508	-116.2788	8/10/2006	21:41:13.251
0.73	37.2737	-116.4029	8/21/2006	11:52:08.417
0.53	36.6180	-115.8332	9/08/2006	14:49:18.783

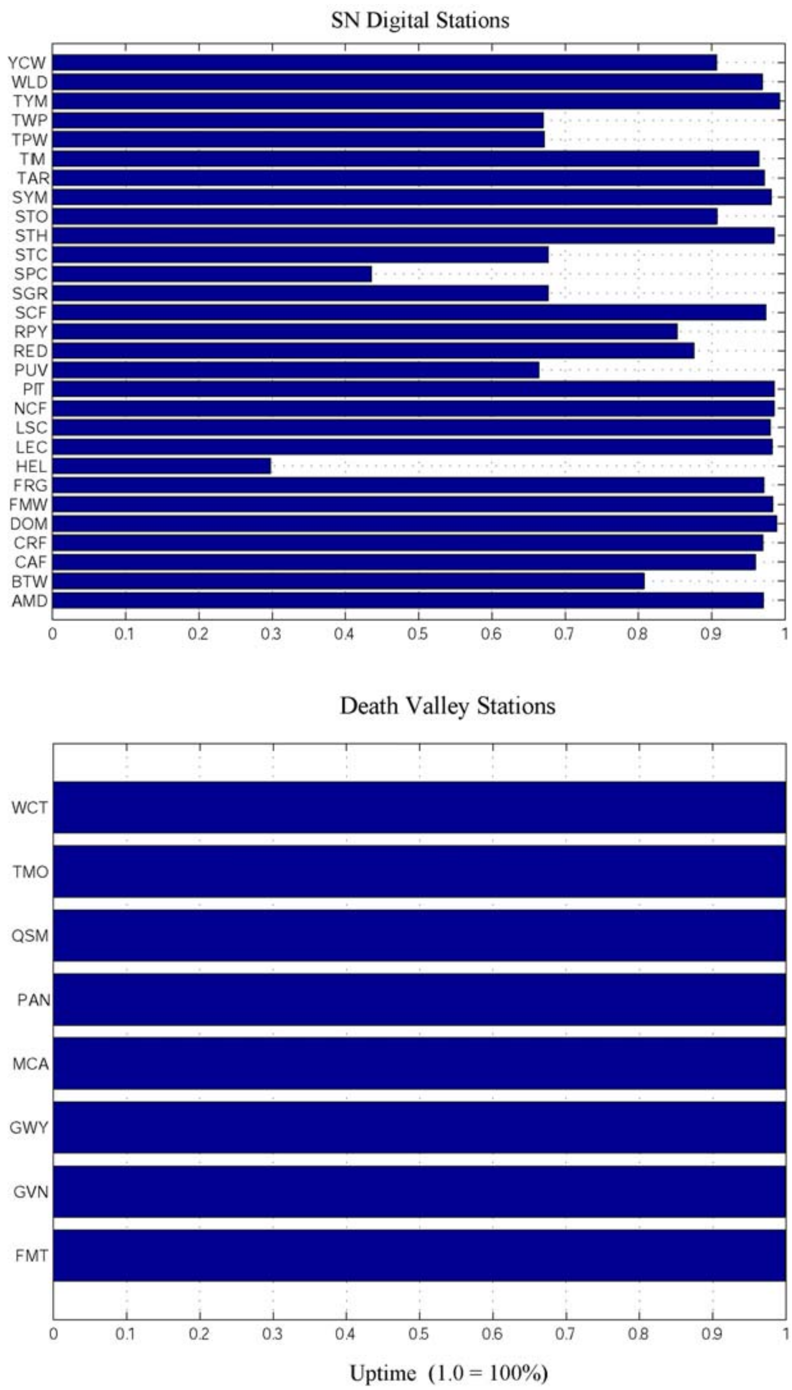

Figure 1. FY05 station uptime.

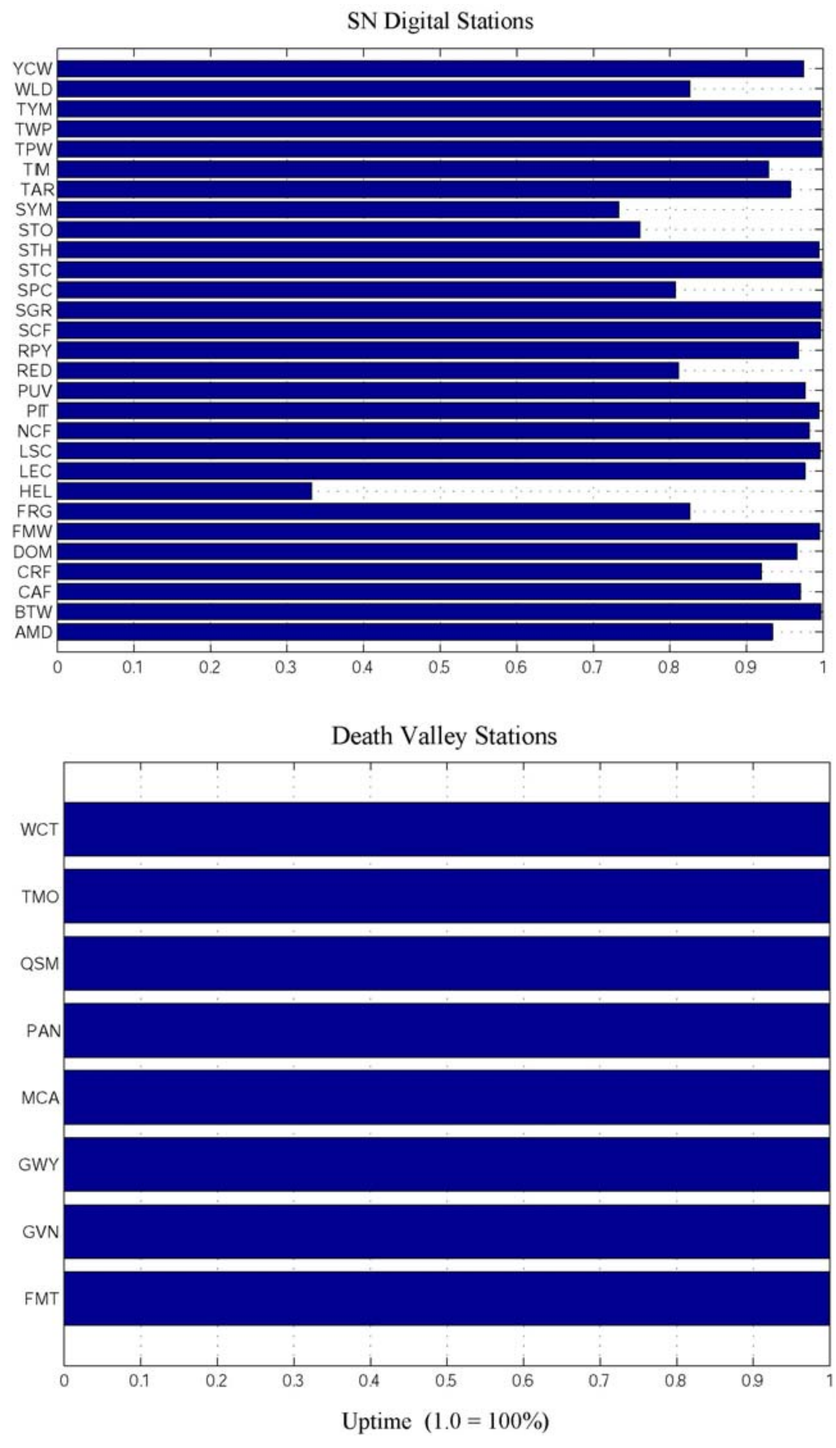

Figure 2. FY06 station uptime.

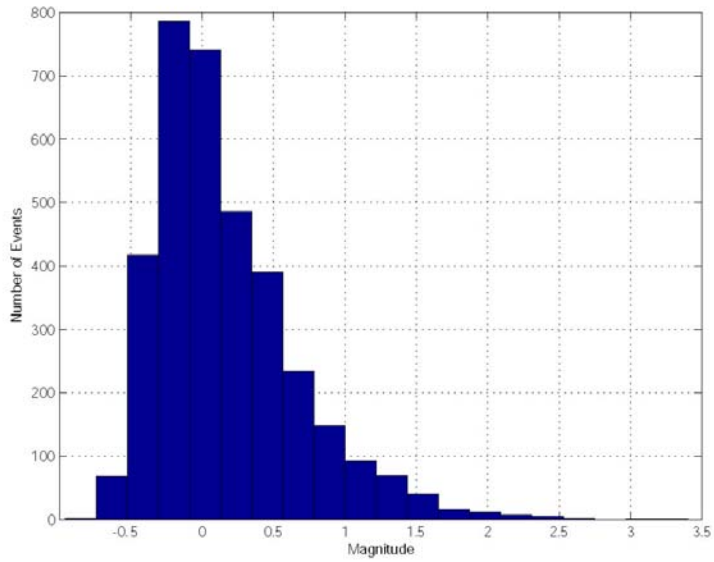

Figure 3. Distribution of earthquake magnitudes from the FY05-06 catalog.

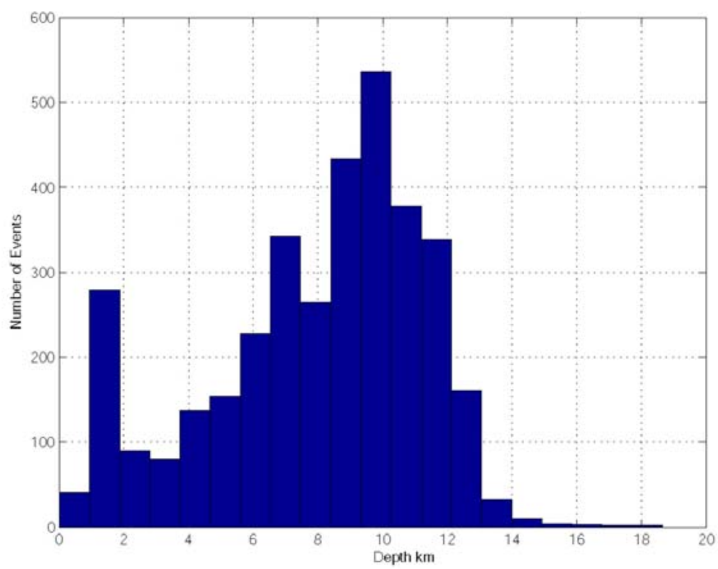

Figure 4. Distribution of hypocentral depths from the FY05-06 catalog.

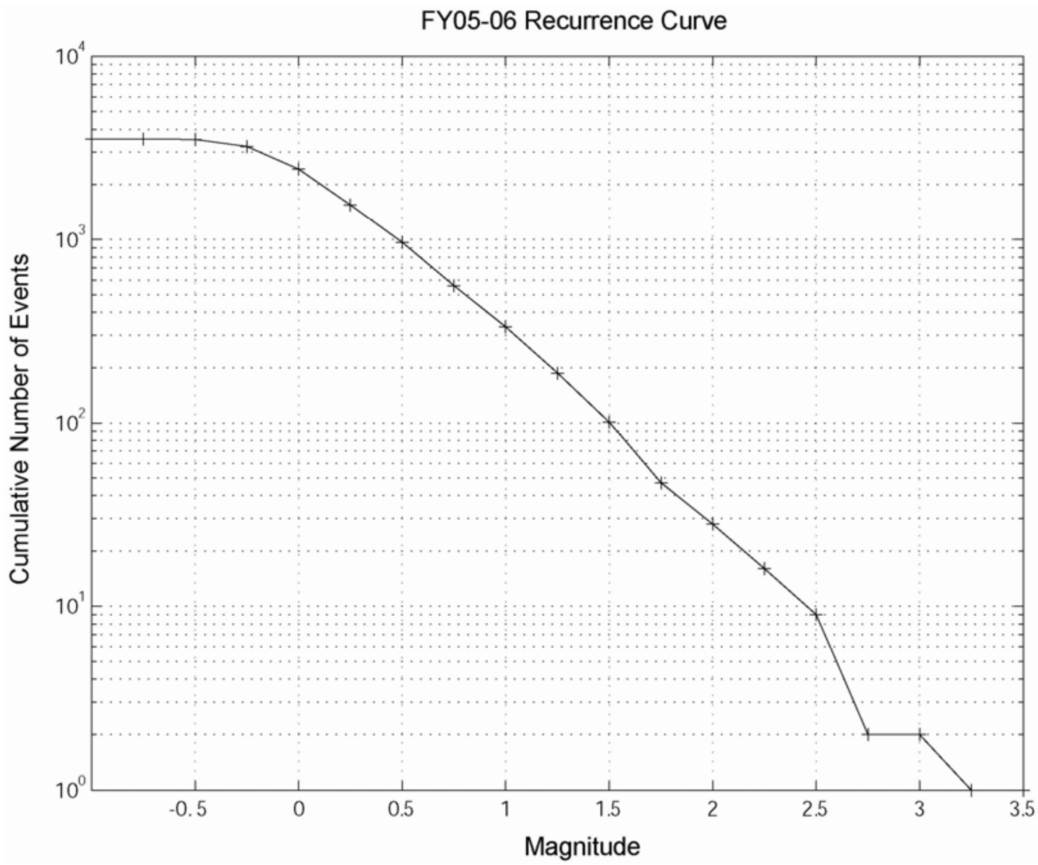

Figure 5. Cumulative magnitude distribution curve for FY05-06.

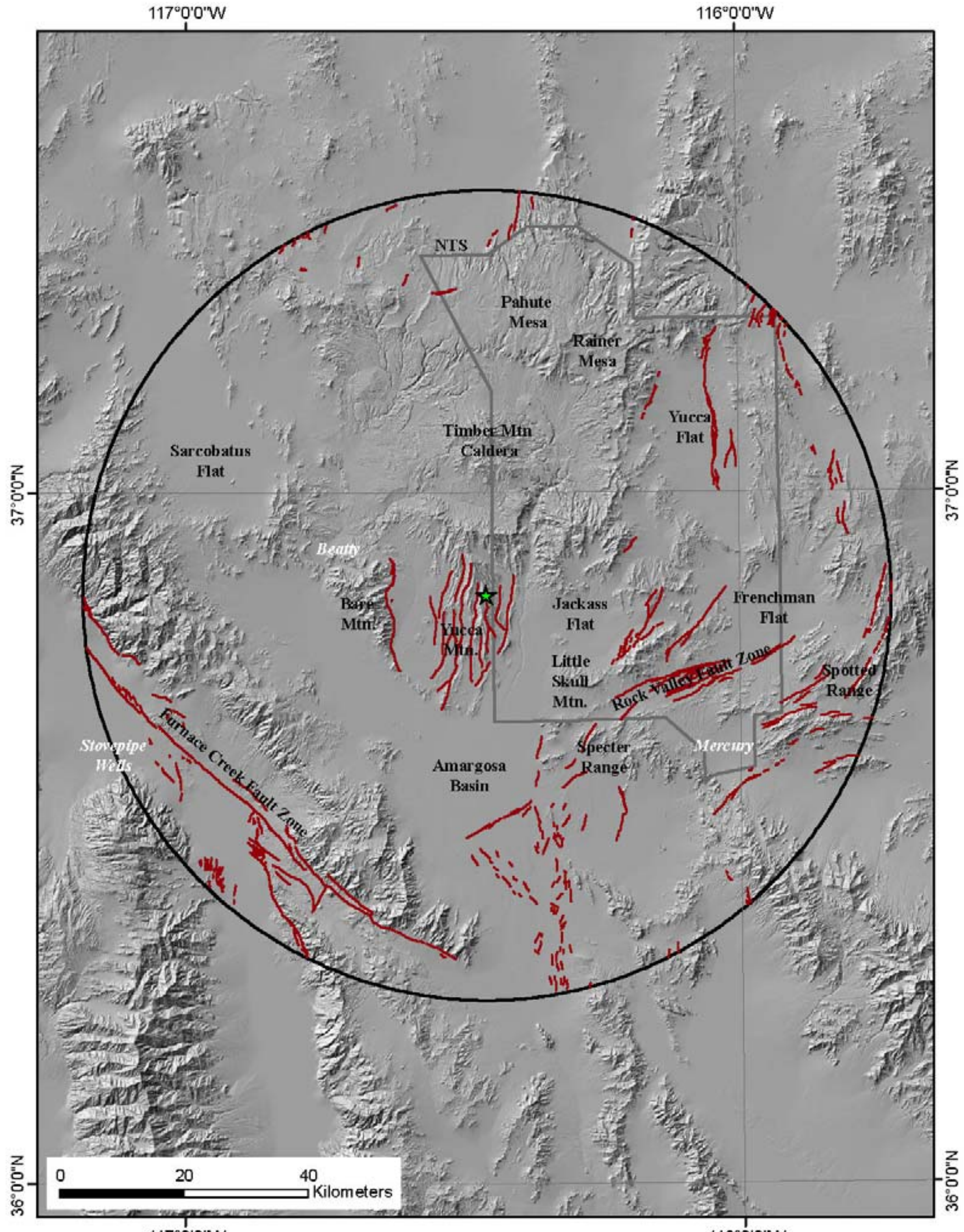

Figure 6. Basemap for geographic reference only. Faults from USGS and NBMG (2006). Star denotes the designated Yucca Mountain repository and the grey line is the boundary of the Nevada Test Site.

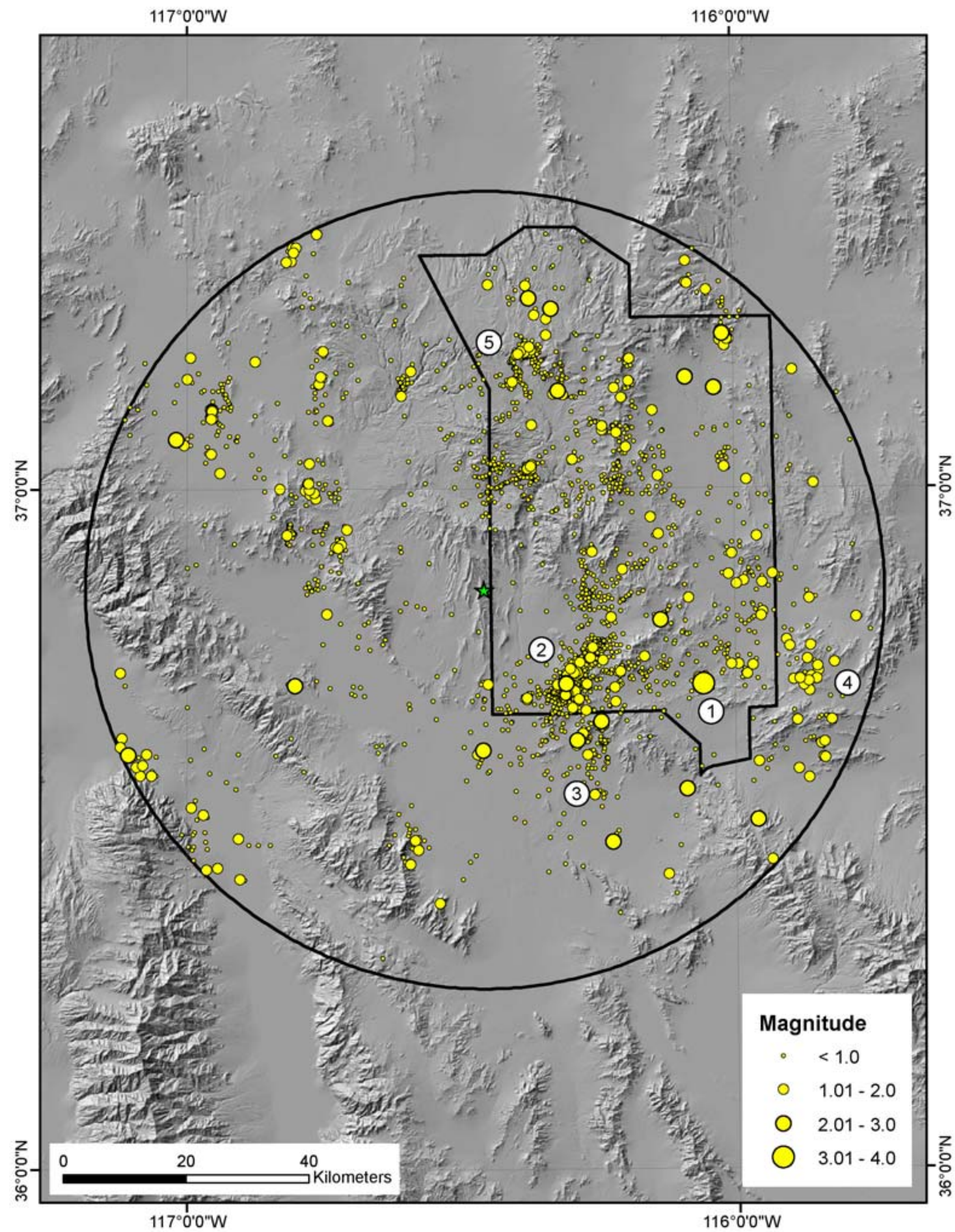

Figure 7. FY05-06 earthquake locations. (1) M 3.40 April 17, 2006, largest event in FY05-06; (2) Little Skull Mountain aftershock zone; (3) West Specter Range N-S seismicity trend; (4) Spotted Range activity; (5) Pahute Mesa FY05-06 activity. See Section 7.2 text for discussion of these specific source areas. Star shows the Yucca Mountain designated repository.

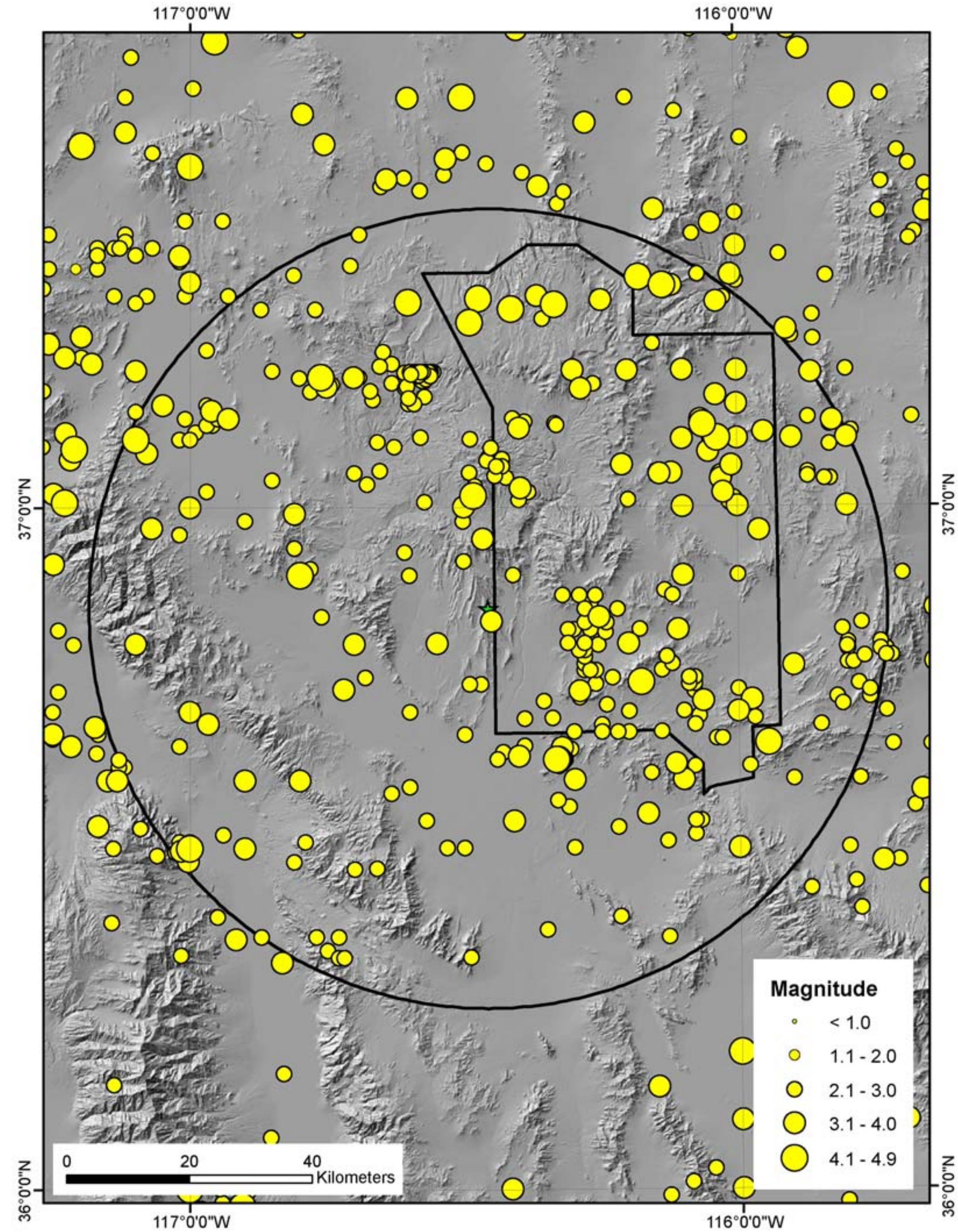

Figure 8. Historical catalog covering 1868 through July 1978 (Meremonte and Rogers, 1987; Unqualified; Corroborative information. Do not use for quality-affecting work).

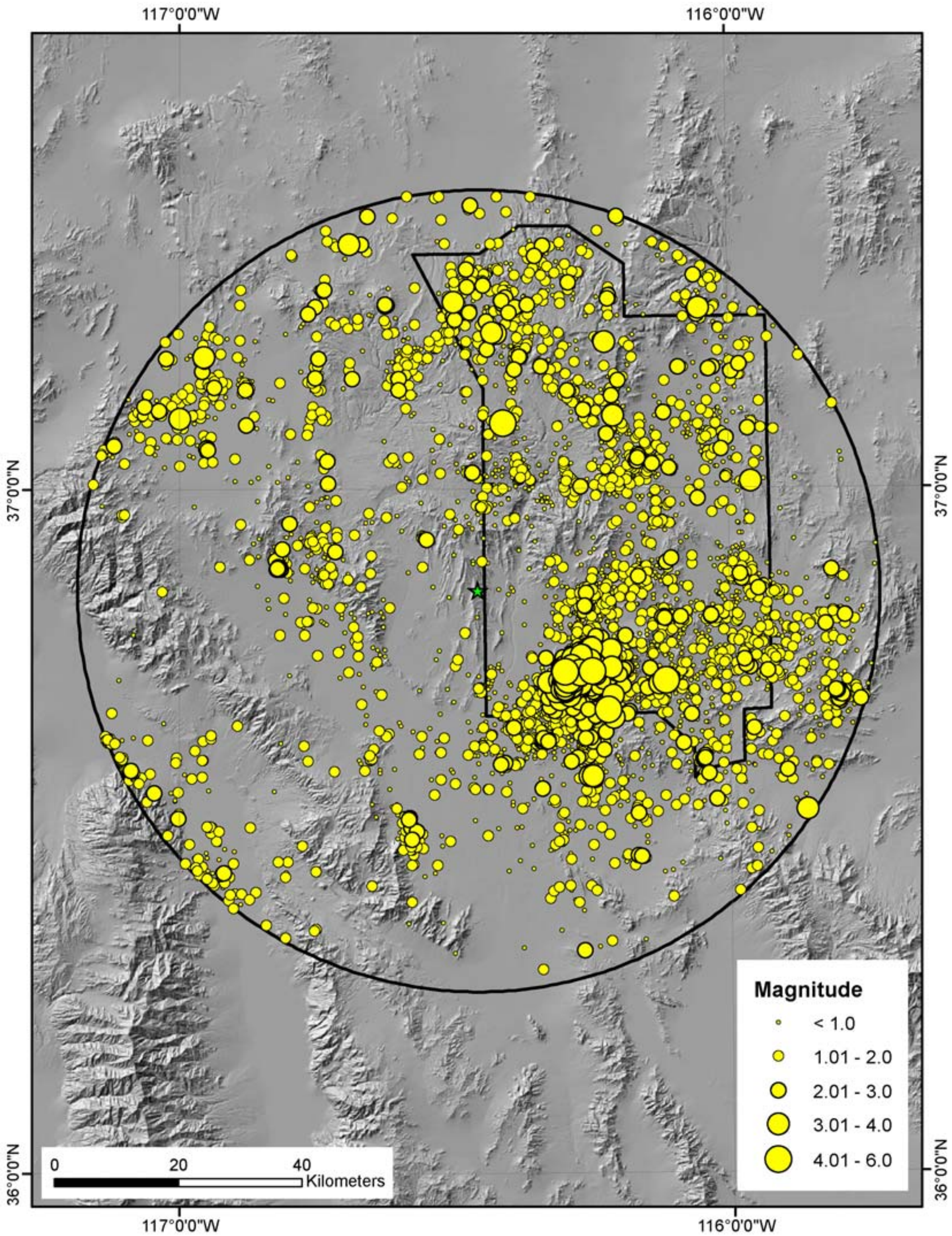

Figure 9. Earthquakes located during the analog network recording period, August 1978 through September 1995 (Unqualified; Corroborative information. Do not use for quality-affecting work).

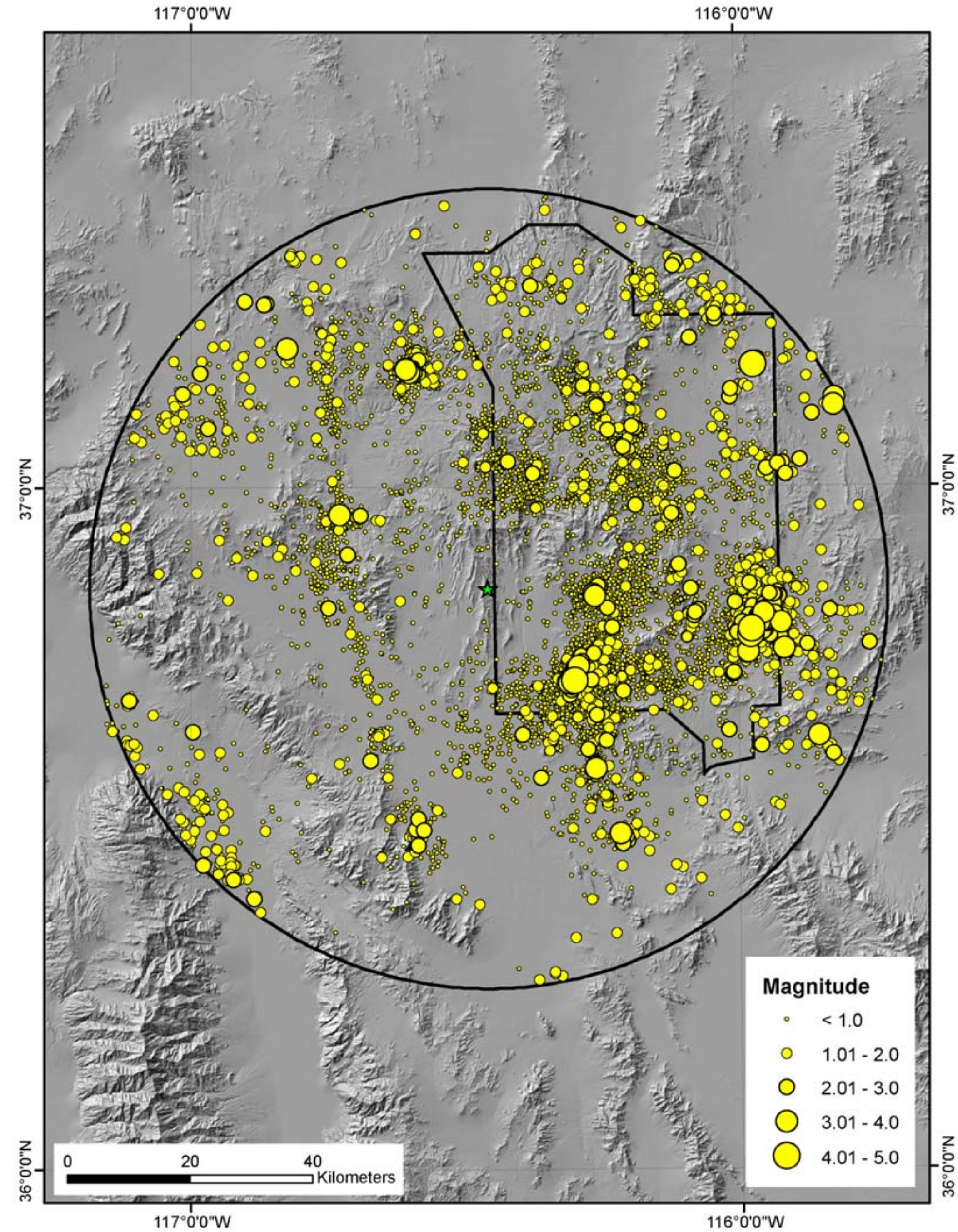

Figure 10. FY96- FY04 earthquake locations.

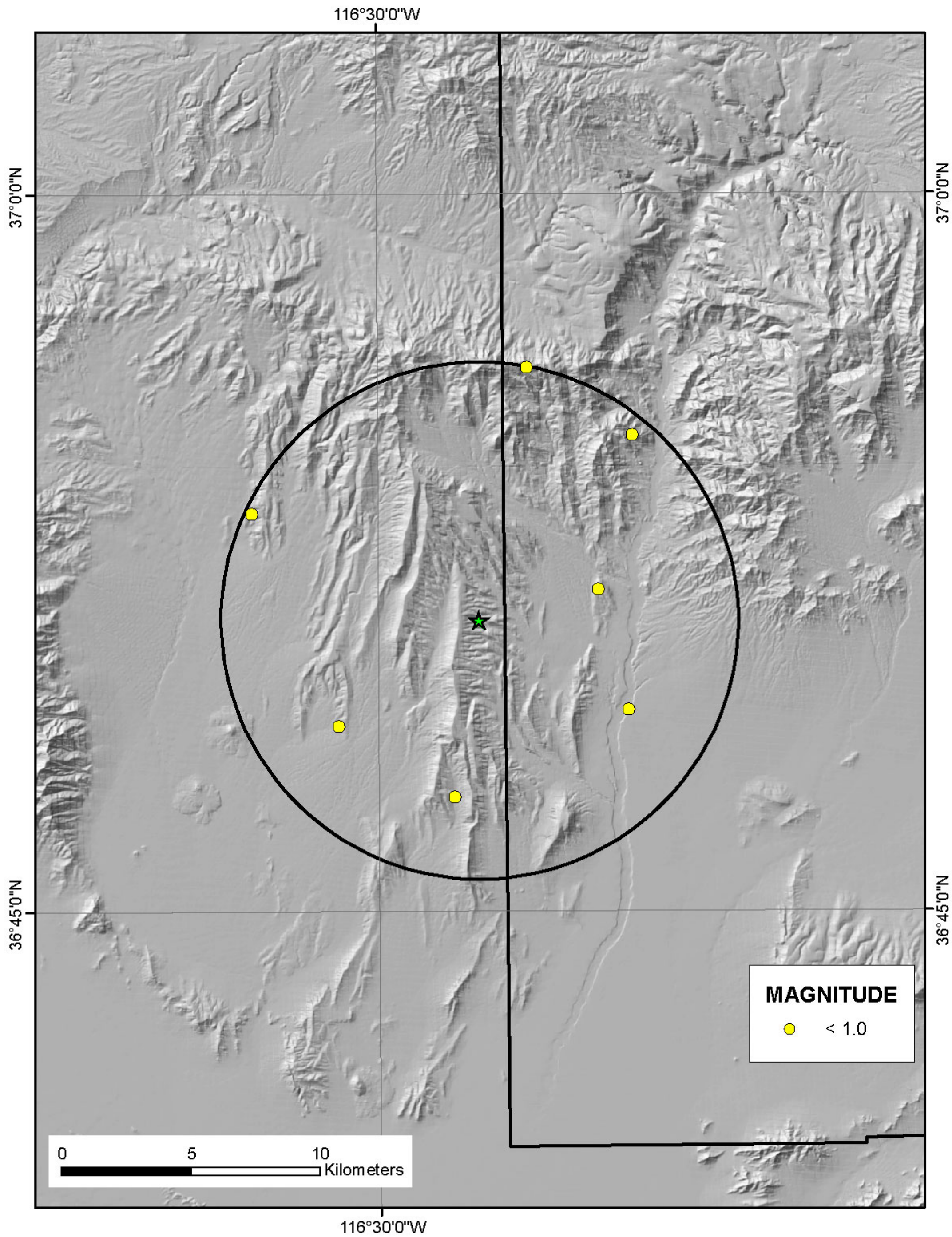

Figure 11. Earthquakes within 10 km of station RPY (central star) in the Yucca Mountain block, FY05-06.

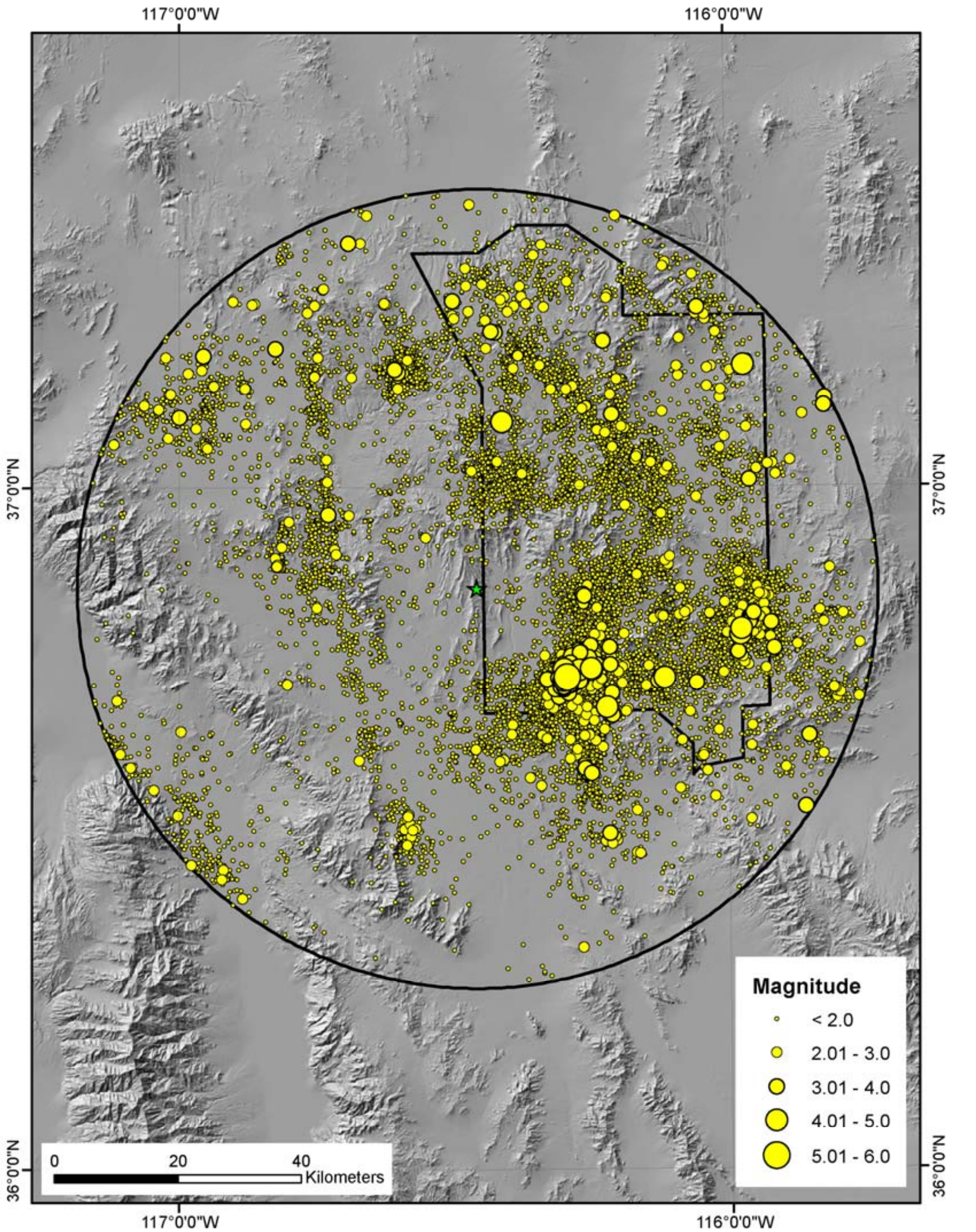

Figure 12. Composite August 1978 through FY06 earthquake locations (Unqualified; Corroborative information. Do not use for quality-affecting work). This combines the earthquakes from Figure 7, 9, and 10.

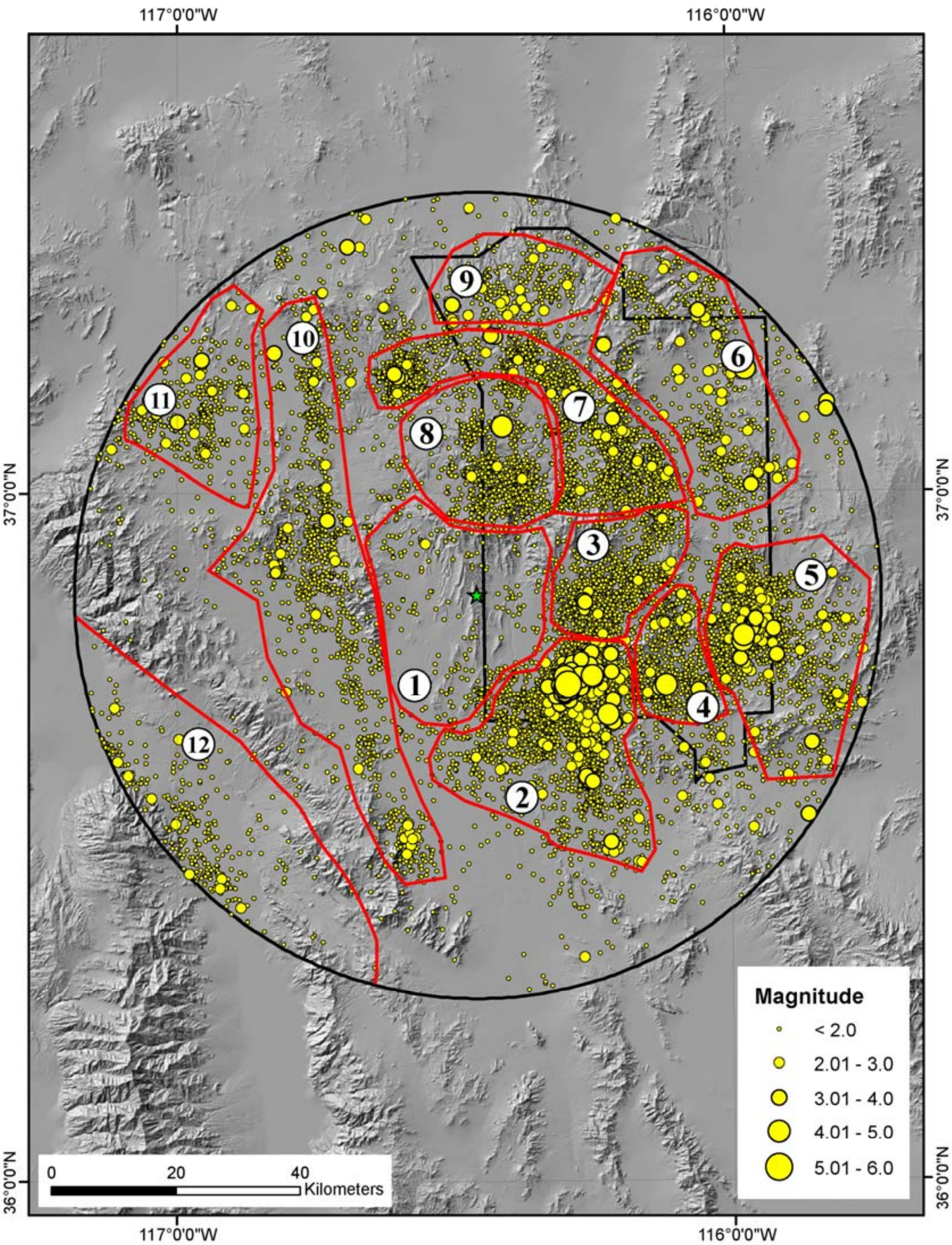

Figure 13. Seismicity zones. Activity from August 1978 through FY06 (Unqualified Corroborative information. Do not use for quality-affecting work).