Quarterly Report to the Harry Reid Center
NSHE-DOE Cooperative Agreement
DE-FC28-04RW12232

Task ORD-FY04-006: Seismic Monitoring
Reporting Period: April 1 through June 30, 2007 FY07 3rd Quarter

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Progress:

- During the third quarter of FY07 (4/1–6/30, 2007) the Nevada Seismological Laboratory has maintained its regional seismic network (weak and strong motion instruments) in the Yucca Mountain, NTS, and Death Valley region. This network consists of 51 seismograph stations with remote communications to the data center at the University of Nevada Reno. The densest part of the network is near Yucca Mountain, which includes most of the strong motion instrumentation. Also in the site area, nine accelerometers in 3 boreholes on the ESF pad and a real-time multi-channel data acquisition system at borehole UZ-16 are in operation. We have also maintained the telemetry infrastructure, combined analog and digital, for real-time data management at UNR. All seismic waveform and event locations (automatic and analyst reviewed) are compiled and archived in an Antelope data management system. Supplement 1 (below) summarizes the regional seismicity for the 3nd Quarter of FY07 (Figure 1) including reviewed and non-reviewed preliminary earthquake locations and magnitudes.

- Installation of seismic recording instrumentation and telemetry systems under the network upgrade subtask is continuing but has been delayed due to funding cutbacks. Eleven stations purchased in FY06 have been configured for installation, and we have only recently received the communications radios to upgrade stations.

- The FY06 earthquake catalog has completed technical review and is in currently in QA review. Raw waveform data, event sheet review forms, timing check forms, and polarity check forms have been submitted according to IPR-001.

- Located seismic events for 3rd Quarter 2007 are shown in Supplement 1.

- A Performance Confirmation Test Plan has been developed under the direction of Sandia National Laboratories.

- With the understanding that seismic monitoring will be moved under the Lead-Lab (Sandi National Labs) for FY08, internal activities to closeout the current Task-006 Coop

have begun. We anticipate the transition to the Lead-lab will require significant effort during the 4th Quarter of FY07. The transition will include closeout of all scientific notebooks, completion of outstanding NCR's, transition of Scientific Work Plans, Implementing Procedures and baseline software to Lead-lab QA.

- Supplement 2 includes a listing of manuscripts and abstracts submitted during the quarter.

Seismicity for the Quarter:

During the 3rd Quarter of FY07 276 earthquakes have been located with 65 km of the proposed Yucca Mountain repository area. Supplement 1 includes a map of located events. The largest events located during the Quarter are shown in Table 1.

Table 1. Largest Earthquakes During the Quarter

M	Lat	Lon	Depth	#phs	Date		Time
1.58	36.8031	-115.8913	9.7	60	2007162	6/11/2007	8:14:48.743
1.22	36.6666	-115.7920	6.2	24	2007099	4/09/2007	6:22:02.418
1.22	36.9898	-115.9585	9.1	55	2007093	4/03/2007	15:22:43.169
1.18	36.6476	-116.3469	4.9	57	2007138	5/18/2007	4:32:06.925
1.14	36.9813	-116.0506	5.3	50	2007119	4/29/2007	20:11:21.620
1.13	36.6497	-115.7890	7.5	33	2007099	4/09/2007	6:22:13.903
1.10	37.1382	-117.0311	6.7	62	2007149	5/29/2007	8:57:12.532
1.03	37.3621	-116.8061	7.4	44	2007175	6/24/2007	7:33:56.008
1.03	36.7324	-116.2917	9.2	59	2007137	5/17/2007	16:34:17.370

M: Magnitude
Lat: Latitude
Lon: Longitude
Depth: Event depth in km
#phs: number of phases used to locate the event
Date/Time: Event origin time

One event was located with 10 km of central repository area station RPY (Figure 2) in eastern Crater Flat. Also included in Figure 2 is the estimated focal mechanism for the event. This is a Magnitude -0.15 (Richter local magnitude) strike-slip earthquake at a depth of approximately 5 km. Shown in Figure 3 are the waveforms from local network stations that were used to estimate seismic phase arrivals. Figure 3 is a 23 second record of seismic waveforms.

Network Upgrade Status/Network Maintenance:

At present, a total of fifteen RT-130 dataloggers, mostly purchased with FY06 funds and others earmarked for portable deployment are available for installation. Backplane boards have been completed for eleven of these installations. 900 MHz Canopy IP radios have been purchased and are in-house after some delays from the vendor. Upgrade of 11 stations in the YM network regions will be completed in the 4th Quarter; anticipated installation in July/August. YM area network stations are targeted for the next round of stations upgrades in order to address 200 MHz interference problems. Several Death Valley area analog stations continue to rely on analog communications through the YM node. Closeout system checks on existing 72A dataloggers and initial system checks on new dataloggers will be conducted during station upgrades.

Seismic Network Maintenance:

Station and communication systems maintenance has been performed regularly over the Quarter. Station AL5 (Alcove 5) and NI3 (Niche 3; backwall coherence study) are the only remaining ESF underground seismic stations. Access to the ESF will be allowed, as we understand, on a quarterly basis.

Data from Earthscope USArray stations have been integrated into the UNR operations stream and into ShakeMap production for earthquake response. USArray stations have improved event locations in southern Nevada, including event locations in and around Yucca Mountain and the Eastern California Shear Zone. They will also contribute to the quality of ShakeMap for the NTS area earthquake notifications in the event of significant earthquakes.

Software Qualification Activities:

Significant progress was made on the Antelope Real-Time System v4.8 software QA. Validation test suites were developed and used as the basis of the Validation Test Plan. The Software Definition Report completed technical and QA reviews, and was approved in mid-May. Software Validation Testing was completed in the second week of June by Validation Tester Ken Smith, with HRC QA representative Morrie Roosa observing. No software issues were identified in the testing, and all the tests passed. The Software Implementation Report was assembled and submitted for technical and QA review on June 25th.

An Antelope 4.9 Software Activity Plan has been drafted. Quality-affecting elements were not changed materially from version 4.8. We intend to closely follow the Antelope 4.8 SDR in preparing a version for 4.9.

An extensive review of the draft revision to QAP 3.2 on Software Management was prepared and delivered to HRC.

New Network Operations Procedure (IPR-043):

New network operations procedure, IPR-043, has completed technical review and QA review comment resolution is expected to be completed in early July. This procedure is intended to accommodate the operations of the network upgrade as well as address existing older data collection systems.

Strong Motion Network Operations (IPR-004):

All IPR-004 relevant stations from the 1995 strong motion deployment have been replaced and integrated under network upgrade subtask activities. QA for these stations is managed under Scientific Notebook 057. This notebook has been closed with QA and technical reviews; IPR-004 is effectively closed.

Borehole UZ-16 Data Collection and Analysis:

A series of Vibroseis experiments at Yucca Mountain have been recorded on the UE#25 UZ-16 borehole array as well as several nearby network stations. The experiment was conducted by the University of Texas team. The main focus of the primary phase of the experiment was at the UZ-16 borehole, where several days of testing occurred. We worked with the experimenters to ensure the safety of our equipment at UZ-16 and to ensure that they could acquire the data that they needed. Signals were recorded well at the UZ-16 bore hole array, but signal-to-noise degraded fairly rapidly with distance with the NI3 backwall array recording the signal well, but stations such as RPY only recording the signals moderately well Station SYM, for example in the southern Yucca Mountain block recording virtually none of the signal. Following the UZ-16 phase of this experiment, we rearranged the recorded set of geophones within the borehole. To better study the shear-wave characteristics of the bore hole, we primarily are recording the horizontal components of the geophones with vertical components only being recorded at the bottom and top of the bore hole. The surface instrument configurations were unchanged. We also supplemented the existing 64 recording channels with two additional 6 channel Reftek dataloggers that record at 500 sps at 24 bit resolution. These new channel were placed on the vertical components of the bottom three levels and top three levels of the bore hole. This allows very precise resolution of the P-waves at the bottom of the hole and to observe P-wave variability up the borehole. These changes will help advance our knowledge of shallow-subsurface effects at Yucca Mountain.

FY06 Seismicity:

The FY06 earthquake catalog has been technically reviewed and is in QA review. Focal mechanism solutions for the larger events (M > 1.8) within about 40 km of Yucca Mountain were also completed. Solutions using Q application FPFIT, which applies first-motion information only, was compared with solutions from a yet unqualified application developed to implement both first-motion and amplitude information from P and S waves. Generally, FY06 focal mechanisms show normal (majority) to strike-slip solutions, all with predominately NW-SE directed T-axes.

Kappa Project:

The original data analyzed by Su et al. (1996) and reanalyzed by Anderson and Su for kappa have been built into an Antelope database for reanalysis with the qualified kappaAH software. These data yielded very low estimates of kappa on Yucca Mountain compared with engineering expectations developed in California. Data from the Blume network including recordings of the Little Skull Mountain earthquake have also been prepared for analysis. These data are proving difficult to use because of the event triggering model that was employed. Analysis is in progress.

Coherence Experiment (ESF backwall)

Despite the closing of the ESF power is available in the Alcove 5 area. The digitizer the is collecting data from the backwall 10 Hz geophones is still operating and recording continuous data. Events with good signal-to-noise-ratio are subset and saved on regular basis.

ESF Pad Borehole Stations:

Pad borehole accelerometer borehole stations are recording continuously. Several local and regional events recorded on the borehole stations have been subset and archived.

Remote Access Communications:

A manuscript has been submitted to Seismological Research Letters on PHP mobile device applications developed to better operate and maintain the IP and IP dataloggers systems in the Yucca Mountain network upgrade. These applications are currently being used to minimize system downtime, monitor and manage remote radios and comm systems, and to perform station installation system checks.

Remote monitoring applications enhancements developed during quarter:

rtmmobile:php: provides capability to monitor real-time processes in main collection system.
nagiosmobile.php: provides capability to check on all currently monitored devices in the network
rtccmobile.php: provides capability to initiate sensor test from remote locations

System Checks:

Semi-automatic code for instrument-replacement an on-going operation system check processes for S-13 sensors were finalized and implemented during the reporting period.

Work is in progress for a routine system check automatic procedure consisting of:
1. Automatic system check pulse generation for the sensors with RT-130 instruments;
2. An automatic, simple procedure for all the other sensors and instruments;
3. Automatic reports of in-service system checks for tracking sensor performance.

NCR's:

We have self issued NCR-UNR-016). Some hard referenced directory locations and specific software STN#'s were not changed in some network operations IPR's prior to application of more recent baselined software and generalization of computer network configuration. DCN's for IPR-001, IPR-002 and IPR-003 have been issued to account for discrepancies.

Problems:

We continue to experience communications problems for some stations through the YM Node comm link due to the interference between the 200 MHz and IP communications systems. This has impacted stations CRF, STO, FRG and TAR, in particular. This problem should be fixed when we complete the IP radio upgrade of all YM node stations; anticipated complete summer 07.

Until the upgrade of the YM area seismic network and communications systems are complete, we will continue to maintain both new and older network datalogger and telemetry systems.

Funding delays will impact completion of the upgrade during FY08, the last year of the current Cooperative Agreement.

Status of Funds:

FY07 funding been received with about a 30% reduction. This will eliminate any upgrade equipment purchases for FY07.

Plans and Notes:

Draft of the FY-05/06 seismicity report is being prepared and completion is contingent on qualification and submittal the FY06 catalog. In the next quarter we plan on installing 11 new RT-130 stations. We anticipate significant effort during the next quarter in activities related to closeout of the Coop for seismic monitoring and transitioning to the Lead-Lab contract planned for October 1. We will continue to monitor earthquake activity in the Yucca Mountain area.

SUPPLEMENT 1: Seismicity: April 1, 2007 through June 31, 2006. There have been 276 earthquakes located within 65 km of Yucca Mountain during the Quarter. These are preliminary event locations; all locations and magnitudes are subject to change following further review.

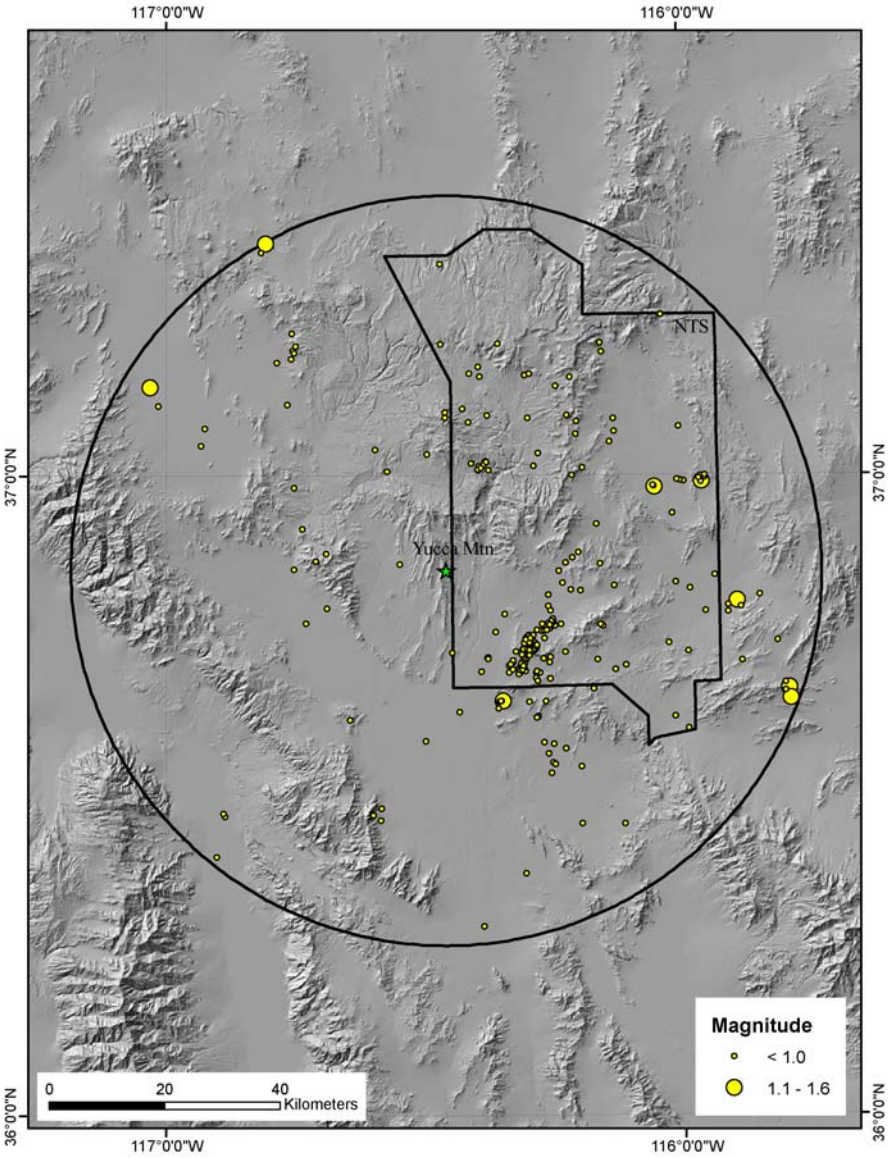

Figure 1. Preliminary earthquake locations for the 3nd Quarter of FY07; circle is 65 km radius from station RPY in the central repository area. There are 276 event locations shown. Seismograph station RPY, in the Yucca Mountain block, is shown as the green star. These are preliminary event locations that are subject to change following final review; blasts may be included.

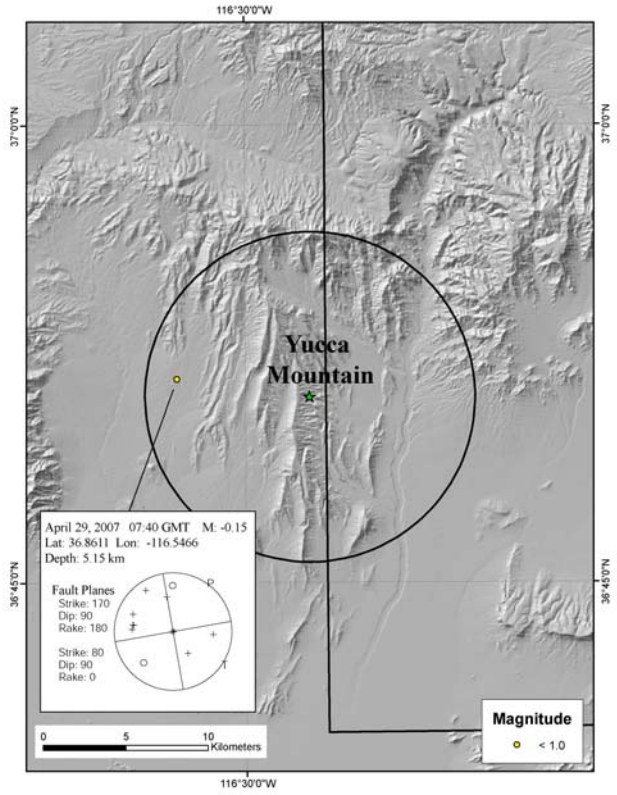

Figure 2. One event was located with 10 km of station RPY in the Yucca Mountain block. Origin Time: April 29, 2007 07:40:29.47 GMT; Magnitude -0.15, Latitude: 36.8611; Longitude: -116.5466; Depth: 5.15 km. Shown are the event location in eastern Crater Flat and the estimated focal mechanism.

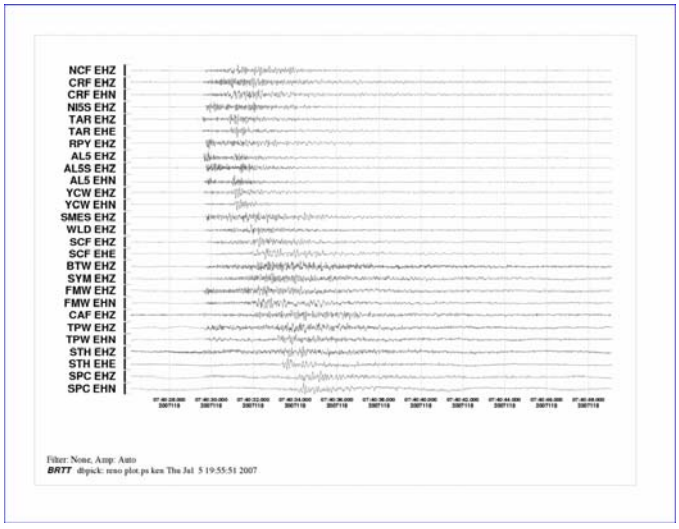

Figure 3. Waveforms of event shown in Figure 2; shown is a 23 second time-series of waveform of station/channels used to develop the event location.

SUPPLEMENT 2: Manuscripts and Professional Meeting Abstracts Submitted

The following is a list of titles and abstracts of publications and abstracts submitted during the Quarter.

Manuscript submitted to Seismological Research Letters:

Use of Mobile Devices for Earthquake Response, Seismic Network Applications, and Diagnostics

Dave Slater[1], Ken Smith[1], Kent Lindquist[2], Rob Newman[3], Carol Freinkel[1], John Torrisi[1], Ileana Tibuleac[1], and Glenn Biasi[1]

[1]Nevada Seismological Laboratory, [2]Lindquist Consulting, Inc. Fairbanks, Alaska, [3]Scripps Institution of Oceanography, University of California, San Diego

ABSTRACT

Mobile devices are reinventing Internet remote communications. These new technologies enable a surprising variety of mechanisms for interacting with seismic networks. We've developed interactive mobile device applications for network diagnostics, access to remote seismograph stations, automatic and semi-automatic network data center operations functions, remote radio diagnostics, timely responses to significant earthquakes, and new approaches for citizens to access seismic information. Challenges to network operators have grown in an age of increasing demand for responsiveness to large, damaging earthquakes. The Advanced National Seismic System (ANSS) program defines an accountability of network operators to first responder's needs in earthquake hazard mitigation, through ShakeMap (Wald *et al*., 2005) and other response criteria. However, these initiatives are met with new challenges to regional network operators. The ShakeMap application computes and graphs estimates of ground shaking based on estimates of the location, time, and magnitude of earthquakes. Such ground motion estimation can be an important resource for earthquake response. However, underlying the need to respond is the more basic need to maintain automated systems 24/7; seismic network operators become increasingly accountable for data network accessibility when products such as ShakeMap become integrated into mainstream network applications and standards. New technologies and approaches are needed to manage such increasingly sophisticated monitoring applications with limited resources available to maintain continuously running operations centers.

We describe an entirely new systems platform for interacting with the Nevada seismic network and presenting earthquake information. This platform provides near real-time feedback to the field staff and network operators for meeting system performance criteria. Mobile Internet Technologies appear to be growing quickly in importance and in widespread use, and these challenges require new response capabilities, new approaches to managing growing seismic networks, and software that is designed to meet these goals. A downlink location for the source code of our mobile applications is included in the References section.

Accepted for Publication Journal of Geophysical Research:

P-wave velocity structure in the Yucca Mountain, Nevada region

Leiph Preston, Ken Smith, and David von Seggern

Nevada Seismological Laboratory

We have performed a crustal tomographic inversion using over 250,000 P arrival times from local earthquake sources and surface explosions in the Yucca Mountain, Nevada region. Within the shallowest 2-3 km, topographic features tend to dominate the structure with high velocities imaged under Bare Mountain, the Funeral Mountains and higher terrain to the east of Yucca Mountain and low velocities imaged under Crater Flat, Jackass Flat, the Amargosa Desert and the caldera complexes. Imaged shallow velocities also show correlation with several known gravity and aeromagnetic anomalies. Below the basins (~2-3 km depth), velocities vary between 5.5 and 6.5 km/s and lose many of the correlations seen in the shallowest layers; however, a few major structures, such as the Bare Mountain block, can be traced to at least 10 km depth. Additionally, we image structures that may be associated with the Wahmonie intrusion and pre-Tertiary structural trends. Yucca Mountain itself is underlain by a high-velocity upper-crustal-scale structure similar to other structures in the region such as Bare Mountain and may represent a Basin and Range style back-tilted block. We explore our tomographic results in the context of four major tectonic models that have been proposed for the Yucca Mountain region.

Manuscript submitted to Bulletin of the Seismological Society of America:

Location and magnitude estimation of the October 9, 2006 Korean Nuclear Explosion, using the Southern Great Basin Digital Seismic Network as a large aperture array

Ileana M. Tibuleac, David von Seggern, John G. Anderson, Ken Smith, Arturo Aburto and Tom Rennie

Nevada Seismological Laboratory

ABSTRACT

The Southern Great Basin Digital Seismic Network (SGBDSN) has been designed for monitoring high frequency (1-40 Hz) local events at and near Yucca Mountain Nevada, the designated site for the national high-level nuclear waste repository. We find that the network is also effective as a large aperture teleseismic array for monitoring events in and close to North Korea, the recent location of an underground nuclear test, that occurred on October 9'th, 2006, 01:35:28, NEIC m_b 4.3. We explain this by 1) low ambient noise; 2) energy efficient propagation paths (the nuclear explosion and nearby deep earthquakes show dominant frequencies between 0.9 and 2.5 Hz); and 3) coherent signal across the SGBDSN. The network, when used as an array, provides a particularly good beam signal-to-noise ratio (SNR) for the nuclear explosion. Estimated beam SNR is 20 dB at frequencies between 0.9 - 2.5 Hz.
Between January 1996 and December 2006, 55% of the events with $7.1 > m_b > 3.3$ located within 300 km of the North Korean nuclear explosion by NEIC are considered large enough to

be confidently picked by an SGBDSN analyst. The first-arrival of the North Korean event itself is apparent on 25 of the 29 SGBDSN unfiltered recordings. The direct *P* phase is confidently identified using horizontal velocity and back azimuth estimated with crosscorrelation and frequency-wavenumber (*fk*) methods. Static time corrections for beamforming are estimated using eleven deep earthquakes within 300 km of the nuclear explosion. Using a statistical method to determine relative delays, we calibrate the nuclear explosion single-array location to the NEIC location, using the delays derived for the eleven earthquakes. The same method is used to estimate magnitude corrections. The SGBDSN magnitude estimate is 4.3 using the Veith-Clawson (1972) body wave magnitude formula.

Manuscript submitted to the Bulletin of the Seismological Society of America:

Seismological Evidence for Low-angle Normal Faulting in the 1993 Mw 6.1 Eureka Valley, California Earthquake Sequence

Donghong Pei, Kenneth D. Smith, Gene Ichinose, and Rasool Anooshehpoor

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ABSTRACT

The 1993 M_w 6.1 Eureka Valley, California earthquake occurred between the Owens Valley and Fish Lake Valley fault zones in the northern Eastern California Shear Zone. Down-to-the-west displacement on a north striking fault projects near the surface expressing of Last Chance Range front in eastern Eureka Valley. The aftershock sequence extends for over 25 km, more than twice as long as the rupture extent expected for an M_w 6.1 event in a complex post-seismic period. Using high quality aftershock relocations (hypoDD) we demonstrate that the deeper aftershocks at the southern end of the sequence project to a low-angle structure illustrating a complex apparent listric fault geometry. Aftershock locations image the mainshock fault evolving to slip on a shallow northwest dipping structure (dip $<10^0$) at depth with a more steeply west dipping northern section (dip $>50^0$ dip). The teleseismic body wave model is improved by partitioning the mainshock moment release approximately equally on the steeply dipping and shallow dipping sections of the mainshock fault plane, consistent with this aftershock geometry. Based on this seismological evidence, we propose a low-angle detachment as the mechanism for slip transfer between the Owens Valley and Fish Lake Valley faults zones. All secondary normal faults located between the Owens Valley and Fish Lake Valley faults, including the Saline Valley fault, toe into the detachment at seismogenic depths.

Abstracts presented at the 2007 Seismological Society of America annual meeting:

LOCATION AND MAGNITUDE ESTIMATION OF THE OCTOBER 9, 2006 KOREAN NUCLEAR EXPLOSION, USING THE YUCCA MOUNTAIN NETWORK AS A LARGE APERTURE ARRAY

TIBULEAC, I.M., VON SEGGERN, D., ANDERSON, J.G., SMITH, K., ABURTO, A., and RENNIE, T., University of Nevada Reno, Seismological Laboratory, Laxalt Mining Engineering Bldg., 1664 N Virginia Street, Mail Stop 174, Reno, NV, 89557

The Yucca Mountan Seismic Network (YMSN) has been designed for monitoring high frequency (1-40 Hz) local events at and near Yucca Mountain Nevada, the designated site for national high-level nuclear waste repository. We find that the network is also effective as a large aperture teleseismic array for monitoring events in and close to North Korea, the recent location of an underground nuclear test. We explain this by 1) low ambient noise; 2) energy efficient propagation paths (the nuclear explosion and nearby deep earthquakes show dominant frequencies between 0.9 and 2.5 Hz); and 3) coherent signal across the YMSN. The network, when used as an array, provides a particularly high beam signal-to-noise ratio for the nuclear explosion (at least 14 db, equivalent to approx. 0.7 magnitude units) at these frequencies. Between January 1996 and December 2006, the YMSN detects 60% of the events with mb >3.3 located within 300 km of the North Korean nuclear explosion by the National Earthquake Information Centre (NEIC). The first-arrival of the North Korean event is apparent on 25 of the 29 YMSN unfiltered recordings. The direct P phase is confidently identified using horizontal velocity and back azimuth estimated with crosscorrelation and frequency-wavenumber (fk) methods. Static time corrections for beamforming are estimated using eleven deep earthquakes within 300 km of the nuclear explosion. We calibrate the nuclear explosion single-array location to the NEIC location, using relative time corrections derived for the eleven earthquakes. A similar magnitude correction analysis results in an array explosion body wave magnitude of 4.3, using the Veith-Clawson formula.

PRECISION RELOCATION OF EARTHQUAKES AT YUCCA MOUNTAIN, NEVADA

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We have relocated the catalog of earthquakes from 1996-2005 in the vicinity of Yucca Mountain, Nevada using waveform cross-correlation times and analyst time picks in the program HYPODD. The 1996-2005 catalog has been all developed with the digital network that became operational in October 1995 and currently has 29 sites. The source catalog contains over 25,000 events within roughly 65 km of Yucca Mountain, the nations designated site for disposal of high-level nuclear waste. This catalog is heavily dominated by small microearthquakes in the M < 1 range. Yucca Mountain lies in the southern Great Basin east of Death Valley and has a complex structure shaped considerably by Miocene volcanism and by E-W to SE-NW extension tectonics more recently. The 1996-2005 seismicity pattern is generally diffuse, punctuated by some notable aftershock sequences including continuing events related to the 1992 Little Skull Mountain M 5.6 earthquake, the largest event in the area since seismic monitoring began for the underground repository siting. Relocated seismicity shows tightened clusters of events (aftershock zones mostly), but no really clear, large planar features. In particular, the source zone of the Little Skull Mountain earthquake is not sharply imaged as a plane but is spread out in a volume likely indicating residual aftershock activity off the main fault. Some very local interesting features, in the form of 3-D lineations, emerge from the relocated seismicity. This relocation study points out some of the difficulties of using cross-correlations in areas of seismicity patterns which have

both diffuse and clustered character. Many isolated or partially isolated events simply drop out of the solution if constraints on linking events are too narrow. We compare the results obtained here with those from a more traditional relocation method using station time corrections.

GROUND MOTION COHERENCY AND CORRELATION STUDIES AT YUCCA MOUNTAIN, NEVADA

PRESTON, L.A. and ANOOSHEHPOOR, R., Seismological Laboratory MS/174, University of Nevada Reno, Reno, NV 89557, preston@seismo.unr.edu

A clear understanding of the engineering impacts of ground motions from seismic events is necessary for the proper design of structures that would be used in the designated high-level nuclear waste repository at Yucca Mountain, Nevada. To gain an understanding of the ground motion variations within the Exploratory Studies Facility (ESF) at Yucca Mountain, we have conducted preliminary analyses of waveforms obtained from a geophone array located along the west wall (backwall) of the ESF tunnel. In the current recording scheme, six geophones of the backwall array are recorded at a time. Two recording layouts were analyzed from September 2005 through December 2006. In the first array the spacing between the geophones was approximately 100 m, and in the second array about 60 m. Each layout has two phases: a vertical-component phase and a horizontal-component recording phase. More than 500 events were recorded on the array during this time period. We explore cross-correlation and coherence measurements of the waveforms from these events to investigate ground motion variations within the tunnel. Both the cross-correlations and coherencies indicate the ground motions lose coherence at distances on the order of 100 - 200 m and frequencies higher than 1 Hz. At distances less than about 200 m, coherency values and correlations are significant to about 10 Hz for both P and S waves, with P waves having higher coherencies and cross-correlations than S-waves. Correlations and coherencies are excellent at frequencies less than 1 Hz for all distances, except for S-waves, which only display moderate values at distances beyond 300 m. These results indicate that the tunnel area exhibits strong scattering, especially of S-wave energy, even over distances as short as 200 m and for frequencies as low as 1-1.5 Hz.

SIMPLIFIED PROBABILISTIC SEISMIC HAZARD ANALYSIS FOR PRECARIOUS ROCKS ON YUCCA MOUNTAIN, NEVADA

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The probabilistic seismic hazard analysis for Yucca Mountain, Nevada evaluated the hazard for a hard-rock site near the crest of Yucca Mountain. Teams of scientists independently developed input models and estimated their associated uncertainties for the analysis. These individual models were used to obtain multiple estimates of the seismic hazard and their differences are taken to represent our epistemic or knowledge based uncertainty in the hazard. The mean of these many hazard curves is inconsistent with precariously balanced rocks on Yucca Mountain.Due to the complexity of the process in which millions of combinations of models were evaluated, we simplified the analysis by developing a simplified input that predicts similar hazard curves. We carried out various investigations regarding the relationship of input decisions regarding the uncertainty levels to the resulting consequences. We tested these various decisions against selected precarious rocks on Yucca Mountain, drawing summary conclusions.The median exceedance rate curve is inconsistent with the existence of the four precarious rocks investigated based on estimates of their fragilities and residence times. In this analysis, a perfect correlation has been assumed between the various ground motion intensity measures utilized

to calculate the precarious rock fragilities. An asymmetric weighting scheme for the epistemic uncertainties on the mean and standard deviation was considered for the ground motion prediction equation (GMPE) with the largest epistemic uncertainties. Even if the probability of ground motions greater than the best estimate of the GMPE is zero, the resulting mean hazard is inconsistent with the precarious rocks. Among the GMPEs we investigated, those most consistent with the precarious rocks have median values and aleatory uncertainties substantially below the model best estimates. Thus the median values and aleatory uncertainties of all of the ground motion models may be too large.

SEISMIC WAVE STUDIES AT THE UZ-16 BOREHOLE, YUCCA MOUNTAIN, NEVADA

PRESTON, L.A. and SMITH, K.D., Seismological Laboratory MS/174, University of Nevada Reno, Reno, Nevada 89557, preston@seismo.unr.edu

The UE#25 UZ-16 borehole array at Yucca Mountain, Nevada provides a prime opportunity to investigate near surface effects on seismic waveforms as a function of depth. The borehole 3-component geophone array consists of 96 depth levels from about 30 m to 500 m depth below the surface; we are continuously recording 18 approximately equally spaced levels. The array was augmented with three 3-component surface instruments that match the borehole sensors: 1) at the borehole, 2) at 30 m and 3) at 70 m from the borehole that sample the engineered pad and adjacent undisturbed ground. Due to the thick cover of Miocene volcanic tuffs at Yucca Mountain, the borehole does not penetrate the underlying Paleozoic basement but does penetrate many tuff horizons of varying thicknesses and properties, including the repository horizon. We present results from several different investigations of the seismic data including spectral ratios and spectral variation as a function of depth. Amplification in the 3 Hz to 15 Hz band occurs in the top 60 m of the borehole with the surface geophones demonstrating the largest amplification in these bands, as expected. Q estimates average about 35 for the borehole. P-velocities of 3.5 km/s at the bottom of the hole drop to ~2.3 km/s near the top; S-velocities, although poorly constrained, are near 2 km/s at the bottom of the hole and drop to just over 1 km/s within the top 50 m. Earthquake spectra show little variation up the hole except for attenuation effects. The spectra from local events with magnitudes less than 3, however, do show unexpected complexity that needs further investigation.

USE OF MOBILE DEVICES FOR SEISMIC NETWORK APPLICATIONS, DIAGNOSTICS, AND RESPONSES

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Mobile devices are reinventing Internet remote communications. This technology is leading to a new paradigm for interacting with seismic network operations applications, remote stations, network diagnostics, automatic and semi-automatic network functions, and responses to significant earthquakes. Antelope-based and Antelope-independent PHP applications facilitate effective interaction with network control systems and real-time earthquake information for both network operators and field staff. The contributed Antelope interface in PHP, a companion to its Perl, C, Fortran, Matlab, Tcl/Tk, and Shell interfaces, provides an easy-to-implement set of tools for real-time ORB and Datascope database interaction. Antelope-independent PHP applications implement secure interactive ShakeMap review functions with the ability to edit ShakeMap input data and rerun ShakeMap, and to remotely manage Reftek RT130 dataloggers. Through Antelope we have implemented remote

hypocenter review, event relocation, and waveform image display tools. Functions ranging from simple pings to dataloggers that confirm communication to the central data center, to more complex radio and telemetry diagnostics now allow field technicians to debug IP network systems remotely from the mobile device. Also, we have developed an application that allows interactive access to the central data center Datascope database from remote sites for initiating and confirming sensor calibrations for regulatory compliance. These applications provide immediate feedback to the field staff for meeting system performance criteria. These systems have created an entirely new platform for interacting with the Nevada seismic network and for providing earthquake information to mobile users.

NEAR-REAL-TIME PRECISION CATALOG OF EARTHQUAKES USING WAVEFORM CROSS-CORRELATIONS

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For any particular earthquake catalog, completeness and event location quality are time-dependent functions of network state, processing techniques and tools, and organizational goals. Typically relocations are performed on subsets of catalogs; such relocation subsets represent a better estimate of the historical seismicity in a specific region of a network. However, these new (better) locations are rarely incorporated in the regional authoritative catalog. The ideal catalog would comprise the best, or not likely to be improved much, assessment of an event location in near-real-time with an objective to minimize analyst time and final review. We approach this ideal by building a near-real-time catalog based on waveform cross-correlation in the Southern Great Basin network in and around the NTS area. Earthquakes since 1995 have been relocated with HYPODD using differenced pick times and cross-correlation times (see von Seggern and Smith, this meeting) within an Antelope database environment to develop a best (precision) recent (1996-2005) catalog. Real-time event locations and associated phase arrivals determined within Antelope are windowed for the southern Nevada network region, triggering an automatic cross-correlation location relative to events in this precision 1996-2005 catalog. We compare a suite of final analyst-developed locations with the automatic cross-correlation locations and post-processed HYPODD cross-correlation locations for an assessment of the robustness of this processing scheme. We also suggest improvements and future strategies in this prototype model. In principle, and as implied by process, each new event could trigger a reassessment (relocation) of an entire catalog. Although this may not be practical for most uses, it does provide a constantly improving best-estimate set of earthquake locations.

SEISMIC MONITORING IN NEVADA: A STATUS REPORT

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The Nevada Seismological Laboratory operates approximately 190 stations in the course of its seismic monitoring of Nevada and easternmost California. The lab supports two complimentary missions, seismic monitoring for the State of Nevada and detailed monitoring around the proposed high level nuclear storage facility at Yucca Mountain. A substantial focus with Advanced National Seismic System (ANSS) support in the coming year will be documenting and improving performance. ANSS performance standards for supported networks have provided useful structure to do so. In Nevada's urban areas we estimate that the catalog is complete to approximately Ml 0.8 in the Reno-Carson City area and Ml 1.3 in the Las Vegas Valley. Moving grid analysis of the catalog shows a range of completeness from Ml 1.6 to -0.3. Incorporation of Transportable Array stations has predictably improved detection and sensitivity throughout the state. Location quality generally meets standards in the northern and western Nevada. Stations added in the past 2 years in the Las Vegas Valley will be improving locations there, but seismicity is too low to assess the improvement easily. A locally developed port of Hypoinverse to Antelope provides improved automatic locations. A second obtained through the Antelope update process provides very rapid locations, and an associator to synthesize

multiple locations calculated as more data come in. Recent work has improved time to ShakeMaps to less than 5 minutes and provides for remote review of significant events via hand-held device. Plans are in work to improve our web display of network and station performance, leveraging tools developed for the Earthscope/USArray Array Network Facility.