Controlled-Source Study of the Las Vegas Basin: Assessing Seismic Hazards in Southern Nevada

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Introduction

The Las Vegas Valley is located in the southern Basin and Range, which has undergone a significant amount of extension that continues today. This extension has resulted in a series of normal faults as well as strike-slip faults that cut across the region. In the Las Vegas Valley, these faults have contributed greatly to the original geometry of the basin. The cities of Las Vegas, North Las Vegas, and Henderson sit atop this fault-bounded basin, which has been shown to have varying amplification factors (e.g., Su et al., 1998). Recent paleoseismic studies have illuminated that several normal faults in the Las Vegas region have Quaternary offsets and have the potential to produce an earthquake of M6.5 to 7.0 (Figure 1) (Slemmons et al., 2001). A gravity inversion, which combined gravity, seismic reflection, and aeromagnetic data indicate there are a series of sub-basins that exist beneath the unconsolidated basin fill, with the deepest sub-basin occurring 5 km west of the fault block bounding the eastern edge of the basin and the basin depth ranging from 2 km in the west-northwest to 5 km in the east-northeast (Figure 1) (Langenheim et al., 2001). As a result, new studies have taken place to characterize the Las Vegas Valley for seismic hazards. The primary questions we have set out to answer are: 1).What is the geometry and velocity structure of the Las Vegas basin? 2). Can we identify existing faults and address their significance for seismic risk? 3). Can we identify of any sub-basins within the larger basin, thereby testing the model produced from the gravity inversion?

Experiment

The first year of this project involved acquiring new seismic refraction data across the Las Vegas Valley. With additional funds secured from Lawrence Livermore National Laboratory (LLNL) and the Applied Research Program at UNLV we were able to add two more profiles a few more shots than was previously proposed in the original U. S. Geological Survey NEHRP Grant. We spent the first 6 months of the project locating shot points and acquiring permits for those locations. Starting May 2003, a team of undergrads and graduate students started surveying the 825 stations locations across the Las Vegas basin at 100 m station spacing. This took about 8 weeks to complete the surveying using a Trimble GPS system. The two weeks prior to the initiation of the experiment involved the purchasing of supplies for the 20 crews that would be sent out to deploy the instruments. Drilling and loading of the explosives took place the week prior to the initiation of the seismic experiment. In August 2003, UNLV with the assistance of the University of Texas at El Paso, Stanford University, University of Nevada Reno and St. John's University acquired seismic refraction data and broadband data across the Las Vegas basin. The SILVVER '03 (Seismic Investigations of the Las Vegas Valley: Evaluating Risk) project was designed to acquire 3-D seismic data across the basin (Figure 2). The experiment consisted of three seismic refraction profiles, two at 55 km in length and one 7 km in length. One profile extended from the northeast, across the Las Vegas Valley Shear Zone and the transition from the deep to shallow portions of the basin to the southwest. The second profile extended from the southeast from Frenchman Mountain to the northwest towards the Nevada Test Site along a corridor that is thought to focus energy into the Las Vegas Valley. The third profile trended east-west in between the other two profiles together. Station spacing along the profiles was nominally 100 to 200 m using both vertical component "Texans" and 3-component RT130's. The RT130's were set for continuous recording while they were deployed. Shot point spacing was on the order of 10 km and 8 shots that were successfully recorded ranging in size from 50 to 1000 lb. The broadband stations were installed with the help of LLNL and were an unexpected addition to our original project.

Data Analysis

The data from the various instruments were merged at UNLV into shot gathers for the 9 shots. Overall the data quality was high with several shots recorded the full length of the array (Figure 3). There is a noticeable traveltime delay of about 1 sec that can be correlated to the basin thickness estimates of about 3 km along this profile. This provided a first order approximation of basin depth that was used in developing the initial velocity model. To produce a velocity model for these data, over 4000 first arrivals were picked from the data for input into a 3D travel time tomography code (Hole, 1992). This algorithm calculates travel times through a starting model using the finite difference solution to the eikonal equation of Vidale (1988; 1990) and then uses the difference between calculated and observed travel times to invert for changes to the velocity model. The velocity model is then updated and is smoothed between iterations thereby regularizing the inversion. The whole process is repeated until the root mean square (RMS) error of the residual travel time is minimized. The initial velocity model was calculated from a 1-D average of velocity versus depth into a 3D grid. The velocity and ray coverage slices are produced from the 3D volume masking out zero or very low ray coverage. Our current velocity model was derived using a 50 x 50 x 10 km model space, and a 200 m grid interval. Ray coverage is good throughout the model to depths of 10 km. The final RMS error travel time residual is ~ 0.20 sec and reflects a good fit of the observed data to the calculated travel times through the model. Further perturbations are necessary to the starting model and smoothing factors to reduce the RMS error to within the picking error of about 0.10 sec.

Interpretation

From inversion, we have been able to identify faults in the sub-surface for the first time (Figure 4). We also have a more detailed image of the basin and its depth, which is consistent with the Langenheim et al (2001) model. In addition, we have for the first time velocity data of the basin fill that has been and will be integrated into various other models for the region. Our group has confirmed the basin thickness, the type sediments, and geologic structures that may control amplification of the basin with strong ground motion. These new data indicate that the northeast portion of the Las Vegas Valley is at highest risk of amplification of strong ground motion.

Future Work

Additional testing of the model and reduction of the RMS error is necessary for the model to be finalized. This will take place over the next several months. These data will be modeled jointly with previous refraction data sets to produce a more refined model. In addition, these newly acquired datasets will be integrated into a 3D community model that is being developed by the working group that will identify areas in the Valley where there could be an increase of amplification due to strong ground motion.

References

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Non-Technical Summary

The SILVVER seismic experiment was designed to image the Las Vegas basin in 3-D. The data recently acquired in August 2003, show that these goal should be met. We deployed 792 seismic recorders across the Las Vegas basin and set off 9 chemical blasts. Overall the data quality is high given that the deployment took place in an urban area where noise is tremendous 24/7. We have imaged the faults in the sub-surface and determined the geometry of the Las Vegas basin.

Reports published

Progress Report submitted to the U. S. Geological Survey NEHRP Program

Data Availability

The SEGY data will be available at the IRIS DMC and will be held for 2 years before being released to the public.

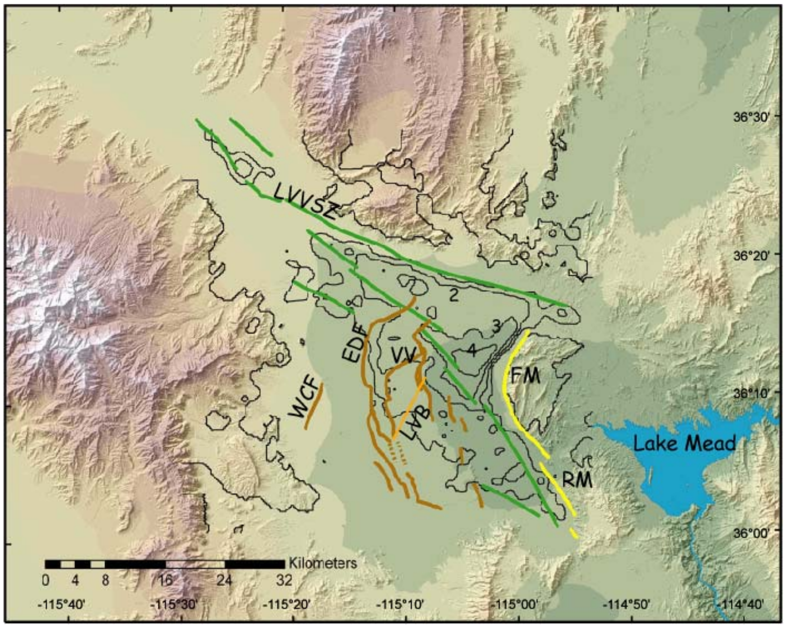

Figure 1. Las Vegas basin fault map. Green lines are strike slip faults that are considered inactive. Brow lines are normal faults with Quaternary motion in the east dipping direction; these are the faults of concern in the basin. Yellow lines are normal and strike-slip faults with Quaternary motion in the west dipping direction. Black contour lines represent current basin thickness estimates in km from Langenheim et al. (2001). Las Vegas Blvd (LVB) is shown by the orange line. LVVSZ - Las Vegas Valley Shear Zone; EDF - Eglington-Decater Fault; VV - Valley View fault; FM - Frenchman Mountain Fault; River Mountains Fault; WCF - West Charleston Fault.

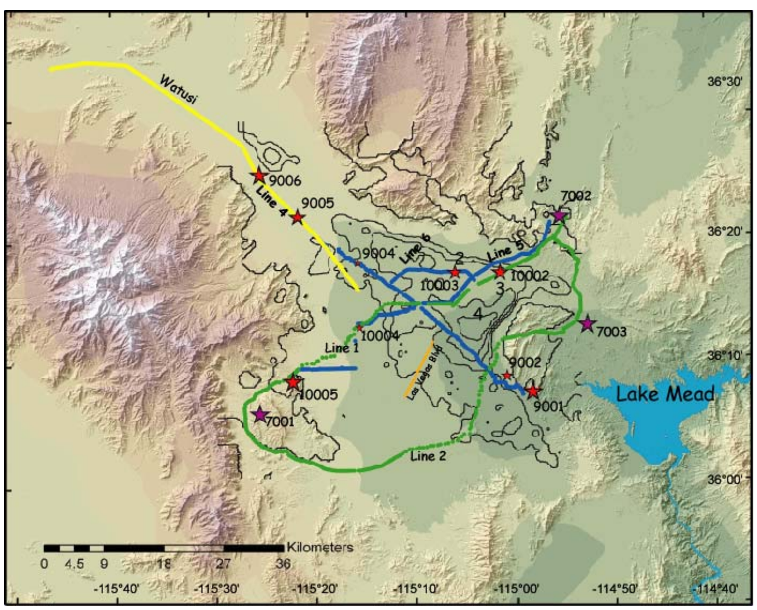

Figure 2. Las Vegas basin map. Green dots and Purple stars are the stations and shots for the Quarry Blast experiment. Yellow dots are the stations for the Watusi experiment. Blue dots and red stars are the station and shots for the SILVVER experiment. Black contour lines represent current basin thickness estimates from Langenheim et al. (2001). Las Vegas Blvd is shown by the orange line.

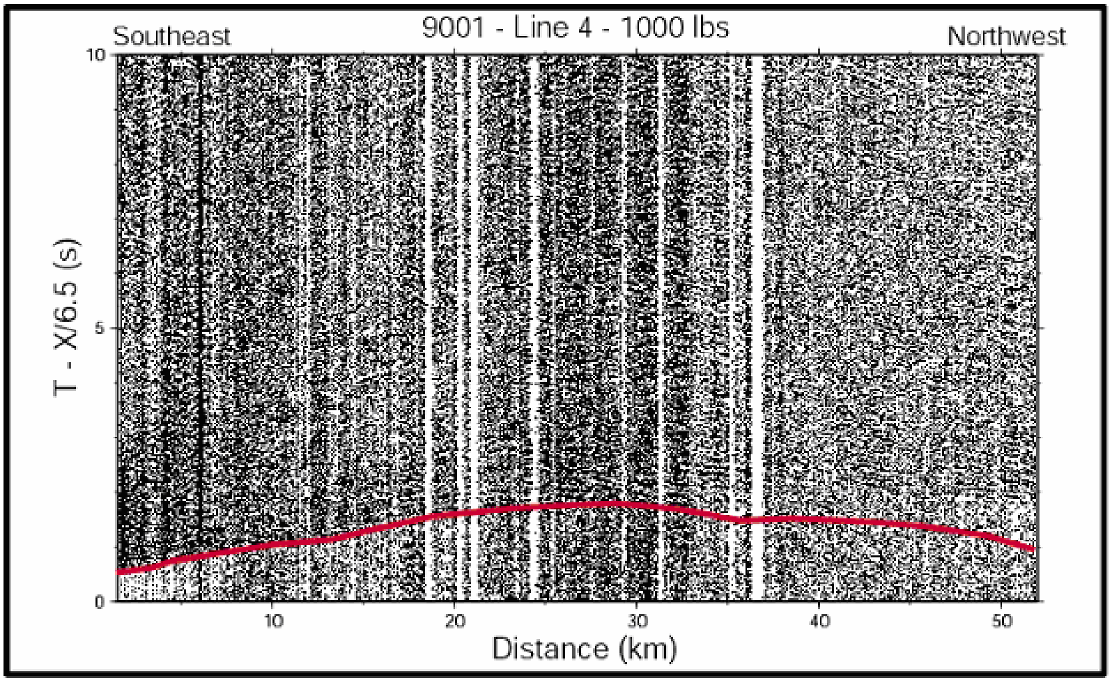

Figure 3. Record section of shot point 9001 along Line 4. This section is reduced at 6.5 km/s. Notice the 1 second traveltime delay (red line).

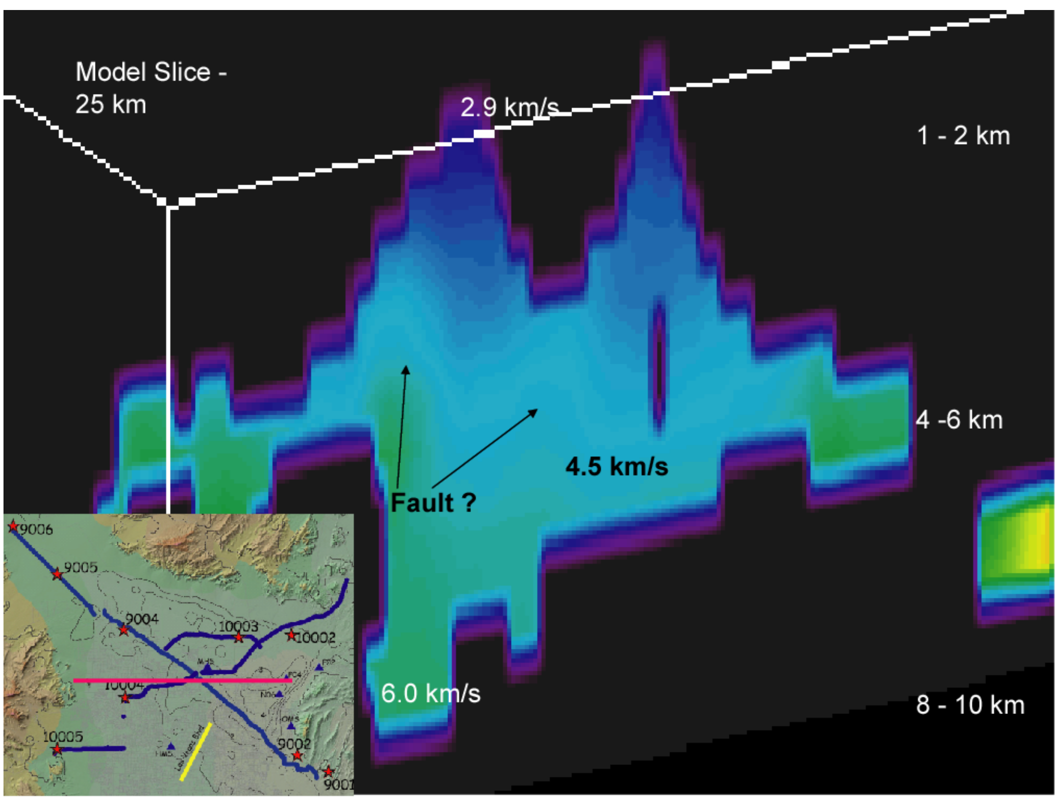

Figure 4. SILVVER velocity model slice. The dark blues are slow velocity where the greens and yellows are faster velocity materials. Note the presence of two faults within the model. These correspond to mapped faults on the surface. Inset is the location on the surface of the slice.