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Mogul Earthquake Swarm: What We Know so Far

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The Mogul, Nevada, earthquake sequence came to our attention on the afternoon of February 28, 2008 with felt earthquakes of magnitude 1.9, 2.2, and 1.6. The largest events of the sequence have been:

- March 8 2:07 AM  Magnitude 3.3
- March 15 8:38 AM  Magnitude 3.0
- March 24 12:16 PM  Magnitude 3.0

These earthquakes, and several smaller events, occurred at shallow depths beneath the Mogul and Somerset subdivisions of west Reno. Although small, they are interesting because they were felt, because they are unusually shallow, and because they have been continuing for 25 days as this is written.

This is a brief summary of the most obvious conclusions obtained to date in our studies of this sequence.

Instrumentation

One temporary deployment, station MOGL, has been operating since the evening of February 29. This station uses the technology developed by Ken Smith to deploy seismic stations at schools throughout Nevada. Besides watching the local station, the software allows the user to bring in seismic stations from a selection of regional and worldwide locations. It provides the capability to display the data in various forms, to export the data to other seismic networks, to pick times and locate earthquakes, and even to look at their Fourier spectra. It is economical and very easy to install.

Utilizing station MOGL, and as the swarm continued, we made special efforts to relocate the earthquakes. Because the earthquakes are within the urbanized area of west Reno, and because our locations were not controlled with as much accuracy as we thought warranted, we decided, during the third week of March, to deploy additional stations on March 24. The M3.0 earthquake that occurred as we were organizing for the deployment confirmed our conclusion that the added instruments would be valuable. Data from this additional deployment has not had an impact on the results in this report.
Table 1 lists the largest events in the Mogul sequence. There are 8 events with magnitude of 1.9 or larger.

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8 events of Mag => 1.9
Times are Coordinated Universal Time (UTC, roughly equivalent to Greenwich Mean Time). Subtract 8 hours for Pacific Standard Time (local time) through March 15, and 7 hours after that when local time switched to Pacific Daylight Savings Time. Locations and depths are subject to revision.

To look at event statistics, we examine the peak amplitudes of the sequence at station MOGL. Events were included in this list if the peak amplitude on at least one component was 1000 counts or higher. Figure 1 shows the cumulative number, with time, of events meeting this criterion. This shows that, since the monitoring began, on average the rate of events has not changed. The average rate is about 3.2 events/day for events meeting this threshold. Experience has shown that events are felt in Mogul when the amplitude there reaches about 5000 counts or greater. Fourteen events, about 1 every 2 days, meet this criterion.

Figure 2 shows the cumulative amplitude of events of this type. This also shows more or less steady behavior, but with different types of behavior – either quiescence or accumulating slip – before the large events.
Figure 1. The cumulative number of events, through 1400 UTC on March 26, that have caused the amplitude at station MOGL to exceed 1000 counts on at least one component.
Figure 2 shows the cumulative amplitude, through 1400 UTC on March 26, from station MOGL. Since most of the event, including all under M=2, show similar waveforms, it is reasonable to assume that the amplitude of these are similar to the cumulative moment. The three largest events, identified above, have more complex waveforms. However we leave the saturated value from MOGL in the plot as a placeholder, allowing more clear examination of the moment release in between events.

Locations

Figure 3 shows a map of the Mogul area with swarm event locations. The three largest events are identified. We consider it significant that the earthquakes occur on a northwest-southeast trend. Ileana Tibuleac and David von Seggern have confirmed this with high-precision relative locations.

We are less convinced that the absolute locations of these events are correct. Typical earthquake location errors might be 1-2 km, and with a sequence this well surrounded by seismographs, we should not do any worse than that. At this level, however, the quality of the location is governed by the quality of the velocity model. Any local systematic bias in the velocity model, compared to the actual velocities in the earth, might cause the entire pattern of epicenters to shift horizontally. We will not be surprised if final locations, when all of the data are analyzed, are shifted systematically to the east from the locations shown in Figure 3. Although this would be a small shift from the viewpoint of
Seismic network analysis, it could be large enough to give a different impression of the earthquake locations relative to the communities of Mogul and Somerset in west Reno.

Figure 3. Locations of earthquakes through March 24, 2008.
Focal Mechanisms

Figure 4 shows the focal mechanisms of the two largest earthquakes, as identified in the figure. These mechanisms consistently show strike-slip motion. The two alternatives are right-lateral strike-slip on a northwest-trending fault, or left-lateral strike-slip on a northeast-trending fault. Because the aftershocks are aligned along a northwest trend, we have high confidence that the causative fault is a right-lateral fault with a strike in the northwest direction.

Figure 4. Focal mechanisms of the largest events.

Causative Fault

One relevant reference for a causative fault is the US Geological Survey Quaternary Fault and Fold Database. This can be accessed from the web site http://earthquake.usgs.gov/qfaults/. Faults from this database can also be downloaded into files compatible with Google Earth. These files were downloaded and all faults in
the database were plotted for the west Reno area. Our conclusion is that none of the faults in this database can match the location and orientation of the earthquake distribution in the Mogul swarm.

On the other hand, Pat Cashman and Jim Trexler have been mapping the faults in bedrock in west Reno. Following the March 8 earthquake, they looked at new exposures in a housing development north of Mogul. The bedrock there, as well as other sites they have mapped in west Reno, is highly faulted. They confirm that a right-lateral strike-slip fault with a northwest orientation is consistent with the fault orientations in the area. With greater precision in the earthquake locations, it may be possible to associate the earthquakes with one of the faults that they have mapped.

**Miscellaneous Thoughts**

There are several interesting aspects of this earthquake swarm that may deserve comment.

First, the swarm is being located at unusually shallow depths. There are few earthquake swarms that are documented at such shallow locations. Therefore there is a fundamental science objective in seeking to understand the sequence.

Second, the swarm is providing a very well-located source that can be recorded throughout Reno or the rest of the region in order to investigate the velocity model.

Third, hundreds of microearthquakes have been recorded in this sequence although the actual number of widely felt ones is only a few. Seismic activity persists at low magnitudes continually even though most events are never felt. The recording of this low-magnitude activity provides important information on fault locations, probable recurrence times of larger earthquakes, and the geologic structure in the area of the activity.

Fourth, as a swarm in an urban area, the question has arisen frequently of whether this might mean that a larger earthquake is coming. The basic answer is that earthquakes cannot be predicted or forecast, and that Reno does have a significant seismic hazard existing uniformly throughout the community and at all times.

According to the seismicity model developed by the USGS for the 2002 National Seismic Hazard Maps, the annual probability of an earthquake with magnitude 5.0 or larger within 200 km of the site of these earthquakes in west Reno is between 7.5% and 9%. Considering the large radius of this circle, the annual probability within 20 km of this site is much smaller, perhaps in the range of 0.075% to 0.09% just based on the difference in area. The ongoing activity could be interpreted to mean that there is some increased probability at this time. The magnitude of the probability gain is unknown and we have no reliable way to estimate it. Therefore it is always wise to be prepared, and this swarm provides a good opportunity to remind all of the residents of the region of the importance of earthquake mitigation.