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Shallow Site Response and Fault-Reflection Recording During LARSE-2

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We were funded for the field costs of special types of seismic recording during the Oct. 1999 Los Angeles Region Seismic Experiment, Phase Two. We made three-component recordings of the LARSE-2 explosions, at the locations of precariously balanced rocks and at a long-term engineering A class rock site. We were also able to record many aftershocks of the Hector Mine earthquake. These data will allow us to evaluate whether anomalous site conditions permit such rocks to withstand events less than 20 km away on the San Andreas fault. We will also record shallow refraction and microtremor data around the precarious rocks (in Feb. 2000, with the remaining current funding), providing near-surface velocities for later analysis of the three-component records. Given the unexpected opportunity to record the aftershocks of the M7 Hector Mine earthquake, we concentrated on 3-component instrument installation and did not attempt fault-reflection recordings of LARSE blasts. We did not propose for the 1999 project year the costs of any LARSE data analysis, or site-response evaluation.

The LARSE-2 explosion line, conducted by the USGS and SCEC in October 1999, gave us the opportunity to evaluate ground-motion amplification conditions at the sites of precariously balanced rocks that have been found within 20 km of the San Andreas fault (Brune, 1999). There are numerous granite outcrops of the type that produce precarious rocks distributed at a range of distances perpendicular to the Mojave section of the fault near Palmdale. This section ruptured in the great 1857 earthquake, and in numerous other large earthquakes in the last several thousand years. Near the fault there are no precarious or semi-precarious rocks, and the outcrops demonstrate an appearance suggestive of intense shaking. As distance from the fault increases semi-precarious rocks (rough upper bounds on acceleration about 0.4-0.6 g) begin to appear at about 10 km, and precarious rocks (upper bounds about 0.2-0.4 g) at about 15 km. Thus, the toppling accelerations of these rocks can be used to constrain strong motion attenuation relationships for great San Andreas earthquakes, provided that there are no anomalous site conditions.

Our LARSE-2 blast records will give us the opportunity to study ground motion attenuation and any unusual site de-amplifications at the location of these semi-precarious and precarious rocks. We deployed matched, calibrated 3-component digital stations with 1 Hz L-4 seismometers at four buttes in the central Mojave (Alpine, Piute, Black, and Lovejoy) where precarious rocks are present within 20 km of the San Andreas. We simultaneously made 3-component recordings at Mill Creek Summit, where the USC strong-motion station MCS is listed to sit on class A hard rock, and had recorded strong motion from the Northridge earthquake. We also recorded at a rock site near Llano, south of the Buttes and a few kilometers from the San Andreas fault. All of these stations except Llano recorded during the first two nights of LARSE-2 blasting. The Lovejoy Butte and MCS sites will soon be recorded with a 24-channel array of vertical instruments as well. Figures 1 and 2 show examples of a LARSE-2 blast and a Hector Mine aftershock recorded at the MCS and Butte sites. For all events examined so far, horizontal particle velocities were larger at Mill Creek Summit than at any of our other sites.

A refraction line run by Gary Fuis provides P-wave velocity estimates over thin alluvium near but not across Lovejoy Buttes. Velocities of the fractured granite below the alluvium may vary by a factor of two, so additional constraints on shallow velocities at the precarious rock sites are needed. In February 2000 we will cross the MCS and Lovejoy Butte sites with 350 m refraction arrays. Each will be recorded with reversed sledgehammer sources.

The same 24-channel instrumentation has been used to passively record microtremor noise in conjunction with broadband arrays by Iwata et al. (1998). P-tau analysis of 4-6 Hz surface waves propagating across these different types of arrays gives similar results for S-wave velocity structure within 100 m of the surface. We will record microtremor data on the 24-channel arrays, as we already have on the 3-component stations, for later independent confirmation of any velocity anomalies that could be defocusing strong motions at the precarious rock sites. Field examination of the ‘‘rock’’ at MCS and the Buttes leads us to believe that the class A rock at MCS will prove to have lower shallow S-wave velocity than the much harder rock at the precarious rocks. Figures 3 and 4 show examples of spectra from the MCS standard rock site, and from the lower-amplitude Buttes sites. For these examples Mill Creek Summit shows significant amplification over any of the precarious-rock sites, especially between 1 and 6 Hz.

Complete data are referenced from the web page: http://www.seismo.unr.edu/ftp/pub/louie/larse/ . Copies of the data on 3 CD-ROMs, in PASSCAL SEG-Y format, can be provided on request.

References

- Brune, James N., 1999, Precarious rocks along the Mojave segment of the San Andreas fault, California: Constraints on ground motion for great earthquakes: *Seismological Research Letters, vol. 70,* no. 1 (Jan./Feb.), p. 29-33.
- Iwata, T., H. Kawase, T. Satoh, Y. Kakehi, K. Irikura, J. Louie, R. Abbott, and J. Anderson, 1998, Array microtremor measurements at Reno, Nevada, USA (abstract): presented at Amer. Geophys. Union Fall Meeting, Dec. 6-10, San Francisco.

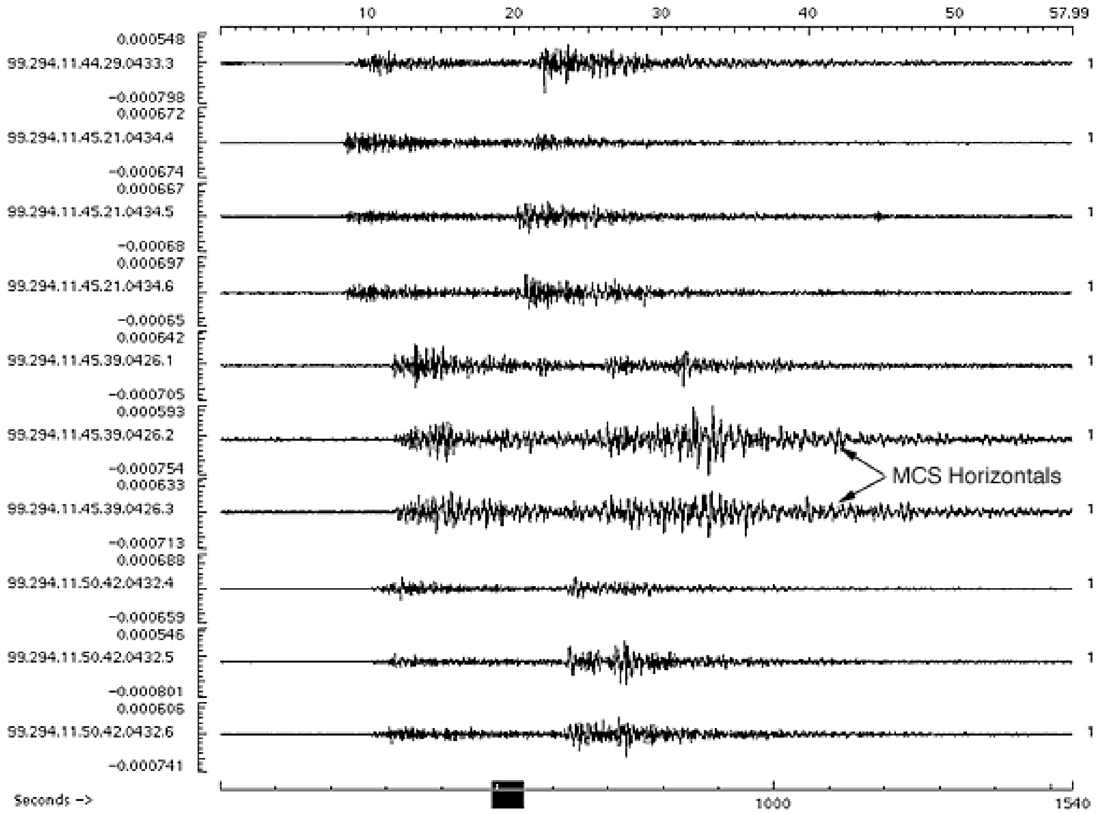

Figure 1. LARSE-2 blast observed on 3-component L-4 seismographs at Mill Creek Summit (location of MCS class A rock strong-motion station), 5th through 7th traces down, and at precarious-rock locations in the central Mojave, 1st through 4th and bottom 3 traces. Trace amplitudes are plotted at constant scale. Note the MCS horizontals (6th and 7th traces down) have the largest amplitude.

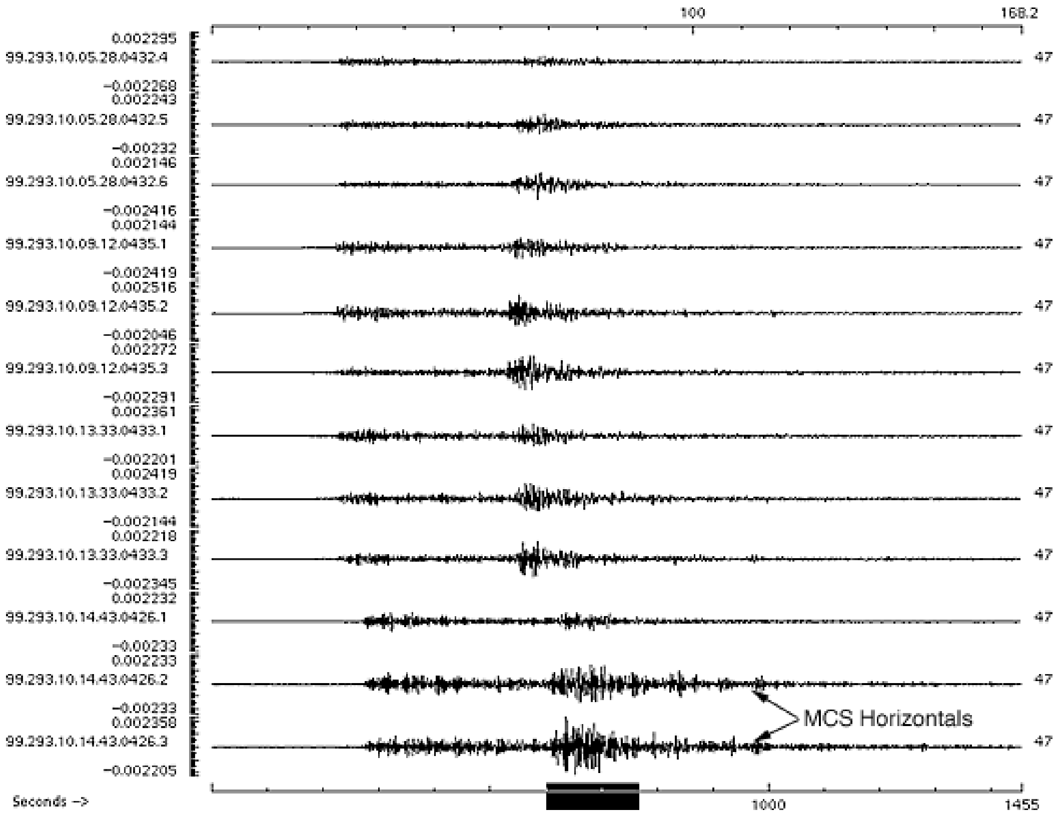

Figure 2. Hector Mine aftershock observed on 3-component L-4 seismographs at Mill Creek Summit (location of MCS class A rock strong-motion station), bottom 3 traces, and at precarious-rock locations in the central Mojave, 1st through 9th traces down. Trace amplitudes are plotted at constant scale. Note the MCS horizontals (bottom 2 traces) have the largest amplitude.

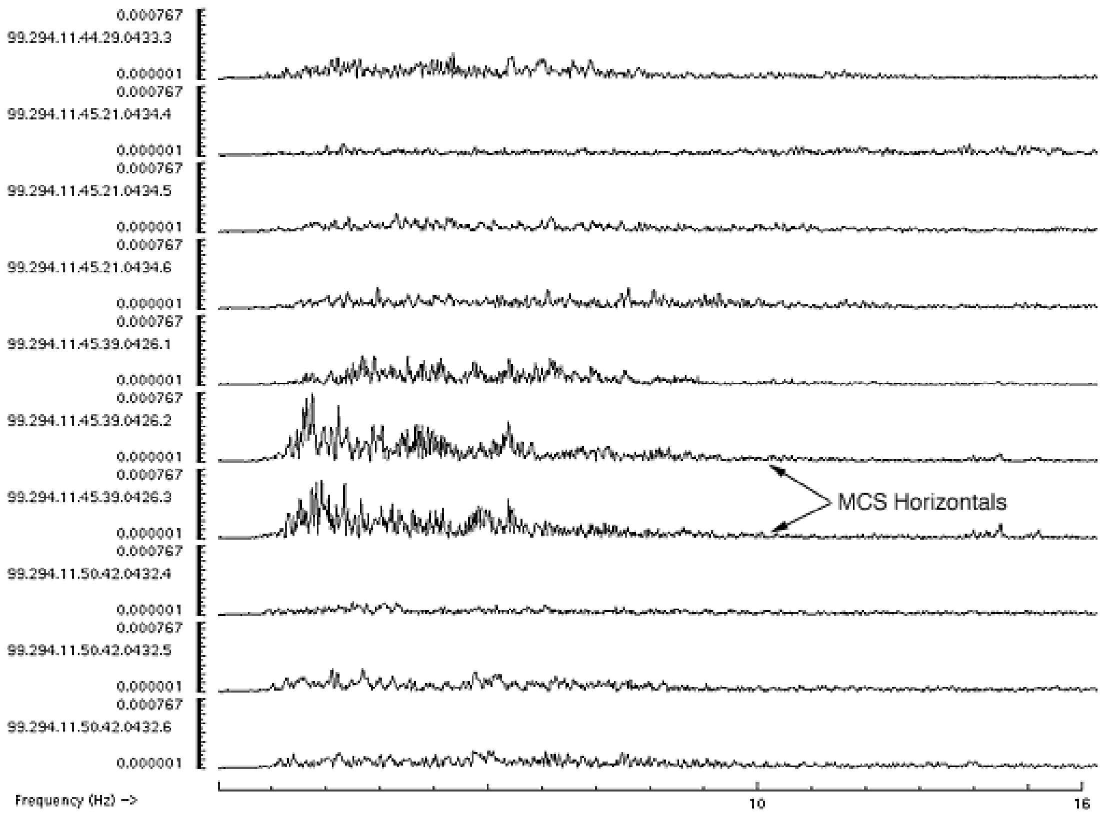

Figure 3. Amplitude spectra of observations of the LARSE-2 blast of Figure 1, in the same trace order. Spectra are plotted at constant scale. The spectra of the MCS horizontals (6th and 7th traces down) have significantly higher amplitudes between 1 and 6 Hz than the spectra of observations at precarious-rock sites.

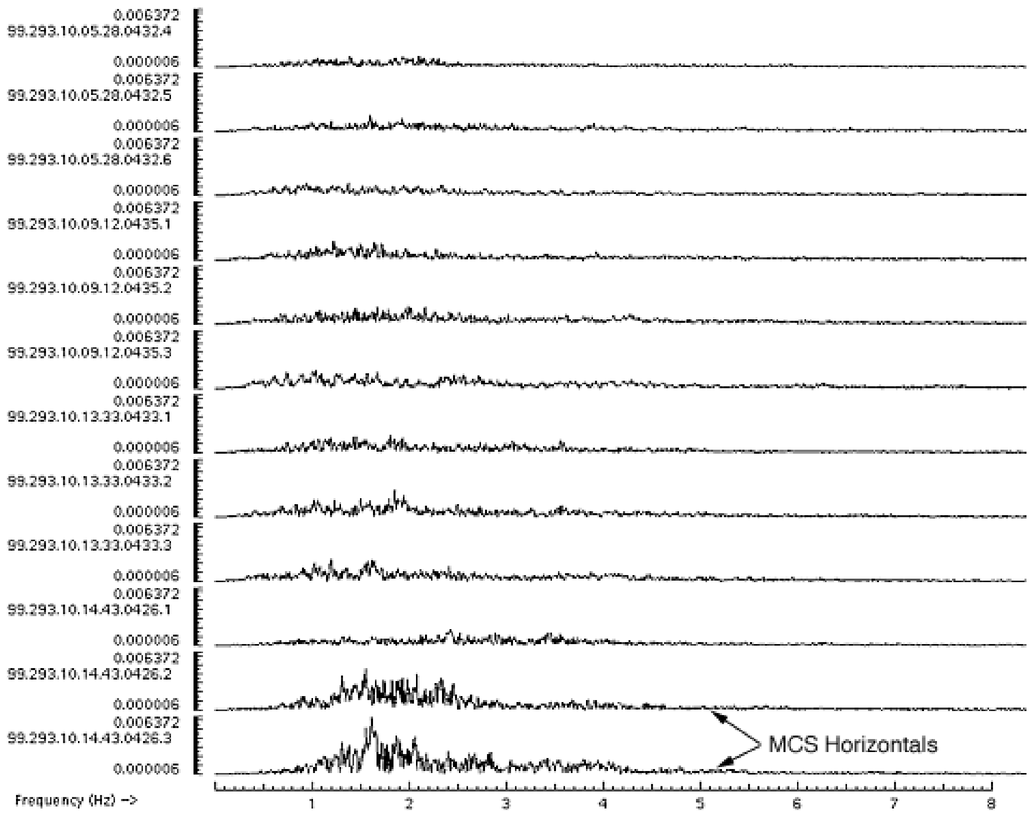

Figure 4. Amplitude spectra of observations of the Hector Mine aftershock of Figure 2, in the same trace order. Spectra are plotted at constant scale. The spectra of the MCS horizontals (bottom 2 traces) have significantly higher amplitudes between 1 and 3 Hz than the spectra of observations at precarious-rock sites.