*Stanford Exploration Project, Report 108, April 29, 2001, pages 1–**??***

Short Note

Preliminary results from a small-scale 3-D passive seismic study in Long Beach, CA

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INTRODUCTION

While helioseismologists routinely crosscorrelate stochastic acoustic noise to produce time-distance curves (Duvall et al., 1993) that look like active-source seismograms, terrestrial geophysicists have had less success. Baskir and Weller (1975) describe the first published attempt to use passive seismic energy to image subsurface reflectivity. They briefly describe crosscorrelating long seismic records to produce correlograms that could be processed, stacked and displayed as conventional seismic data. Unfortunately their field tests seem to have been inconclusive. Cole (1995) crosscorrelated data collected using a 4000 channel 2-D field array on Stanford campus. Unfortunately again, possibly due to the short (20 minute) records or bad coupling between the geophones and the dry California soil, his results were also disappointing.

In this paper we present results from a small environmental-scale passive 3-D survey, recorded in Long Beach, California. In total, about four hours of 60-channel passive data were recorded and processed. Although no clear reflection events are visible, a coherent dispersive ground-roll event is visible, and the correlograms do resemble active source seismograms.

EXPERIMENTAL SETUP

The array consisted of 60 40-Hz single-component geophones arranged in a 6-by-10 grid 25 m wide and 45 m long. Figure 1 shows the array's orientation relative to a U.S. Geological Survey high-resolution shotgun-source survey that was performed 2 days prior to this exercise. The array was shifted 1 m northwest of the USGS line to avoid placing geophones on the asphalt road. Figure 1 also shows the location of a deep well that was being drilled at a depth of nearly 150 m during data acquistion.

A manually triggered Geometrics RX-60 seismograph recorded 60 channels at a sample interval of 4 ms; no filters were used. Over two days, this passive experiment produced approximately 170 minutes of 10-second long records and 20 60-second long records. During each of

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the 60-second records, the first author performed a “two footed” stomp at one the geophones along the northeastern and southwestern edges of the array. The array also recorded energy from the intermittant operation of the nearby drill-bit, drill-truck engine, and the gasoline-powered water pump. Figure 2 shows five seconds of recorded data after notch-filtering.

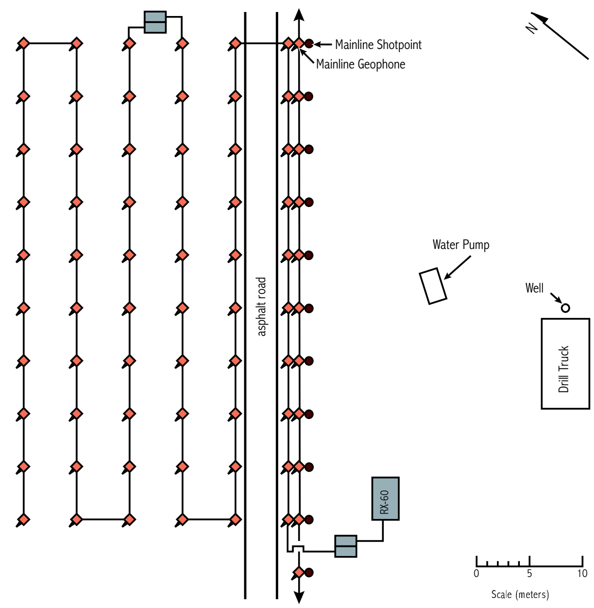

Figure 1: Long Beach passive array. “Mainline Shotpoints and Geophones” denote the source and receiver locations for the USGS high-res survey (see text). Approximate locations of the well, drill-truck, and water pump are also shown. bckerr-arraytest [NR]

PROCESSING FLOW

We processed the raw data records with the following steps:

1. Notch-filtering to remove spectral spikes (e.g. 60 Hz noise).
2. Sort into (x, y, t) cube.
3. Zero pad x and y-axes.
4. 3-D autocorrelation or spectral factorization (Rickett and Claerbout, 2000).
5. Stack over record axis.
6. Stack over radius (distance from zero spatial lag).
7. Low-pass filter to 30 Hz.
8. Offset dependent gain correction $[d'(h_i) = h_i\, d(h_i)]$ for display purposes.

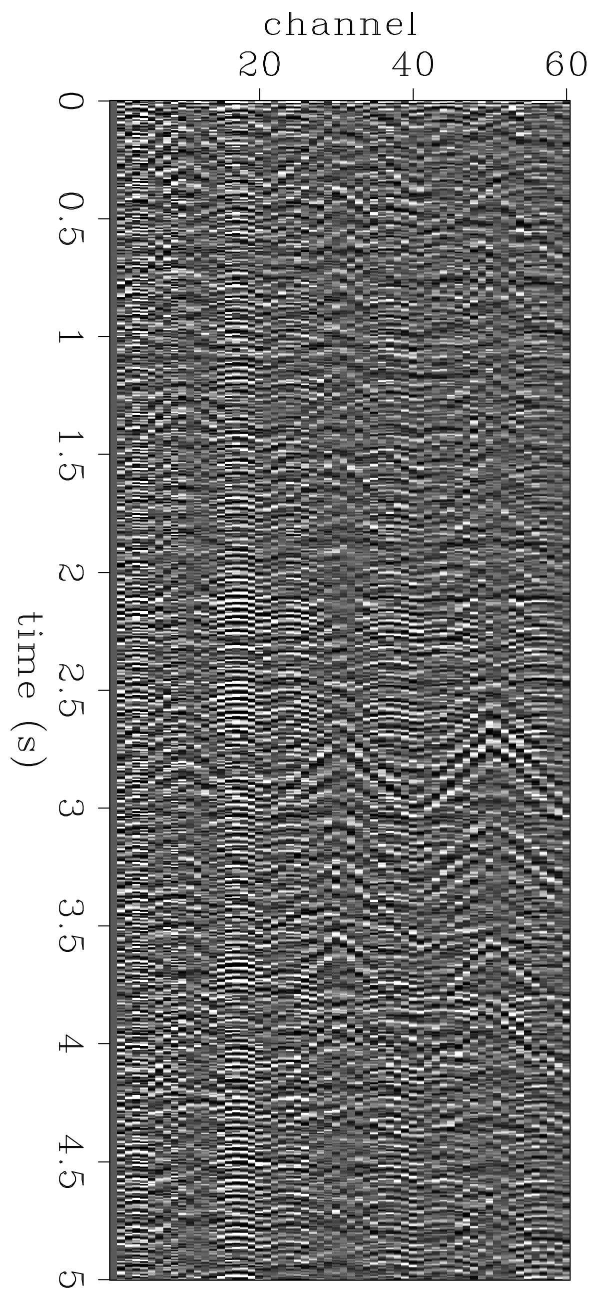

Figure 2: Five seconds of passive seismic data after notch-filtering. bckerr-strip [CR]

RESULTS

Figure 3 shows the impulses reponses derived by autocorrelation and spectral factorization. The ground-roll cone is clearly visible with a velocity of about 150 m/s. Events that may possibly be reflections are visible, however results are definitely not conclusive.

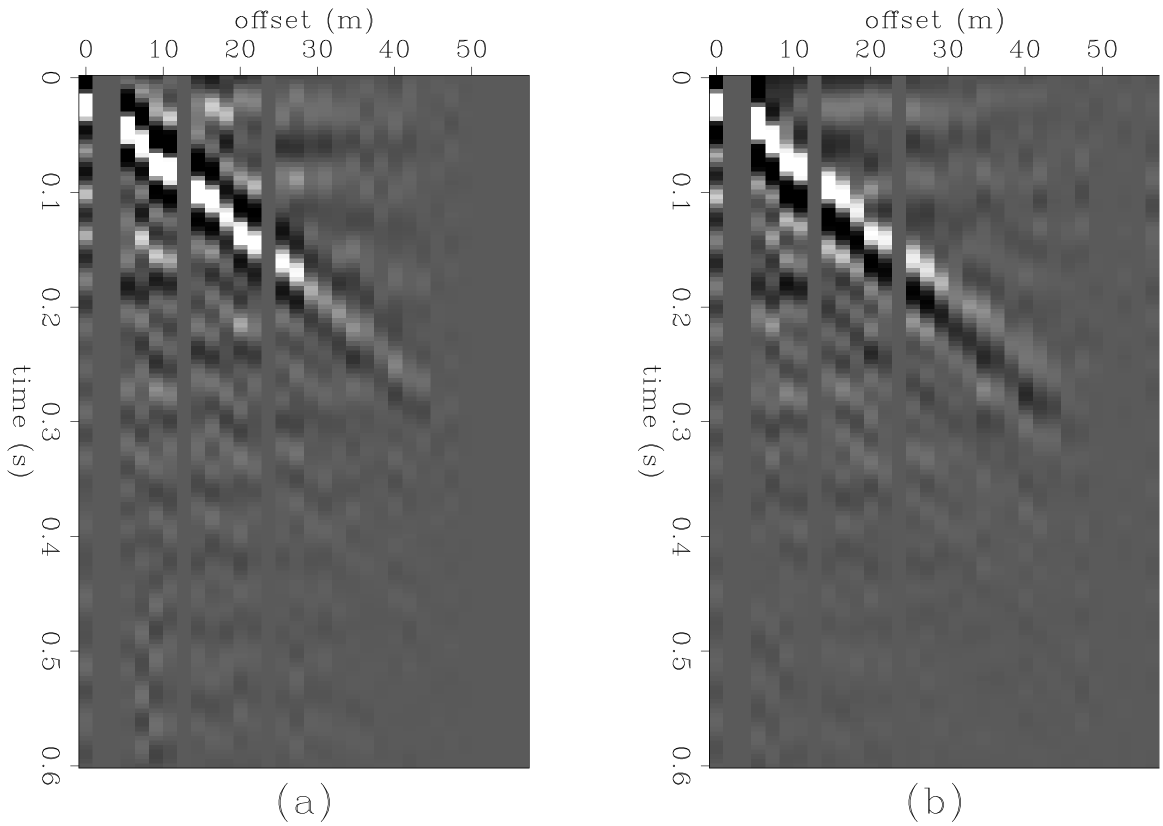

Figure 3: Impulse response calculated by (a) 3-D autocorrelation, and (b) spectral factorization. Compare with Rickett and Claerbout (2000), Figure 3. bckerr-longimp [CR,M]

Remaining processing problems include how to adaptively remove monochromatic frequency spikes from the raw data, as noise sources drift in and out over time. Ground-roll removal is also a problem since with the 5 m geophone spacing, the 150 m/s velocities are spatially aliased at all frequencies above 15 Hz. The other option of imaging reflectors outside the ground-roll window is restricted by the maximum-offsets of the experiment to events less than 200 ms two-way traveltime.

CONCLUSIONS

The clearly visible ground-roll event in the impulse responses is promising for future attempts at passively imaging subsurface reflectors. Further processing of this data set might be able to bring reflections out above the noise. It should be noted that this was a spontaneous experiment. Time was not available to properly design the array such that ground-roll attenuation was maximized.

ACKNOWLEGEMENTS

We thank Rufus D. Catchings and the U.S. Geological Survey for lending us the geophones, CDP cable, and Geometrics seismograph allowing us to conduct this experiment.

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