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Short Note

Imaging the very near surface with a high-resolution 3-D seismic survey

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keywords: *high-resolution, environmental, acquisition*

INTRODUCTION

We designed and completed a very high-resolution 3-D seismic survey at Moss Landings, California. The survey was part of an ongoing series of experiments being conducted by one of the authors (Ran Bachrach of the Stanford Rock Physics and Borehole group, SRB) exploring the resolution limits of shallow/environmental reflection seismology particularly with regards to detection and monitoring of viscous fluid contaminants. This project is also part of an on-going collaboration between SRB and SEP.

Figure 1 shows a 2-D shot gather in the study area. The hyperbolic water-table reflector is clearly visible at 20 ms traveltime. Unfortunately the very shallow reflectors in the sand above the water-table only appear on the near offset traces, as they are masked by the direct arrival and the water-table refraction at larger offsets.

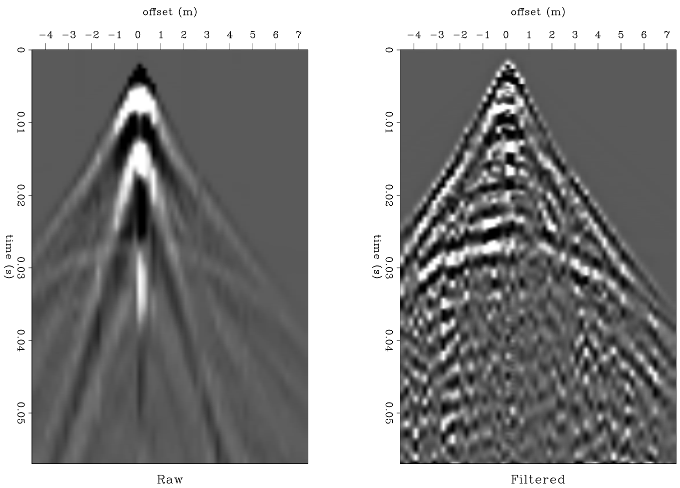

Figure 1: 2-D shot gather in the study area. james4-conventional [NR]

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The water-table itself is only 2-3 m below the surface, so shallower reflections are not visible on offsets greater than about 3 m. The desire to record useful information on all sixty of the available channels, and physical limitations due to the size of the geophones forced us into a 3-D geometry. Moving to 3-D also gives us the potential to image structures that are not usually visible with conventional 2-D geometries.

As an aside, the full 3-D dataset is less than 220 Mb in size, and so provides an excellent test bed for SEP's in-house processing system, SEPlib3D.

GEOMETRY

We set out our 60 geophones in a 8×8 array with 4 empty locations. Geophone spacing was 20 cm in both X and Y directions. We then recorded shots at 23 locations spaced 40 cm apart, keeping the receiver geometry fixed. Shots consisted of 7 pings with a small hand-held hammer on a metal plate. Figure 2 shows a photograph of the study area, and the receiver array. Source and receiver geometry is shown in the left panel of Figure 3.

Figure 2: Photograph of study area and very high-resolution 3-D receiver array. james4-monterey [NR]

This acquisition geometry led to a CMP spacing of 10 cm, as shown on the right panel in Figure 3. The fold map (Figure 4) is somewhat irregular as may be expected given the low number of shots; however, the fold ranges from about 6 to 13 in the main diagonal swath, which is 0.8 m wide and 1.2 m long.

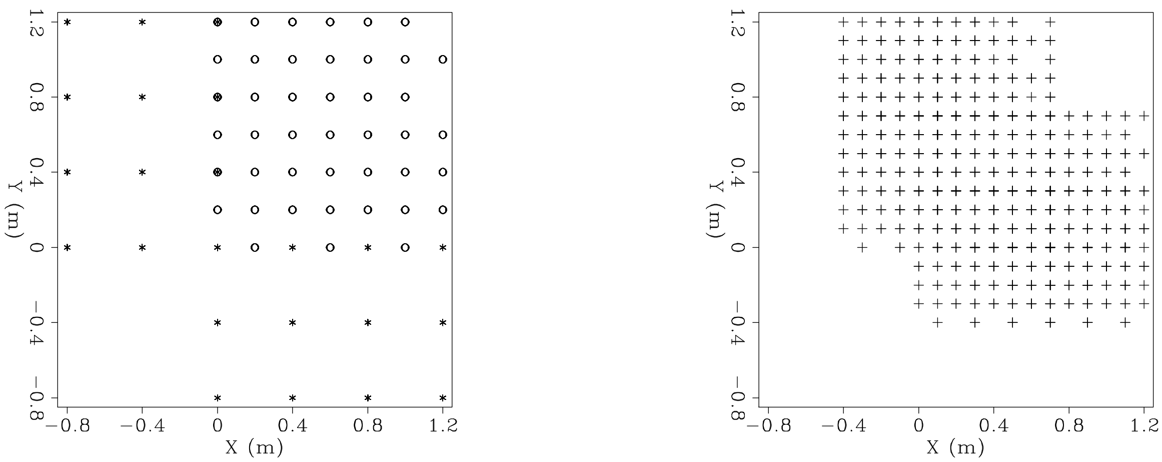

Figure 3: The left panel shows shot (*) and receivers (∘) locations. The right panel shows CMP locations. james4-geometry [CR]

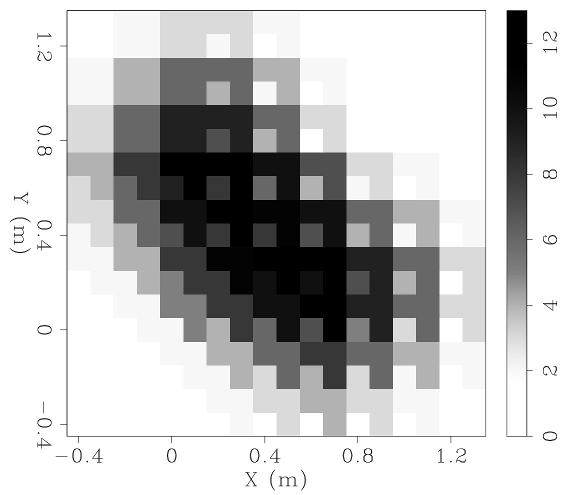

Figure 4: Fold chart with 0.1 cm bins. james4-fold [CR]

DATA PROCESSING

Figure 5 shows a super-gather, consisting of all the traces in the survey binned as a function of offset. The left panel shows the raw data, and the center panel shows the same data after pre-processing.

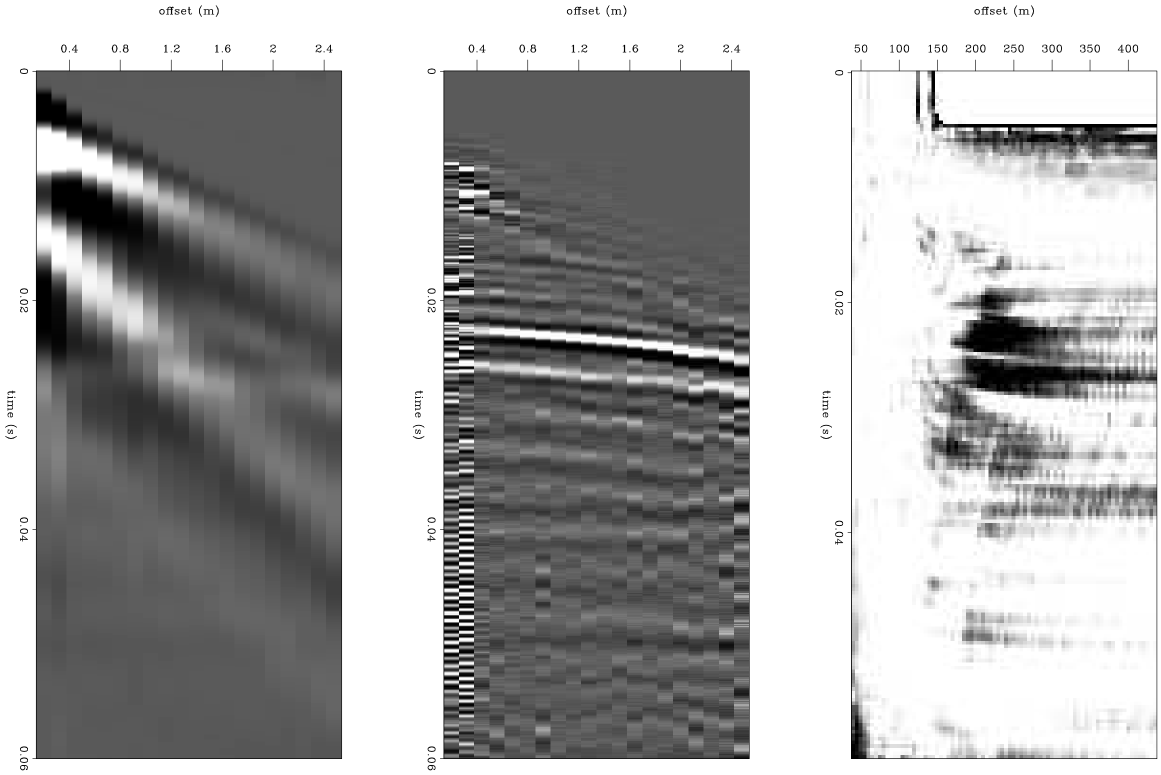

Figure 5: Super-gather: entire dataset stacked into offset bins. Left panel shows raw data, center panel show processed data after pre-processing, and right panel shows semblance scan $\boxed{\text{james4-sgather}}$ [CR]

We processed the data with our in-house software, SEPlib3D, which provides a flexible environment for research in 3-D seismology. The simple processing flow consisted of:

1. Trace edits
2. Groundroll removal: A low-cut filter was sufficient to remove the groundroll. See Figure 6 for its impulse response and spectrum.
3. Top mute to remove the refracted arrivals.
4. Time-varying gain correction: `tpow=2`.
5. NMO and stack: The right panel of Figure 5 shows a semblance scan from the super-gather. The velocity information provided by the 3-D dataset was limited

by the small maximum offset. However, the small maximum offset also means the dataset is not very sensitive to move-out velocity. In any case, NMO was applied with a constant velocity of 240 m/s, the RMS velocity of the water-table reflector, which had been more accurately estimated from the larger offset 2-D surveys.

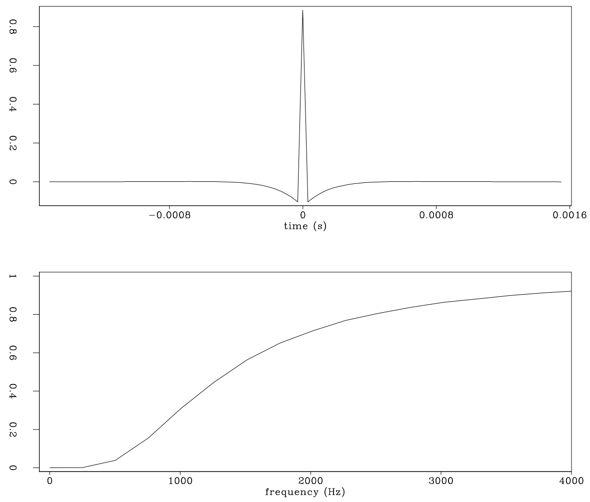

Figure 6: Impulse response of low-cut filter. james4-impulse [ER]

RESULTS AND CONCLUSIONS

Analysis of the super-gather shown in Figure 5, suggests the higher effective fold at near offsets (compared to 2-D experiments) leads to improved vertical resolution in the very near surface. Hyperbolic reflection events are clearly visible above the water-table reflector. Additionally, the frequency content of the data is sufficiently high to see that what appeared to be the water-table reflector at lower frequencies is in fact two distinct events of positive polarity separated by about 4 ms ($\approx$ 50 cm).

Unfortunately, the low signal-to-noise ratio makes it difficult to resolve 3-D structure on the water-table or the weaker reflectors both above and below it. Figure 7 shows the stacked 3-D data, stacked again in the X and Y directions. There does indeed appear to be a small amount of structure in the X direction (perpendicular to the shoreline). This is also apparent on the timeslice shown in Figure 8. It is unlikely to be an artifact of the acquisition geometry or processing, since the feature is not symmetric in the $X = Y$ plane.

ACKNOWLEDGEMENTS

We would like to thank Ranie Lynds for her help acquiring the data.

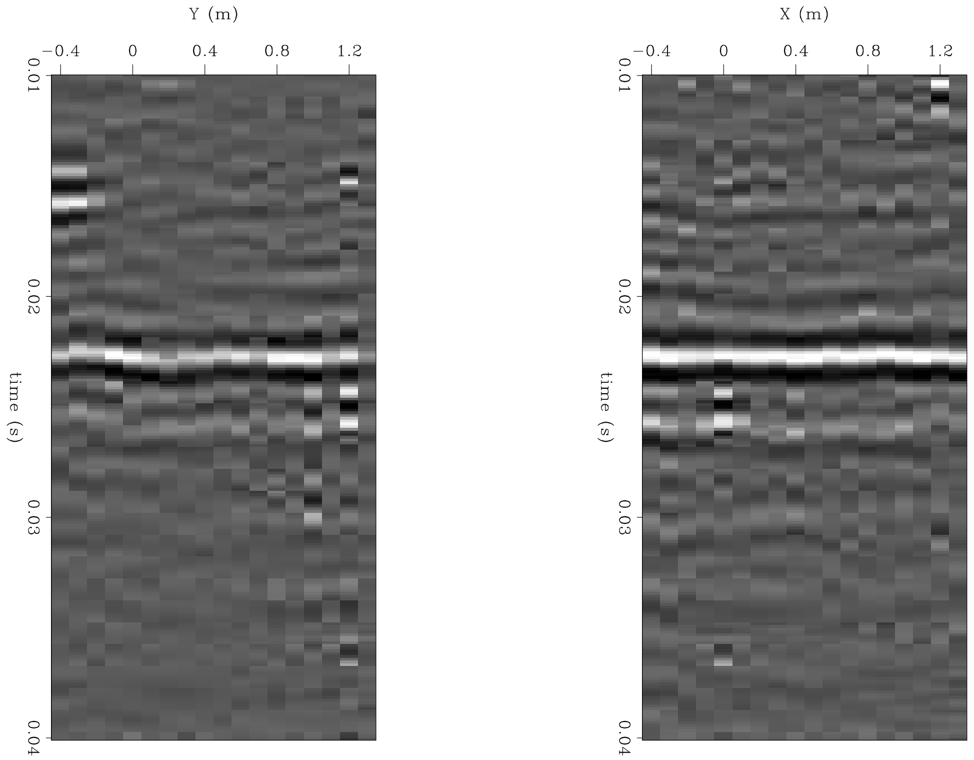

Figure 7: Stacked 3-D data-cube projected onto $X = 0$ (left panel) and $Y = 0$ (right panel) planes. james4-nmostack [CR]

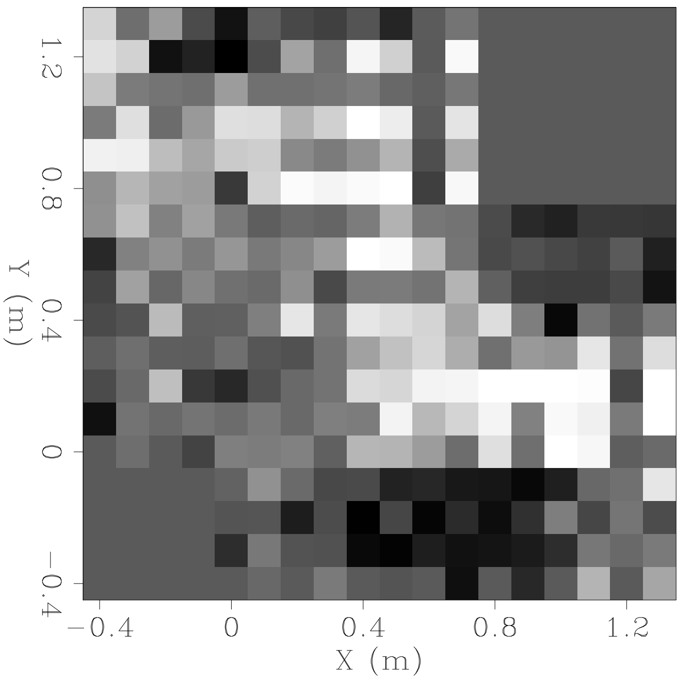

Figure 8: Time-slice though 3-D stacked cube at the water-table reflector (23 ms). james4-tslice [CR]