Stanford Exploration Project, Report 67, January 13, 1998, pages 1–30

Rotation and wavelet estimation using crosshole data

Steve Cole & Martin Karrenbach[1]

keywords: *wavelet, deconvolution*

INTRODUCTION

A first task in processing our three-component crosshole dataset is to separate P and S wavetypes. Given the arrival direction of incident energy, one can rotate and combine the three components to produce P, SV, and SH wave sections.

We developed an automatic scheme to perform this separation. A window of data is rotated over all possible arrival directions and the direction that maximizes the power of a given wave type is chosen. The entire trace is then rotated according to this direction to produce P, SV, and SH traces.

Traces can be NMO corrected and stacked to produce an estimate of the wavelet for a particular event, which can be used in deconvolution.

DATA ROTATION

Figure 1 shows a portion of a three-component crosshole record. The first event on each component, with its apex near 0.4 seconds, is a direct P-wave arrival. The event having a minimum traveltime of approximately 0.8 seconds is a converted SV arrival.

We would like to rotate these data to a coordinate system where the P and SV particle motion directions lie along two of the axes. Such a rotation separates the two events and could also reveal SH wave energy, having a particle motion perpendicular to both P and SV.

The transformation from X, Y, and Z components to P, SV, and SH wavetypes is described by the equation:

$$\begin{pmatrix} P \\ SH \\ SV \end{pmatrix} = \begin{pmatrix} \sin\theta\cos\phi & \sin\theta\sin\phi & \cos\theta \\ -\sin\phi & \cos\phi & 0 \\ -\cos\theta\cos\phi & -\cos\theta\sin\phi & \sin\theta \end{pmatrix} \cdot \begin{pmatrix} X \\ Y \\ Z \end{pmatrix}, \tag{1}$$

[1]**email:** not available

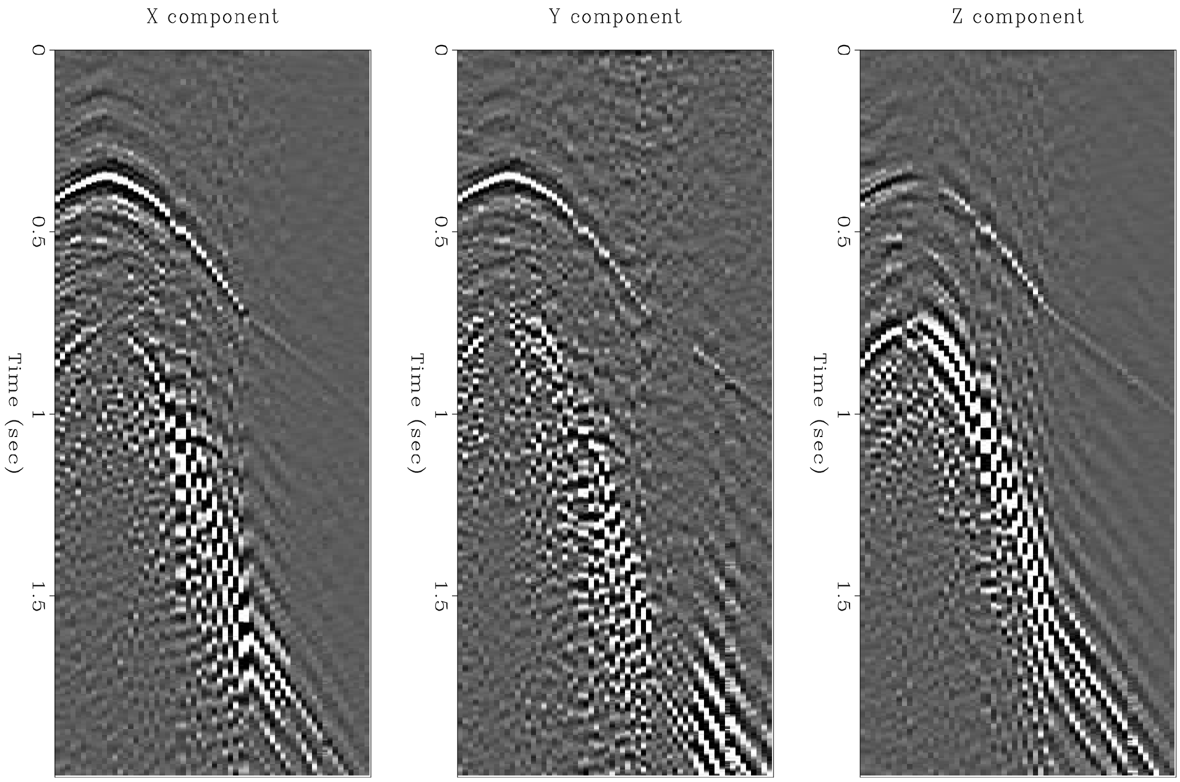

Figure 1: A portion of a three-component crosshole record. steve2-data [NR]

where θ and ϕ are two angles, the azimuth and the dip angle, that parameterize the raypath of a wave arriving at a receiver. For more details on the transformation, see Karrenbach and Cole (1989).

We need to know θ and ϕ for each receiver in order to perform the rotation. To compute them, we rotate a small window of data (centered around one of the events) using all possible combinations of the two angles. Then we select the combination of angles that maximizes the power of the appropriate wavetype after rotation.

Figure 2 shows the arrival direction picks for the P event. Since this is a crosshole experiment, we expect the source-receiver azimuth to be constant. It is generally consistent; the small variations could be due to raypath effects. We expect the dip angle to vary depending on the relative depths of the source and receiver. Without knowing more about the experiment geometry, we can't confirm that the observed dip angles are reasonable.

Figure 3 shows the data from Figure 1 after rotation using the picked arrival directions. We have done a pretty good job of separating the P and SV events. Unfortunately the SH section doesn't seem to show any SH events, only residual energy left after rotation.

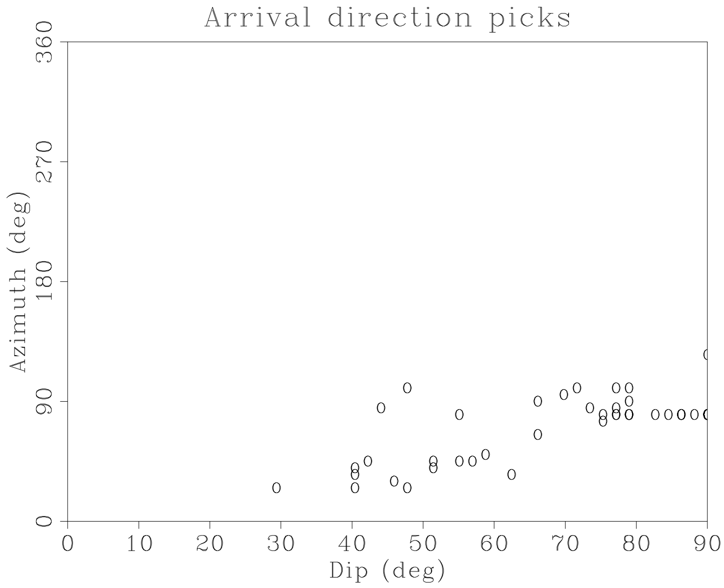

Figure 2: For each trace, the azimuth and dip angles that maximize the power of the P event after rotation have been picked. steve2-picks [NR]

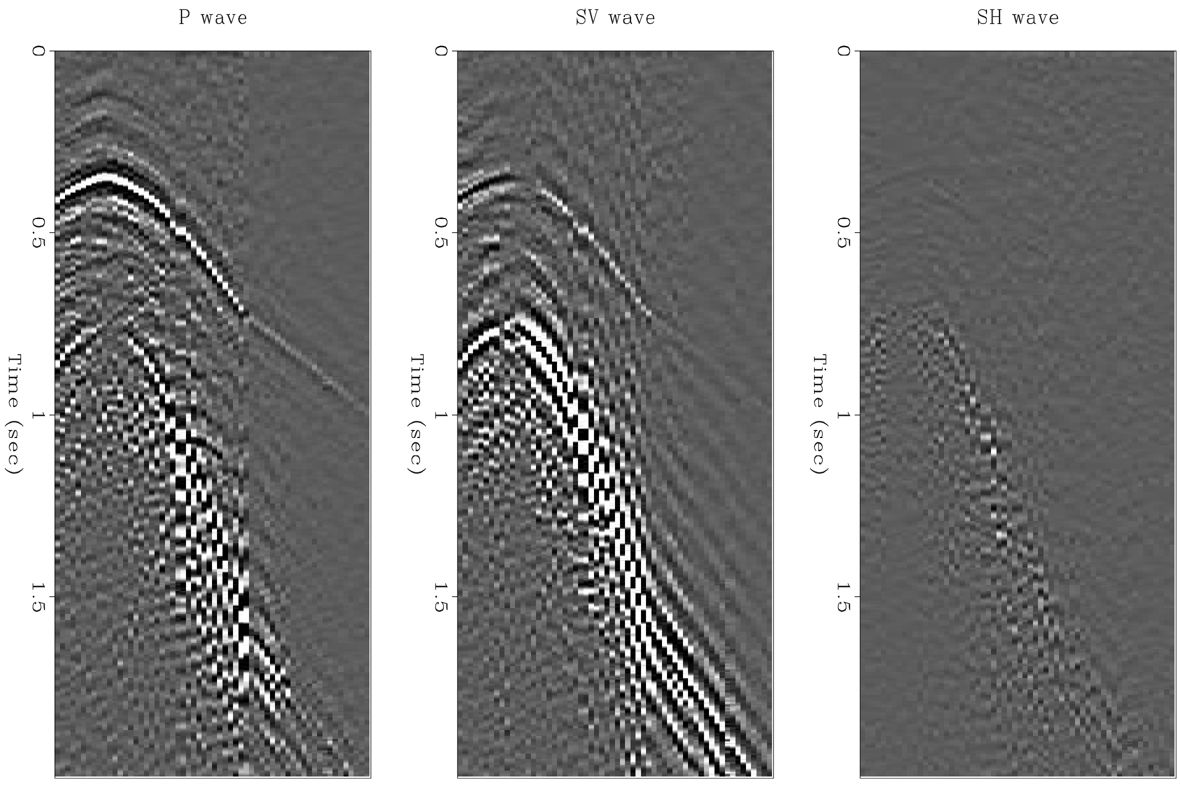

Figure 3: The data from Figure 1 after rotation. The P and SV events have been separated fairly well. The SH section contains little of interest. steve2-rotate [NR]

WAVELET ESTIMATION

Having rotated the data, we can now stack to produce an estimate of the source wavelets for use in deconvolution. We would like to deconvolve in order to sharpen the SV event and (hopefully) reveal distinct SH events that have arrival times that differ only slightly from the SV.

Figure 4 is a wiggle-trace display of a small window of the P wave section after rotation (and NMO correction). Trace balancing has also been performed to emphasize variations in wavelet shape (rather than amplitude) from trace to trace. The window is centered around the P event. The wavelet shape is quite consistent, leading us to believe that we have done a good job of rotation, and that the wavelet produced by stacking will be meaningful.

We repeated the entire processing sequence using a window of data containing the SV event. The picked arrival directions were very similar to the P case. Figure 5 shows the P and SV wavelets produced by stacking. These have been used by Leonid Vanyan (Vanyan, 1990) to deconvolve the data.

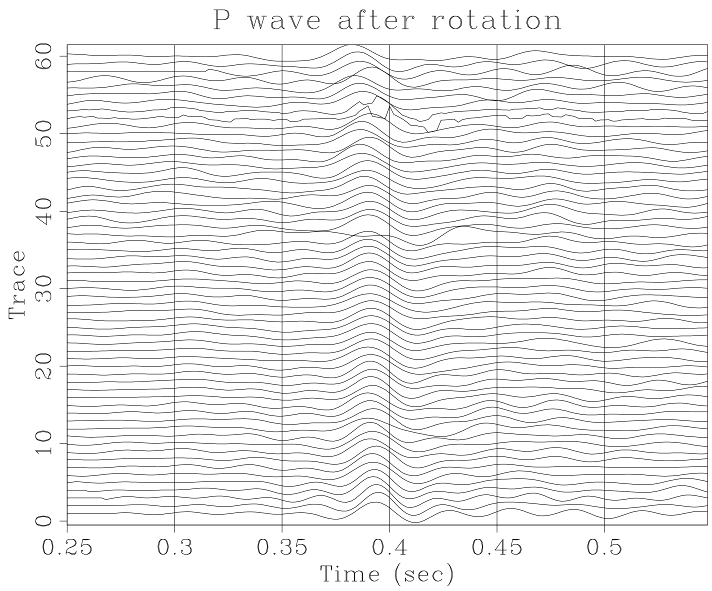

Figure 4: A small portion of the P wave section after rotation and NMO correction. The shape of the arrival is quite consistent. steve2-rotwin [NR]

CONCLUSIONS

Our rotation scheme seems to have done a good job. The SH section, at least before deconvolution, unfortunately contains no obvious events.

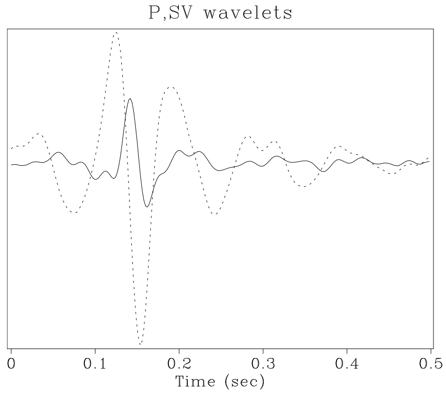

Figure 5: P (solid line) and SV (dotted line) wavelets obtained by stacking the data after rotation. These wavelets can be used in deconvolution. steve2-wavelets [NR]

REFERENCES

Karrenbach, M., and Cole, S., 1989, Beam steering of three-component data: SEP–**61**, 243-260.

Vanyan, L., 1990, Deconvolution of crosshole data: SEP–**67**.