Geophone orientation versus event polarization on land multicomponent data

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SUMMARY

The relation between a geophone's physical orientation (the source-receiver azimuth) and that determined from polarization analysis of recorded arrivals is tested in multicomponent seismic data. We use several different events including the first arrivals (P-wave refractions), S wave refractions, and ground roll. Three polarization analysis methods are used to perform these tests: hodograms, histograms and the covariance matrix method. From the results, a strong correlation between the polarization direction and source-receiver direction is observed in S-wave arrivals and ground roll, but a weaker correlation is observed in the P-wave refracted arrival. These characteristics show promise for the automatic orientation or checking of orientation of multicomponent seismic sensors.

Introduction

Geophone orientation is an important matter in the multicomponent method for optimal data recording and analysis. To that end, considerable time and effort is spent in careful geophone deployment in land multicomponent acquisition. The polarization of seismic events is related to wave-propagation direction, but also contains information on geophone orientation. Polarization has been used to obtain the geophone (sonde) orientation in VSP and marine data. In these cases, the seismic event of choice has been the first P-wave arrival. In this work, a study of polarization and geophone orientation in land data is presented, comparing the polarization of first-arrivals (P-wave refractions), S-wave refractions, and ground roll. Polarization analysis results are compared with the field geometry in real data.

Theory and method

Polarization is the particle trajectory resulting from wave propagation, characterized by direction and shape. For an isotropic, homogeneous medium, the P-wave's polarization is linear in the wave propagation direction, and the S-wave's polarization is linear normal to the wave propagation direction. The polarization direction is related to the propagation direction, thus to geophone orientation. Use of this approach on land data was proposed by Bland and Stewart (1996).

Three analysis methods are used in this paper to assess polarization: hodograms, histograms (DiSiena et al., 1984), and the covariance matrix technique (Flinn, 1965). Each one of them measures polarization with a different approach: the hodograms allow visual estimation, histograms make possible to obtain polarization direction from a statistical analysis, and the covariance matrix allows to calculate an elliptical approximation to the particle trajectory. These methods where applied to real data from Blackfoot III, an experimental 3-C high-resolution survey carried out in Alberta, Canada in 1997 (Hoffe et al., 1998). A map of the spread used is shown in Fig. 1 and the corresponding vertical- and radial-component geophone data are plotted in Fig. 2.

Results

We analysed four events: The P-wave refraction, two types of apparent S-wave refractions, and ground roll. Two of those events are shown here – the P-wave refraction and S-wave refraction. Figures 3 and 4 show the hodogram and histogram analysis of some traces for each one of the two events. In these figures column *a* shows the lateral view hodogram, column *b* the top view hodogram, and column *c* the histogram. Theoretical azimuths from field geometry are shown with arrows in column *c*. Comparing the results of both events, a better correlation with field geometry can be observed for the S-wave event.

Figure 5 shows the covariance matrix analysis of the horizontal components for each event, first-breaks in Fig. 5(*a*) and S- refraction in Fig. 5(*b*). These results confirm that a better correlation can be found for the S-wave refraction than for the P-wave refraction. The anomalous polarization indicated with numbers in Figure 5(*b*) correspond to trace reversals in Fig. 2.

We conclude that there is quite good azimuthal information in the S-wave refraction (as opposed to the much more scattered azimuths from P-wave refractions). In fact, all of the events with significant horizontal motion (ground roll, multiply converted refractions) can provide good azimuthal estimates of the wave propagation direction and thus the geophones' orientation.

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References

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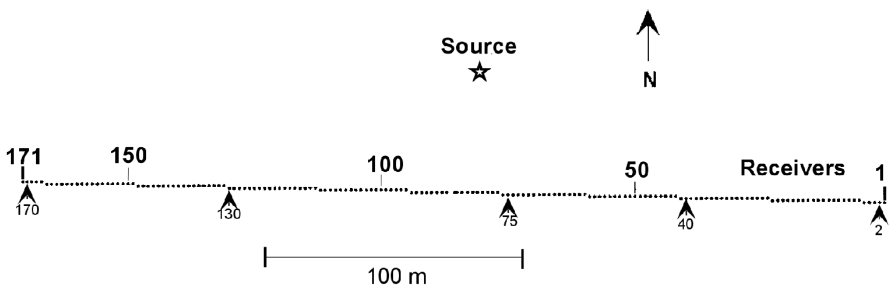

Figure 1. Geophone layout and source location used for the experiment.

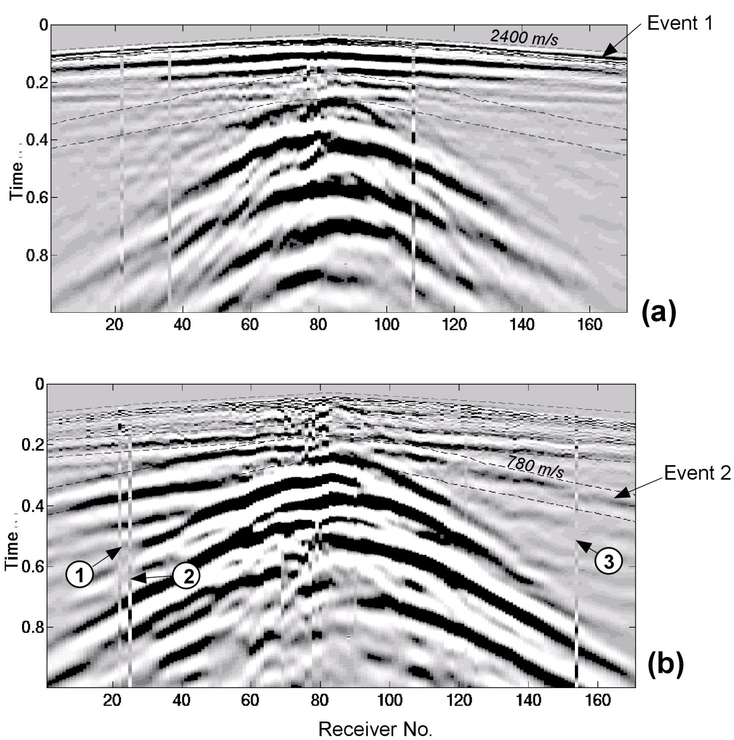

Figure 2. Seismic data set used.. (a) vertical component (b) horizontal in-line component. Windows corresponding to the events analyzed are illustrated. The numbers inside circles indicate reverse traces.

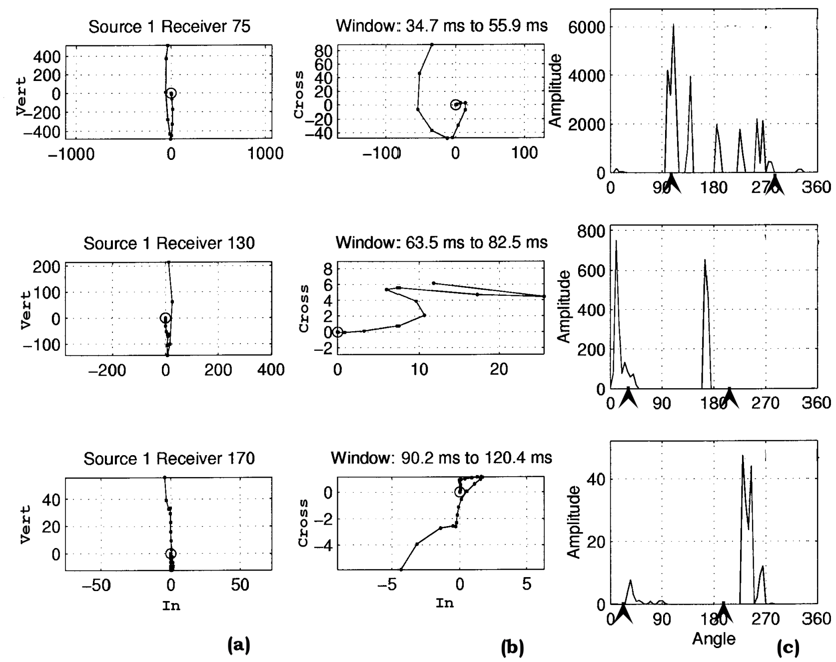

Figure 3. Hodogram and histogram analysis of the first event (P-refraction). (a) Side hodogram (b) top hodogram (c) histogram. Arrows indicate angles from field geometry.

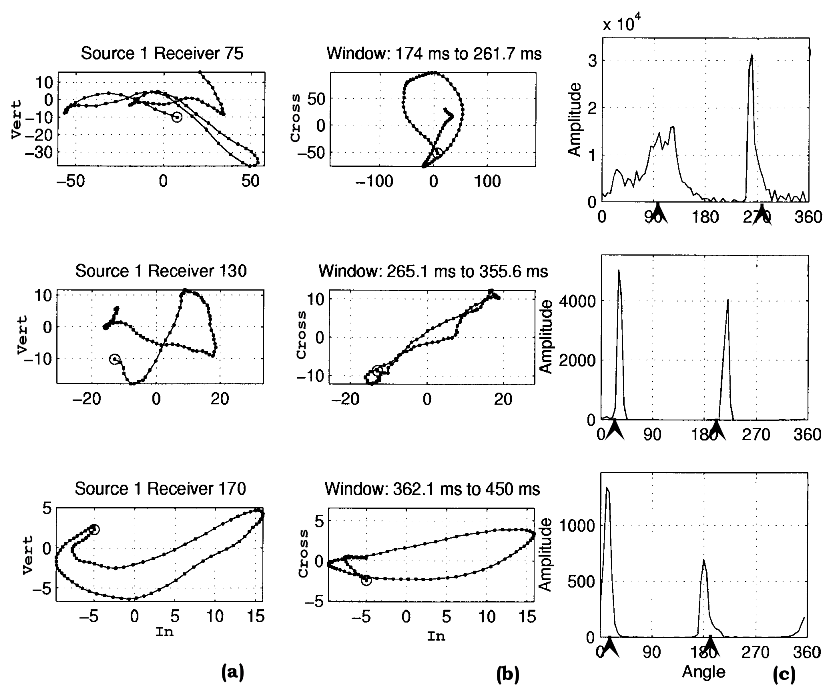

Figure 4. Hodogram and histogram analysis of the second event. (S-refraction). (a) Side hodogram (b) top hodogram (c) histogram. Arrows indicate angles from field geometry.

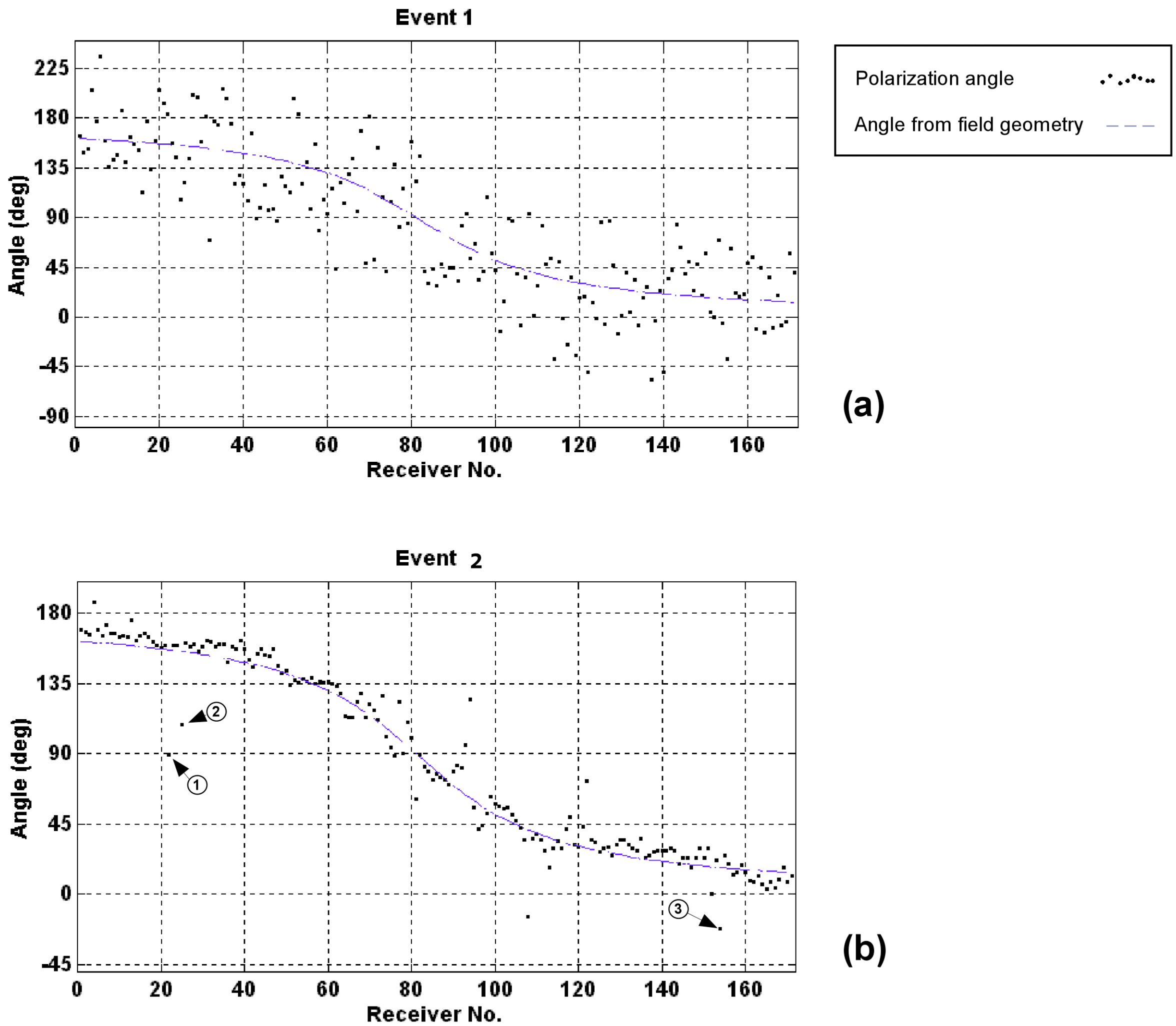

Figure 5. Covariance matrix analysis of the two events. (a) First breaks – P-wave refractions (b) S-wave refraction. Numbers inside circles correspond to reverse traces in Fig. 2.