Offset and aperture requirements for azimuth parameter estimation using azimuth migration scanning

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Summary

Azimuth parameters computed for synthetic data show that accurate azimuth parameters depend on having offsets up to 1.5 times depth and the offsets below 1.0 times depth should be muted and not be used in the computation. Azimuth variations can only be observed for traces where the waves propagate horizontally within the rock layers. This requires long offsets in the acquisition and maximum offset is of primary importance to deriving good azimuth parameters. The azimuth and fold distribution are also important but not as important as offset. Aperture requirements for azimuth migration scanning are dependent on the type of coherent noise in the data and the overall signal to noise. For low coherent noise and high signal to noise, a small aperture of 20% of depth works well. For high coherent noise and low signal to noise, a lager aperture of 50% of depth is required. Results derived using synthetic computations are borne out in real data. The questions to be addressed for acquisition design are: 1) required offsets; 2) azimuth distributions; and 3) fold versus azimuth.

Introduction

Azimuth migration is a modified Kirchhoff migration in which the velocity changes with azimuth are incorporated in the migration. Sicking, 2007, presented the concept of and uses for azimuth migration. Sicking, 2008, presented comparisons between migration analysis and sectored migration. Treadgold, 2008, discussed the uses of azimuth parameters in fracture and reservoir analysis. The primary output from azimuth migration scanning is a 2 dimensional trace gather as shown on the left in Figure 1. This gather is from the field data. The two dimensions are direction of the fast velocity and the magnitude of the fast velocity. The right side of Figure 1 shows a slice from the 2 dimensional gather at the time of a strong reflector. It is a slice of this volume that is shown in the other figures of this paper. Figure 2 shows the azimuth scanning methodology. Azimuth migration is run many times at the same output location. Each run uses a different set of azimuth parameters. The magnitude of the fast velocity and the direction of the fast velocity are varied for each run. In Figure 2, the direction of the fast velocity was varied between 0 and 165 degrees in steps of 15 degrees and the magnitude of the fast velocity was varied between 0 and 4% in steps of 0.5%. A total of 108 migrations were run to make the semblance plot in the top panel of Figure 2. Three gathers are shown for three of the parameter pairs. The first gather is the result of migration with 15 degrees direction and 2.5% magnitude. The second gather is the result of migration with 60 degrees direction and 2.5% magnitude. The third gather is the result of 105 degrees azimuth and 2.5 % magnitude. The black dots in the stack power plot in the right panel show the values for the gathers in the slice plane of the output gather. The input model data was built with the earth parameters 15 degrees and 2.5% magnitude. Picking the maximum stack power in the top panel yields the correct parameters for the input data.

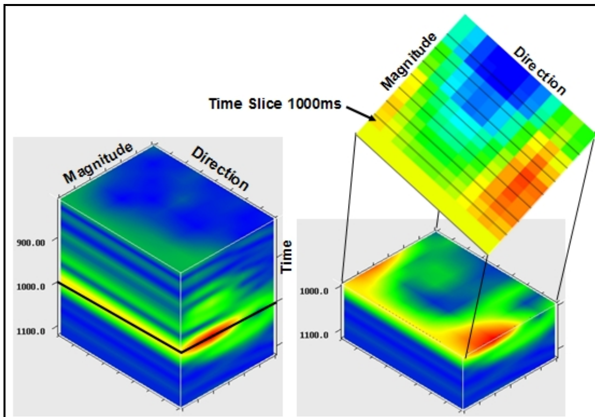

Figure 1: Left panel shows a 2 dimensional trace gather output from azimuth migration scanning at one image location. The dimensions are direction and magnitude of the fast velocity. A slice of the trace volume is shown on the right at the time of a high amplitude reflection. Data gather is one location in the field data. All CMP locations were analyzed for later plots.

Measuring azimuth parameters from seismic has become important and acquisition designs must be modified to accommodate azimuth analysis. The questions to be addressed for acquisition design for azimuth analysis are: 1) required offsets; 2) azimuth distributions; and 3) fold versus azimuth. Azimuth variations in seismic depend on the waves propagating horizontally within the rock layers. This requires long offsets in the acquisition and maximum offset is of primary importance to deriving good azimuth parameters. The azimuth and fold distribution are also important but not as important as offset. The Vector Offset Tile methodology requires uniform sampling in azimuth and offset. Methods that measure azimuth parameters from super gathers of unmigrated traces, require high fold and good distribution of azimuths. Azimuth migration scanning does not require uniform sampling in azimuth nor does it require uniform sampling in offset. Migration scanning works on low fold and poor azimuth distribution acquisitions. The large offsets are required by all techniques.

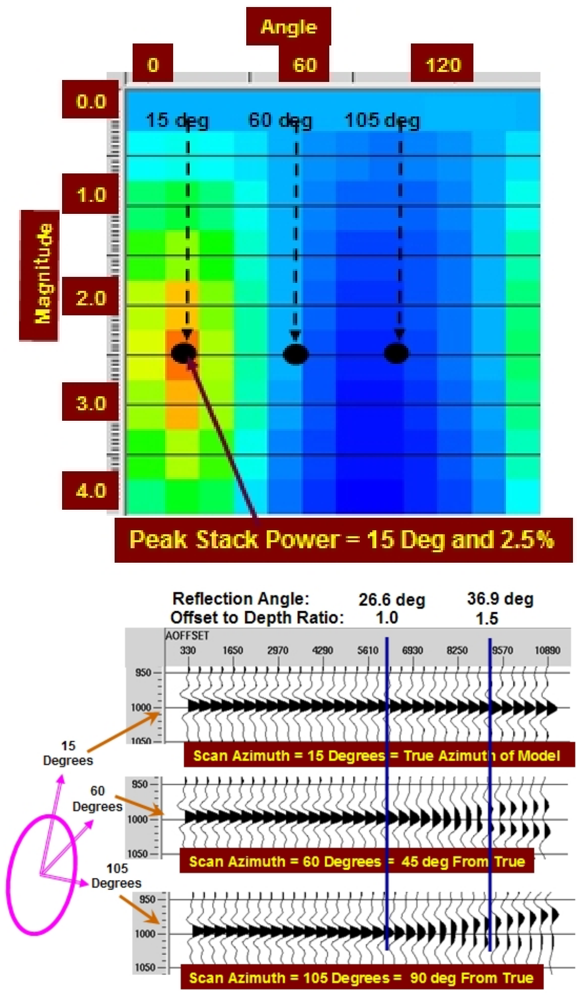

Figure 2: Azimuth scanning methodology. Azimuth migration was run 108 times for this target. The direction was varied from 0 to 165 degrees in steps of 15 degrees and the magnitude was varied from 0 to 4.0% in steps of 0.5%. The black dots in the top plot show the stack power for the 3 gathers for the offset range indicated.

Synthetics for study

A depth model was created with a single diffraction point at a known CMP location and depth. The modeling used constant velocity. The travel times and amplitudes for each created event in the traces is based on the Kirchhoff response. The travel time is computed using the background velocity but modified by the azimuth parameters. The source azimuth travel time and the receiver azimuth travel time were computed using the azimuth velocity parameters and summed to get the travel time for each event. The synthetics are computed using the actual traces of field data. The field traces are read and the amplitudes set to zero. A single event for that trace is added to the trace at the travel time and the amplitude based on the source and receiver locations with respect to the diffraction point location in space. All of the traces from the field data that fall within the aperture of the diffraction point location were used for the synthetic. The synthetic traces were used to evaluate the sensitivity of azimuth analysis to aperture and offset.

The synthetic data set was used to generate Figure 3. This figure illustrates the degradation in the far offsets when isotropic migration used for migration of data with azimuth velocity variations.

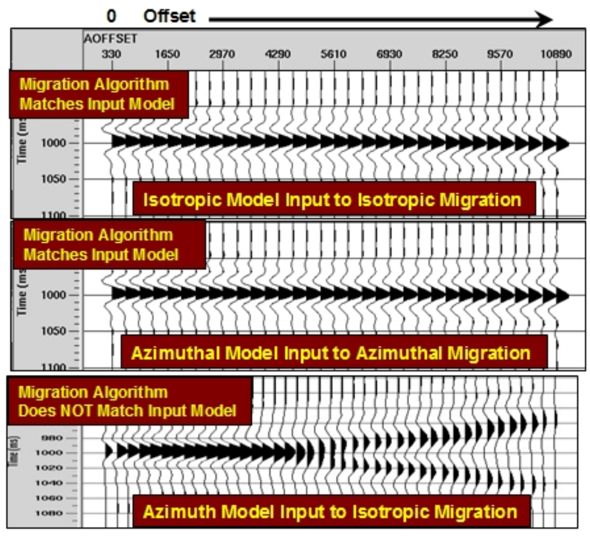

Figure 3: Gathers showing the defocusing cuased by isotropic migration of data with azimuth vaying velocity .

Field Data

The primary field data for this study is 3D data set from the Barnett Shale. The acquisition design precludes the use of Vector Offset Tile (VOT) analysis. See Figure 4. However, azimuth scanning works well on this data because the method is not sensitive to the acquisition design. This is demonstrated by carrying out the full analysis using only a subset of the azimuths and aperture available in the data. Even when some azimuth ranges are eliminated the analysis yields the same parameters.

Offset and aperture requirements for Azimuth parameter estimation

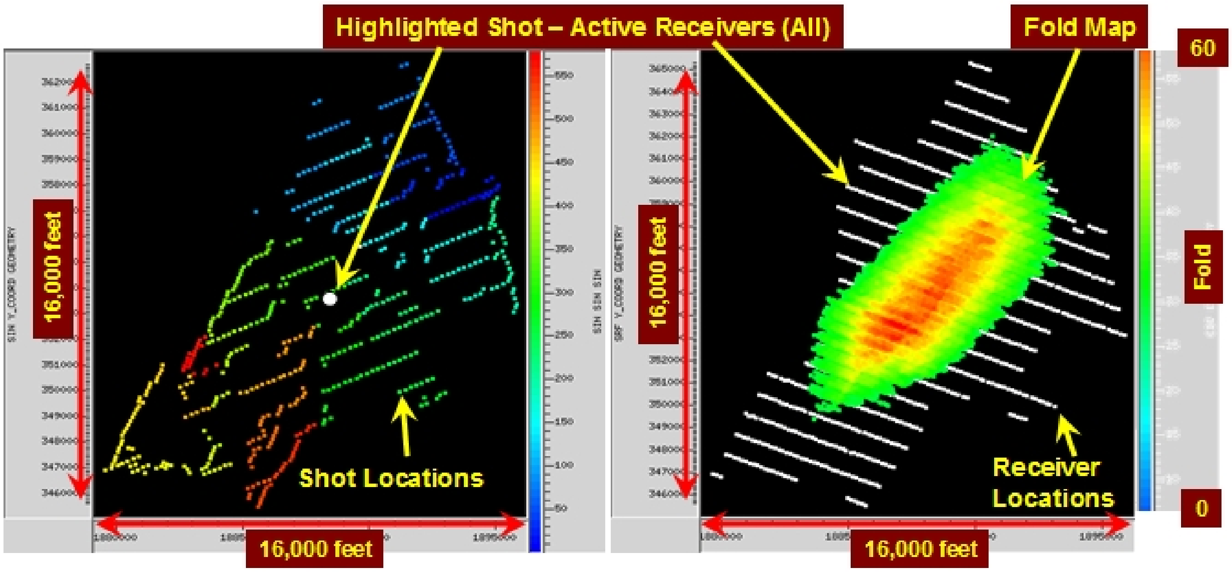

Figure 4: Field data layout. The survey was small so that all recievers were live for each shot. The fold map shown in the left figure shows all of the CMP locations with fold greater than 30.

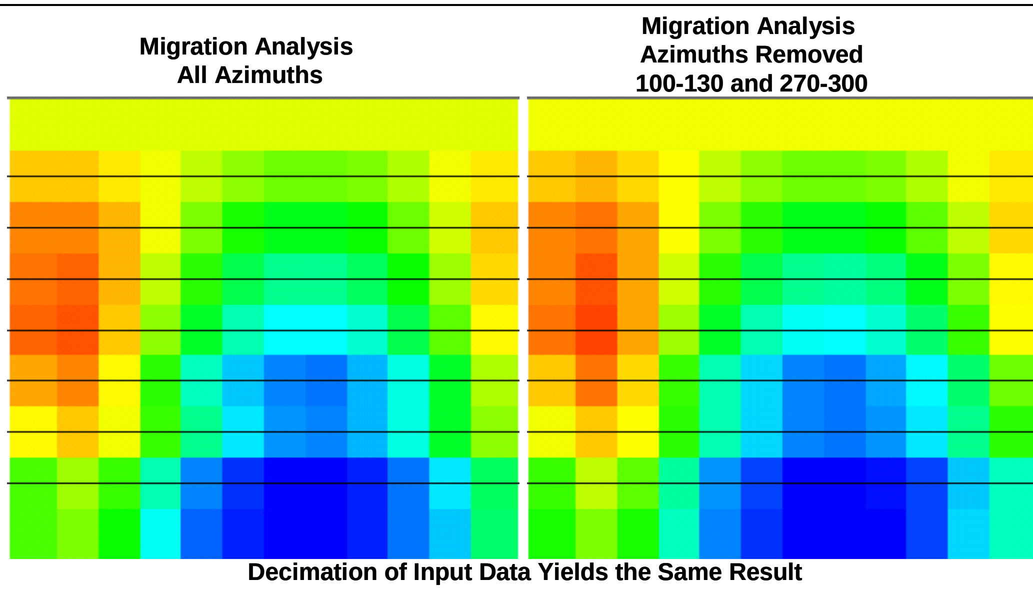

Figure 5: Left: Magnitude of fast velocity computed using all azimuths of input data. Right: Magnitude of fast velocity computed from input data with the azimuth sectors 100-130 and270-300 excluded. The results show that azimuth migration scanning does not have an acquisition foot print caused by poor azimuth distribution. As more azimuths are excluded the magnitude slowly moves toward zero.

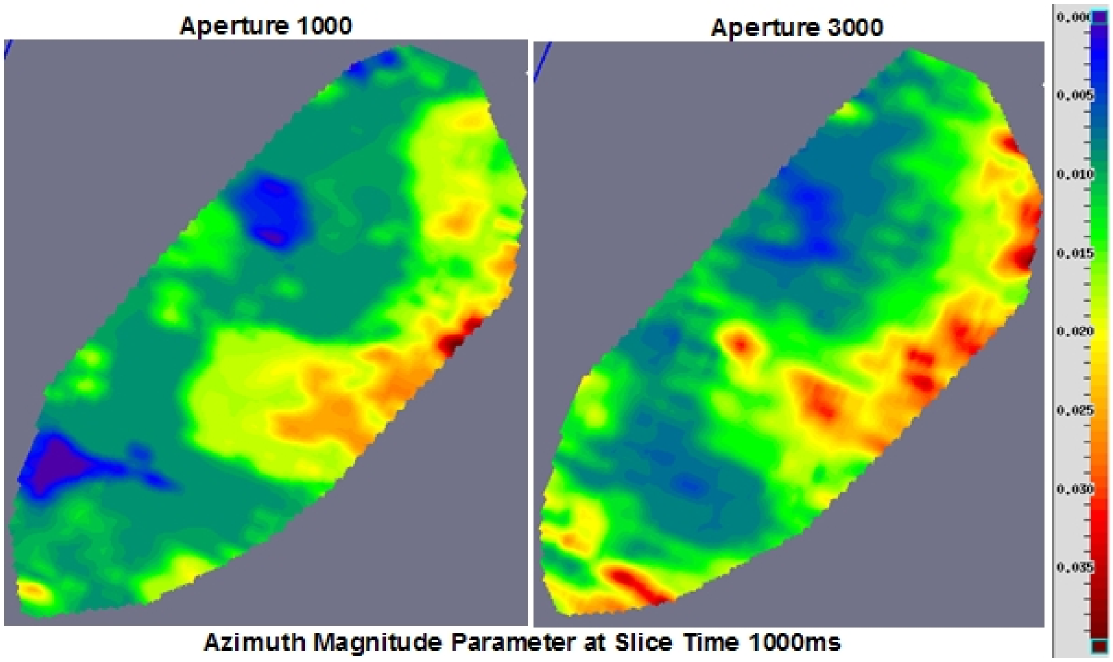

Figure 6: Azimuth parameter computation using 2 different apertures in the migration analysis. Comparison of the 1000 foot aperture result to the 3000 foot aperture results at time slice 1000 ms. The depth to the horizon is 6000 feet.

Acquisition Foot Print

Computing the azimuth parameters for synthetic and field data using subsets of the input data demonstrates that the same parameters are obtained even when substantial azimuth sectors of the data are eliminated from the data input to the analysis. Figure 5 shows the azimuth parameters for the full data input and for different subsets of the input data. These results show that there is not an acquisition footprint in the parameters and the azimuth scanning technique is robust and dependable when the acquisition is otherwise considered low fold and under sampled.

Aperture Requirements

The value of aperture for azimuth parameter estimation is that it increases the S/N. When the S/N is high, a small aperture of 20% of depth to target works well. When there is a lot of coherent noise or background noise, an aperture of 50% of target depth will be required to get better quality of azimuth parameters. Figure 6 shows the magnitude of fast velocity for 1000 foot aperture (17% depth) and 3000 foot aperture (50% depth). The depth to the horizon investigated is 6000 feet. The two results are very similar.

Offset Requirements

Figure 2 shows that the gathers output from migration are defocused at the far offsets when the azimuth parameters do not match the azimuth parameters in the input data. Reviewing the figures shows that offsets in the range of 1.0 to 1.5 times depth should be used in azimuth analysis.

Conclusions

It has been shown that the requirements for azimuth parameter computation are offsets between 1.0 and 1.5 times the depth of the target. Azimuth travel time variations and azimuth amplitude variations can only be observed for traces where the waves propagate horizontally within the rock layers. This requires long offsets in the acquisition and maximum offset is of primary importance to deriving good azimuth parameters. Acquisition designs should be modified to capture larger offsets in the cross line direction than is now the practice. The aperture needed for the computations varies between 20% and 50% of depth to the target. The azimuth and fold distribution are also important but not as important as offset. The results presented show that azimuth migration scanning is not especially sensitive to azimuth and offset distributions or to aperture.