

Benefiting from 3D AVO by using adaptive supergathers

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3D surface seismic data have many useful features (e.g., fine sampling, better resolution) that, coupled with the fact that 3D prestack time or depth migration yields accurate imaging of subsurface features, are good reasons to conclude that performing AVO analysis on 3D data will be beneficial as it is on 2D data.

This begins, especially for stratigraphic objectives, with "AVO friendly" processing that restores true amplitudes to prestack 3D data. Supergathers (gathers generated by collecting traces from adjacent CMPs) and Ostrander gathers (gathers generated from supergathers by stacking traces with similar offset intervals) are then generated. Next, AVO attribute pairs, such as Rp and Rs or intercept and gradient, are extracted. While interpretation can be directly carried out on the intercept and gradient attributes, Rp and Rs attributes are put through impedance inversion from which

LMR (lambda-mu-rho) attributes are extracted and then interpreted.

An identical processing flow is followed for 2D data sets. However, there are many differences between the two types of data, and a comprehensive study was conducted at Arcis to investigate such differences. The impact of geometry on 3D data is reported in this paper.

For 2D surface data, fold and offset usually have a one-to-one correlation. Unfortunately, this is not true for most 3D data sets. Figure 1 shows some 3D data gathers in which the offset variation is in red and the fold variation in blue. One notices at a glance that, for near and far offsets, the fold is low and traces with intermediate offsets dominate the overall fold in this set of gathers. We attempted to try to understand the impact of such a variation of fold with offset on the extraction of AVO attributes.

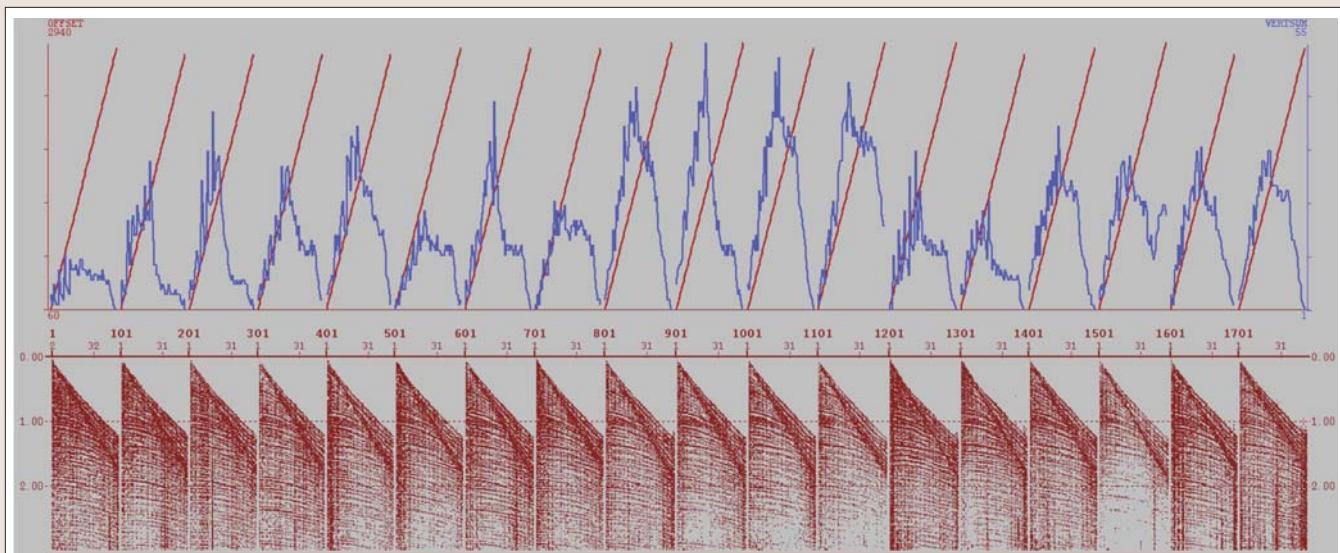


Figure 1. Example of fold (blue) versus offset (red) distribution in a 3D data set. Fold is low at near and far offsets.

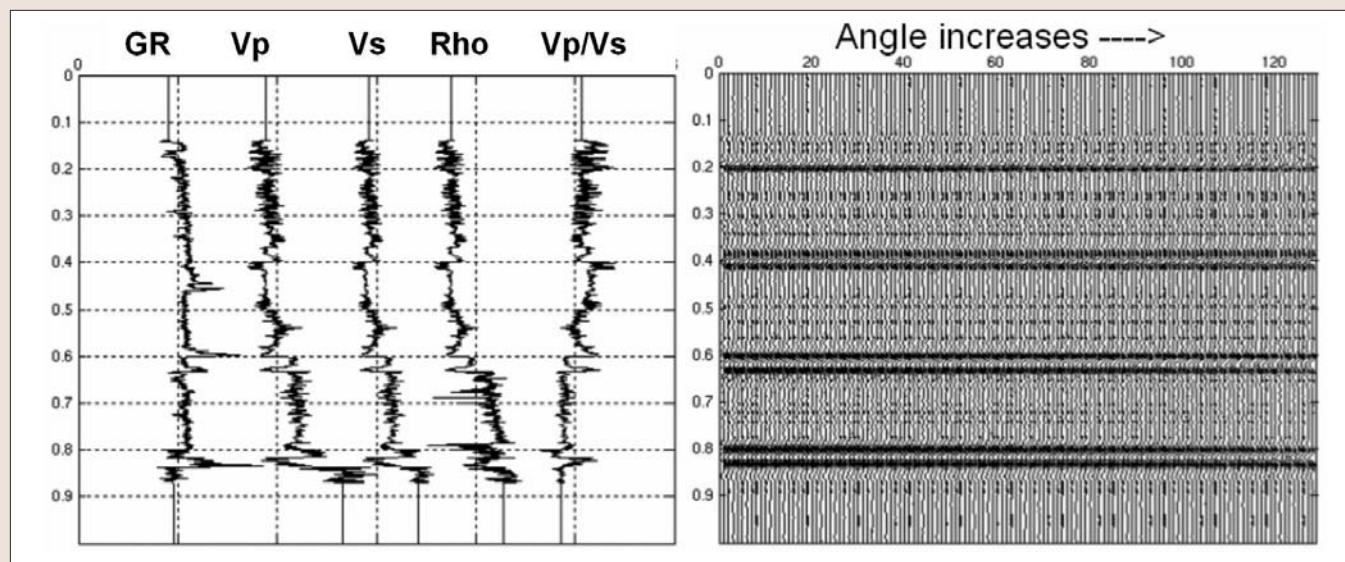


Figure 2. A synthetic gather (right) generated from the log curves on the left.

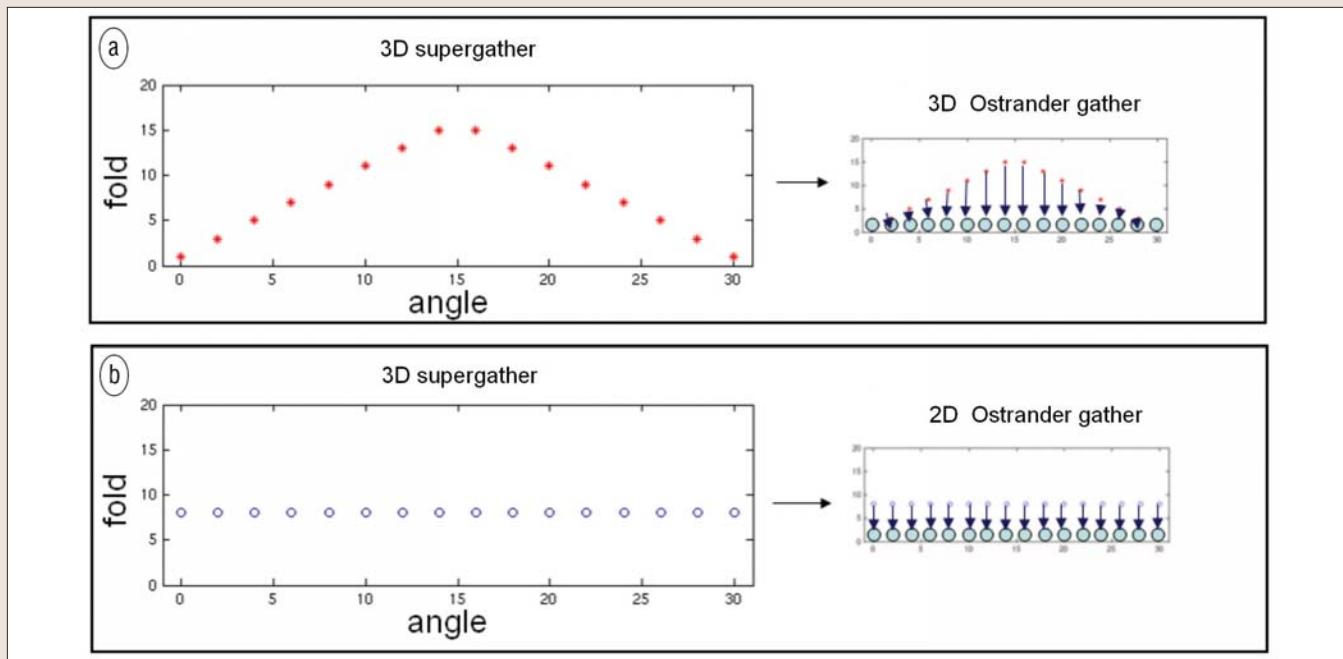


Figure 3. Fold distribution for (a) 3D and (b) 2D supergatherers and for the Ostrander gathers derived from them.

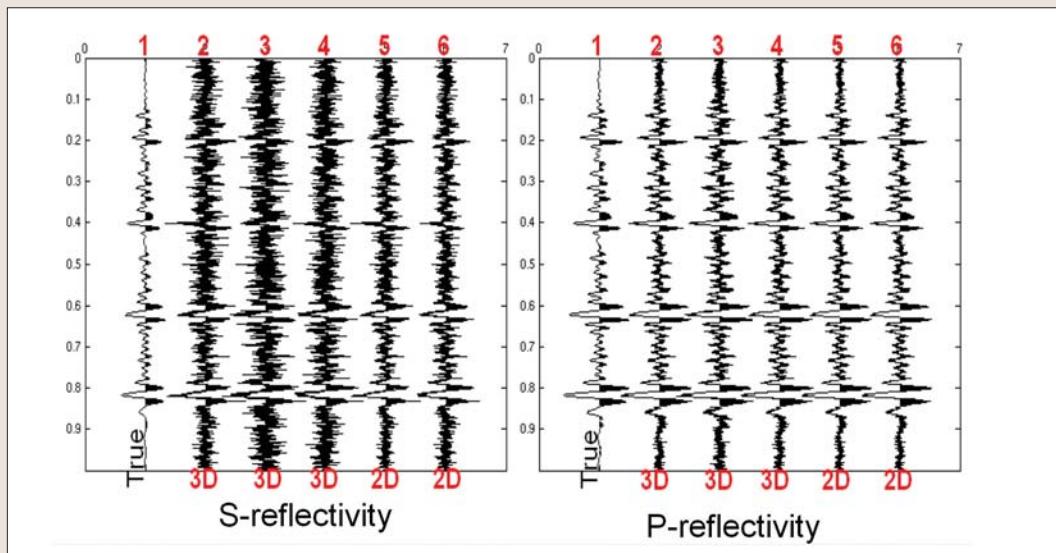


Figure 4. Comparison of P-reflectivity and S-reflectivity extracted from different supergatherers and Ostrander gathers.

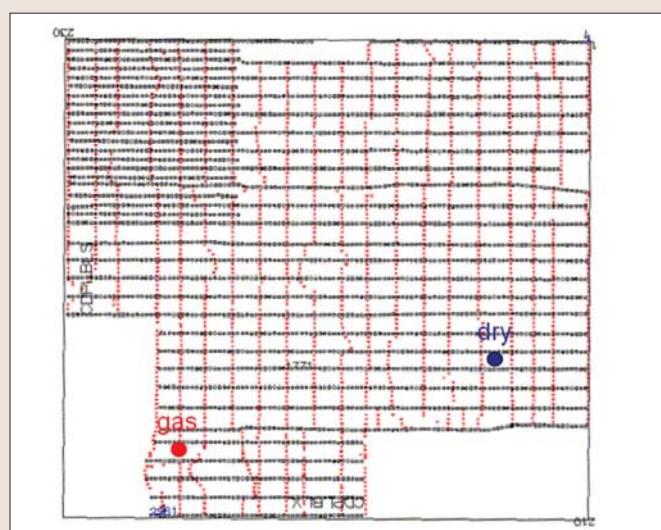


Figure 5. Survey map for a 3D data volume from Alberta, Canada. Also shown are the locations of gas well and a dry well.

Investigation on synthetic data. Synthetic gathers were generated using log data as input. Figure 2 shows the log curves and an angle-domain gather generated from them. Figure 3 shows two gathers generated, with the same number of traces in each and 0–30° angle coverage, but with different fold distribution and with random noise added. These gathers mimic the supergatherers in real seismic data, and for convenience we refer to them as 3D and 2D supergatherers. Ostrander gathers were generated from the two supergatherers by stacking traces with the same angle into a single trace.

As the objective is to understand the effect of this variation of fold with offset on AVO attributes, P-reflectivity (R_p) and S-reflectivity (R_s) were extracted from the gathers using Fatti's approximation and least-squares fitting, and the results were compared. The left panel in Figure 4 compares the S-reflectivity extracted from the different gathers and the right panel compares P-reflectivity. Trace 1 represents the true answer, trace 2 is from the 3D supergather, trace 3 is from the 3D Ostrander gather, trace 4 is from the 3D Ostrander gather with weights based on the local fold

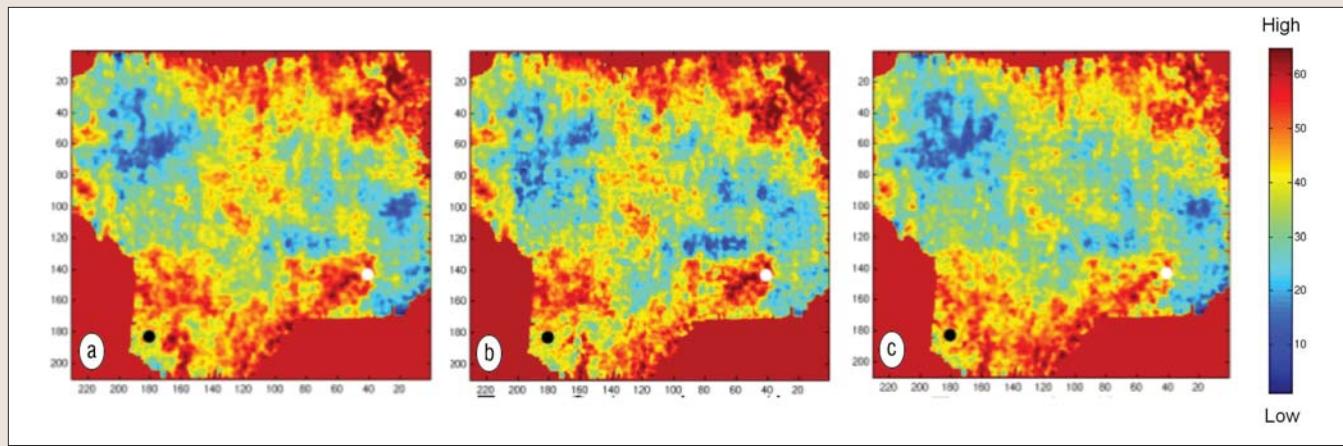


Figure 6. P-reflectivity horizon slices from three different types of gathers: (a) 3×3 supergather, (b) Ostrander gather derived from the 3×3 supergather, and (c) adaptive supergather.

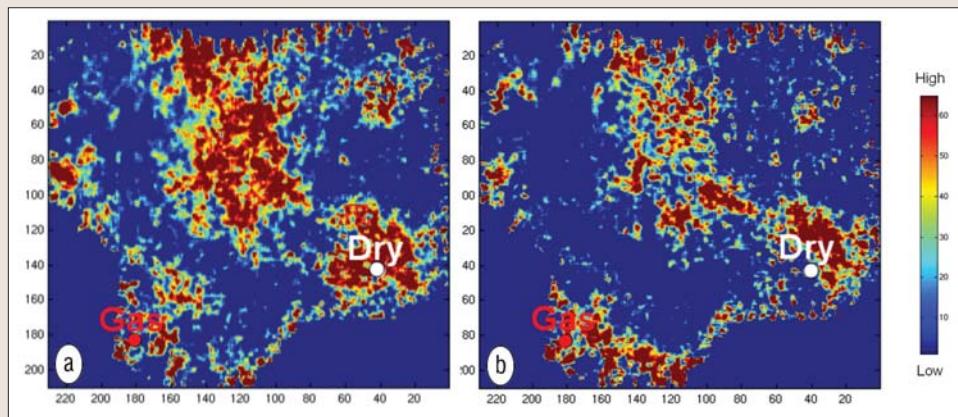


Figure 7. Comparison of fluid-factor horizon slices from (a) 3×3 supergathers and (b) adaptive supergathers.

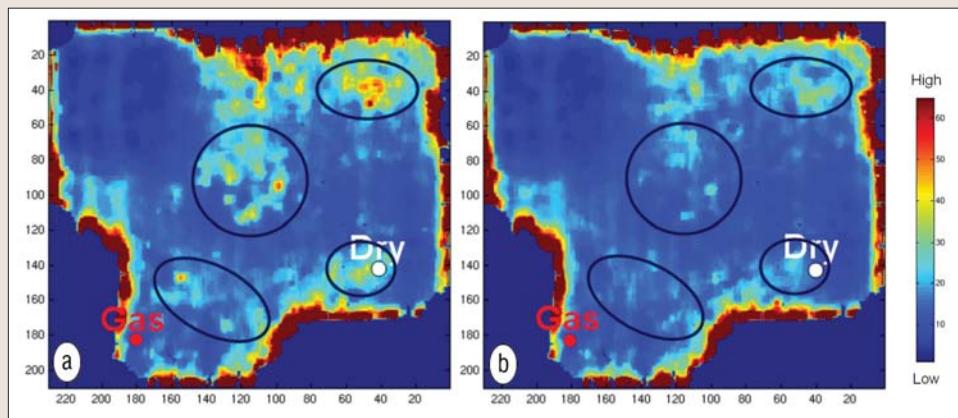


Figure 8. Comparison of reliability horizon slices from (a) 3×3 supergathers and (b) adaptive supergathers.

applied in a least squares sense, trace 5 is from the 2D supergather, and trace 6 from a 2D Ostrander gather.

In comparing traces 2 and 5 on the left panel, one notices that the 2D supergather appears more reliable. In comparing traces 2, 3 and 4, the Ostrander gather on 3D appears worse than the supergather. However, the weighted Ostrander gather tends to improve the result. For the 2D case, only subtle differences can be noticed.

The P-reflectivity traces on the right panel look quite similar, with the exception of trace 3, corresponding to R_p extracted directly from the 3D Ostrander gather. The above observations may be summarized as follows:

- Although useful for quality control and understanding AVO responses, Ostrander gathers may not improve extraction of AVO attributes from 3D data.
- An even distribution of fold with offset/angle results in better extraction of AVO attributes.

The above exercise on synthetic data demonstrates that, although generating supergathers in 3D seismic data is necessary to improve the signal-to-noise ratio, events get smeared and this could be a problem for subtle AVO anomalies. To address the issue of uneven fold-distribution in supergathers, an adaptive approach to supergathers is suggested. It entails borrowing traces from adjacent CMP locations to create an even fold distribution with offset.

Application on real data. The adaptive supergather approach was applied to a 3D data volume from Alberta, Canada, to test its impact on extraction of AVO attributes. Figure 5 shows the survey map for the 3D volume and the location of a gas well and a dry well. Notice that the top left corner has a higher fold than the rest of the survey. To make a fair comparison, AVO extraction was done on three different types of gathers: 3×3 supergathers, Ostrander gathers generated from 3×3 supergathers, and adaptive supergathers.

Figure 6 shows P-reflectivity horizon slices at the target level extracted from these three types of gathers. Although the noise level and acquisition footprint patterns are somewhat more pronounced, the P-reflectivity from Ostrander gathers (Figure 6b) is as good as that extracted from the supergathers (Figure 6a). P-reflectivity extracted from adaptive supergathers (Figure 6c) retains most of the character on the other two, but its noise level and footprint are subdued.

Figure 7 compares the fluid-factor horizon slices at the target level, for a 3×3 supergather and an adaptive supergather. Red indicates potential pay. Notice, that Figure 7a (from the 3×3 supergather) shows anomalies which do not match the production from the two wells. The equivalent display from the adaptive supergathers (Figure 7b) provides a much better match with well production. Besides this match with production data, the size of the anomalies seen on both displays are quite different; Figure 7a shows stronger anomalies except the one around the gas well. In an attempt to understand the difference in the anomalies caused by different supergather schemes, a reliability analysis of the AVO inversion was carried out. A reliability function (R) was defined depending on the geometry parameters, data error, and uncertainty in the extraction.

Figure 8 shows equivalent horizon slices to those in Figure 7, with red indicating higher unreliability. Apparently, adaptive supergathers improve the reliability for different portions as shown in black rings on the slices. By comparing the reliability maps with the fluid-factor maps, we see that reliability difference has good correlation with fluid-factor difference.

Conclusions. Our comparison of the 3D adaptive supergathers with 3D conventional supergather and Ostrander gath-

ers leads to the following conclusions:

- The usual 3D fold distribution may lower the reliability of AVO attributes extracted from these data sets as compared to those from 2D. The adaptive supergather approach provides superior results to the 3D supergather approach.
- Fold distribution in AVO gathers has a direct influence on the reliability of extracted AVO attributes.
- Reliability mapping helps evaluate meaningful AVO anomalies and confirms the first conclusion. [TLE](#)

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