Effect of Structure on Wide Azimuth Acquisition and Processing

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Abstract

This model study shows that narrow azimuth acquisition may be adequate for structures which are oriented dip to the acquisition direction but strike components are not well imaged. Wide azimuth acquisition with sufficient cross line offset gives improved results compared to narrow azimuth acquisition for both dip and strike components since this method is actually "directionless". Also, 3D SRME on narrow azimuth data shot dip gives a good image but narrow azimuth strike data does not yield a comparable uplift from 3D SRME. The application of 3D SRME to wide azimuth data shot either dip or strike yields a very good image which is superior to any of the results without 3D SRME. Results from the datasets with the multiples suppressed shows that dip components are well imaged with narrow azimuth acquisition but strike components may not be. Even if one suppresses all the multiples, wide azimuth is needed to image the strike components of the structure. Ray trace illumination maps can be used to determine the shadow zones in the model and help determine the width and direction of wide azimuth acquisition required to minimize these shadow zones. Finally, a real data comparison of NAZ versus WAZ acquisition and processing shows that the observations seen in the model data are also confirmed in the real data.

Introduction

Recent studies (Michell, et al., et al, 2006) have shown that wide azimuth (WAZ) acquisition can lead to significantly better results in subsalt imaging compared to traditional narrow azimuth (NAZ) acquisition. An integral part of these studies was the use of 3D model data to guide and evaluate the acquisition designs (Regone, 2006). Additional studies have shown that the reduction of multiple noise in the resulting images comes from the way the multiples cancel in the stack due to the areal distribution of the receivers (VerWest and Lin, 2006). In addition it has been shown that 3D SRME performs better with WAZ input data and can further improve the subsalt images. However, in recent model tests of WAZ acquisition using 2.5D model data, the 3D SRME results using NAZ acquisition yielded results nearly as good as the WAZ results, leading to the question of whether WAZ is really needed. In this paper we will show that the improvement in the images for WAZ versus NAZ acquisition depends on the orientation of the survey to the structural dip of the subsurface. To remove the multiples and to properly image the strike components of the structure, NAZ data is insufficient and WAZ acquisition yields improved results. Since 3D structures have a combination of dip and strike components, the imaging of the strike components is the critical component in the improved images form WAZ acquisition. We will also show how ray trace illumination maps may be useful in dealing with shadow zones in WAZ acquisition planning.

Modelling and Processing of WAZ Data

Acoustic two-way finite difference modelling was used to generate data both with free surface multiples. The input velocity model is shown in Figure 1. The model was a 2D model of a salt related structure in the deep water Gulf of Mexico. It was extended in the perpendicular direction for the sake of generating wide azimuth data. Shots were modelled with receivers running the length of the section and extending 6000m perpendicular to the shots. The bandwidth of the data is 0 to 20 HZ with a peak frequency at 10 Hz. The resulting dataset was decimated to yield a variety of acquisition scenarios. First, the receivers for each shot were limited to +/-8000m offset along the section (inline offset) and 0 to 4000m perpendicular to the section (cross line offset). We will refer to this as the "WAZ Dip" dataset. This was then further restricted to the range of 0 to 500m perpendicular to the section which produced the "NAZ Dip" dataset. Then another dataset was generated with offsets +/-6000m perpendicular to the section (inline offset) and 0 to 4000m along the section (cross line offset). We will refer to this dataset as the "WAZ Strike" dataset. This dataset was then further restricted to 0 to 500m along the section to produce the "NAZ Strike" dataset. For all the results in this paper, the sailline spacing was 500m and the shot spacing within a sailline was 150m.

The NAZ and WAZ data with free surface multiples were processed with 3D SRME (Lin, et al., 2007) to test the effectiveness of this multiple removal technique for different acquisition configurations and orientations. The datasets with multiples, both with and without 3D SRME, were then imaged using finite difference common shot migration for both the NAZ and WAZ acquisition and the dip and strike directions. In all cases the final image bin size was 25x50m.

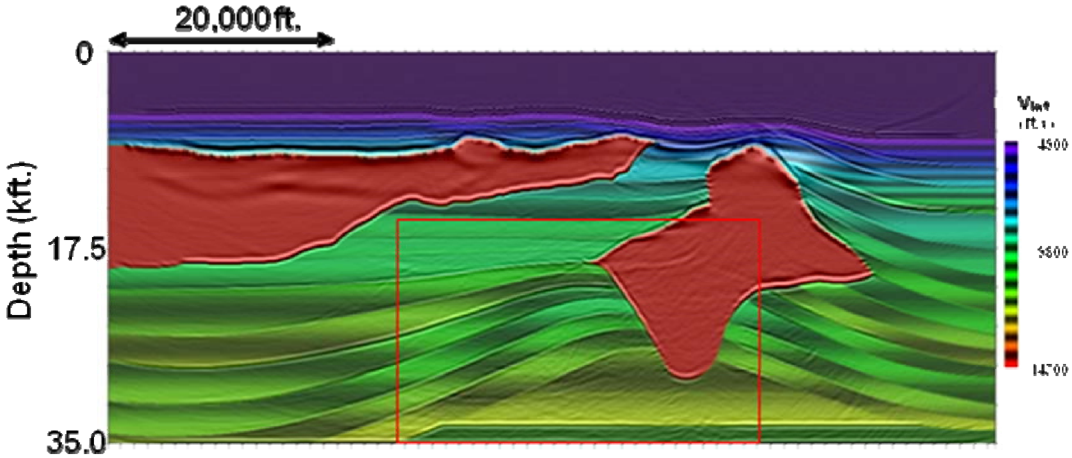

Figure 1. Velocity model for synthetic data. The red rectangle indicates the area shown in subsequent displays.

Imaging Results

The various datasets were imaged using a shot record wave equation migration. The subsalt images for the NAZ acquisition for both dip and strike orientation are shown in Figure 2. Both sections show considerable multiple contamination but the dip result is slightly better. The left base of salt is recognizable as well as the flat reflector at the bottom of the section. The WAZ result is shown in Figure 3. Here the image is significantly improved over the NAZ result and the dip and strike results are similar even though they have slightly different residual noise. This is not unexpected since as the cross line offset of the WAZ acquisition is increased the surveys become directionless. One notable difference in the two results is the shadow below the base of salt in the strike result. The 4 km cross line offset was insufficient to undershoot the salt in the strike orientation while the 8 km inline offset was sufficient to partially undershoot the salt

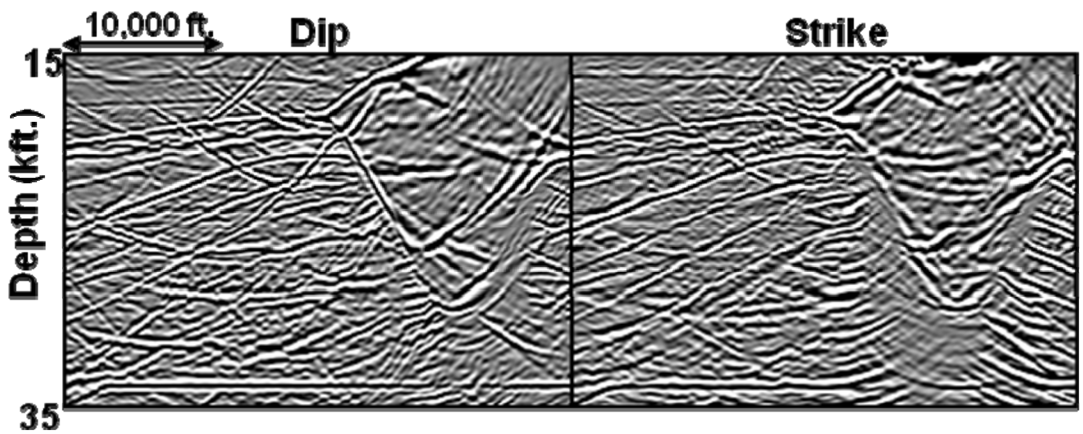

Figure 2. The imaging results for NAZ acquisition.

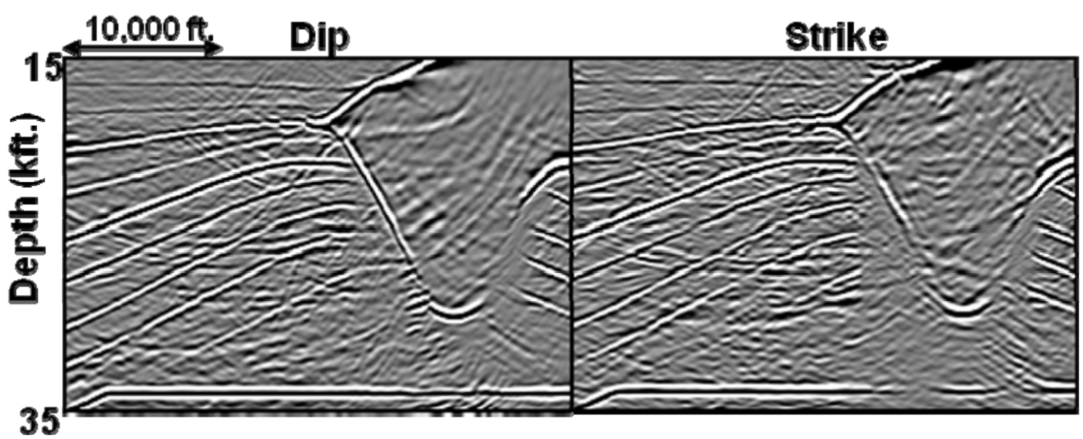

Figure 3. The imaging results for 4 km WAZ acquisition.

in the dip orientation and better illuminate the events next to and beneath the salt keel.

The 3D SRME results for the NAZ and WAZ acquisition are shown in Figures 4 and 5. The "NAZ Dip" result with 3D SRME is significantly better than the "NAZ Dip" result without 3D SRME and is slightly noisier and almost as good as the "WAZ Dip" result without 3D SRME. This result led to the questioning of the value of WAZ acquisition. It appeared that nearly equivalent results could be obtained simply by using 3D SRME on NAZ data. However, the situation is very different for the strike orientation. Here the "NAZ Strike" result with 3D SRME is better than without 3D SRME but still shows considerable multiple contamination beneath the deeper salt body and the flat event at the bottom of the section is still unrecognizable. The 3D SRME results on the WAZ data show significant improvement. These results again are similar for the dip and strike orientation except for the shadow beneath the salt in the strike orientation. These results are considerably better than the WAZ results without 3D SRME shown in Figure 3. Other tests with a 2 km WAZ acquisition configuration have shown that 2 km WAZ acquisition with 3D SRME may yield better images than 4 km WAZ acquisition without 3D SRME.

Ray Trace Illumination Modeling

In order to better understand the illumination effects, ray trace illumination maps were generated for a flat target horizon at the depth of the deep flat reflector in the model. This was done for the 4 km WAZ acquisition in both the "dip" and "strike" direction. This event showed a shadow zone beneath the salt keel and its extent and variation with acquisition direction is seen most clearly in Figure 5. The resulting illumination maps are shown in Figures 6 and 7 where red represents high illumination and blue low illumination. The purple areas have essentially no illumination. Both directions show a low illumination zone under the salt keel, but the low illumination zone for the "strike" direction is much wider. This is in agreement with the wave equation modeling and imaging results shown in Figures 2-5. Similar maps for NAZ acquisition show similar patterns which implies that the critical offsets for reducing the shadow zone are those between 4km and 8 km in the dip direction. One of the key planning issues for WAZ acquisition is determining the required width and direction of the acquisition to image the subsalt targets. Generating full wave equation models and imaging them for multiple scenarios is time consuming and expensive. Ray based illumination maps may be a way to more quickly identify shadow zones and how they change with changes in the WAZ acquisition width and direction.

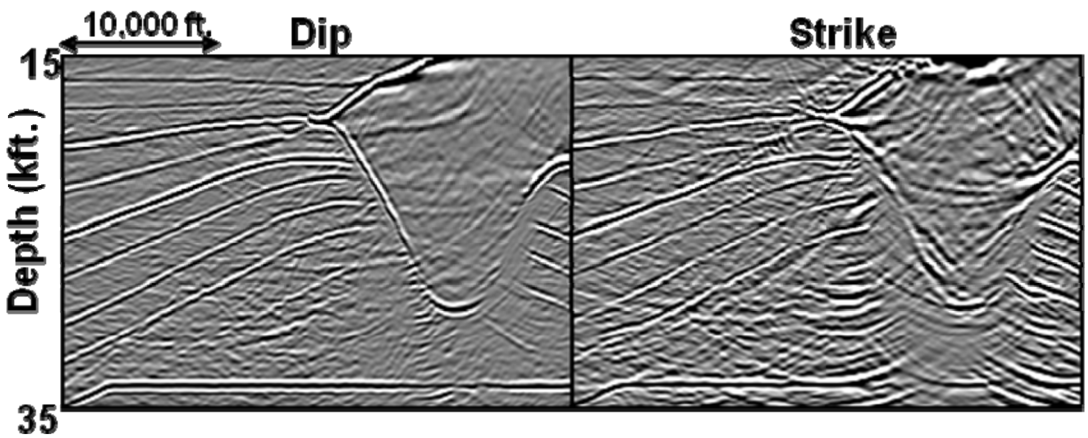

Figure 4. The imaging results for NAZ acquisition including 3D SRME.

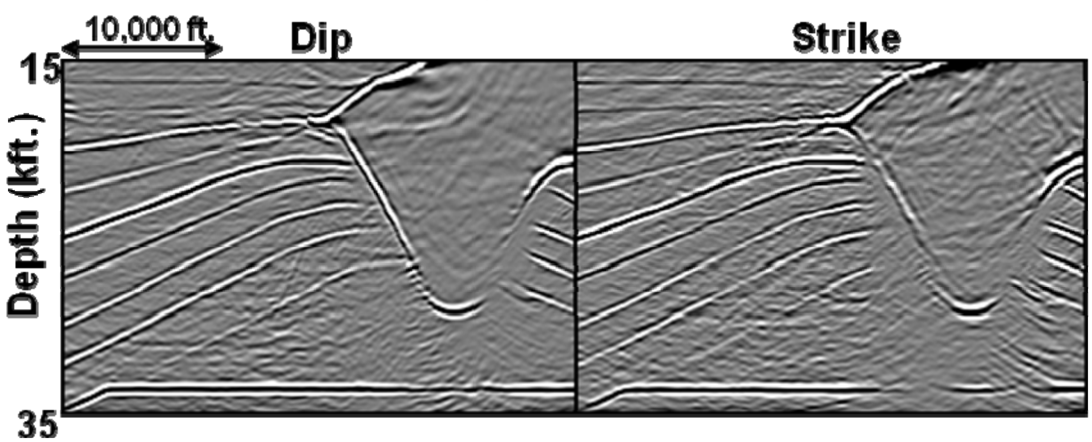

Figure 5. The imaging results for 4 km WAZ acquisition including 3D SRME.

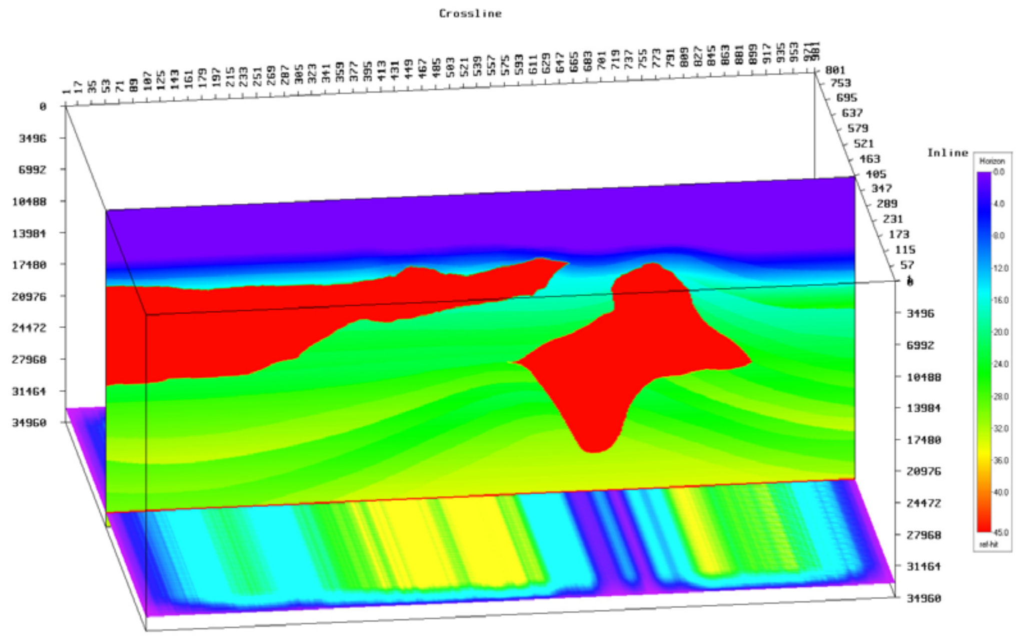

Figure 6. Ray trace illumination map for 4 km WAZ acquisition in the "dip" direction.

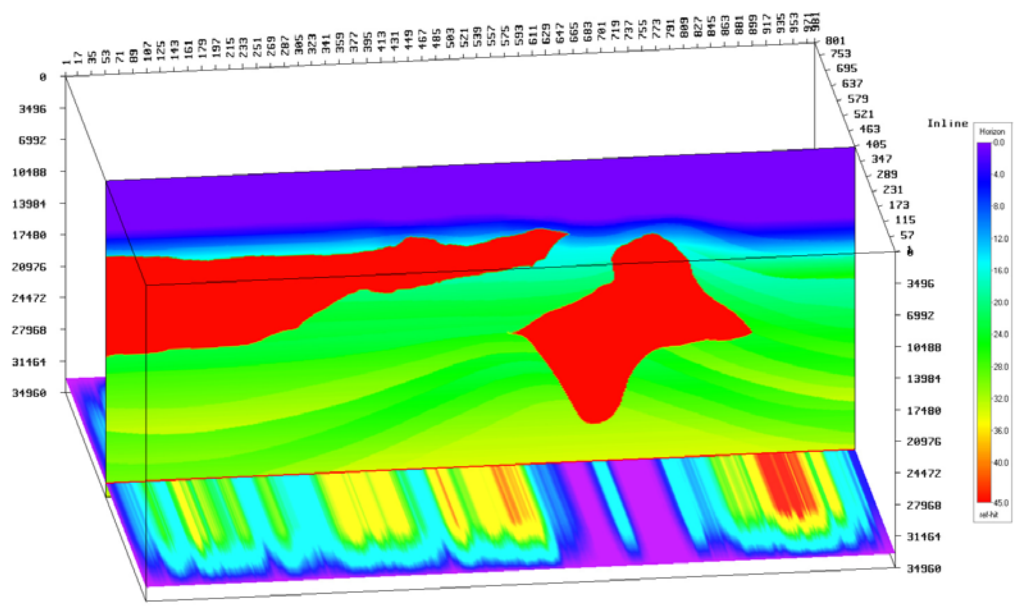

Figure 7. Ray trace illumination map for 4 km WAZ acquisition in the "strike" direction.

Real Data Example

WAZ data has been acquired over a portion of the Walker Ridge area of the deep water Gulf of Mexico. This is the same area that the data in this study was simulating. In addition the WAZ acquisition parameters are the same as the model data. NAZ data had previously been acquired and imaged using prestack depth migration over this same area. The NAZ data were fully processed using various noise reduction algorithms, 3D SRME and then imaged using wave equation prestck depth migration. The WAZ data were acquired and initially processed with a simple filter and gain and then imaged with wave equation prestack depth migration using the same velocity model that was derived from and used in the NAZ imaging. A comparison or these results is shown in Figure 8. First, the WAZ data shows better definition of a number of the complex features at the top of salt. In addition, the base of salt is better defined in the WAZ data. Finally, beneath the salt there is a significant improvement in the image continuity and a reduction of noise in the WAZ image, especially at the locations indicated by the arrows in Figure 8. These were areas that were shadow zones in the NAZ acquisition and contaminated by residual multiples. The WAZ data has

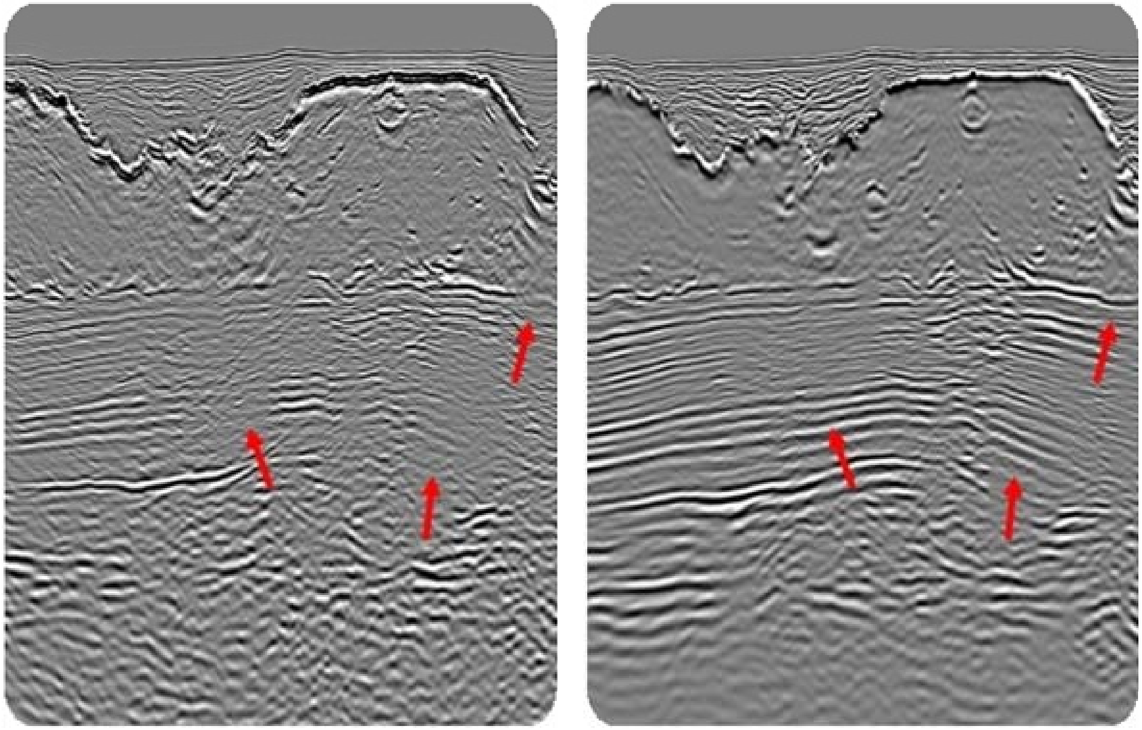

Figure 8. Comparison of NAZ final migration (left) and WAZ fast track migration (right) from Walker Ridge area of GOM.

had no multiple suppression processing applied but the natural multiple suppression due to the areal WAZ acquisition has reduced the multiple noise in this part of the section. Thus the real data shows the same improvement in the subsalt image that was predicted using the synthetic seismic data.

Conclusions

This model study has shown that NAZ acquisition may be adequate for structures which are oriented dip to the acquisition direction but strike components are not well imaged. The WAZ acquisition with sufficient cross line offset gives improved results compared to NAZ acquisition and the results are similar for both dip and strike components since this method is becoming more “directionless”. Since most salt bodies are very three dimensional, no single acquisition direction can be found which is dip to the structure. This is where WAZ acquisition will have a significant advantage. In addition the diversity of azimuths and offsets in WAZ acquisition results in a significant attenuation of multiple noise. The application of 3D SRME on NAZ data shot dip gives a good image due to the 2.5D nature of the model, but NAZ strike data does not get a comparable uplift from 3D SRME. The application of 3D SRME to WAZ data acquired either dip or strike yields a very good image which is superior to any of the NAZ or WAZ results without 3D SRME. In addition, WAZ data with more limited cross line offsets with 3D SRME may produce an equivalent image with respect to multiple noise reduction than WAZ data without 3D SRME and a larger cross line offset range. However, the larger crossline offset range may still be required to solve illumination problems.

The model data showed that there is a shadow zone beneath the salt keel which changed as the orientation of the survey relative to the structure changed. The shadow was larger for this model for WAZ data acquired strike to the structures. In planning WAZ surveys, one of the key parameters to be determined is the width and direction of the acquisition. Ray trace illumination maps may provide a quick way of locating and quantifying illumination shadows as a function of survey direction and width.

In addition, the real data from the same area shows that WAZ acquisition and processing yields the same image improvements compared to NAZ acquisition that are predicted by the model data.

Acknowledgments

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