Imaging of Basement Control of Shallow Deformation; Application to Forth Worth Basin

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Summary

By definition, the focus of seismic exploration for hydrocarbons is to directly image structural, stratigraphic, and diagenetic features in the 'soft' sedimentary sequence. However, understanding the geologic processes that gave rise to these shallow features often requires an understanding of the structural deformation of the more 'rigid' basement. In our study area from the Fort Worth Basin of North Texas we see on pre-existing pre-stack time migrated sections that the shallow faulting appears to be basement controlled. In neighboring surveys, there is some question as to whether the collapse features in the sedimentary section are controlled by what appear to be rhombochasms in the basement, or whether these rhombochasms are a velocity push down artifact due to infill of the collapse features by a slower velocity material. In this paper we apply a suite of migration schemes ranging from simple stack to prestack depth migration to evaluate the importance of velocity-depth models and imaging algorithm on illuminating basement control.

The key to accurate imaging is accurate velocity analysis. Geometric attributes imaging lateral inhomogeneities have been computed from the pre-stack time migration. Rather than perform our velocity analysis on a regular grid, we have used these attribute images to avoid using inaccurate velocity estimates near faults and to add extra velocity analysis points within the collapse features to avoid smoothing through them. Given an accurate velocity model, we have applied 3D Kirchhoff post, pre-stack time migration and post stack depth migration to the data set using commercial software. Finally, we try to give another direction to the interpretation of the deformation components of the shallow sedimentary structure in terms of deformation in the more rigid basement.

Introduction

Each steps of the processing and imaging has the same general purpose to improve our seismic image of the subsurface and to help the interpretation of the data. Modern migration algorithms help us reach this purpose. In general, prestack time migration provides excellent images of target reservoirs lying above the high velocity Ellenburger formation in the Fort Worth Basin. However, a more complete understanding of the tectonic and diagenetic control of the reservoir facies requires illumination of faulting in the basement. In this study, we evaluate the importance of depth migration in imaging such surveys where basement control can play a role in reservoir heterogeneity. We therefore conduct a systematic study in which we have produced post-stack and pre-stack time migration as well as post stack depth migration images of a survey acquired in the Fort Worth Basin and demonstrate the improvement of the interpretability of the results.

Field Description

Geologic Setting

The Forth Worth Basin formed as a foreland basin as a result of convergence of North and South America during the Paleozoic (Walper, 1982), and lies between the Ouachita fold and thrust belt (Figure 1). Shallow marine late Ordovician Viola limestone unconformably overlays the early Ordivician Ellenburger carbonates which in turn are underlain by granite diorite basement of the Precambrian. An unconventional shale reservoir along as well as the Marble Falls carbonates were deposited during late Mississippian and early Pennsylvanian (Sullivan, 2005) followed by deposition of the Caddo limestone over the Atoka sands and shales during middle Pennsylvanian (Walper, 1982). Karst features, especially within the upper 100 meters of the Ellenburger occurred multiple times during subaerial exposure. Ellenburger carbonates and Simson sandstone filled these collapsed karst structures in Ellenburger. Continental collision between North and South America during the Paleozoic and opening of the Gulf of Mexico during Mesozoic caused compression and extension in the Forth Worth Basin respectively (Ball and Perry, 1996; Hoskins, 1982).

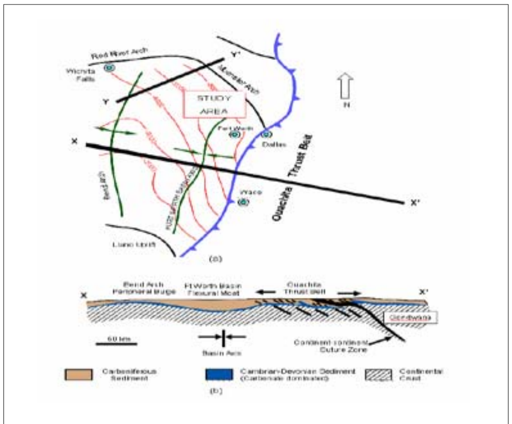


Figure1. The Fort Worth Basin and the Pennsylvanian Ouachita thrust belt. The Fort Worth Basin experienced compression during Pennsylvanian and extension during Mesozoic and Cenozoic (after Hardage et al., 1996).

Imaging of Basement Control of Shallow Deformation

Seismic Data

A wide azimuth 3D data survey over the Forth Worth Basin was acquired by Devon Energy; pre-processing steps consist of noise attenuation, deconvolution and statics.

Imaging Steps

Post Stack Time Migration

We began by taking the pre-processed dataset and subjecting it to post stack imaging. Figure 2 shows a representative NMO-corrected gather from the data set. We used the resulting stack and RMS velocity volumes (Figures 3 and 4) as input files to the post stack time migration process. First we conducted a process of systematic velocity model building, beginning with a coarse grid of velocity analysis. During the second iteration in building our velocity model, we made our grid four times finer and then inserted irregularly located velocity analysis points where the initial images and geometric attributes (coherence and most negative curvature) indicated the existence of collapse features. Finally we applied 3D Kirchhoff time migration to the data set using our new velocity model that was relatively more sensitive to the collapse features. Figure 5 shows a vertical section through the post stack migrated volume while Figure 6 shows a time slice at t = 1.4 s at the Ellenburger level.

Prestack Time Migration

Next, we subjected the same pre-processed data set to prestack time migration. Velocity model building process consisted of two basic steps in this level of the imaging. First, we used the stacking velocities from the previous step, imaged the data, and subjected the results to residual move out (RMO) analysis. With these new RMO-updated velocities we remigrated the data. Finally, we generated a horizon-based velocity model. This last velocity model accounted for faults and collapse features. Finally we imaged the data by the help of 3D Kirchhoff pre-stack time migration with horizon based velocity model (Figures 7 and 8).

Post Stack Depth Migration

For 3D Kirchhoff post stack depth imaging, we used our best time stack volume and interval velocities converted from our horizon-based RMS velocity used in prestack time migration. Figures 9 and 10 show a representative migrated section and depth slice.

Discussion of Results/Conclusions

At the end of the imaging process, we have three migrated volumes. Since one of the volumes is in depth domain, it is reasonable to compare both post stack time migration and pre-stack time migration cubes each other. Our velocity picking strategy hardly affected our PostSTM results because the nature of its algorithm is less dependent on the velocity than the other migration algorithms. In contrast, PreSTM showed improved results using our velocity picking strategy. In the PreSTM image, the basement shows more fractures and collapse features then the post stack migration. This result may bring us to the new unique interpretation for basement. At the beginning of the study, there was a doubt about the collapse feature in the sedimentary section whether they are controlled by basement, or a velocity push down artifact causes these features. The idea of the shallow deformation controlled by the basement is more dominant from our perspective after this study.

On the other hand, depth migrated cube clearly shows that all the events move to their original location in space domain, this depth image gives us a more detail at the basement.

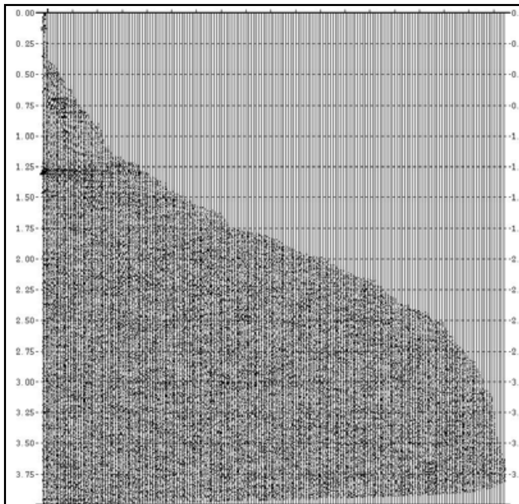
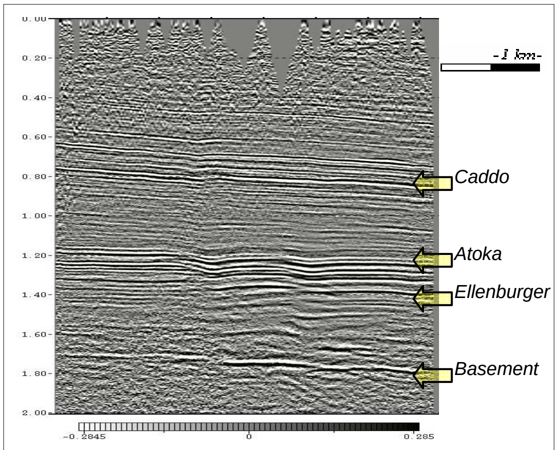


Figure 2. A CDP Gather containing 231 traces.

Acknowledgements

The authors would like to thank Devon Energy for permission to use and publish data. Thanks to Joe Rielly of ExxonMobil for warning us of the possibility of velocity pull up on our basement structures. Suat Aktepe gives special thanks to Dr. Edip Baysal, Dr Orhan Yilmaz and Irfan Tanritanir for sharing their guidance, expertise, and encouragement during the study. Part of this study was supported by DOE contract on seismic illumination of karst.



*Fi*gure 3. Stack section showing Caddo, Atoka, Ellenburger and Basement horizons.

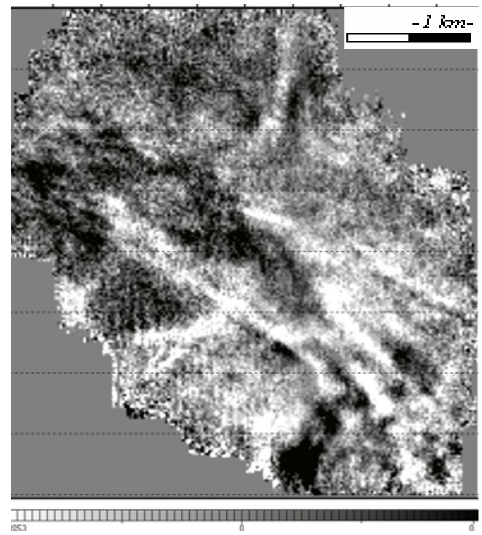


Figure 4. Time slice from stack volume at 1400 ms.

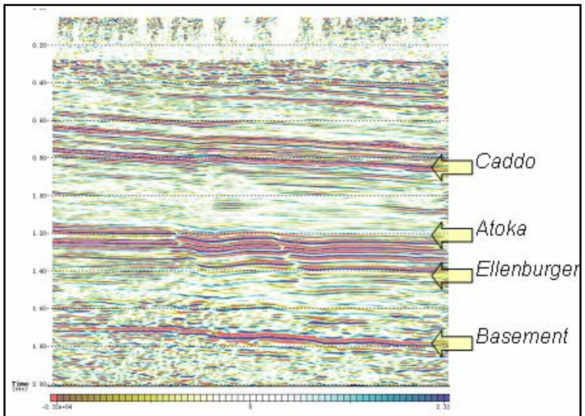


Figure 5. Post stack time migrated (PostSTM) section along the inline direction.

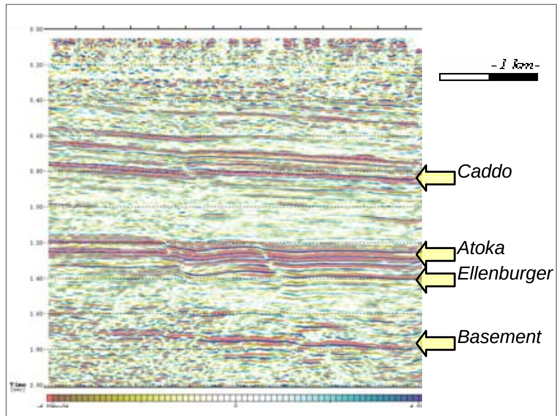


Figure7. A prestack time migrated (PreSTM) section along the inline direction.

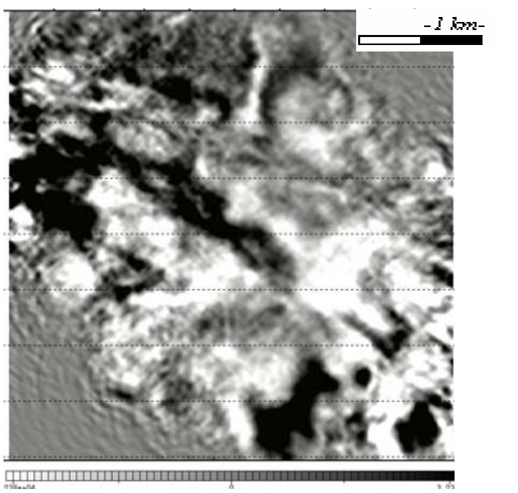


Figure 6. Time slice from PostSTM volume at 1400 ms.

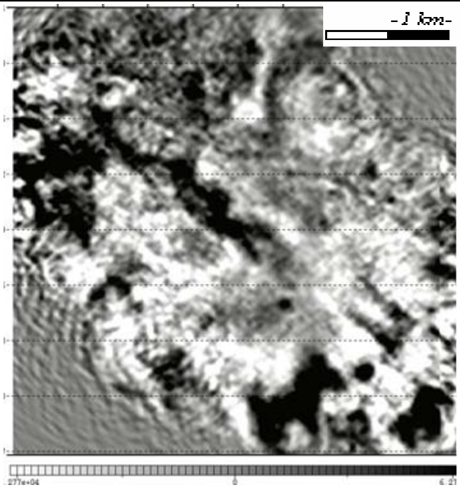


Figure 8. Time slice from PreSTM volume at 1400 ms

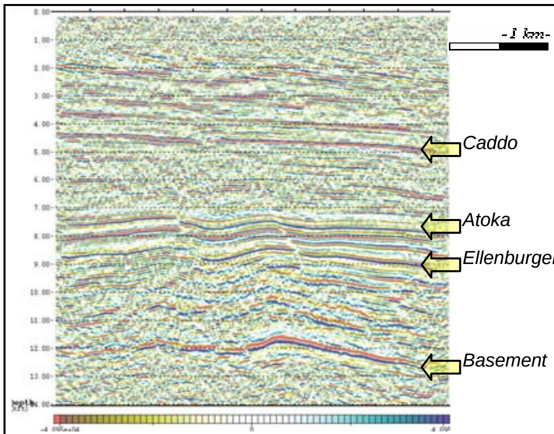


Figure 9. Section from post stack depth migrated (PostSDM) volume along the inline direction.

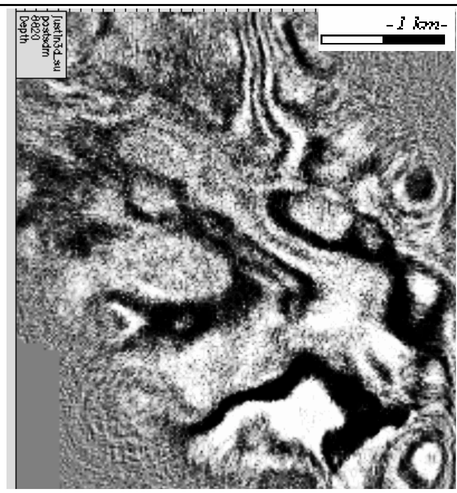


Figure10. Depth slice from PostSDM at 3000 m.

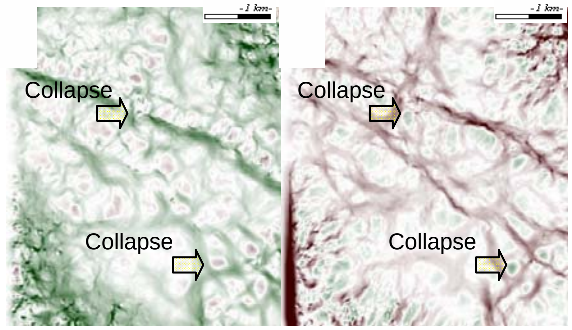


Figure 11. Most negative and most positive curvature slices at 1400 ms, generated from PostSTM.

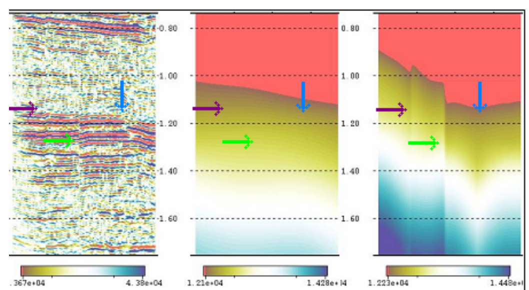


Figure 12. a) Pre-stack time migration section, Velocity model b) horizon based c) from vertical velocity functions (initial RMS velocity). The seismic section shows three different faults. Arrows indicate that after horizon based velocity analysis, initial RMS velocity model starts to resemble of real structures, and faults are identified in velocity model. It is not clear in RMS velocity model.

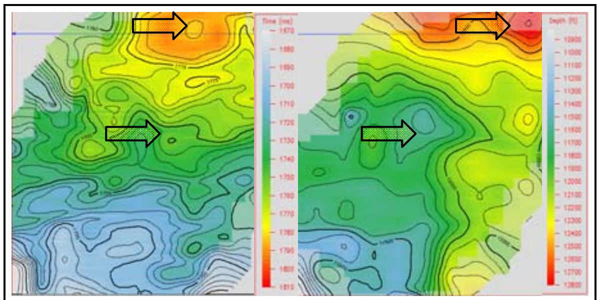


Figure 13. a) Time-Structure map along the basement. b) Depth-Structure map along the basement. Arrows showing possible collapse feature at the basement level.

EDITED REFERENCES

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