3-D processing success of difficult seismic data in the Val Verde Basin, Texas

Gary A. Leaf, Mobil Exploration and Producing U.S., Inc.
Sam C. Ting, Mobil Exploration and Producing Technical Center*
Jonathan G. Fried, John Young, and Richard R. Van Dok, Western Geophysical, Western Atlas*

SUMMARY

The Val Verde Basin of west Texas has been well known for its poor quality seismic data due to the detrimental effects of karsted limestone at the surface. 2-D data in the past suffers severely from scattered noise and its quality generally ranges from very poor to marginally useful. In spite of the high risks of getting poor seismic data, a 3-D survey was carried out over the Brown Bassett gas field located in the midst of karsted limestone in the northwestern part of the Val Verde Basin.

Preliminary stack of the 3-D volume as expected is dominated by noise with very few recognizable reflection events. Extensive testing of numerous processing steps and parameters only gradually improved the data quality. The fmal quality for the 3-D volume becomes significantly better only after the iterative and collective application of optimal parameters for a suite of sound, albeit very fundamental, algorithms such as refraction statics, deconvolution, residual statics, random noise attenuation, DMO, and migration.

The processing of the extremely treacherous data in the Val Verde Basin didn't follow a straight path and was preceded by many failures. Any mishap during the long journey of processing optimization could have led to much inferior outcome. Frequent communication and quality controls, particularly at key junctures of the processing flow, between Mobil and Western Geophysical were instrumental in arriving at the optimized processing steps. Persistence, meticulous testing, and experience based on solid processing algorithms were proven to be absolutely essential in the unqualified processing success for one of the most challenging seismic surveys.

INTRODUCTION

A large part of the Val Verde Basin of west Texas is covered with the Edwards limestone. Karsting and erosional processes have created a landscape of mesa, valley and rough slopes in between. Cavities within the limestone have been documented to exist extensively throughout the entire area. Traditional seismic data has been either totally useless or barely interpretable at best. Exhaustive studies in the past few years have demonstrated the main cause of poor seismic data is due to scattered noise from the karsted limestone at the surface.

The Brown Bassett gas field is located in the northwestern Val Verde Basin (Figure 1) where karsting is well expressed with several hundreds of feet of elevation relief between the mesa and valleys. Although there are a number of previous 2-D seismic lines over the field, poor data quality and the 3-D structure attributes at depth evidenced from wells have diminished the value of most, if not all, of the 2-D seismic data. Field development requirements dictated that a 3-D seismic image must be obtained for the highly faulted heterogeneous reservoir.

In spite of the well known seismic data problems, a 3-D survey was recommended for effective field development. The survey was completed in early 1995 and judicious processing didn't begin until July when Mobil realized the difficulty of processing data with so much overwhelming amount of scattered noise. Many of the processing steps such as deconvolution and statics have the underlying assumption of dealing with signal, however, our data is mostly noise, especially scattered noise which the CDP stacking process can't do much about it. Any improvement during the pre-stack steps not only requires extreme optimal selection of parameters but also needs a good overall processing strategy. This paper intends to share our experiences and precious success in this regard.

SURVEY DESCRIPTION

The surface coverage of approximately 70 square miles is shown in Figure 2. Sources are basically unbricked straight lines perpendicular to the north-south running receiver lines. Due to the severe topographic relief and obstructive limestone boulders on the slopes, offsets, line bends, and breaks happen often. It is hard to maintain rigorous surveys for good CMP clusters in the bins. CMP smearing as we discovered later in processing turns out to be much more than that from all other land 3-D surveys we previously evaluated. Rough slope surfaces prevent vibrator access. To maintain uniform coverage, surface dynamite, Poulter, was the only possible alternative to make up about 30% of the area where vibrators have access problems. Several area1 patterns for the Poulter source were tested and deployed mainly on the rugged slopes.

1) Strong communication effort between Western Geophysical and Mobil, particularly at key junctures of the processing flow.
2) A sense of commitment by both companies to succeed.
3) Both companies were willing to make mistakes and admit them.
4) A strong sense of scientific prowess from both companies.
5) Frank technical discussions between Western Geophysical and Mobil. Both sides listened to each other.
6) Western Geophysical was keenly aware of Mobil's business needs and priorities..

ACKNOWLEDGMENT

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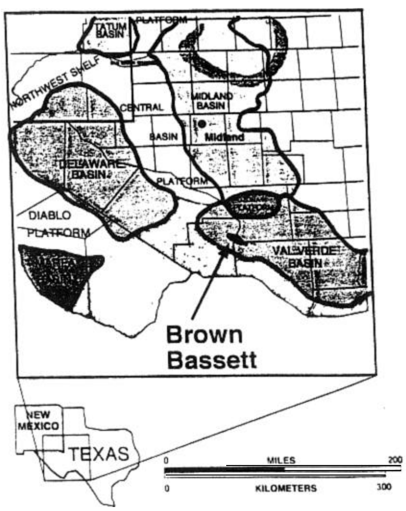

Figure 1. Location Brown Bassett gas field in the Val Verde Basin

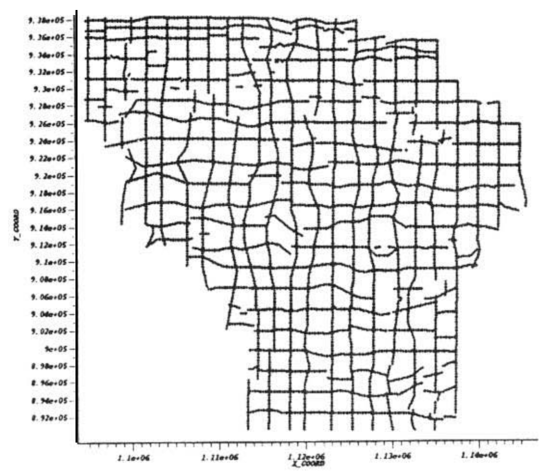

Figure 2. 3-D seismic survey area showing irregular source (E-W) and receiver (N-S) lines.

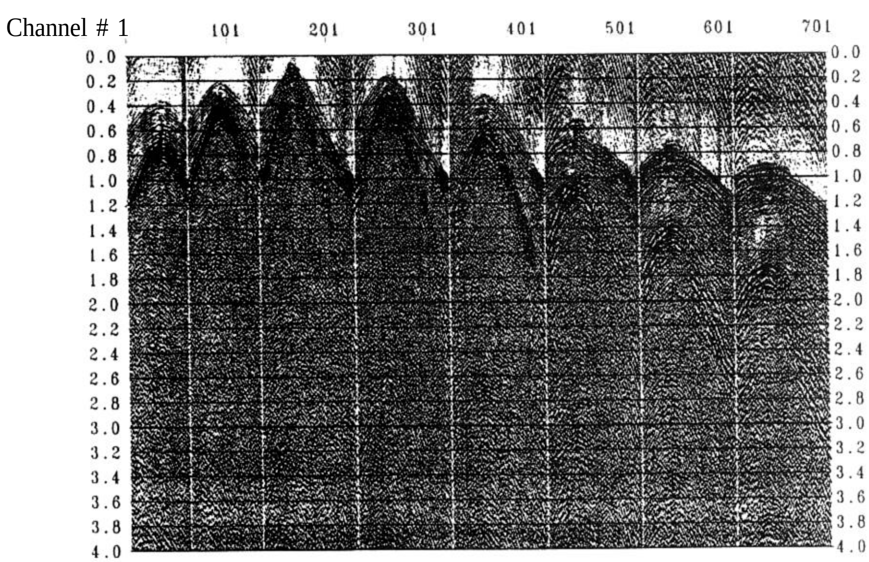

Figure 3. Typical shot record of the 3-D survey showing poor quality with severe scattered noise

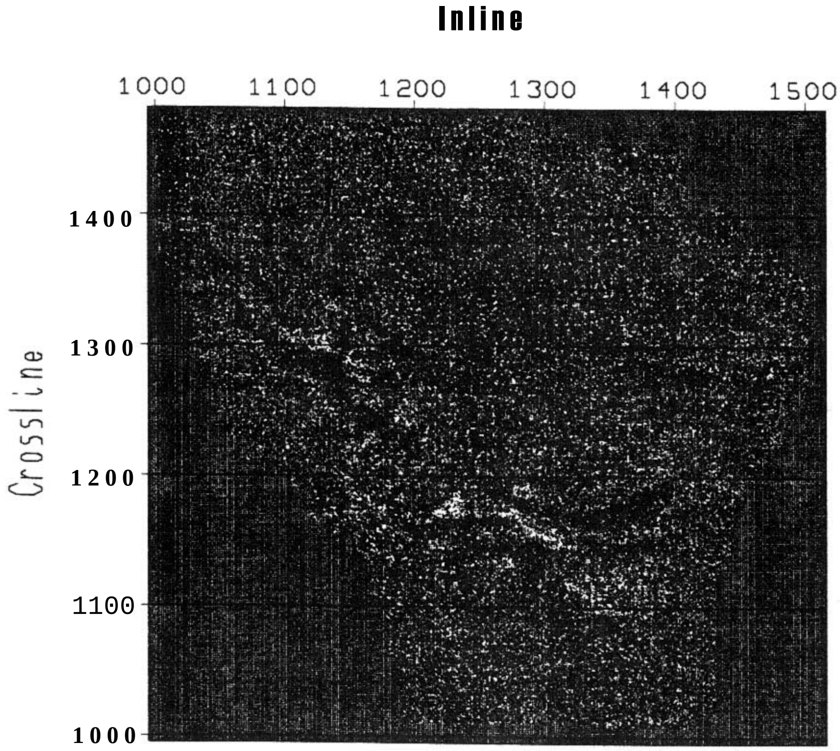

Figure 4. Time slice at 1920 ms extracted from 3-D stacked volume without optimized processing steps.

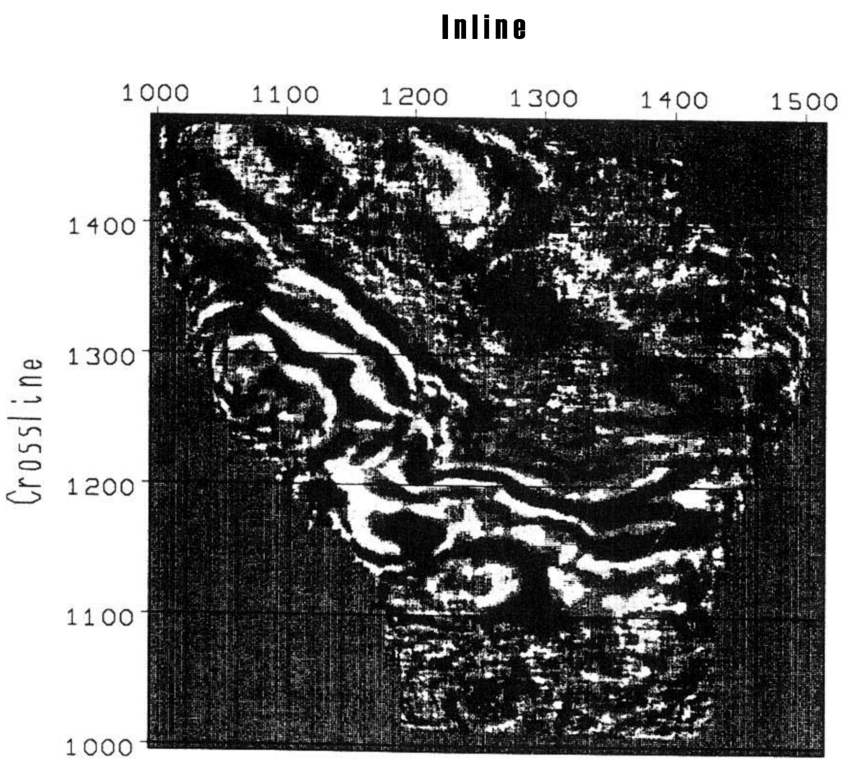

Figure 5. Time slice at 1920 ms extraced from 3-D migrated volume after applying optimized processing steps

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The I/0 System One was employed as the recording system in the field with a maximum number of 1200 channels. Source and receiver arrays had to be optimized for terrain and statics considerations. A typical swath consists of ten receiver lines with a maximum offset of about 15,600 feet. The basic design philosophy is to maximize imaging aperture and sampling without too much emphasis on noise attenuation which we felt could be dealt with later in processing as described in the following.

PROCESSING STEPS AND RESULTS

A typical shot record as seen in Figure 3 contains no recognizable reflection event by any stretch of imagination. Trapped refractions, ground rolls, and most importantly the scattered noise thereof are the overwhelming energy in the shot record. Due to such extremely poor data, all quality controls were based on results after stack, and in some cases, migrations. The overriding concern was that no process could degrade the previous migrated image. As with all other successful processing projects, attention to details and extensive quality control proved to be the keys to successfully processing this survey. Mobil supplied velocity functions derived from previous 2D lines and sonic logs available in the area. Velocity analysis was tried after refraction statics, residual statics, and with DMO monitors. Semblance programs were tried with no usable results. Constant velocity stacks were run with only poor results. Crossline CDP's were combined and the constant velocity stacks were rerun. The resulting velocities were much more pickable, but the original velocities still proved better.

Refraction statics, in this area of low quality fast breaks, was recognized very early as a critical first step. Traces with short offsets showed shingling first arrivals, only traces with an offset greater than 6600 feet seem to contain consistent first breaks. All picks were made at the fast high amplitude positive lobe. There was no attempt made to pick the Poulter sources differently. Several attempts were made through the refraction statics program with varying parameters. The weathering velocity in the model was tested with several constant velocities and with spatially varying velocities from an independent refraction survey. Several other parameters were tested including a time correction for the Poulter pick times. The final solution incorporated a variable weathering layer velocity but no additional correction for the Pouter data.

Prior to deconvolution, an adaptive monochromatic noise suppression program to remove 60 hertz power line noise was run, a trace balance was applied, and an offset-consistent, time-variant scalar was applied. A source, receiver, and offset consistent deconvolution was then applied with a long operator length, Western's model-based wavelet compensation was calculated for both a vibrator source and an impulsive source. They were applied to the vibrator and Poulter sources respectively. A deterministic approach to phase matching was also investigated comparing separate stacks of Vibroses data and Poulter data but no consistent phase correction could be determined for the entire survey.

Residual or reflection statics are significant and yet very difficult to obtain due to the poor S/N in the data. The problem was creating the correlation model from stacked data which at this point had very few reflection events. Several methods of model building were used including the use of Vibroses data only. This was intended to create a Vibroses model and calculate a static shift to correctly align the Poulter to the vibrator data. The results showed significant improvement, however, when a second pass was attempted, the results degraded. Enhancement techniques were then applied to build better correlation models. In addition, a cascaded approach was found to be quite successful. The second attempt of residual statics using the cascaded approach with enhanced model provided another significant improvement on our way to the DMO processing.

Random Noise Attenuation or F-XY deconvolution after DMO enhanced the signal prior to migration. The migration used the Extended Stolt algorithm and a single time variant average velocity function. Radial Predictive Filtering (RPF) was applied to further improve the migrated volume. By using weighted summation of adjacent traces that have been time-variantly shifted to line up at the angle of maximum coherency, this procedure enhances the most coherent signal within a range of specified dip angles and suppresses the remaining noise in the migrated volume. Figure 4 shows a time slice extracted from the 3-D stacked volume which was processed without the benefits of optimized steps. The image quality looks poor and certainly not sufficient in delineating the reservoir. After applying all the optimized processing steps as discussed herein, the equivalent slice is from the fmal migrated displayed in Figure 5 for comparison which clearly shows the significant quality improvement and the interpretable image of the reservoir structure.

CONCLUSION

One of the most difficult 3-D seismic survey in the Val Verde Basin was carried out in spite of the high risks associated with the extremely noisy data. Exhaustive parameter testing based on solid algorithms prove to be absolutely critical in getting the interpretable data quality meeting geological objectives. In addition to the technical factors, the final results would not have been as successful without the following ingredients: