The Paradigm or the Process? An Ongoing Case Study Using Stretch Free Stacking

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Summary

A 2-D seismic line (and later a full 3-D survey) was shot over a set of spatially complex channel leads that were thought to be charged with both gas and water. The prospects being investigated suffered from spatial and temporal reservoir resolution problems as well as fluid risks. In the attempt to address these challenges, the seismic data was processed using a new algorithm that promised to handle the long offset information advantageously. In applying the new algorithm, an unusual amount of emphasis was placed on the velocity analysis and offset range of the data. In effect, a paradigm was grown around using the new algorithm effectively. Numerous versions of the data were produced as a result of the new paradigm and the emphasis that it brought to the pre-stack data. Both the process and the paradigm helped to identify a successful drilling location on the 2-D line. A 3-D survey was subsequently shot and processed with the same vigour. Numerous new prospects were identified on the 3-D survey, one of which could not have been identified without the Stretch-Free Stack (SFS[1]) and AVO analysis.

Introduction

The Cretaceous in Central Alberta, Canada, where this study focuses, contains a series of cross-cutting fluvial channels and marine sands. Both the marine and the fluvial facies have tight, low energy silt or shale fills as well as porous beaches or point bars with porosities over twenty percent. The thickness of sand in the regional facies tends to be on the order of a few metres thick, while the channel sands have much greater variability. The explorability of this area depends upon the ability of the seismic data to resolve the porous sands, image the breaks between the various sands, and to indicate the presence of hydrocarbons. These requirements are not always easy to achieve.

Theory: The Stretch Free Stack (SFS [1]) Process

Valuable information is contained in the data traces that are recorded with offset to depth ratios of greater than one. Most often this information is simply discarded with the application of a standard front mute for two principle reasons. Firstly, at the far offsets the delay times become non-hyperbolic and exhibit the classical 'hockey stick' effect after conventional two-term NMO is applied. Since this information can not be flattened it is not useful to include it in the conventional CDP stack so this data is often simply muted out. Secondly, even if the data can be flattened with the use of a higher-order NMO, there is still the problem of extensive NMO stretch effects that cause instability in the AVO/AVA inversion process.

Modern velocity analysis techniques have been utilized to solve the non-hyperbolic NMO problem; however, the NMO stretch problem is intensified because of the attempt to retain the very far offsets. Methodologies to enable subtle stratigraphic interpretations involve sophisticated techniques to remove noise from the deconvolution operator design to ensure optimal wavelet inversion and lateral wavelet stability. After taking tremendous care to preserve this wavelet information it is routinely stretched beyond recognition in the NMO process. The goal of NMO should be to convert a trace that was actually recorded at some offset X to a trace that would have been recorded at zero offset but that still contains the reflectivity information associated with the actual incident angle. To succeed, it must be understood that NMO is not a single valued problem. The wavelets overlap differently at the long offsets so they must be decomposed in a manner that would simulate the same level of overlapping that would have occurred if the trace were a zero offset trace. This problem led to the development of a technique called Stretch Free Stacking (SFS[1]).

The SFS method used in this study is described in greater detail in this year's convention paper "Stretch Free Stacking" by Stewart Trickett. As described in Trickett's paper the attempt to remove the stretch is through an inversion process with a highly specialized Radon Transform.

SFS Gathers

This method normally produces one trace inverted for each CMP gather. The algorithm may also be used to create local solutions for smaller offset ranges along the gather's velocity trajectories. This allows for the creation of pseudo gathers where the inversion has been applied over a series of overlapping offset limited gather traces. The resulting SFS gathers have a smoothed appearance, but retain the general AVO trend of the gather with NMO stretch effects minimized. The offset length used in the overlapping windows is important and is chosen to be short enough to retain the AVO information but long enough to yield a good inversion result. If the offset range is too short the inversion will be both unstable and the NMO stretch will not be removed. It should be noted that the sum of the SFS pseudo gathers will not yield exactly the same result as the standard global SFS method that produces one trace for each gather. With the ability to create SFS pseudo gathers comes the ability to create offset limited SFS products or even SFS gathers for AVO analysis.

The applicability of the SFS pseudo gathers is illustrated in figure 1 where the well log data from a well with a thin gas sand is used to create two Zoeppritz equation model gathers. The first model gather was produced with NMO and needed NMO correction for display. This gather suffered some relatively minor NMO stretch. The second model gather was created using a plane wave source, but with the Zoeprittz AVO reflectivity. This second gather represents an estimate of the "correct" AVO gather with no NMO stretch effects. Beside these models is displayed the SFS pseudo gather made from the first model. Much of the NMO stretch present in the first model has been removed. Note that although it does not look exactly like the second or "stretchless" gather, it is very similar. The match is not, however, perfect. Some of the differences between the SFS pseudo gather and the "stretchless" gather may be due to the lateral window size used in the SFS process.

Related Issues Involving Long Offset Information: The Paradigm

The inclusion of this new process in the workflow has forced a change in paradigm regarding the treatment of pre-stack data in the processing workflow. More attention has to be paid to issues such as modeling and removal of noise on the far offset traces; the picking of ETA and 'slow velocity' parameters for higher-order NMO; the picking of far offset mutes; the selection of subtle SFS[1] parameters; the use of traditional AVO/AVA related displays; and the integration of full AVO modeling to form an interactive feedback loop with the processing flow. Naturally, the interpreter tends to become much more involved in this type of interpretive processing than the traditional involvement when using conventional NMO plus stack.

2-D Case Study: Find the Break and Drill a Well

A 2-D line was shot over a channel sand prospect and processed in a standard manner. Two wells were drilled on the line, Well A and Well B (Figure 2). Each of well A and B encountered commercial gas over water, but with radically different gas/water contacts. From these different contacts it was concluded that a break must occur in the channel sand, but the location of that break was not clear. A new well (Well C) was proposed down dip of a possible break in the sand. The line was reprocessed in an attempt to more confidently define the break. The SFS[1] algorithm was employed along with the higher-order velocity analysis, and the careful, but aggressive mute picking that are part of the paradigm described above.

Figure 3 shows the optimal SFS[1] result. The break is more apparent than in the original processing. Numerous other processed results were produced, including results where the Stretch-Free paradigm was used without the SFS[1] process. Figure 4 shows a comparison of the target trough amplitude along the line for each version of the processed data. These changes are very apparent as measured (figure 4) but somewhat difficult to visualize qualitatively on the sections. All of the versions of the data have approximately similar amplitudes along the area of the line where the break is hypothesized. The original processing and standard (non Stretch-Free paradigm) reprocessing show a small amount of discrimination between the hypothesized break and the sands. The SFS[1] stack enjoys the best discrimination, but the conventionally stacked data that uses the Stretch-Free paradigm is almost as good.

After this work was completed, Well C was drilled. It was a successful, high rate, gas well.

3-D Ongoing Work: A New Prospect

A 3-D survey was later shot to pursue other leads in the area. The data was processed with the SFS[1] process and the Stretch-Free paradigm. AVO Fluid Factor analysis as well as near and far offset stacks were produced. Near and far offset stacks were also made using the SFS[1] algorithm.

The far offset SFS[1] stack illustrated in the amplitude map of figure 5b identified a new prospect (Well D) that was not apparent in the standard stacks of the data. Figure 5a shows the amplitude map of the standard stacking method that does not identify this prospect. Strong amplitudes are indicative of sand presence, and are colored white. Weaker amplitudes are dark. AVO Fluid Factor analysis was also performed on the data. Figure 6 compares the Fluid Factor map as created from standard gathers to the Fluid Factor maps created from SFS pseudo gathers. The SFS Fluid Factor map is much more optimistic than the standard one, and has a shape similar to the SFS far offset stack of figure 5a. Figure 7 compares the difference in east-west lines in these two data volumes. Well D is currently being evaluated as a potential new drilling prospect. If it is drilled, it will have been identified as a direct result of the SFS[1] process

Conclusion

It is clear that the 2-D seismic line's ability to resolve breaks in the target sand improved as a result of the special processing efforts. The SFS[1] method required further thought in regards to the moveout correction and the offsets to be stacked. The better mute and velocity analysis yielded the majority of the improvement to the data, with the SFS[1] stack producing what appeared to be the most discriminating result. A successful well (Well C) was drilled with greater confidence due to this work.

The SFS[1] process also proved useful on the 3-D survey; both for the new prospect that it uniquely identified and for the larger set of enquiries and products that its responsible use encouraged. At this time it is difficult to conclude how accurate the SFS gathers are compared to the correct answer, which we never know exactly. The prospect (D) that the SFS work identified is of great interest, but we should again be cautious in our conclusions. Further drilling in this area will hopefully shed more light on this exploration problem. Updated results may be available by the time of the convention. It is worth noting that the algorithm (and for that matter the case study example) is unique, while the paradigm is not. Since all tools may fail on any particular dataset, the detailed, interrogative, approach of the paradigm may be more universally applicable. Once again, a new technique has emphasized the necessity to look at pre-stack seismic data in a careful manner.

Looking Ahead: Beyond Research and Case Studies, When the Process Becomes Part of the Paradigm

The SFS method that was tested in this case study is not the only technique being presented at this convention that attempts to minimize the effects of NMO stretch in some way. Downton et al are also presenting a paper called "NMO, AVO, and the Stack" where they continue the exploration into the NMO stretch problem. NMO stretch, and its relationship to stack and AVO response has become an important issue in the quest to improve seismic processing and analysis. It is too early to draw conclusions on how much of an improvement that these various techniques will yield, or where they will be useful, but these papers are illustrating that the study is a worthy one. The Paradigm that we spoke of in this paper, or something very like it, will almost certainly become commonplace among geophysicists who are concerned with offset response. If the processes of minimizing NMO stretch continue to show their applicability, they may eventually be rolled into the generalized approach and become part of what will be a new and valuable paradigm.

References

Trickett, Stewart, 2003, Stretch Free Stacking, This convention

Downton, J., Guan, H., Somerville, R., NMO, AVO and stack, This convention

Special thanks are extended to the management of Ketch Resources LTD., and Acclaim Energy Inc., for their permission to show this data example.

SFS[1] Stretch Free Stack - Patent Application in Process

Figure 1: Comparison of Model Gathers. Left uses Standard NMO, Middle uses SFS, Right is the Plane Wave Solution. Tighter Trough at Far offsets Seen on SFS Gathers & Plane Wave "Stretchless"

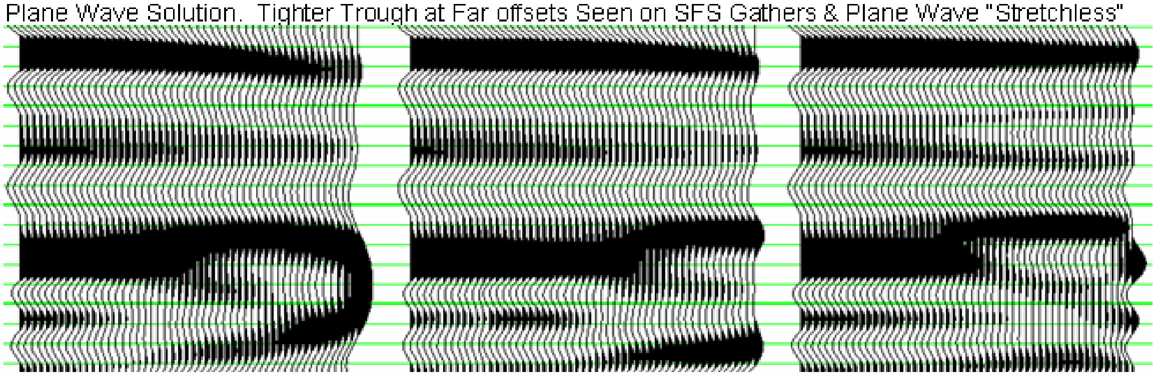

Figure 2: Standard Processing of 2-D Line.

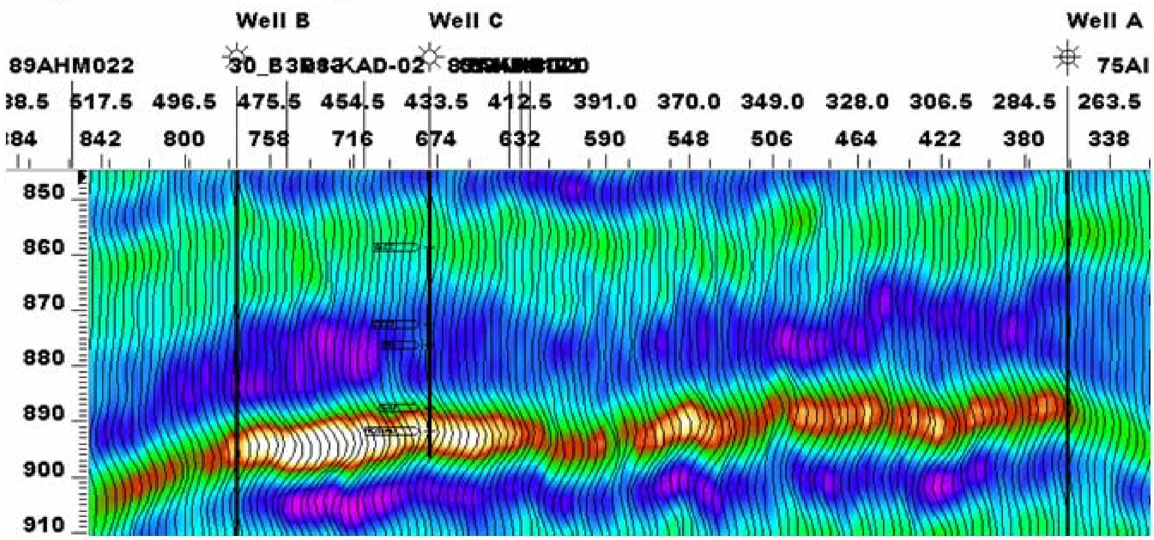

Figure 3: Stretch Free Stack of 2-D Line

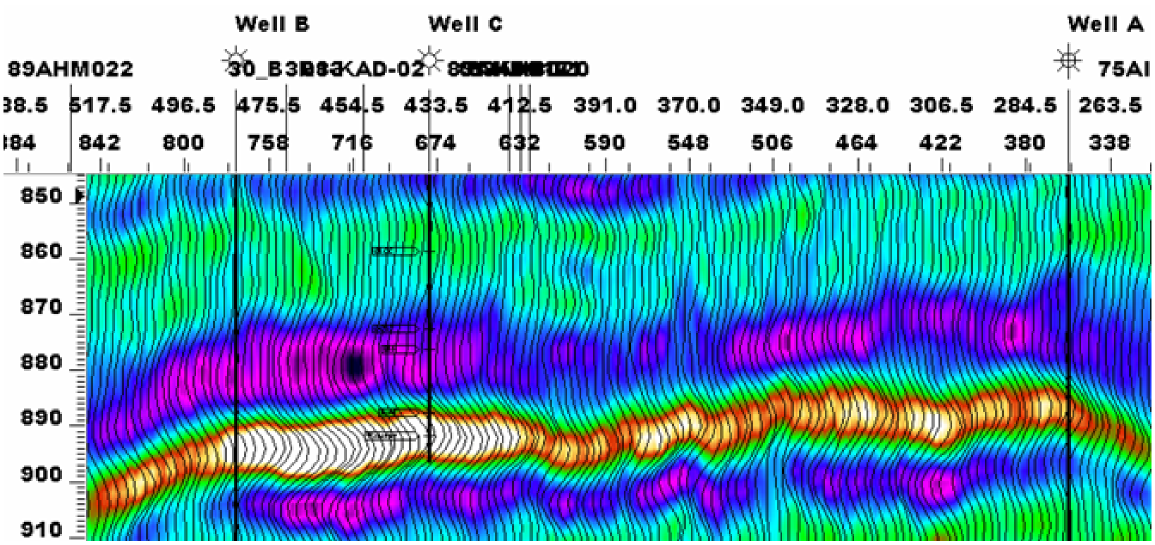

Figure 4: 2-D Line Illustrating Sand Level Amplitudes For Standard Stack, Stretch Free Stack and Stretch Free Paradigm (Without the Process)

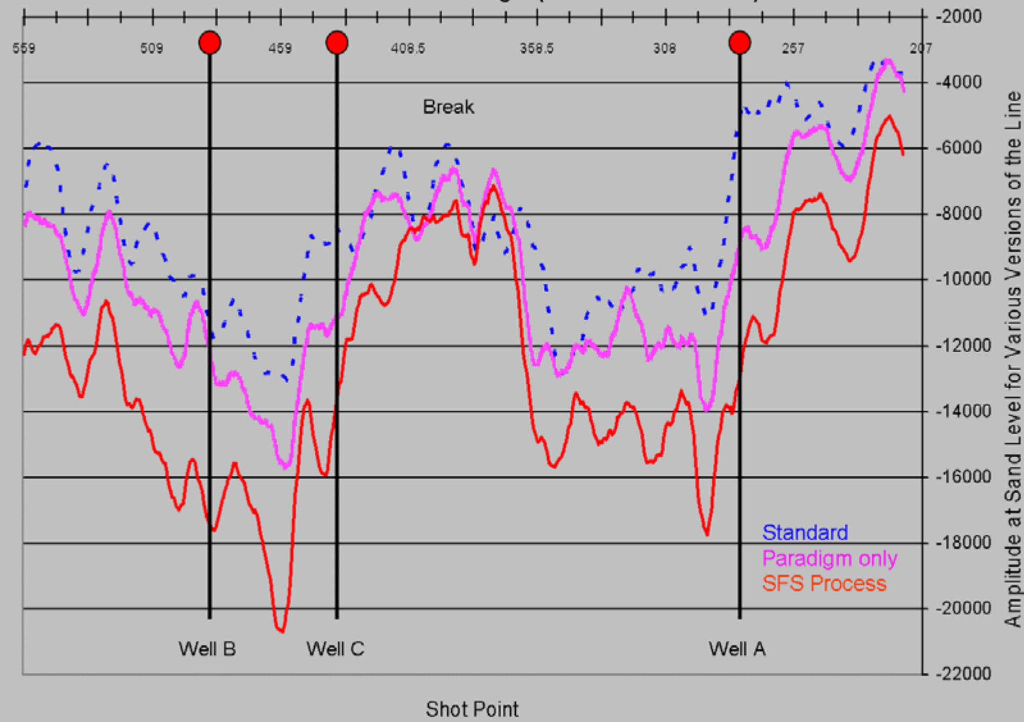

Figure 5a: Amplitudes Far offsets, Standard Stack

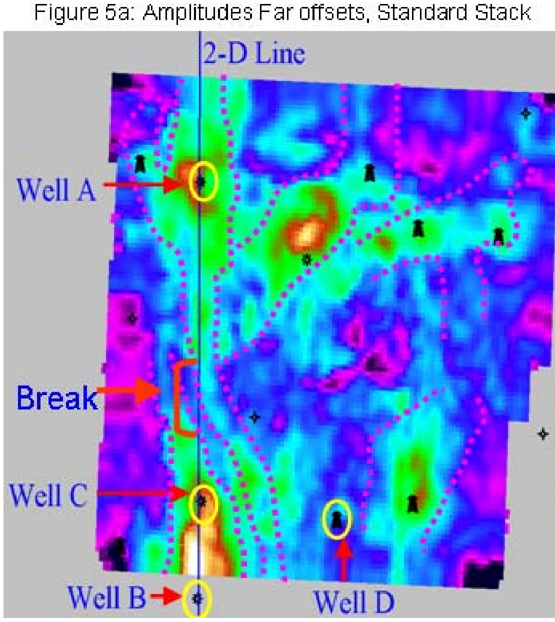

Figure 5b: Amplitudes Far offsets, Stretch Free Stack

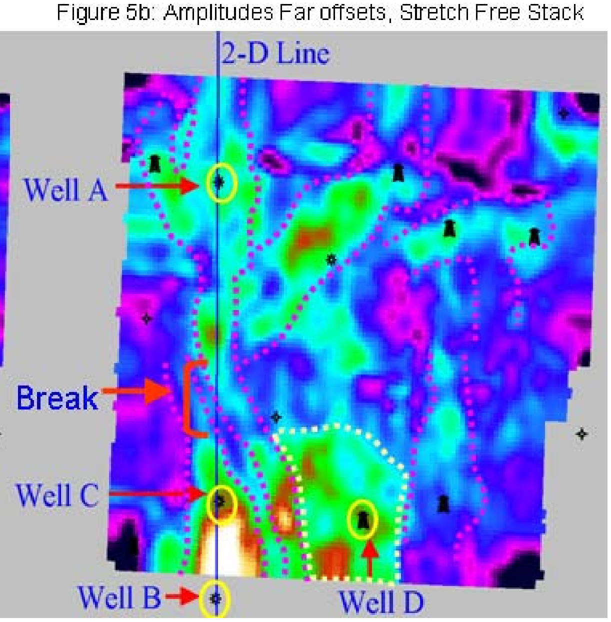

Figure 6a: AVO Fluid Factor, Standard Stack

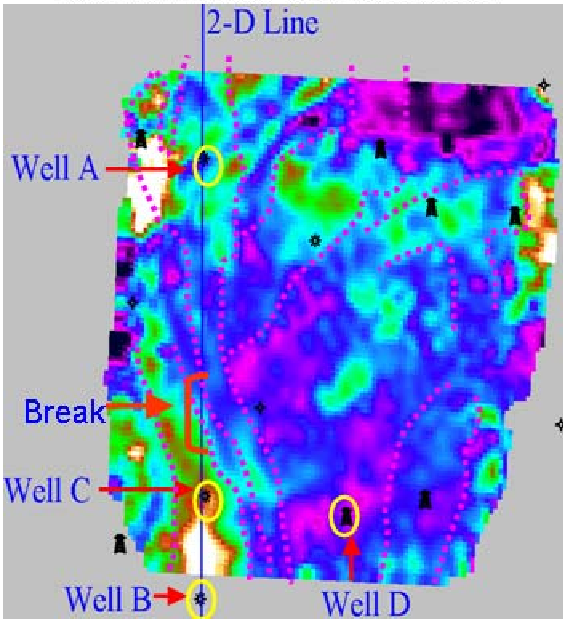

Figure 6b: AVO Fluid Factor, Stretch Free Stack

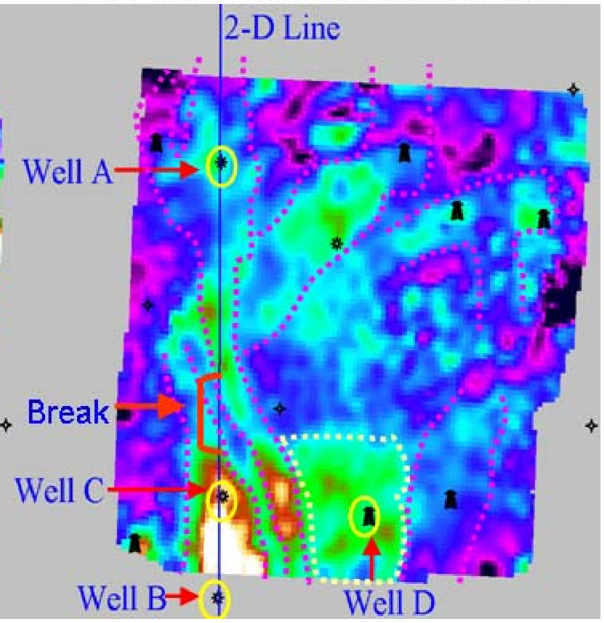

Figure 7: Comparison of East West Lines: Well C and Well D (Prospect)

Standard Stack with Stretch Free Paradigm