Improved 3D seismic processing leads to improved interpretation capabilities: example from the Fold and Thrust Belt of western San Joaquin Basin

William W. Bayne, Independent, Dalila Cherief, Shell Global Solutions Canada, Gary Myers, Aera Energy, LLC

Summary

A joint processing project between Aera Energy LLC and Shell Canada Ltd has taken place during the last five years merging seven surveys of various vintages along the west side of the San Joaquin basin. We show here how we accomplished substantial improvement over previous processing and how that improvement aided our interpretation efforts.

Introduction

The west side of the San Joaquin basin is an area of fold and thrust belts adjacent to the San Andreas Fault system. This area is traditionally an extremely difficult seismic data quality area due to the complex geology. These complexities challenge data quality by causing rapidly changing velocities, significant elevation changes, a highly variable near-surface environment (steep dips, rapid substrate variations), weak signal, strong noise (coherent and random), and enormous illumination challenges throughout the recorded data. The terrain makes for irregular shooting geometries and a mix of Vibroseis and Dynamite source types. Our dedication to improved results started in the field, continued through multiple versions of processing, and culminated as a better interpretation product.

Our improvements were the result of painstaking application of the basic upfront processing, such as, refraction analysis and static solutions, along with careful survey to survey matching, and noise attenuation. Many of these technologies were evolving over the duration of the project. Some included vendor software, some included Shell proprietary noise attenuation processes that needed refinement to succeed. Certain improvements resulted from meticulous, hard work, for instance, velocity picking in the PSI PSTM domain. This labor eventually paid-off a quantum leap in data quality and illumination. Further improvement was achieved by doing Pre-Stack Kirchoff Depth Migration.

All these efforts have improved our ability to make geologically sound interpretations. Even with these advancements, there are still areas where constantly evolving technology and technical applications could potentially continue to uplift the image. For instance, we believe another level of improvement is possible by eliminating migration artefacts.

Interpretations were done on several earlier versions of the data for business reasons and to help validate the processing. There is deformation through-out the whole area with deformation being the least in the East increasing to the West towards the San Andreas Fault. Data quality follows suit with the best data quality shallower in the Eastern portion of the merge, becoming unreliable in the Western most portions where the structures become complex. Dips in many areas can reach more than 70 degrees, which is almost always under-imaged on the seismic data.

Method

Our goal is to create a realistic representation of the complex sub-surface. Our data contains signal that is weak relative to the noise, mispositioned and indiscernible due to many complex factors. Contaminating the signal is intense noise both coherent and random. Careful attention to attaining some signal improvement at each step of the processing sequence allowed an additive improved result. The removal of noise without sacrificing signal also played a key role.

Processing strategy consisted seeking improvement in the basic processing sequences:

- Ground-roll, air-wave, oil-field noise attenuation, surface-consistent scaling in shot and receiver domain, and random and coherent noise attenuation
- Refraction – tomographic model building guided by geology and interpretation
- Survey Match
- Data regularization and proprietary noise attenuation processes.
- Velocity picking and model building guided by sub-surface control and interpretation
- Application of pre-stack signal enhancement technology after migration
- Switched from Time Migration to Depth Migration which yielded another increase in quality

Interpretation evolved as the data quality improved:

- Multiple interpretation versions created with each version of the processing, looking areas for prospective geometries and potential processing issues to feed-back to processing analyst.
- Early interpretation on time volumes were exceedingly difficult. A methodology using a velocity volume in combination with a dense well control helped to constrain the possible interpretations.
- Early interpretations on the time volumes lacked any meaningful deep events. The shallow data were discontinuous and did not image steep events. Thus, the interpretation had multiple fault blocks with faults that dangled
- Once greater continuity and improved deep data were achieved, we were able visualize a more synergetic less disjointed interpretation
- Certain areas were never fully imaged as hoped and remain a challenge for future workers

Examples

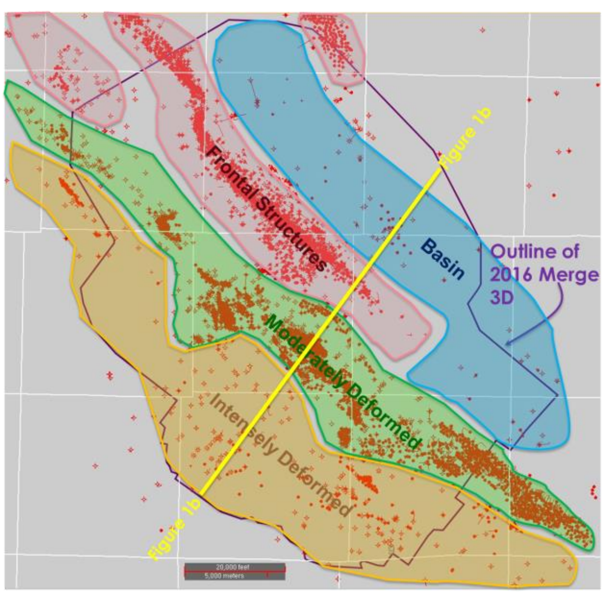

Figure 1a: Mp location of seismic example in Figure 1b on the west side of the San Joaquin Basin. Line crosses from the *Intensely Deformed* to the *Moderately Deformed* to the *Frontal Structures* and finally into the *Basin*.

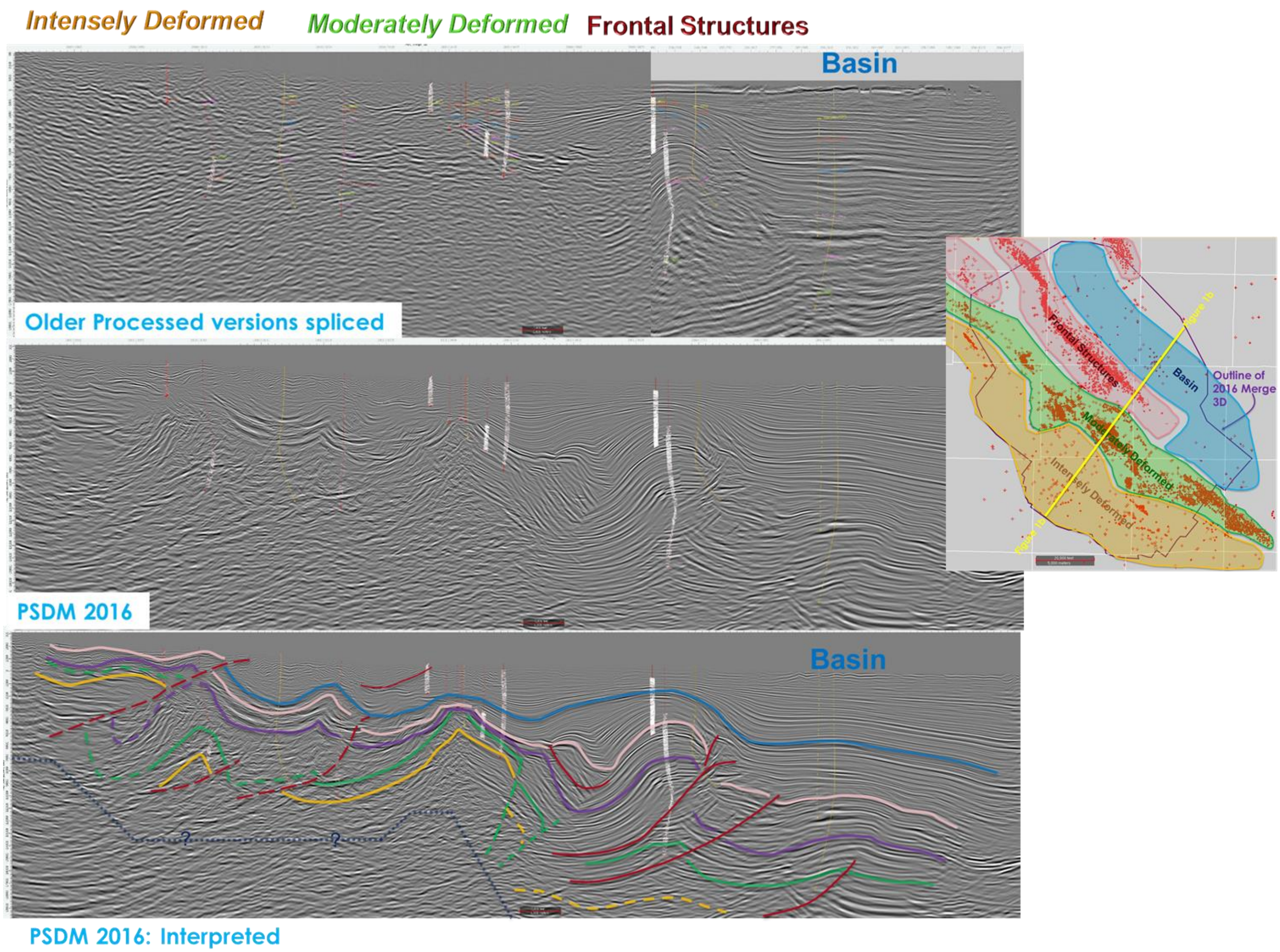

Figure 1b: Seismic line example showing data quality improvement across the fold and thrust belt into the basin with improved processing. An interpretation is shown that matches well tops and dip-meter readings.

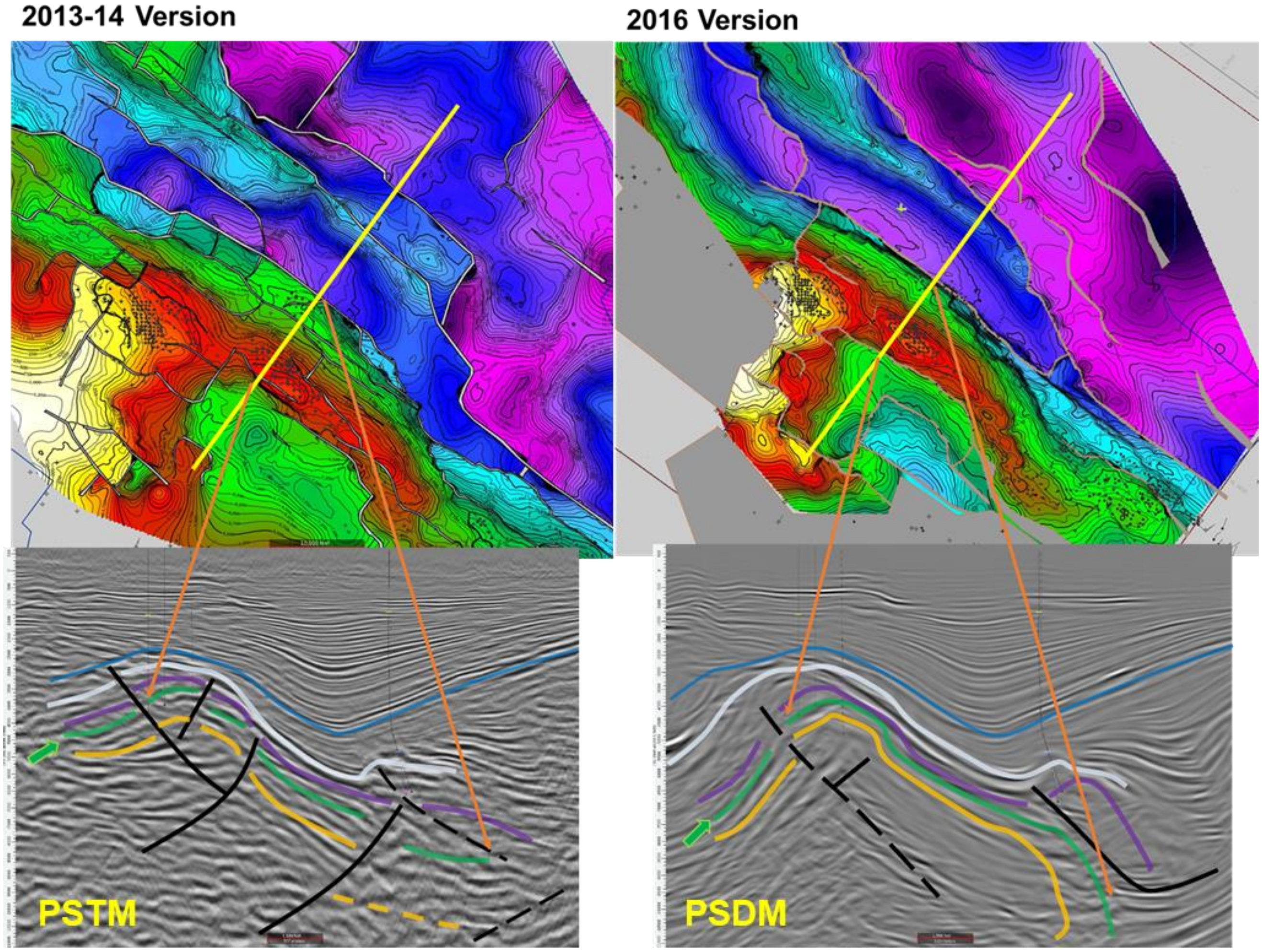

Figure 2: Improved quality of mapping from 2013 PSTM version to 2016 PSDM version. Note more faulting interpreted on older data set.

Conclusions

Diligent application of basic processing flows, along with some creative noise attenuation and signal enhancements, and has paid off in improved seismic data quality. This in turn led to a more constrained interpretation. Lessons learned from this project are directly applicable to other fold and thrust belt projects through-out the world. The potential for additional improvement in data quality exists. There are areas where further experimentation with new technologies, such as, migration artefact attenuation and increased migration velocity model resolution of small structures could make a difference.

Acknowledgements

Bonnie Jones, Peter Gagliardi, Karol Rohraff, Maggie Jiao, Ashley Leonard, Gary Zilik, Simon O’Brien, Johannes Grimm, Lisa Alpert, Sean O’Connor, Paul Webster, Chad Severson, Matteo Molinaro, Thomas Hauge, Tony Salem, Paul McColgan, Emily Fisher, and Dave Miner.