

Pitfalls in Rock Properties and Lithology Prediction in Dolomite

John D. Logel, Anadarko Canada Corp.



2004 CSEG National Convention

Abstract

Dolomite reservoirs are primary and attractive exploration targets throughout the western Canadian basin and stratigraphic column. To mitigate the risk and improve the chance of success seismic data has been used for decades to explore for these targets, first 2D data and now predominantly 3D seismic. Seismic data has limitations and ambiguities that have been stretched and in some cases blatantly abused. Seismic data were first used for structure and growth interpretation and mapping, later techniques to identify lithology, and porosity from seismic data helped to identify reservoirs. In recent years AVO and related techniques have been used to simultaneously predict lithology, reservoir and in some case fluid content. This paper will use some old theories, methods and new data and techniques to look at some of the pitfalls and false friends that can lead us to mis-interpret our data and potential anomalies. The integration of VSP, petrophysical logs and detailed investigation into multiples, imaging and attenuation effects will lead to a better interpretation and higher success rates.

Introduction

Seismic data has been a very powerful tool used in the exploration of reservoirs throughout the world and no less so in the western Canadian basin. Seismic 2D data criss-cross our countryside and now 3D data is commonplace throughout the exploration/production process. It does not come without a physical cost as well as a level of un-earned optimism and some complacency. In post-mortem disappointing well results and integrating the learning's from them some surprises and old 'foes' have shown up and will have to be overcome in the future.

Exploring for Dolomite reservoirs complicates this problem because of the usually deep objective, thin, (sub-tuning) thicknesses, low porosities, and high bulk and shear moduli. Table 1. shows typical reservoir and environmental rock properties.

Rock Properties

• Dolomite	• Limestone	• Shale
– 2.87 g/cc	– 2.71 g/cc	– 2.58 g/cc
– 7000 P m/s	– 6450 P m/s	– 5800 P m/s
– 3960 S m/s	– 3440 S m/s	– 2000 S m/s
– 20090 AI	– 17479 AI	– 15000 AI
– 11365 SI	– 9322 SI	– 5200 SI
– 1.77 Vp/Vs	– 1.88 Vp/Vs	– 2.9 Vp/Vs
– 95 Gpa Bulk	– 77 Gpa Bulk	– 21 Gpa Bulk
– 45 Gpa Shear	– 32 Gpa Shear	– 7 Gpa Shear

*AI Dolo with 6 % por = LS 10% por = Shale
Vp/Vs changes less*

This data shows that the contrasts are subtle but do exist, the integration of offset data to estimate VP/VS ratios could greatly aid in our exploration for dolomite and risk assessment of those prospects.

Method

Li et al, Rafavich et al, and Goodway et al. eloquently demonstrated the abilities to explore for these reservoirs and methods for identifying and differentiate them from there surrounding seals and regional rock. Several papers have recognized the need for detailed, non-distortive, high frequency and phase/amplitude controlled seismic processing. This paper will agree with these papers and only concentrate on seismic phenomenon that can distort and degrade these results, and lead to false anomalies.

The seismic data used in this area were processed in a controlled amplitude/phase methodology, with Pre-Stack Time Migration, 2 passes of detailed geologic consistent velocities, and 2 passes of state-of-the-art de-multiple. The data were then analyzed in an AVO workflow that included IP and IS inversion and transform to LMR attributes.

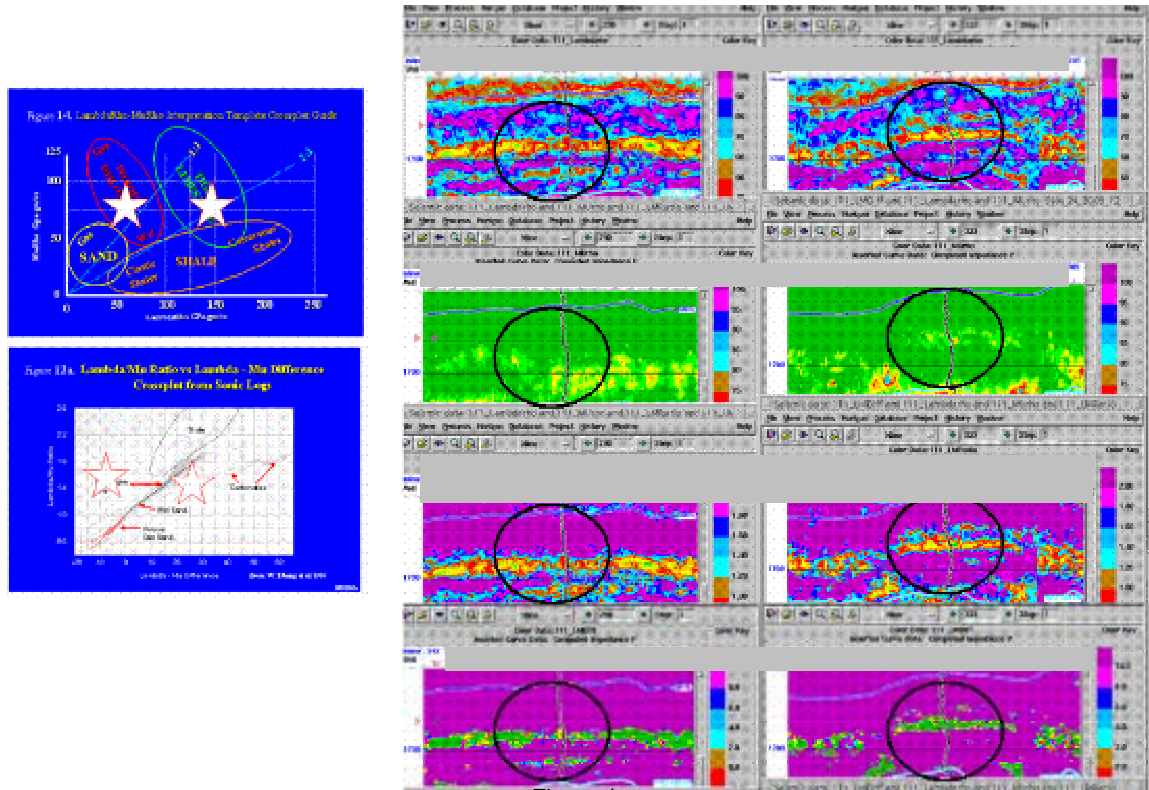
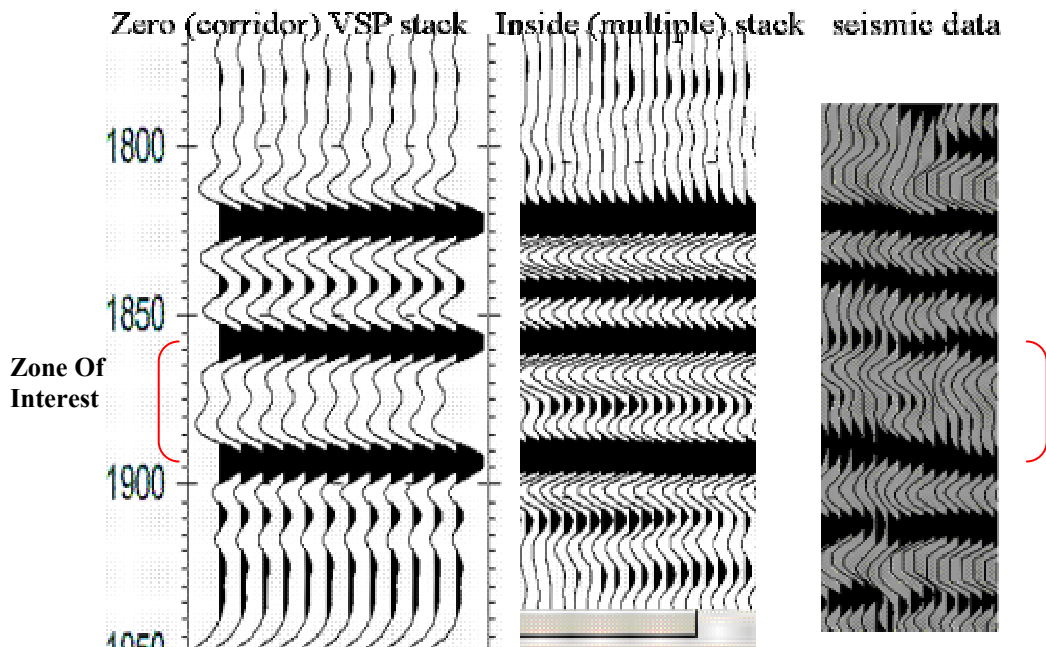


Figure 1.

Figure 1. shows composite views of LMR attributes over a known dry well that encountered only regional shale on the right, along with a prospect on the left. The low lambda and Mu values as well as the low lambda/mu ratio leads to the conclusion that this prospects appears to have a very high chance of success of encountering dolomite with porosity and indications of being gas filled.

Post drill analysis for the well shows a tight limestone well with no indication of dolomite or porosity. The petrophysical logs from the well are excellent quality with very few washouts, but do not tie the surface seismic with a very high confidence. Why???

VSP data were collected in the well, and processed to understand and reduce the differences between the wireline logs and the surface seismic. Figure 2. show the detailed results of the VSP and the surface seismic.



Figure

In comparing the sections in figure 2, we see that the zero offset VSP does not tie the surface seismic with a great amount of confidence. There appears to be strong variations in amplitude in the zone of interest as well as an apparent phase difference. This dataset was processed with great care to preserve and control the phase and amplitude. The final phase matching to known geologic tops of predictable acoustic properties was carried out throughout the section but still there is a problem. With greater investigation the inside stack appears to tie better from an amplitude perspective, the phase also appears to be distorted but to a much lesser extent. Or is it? A well shows that the phase will have to be rotated between 45 and 90 degrees for the greatest correlation. This is in direct contradiction with the pre-drill shallow phase matching and exhibits a strong time varying effect. The easiest explanation for this is attenuation or 'Q'.

The concept of attenuation 'Q' has been around for years and numerous papers have been written on the time varying phase effects of shales and anisotropic rock on seismic waves and apparent phase at reflectors. Rio et al. demonstrated the effects of lamination of varying thickness to wavelength proportions on the phase and amplitude of the propagated wave, and Tonn, compared different methods and their overall correction of the seismic data. Figure 2 shows a modeled theoretical effect using a constant high Q (non-attenuative) and a variable Q, on the amplitude and more importantly the phase of the data. There is little effect at reflection 1 where the amplitude and the phase are virtually equal and the phase is unaffected. At reflection 2 after propagating through the laminated anisotropic section the amplitude and the phase are distorted quite drastically.

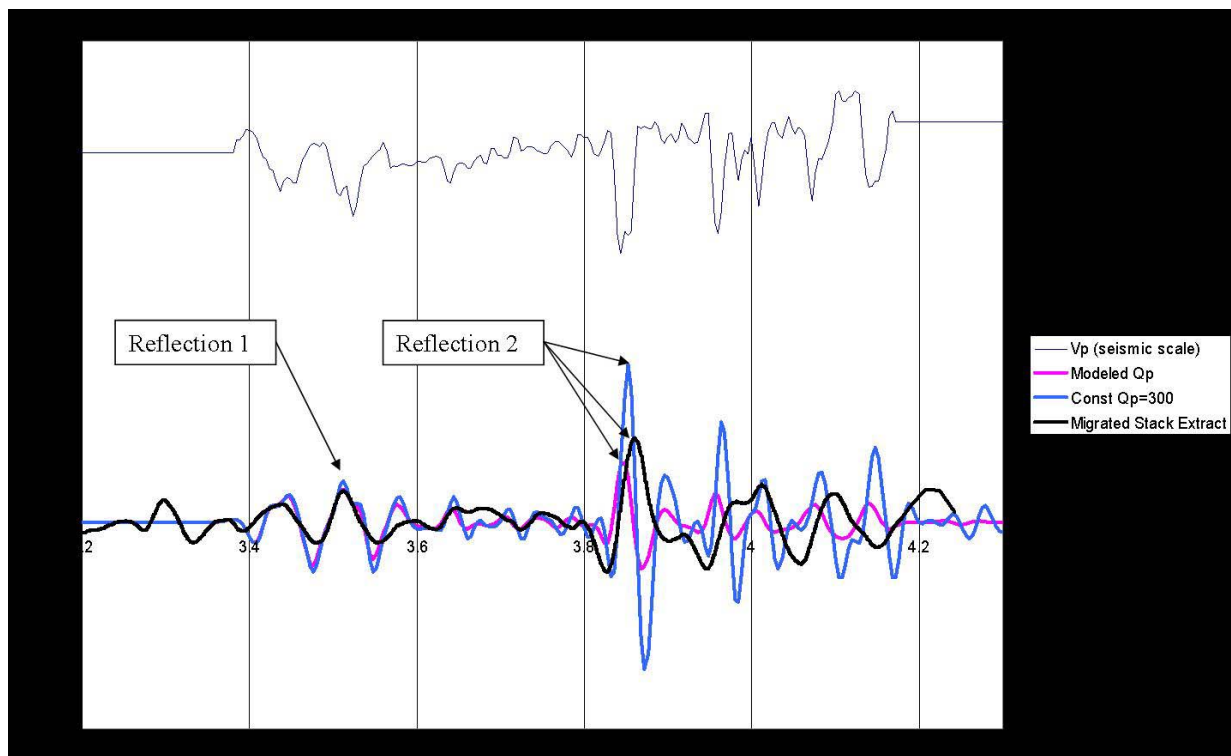


Figure 3.

To compound this effect with additional contamination by higher order, short period multiples, with little residual moveout, could, and have led to erroneous interpretations. The phase shifted multiple ridden zone can take on the appearance of perspective reservoir with porosity and desired fluid fill.

Conclusions

Seismic data can be degraded and contaminated to lead to incorrect interpretations. Detailed analysis, investigation of potential seismic contamination as well as full integration of a robust and sound geologic model can mitigate some of these effects. The correction for these distortions and "noise" is quite straight forward and can be carried out in most processing centers but must be understood and quantified through VSP data and models. De-multiple is critical to the preservation of the geologic information within our seismic data and must be applied in a logical and informed manner to remove the multiple without affecting the primary amplitude or phase. Attenuation can be determined from wireline logs and VSP data, or from other methods derived from the seismic data only, and again, must be applied with care and quality control.

This paper has demonstrated the effects of these potential distortive processes on prospecting for dolomite in the western Canadian basin. The understanding of them, proper correction for them and interpretation with them in mind can help to mitigate risk in these deep reservoirs but the caveat must be stated, the mis-use or abuse of these correction, or the generic application of these results can and will be disastrous.

References

- Goodway, W., Chen, T., and Downton, J., 1997, Improved AVO fluid detection and lithology discrimination using Lamé's petrophysical parameters, CSEG Recorder, 22, No7, 3-5.
- L, Y.Y., Goodway, W., and Downton, J., 2003, Recent advances in application of AVO to carbonate reservoirs: case histories, CSEG Convention abstracts.
- Rafavich, F., Kendall, C. H. St. C., and Todd, T. P., 1984, The relationship between acoustic properties and the petrographic character of carbonate rocks, Geophysics, 49, 1622-1634.
- Rio, P, Mukerji, T., Mavko, G., Marion, D., 1996, Velocity dispersion and upscaling in a laboratory-simulated VSP, Geophysics, 61, 584-593.
- Tonn, R., 1991, the determination of seismic quality factor Q from VSP data: A comparison of different computational methods. Geophysical Prospecting, 39, 1-27.

Acknowledgements

We would like to thank Tim Hughes and Dominion Canada, and Anadarko Canada Corporation for permission to publish this paper. We would like to thank ARCIS corporation for permission to use there data. We would also like to thank Rick Kuzminski and Computlog for there VSP, help and guidance.