# Simultaneous AVO Inversion: Quality Control and Interpretation

John Pendrel*
Fugro-Jason, Calgary, AB, Canada
jpendrel@fugro-jason.com

Mixed-Norm Simultaneous Inversion has become a stable mature procedure since its introduction several years ago. Along the way, we have identified several important quality control issues which we feel should play an integral role in any reservoir characterization project. The more important ones include:

- Partial Stack alignment
- Wavelet Scale refinement
- Parameterization
- Low Frequency Imprint
- Bias
- Validity
- Stability
- Noise Attenuation

Figure 1 is a demonstration of the importance of alignment. P Sonic, S sonic and Density logs have been used to build a synthetic gather to 30 deg. The seismic band covers 10-80 Hz., except on the last two traces where 10 Hz is missing on the high end. The Figure shows the results of successive Simultaneous AVO Inversions to P Impedance and Vp/Vs. The last two traces have been shifted by amounts ranging up to 2 ms (1 sample). In each panel, a smooth version of the logs is superimposed upon the inversion. The results demonstrate that small shifts of ¼ sample can be tolerated. Beyond that, deterioration of Vp/Vs becomes significant and unacceptable above shifts of 1 ms (½ sample).

In Figure 2, we show the low frequency contribution in Vp/Vs from an AVO Inversion of the Blackfoot data. It was constructed from interpreted horizons and well logs. A simple interpolation between the wells was used. The well locations are indicative of valley development and the presence of reservoir sandstones. There is a clear imprint of Vp/Vs in the low frequencies which lie below the band recorded by the seismic field programme. It is vitally important to recognize the bias that the lower frequencies can add to an inversion. Conscious decisions need to be made regarding the handling of the missing information. Possibilities include using only a single well in the low frequency model or perhaps using a more sophisticated modelling procedure. This could include varous geologic information or assumptions.

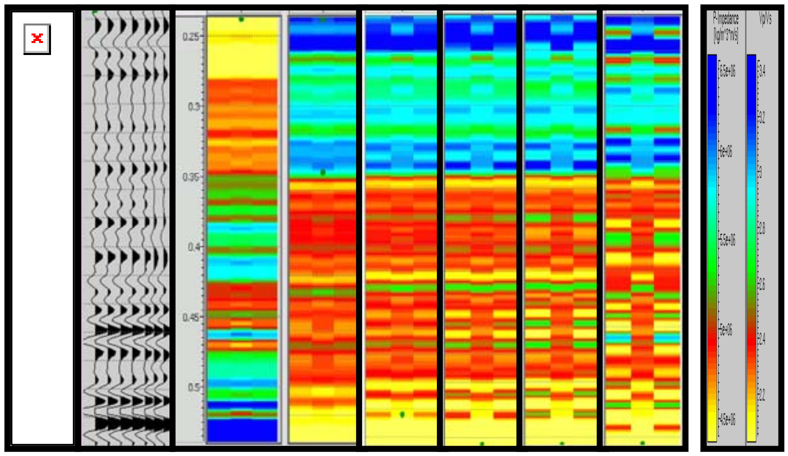

**Figure 1.** The logs in the first panel were used to compute the synthetic gather to 30 deg. AVO Inversion to P Impedance and Vp/Vs was done using an 80 Hz wavelet. The third panel is P Impedance from inversion with the smoothed P Impedance log overlain. The other panels are Vp/Vs, first with aligned gathers and then with successive shifts of ¼ sample applied to the last two traces in the gather.

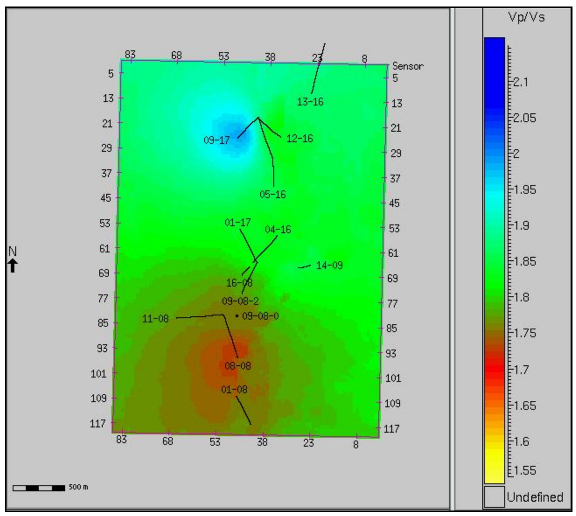


**Figure 2.** The figure shows the contribution of the low frequencies (<10 Hz) from modelling which are needed to complete the band below that of the seismic. There is a clear imprint of the gas-charged reservoir in the South which will bias the AVO inversion.

In Interpretation, good use can be made of cross-plotting tools. Reservoir facies which appear distinctive and anomalous on log cross-plots shoud behave in exactly the same way when cross-plotting the resuts of inversion – albeit in a narrower band.

However, there is more that can be done. Using Bayesian inference, and the statistics of facies from logs, the outputs of inversion can be interpreted in terms of the probabilities of existence of any of the facies. From these, most-probable facies volumes can be constructed. Figure 3 shows the results of such an analysis on the Blackfoot data. It shows an arbitrary line through the probability volumes for sandstone and limestone. We can see the three-valley system clearly in the sandstone figure and the roughness of the Devonian unconformity in the limestone panel. Figure 4 shows the same line through the most-probable facies volume.

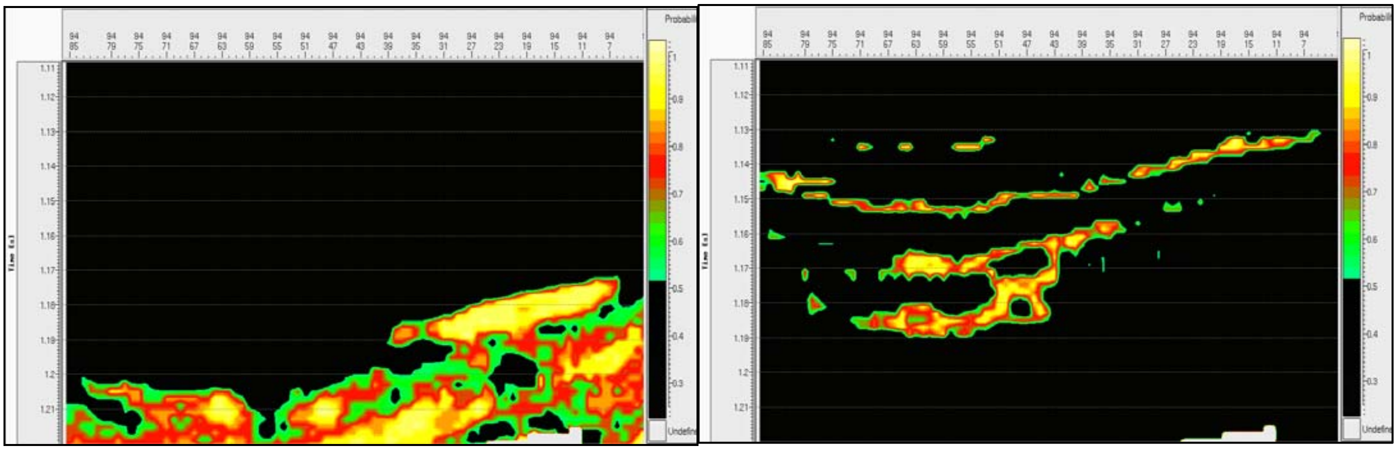

**Figure 3.** The figure shows arbitrary lines through the probability volumes for sandstone (left) and limestone (right). The inputs were P Impedance and Vp/Vs from Simultaneous AVO Inversion. Note the definition of the roughness of the Devonian unconformity in the right panel and the imaging of the upper and lower sandstones in the left panel.

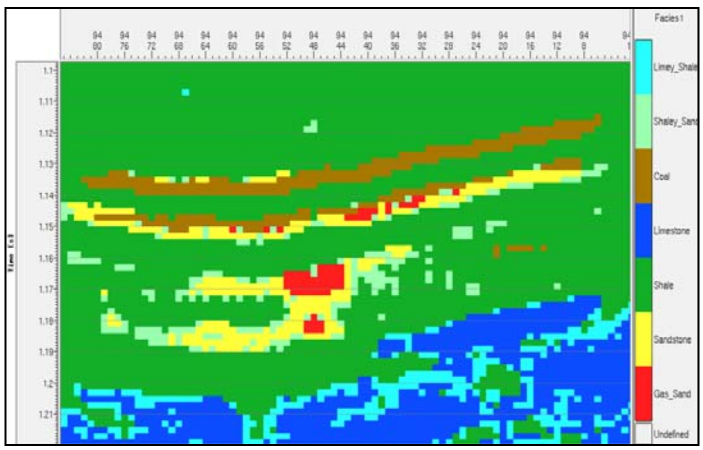


**Figure 4.** This is a line through the most-probable facies volume determined from the individual probability volumes for the entire set of facies.

In the LMR (Lambda, Mu, Rho) domain, facies distinctions can often become more clear. We find it useful to make cross-plots of MuRho vs LambdaRho for the outputs of the AVO Inversion and then superimpose upon them, lines of constant Vp/Vs or Impedance.

**Acknowledgments**

Seismic Data: EnCana Corp.

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