Experiments with AVO Inversion

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2005 CSEG National Convention

Introduction

AVO (Amplitude Versus Offset) processing and analysis has evolved significantly since the early 1980's, since Shuey's classic paper. The industry has moved past simple gradient analysis and brought AVO into the world of inversion. Analogous to the more familiar full-stack inversion, explorationists are now free to view the Earth as layers rather than as elastic layer boundaries. Volumes of P Impedance, S Impedance and density (with large enough angles), can be inverted from PP reflection data. Conversion to other properties such as Vp/Vs, Poisson's Ratio, LambdaMu and RhoMu are easily done. Joint inversion of PP and PS (or indeed, any other mode) are possible. In this paper, we pause to consider some of the inputs to AVO Inversion and the importance of inaccuracies in these inputs upon the final results. In particular, we will look at bandwidth and its variation with offset and time alignment (NMO).

In our experiments, we will use the method which has come to be known as *Simultaneous AVO Inversion*. Its inputs are partial angle or offset stacks and logs. Its outputs are volumes of P Impedance (Ip), Vp/Vs and Density. When the high angles necessary for density determination are not present, density becomes constrained to follow the character of the P Impedance. At least two partial stacks must be available. In practice, more is better and as many as twelve have been used. For each partial stack, a unique wavelet is estimated. *EarthModels* of Ip, Is and Density are also computed from the available logs. As in post-stack inversions, only the low frequencies from these models are used to complete the low frequency band of the final inversion. They in no way affect the higher inversion frequencies and all the wells can be effectively considered to be "blind". All the models, all the partial stacks and all the wavelets are input to a single inversion procedure.

Method

We have recently completed several experiments with synthetics. The idea was to try and replicate a real AVO inversion situation. A log set which included P Sonic, S Sonic and Density from an Alberta Cretaceous play was used to create angle synthetics using typical wavelets which potentially contained offset-dependent bandwidths. Full-Zoeppritz modelling was used. Low frequency models of P Impedance, Vp/Vs and Density were made from the same logs to complement the band in the inversion below that of the wavelet. The AVO inversion of the synthetics should match the logs (hi-cut-filtered to the upper frequency of the wavelet) when the noise is low and large enough angles have been used to capture the AVO effects. The importance of alignment can be checked by placing deliberate misalignments in the angle gathers. The wavelet-bandwidth effects could be determined by using constant wavelets with offset, when the synthetics contained angle-dependent degradation.

Results

Figure 1 shows some of the results of experiments with wavelet bandwidth. In the figure, are the wavelet and three coloured panels representing P Impedance, Vp/Vs and Density. In each, the background is the AVO Inversion with the appropriate high-cut-filtered log superimposed. Also shown are the input logs and the synthetic angle gather (0-30 deg) derived from them along with the wavelet. The band of the wavelet is 15-80 Hz, except for the last two traces where it is 15-70 Hz. The P Impedance match between the AVO inversion and the log is very good. The Vp/Vs match has some problems. The density match has difficulties too, but for different reasons. Thirty degrees is not enough to resolve density from PP data. In Figure 2, the correct far-offset wavelets have been used. The Vp/Vs agreement has improved significantly while, as expected, the density problems remain. We will show that they can be resolved by the use of larger angles. In Figure 3, a 0.5 ms shift has been applied to the last two traces in the angle gather, thus creating some degree of misalignment. The Vp/Vs inversion has been degraded, especially near the more subtle reflectors.

Conclusions

Our experiments show that small changes in wavelet bandwidth with offset can have a significant affect on the estimation of elastic parameters and should be taken into account. In addition, misalignments of one ms or less are also important and need to be addressed. Parenthetically, we note that many of the AVO effects are subtle and their manifestation in seismic reflection gathers often appears to give a visual misalignment.

Acknowledgments

We gratefully acknowledge permission to use the log data by a company which wishes to remain anonymous.

References

Pendrel, J.V. and Dickson, T.D., Simultaneous AVO Inversion to P Impedance and Vp/Vs, 2003 CSEG Ann Mtg. Abs.

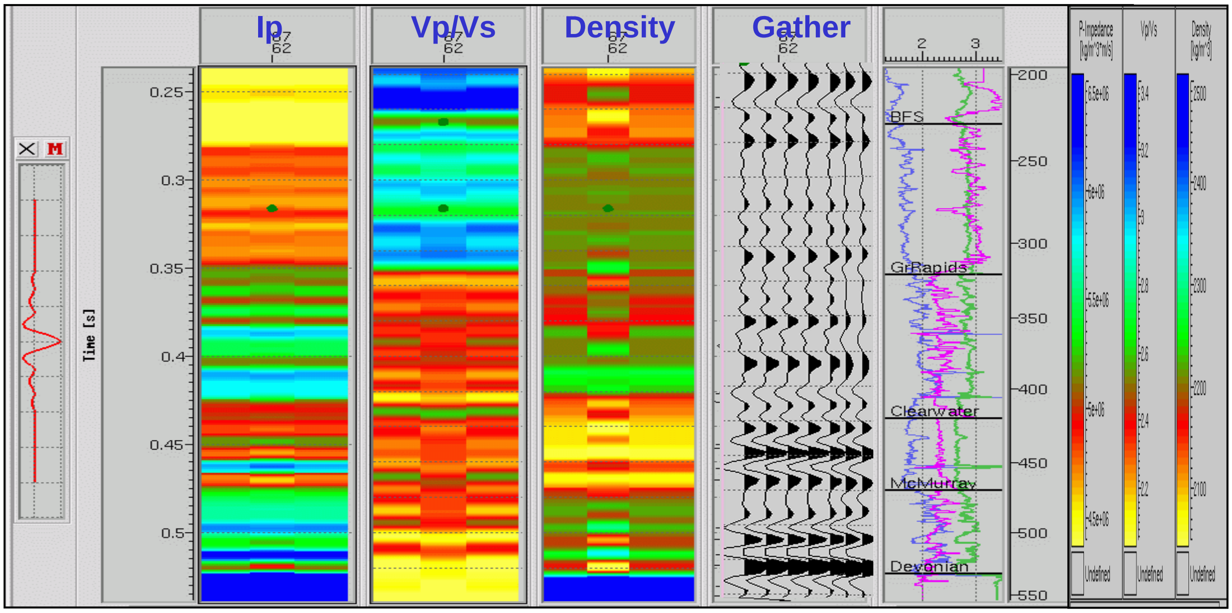

Figure 1: Next to the wavelet are three coloured panels representing P Impedance, Vp/Vs and Density. In each, the results of the AVO Inversion are in the background with the corresponding high-cut-filtered log superimposed. The input angle gather (0-30 deg) and the input logs are shown in the next panels. In this example, a constant, offset-independent wavelet was used, although the wavelet used to make the synthetics lost 10 Hz in the final two offsets. The P Impedance agreement is very good but there are serious mis-matches in the Vp/Vs. The density also has problems because 30 deg is not large enough to resolve it.

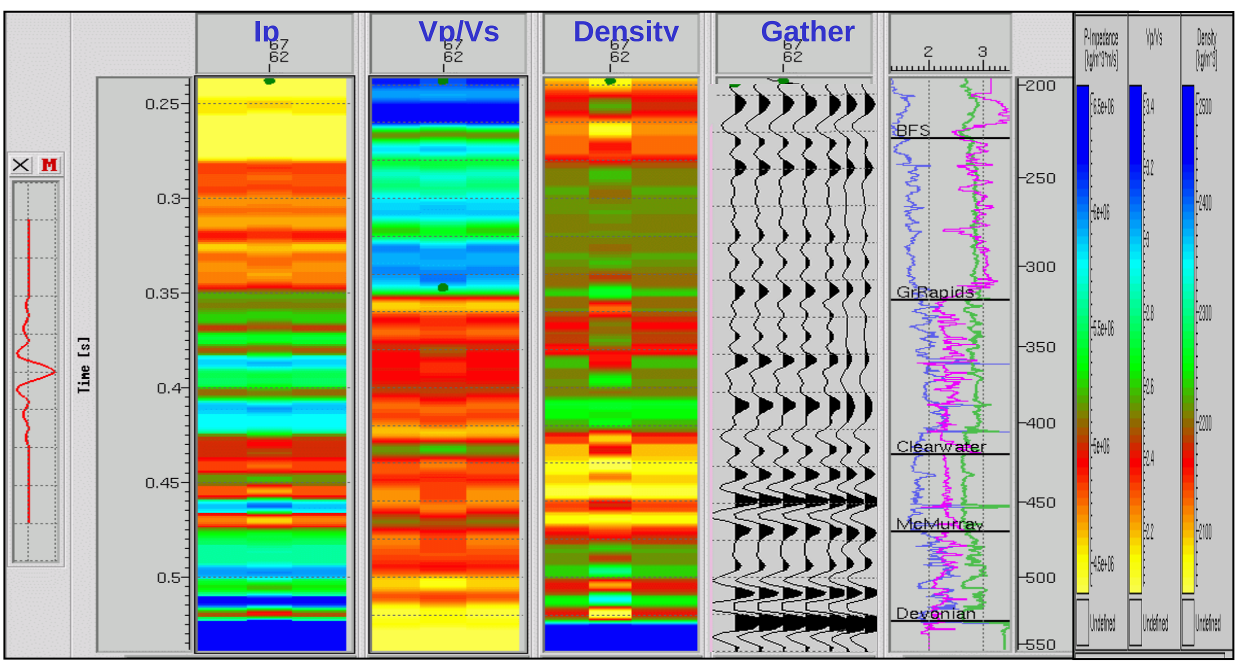

Figure 2: When the correct offset-dependent wavelets are used, the Vp/Vs inversion is improved. The density match remains difficult. The rock densities can not be explained by a Gardner-type relation.

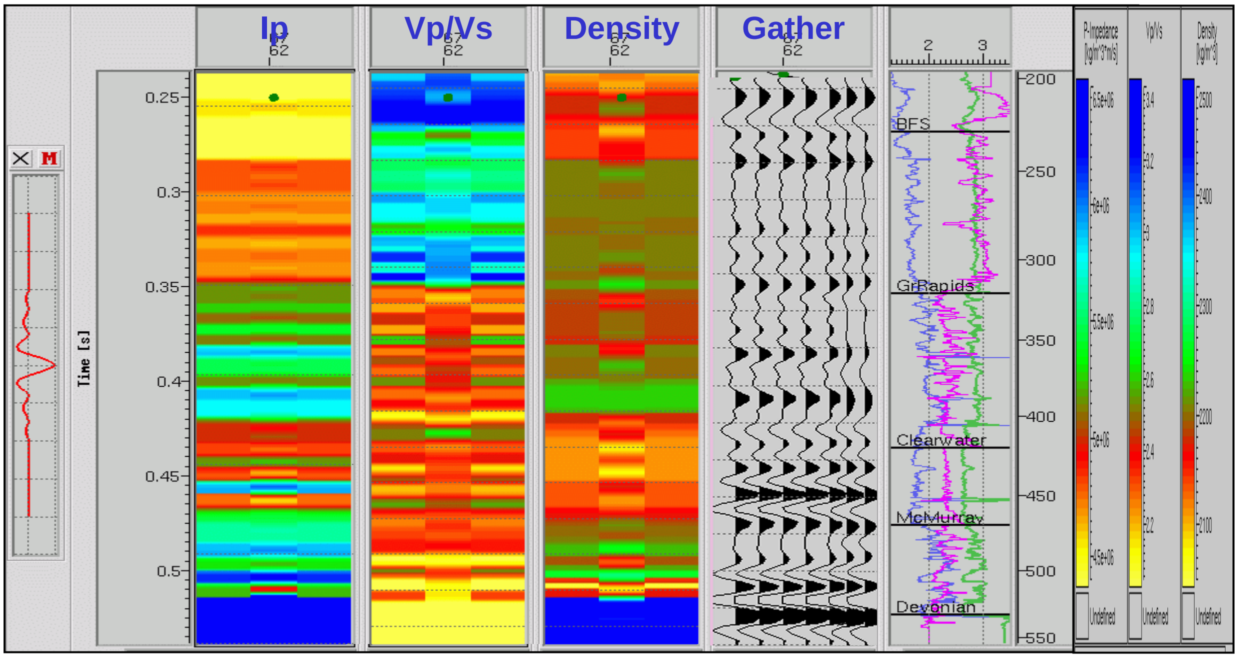

Figure 3: The Vp/Vs Inversion is degraded again when the first two traces in the angle gather are shifted by 0.5 ms (not shown shifted in the above figure).