Application of Multicomponent Data in Lithology and Fluid Discrimination*

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Abstract

For the past twenty-five years, seismic shear-wave data have been sparingly applied in the petroleum exploration, development, and production industry. Theoretically, converted-wave data should add significant information to the conventional P-wave interpretation. In practice, it is often difficult to use the converted-wave information directly in an integrated interpretation because of the registration of events between the P-wave and converted wave datasets. Even when this is successfully accomplished it is often hard to assess the direct contribution of the converted wave data to the final interpretation.

There is lots of discussion about the application of multicomponent data, and how they can be incorporated into interpretation. Presently, some 500 published application examples are accessible through browsers focused on either interpretive applications (objectives) or by historical and geographic projects (Tatham, 2006). In this paper we present one of the applications of multicomponent data, that being lithology and fluid discrimination based on Vp/Vs ratios derived directly from the jointly inverted PP and PS (registered in PP time) information. The point is that for every project the processing of a multicomponent survey should be followed by joint interpretation of the PP and PS data.

Introduction

Traditionally, lithological and pore fluid properties for reservoir characterization are derived from prestack seismic data with the use of amplitude versus offset (AVO) analysis. In this paper, PP and PS (registered in PP time) data were jointly inverted, providing P-impedance, S-impedance, Vp/Vs, and density volumes for more reliable log property mapping. We compare these results with the output of the simultaneous inversion of pre-stack PP data and conclude that joint inversion produces a better estimation of the shear impedance. Also, reservoir elastic properties such as LambdaRho ($\lambda\rho$) and MuRho ($\mu\rho$) were computed for pore fill and lithology identification.

Examples from two multicomponent prestack and poststack joint inversion studies over one heavy oil and one clastic prospect show how inverted rock properties and fluid estimations can be achieved with multicomponent data. The first case is from Plover Lake, Saskatchewan and

we compare the inversion results from prestack PP data with the results from joint inversion of the PP and PS (registered in PP time) data for better lithology differentiation (sands versus shales).

In the second area (Southern Alberta) we have a number of channels with producing sands but sometimes it is possible to encounter heavy oil plugs in the system instead of gas. Outside the channel is just a little sand. The objective of the multicomponent survey was primarily, therefore, to identify lithology and fluids.

These inversions can be used to map reservoir parameters through all stages of field development and production.

Method

Inverting both the P-wave (PP) and converted wave (PS, registered in PP time) seismic volumes can facilitate the integrated interpretation of the datasets by converting them to P and S impedance estimates which are more directly related to rock properties. However, inverting the datasets independently can lead to incorrect estimates of Vp/Vs ratio because the inversions optimize each property in isolation (Hirsche et al., 2005).

Joint inversion of PP and PS data requires registration of the PS data to PP time. The registration of PP and PS data remains a topic of concern among some interpreters, as well as a focus of technology development.

The method used for jointly inverting P-wave and converted wave (PS) seismic volumes accounts for the physical relationship that exists between P-impedance, S-impedance, and density and provides a significant improvement over separate inversions of the two datasets and particularly for Vp/Vs ratio estimates. We applied this inversion technique to two multicomponent datasets from Canadian (Alberta and Saskatchewan) prospects.

Results

The first case is from Plover Lake 3D example that was the subject of a paper presented at the 2006 CSEG (Dumitrescu et al., 2006). Now we compare the inversion results from prestack PP data with the results from joint inversion of the PP and PS (registered in PP time) for better lithology differentiation (sands versus shales). Figure 1 shows that the Vp/Vs results obtained from the two inversions are comparable but it is easy to observe that the joint inversion results are less noisy and better connected to the geology.

Figure 2 shows the MuRho (rigidity) and LambdaRho (incompressibility) volume from the second prospect where we have a number of channels with producing sands that sometimes encounter heavy oil plugs in the system instead of gas. Outside the channel is just a little sand. The objective of the multicomponent survey was to identify lithology and fluids. There is good correlation between the well data and lithological indications from the inverted rock properties.

If we make a crossplot of LambdaRho and MuRho from the wells (Figure 3) and from the seismic volumes, we can differentiate between the gas sands, shales, and tight rocks.

Conclusions

PP and PS seismic data were jointly inverted to P-impedance, S-impedance, Vp/Vs ratio, and density. The lithology predictions from inverted rock properties show good correlation to wells; however, the prediction of fluid fill is not as clear-cut as would be suggested from crossplot analysis of the available well data.

These results compare very well with the output of the prestack inversion of PP data, with the shear impedance being better estimated.

From inverted volumes, physical rock parameters such as rigidity and incompressibility can be easily computed for better fluid and lithology identification. The log property mapping for reservoir properties and wellbore stability applications can also substantially benefit from shear impedance and density estimates.

Acknowledgements

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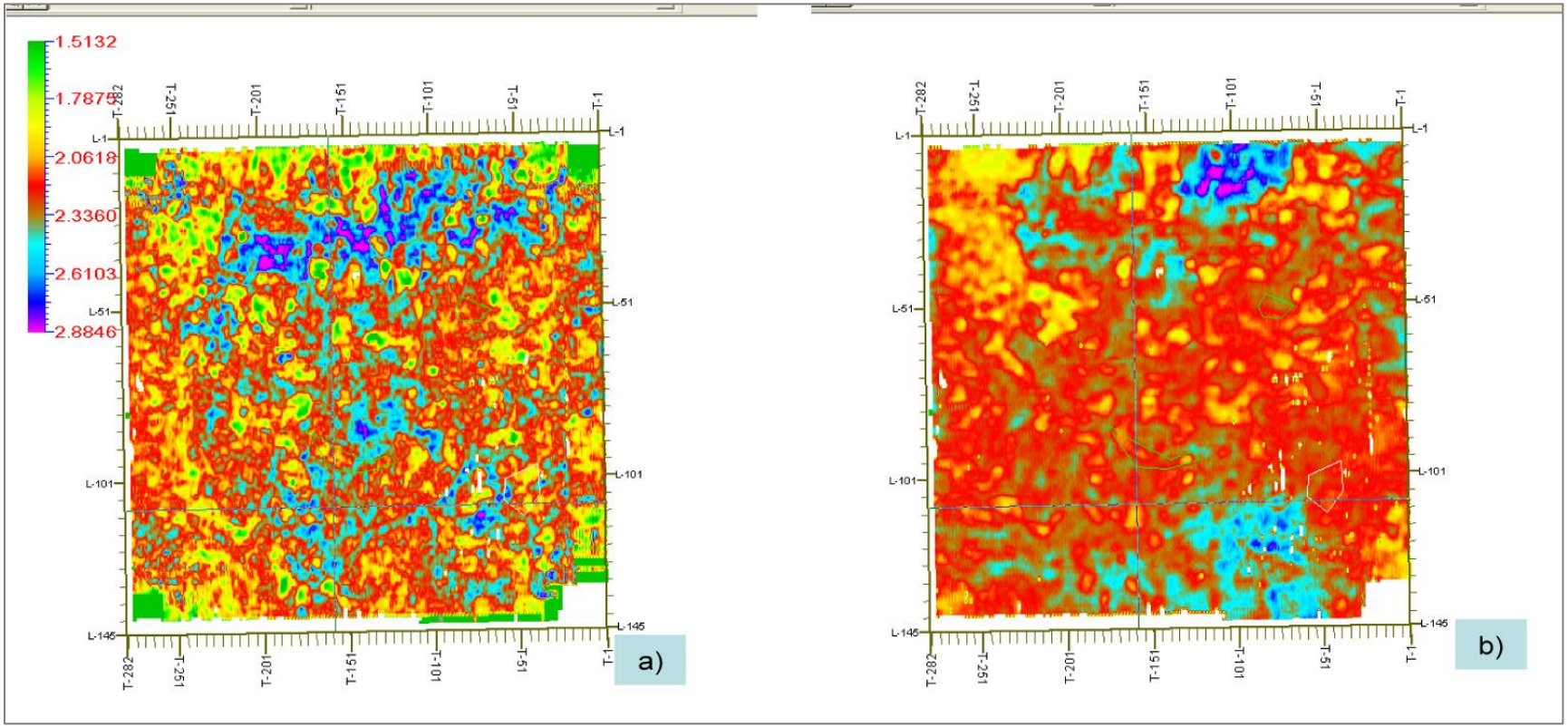

Figure 1. Horizon slice at Bakken+2ms on Vp/Vs volume obtained from (a) prestack inversion of PP data and from (b) joint inversion of poststack PP and PS data.

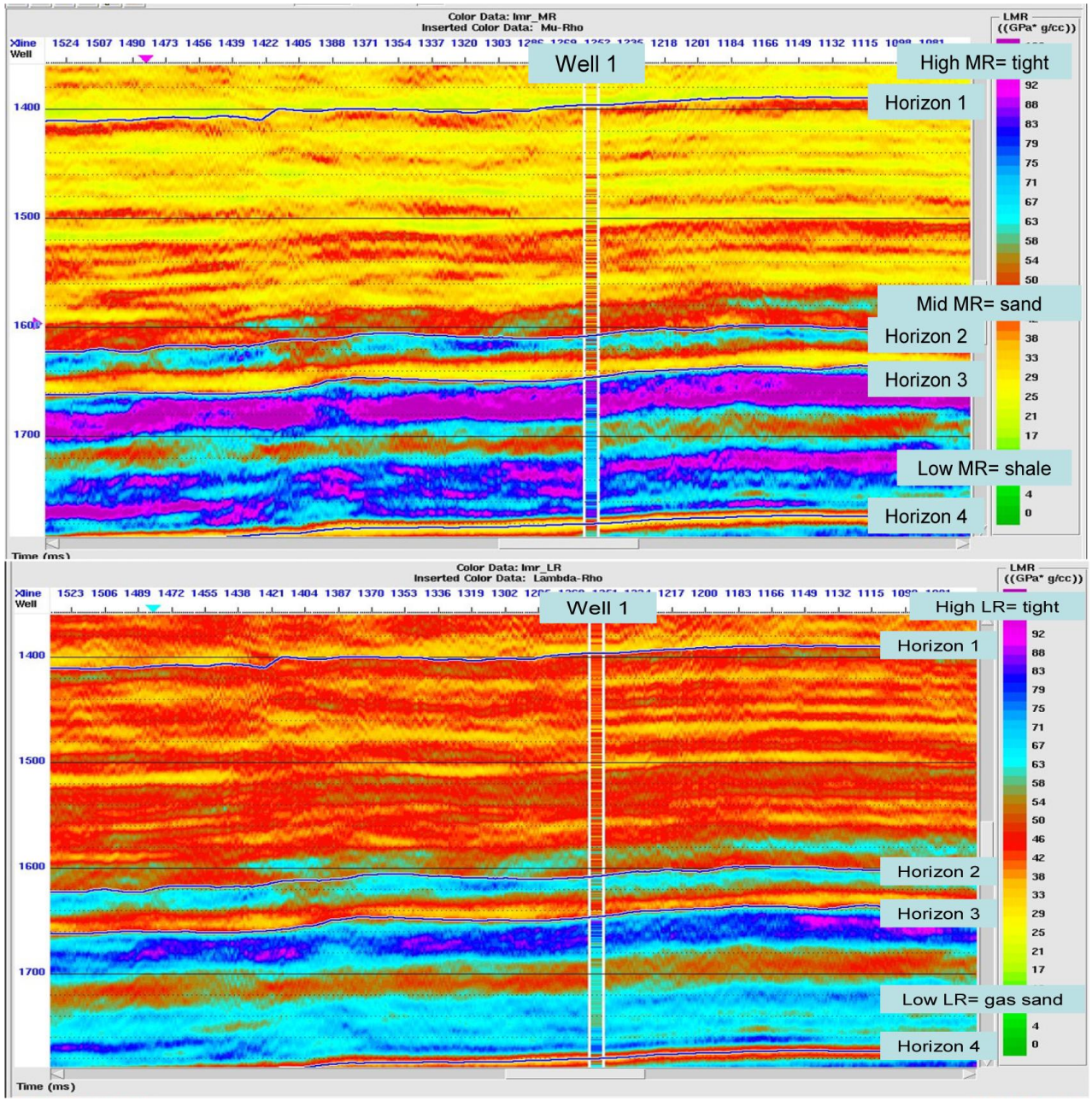

Figure 2. MuRho (top) and LambdaRho (bottom) obtained from joint inversion of poststack PP and PS data.

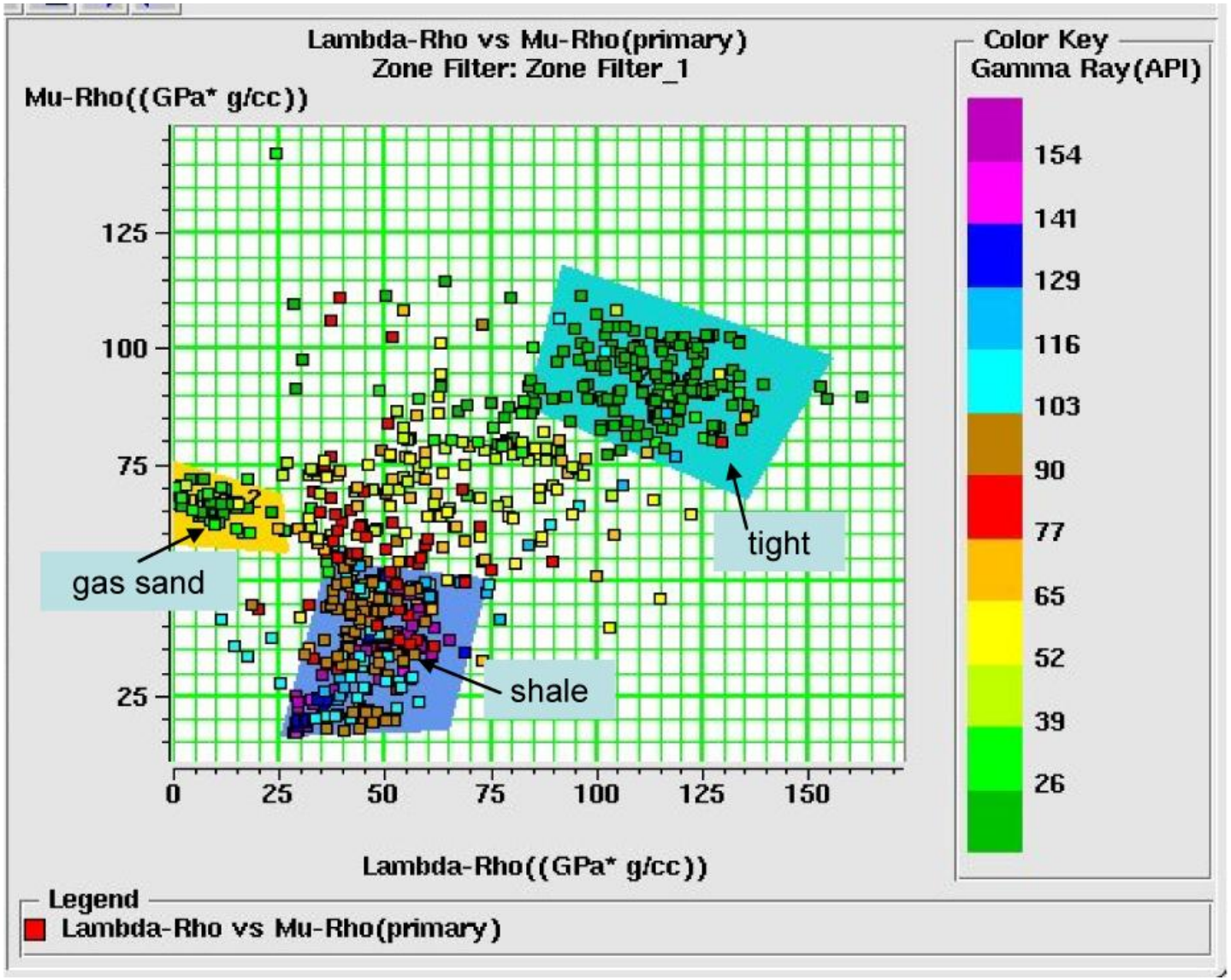

Figure 3. Crossplot of LambdaRho (x-axis) and MuRho (y-axis) over an interval that includes the zone of interest at one well in the area.