Beyond Seismic Inversion

Case Study: Facies Probabilities from Seismic

Geoscientists are usually faced with the difficult task of interpreting multiple inverted attributes provided by the geophysicist (AI, SI or density, for instance) in terms of the objective they are trying to map in the reservoir. To help the geoscientist achieve their goals and complete their projects with quantitative results, we propose a simple method to estimate facies probabilities based on statistical analysis of multidimensional crossplots of inverted seismic attributes and facies flags. We can estimate the probability of target lithologies or scenarios much better than when we crossplot two attributes at a time. Unlike commonly used approaches to map facies or lithologies from seismic data based on selecting regions in seismic attribute crossplots, our approach accounts properly for overlap among different facies and quantifies the probability of their occurrence.

This technique and a detailed analysis and calibration of results with well and production data has proven very useful to identify areas for potential drilling. Probability results from seismic can also be directly incorporated into geological models to help the distribution of geological facies.

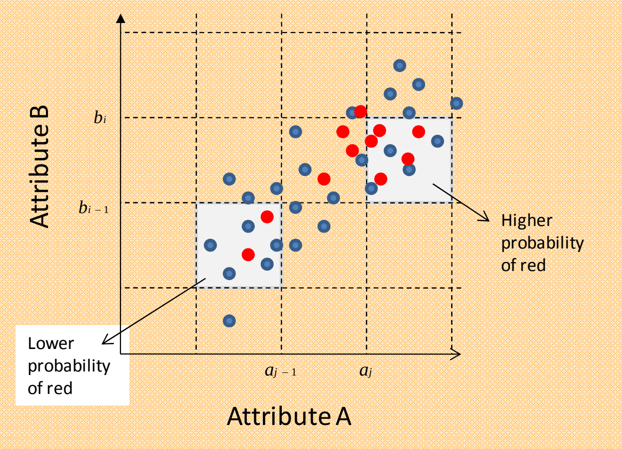

Figure 1. Probability estimations from crossplots. A rectangular grid is superimposed to the crossplot and individual probabilities of the different scenarios (red and blue dots) are calculated for each rectangle. These probabilities are then assigned to the whole seismic volume.

Case Study: Tight Gas Mamm Creek field, Piceance Basin

Mamm Creek field is located in the Piceance Basin, northwestern Colorado, in the United States. Most of the gas production in Mamm Creek field comes from fluvial sands in the Williams Fork formation, but marine sands in the Corcoran, Cozzette and Rollins members of the Iles Formation and the middle and upper sands of the Williams Fork Formation also contribute (Scheevel and Cumella, 2009). Mapping the distribution of sands is critical for early effective development of the field but, unfortunately, seismic data have not been used extensively for this purpose because elastic properties of sands and shales show large overlap in rock physics diagnostics. Application of this method at Mamm Creek field shows that even when no single attribute or pair of attributes yields good separation of sandy and background facies, probability estimates obtained by combining more than two attributes compare favorably with facies information at well locations. When using PP data only, good results are obtained by using simultaneously Vp, Vs and density derived from 3-term AVO inversion. However, the best results are obtained when using jointly these three attributes from PP data with pseudo S-impedances fast and slow derived from inversion of PS data. Sensitivity of PS amplitudes to azimuthal anisotropy helps to improve identification where sands are more anisotropic than the background.

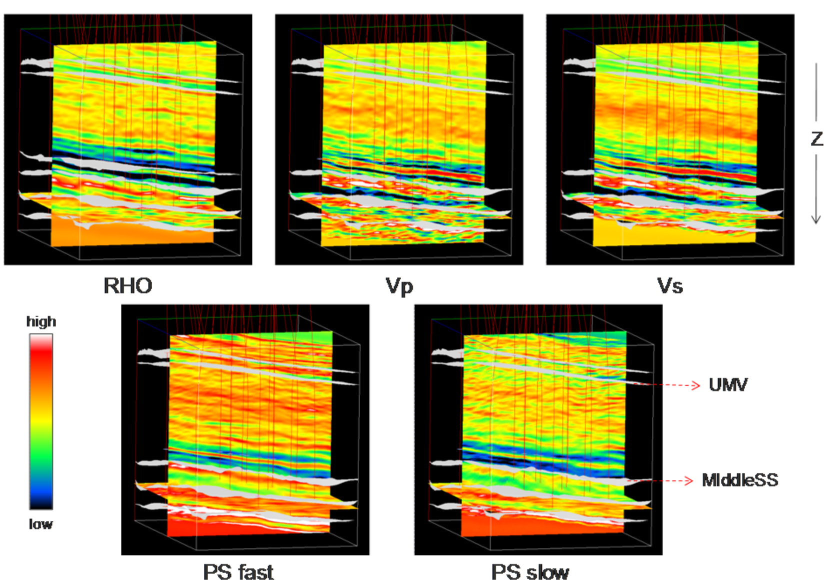

Figure 2. Inverted seismic attributes from 3D pre-stack data and PS fast and slow stacked volumes. Our method uses all these attributes simultaneously to generate probabilities of the properties of interest.

Workflow in Mamm Creek field

1) Petrophysical analysis and generation of facies flags based on lithology and thickness.

2) Log scale analysis of relations between petrophysical properties of target facies and seismic attributes derived from AVO inversion and inversion of PS stacked data.

3) Three-term AVO inversion of PP pre-stack gathers and post stack inversion of 3D PS stacked data. The results of this step are volumes of Vp, Vs, density, pseudo S-impedance fast (pSIf) and pseudo S-impedance slow (pSIs). Pseudo shear impedance was estimated using the algorithm described in Guliyev and Michelena (2009) Continues next page..

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Case study of facies probabilities (cont.)

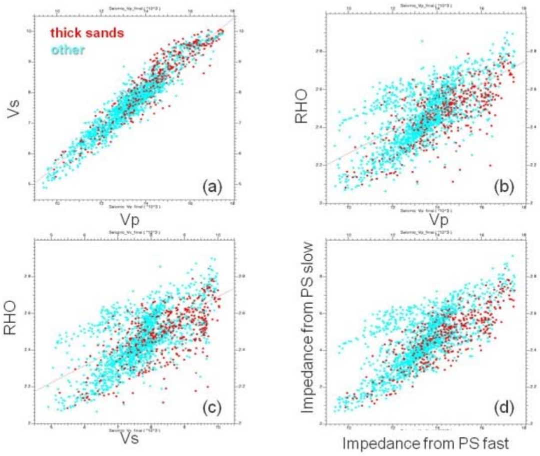

Figure 3: Crossplots of seismic scale attributes from inversion at 30 well locations and colorcoded by facies flags at log scale. The overall position in the crossplot of facies flags (red) with respect to the background (cyan) is expected from rock physics diagnostics at log scale.

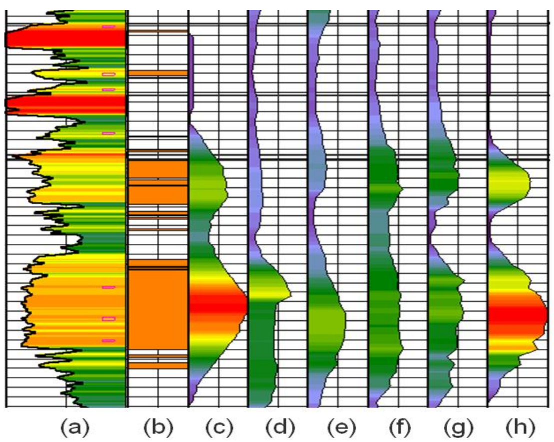

Figure 4: Log data vs. probability estimates from seismic data using different combinations of attributes at a selected well location. (a) Gamma Ray; (b) Facies flag; (c) Moving average of facies flag; (d) to (h) Probabilities from seismic attributes, (d) Vp-Vs; (e) Vp-RHO; (f) Vs-RHO; (g) Vp-Vs-RHO; (h) Vp-Vs,-RHO-pSIf-pSIs.

Workflow in Mamm Creek field (cont.)

4) Velocity model building and time to depth conversion of seismic derived information honoring depths of five formation tops picked along 107 wells.

5) Analysis of relations between seismic attributes and log scale facies within intervals of similar geologic characteristics (Figure 3). Inverted seismic attributes along well trajectories are extracted from 3D volumes for 30 wells in the study area. Facies flags (red) in Figure 2 fall in the same crossplots areas predicted by log scale analysis.

6) Estimated probabilities using different combinations of seismic attributes. This step estimates the likelihood of thick sands from crossplots of seismic attributes colored by facies flag (Figure 3). Some of the attribute combinations tested were Vp-Vs, Vp-RHO, Vs-RHO, Vp-Vs-RHO and Vp-Vs-RHO-pSIf-pSIs. Figure 3 shows the results of these probabilities estimated from different attributes combinations at a selected well location. The best predictions using P-wave data attributes only is obtained by combining Vp-Vs-RHO (Figure 4g). Finally, using P-wave and multicomponent derived attributes together (Figure 4h) gives the best predictions where estimated probabilities resemble very closely the shape of the average facies flag from well data (Figure 4c).

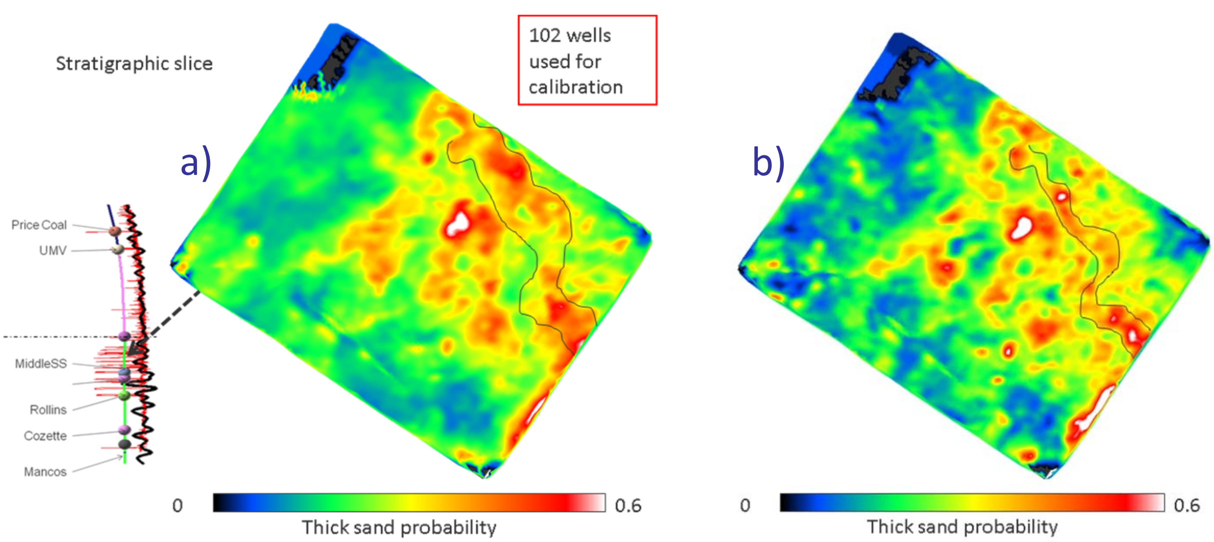

Figure 5: Stratigraphic slice for two different probabilities estimation: a) Thick sand probability using Vp, Vs, and RHO; b) Probability using Vp, Vs, RHO, Zps_fast and Zps_slow. Same trends are observed but a better definition is achieved when using 5 attributes.