Facies Driven Seismic Inversion for Improved Reservoir Characteristics in the Montney Formation

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Summary

Conventional simultaneous inversion has been the main workhorse of the industry for long time. It requires the building of low frequency background model which is often interpolated from well data, and rock physics relationships for different rock types are over-simplified in the process. In this work, we present the facies driven inversion (Joint Impedance Facies Inversion) which relies on facies-based depth trends instead of a possibly biased background model. Improved characterization of the reservoir zone is shown when facies-based inversion is used. The seismic derived impedances are further utilized as the input for constructing the analytic 3D geomechanics models which are critical for the development of unconventional plays. The benefit of using a facies-based approach is highlighted in this work.

Overview of the workflow

Seismic data for the study was acquired in the late 2000s, and recently reprocessed. Part of the seismic survey was found to be higher noise level than the remaining area, and seismic amplitudes in some areas are also affected by near surface river channel, with significant footprint shown in extracted amplitude within the zone of interest. Effort was directed towards conditioning the seismic data prior to the seismic inversion, and wavelets were extracted per partial stack to account for the amplitude and phase spectrum of each partial stack.

Instead of building a background model that is often interpolated from well log data and biased by the well locations, a facies-driven seismic inversion is based on depth trends per facies. Well data are first shifted to the chosen datum where the trend will reference. Based on available well data, probability density functions (PDF's) are then defined for each facies in Vp, Vs and density in two-way time. Rock physics are properly captured for each facies based on the relationship between Vp, Vs and density.

Seismic inverted impedance using both traditional simultaneous inversion and facies-based inversion were further transformed into reservoir properties that are key for well positioning. An arbitrary line across chosen wells were used for highlighting the benefit of inverting for discrete (facies) and continuous (impedance) properties at the same time. The results are improved resolution, as well as more realistic impedance and density values, which are key for differentiating the porous, and TOC rich facies in unconventional play.

Depth Trend, Seismic Inverted Impedance and reservoir property

For improved delineation of the facies in elastic space, unsupervised classification of petrophysical and elastic logs are used for facies classification at the well. The well data are shifted to a chosen datum prior to the definition of probability density function (PDF) for each facies in the study area.

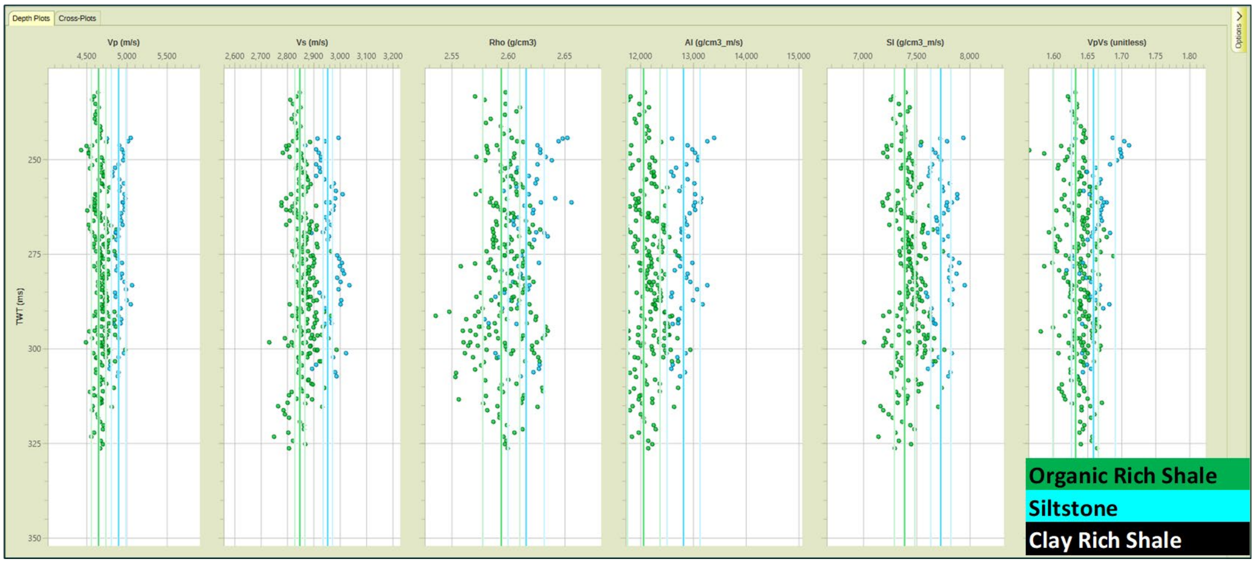

Figure 1. *Typical depth trends in the target formation with rock physics relationship captured in the facies PDF. Mean and 1st standard deviation of the elastic properties are represented respectively by the solid and dashed lines.*

We are targeting TOC rich facies, which normally have lower acoustic impedance and density compared to other facies present in the area. The ability to invert for the true impedance and density value will be critical for the play.

As shown in the acoustic impedance along the arbitrary line, both inversion methods show variable results on left side of the line where input seismic data have a higher noise level. Simultaneous inversion appears to be settling on intermediate values in many places along the line, whereas the impedances from the facies inversion are closer to the true values. The differences can best be seen in the Doig formation, where there are alternating layers of organic rich carbonate, organic lean carbonate as well as organic free sandstone. Impedance contrasts between the facies are strong, and a facies-driven approach captures the low and high values more accurately as they are constrained by the facies PDF, which is part of the inversion input.

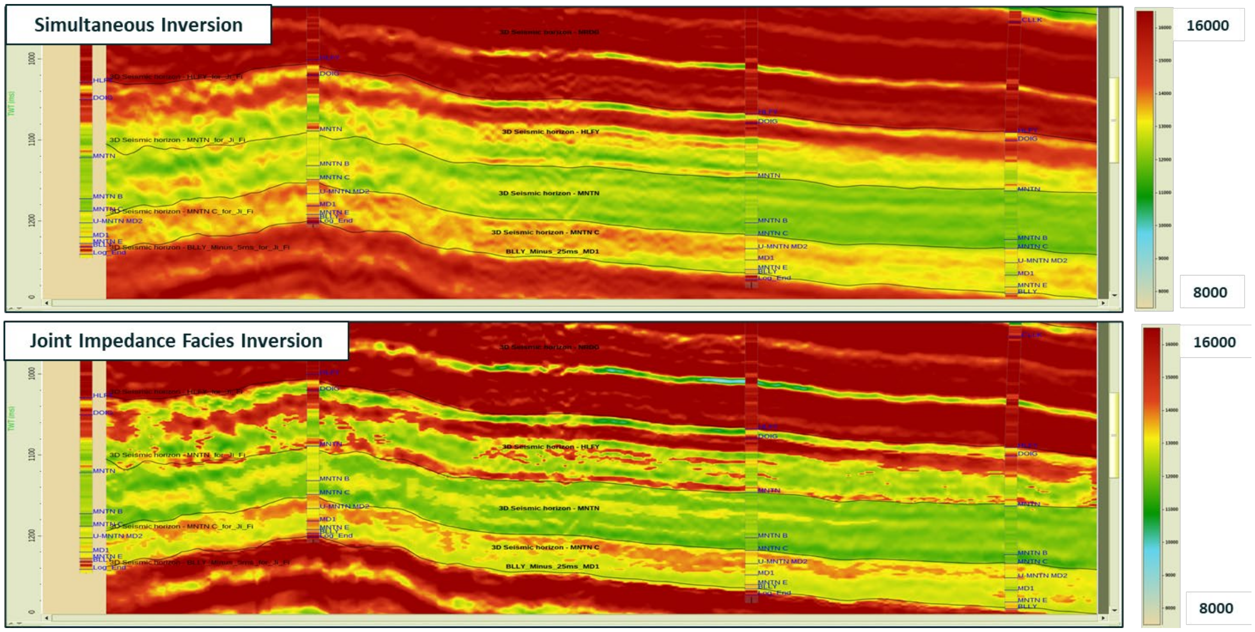

Figure 2. Seismic inverted acoustic impedance from simultaneous inversion and facies driven inversion. Seismic input and wavelets are consistent for both images.

By solving the discrete (facies) and continuous (impedance) properties at the same time, results from facies driven inversion often show a wider spectral bandwidth than the results from a simultaneous inversion. In the Montney formation, the TOC rich facies show a density close to 2.58 g/cm3, and tight siltstone facies at 2.62 g/cm3. Red and blue arrows indicate the two facies on the color scale. Vertical resolution is much improved with the facies approach, which should benefit the positioning of development wells in the zone.

The clay rich facies in the lower Montney formation are also better characterized by facies inversion, and this enables more accurate derivation of key petrophysical properties including TOC and porosity from the inverted impedance volume.

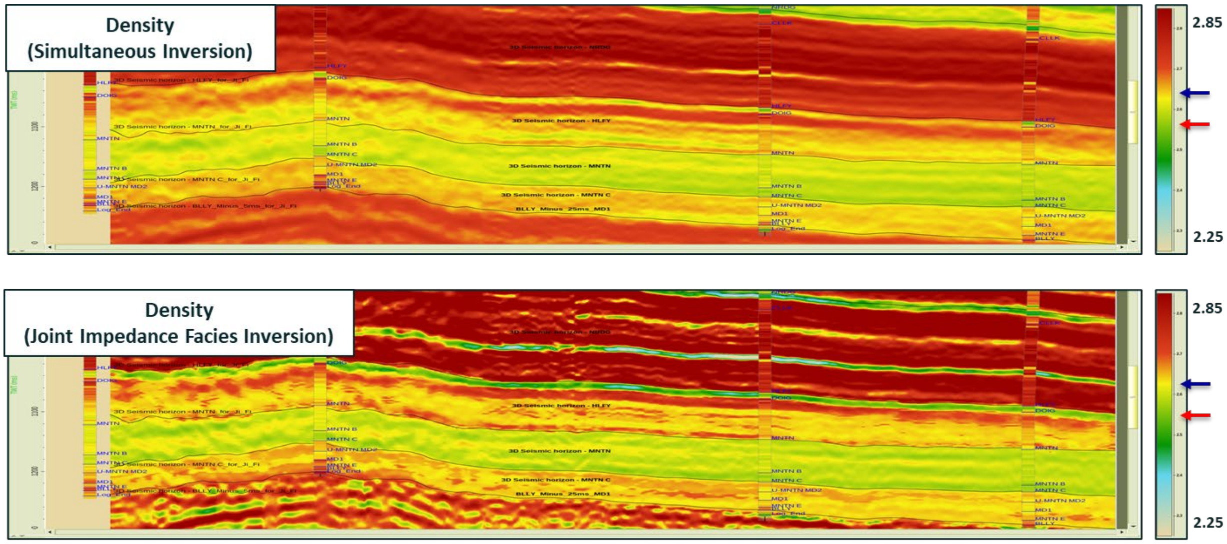

Figure 3. Seismic inverted density from traditional simultaneous inversion and a facies driven approach. Seismic input and wavelets are kept consistent to eliminate factors other than the inversion method itself. The red arrow represents density values for organic rich facies, and the blue arrow represents density values for tight siltstone facies.

Conclusion

In this study we have applied both simultaneous inversion and facies inversion on a recently reprocessed legacy seismic survey. Comparison of inverted impedance shows the result from simultaneous inversion are often settling on intermediate values, whereas the impedance from facies driven inversion are closer to true values, as they are bound by the pre-defined probability density functions of the representative facies. By inverting for discrete facies and impedance at the same time, the facies-driven approach has brought the added benefit of improved resolution. These enhancements have proven to be of critical importance for enhancing the quality of seismic derived reservoir properties and geomechanics volumes, both of which are required for development operations.

References

James Gunning and Mark Sams, 2018 Joint facies and rock properties Bayesian amplitude-versus-offset inversion using Markov random fields

Michael Kemper and James Gunning, 2014 Joint Impedance and Facies Inversion –Seismic inversion redefined