Unconventional Reservoir Characterization Using Conventional Tools

The application of an integrated workflow comprising seismic attributes is shown to better characterize the unconventional Montney shale formation in Canada.

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Shale gas plays differ from conventional gas plays in that the shale formations are both the source rocks and the reservoir rocks. There is no migration of gas as the very low permeability of the rock causes it to trap the gas, forming its own seal. The gas can be held in natural fractures or pore space or can be absorbed onto the organic material.

Apart from the permeability, total organic carbon (TOC) and thermal maturity are the key properties of gas potential shale. Generally, it can be stated that the higher the TOC, the better the potential for hydrocarbon generation. The organic content in these shales, which are measured by their TOC ratings, influence the P and S velocities as well as the density and anisotropy in these formations. Consequently, it should be possible to detect changes in TOC from the surface seismic response.

Different seismic workflows for characterizing the shale formations have been proposed. One such workflow attempts at estimating the brittleness of a shale formation in terms of Poisson's ratio Young's modulus from seismic data, using simultaneous prestack inversion. This process yields P impedance, S impedance, a VP/VS ratio, Poisson's ratio, and in some cases meaningful estimates of density. Zones with high Young's modulus and low Poisson's ratio are those that would be brittle as well as have better reservoir quality (higher TOC, higher porosity).

An integrated workflow starts by using well data as well as seismic data to characterize the hydrocarbon bearing shale. This begins with the generation of different attributes from the well log curves. Then, using the cross-plots of these attributes, the hydrocarbon-bearing shale zones are identified. Once this analysis is done at the well locations, seismic data analysis is picked up for computing appropriate attributes. Seismically, prestack data is essentially the starting point. After generating angle gathers from the conditioned offset gathers, Fatti et al.'s approximation to the wave equation can be used to compute P reflectivity, S reflectivity, and density, which depends on the quality of input data as well as the presence of long offsets. Due to the band-limited nature of acquired seismic data, any attribute extracted from it will also be band-limited and so will have a limited resolution.

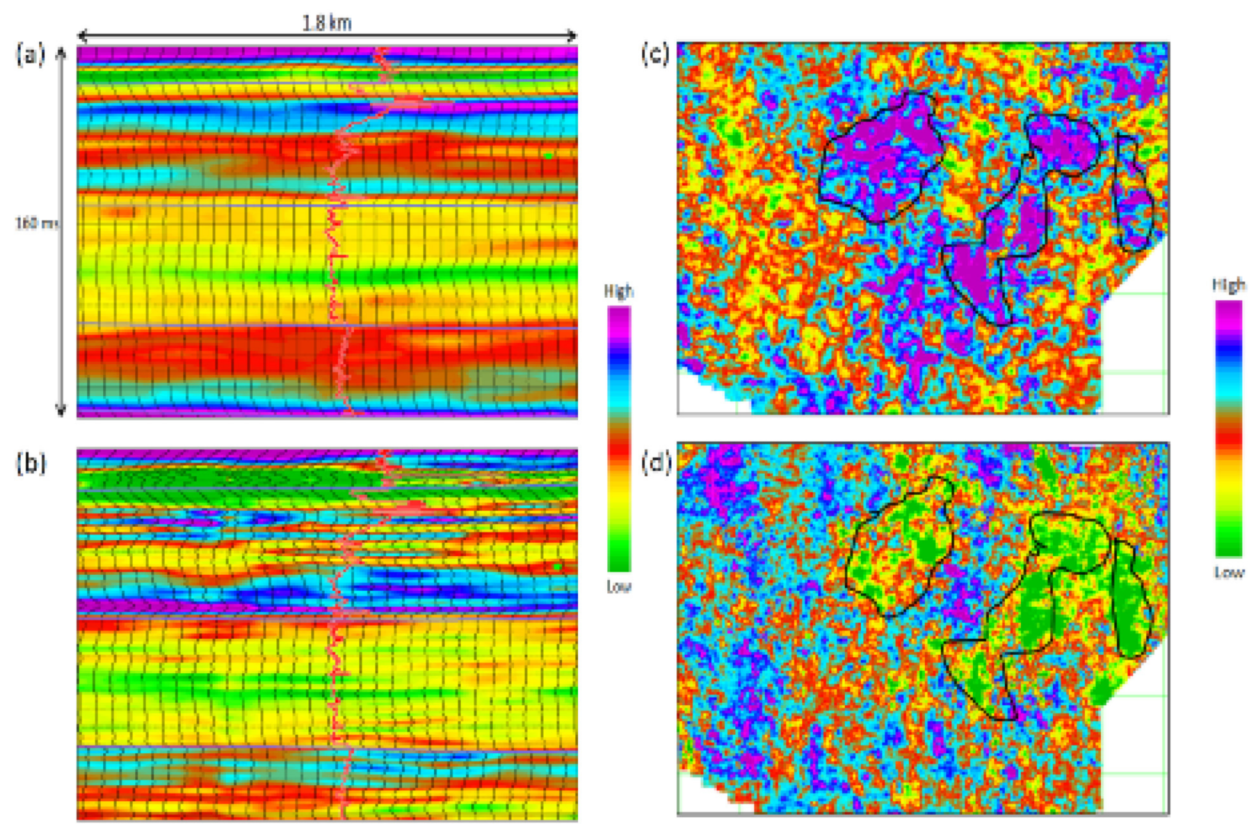

Figure 1: The $\lambda\rho$ section is computed (a) using a commonly used workflow and (b) using the proposed workflow. Notice the higher resolution, more detailed information, and its correlation with the well data. In 1c, horizon slices for the Upper Montney formation are derived from Young's modulus, and in 1d Poisson's ratio volumes are derived from the seismic data. Brittle and hydrocarbon-bearing shale is mapped by black polygons. (Image courtesy of Arcis Seismic Solutions, TGS)

While shale formations may be thick, some high-TOC shale units may be thin. So it is desirable to enhance the resolution of the seismic data. An appropriate way to do this is the thin-bed reflectivity inversion. Following this process, the wavelet effect is removed from the data, and the output of the inversion process can be viewed as spectrally broadened seismic data retrieved in the form of broadband reflectivity data that can be filtered back to any bandwidth. This usually represents useful information for interpretation purposes. Further, the output of thin-bed inversion is considered as input for the model-based inversion to compute P impedance, S impedance, and density. Once impedances are obtained, we can compute other relevant attributes that can be used to measure the pore space properties and get information about the rock skeleton. Young's modulus can be treated as brittleness indicators and Poisson's ratio as a TOC indicator.

Characterizing the Montney shale formation in western Canada by following the proposed integrated workflow begins with the computation of different attributes from the seismic data. Figure 1a shows the Lambda-rho ($\lambda\rho$) section computed using the conventional workflow, while the same section computed using the proposed workflow is shown in Figure 1b. Notice the higher resolution in the latter display. Shale source rocks must exhibit high brittleness (as they would then frac better) and low Poisson's ratio, and so a cross-plot of these two attributes is generated. Polygons enclosing cluster points corresponding to brittle and ductile shale can be drawn on these cross-plots. The back projection of such polygons on the seismic section can highlight laterally the sweet spots. The horizon slices of Young's modulus and Poisson's ratio for the Upper Montney formation are shown in Figures 1c and d, respectively. Brittle and hydrocarbon-bearing shale is shown mapped by the black polygons.

Using this proposed workflow indicates that seismically derived attributes can be used to characterize the Montney formation directly, and on comparison these derived attributes are seen to delineate the Montney formation better than those of a commonly used workflow.

We thank Arcis Seismic Solutions, TGS, for allowing us to present this work. ■