[GC] An Effective Way to Find Formation Brittleness*

Ritesh Kumar Sharma[1] and Satinder Chopra[1]

Search and Discovery Article #41024 (2012)
Posted September 10, 2012

*Adapted from the Geophysical Corner column, prepared by the authors, in AAPG Explorer, September, 2012. Editor of Geophysical Corner is Satinder Chopra (schopra@arcis.com). Managing Editor of AAPG Explorer is Vern Stefanic; Larry Nation is Communications Director.

[1]Arcis Corp., Calgary, Canada (schopra@arcis.com)

General Statement

The discrimination of fluid content and lithology in a reservoir is an important characterization that has a bearing on reservoir development and its management. For the unconventional reservoirs, such as shale gas formations, besides other favorable considerations that are expected of them, it is vital that reservoir zones are brittle. Brittle zones frac better, and fracing of shale gas reservoirs is required for their production.

Among the different physical parameters that characterize the rocks, Young's modulus (E) is a measure of their brittleness. Attempts are usually made to determine this physical constant from well log data, but such measurements are localized over a small area. For studying lateral variation of brittleness in an area, 3-D seismic data needs to be used, because computation of Young's modulus from seismic data requires the availability of density (ρ). The computation of density, in turn, requires long offset data, which usually is not available.

In this study, we propose a new attribute (Eρ) in the form of a product of Young's modulus and density, which can be determined from seismic data without the requirement for long-offsets. For a brittle rock, both Young's modulus and density are expected to be high, and so the Eρ attribute would exhibit a high value and serve as a brittleness indicator.

Mechanical Characterization of Rock

The determination of lithology and fluid content distribution in a reservoir is a desirable objective for its characterization and subsequent management. Physical properties such as porosity and permeability make it possible to evaluate a hydrocarbon reservoir – however, the properties that have a direct impact on the relevant elastic constants, among others, are bulk modulus, shear modulus and Young's modulus.

● Bulk modulus is a measure of a material's resistance to change in volume and is known as incompressibility. It is treated as a porosity indicator.

● Shear modulus is a measure of rigidity of a rock or resistance to deformation taken in a shear direction and is treated as a lithology indicator.

● Young's modulus (E), also known as stiffness modulus, is a measure of the stiffness of the material of the rock.

Historically, geoscientists have attempted to delineate the fluid and lithology content of a reservoir on the basis of these physical properties.

An estimation of the physical properties described above requires P-impedance, S-impedance and density. For computing these prerequisites, prestack inversion of surface seismic data is usually performed. Extraction of density from seismic data needs far-offset information – but it also is true that the quality and amplitude fidelity deteriorate significantly at large angles of incidence. So, the computation of density is considered an arduous task.

In the absence of density, efforts have been made for characterization of a reservoir in terms of lithology and fluid content. For this purpose, P-impedance and S-impedance are used for litho-fluid discrimination, as the former is sensitive to fluid, whereas the latter is not. The determination of rock physics parameters such as Lame's constants λ (sensitive to pore fluid) and μ (sensitive to the rigidity of the rock matrix) may be difficult to isolate from seismic data, and so their product with density are usually sought – i.e. $\lambda\rho$ and $\mu\rho$ can easily be determined from P-impedance and S-impedance.

The stiffness of a rock is an important property – especially for shale gas reservoirs where fracing is employed for stimulation. Stiffer shales frac much better than ductile ones and enhance the permeability of those zones. Young's modulus can characterize such stiffer pockets in shales.

Considering the importance of a lithology indicator as well as an attribute that could yield information on the brittleness of a reservoir, we propose a new attribute, $E\rho$, which is the product of Young's modulus and density. It can be derived from the P-impedance and S-impedance and can be shown to be a scaled version of $\mu\rho$.

For a brittle rock, Young's modulus would be high – and density would be high, too –therefore the product of Young's modulus and density would be high as well and would accentuate the brittleness of the rock.

Example

In Figure 1 we show a comparison of the μρ and Eρ curves for a well in northern Alberta. Notice the Eρ curve emphasizes the variation corresponding to lithology change more than in the μρ curve. For ease in interpretation, we segment the input log curves – and the results shown in Figure 2 stand out nice and clear.

For implementation of this analysis on seismic data we considered the gas-impregnated Nordegg Member of the Jurassic Fernie Formation of the Western Canadian Sedimentary Basin. The Nordegg Member of the Fernie Formation varies throughout the WCSB. It consists of predominantly brownish, greyish and black shales, which vary from siliceous rich cherts and dolomites to carbonate rich shale. Due to the complex geology of the reservoir in the Nordegg, differentiating the lithology and fluid content is a challenge.

The Nordegg-Montney interface is a regional unconformity that separates the Jurassic and Triassic strata in the area. The Montney Formation is composed of fine-grained siltstone grading to fine-grained sandstones, with limited shale content. There is a diagenetic dolomitic overprinting on the siltstones and sandstones. In local areas of the Montney there is a coquina facies made up of bivalves.

As the first step, simultaneous impedance inversion was run on the preconditioned 3-D seismic data to obtain P-impedance and S-impedance volumes. Next, these impedance volumes were transformed into μρ and Eρ volumes.

In Figures 3a and 3b, we show segments of vertical sections from the μρ and Eρ volumes, respectively. Notice Eρ has a higher level of detail than the μρ attribute. The upper parts of the figures exhibit lower values of the attributes as they correspond to the sandstone presence, whereas the higher values are seen in the lower part, verifying the availability of dolomitic siltstone in this zone.

Conclusion

We have proposed a new attribute (Eρ) in the form of a product of Young's modulus and density, which is a good lithology indicator. We describe it as a scaled version of the μρ attribute and illustrate that it intensifies the variation in lithology. This attribute can be derived seismically, and we have shown that with it we can determine the brittleness of a formation.

Acknowledgments

We thank Athabasca Oil Corporation for giving us permission for presentation of the results shown in this study. We also thank Arcis Seismic Solutions for permission to present this work.

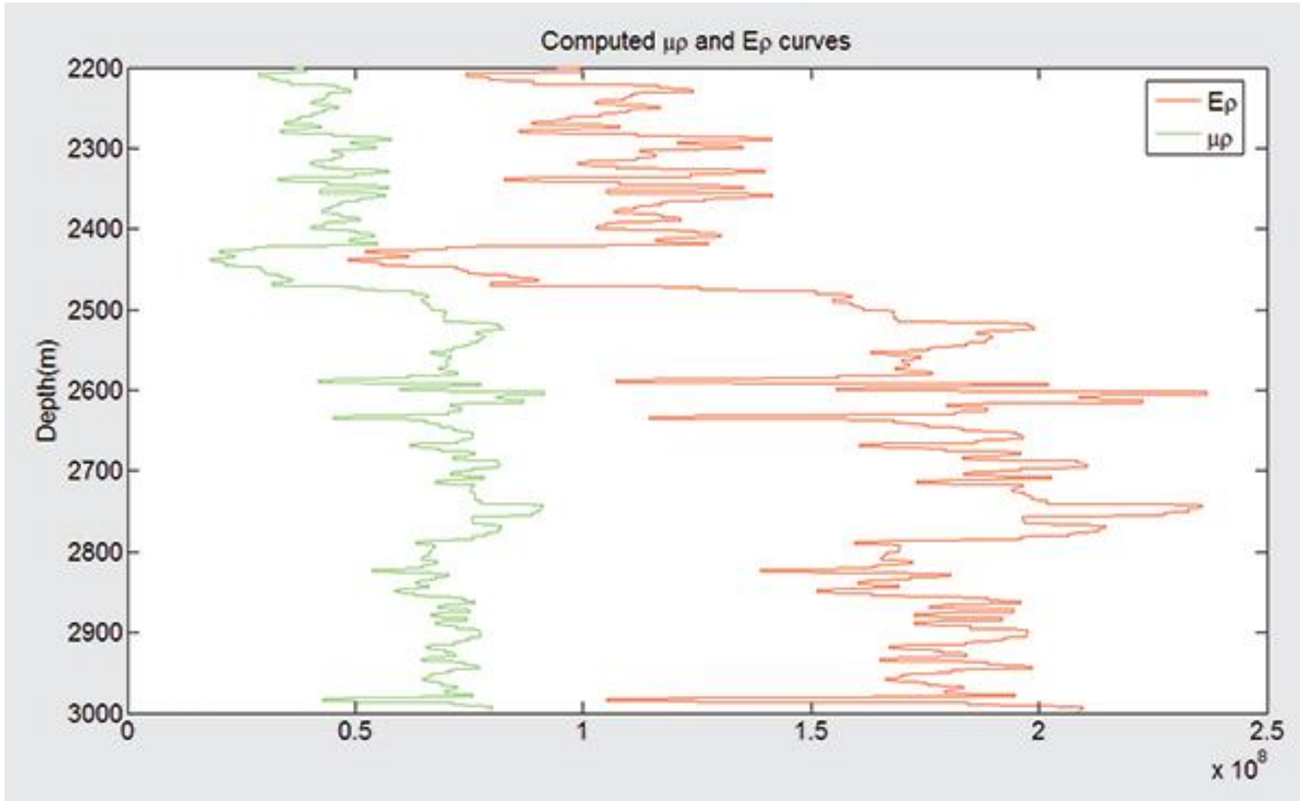

Figure 1. Computed μρ curve (left, green) plotted against the Eρ curve (right, red). Notice, the Eρ curve shows more emphasized lithologic variation than the μρ curve.

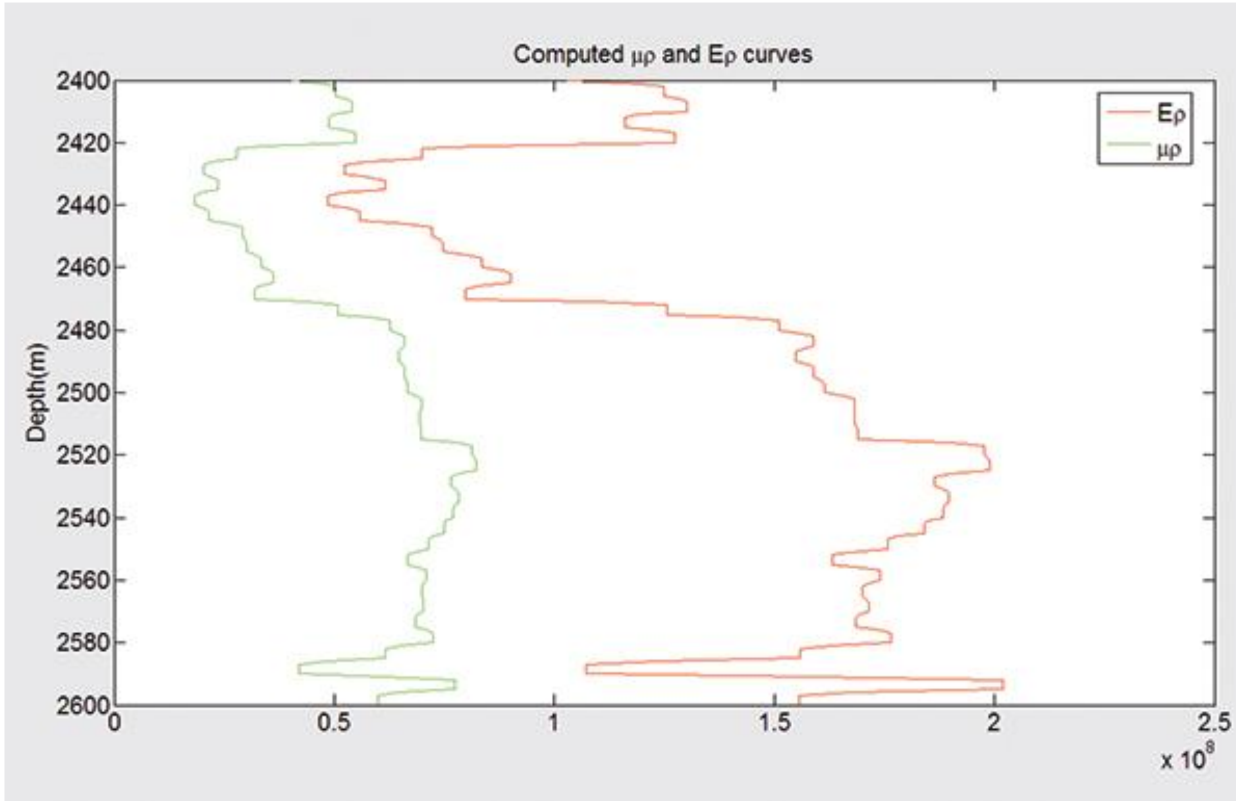

Figure 2. μρ and Eρ curves computed from segmented input logs for the same well. More emphasized lithologic variation is seen on the Eρ curve (right, red) than on the μρ curve (left, green).

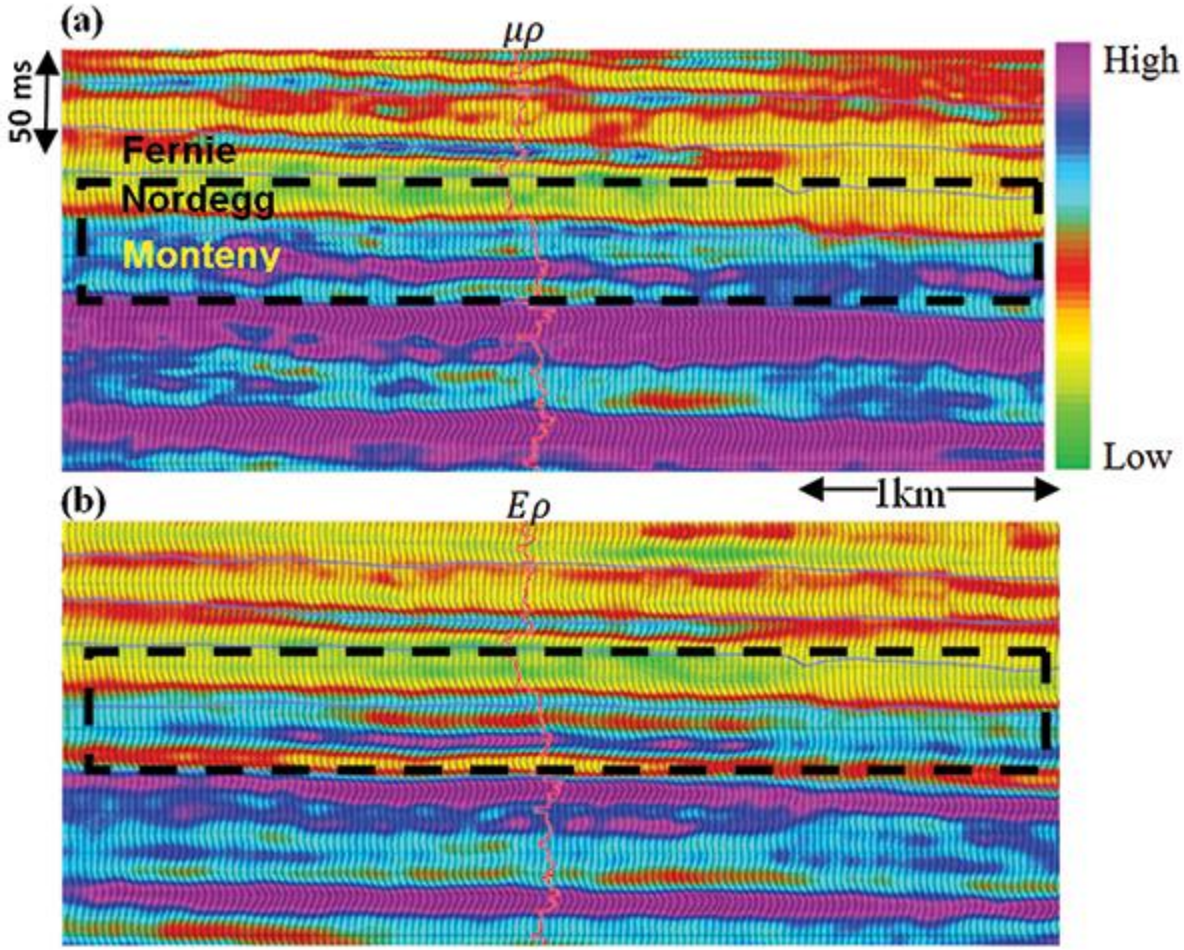

Figure 3. Comparison of (a) μρ section with (b) Eρ section. Comparison illustrates the more detailed lithology information seen in the Eρ section than in the μρ section, especially in the rectangular highlighted area.