An Effective Way to Find Formation Brittleness

By RITESH KUMAR SHARMA and SATINDER CHOPRA

For computing these prerequisites, impedance, S-impedance and density. properties described above requires P-basis of these physical properties. 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.

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 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 to fluid, whereas the latter is not. The determination of rock physics parameters such as Lamé’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. Eρ and μρ 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 fracking 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, Eρ, 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 μρ.

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, which would accentuate the brittleness of the rock.

Examples

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 the μρ curve. For each 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 a 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 sands grading to fine-grained sandstones, with limited shale content. There is a diagenetic dolomitization overprinting on the siliciclastics. 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 pre-conditioned 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 b, we show segments of vertical sections from the μρ
and $E_{\rho}$ volumes, respectively. Apparently, we notice $E_{\rho}$ has a higher level of detail than the $\mu_{\rho}$ 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.

Conclusions

We have proposed a new attribute ($E_{\rho}$) 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 $\mu_{\rho}$ 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.

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(Editor’s note: Both Sharma and Chopra are with Arcis Seismic Solutions, Calgary, Canada.)

Multi-Disciplinary URTeC Opens Call for Papers

URTeC, sponsored by AAPG, the Society of Petroleum Engineers and the Society of Exploration Geophysicists, will be held Aug. 12-14 in Denver.

Organizers are seeking papers from petroleum engineers, geologists, geophysicists and other professionals interested in sharing innovations, best practices and experiences in integrated approaches for North American unconventional resource plays. The event, organizers say, fills the unique need for a peer-reviewed, science-based unconventional resources conference that will take an asset team approach to development of unconventional resource plays—similar to how oil and gas professionals work in today’s market.

Papers will be accepted through Nov. 15. The program includes 20 themes applicable to unconventional resources and appeals to engineers, geologists and geophysicists, including:

- Unconventional Project Development.
- Unconventional Reservoir Characterization.
- Unconventional Shale Plays.
- Unconventional Tight Oil and Tight Gas.
- Unconventional Coal Seam/Bed Methane.
- Other Unconventional Reservoirs.
- Formation Evaluation of Unconventional Reservoirs.
- Fracture Characterization.
- Lateral Well Characterization.

The three technical program co-chairs are AAPG Honorary Member and past president Steve Sonnenberg, with the Colorado School of Mines; AAPG member Ken Beeney, with Devon Energy; and Luis Baez, with BG Group. “The combined power of these three leading scientific organizations means URTeC has the potential to be the most substantial inter-society collaboration since the Offshore Technology Conference began in the 1960s,” they write.

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