geoconvention
Calgary • Canada • May 13-17 2019

Elastic Anisotropy and Dynamic Rock Mechanical Properties of the Montney and Duvernay Formations (Canada): A Comparative Laboratory Study

C.R. Clarkson[1], N. Riazi[1], A. Ghanizadeh[1], A. Vahedian[1], A. Younis[1], J.M. Wood[2]

[1] Department of Geoscience, University of Calgary

[2] Encana Corporation

Summary

The Montney and Duvernay formations in the Western Canadian Sedimentary Basin contain massive resources of hydrocarbons in a variety of phases (oil, gas, and condensate). The development of liquid-rich intervals within these tight formations is currently a primary focus of the industry in Western Canada due to low natural gas prices. A key consideration for the successful completion of these tight, liquid-rich reservoirs is targeting reservoir intervals that are amenable to hydraulic fracture stimulation. Combined with "in-situ" stress regimes, elastic and rock mechanical properties (e.g. Young's Modulus, Poisson's Ratio) play a key role in evaluating drilling, completion and hydraulic fracturing strategies in these reservoirs. These parameters are commonly used as direct inputs for hydraulic fracture simulators which are used, in turn, for optimizing hydraulic fracture stimulation design.

This work presents results from an ongoing laboratory study, investigating elastic anisotropy and dynamic rock mechanical properties of a diverse sample suite from the Montney and Duvernay formations (Alberta, Canada). The primary objectives are to 1) compare these parameters for the Montney and the Duvernay at varying stress conditions for a variety of reservoir samples (intact/fractured core plug samples) and 2) identify lithological controls (mineralogical composition, total organic carbon (TOC) content, rock fabric) on stress-dependent elastic anisotropy and dynamic rock mechanical properties for intact, and more importantly, fractured (with and without proppant) core plug samples.

Theory / Method / Workflow

A total of eleven core plugs with a diameter of 1.5" (3.8 cm) and length of 2" (5.1 cm) are the focus of this study. Eight of these core plugs, obtained from the Montney Formation, were the subject of previous studies (Riazi et al., 2017a,b), while three of these core plugs, obtained from the Duvernay Formation, were analyzed in this study. All core plugs were drilled horizontally from the core materials obtained from three vertical well drilled within fine-grained intervals of the Montney and Duvernay formations (Alberta, Canada). Ultrasonic velocity measurements were performed using an acoustic velocity, triaxial core holder (AVC series; CoreLab®) which uses the pulse transmission technique, assuming a straight path for the propagation of the incident wave through the sample. The ultrasonic velocity measurements were conducted at an approximate frequency of 100 kHz under controlled effective stresses ranging between 500 and 3200 psi (3.4-22 MPa). Of particular interest to this study, the application of a sonic coreholder used in the permeameter device enabled ultrasonic velocity measurements to be performed simultaneously with permeability measurements on intact and fractured core plug sample with/without proppant.

Bulk mineralogical compositions were derived from the X-ray diffraction patterns measured on randomly oriented powders obtained from crushing/sieving of the trimmed ends of the core plugs. The measurements were conducted using a Rigaku® MultiFlex X-Ray Diffractometer. Mineral phase identification and quantification were carried out using the PDXL software (version 2.8.1.1). The quantification of the mineralogical composition of the analyzed samples (i.e. eleven core plug samples) – which was not part of the previous studies – was essential for assessing compositional controls on stress-dependent elastic moduli and dynamic rock mechanical properties of intact/fractured core plug samples. To quantify the TOC content, small amounts of sub-samples (~70 mg) randomly selected from crushed-rock materials were analyzed using standard Rock-Eval analysis. The latter analysis was performed at the Geological Survey of Canada (Calgary) using a Rock-Eval 6 (Vinci Technologies®). The rock fabric and orientation of primary minerals were analyzed for selected samples using the scanning electron microscopy (SEM) technique.

Results, Observations, Conclusions

Experimental results suggest that P- and S-wave velocities increase with increasing effective stress for both intact and fractured core plugs, regardless of the formation. However, compared to the Montney (Riazi et al., 2017a), the stress sensitivity of P- and S-wave velocities appears to be smaller for the Duvernay. Similar to the previous observations reported for the Montney (Riazi et al., 2017a), the ultrasonic velocities, and derived mechanical properties, measured for intact Duvernay core plug samples compare well with log-derived values (maximum discrepancy: ±8%) despite the difference in scale and (sonic) frequency used in laboratory (100 kHz) and field (well-log) (10 kHz) measurements. The latter observation is important, suggesting that heterogeneities affecting sonic velocities likely occur at the sub-core plug scale for the analyzed reservoir intervals. As opposed to the previous observations reported for the Montney (Riazi et al., 2017a), the stress sensitivity of shear wave splitting (an elastic anosotropy measure) appears to be similar for both the unpropped and propped Duvernay fractured core plug samples, particularly at higher stress conditions (> 2100 psi; 15 MPa). These observed similarities and discrepancies can be rationalized in terms of a combination of lithological factors, including the content and orientation of major minerals (e.g. clay, quartz), TOC content, and rock fabric (laminated vs. bioturbated), and proppant composition, size, and distribution of proppant on the fractured core plug surface.

Novel/Additive Information

Laboratory-based measurements of ultrasonic velocities are important for tight, liquid-rich intervals within the Montney and Duvernay, enabling the operators to estimate elastic anisotropy and dynamic rock mechanical properties, which in turn can be used for 1) calibration of sonic logs to inform 3D/4D seismic/microseismic interpretations and 2) constraining field-scale geomechanical models developed for optimizing hydraulic fracturing stimulation in these reservoirs.

Acknowledgments

The authors gratefully thank the sponsors of the Tight Oil Consortium hosted at the University of Calgary. Chris Clarkson would like to acknowledge Shell and Encana for support of his Chair position in Unconventional Gas and Light Oil at the University of Calgary, Department of Geoscience. The authors also gratefully thank Chris DeBuhr, Omid H. Ardakani (Geological Survey of Canada) and Rob Marr (University of Calgary) for SEM imaging, providing the Rock-Eval data and helping with XRD analysis, respectively.

References

Riazi, N., Clarkson, C.R., Ghanizadeh, A., Vahedian, A., Aquino, S., Wood, J.M., 2017a. Determination of elastic properties of tight rocks from ultrasonic measurements: Examples from the Montney Formation (Alberta, Canada). Fuel 196, 442-457.

Riazi, N., McKean, S., Ghanizadeh, A., Clarkson, C.R., Vahedian, A., Priest, J., 2017b. A comparison of dynamic and static geomechanical properties of the Montney Formation: An integrated experimental study. Geoconvention 2017; Calgary, Canada, May 15-19.