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Stochastic geomechanical characterization of tight rocks using multistage triaxial testing and ultrasonic pulse transmission testing: A comparative study

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Summary

Unconventional reservoirs provide geomechanical challenges for wellbore stability, completions optimization, interwell connectivity, and induced seismicity. Yet, all of these processes depend on a reservoir's poroelastic properties and strength. Unfortunately, the scale of these processes is several of orders of magnitude larger than laboratory characterization techniques. It is therefore impossible to accurately define the variability and true values of geomechanical parameters. Seismic surveys and well logs are useful in this respect, but they can be of limited use in identifying anisotropic depositional fabrics, and scale-dependent properties. Engineers and geologists therefore turn to analogues, heuristics, or stochastic methods for making critical decisions.

This study investigates four distinct types of samples using multistage triaxial testing and ultrasonic pulse transmission. The samples are from the Montney Formation, an outcrop analogue of the Duvernay Formation, the Kaybob area of the Beaverhill Lake Formation, and an outcrop analogue of the Montney Formation. We compare the results of the triaxial testing with simpler tests including microhardness, Brazilian tests, and x-ray fluorescence analysis. This study shows that disparate reservoirs and simple tests can be used to inform subsurface decisions and that there is a wide variability and uncertainty in geomechanical testing results.

The results from both the experiments in this study and those available in public data are presented. The triaxial behaviour is similar in the unconventional reservoirs and their outcrop analogues and significantly different from the Beaverhill Lake formation (a conventional carbonate reservoir). There is poor correlation between static and dynamic elastic properties in each reservoir. The ultrasonic pulse transmission results similarly showed a wide variability. Porosity and heterogeneity are good predictors of brittleness, strength, and the overall geomechanical behaviour. We show that the microhardness results showed similar trends to those observed during triaxial testing and may provide sufficient information for characterizing scale-dependent heterogeneity.

These results show that the quantification of heterogeneity and depositional structures may more important that the exact quantification of elastic properties, which can be predicted using cost effective laboratory techniques like microhardness and x-ray fluorescence. There is a strong correlation between static geomechanical tests. Thus, focusing on the stochastic variability of one formation relative to another becomes more important that defining absolute values within a formation. We present a statistical approach to predicting static properties from well logs and ultrasonic pulse transmission results that may prove useful for practitioners.

In conclusion, a workflow that consists of simple tests for quantifying heterogeneity, the widespread use of analogues, and the use of predictive models that use simple tests and dynamic measurements may prove superior to large testing programs. There are many challenges in this approach, but it should provide a more robust understanding of unconventional geomechanics and lead the way to stochastic geomechanical models.