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Profile Ultrasonic Velocity Measurements for Estimating Dynamic Rock Mechanical Properties in the Leduc CO_2 Storage System

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Summary

Deep saline aquifers, such as those hosted in the Leduc Formation of Alberta, are a primary target for subsurface CO_2 storage for the purpose of mitigating greenhouse gas emissions. A key consideration when injecting CO_2 into such systems is the mechanical properties of the reservoir and the ability of the caprock to prevent upward migration of CO_2. The caprock must maintain structural integrity during the CO_2 injection/post-injection period. Caprock integrity can be evaluated using in-situ tests, such as a diagnostic fracture injection test (DFIT), and controlling properties (e.g., geomechanical properties) may be estimated from well log data ideally correlated to laboratory geomechanics tests. The latter typically involves static geomechanical testing of cores/core plugs.

This study explores the use of profile ultrasonic data collected on slabbed cores to evaluate dynamic rock mechanical variability within the Leduc Formation and its associated caprock (the Ireton Formation). The tool applied herein was first developed by Tight Oil Consortium (hosted at the University of Calgary) to study fine-scale rock mechanical properties variations in low-permeability (unconventional) hydrocarbon reservoirs.

This proof-of-concept study represents the first application of this tool to study the Leduc CO_2 storage system, with a focus on the Ireton caprock. The ultimate goal of this study is to provide facies-level estimates of dynamic rock mechanical properties for the Ireton, with correlations developed with other petrophysical (e.g., profile permeability) and geochemical (e.g., profile XRF) data, to assist with caprock integrity evaluations and well log calibrations.

Methods

The profile ultrasonic tool used in this work (**Fig. 1**) is a modification of the tool first described by Mohammed et al. (2024). The measurement principle is based on the pulse-echo technique (Rabbani and Schmitt, 2018). Samples are placed in a V-shaped core holder, and contact is ensured using a screw press. The transducer is used to transmit and receive the signal. The output is voltage-versus-time, which is recorded on a digital oscilloscope connected to a computer. Additional descriptions of the instrument and its application are provided by Mohammed et al. (2024). Example first-arrival picks of the P-wave is provided in **Fig. 2**.

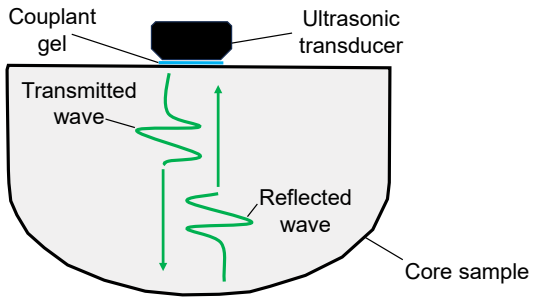


Fig. 1 – Illustration of the ultrasonic profile velocity measurement system. Modified from Mohammed et al. (2024).

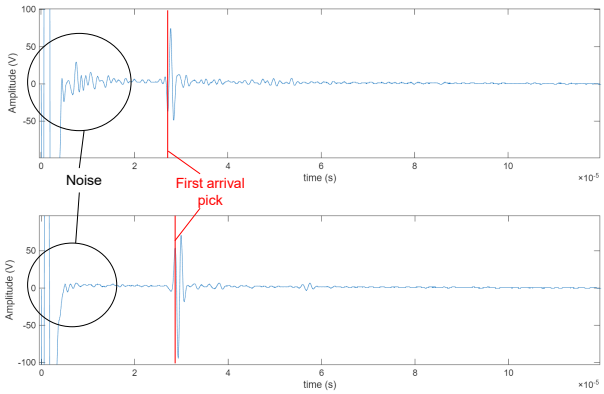


Fig. 2 – Example P-wave arrival picks using the profile ultrasonic tool.

Results, Observations, Conclusions

A slabbed core covering the top ~10 m of upper Leduc aquifer, ~30m of the Ireton, and ~10m of the lower Nisku, was used for profile ultrasonic measurements.

A plot of P-wave velocity versus depth is compared with the profile permeability, microhardness, and XRF data collected by Younis et al. (2024) in **Fig. 3**. Only the Ireton yielded consistently good quality readings with an average P-wave velocity of 4361 m/s. Data collected in the Leduc and Nisku, though more sparse, generally suggests higher velocities for these intervals.

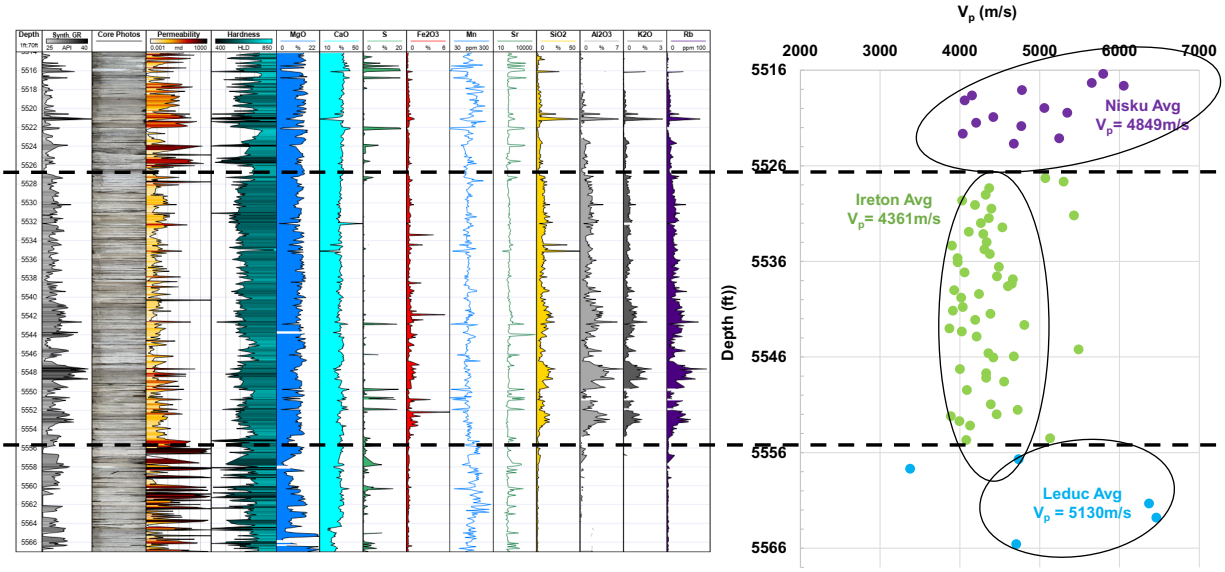


Fig. 3 – Comparison of collected profile ultrasonic P-wave velocity (Vp) data with profile permeability, microhardness, and XRF data collected by Younis et al. (2024).

At the time of writing, detailed comparisons between the profile ultrasonic velocities collected herein, and the profile data collected by Younis et al. (2024), are being performed and will be reported on in future work. In addition, dynamic rock mechanical properties will be calculated for these intervals, and a comparison will be performed with static rock mechanical properties collected on core plug samples.

In summary, preliminary results suggest that profile ultrasonic velocity data exhibits repeatable trends specific to formations within the Leduc CO_2 storage system, and that these data can be integrated with established datasets such as XRF, profile permeability, and microhardness. Furthermore, preliminary data collected at lower frequencies also exhibits good quality readings with repeatable trends, suggesting that the ultrasonic data could be used to calibrate sonic logs.

Novel/Additive Information

Profile ultrasonic data is collected for the first time in the Leduc CO_2 storage system with the intent of developing facies-scale evaluation of dynamic rock mechanical properties. These data may ultimately be useful for evaluating caprock integrity and calibrating sonic logs in the field.

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