Quest CCS facility: Time-Lapse Seismic Campaign

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Summary

In August 2015, CO2 injection commenced at the Quest CCS project located near Fort Saskatchewan, Alberta, Canada. Quest is a fully integrated CCS project with a capture target of just over one million tonnes of CO2 per year. CO2 is injected into a deep saline aquifer, the Basal Cambrian Sand (BCS), at a depth of about 2 km below ground.

In order to demonstrate containment and conformance of the injected CO2, a Measurement, Monitoring and Verification (MMV) plan has been implemented. Four domains are monitored as part of the plan, namely Atmosphere, Biosphere, Hydrosphere and Geosphere. Time-lapse seismic methods are currently utilized for containment and conformance monitoring of the CO2 plume within the Geosphere domain. These methods currently include 3D surface seismic, 2D surface seismic and 2D borehole DAS VSP.

The aim of this presentation is to showcase the different baseline and monitor datasets that have been acquired at the Quest CCS facility and describe the current Time-lapse strategy resulting from our most recent campaign in February 2019. Five key seismic acquisition campaigns have occurred at Quest through the pre- and post-start of injection periods, including an initial 3D seismic acquisition, a pre-injection baseline 2D borehole DAS VSP acquisition, and three monitor 2D borehole DAS VSP acquisitions. 2D surface seismic acquisitions have also been acquired as part of two of the monitor campaigns. All campaigns have occurred over the winter season, to facilitate surface access, minimize impact on the land and farming/harvest activities, and to ensure maximum repeatability.

Time-Lapse Response of the CO2

Time-lapse seismic methods yield an image of the CO_2 that is injected into the BCS pore space, displacing some of the brine in the saline aquifer. Since the injected CO_2 is more compressible and less dense than brine, the velocity of seismic p-waves traveling through the BCS will be reduced in those places containing CO_2 and will remain unchanged elsewhere. Differences in seismic images of the BCS obtained before and during CO_2 injection will arise due to the presence of CO_2 in two characteristics ways:

- Travel-time across the BCS will become longer due to the slower p-wave velocity inside the BCS.
- Reflections from the base of the BCS will become stronger as the impedance contrast with the underlying granite basement increases.

Petrophysical data from the injection wells were used to calculate the saturation dependence of acoustic properties for the BCS using properties for brine and supercritical CO_2. To analyse the expected seismic response from CO_2-brine substitution, Gassmann fluid substitution was used.

Modelling indicates that the acoustic changes are sufficient to define the CO_2 front qualitatively, but not the distribution of CO_2 saturations within the plume.

The Role of Time-Lapse Seismic in MMV at Quest

The initial time-lapse seismic strategy called for 3D surface seismic to be employed after a few years of injection operations. Borehole VSPs were proposed as cost-effective and flexible alternative while injection volumes are small. Inherently the effectiveness of VSPs is dependent upon the injection volumes, plume offset from the injection wells and acquisition geometries. After evaluating the concentric plumes predicted from the dynamic modelling results, and the operating logistics of an acquisition at the Quest CCS well-sites, a 2D multi-azimuth walk away DAS VSP (2DVSP) program was proposed.

In 2017 and 2019, 2D surface seismic was recorded in addition to the 2DVSP surveys. Geophones were deployed along the 2DVSP multi-azimuth shot locations, recording a pseudo-3D or cross-spread survey. 2D surface seismic will be evaluated as another seismic method to potentially monitor CO_2 plume development in the BCS.

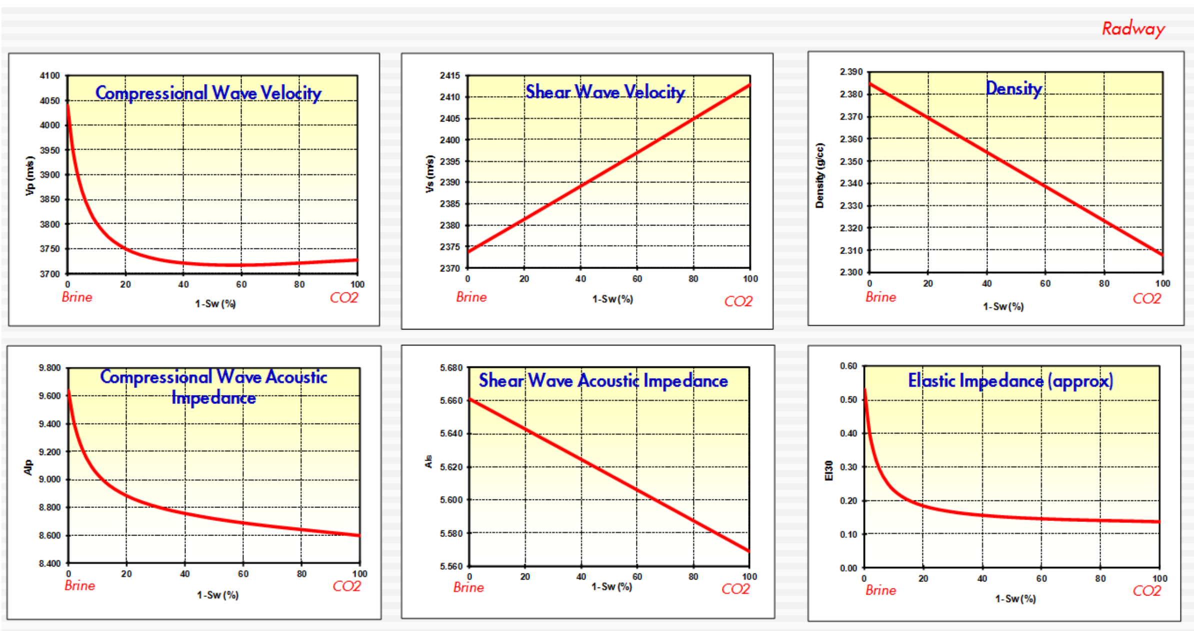

Figure 1 *Calculated layer average acoustic property changes in the BCS at well SCL-Redwater 8-19-59-20W4 in response to changes in CO_2 vs brine saturation.*