Advancing Containment, Conformance and Injectivity Technologies for Effective Geological Storage

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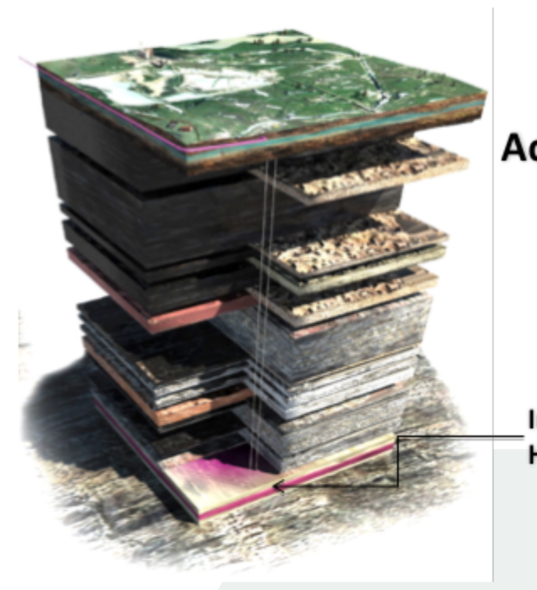
BACKGROUND

Carbon Capture and Storage (CCS) is a geologic and engineering enterprise designed to reduce atmospheric emissions of greenhouse gases (GHGs). CCS technology could play an important role in efforts to limit the global average temperature rise to below 2° C, by removing carbon dioxide originating from fossil fuel use in power generation and industrial plants. The integrated CCS process captures carbon dioxide (CO_2) generated at large-scale industrial sources (power plants, refineries, gasification facilities, etc.) and transports it to an injection site to be permanently stored in the subsurface – typically in saline reservoirs or depleted oil and gas fields. Canada is a world-leader in Carbon Capture and Storage (CCS) technology with two operating projects: Shell-Quest in Alberta; and Boundary Dam in Saskatchewan. Together these projects currently capture more than 2 Mtpa of CO_2. At Quest, more than 1 Mtpa is injected directly into a deep subsurface storage formation (Basal Cambrian) using three injection wells. At Boundary Dam, most of the captured CO_2 is sold for use in the Weyburn CO_2-EOR project with the remainder also injected into the Basal Cambrian storage complex via a single 3400m deep injection well as part of the Aquistore Project. There is an immediate opportunity to expand both of these projects that could lead to significant CO_2 reductions (i.e., Mtpa) in a short time (i.e. the injection capacity. At Boundary Dam, the operator (SaskPower) faces an imminent decision whether to add carbon capture capacity to its upcoming retrofits on Boundary Dam -4 and -5 power station units. That decision depends in large part on the capacity of the Basal Cambrian storage formation to store increased amounts of CO_2.



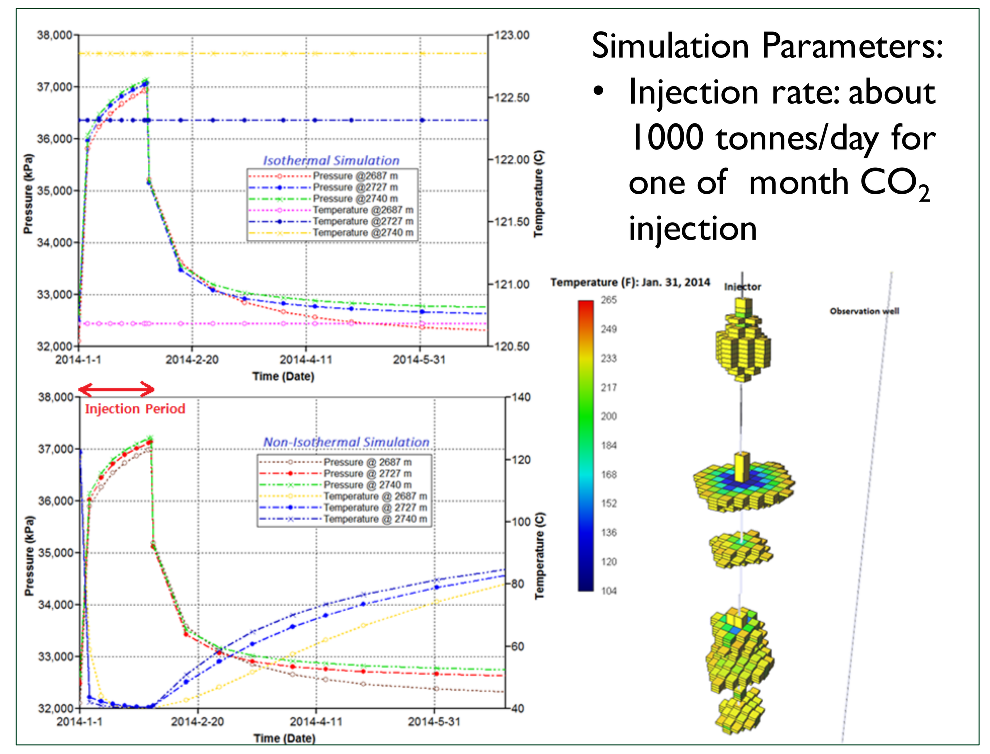
SHORT-TERM OBJECTIVES

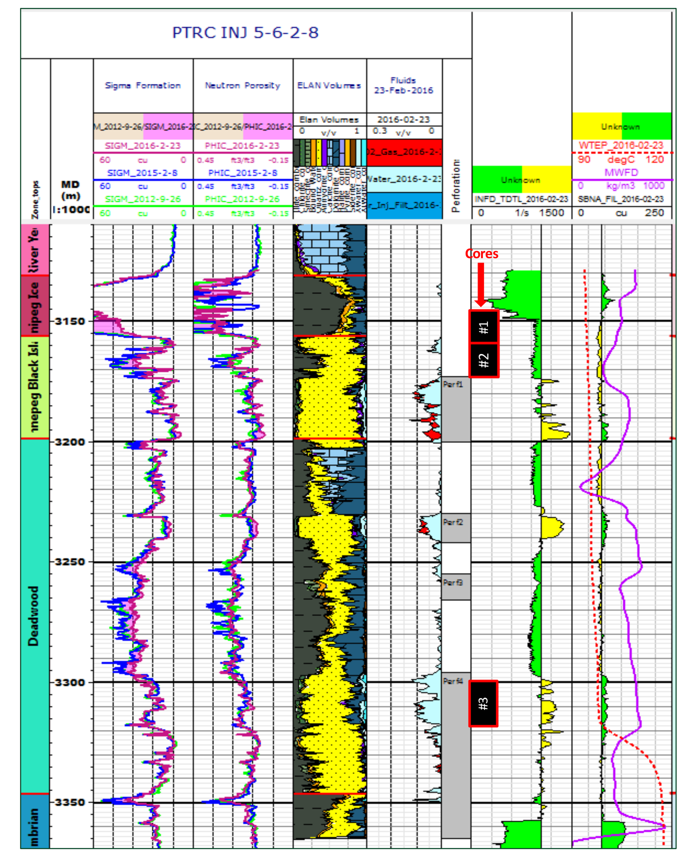
To support research efforts to advance our understanding of containment, conformance and injectivity associated with the geological storage of CO_2 our short terms objectives are:

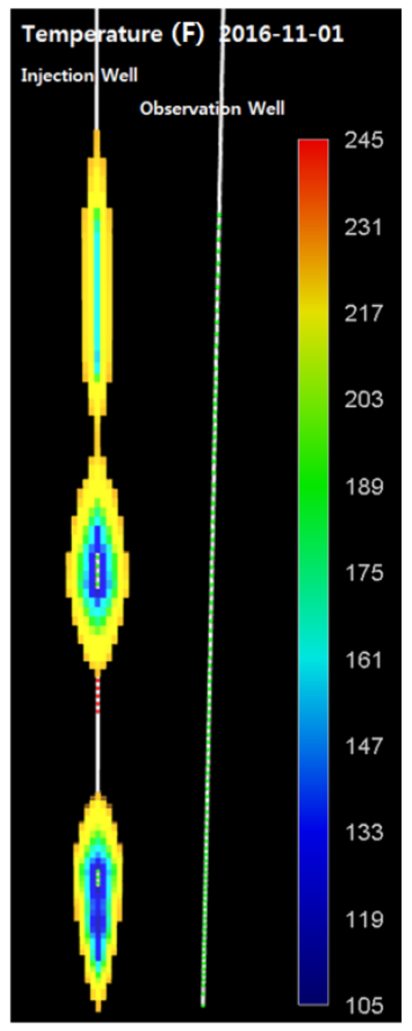
- **Understanding of potential subsurface issues related to cold CO_2 injection**

PROJECT OVERVIEW

Aquistore is helping to address one of the key research subsurface formations (in Aquistore's case, the Deadwood Formation) to receive and safely store CO_2 over long periods of time and to support the regulatory framework of CCS and to alleviate any public concerns about this technology. When CO_2 is injected into the reservoir, it undergoes pressure and temperature changes to reach equilibrium with in-situ conditions. These changes will induce both pressure and temperature gradients around the injection well. These gradients lead to the development of thermal stresses, which may affect the local hydraulic properties, including both the integrity of the bounding seals, as well as the reservoir injectivity. The impact of cooling on the stress state inside the reservoir (due to the injection of a different temperature of CO_2) may be quite dramatic. While cooling causes a decrease in the reservoir stresses, changes in formation fluid pressures will be increasing due to the CO_2 injection, which, in turn, will impact geomechanical behavior within the reservoir or the bounding seal horizons. For the Aquistore Project, the temperature of the injection zone (at approximately 3300 m depth) is about 120°C and the CO_2 enters the wellhead at approximately 40°C and warms only to approximately 60°C before entering the reservoir thus producing a significant cooling effect within the near well region of 60°C. Although cooling effects will be most acute in the injection zone, the potential exists for it to have some influence on the overlying shale (which serves as the primary seal). It is difficult to quantify the thermal effects without focused reservoir geomechanical testing and modeling.







THEME OVERVIEW

Carbon capture involves the development of technologies that can concentrate CO_2 from power plant flue gas or intermittent streams. Comparison of energy consumption of these processes with the thermodynamic minimum indicates significant room for improving these processes. Support for developments of next generation of capture technologies and large demonstrations is required to push us down the cost curve.

Utilization of CO_2 through conversion into useful chemicals of commercial importance, or utilizing CO_2 for oil extraction would add economic value to this greenhouse gas. The current view, primarily in the United States, is that the "U" in CCUS is primarily related to CO_2 Enhanced Oil Recovery (CO_2-EOR).

Long-term or permanent storage of CO_2 becomes the final key stage for the CCUS framework. While storage typically accounts for a relatively small fraction of the total cost in a fully integrated CCUS project, it has been shown to be one of the more difficult steps in the project value-chain. Any viable system for storing carbon must be effective and cost competitive, stable as long-term storage, and environmentally benign. Unique aspects of CO_2 storage, including containment, regulations, pore ownership, liability, public outreach, and pressure/plume management require large-scale CO_2 storage demonstrations to realize this technology.,

EXPECTED OUTCOMES

We are executing an experimental program that will directly measure and assess the thermo-hydro-geomechanical properties of both the reservoir and the overburden layers at the Aquistore site. The suite of tests will include the following:

Core Handling & Preservation

- Caprock and Aquifer Core Storage in Moisture Control Room
- Caprock X-ray imaging

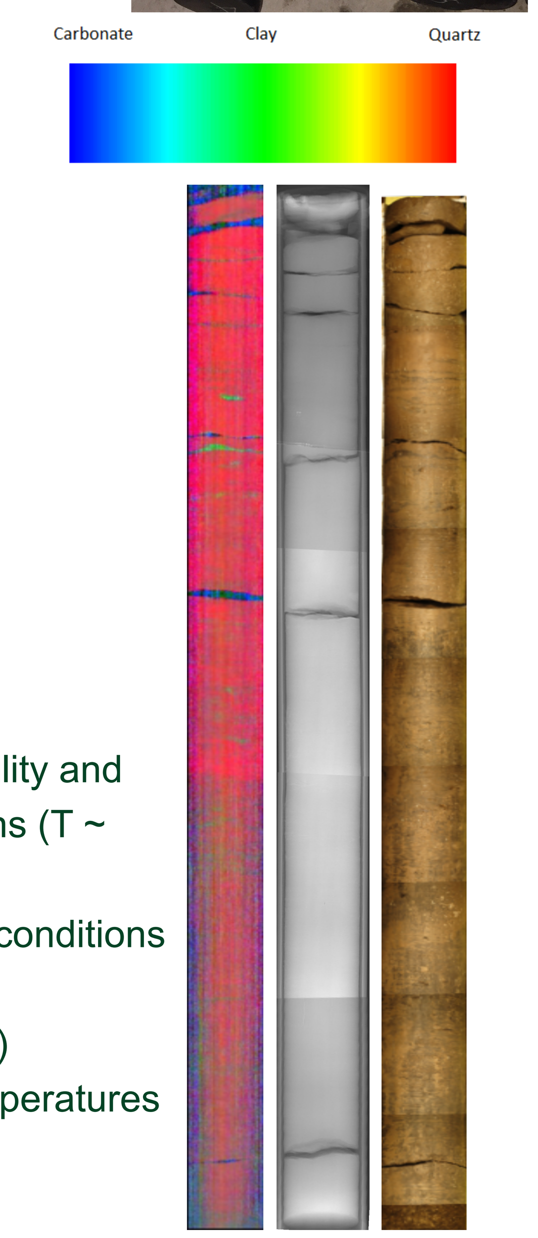
Petrographic

- Basic properties, such as density, porosity, etc. and before/after photographs
- Thin sections, SEM analysis, general petrographic analysis w/ photomicrographs
- XRD, QEMScans and reflectance spectroscopy

Geomechanical Properties

A majority of the following tests will be conducted on **Caprock** and **Aquifer** specimens and will cover the temperature range from 20°C to 120°C :

- Unconfined Compressive Strength (UCS)
- Triaxial Shear Strength w/ pore pressure and V_p/V_s measurement
- Direct shear
- Point load - Strength anisotropy index
- Static & dynamic elastic properties (ultrasonic frequencies)
- Tensile strength (Brazilian test)
- Dynamic elastic properties at seismic frequency
- Confined velocities @ varied brine-scCO_2 saturations



Hydraulic Properties

- Vertical (and hopefully, Horizontal) Caprock brine permeability and CO_2 breakthrough pressure at ambient and in situ conditions (T ~ 90°C)
- Air and brine permeability of Aquifer at ambient and in situ conditions
- Brine permeability variation during triaxial tests
- scCO_2 permeability variation at in situ conditions (T ~ 40°C)
- Brine – CO_2 relatively permeability at in situ stress and temperatures of 20°C, 40°C and 80°C (hopefully)

Thermal Properties

- Thermal expansion coefficient - unconfined and 20°C conditions
- Thermal expansion coefficient - confined and 20°C to 120°C conditions
- Thermal conductivity and specific heat capacity - unconfined and 20°C conditions
- Thermal conductivity and specific heat capacity - confined and 20°C to 120°C conditions

EXTERNAL PARTNERS

ptrc Petroleum Technology Research Centre

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