A Test Problem for Modelling CO_2 Injection, Migration and Possible Leakage - Wabamun Lake Area, Alberta, Canada

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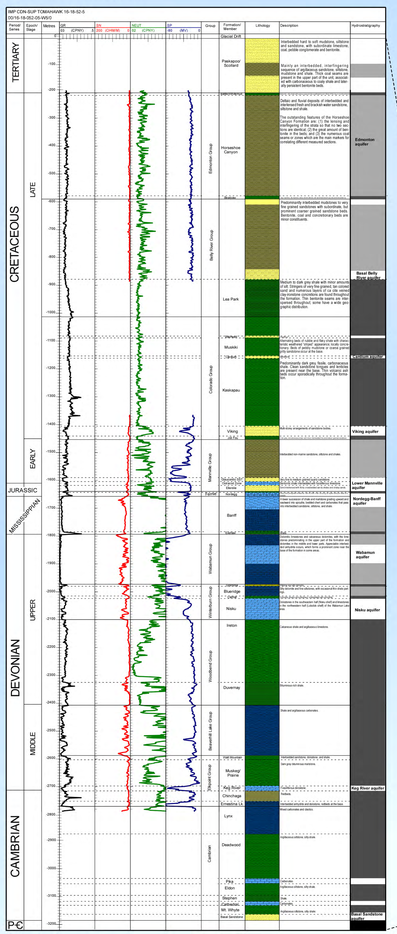
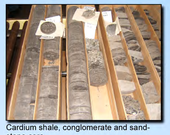
EUB Alberta Energy and Utilities Board | AGS Alberta Geological Survey www.ags.gov.ab.ca

Stratigraphy and Rock Characteristics

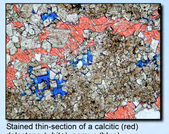
The main source of information are data collected by the petroleum industry in Alberta during drilling and production of a well. The well data are submitted to the Alberta Energy and Utilities Board (EUB), including drill cores that are stored at the EUB's Core Research Centre. Generally, data abundance decreases with depth, and testing and sampling occurred in aquifer units and reservoir rocks, predominantly in the hydrocarbon-bearing units.



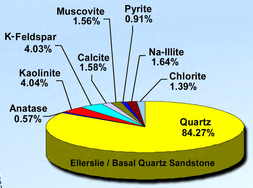

Cardium shale, conglomerate and sandstone core


Cardium conglomerate hand-sample

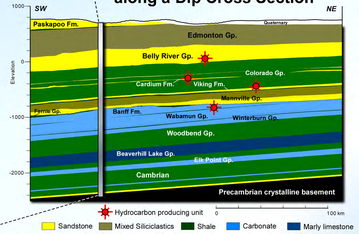

Porous dolostone


Stained thin-section of a calcitic (red) dolostone (white), porous (blue)

A mineralogical assessment was performed on core samples from potential injection horizons. Polished thin sections were prepared for mineralogical analysis by electron microprobe. Powdered samples were analyzed by XRD, X-Ray Fluorescence (XRF), and Inductively-Coupled Plasma Mass Spectrometry and normative mineralogical composition was calculated and can be used for geochemical reaction modelling.



General Stratigraphy along a Dip Cross Section



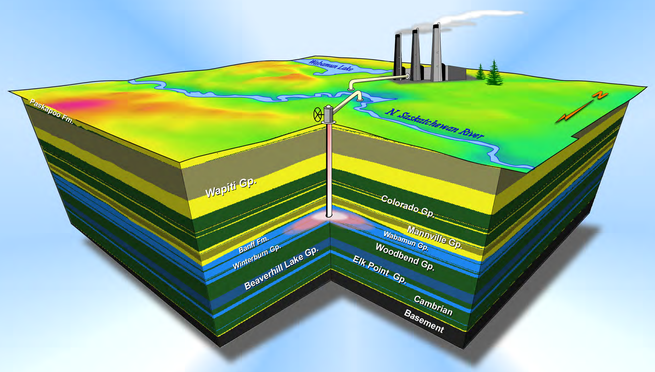
In more than 1000 wells, the stratigraphy was picked and reported based on geophysical logs. The accuracy and resolution in the picks dataset varies as a result of different methods and geological interpretation by various geologists. Therefore, consistency of the stratigraphic framework was established by confirming the correct stratigraphic succession within each individual well, as well as ensuring lateral consistency for individual horizons.

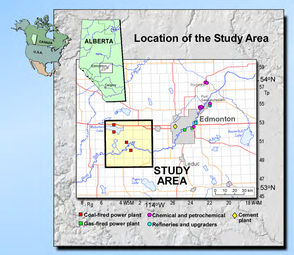
Background

Geological storage of CO_2 in deep saline aquifers is an option for significantly reducing emissions into the atmosphere. In November 2005, participants at a Workshop on Geological Storage of CO_2 at Princeton University agreed on the need for a common test problem to assess various models for simulating the fate of CO_2 injected into the subsurface. The Alberta Geological Survey offered to make available the data for the Wabamun Lake area in Alberta, Canada, that were assembled for the purpose of developing a comprehensive model for studying CO_2 geological storage.

The Wabamun Lake area, southwest of Edmonton in central Alberta, was selected by AGS because a variety of favourable conditions identify it's a potential site for future large-scale CO_2 injection. Several large industrial CO_2 point sources are located in the vicinity, resulting in short transportation distances of the captured gas. Various deep-saline formations with sufficient capacity to accept and store large volumes of CO_2 in supercritical phase exist at the appropriate depth and are overlain by thick, confining shale units. Most importantly, a wealth of data exist (i.e., stratigraphy, rock properties, mineralogy, fluid composition, formation pressure, information about well completions, etc.), which were collected by the petroleum industry and submitted to the provincial regulatory agency the Alberta Energy and Utilities Board. For these reasons, the Wabamun Lake area is an ideal location for the comprehensive characterization of a CO_2 storage site and for analyzing the potential risks associated with such an operation.

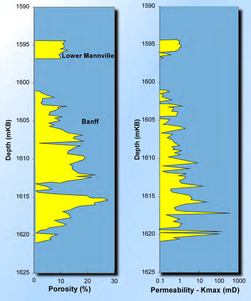
The Banff to Cardium aquifers are currently producing hydrocarbons and could be considered for CO_2 enhanced oil or gas production. In contrast, the absence of hydrocarbon occurrences in the Cambrian to Devonian succession and the presence of additional overlying aquitards make aquifers in this stratigraphic interval good candidates for long-term CO_2 storage. A data collection for the Wabamun Lake area and additional information can be found at www.ags.gov.ab.ca/activities/wabamun/.



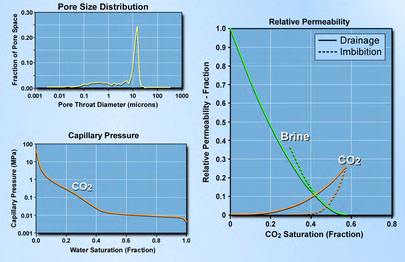


Core Measurements

Drill cores were taken in many wells and core analyses exist for selected intervals in approximately 550 wells, mainly in reservoir rocks. In addition to lithological description, parameters typically measured on core plugs are porosity, permeability and grain density. In addition, relative permeability tests for supercritical CO_2 displacing brine were conducted on selected carbonate, sandstone and shale core samples.



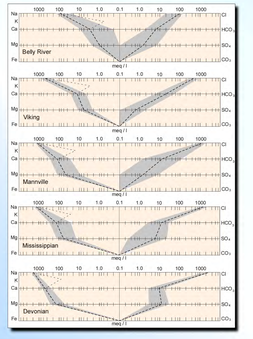
Relative Permeability Measurements for Viking Fm.



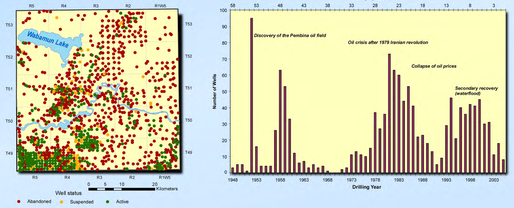
Formation Water Chemistry

Samples of formation water are taken from DSTs or during well production. The typical chemical analysis includes major ion and total dissolved solids (TDS) concentrations, pH, temperature, density and resistivity.

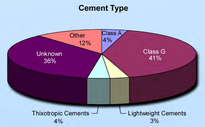
The salinity of formation water generally increases with depth, reaching 10 g/l in the Basal Belly River aquifer. All aquifers below the top of the Colorado Group shales contain brines with salinity values above 20 g/l and up to 170 g/l in the Upper Devonian aquifers. No data exist for the Middle Devonian to Cambrian aquifers in the Wabamun Lake area, but regional-scale studies indicate salinity of formation waters of up to 300 g/l.

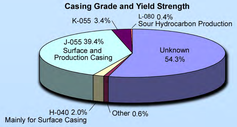


General Well Information



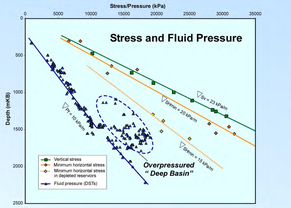
Approximately 1350 wells have been drilled in the Wabamun Lake area for hydrocarbon exploration and exploitation. For each borehole, records exist of the geographic location, the surface elevation, the total depth, the various operational dates, and the well status. In many cases, information exists on the casing, completion and cement types and their location in the borehole. Production volumes and rates are available for producing wells.





Pressure and Stress Regimes

The overburden pressure of vertical stress Sv was estimated by integrating density logs. The smaller principal stress, SHmin, was measured by or estimated through hydro-frac, mini-frac or leak-off tests.



Drillstem tests (DSTs) are performed by the petroleum industry to determine pressure and permeability in potential reservoir units. Formation pressures and permeability values are determined from DST results using a Horner plot analysis.

The lower part of the succession, from the Cambrian to the Lower Cretaceous Viking aquifer, is underpressured, with pressures ranging from 28 MPa at 3000 m to 6.5 MPa at 1000 m depth. Exceptions are overpressured "Deep-basin style" hydrocarbon accumulations in the respective aquifer located downdip of the water leg. The shallow aquifers in the upper succession above the Colorado Gp. shales aquitard are normally to slightly sub-hydrostatically pressured.