COMPREHENSIVE CHARACTERIZATION OF A POTENTIAL SITE FOR CO_2 GEOLOGICAL STORAGE IN CENTRAL ALBERTA, CANADA

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INTRODUCTION

Geological storage of CO_2 in deep saline aquifers is an option for significantly reducing emissions into the atmosphere. The Wabamun Lake area southwest of Edmonton in central Alberta (Figure 1) was identified as a potential site for future large-scale CO_2 injection for a variety of favorable conditions. Several large industrial CO_2 point sources are located in the vicinity, resulting in short transportation distances of the captured gas.

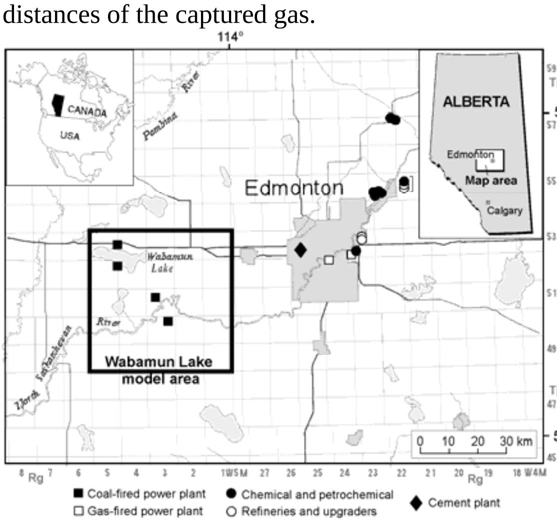

Figure 1. Location of the Wabamun Lake study area in Alberta, Canada.The study area covers 5 x 5 townships, which is equivalent to 900 square miles or 2500 km^2.

Various deep saline formations that have 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 exists (i.e., stratigraphy, rock properties, mineralogy, fluid composition, formation pressure, information about well completions), which was 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. In addition, this comprehensive data set offers the opportunity to test and to benchmark various models for predicting the performance of sites for CO_2 geological storage and the long-term fate of the injected CO_2.

GEOLOGY AND HYDROSTRATIGRAPHY

Overlying the Precambrian basement, the sedimentary succession in the Wabamun Lake area has a maximum thickness of up to 3000 m. It consists at its base of passive margin sediments, including evaporites and marine carbonates and shales of Cambrian to Jurassic age. The upper part is formed mainly by coarse to fine siliciclastic that were deposited in the Rocky Mountain foreland basin during the Cretaceous to present period. Due to pre-Cretaceous erosion, Mississippian carbonates subrop below Lower Cretaceous sandstones in the northeastern part of the study area. The sedimentary succession dips gently towards the southwest with a slope of 9 m/km (Figure 2). There are no known major faults in the area.

Figure 2 shows the general stratigraphy in the Wabamun Lake area along a dip cross section. Typically, sandstones and carbonates are aquifers, whereas shales and evaporites form aquitards. The sedimentary succession is subdivided by two thick aquitards, the Woodbend Group shales and the Colorado Group shales, into three main hydrostratigraphic groups: a) the Cambrian-Middle Devonian, b) the Upper Devonian-Lower Cretaceous, and c) the post-Colorado. Each major hydrostratigraphic group contains several aquifers and intervening aquitards. Some units also host hydrocarbon reservoirs and oil and gas production occurs mainly from the Banff Formation, the Lower Mannville Group, the Viking Formation, the Cardium Formation and the Basal Belly River Group (Figure 2).

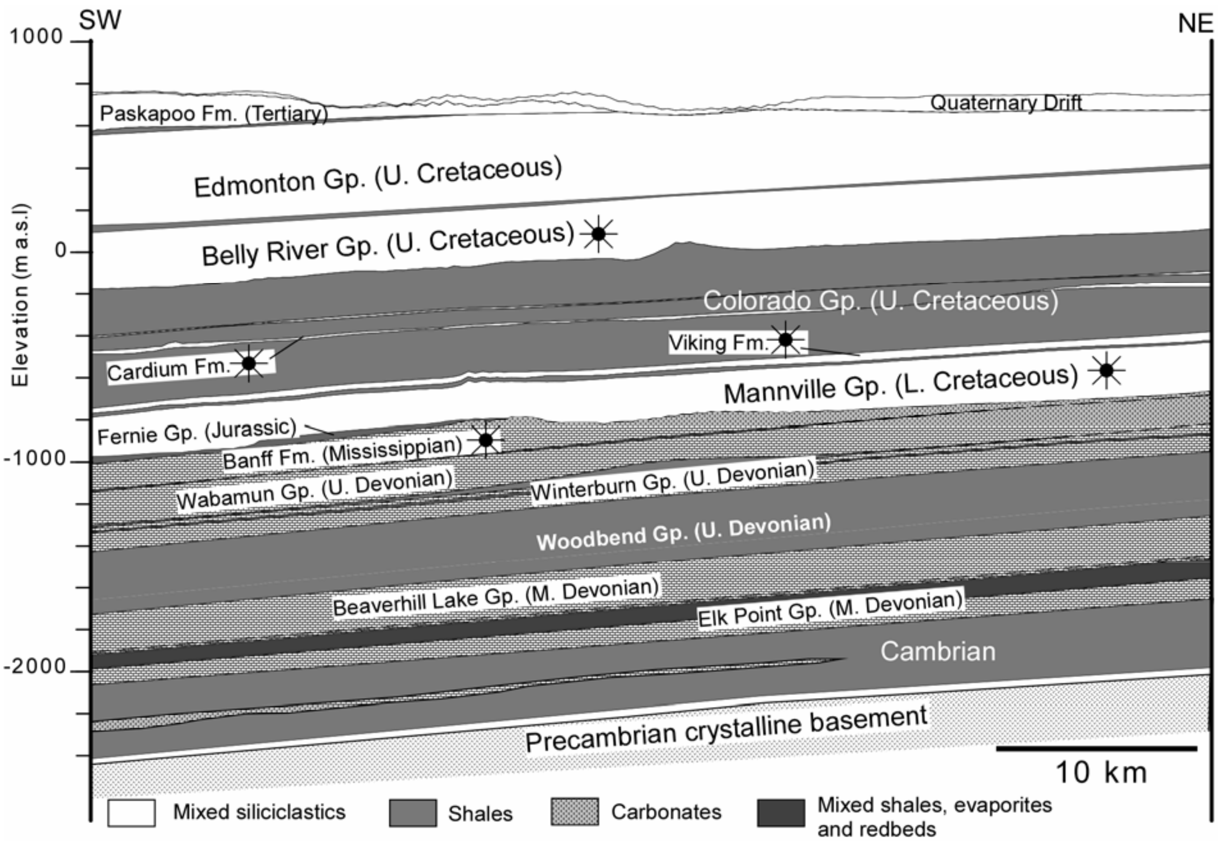

Figure 2. Dip cross section through the sedimentary succession in the Wabamun Lake area, Alberta, Canada, showing the general stratigraphy and lithology distribution.

FORMATION FLUIDS

Three different pressure regimes govern the flow of formation fluids in the Wabamun Lake area. 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 Lower Mannville and Cardium aquifers, which are hydrocarbon-saturated areas 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, and formation water flow is driven by the topography in the Wabamun Lake area. 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 (Bachu, 1999; Anfort et al. 2001).

DATA SOURCES, TYPES AND QUALITY

Approximately 1400 wells have been drilled in the Wabamun Lake area for hydrocarbon exploration and exploitation. Data collected by the petroleum industry in Alberta 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 (Table 1). The following data are digitally stored in databases at the Alberta Geological Survey and were used in this study.

General well information

For each borehole, records exist of the geographic location, the surface elevation, the total depth, the various operational dates, and the well status. In most 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.

Table 1. Count of selected parameters that were collected in the various aquifer units.

	Number of wells with:			
Aquifer	Strat.	DST	Chem.	Core
Belly River	503	49	45	7
Cardium	861	6	2	183
Viking	845	26	18	4
Mannville	882	37	43	257
Nordegg (Jur.)	212	6	3	17
Banff	779	20	15	81
Wabamun	82	4	12	4
Nisku (Winterb.)	39	6	18	14
Slave Point	14	-	-	-
Keg River	3	-	-	-
Pika (Cambrian)	1	-	-	-
Basal Sandstone	1	-	-	-

Stratigraphic picks

In more than 1000 wells, the stratigraphy was picked and reported by the geologist in charge using 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. Data that caused stratigraphic inversions or anomalies in mapped surfaces were individually checked and either corrected or removed from the data set.

Drillstem test data

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 data were allocated to the respective aquifers and were culled for erroneous tests, including production influence (Michael and Bachu, 2002).

Formation water composition

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. After assigning the chemical analyses to their respective hydrostratigraphic unit, erroneous analyses were removed using methods presented by Hitchon and Brulotte (1994).

Core analyses

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 (Bennion and Bachu, 2005).

Mineralogy

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. The computer code LPNORM (Caritat et al., 1994) was used to perform a normative analysis from the chemical analysis to obtain a normative mineralogical composition.

CONCLUSIONS

Favorable geological conditions, infrastructure, and comprehensive data holdings make Alberta and specifically the Wabamun Lake area southwest of Edmonton an ideal location for a detailed study and characterization of future CO_2 storage sites. Several deep saline aquifers are located at the appropriate depth at which CO_2 can be stored as a supercritical, dense fluid. They are confined by one or more thick, low-permeability aquitards, preventing upward leakage of injected CO_2. 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.

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