Reservoir and Seal Pairs: Carbon Sequestration in Atlantic Canada

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Summary

The Maritime Provinces of Eastern Canada have several candidate Paleozoic and Mesozoic basins for CO_2 storage near several major sources. Both carbonate and clastic reservoirs have seal pairs. Many are capped by thick shale deposits or evaporite deposits of the Windsor Group and Argo Formation which can form excellent seals for potential storage reservoirs.

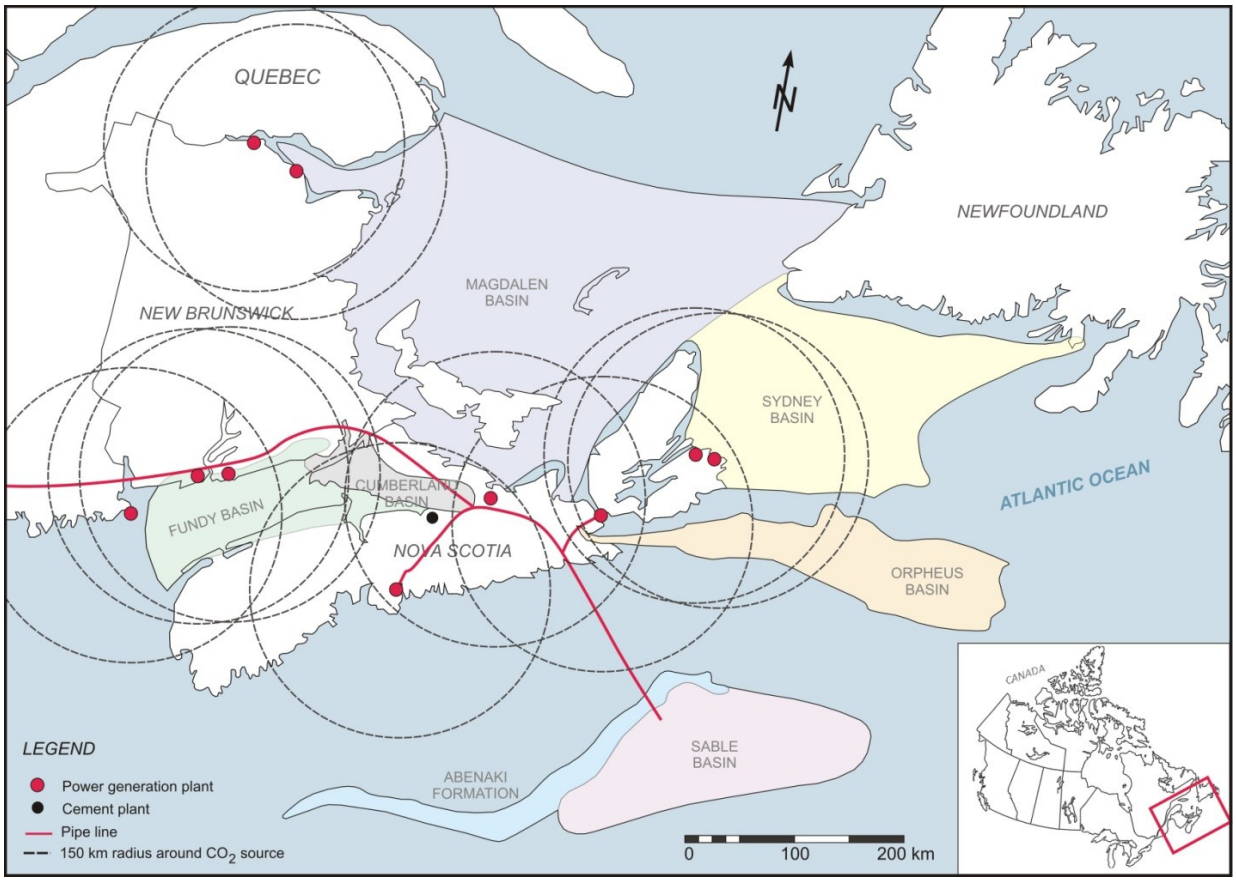

Figure 1: Map of Atlantic Canada illustrating locations sedimentary basins with potential for CO_2 storage adjacent to major sources of CO_2 emission sites (modified from Enachescu, 2006).

Introduction - Reservoir and Seal Characterization

The geological sequestration of carbon dioxide is seen as a solution to reduce greenhouse gas emissions. The process begins with identifying and characterizing prospective storage sites within economical distances from CO_2 sources. An ongoing study of the sedimentary basins of Atlantic Canada has shown good potential for CO_2 storage (Figure 1).

For site evaluation, reservoir and seals pairs are usually delineated with a high degree of confidence from logs and 3D seismic data. However subsurface geological data are seldom adequate to properly characterize the bedform scale in reservoirs needed to monitor the distribution of high volumes of injected CO_2 and the potential diagenetic effects on reservoir performance over time. Our preferred approach is to use analog reservoir models developed from detailed outcrop study of formations correlated with equivalents offshore. We incorporate high resolution photography, LiDAR, GPR (ground penetrating radar), scintillometer (Gamma Ray) and outcrop permeameter data, with bed-scale outcrop measurements of outcrop geometry to define the architectural elements that are input to geologic and reservoir models using Schlumberger Petrel® and Eclipse®. Outcrop and core samples are examined petrographically to enhance our understanding of potential diagenetic effects at bed contacts coupled with detailed measurement of effective and ineffective porosity and permeability. In sedimentary basins, salt bodies at depths exceeding 3 km may contain a stable interconnected brine-filled porosity, resulting in permeabilities comparable to those of sandstones. These parameters are used to populate detailed geological and reservoir models for simulation of various fluid types and injection strategies through time.

Regional Geology

The Maritimes Basin lies within the present-day Gulf of St. Lawrence and includes the Sydney, Magdalen and Cumberland subbasins. Coarse clastics underlie thick evaporites that in tectonically complex basins form, to date, non-commercial gas reservoirs; large salt diapirs occur near-surface that could provide solution cavities for storage. Above the evaporites there are clastic formations and coal beds alternating with shales. The coarse grained clastics could be potential reservoirs.

The Scotian Basin is located offshore Nova Scotia and includes the Orpheus and Sable subbasins, as well as the carbonate Abenaki Fm. The majority of the succession is a passive margin basin fill of sand and shale sequences deposited in response to global relative changes in sea level. In the later Jurassic and Cretaceous the Sable and Laurentian deltas preserved transgressive and regressive packages of deltaic, shelf margin and slope deposits (Wade and MacLean 1990; Kidston, et al., 2002). The ages of the rock units present in each basin is outlined in Figure 2.

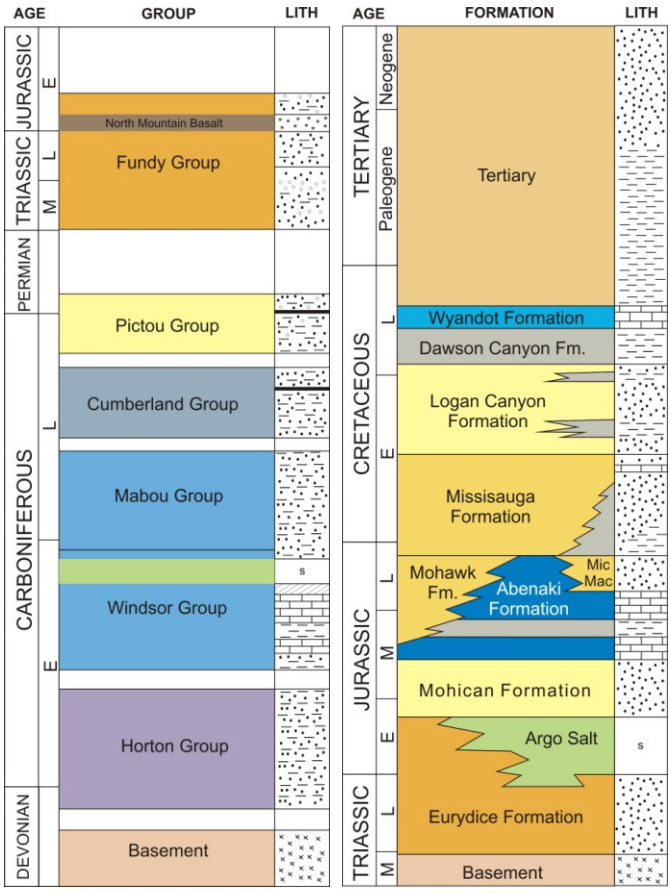

Figure 2: Stratigraphic columns of the Maritimes Basin (left) and the Scotian Basin (right) (modified from Hu (2008) and Natural Resources Canada).

Scotian Basin

Triassic to Neogene strata in the offshore Orpheus, Abenaki and Sable subbasins offer realistic possibilities for CO_2 storage, and recent petroleum exploration provides suitable seismic and petrophysical data from wells, to assess the sequestration potential (Figure 3). Autochthonous and allochthonous Jurassic salt provides potential reservoir traps, as well as seals, and the Cretaceous and Cenozoic strata contain significant porous formations that have led to economic oil and gas exploitation. The Orpheus Graben subbasin includes Mesozoic sediments of the syn-rift sequences related to the opening of the Atlantic. The structurally deformed basin contains suitable sands and subsalt plays and should be the focus of future carbon sequestration studies an adjacent to emission sites in Cape Breton.

A few of the best suited (Cretaceous) sands for storage are those occupied by compartmentalized and overpressured gas reservoirs in the Sable subbasin. They are rather distal from the CO_2 sources (more than 150 km), but pipeline infrastructure is already in place. Shelf margin deltas have been interpreted for several of the Sable subbasin gas fields (Cummings and Arnott 2005). The paleo-shelf edge has potential for both sandstone and carbonate reservoirs for CO_2 storage particularly with the existing Sable gas fields and new (2010) development of Deep Panuke carbonate trend. Limestone in the mixed-carbonate-siliciclastic settings has not been porous and may provide additional untested seal capacity to the associated sandstone reservoirs.

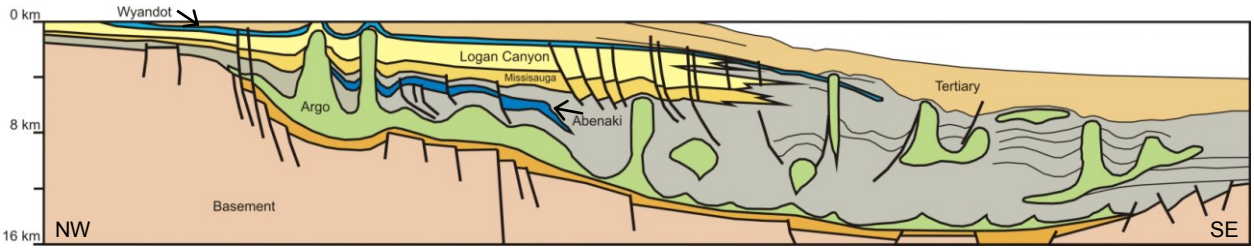

Figure 3: Cross section of the Sable Basin and Abenaki Formation offshore Nova Scotia (modified from Kidston,2007).

Conclusions

In Atlantic Canada several basins with excellent reservoir/seal pairs are candidates for the geological storage of CO_2 in either a liquid or gas phase. Candidate seals include thick marine transgressive shales and evaporites, which both exhibit broad lateral extent and thickness, and can be paired with both carbonate and coarse clastic reservoirs. Reservoir and seal pairs for the Atlantic Canada basins are summarized in Table 1.

Seal is the most important component of the CO_2 geologic sequestration system. Thick shales and evaporites form membrane seals. We consider hydrodynamic seals to carry a greater risk than caprock, or membrane seals. The stratigraphic continuity of caprock and thickness can be more readily ascertained by drilling and seismic imaging. Post injection monitoring of the CO_2 in a liquid or a gas phase will be more difficult though a hydrodynamic seal, compared to a seal of rigid, or near rigid lithology.

What remains to be completed is detailed analysis of samples to discern storage capacity, including injectivity rates, lateral continuity and characterization of storage reservoirs to determine storage capacity, seal integrity, regional and local stress fields and the effect CO_2 will have on the reservoir through time. We have begun detailed reservoir characterization and modeling of an analogous reservoir in outcrop, the Triassic Wolfville Formation exposed along the Minas Basin and Bay of Fundy.

Table 1: Reservoir-seal pairs of Atlantic Canada sedimentary basins.

Maritimes Basins	
Fundy	Reservoir - fine grained to conglomeratic clastics (Blomidon and Wolfville Fms.) Seal - North Mountain Basalt
Cumberland	Reservoir - Pennsylvanian coarse clastics (Joggins and Polly Brook Fms.) Seal - Windsor evaporites
Magdalen	Reservoir - Devono-Carboniferous to Permian age coarse clastics Seal - Mississippian evaporites and salt
Sydney	Reservoir - Devono-Carboniferous to Permian age coarse clastics Seal - Mississippian evaporites and salt
Scotian Basins	
Orpheus	Reservoir - fine grained to conglomeratic clastics (Eurydice Fm.) Seal - thick evaporites (Argo Fm.)
Sable	Reservoir - thick deltaic sands (Missisauga Fm.) Seal - thick transgressive prodelta shales
Abenaki	Reservoir - carbonates with fracture and dolomitic porosity (Abenaki Fm.) Seal - thick transgressive prodelta shales

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