



CO₂ Geological Storage in the Province of Québec, Canada

Basin-scale prospectivity assessment and capacity evaluation

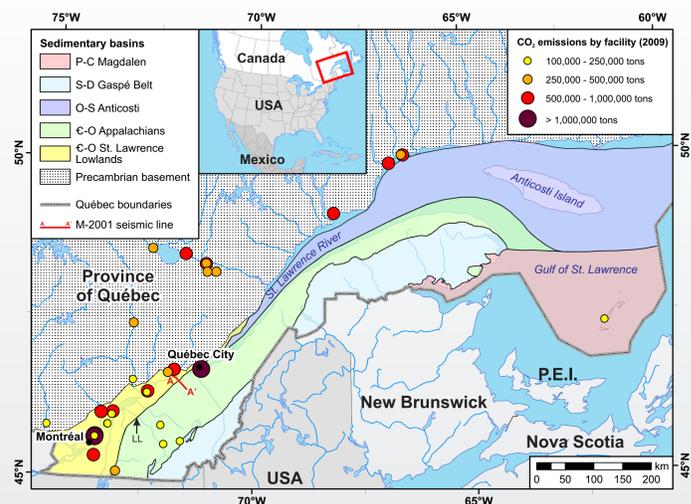
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BASIN SUITABILITY FOR CO₂ STORAGE

The basin classification method used for Southern Québec is based on the work of Bachu (2003) and Kaldi and Gibson-Poole (2008). Five (5) basins were evaluated :

- Magdalen Basin
- Silurian-Devonian Gaspé Basin
- Cambrian-Ordovician Appalachian Basin
- Anticosti Basin
- St. Lawrence Lowlands Basin



BASIN EVALUATION AND RANKING FOR CO₂ STORAGE

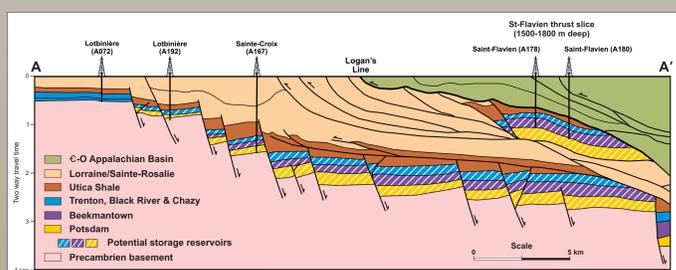
The **St. Lawrence Lowlands Basin** is, by far, the most prospective for CO₂ sequestration in the Province of Québec. It contains **excellent reservoir-seal pairs**, many well and seismic data are available, **several large CO₂ emitters** are present directly in the basin, accessibility is easy and infrastructure is extensively developed. **Deep saline aquifers** present in the autochthon sedimentary units are considered as potential CO₂ reservoir in the basin.

| | More favorable | Less favorable | ST. LAWRENCE LOWLANDS | ANTICOSTI | APPALACHIAN | GASPÉ | MAGDALEN |
|---|------------------|----------------------------------|-----------------------|------------------|----------------------|----------------------|----------------------|
| SEISMICITY (tectonic setting) | Low (4) | Low (4) | Low (4) | Low (4) | Low (4) | Low (4) | Low (4) |
| Size | Medium (3) | Very large (5) | Very large (5) | Very large (5) | Large (4) | Large (4) | Large (4) |
| Depth | Intermediate (4) | Intermediate (4) | N/A | Intermediate (4) | Intermediate (4) | Intermediate (4) | Intermediate (4) |
| DEFORMATION (faults and fractures) | Limited (3) | Limited (3) | Extensive (1) | Extensive (1) | Limited (3) | Limited (3) | Limited (3) |
| Reservoir-seal pair | Excellent (3) | Excellent (3) | Poor (1) | Poor (1) | Excellent (3) | Excellent (3) | Excellent (3) |
| Geothermal | Cold basin (3) | Cold basin (3) | Cold basin (3) | Cold basin (3) | Cold basin (3) | Cold basin (3) | Cold basin (3) |
| Hydrocarbon potential | Medium (3) | Medium (3) | None (1) | Small (2) | Large (4) | Large (4) | Large (4) |
| Evaporites | None (1) | None (1) | None (1) | None (1) | Domes (2) | Domes (2) | Domes (2) |
| Coal | None (1) | None (1) | None (1) | None (1) | Deep (2) | Deep (2) | Deep (2) |
| Maturity of exploration | Developing (3) | Exploration (2) | Unexplored (1) | Exploration (2) | Exploration (2) | Exploration (2) | Exploration (2) |
| On/Off shore | Onshore (4) | Shallow offshore and onshore (3) | Onshore (4) | Onshore (4) | Shallow offshore (2) | Shallow offshore (2) | Shallow offshore (2) |
| Climate | Temperate (5) | Temperate (5) | Temperate (5) | Temperate (5) | Temperate (5) | Temperate (5) | Temperate (5) |
| Accessibility | Easy (4) | Difficult (2) | Easy (4) | Easy (4) | Difficult (2) | Difficult (2) | Difficult (2) |
| Infrastructures | Extensive (4) | Minor (2) | Extensive (4) | Extensive (4) | Minor (2) | Minor (2) | Minor (2) |
| CO₂ sources | Many (5) | Few (2) | Moderate (3) | None (1) | Few (2) | Few (2) | Few (2) |
| General score R_i | 0.84 | 0.70 | 0.51 | 0.59 | 0.68 | 0.68 | 0.68 |

Malo and Bédard (2012); Bédard et al. (2011)

ST. LAWRENCE LOWLANDS BASIN CHARACTERISTICS

The **St. Lawrence Lowlands Basin** is made up of Cambrian to Upper Ordovician rocks resting unconformably on the Precambrian Shield. It represents a complete siliciclastic and carbonate platform succession. NE-SW normal syn-sedimentary faults affect the succession as well as the bedrock which result in a deepening of the basin toward to Appalachians to the SE.

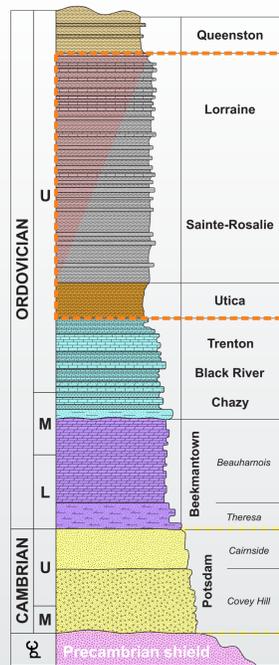


Modified from Castonguay et al. (2010)

3D MODEL OF THE ST. LAWRENCE LOWLANDS BASIN

The evaluation of the effective storage capacity of the St. Lawrence Lowlands was performed using a 3D geological model of the basin. This allowed calculating the volume of the potential reservoirs as well as the density of CO₂ in every cell of the model.

The Covey Hill and Cairnside formations are considered in the basin-scale storage capacity evaluation. The Trenton, Black River, Chazy and Beekmantown groups are not considered because of their low global porosity.



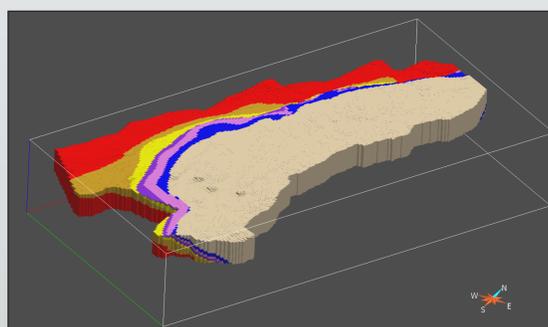
CAPROCKS

- Lorraine / Ste-Rosalie groups**
Shales, siltstones, sandstones
- Utica Shale**
Black calcareous shales

TARGETED RESERVOIR ROCKS

- Cairnside Formation**
Sandstones
Quartz (99%)
Fine to medium grained
Well rounded and well sorted
Average porosity : ~3%
- Covey Hill Formation**
Sandstones, conglomerates, shales
Quartz, feldspars, others
Poorly sorted
Average porosity : ~5%

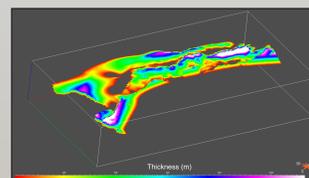
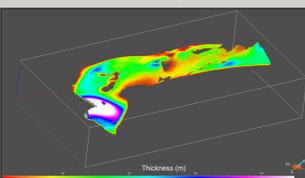
DEPTH : 800-3500 m



FORMATION THICKNESS

Cairnside average : ~180 m

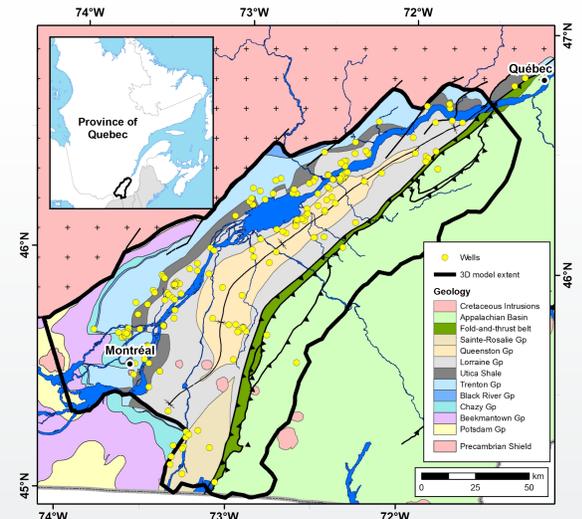
Covey Hill average : ~400 m



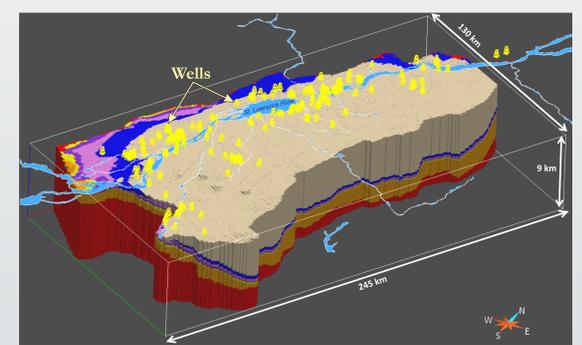
3D MODEL INPUT DATA

- Well data** : formation tops in depth
- Geological map** : formation limits at the surface
- Bedrock map from seismic lines** : bedrock geometry

GEOLOGICAL MAP



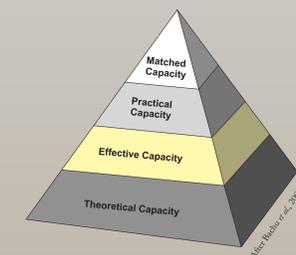
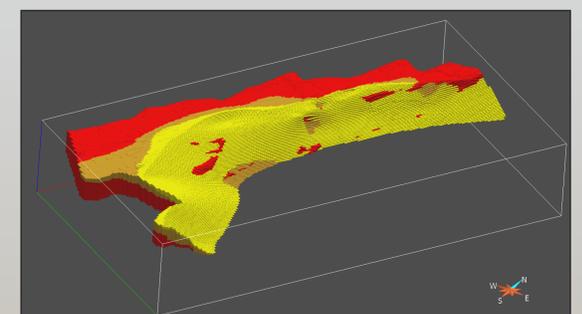
3D GEOLOGICAL MODEL



LEGEND

- Caprocks
- Trenton/Black River/Chazy
- Beauharnois
- Theresa
- Cairnside
- Covey Hill
- Precambrian basement

COVEY HILL AND CAIRNSIDE : 800-3500 m



A_t = Total area of the formation (m²)
 h_g = Gross thickness of the formation (m)
 $A_t \times h_g$ = Gross volume of the formation (m³)
 Calculated directly with 3D model.

ϕ_{tot} = Total porosity of the formation (%)
 Cairnside = 3%
 Covey Hill = 5%

G_{CO_2} = CO₂ storage resource mass estimate (kg)

$$G_{CO_2} = E_{saline} \times A_t \times h_g \times \phi_{tot} \times \rho_{CO_2}$$

E_{saline} = Storage efficiency factor for saline formation (%)

Defined by the Carbon Sequestration Atlas of the United States and Canada (DOE-NETL, 2010)

| Lithology | Formations | E(P ₁₀) | E(P ₅₀) | E(P ₉₀) |
|-----------|-------------------------|---------------------|---------------------|---------------------|
| Clastics | Cairnside Covey Hill | 0.51% | 2.0% | 5.4% |

ρ_{CO_2} = CO₂ density (kg/m³)

Calculated for each cell of the 3D model.
Function of temperature and pression.

802 to 818 kg/m³ between 800 and 3500 m.

Acknowledgments

Développement durable,
Environnement
et Parcs
Québec