Bedded Salt in Ontario: Geology, Solution Mining and Cavern Storage

Terry Carter, Chief Geologist
Petroleum Resources Centre
Ministry of Natural Resources
London, Ontario

Ontario Petroleum Institute annual meeting, Sarnia, 2009
Salt basin

- Shallow inland sea
- Restricted outlets to ocean
- Arid climate
- 30 degrees south of equator
**Salt cycle**

These cross-sections (at left) show the cycle that built up Michigan’s salt beds:

**A** Reefs surrounding a shallow basin restrict the flow of sea water.

**B** Sunlight and warm temperatures cause the water to evaporate.

**C** Eventually, so much water evaporates that the remaining water can no longer hold the salt in solution. The salt begins to precipitate, falling to the sea bottom.

**D** More sea water flowing into the basin starts the cycle again.
Salt basin – Great Salt Lake
Sedimentary Basins
Salina Group Salt Isopach

in GSA Special Paper 308, 1996
Stratigraphy, Oil, Gas and Salt in Ontario
Subsurface Resource Uses

- Oil & Gas production
- Cavern storage
- Salt solution mining
- Natural gas storage

1. Salt cavern hydrocarbon storage
2. Oil & gas reservoir
3. Natural gas reservoir storage
4. Transmission pipeline
5. Compressor
6. Gathering pipeline
7. Emergency shut down valve
Pinnacle Reefs
oil & gas and gas storage
Lambton County – Guelph Fm
Burial of reefs by A-2 Salt and A-2 Carbonate limestone
Oil, Gas, Gas Storage, Cavern Storage in Sarnia Area
Salina Group
Stratigraphy

SILURIAN

MIDDLE

AMABEL

Natural gas storage

Cavern storage
- Uppermost and shallowest salt beds, 275 – 450 m.
- Several separate beds with max combined thickness 90 m
- Underground mining at Windsor
Salina D Unit

- thinnest salt in Ontario – 12 m max
- no mining
- thickest salt in Ontario – 90 m with numerous interbeds of dolomite and anhydrite
- 16,000 km²
- solution mining Goderich, Windsor
- cavern storage Sarnia, Windsor
Salina A-2 Salt

- Lowermost and deepest salt bed in Ontario, 500 – 775 m.
- One bed up to 45 m.
- Underground mining at Goderich
- Cavern storage Sarnia
Bedded Salt
Non-salt Rocks

- limestone
- anhydrite
B Salt Lithology

OGS 82-2 Chatham
Harwich 1-25-IECR
Salt Dissolution

• All Salina salt beds exhibit evidence of dissolution after deposition

• Timing variable

• B Salt: Eastern edge is dissolution front – thin from 30 m to zero in 1 km
Salt Dissolution

B Salt: Windsor area
Salt Dissolution
Collapse breccias
**Mining and Cavern Storage**

<table>
<thead>
<tr>
<th>Layer</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>G Unit</td>
<td>Underground mining - Windsor</td>
</tr>
<tr>
<td>F Unit</td>
<td>Solution mining – Goderich, Windsor</td>
</tr>
<tr>
<td>F Salt</td>
<td>Cavern storage - Sarnia</td>
</tr>
<tr>
<td>E Unit</td>
<td>Underground mining – Goderich</td>
</tr>
<tr>
<td>D Unit</td>
<td>Cavern storage - Sarnia</td>
</tr>
<tr>
<td>C Unit</td>
<td></td>
</tr>
<tr>
<td>B Unit</td>
<td></td>
</tr>
<tr>
<td>B Salt</td>
<td></td>
</tr>
<tr>
<td>A-2 Carbonate</td>
<td></td>
</tr>
<tr>
<td>A-2 Evaporite</td>
<td></td>
</tr>
<tr>
<td>A-1 Carbonate</td>
<td></td>
</tr>
<tr>
<td>A-1 Anhydrite</td>
<td></td>
</tr>
</tbody>
</table>
Solution Mining

- Windsor and Goderich
- 20 active solution mining wells
Cavern Storage in Ontario

112 wells
70 caverns
27 million bbl
Lpg, oil
Hydrocarbon storage cavern

*Nominal Depth
Natural Gas Storage in Caverns – U.S.

Ledges in caverns

Interbeds of insoluble limestone, anhydrite form ledges in caverns
Salt dissolution and recrystallization

Insoluble residue
Roof slabbing and debris pile

- Roof
- Edge of slab
- Debris pile
Summary

- Bedded salt occurs in several layers tens of metres, 275-775 m depth, underlying up to 16,000 km² in subsurface of Ontario
- Salt layers deposited on floor of ancient sea
- Post-depositional dissolution of salt in subsurface – recrystallised salt, dissolution fronts, breccias
- Underground mining and solution mining at two locations
- 70 solution-mined caverns used for storage of hydrocarbons
- Non-salt layers in the salt beds may interfere with solution mining and cavern storage operations
- Natural gas storage and oil/gas production in reef structures beneath the salt
Partial burial of reefs by lime mud
First salt deposition – A-2 Salt

Lambton County – A-2 Salt Fm
3D Subsurface Geology
Deposition of B Salt

Lambton County – B Salt Fm