OIL AND GAS PLAYS OF THE MICHIGAN BASIN, SOUTHERN ONTARIO

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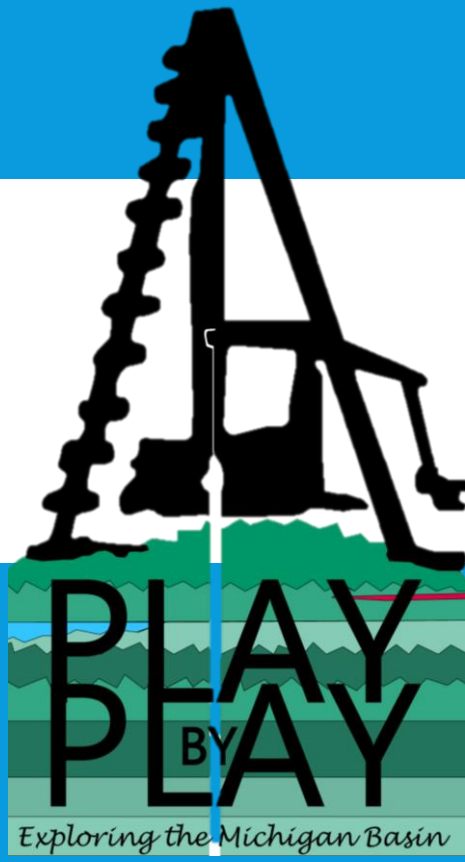


Ontario Petroleum Industries

- **Oil and Natural Gas**
  - 1250 oil wells, 1200 gas wells, annual production 400,000 bo, 5.7 bcf natural gas, 100 different producers
  - 5 wells/yr, 27,000 well records
- **Hydrocarbon Storage in Geological Formations**
  - 270 bcf natural gas in 35 depleted reservoirs, 275 wells
  - 22 million bbl refined petroleum products in 71 solution-mined caverns at Sarnia-Windsor area refineries/petrochemical plants – 95 wells
- **Salt Solution Mining**
  - 250,000 tonnes/yr, 18 wells

Industry Participants

- **Oil & Gas**
  - Historically and presently exploration and production is dominated by small (mostly), Ontario-based operators
  - History of periodic interest from large Calgary-based and international companies
  - Small companies are low-cost, maintain operations through down-cycles, generate new plays, raise local capital
  - Local companies have grown into large national and international corporations with long-term economic impact;
    - Imperial Oil, Union Gas, and former McColl-Frontenac (Texaco Canada), British-American Oil Co. (Gulf Canada) and White Rose (purchased by Shell Canada)
- **Hydrocarbon Storage**
  - Natural gas storage dominated by one large +billion$ company
  - All cavern storage operations owned by large +billion$ petrochemical companies
- **Salt solution mining**
  - Two operations owned by large corporations

Ontario Oil and Gas History & Firsts

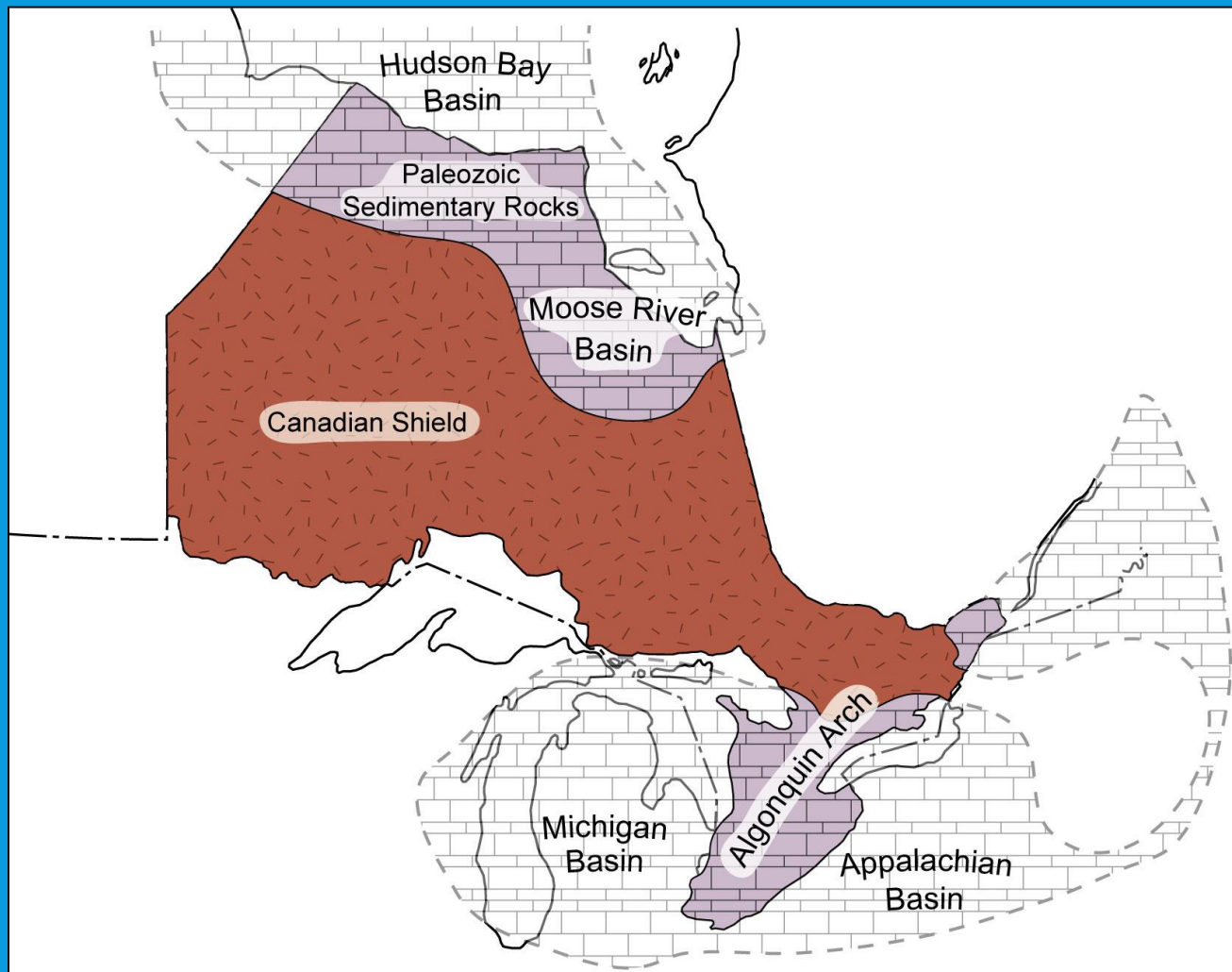
- 1858 - first commercial oil well in North America at Oil Springs (and first oil spills)
- 1866 – first salt solution mining well at Goderich
- 1870 – first oil exports to U.S
- 1873 – first export of technology – first Canadian drillers leave for Indonesia
- 1889 - commercial gas production at Kingsville and Welland
- 1890 – first export of natural gas to U.S.
- 1913 – first offshore well in Lake Erie
- 1915 – first subsurface injection of natural gas for storage
- 1914 – Ontario Natural Gas and Oil Wells Act
- 1985 - year of peak gas production
- 1995 - year of peak oil production

Geological Setting

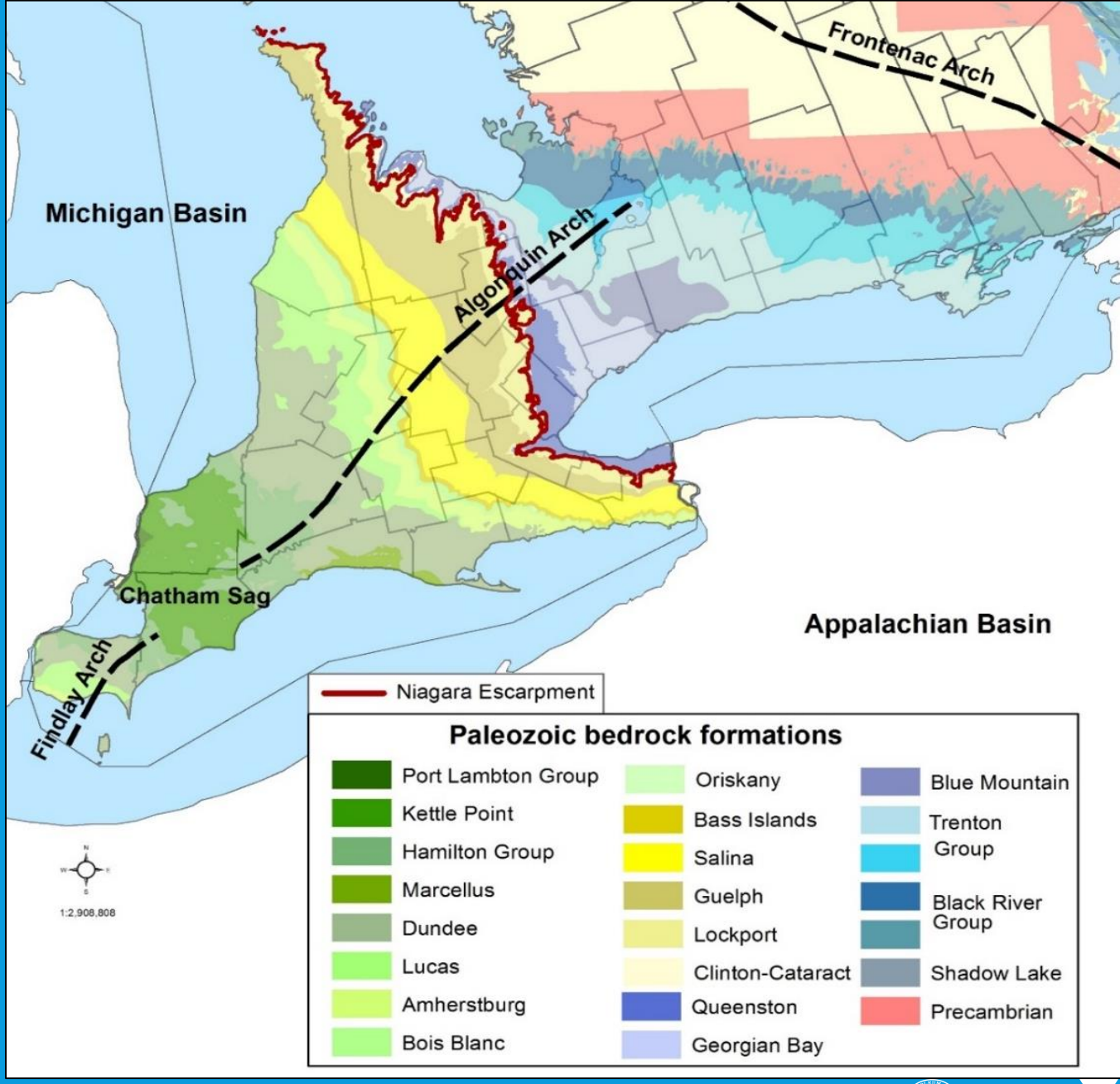
-Precambrian crystalline rocks of Canadian Shield form core of the North American continent, > 1 billion years old

-Sedimentary rocks deposited on top of these crystalline rocks around edges of the continent

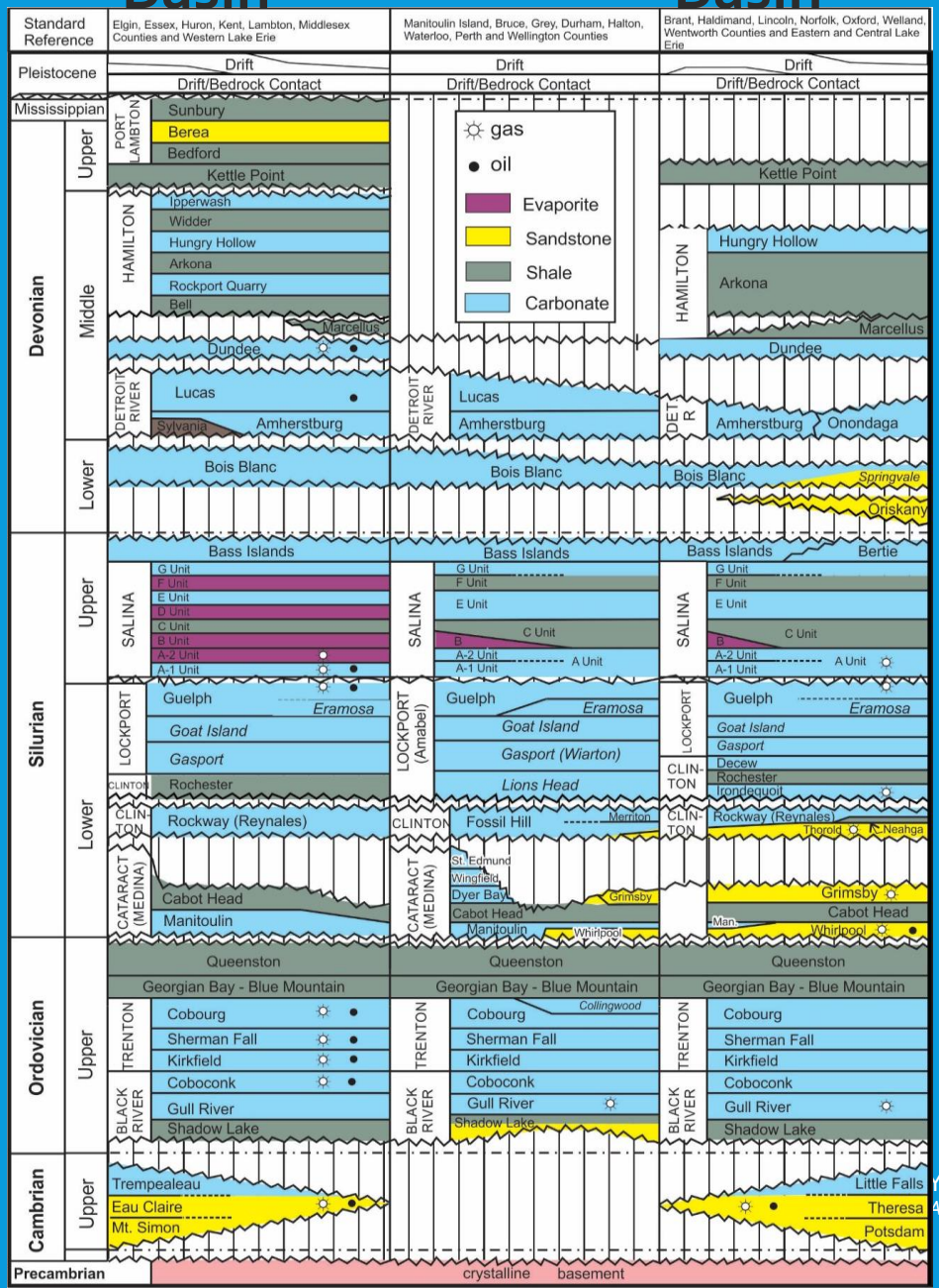
-Oil and gas production only in Michigan & Appalachian basins



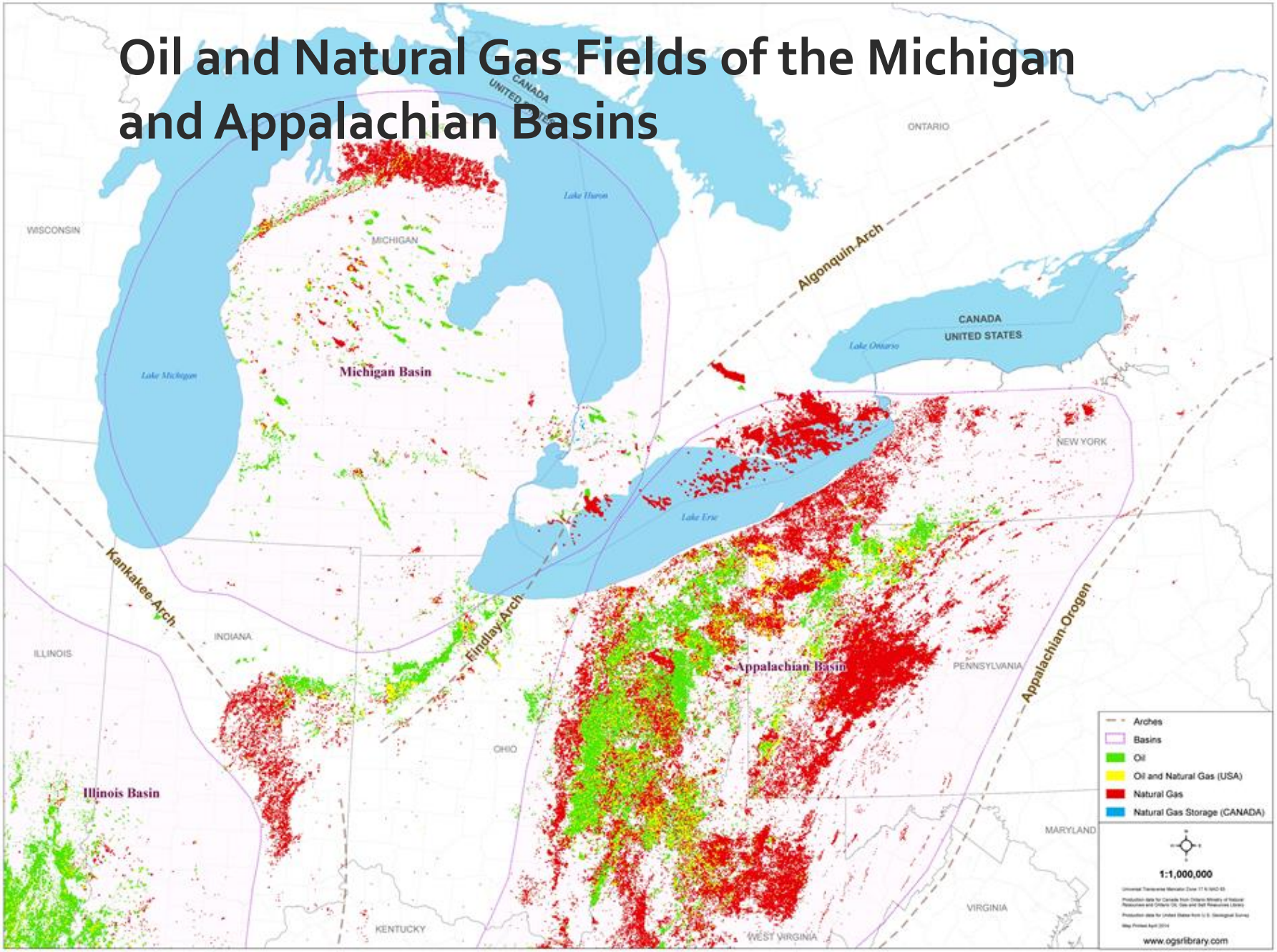
Bedrock Geology of Southern Ontario



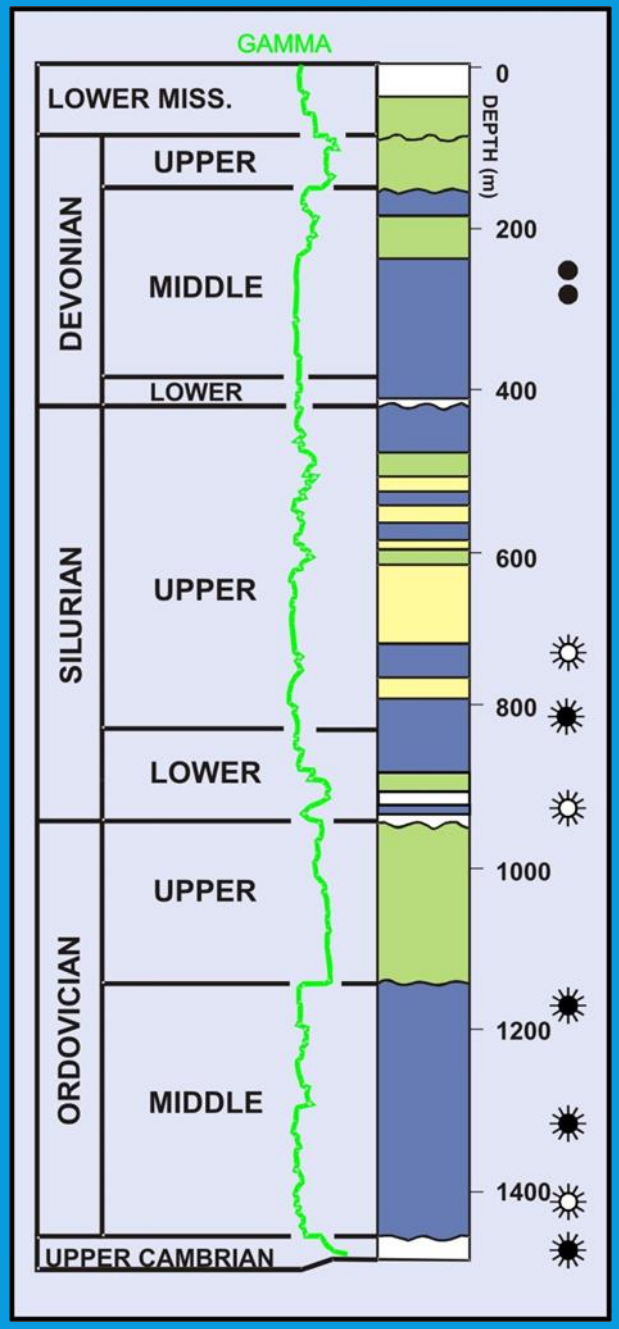
Paleozoic Stratigraphy of Southern Ontario



Oil and Natural Gas Fields of the Michigan and Appalachian Basins



Oil and Natural Gas Plays of the Michigan Basin, Ontario



DEV – structural traps in Devonian carbonates and sandstones

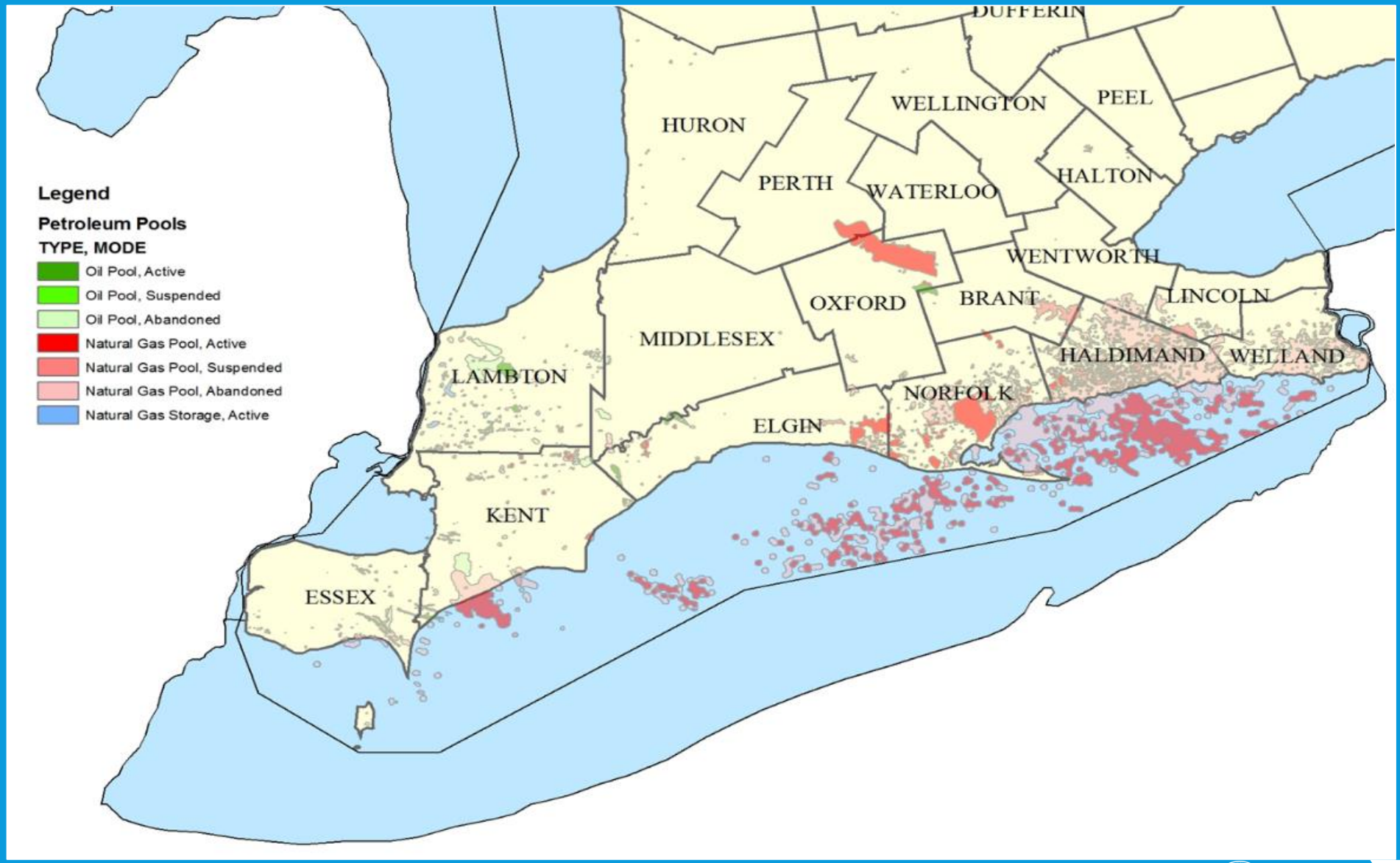
SAL – reefs and structural traps in Silurian carbonates;

~~CLI~~

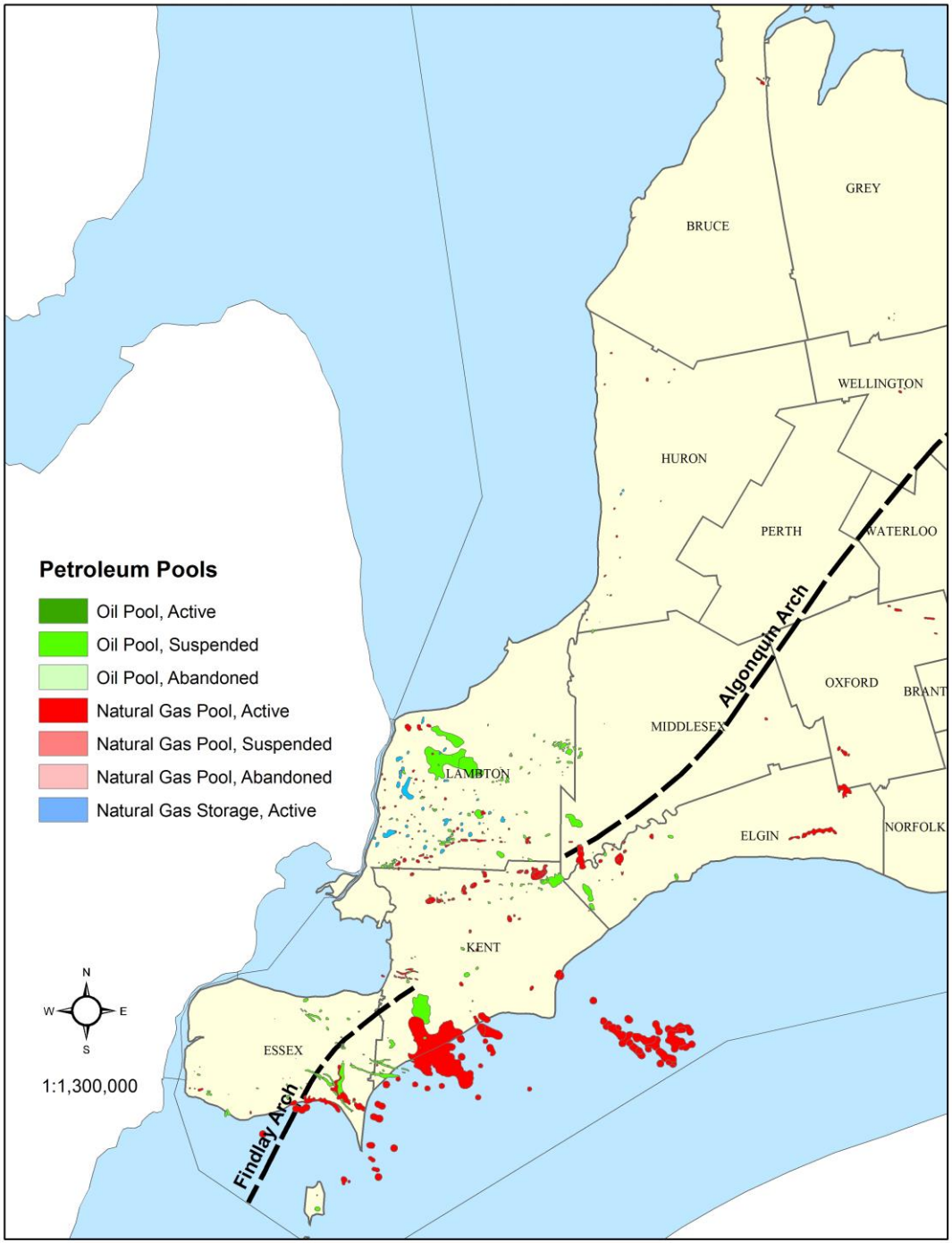
ORD – hydrothermal dolomite traps in Trenton and Black Groups (U. Ordovician)

~~CAM~~

Oil and Natural Gas Fields of Ontario



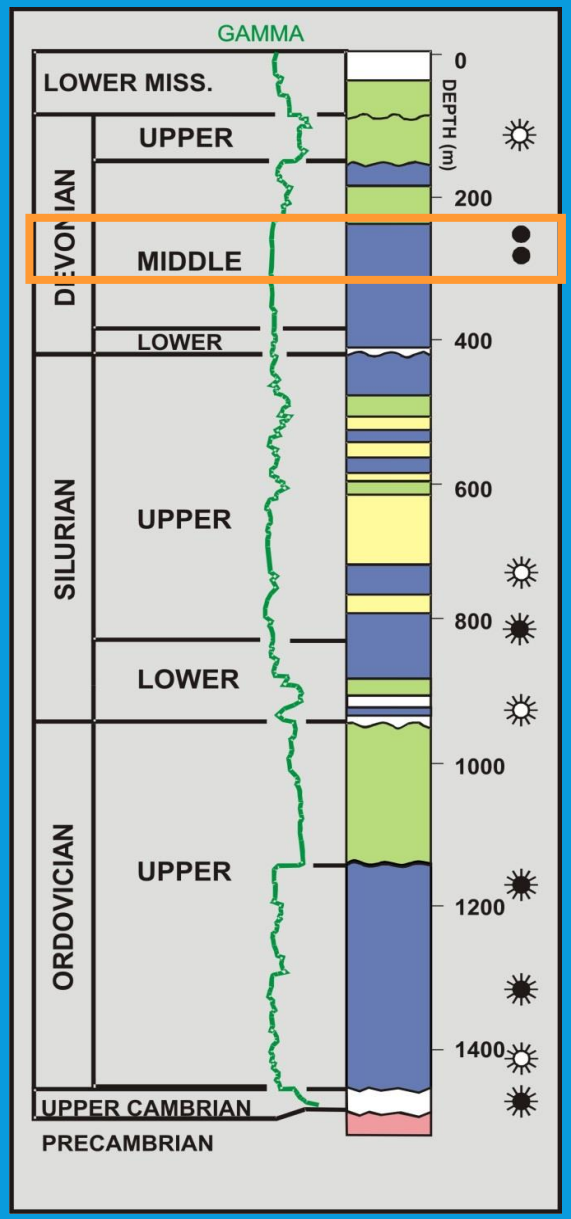
Oil and Natural Gas Fields of the Michigan Basin, Ontario



Ontario Oil and Gas Plays

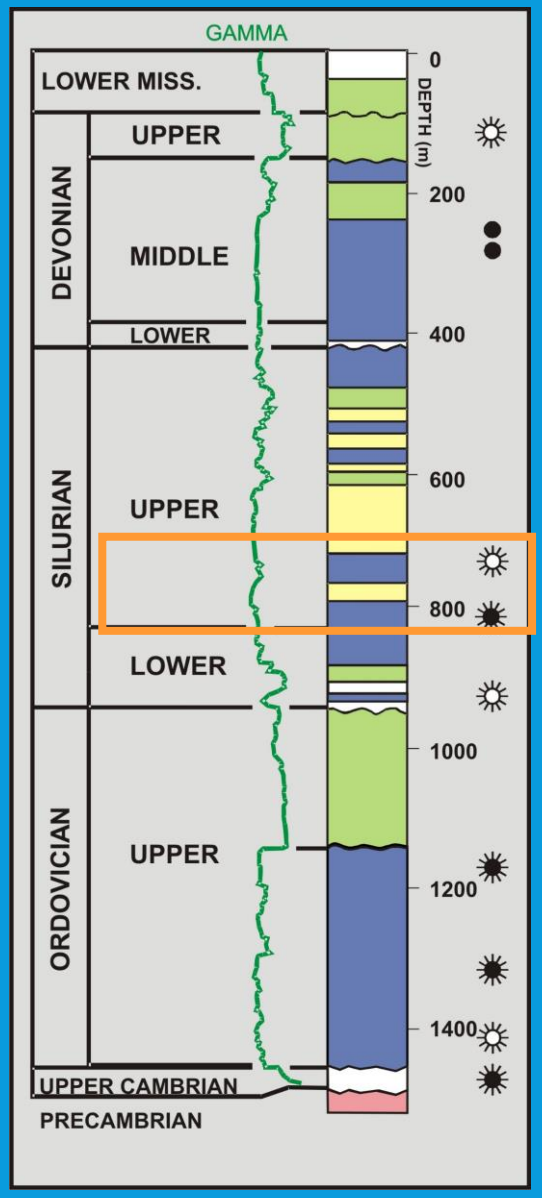
Play	Description	Depth m.	Cum. production
DEV	Structural traps in fractured Devonian carbonates and sandstone – structural domes related to differential salt dissolution	100 - 150	**45 mmbo**
SAL	Silurian carbonates - pinnacle, incipient and patch reefs - fault traps	300 - 700	**15 mmbo** **748 bcf** **250 bcf gas storage capacity**
CLI	Lower Silurian sandstones basin-centre stratigraphic trap	150 - 500	0.05 mmbo 507 bcf
ORD	Ordovician carbonates – hydrothermal dolomite reservoirs	800 - 900	**25 mmbo** **43 bcf**
CAM	Cambrian sandstones – stratigraphic traps, fault traps	700 - 1200	5.3 mmbo 32 bcf

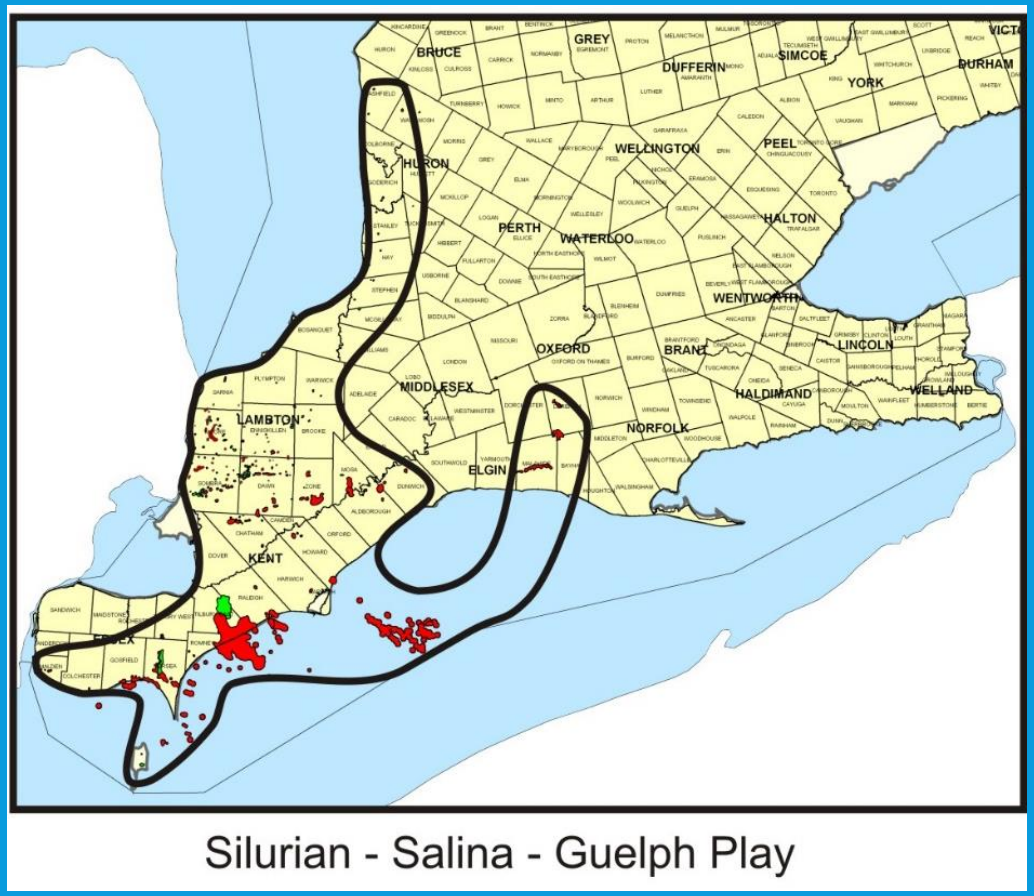
DEV: Devonian structural traps



Devonian Play

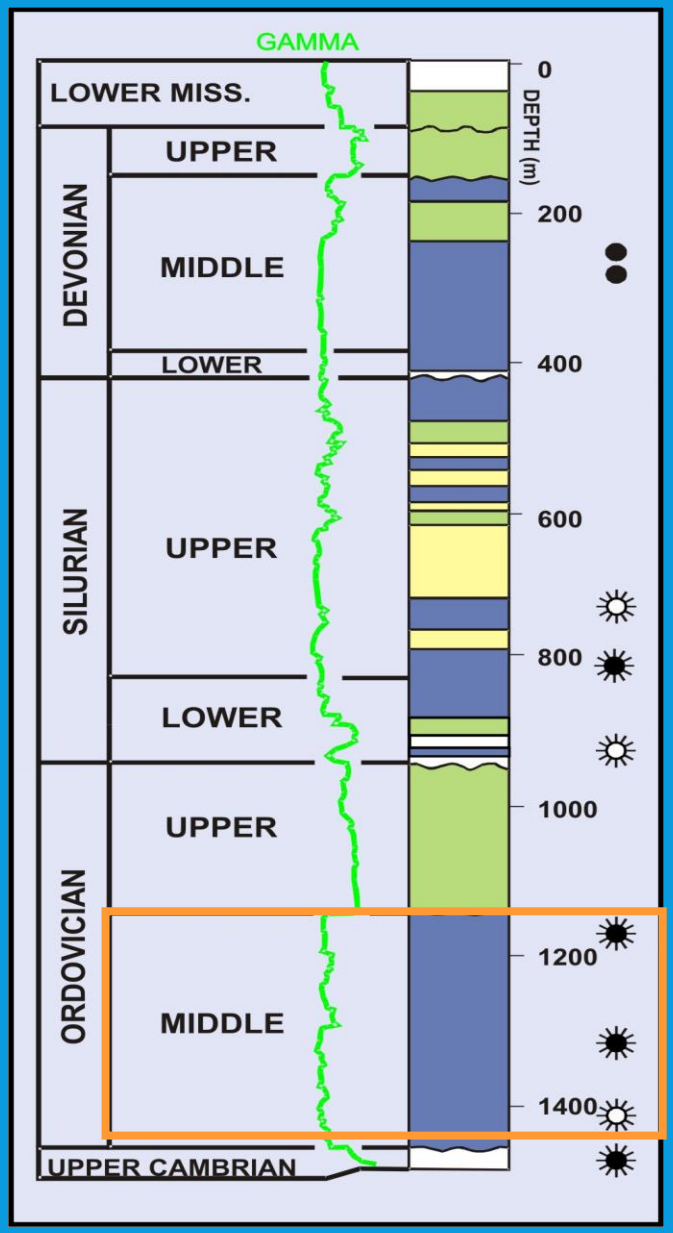
SAL: Silurian carbonates

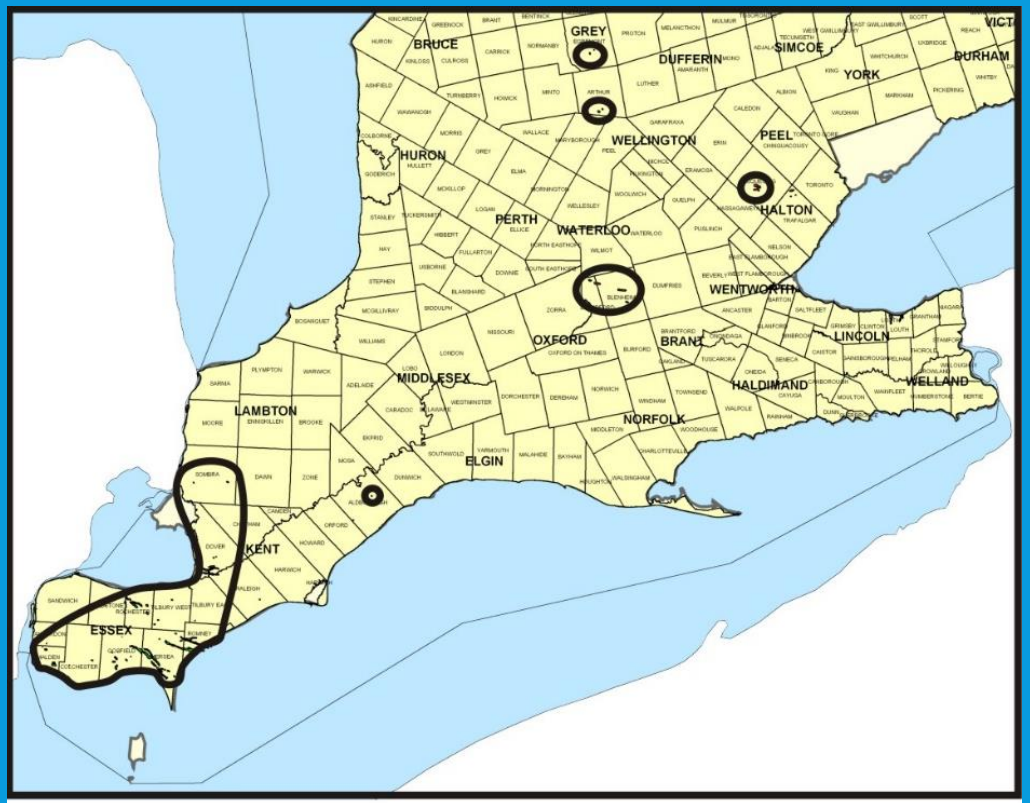




Silurian - Salina - Guelph Play

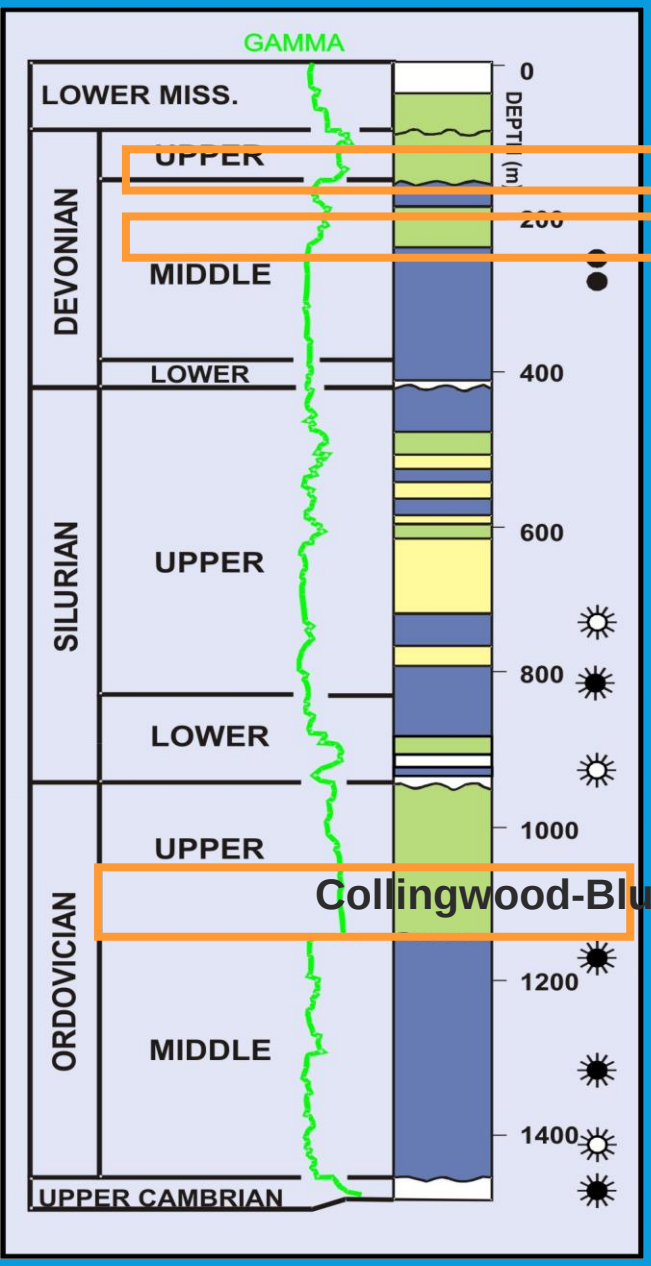
ORDOVICIAN HYDROTHERMAL DOLOMITE





Ordovician Play

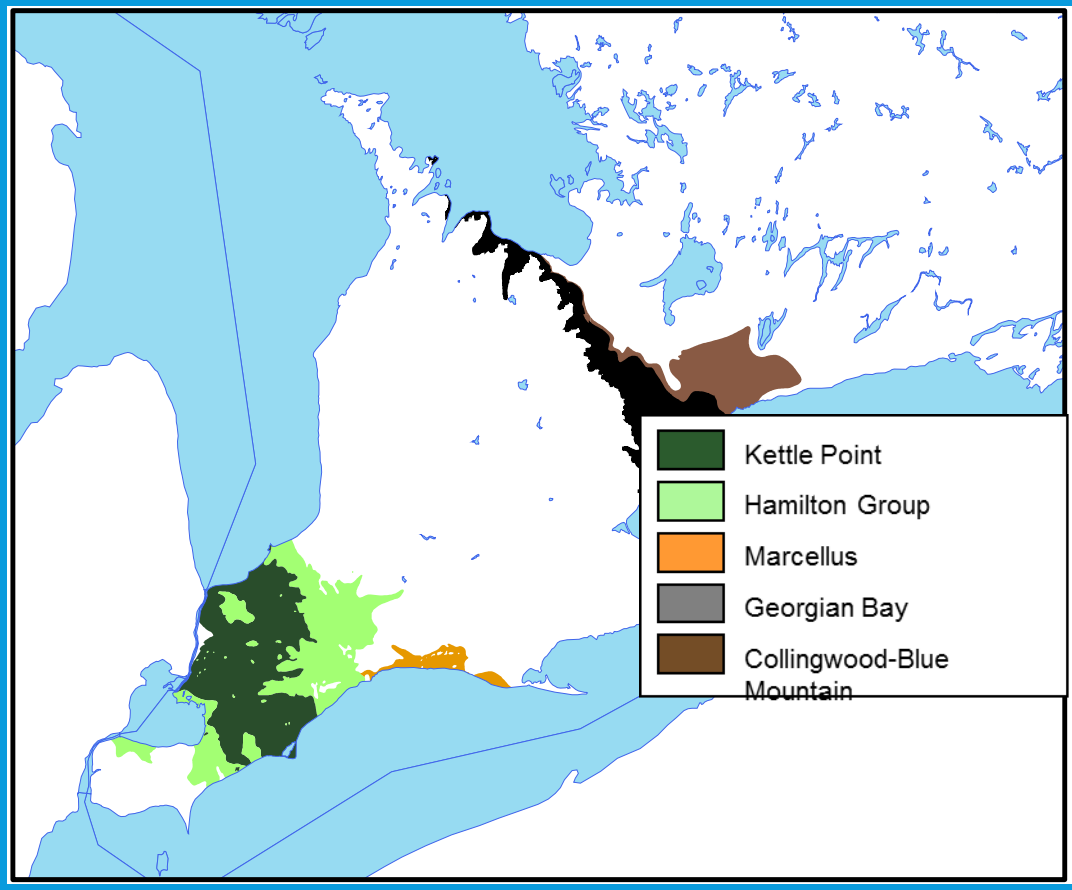
Shale Potential



Kettle Point (Antrim)

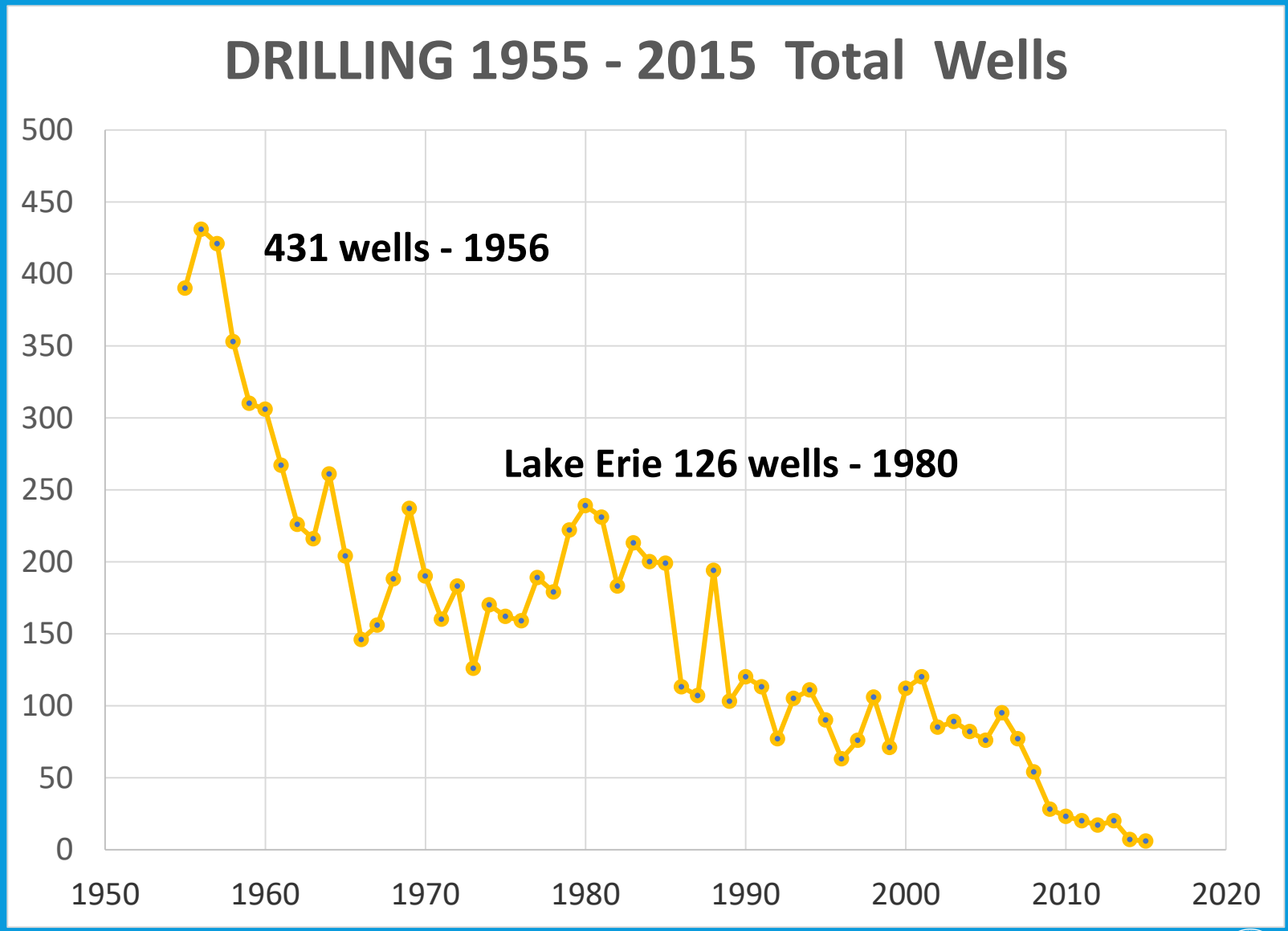
Marcellus

Collingwood-Blue Mtn

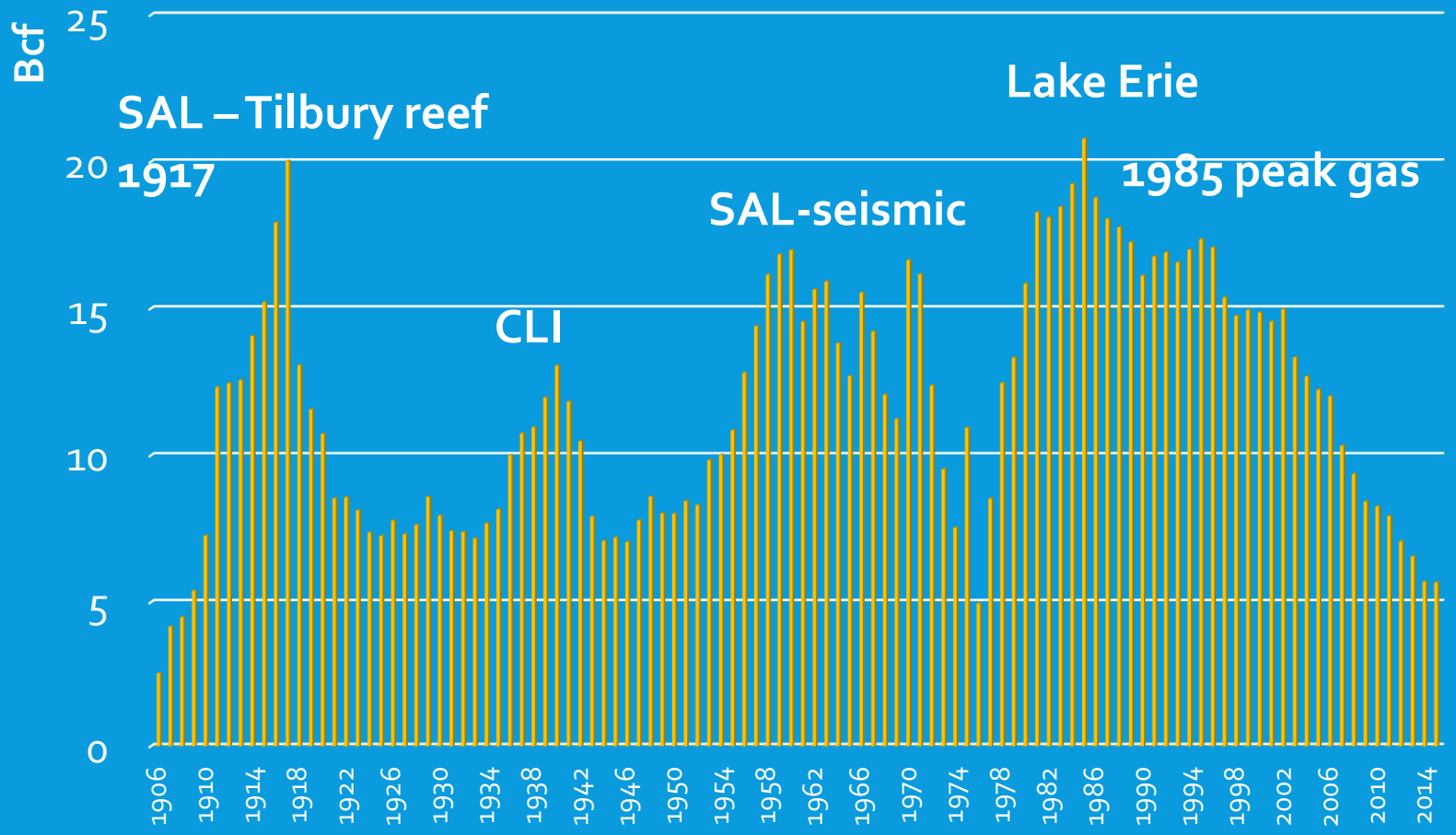


POTENTIAL SHALE PLAYS

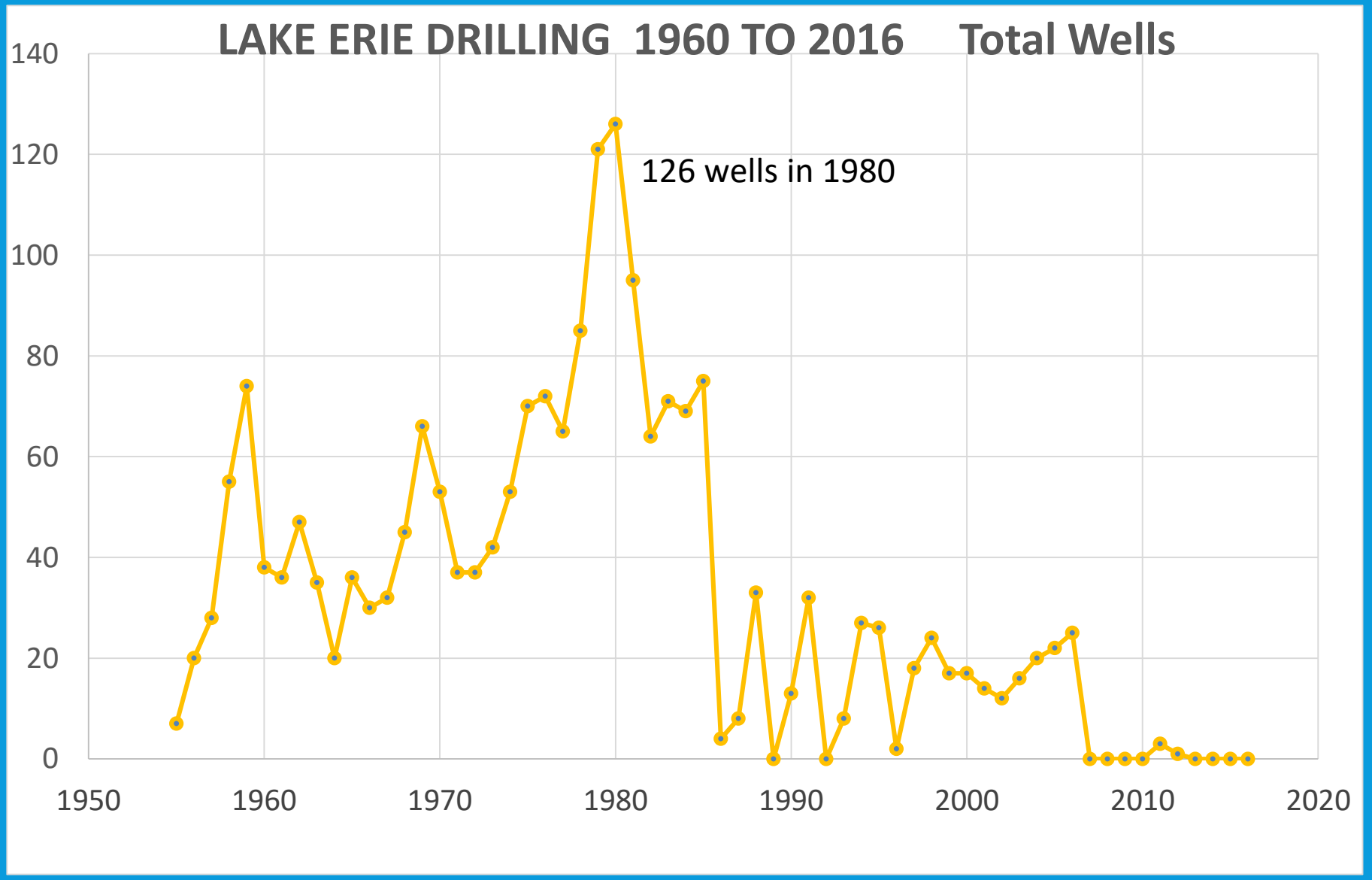
	Kettle Point	Marcellus	Collingwood-Blue Mountain
Thickness	30-105	1-12	10-50
Max depth m.	143	225	1000
Area km^3	9500	4700	70,000
TOC	3 – 15%	1 – 11%	1 – 11%


DRILLING 1955 - 2015 Total Wells
500
450
400
350
300
250
200
150
100
50
0
1950
1960
1970
1980
1990
2000
2010
2020
431 wells - 1956
Lake Erie 126 wells - 1980

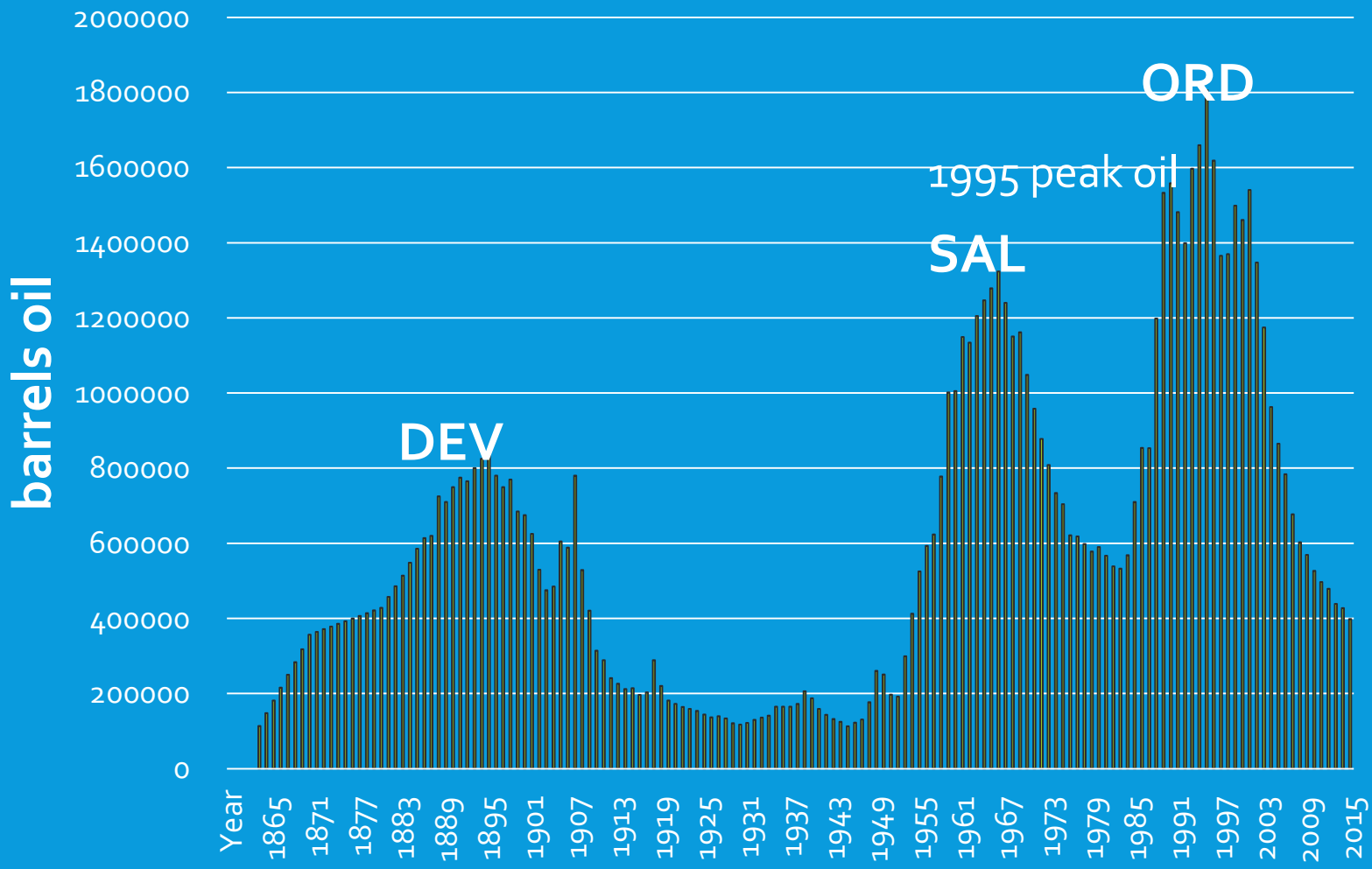
Annual Gas Production 1906-2015



Gas peaks in 1917, 1940, 1960,1985 corresponding to technological advances in seismic and offshore drilling


LAKE ERIE DRILLING 1960 TO 2016 Total Wells
126 wells in 1980
140
120
100
80
60
40
20
0
1950
1960
1970
1980
1990
2000
2010
2020

Annual Oil Production 1863 - 2015



Oil peaks in 1895, 1966, and 1995 corresponding to successive discovery of deeper plays, seismic and new exploration models

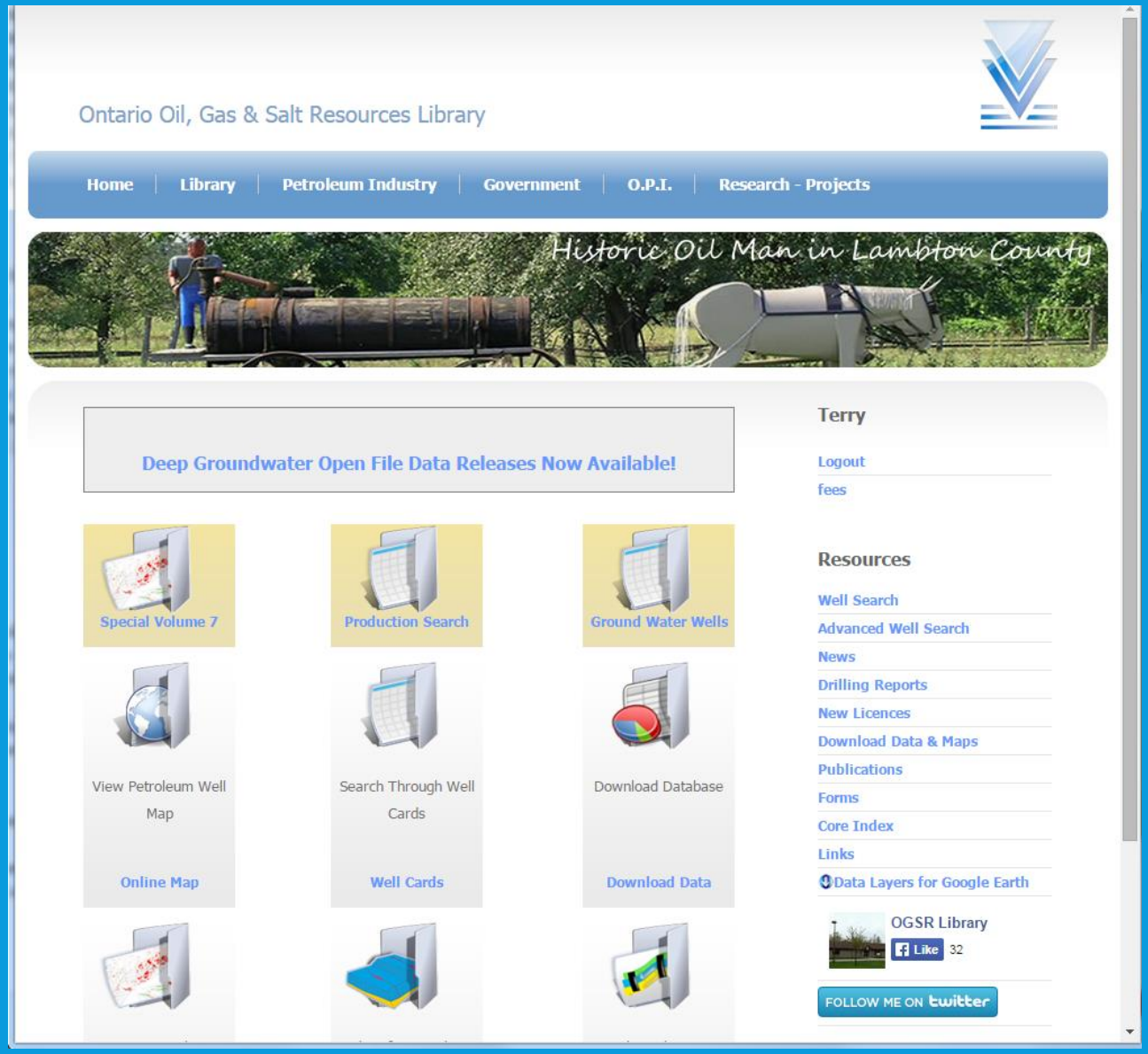
Oil, Gas and Salt Resources Library

- Not-for-profit centre for management of publicly accessible data on oil, gas, salt, hydrocarbon storage resources, and subsurface Paleozoic geology of Ontario
- Industry-operated
- Both free and fee-based access to data
- 669 Exeter Road, London, ON
- www.ogsrlibrary.com

Data Resources

- Petroleum well files 26,500 +20/yr
- Scanned well file images 500,000+
- Drill cuttings 11,000 wells +20/yr
- Drill core 1,100 +4/yr
- Monthly production reports 40,000 +2,000/yr
- Injection+disposal reports 10,000 +150/yr
- Maps & Reports 2,500 +10/yr
- Geophysical logs 21,000
- Oil and gas pool map
- Journals, reprints, government reports
- ArcGIS workstation
- Digital petroleum well database
- Oil, gas, water analyses, isotopic analyses
- Deep groundwater maps
  89 water type, 17 potentiometric

Digital Data: www.ogsrlibrary.com



What Next?

- Large unexplored areas in Ordovician
- Undiscovered incipient reefs
- Low drilling density in Huron County
- Lake Huron reefs?
- Conversion of more depleted gas pools to storage
- Technological improvements in enhanced recovery from known oil reservoirs
- Historic Devonian oil pools now account for 20% of Ontario annual production – flat production decline
- New play concepts
- Unassessed shale gas/oil potential
- Excellent data availability at OGSR Library

QUESTIONS?