

Mississippian Lacustrine Horton Formation Source Rocks from Nova Scotia and New Brunswick, Eastern Canada: Major Shale Gas and Oil Shale Resource Plays*

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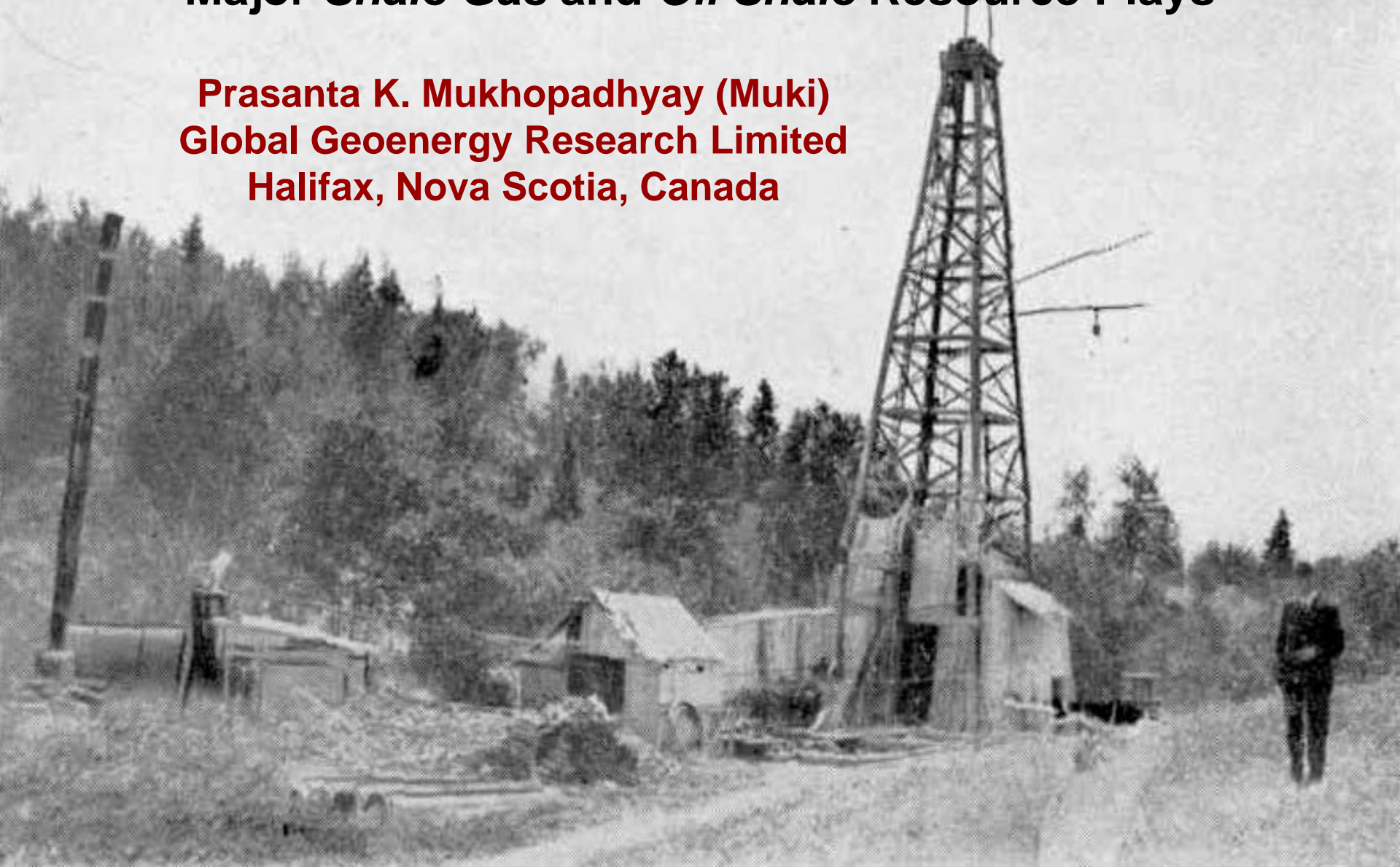
Abstract

Based on regional geology, geochemical fingerprinting, and heat flow histories related to major faults, selected Mississippian Horton Group lacustrine shales and siltstones (usually 100-500 m in thickness; of variable organic facies with kerogen Types II, II-III, III) from various basins of Nova Scotia and New Brunswick, Eastern Canada have been identified as major oil shale and shale gas resource plays. These basins include the Cumberland, Windsor, Antigonish, Western Cape Breton, and Moncton. The organic shales in these basins are similar to the Mississippian Barnett Shale in the Fort Worth Basin of Texas. Calculations of the methane generation potential of the Mississippian Horton group shales range from 75 to 300 scf/ton.

The current work has also documented the influence of regional maturity (R_o : 0.7 to 2.5%), specificity of organic facies (ratio of the lacustrine versus terrestrial organics), the mineralogy (ratio of quartz, clays, and carbonates), regional stress and fracture patterns on the amount of both adsorbed and free gas or the extractable hydrocarbons within these unconventional shale resources from the basins of Nova Scotia and New Brunswick. Preliminary evaluation of the gas composition and the micro-fracture patterns within the shale network indicates the presence of moderately high free gas compared to the adsorbed gases, especially at a vitrinite reflectance (R_o) above 2.2%. The proposed regional resource assessment potential of the Mississippian Horton Group shales, based on petroleum system analysis, illustrates the location of the boundary zones between gas cell and oil cell zones within this unconventional resource play.

Mississippian Lacustrine Horton Group Source Rocks from Nova Scotia and New Brunswick Eastern Canada Major *Shale Gas* and *Oil Shale* Resource Plays

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**Location of Maritimes Basin,
Canada
within
North America**

**Kennetcook #1 well drilled
for Shale Gas Prospect,
Windsor Basin, Nova Scotia
2007**

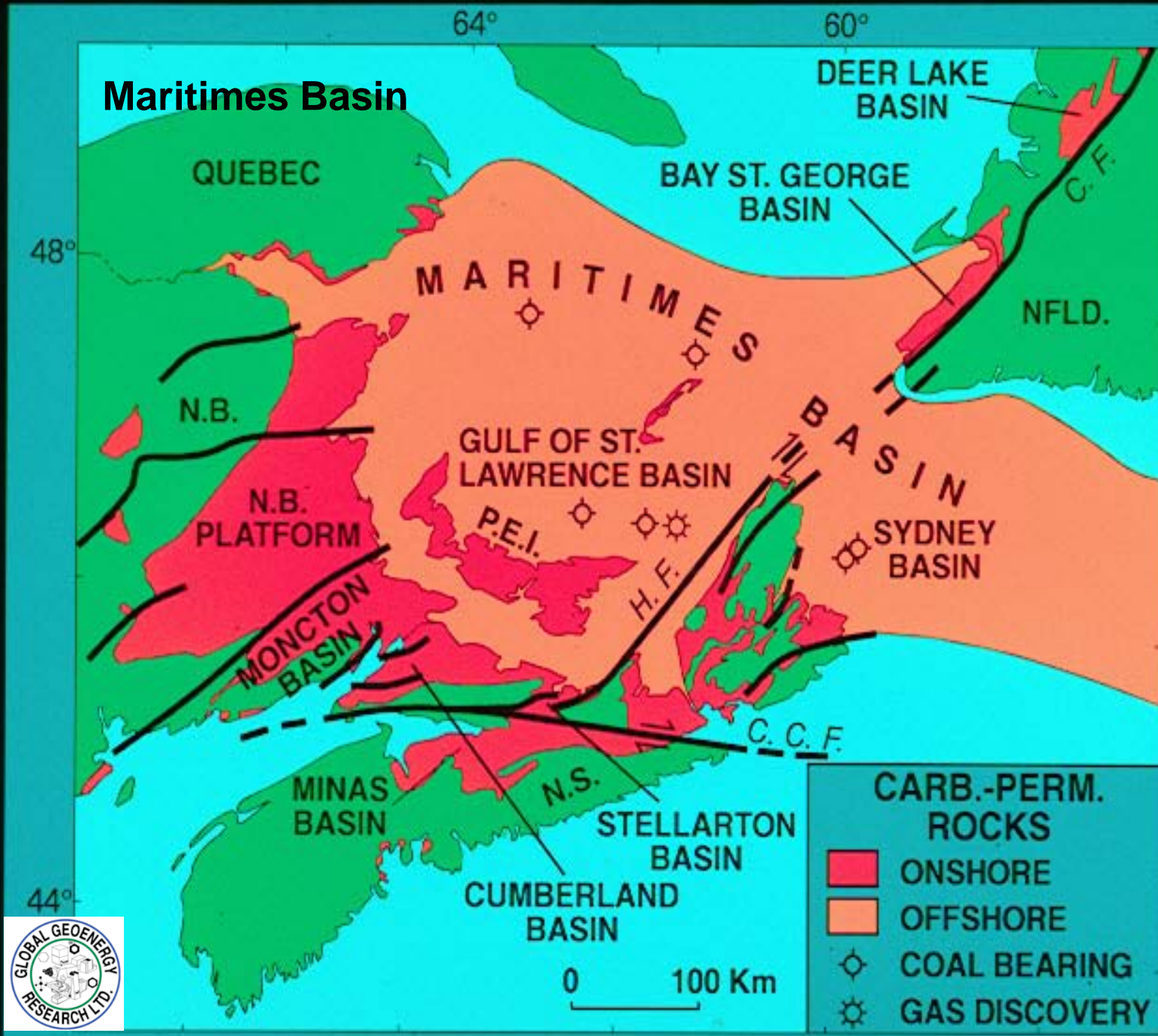


**Oil well drilled in Mid-1990's D'Arcy 1
Stony Creek Field, Moncton Subbasin
New Brunswick**

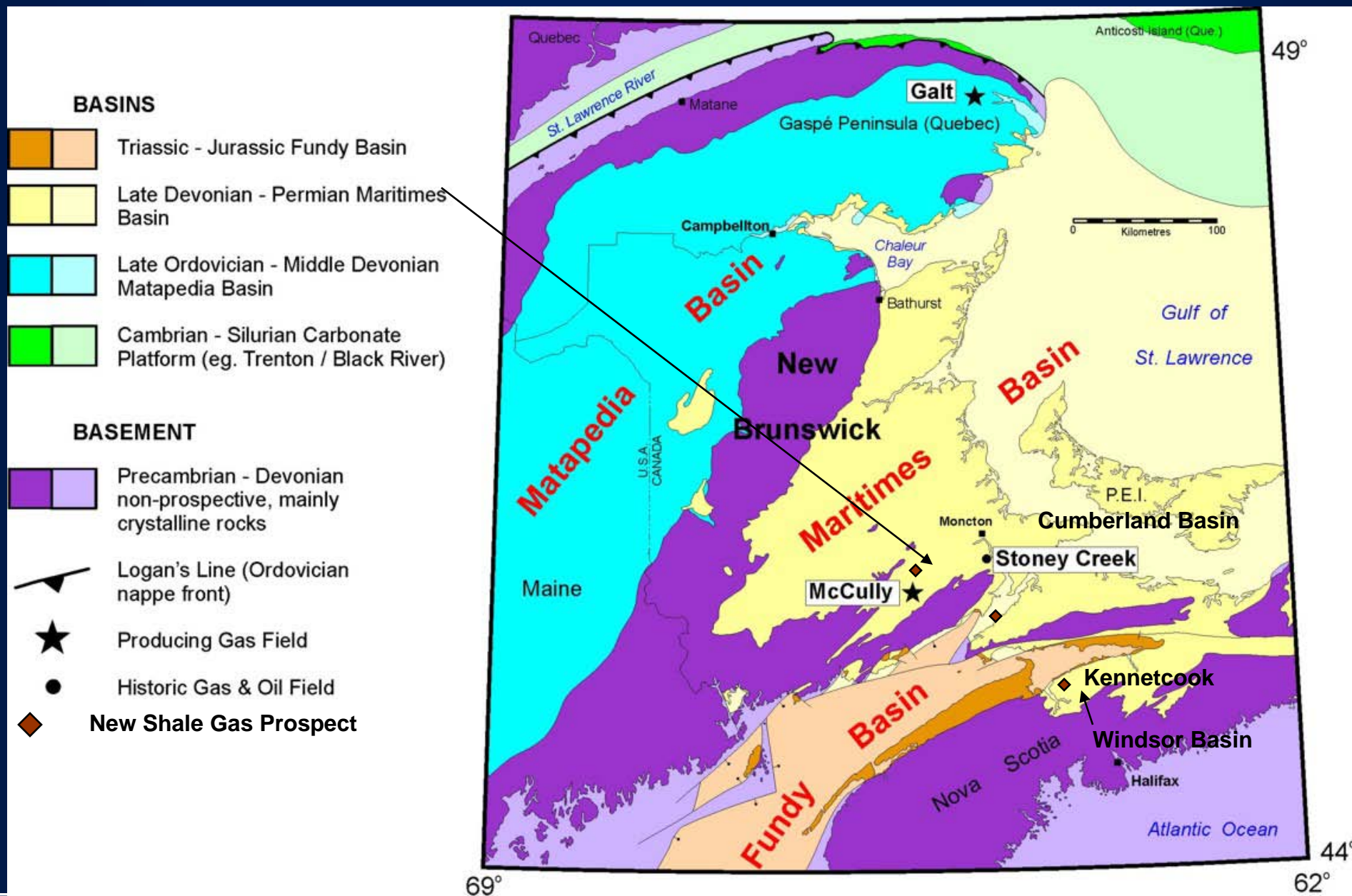
Eastern Canadian Prospects

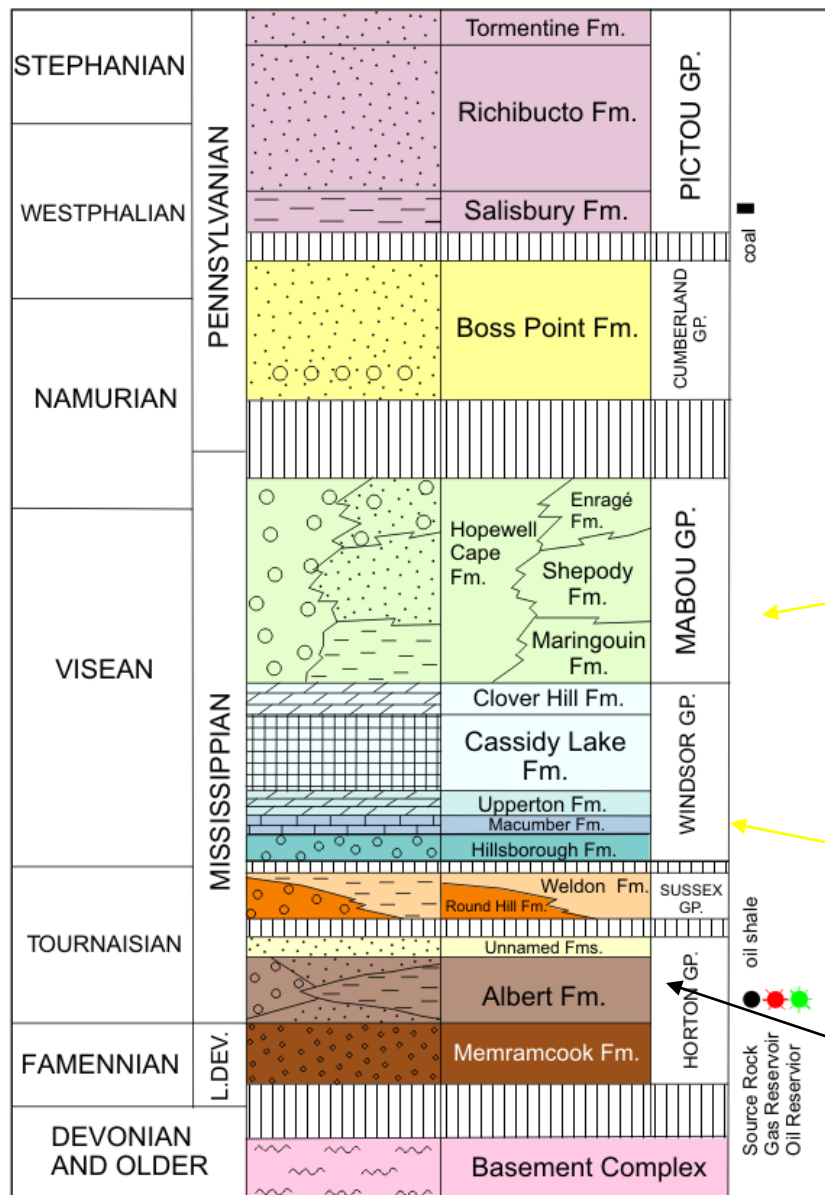


Maritimes Basin



Western Maritimes Basin: Conventional and Unconventional Prospects



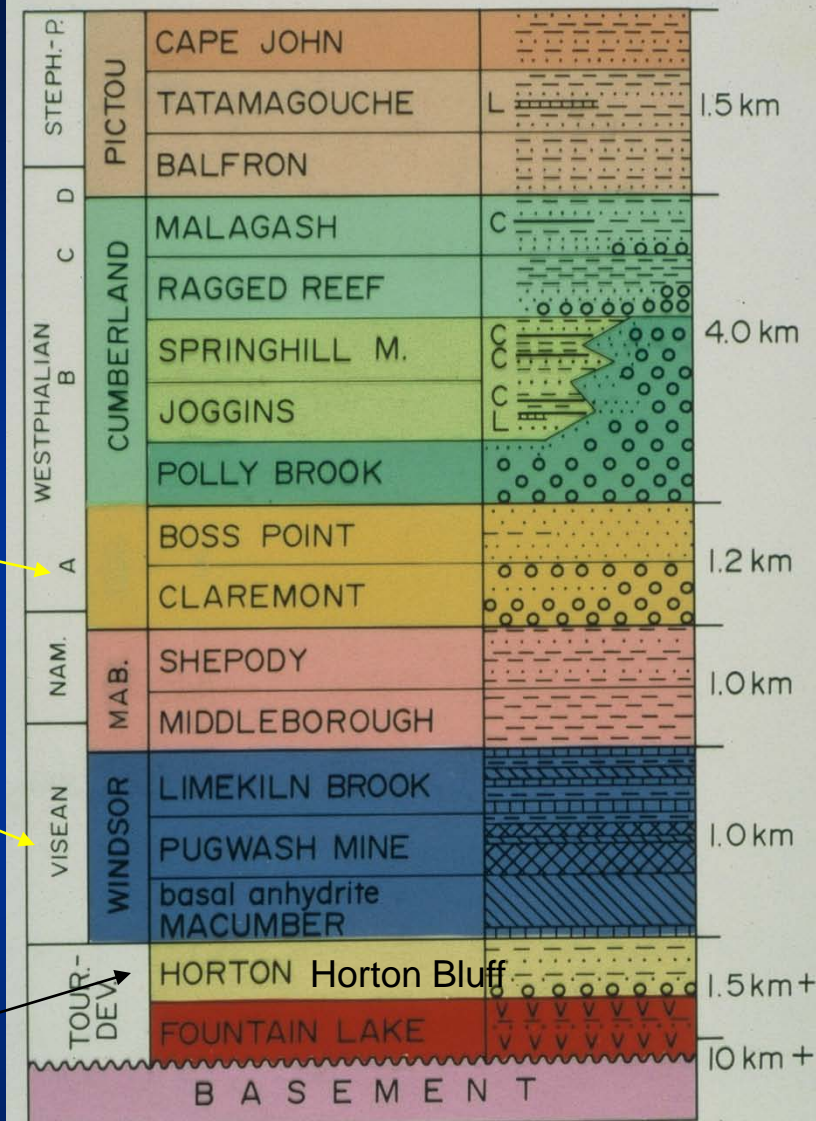


Fluvial
(coal, sh,
and sst)

**Fluvial to
Lacustrine**
sst and sh

Marine
salt, lst, ev.

**Lacustrine
Fluvial**
(sh & sst)



New Brunswick

Nova Scotia

Stratigraphy of Carboniferous and Permian Sediments Nova Scotia (NS) and New Brunswick (NB)

Mississippian Shale and Sandstones in Nova Scotia and New Brunswick

Hybrid Tight Gas Sandstones, Shale Gas, and Oil Shale Prospects

- Mostly Up Devonian to Tournaisian Age: Horton Group
- Called Albert Fm Shale in NB and Horton Bluff Fm in NS
Lacustrine to Fluvial Depositional Regime

- 150 m (~300 ft) to 1500 m (~ 4500 ft) thickness

Mostly Organic Rich (1-20% TOC) laminated algal or coaly or mixed source rocks

- Presence of oil and gas seepages in most basins

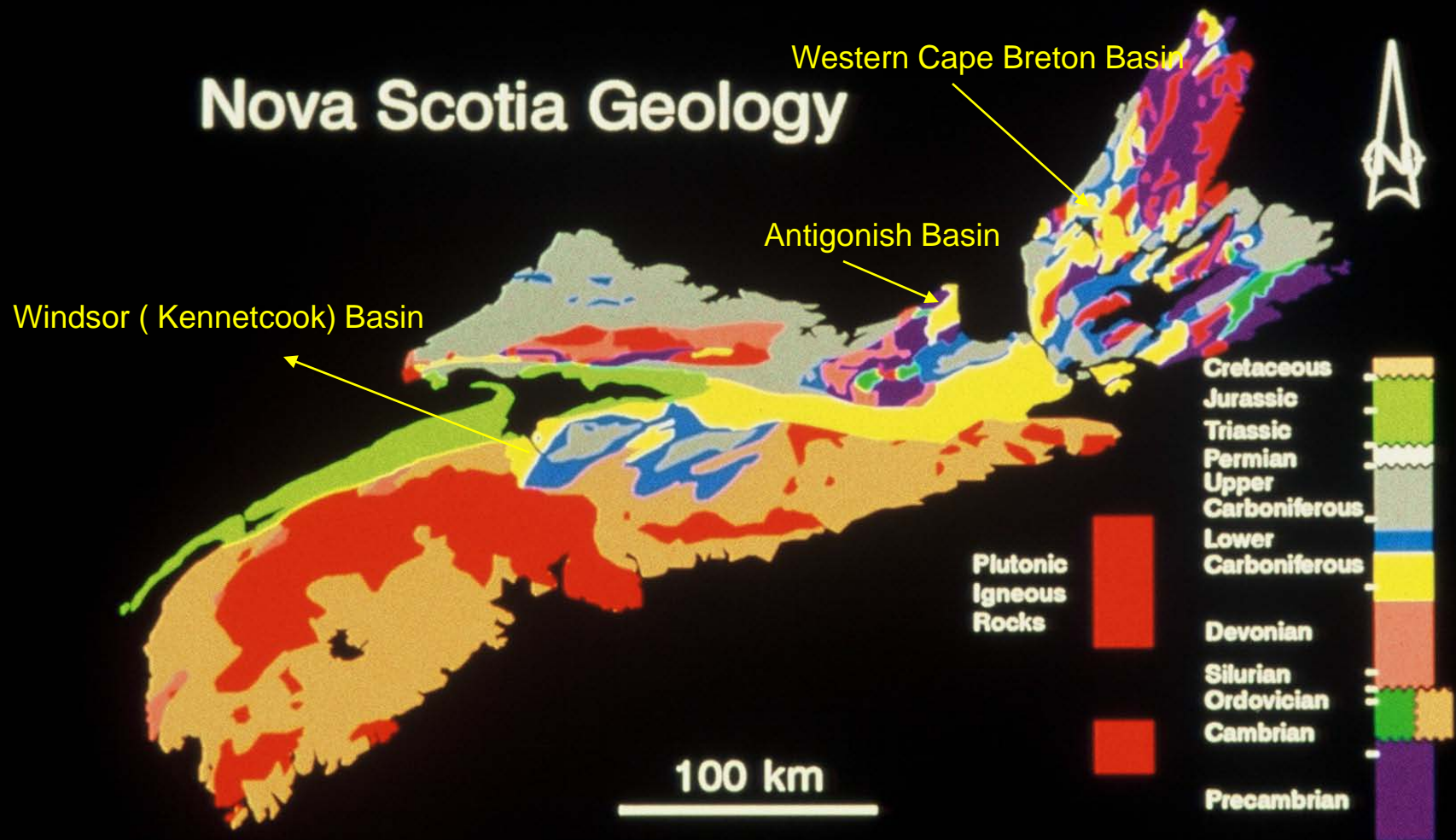
Current Production: Tight Gas in the McCully Field, New Brunswick

Salient Features: Present Study

- Stratigraphy of the Carboniferous Sediments and Oil or Gas seepages
- Macro and Microscale Organic Facies and Source Rock Potential
- Maturation Boundaries based on Organic Facies and its implication to Free and Adsorbed gas
- Timing of hydrocarbon expulsion from Horton Group Sediments
- Selected desorption data from Kennetcook #1 well, Windsor Basin, Nova Scotia (NS)

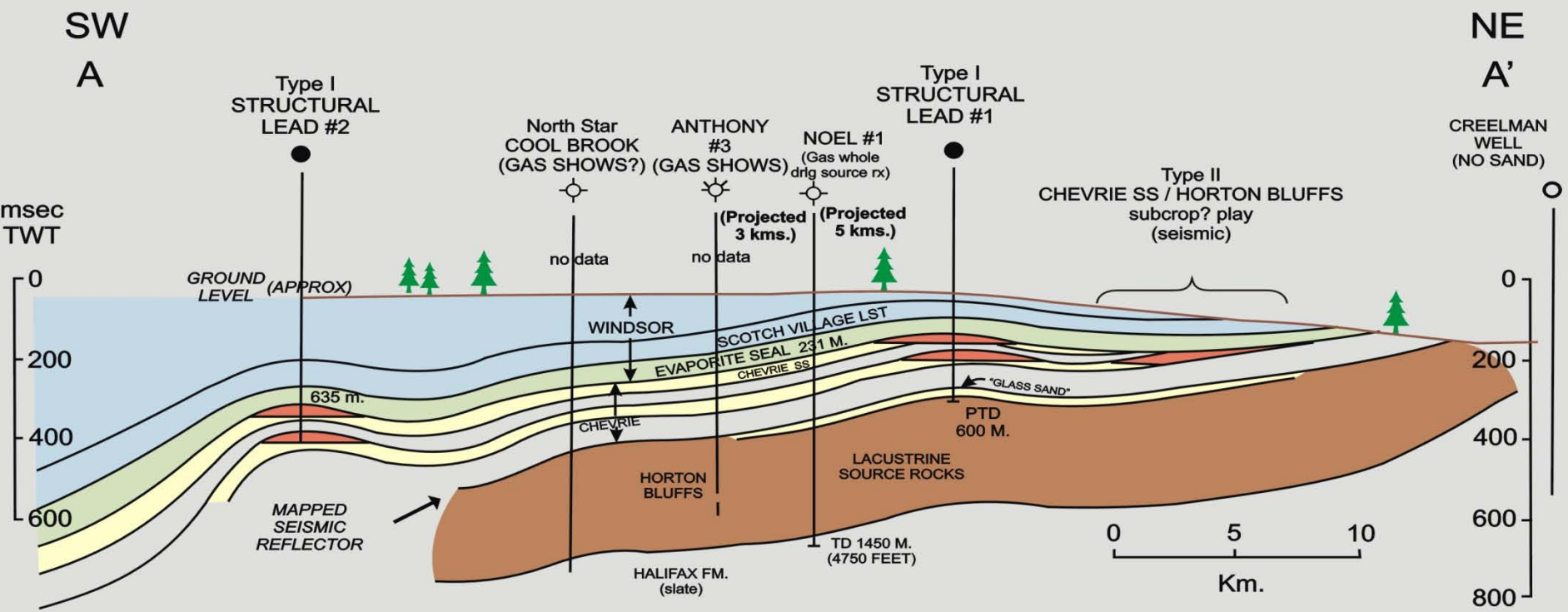
**Basin Locations, Stratigraphic Cross Sections
And
Location of Oil and Gas Seepages (NS)**

Nova Scotia Geology with three Mississippian Shale Gas Prospective Basins in Nova Scotia

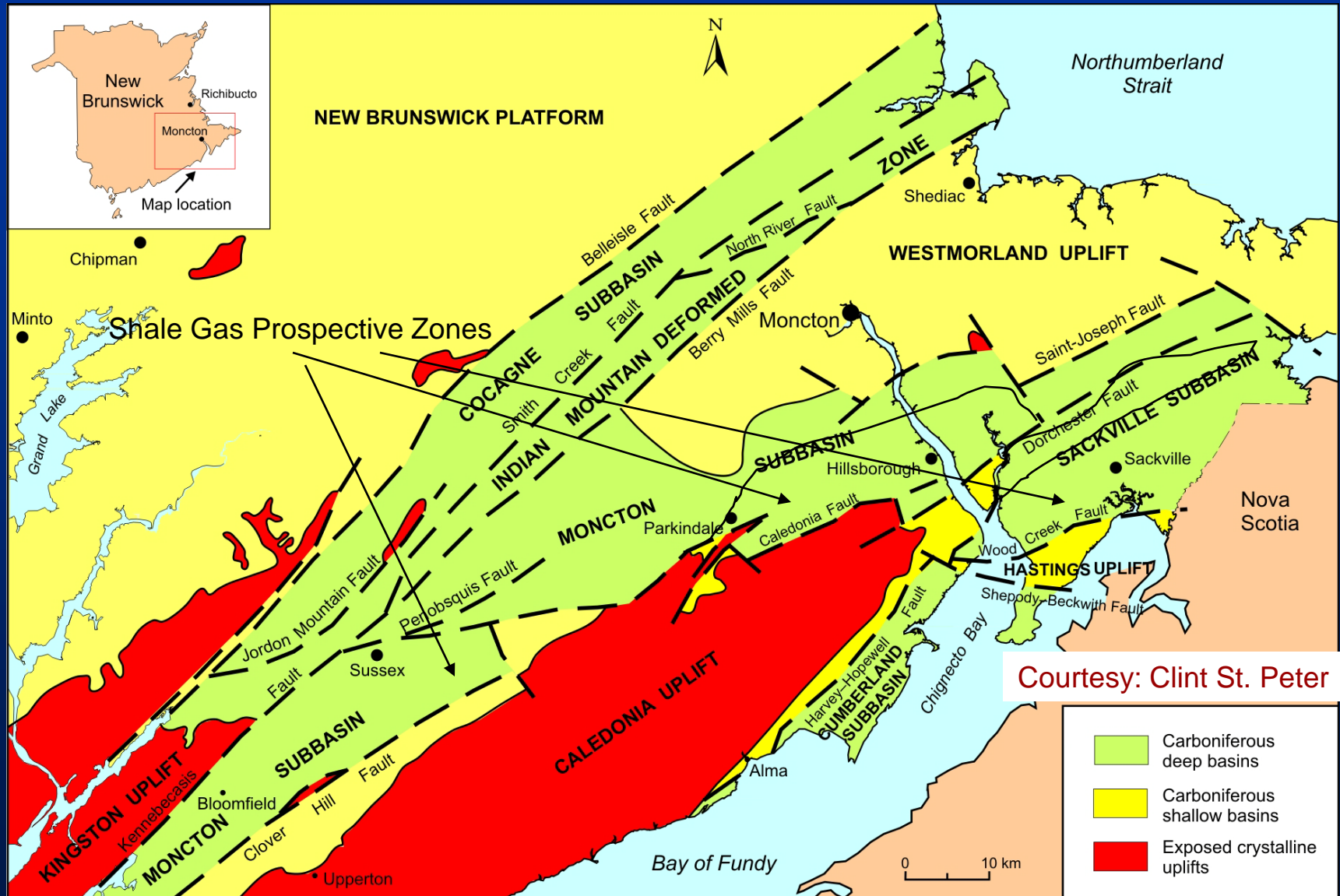


Schematic Stratigraphic Cross Section of the Windsor Basin

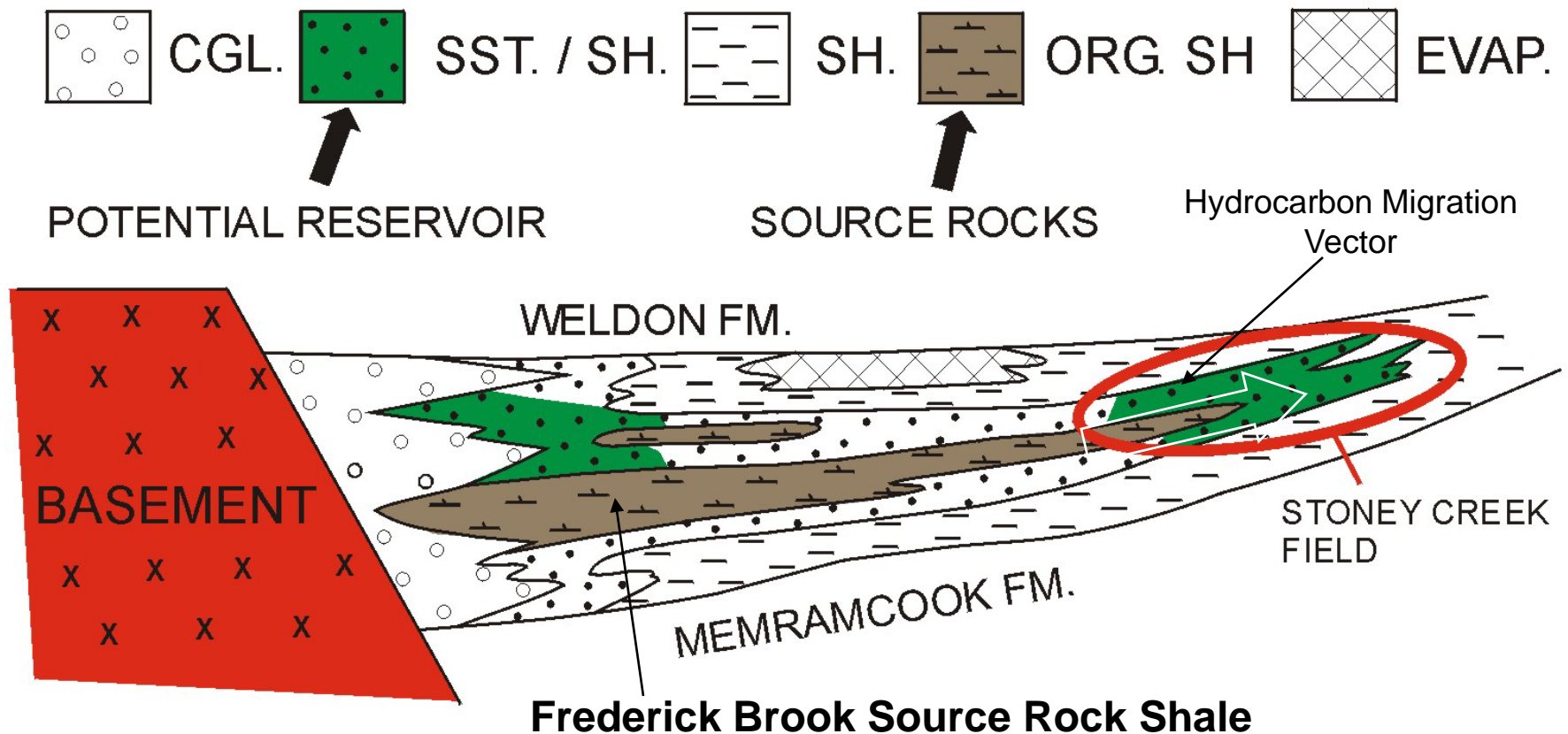
WINDSOR BLOCK:
HORTON PLAY TYPES: I. Closed structures
 II. Subcrop beneath evaporites



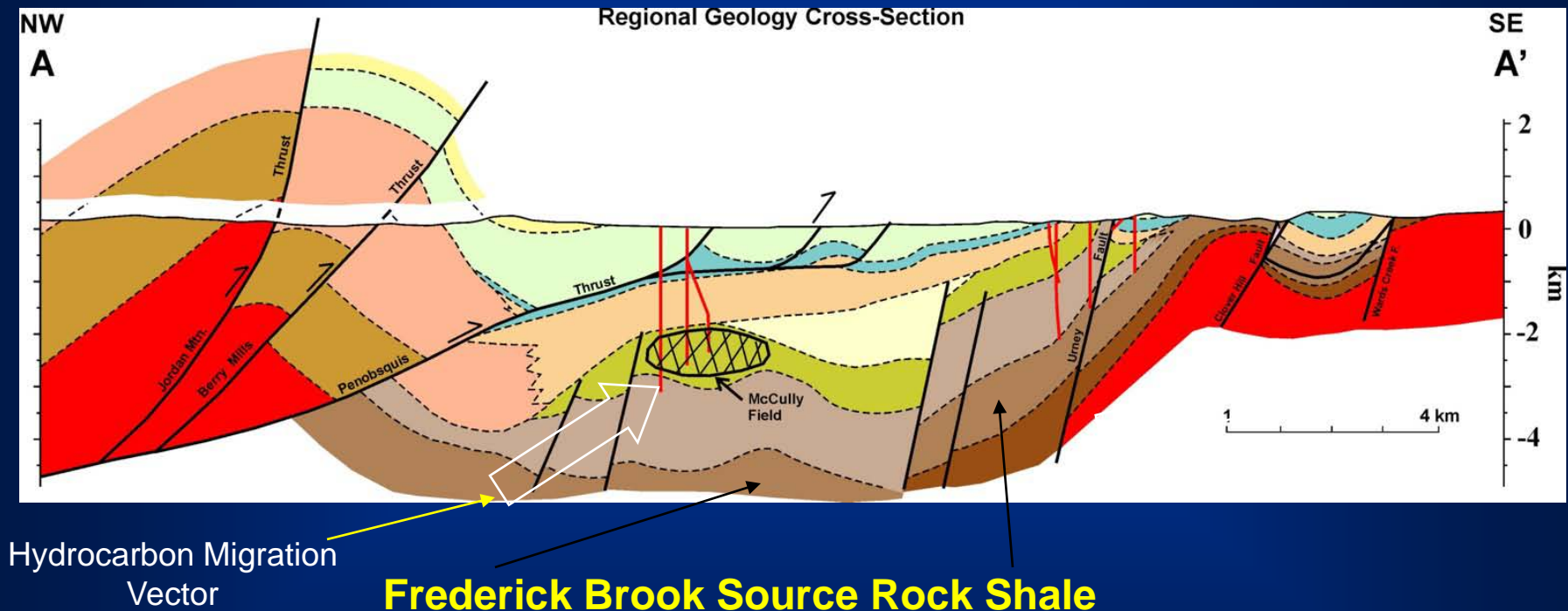
New Brunswick Geology showing the Locations of Two Important Subbasins where Major Shale Gas Prospect Exist



ALBERT FM. LITHOFACIES / MONCTON SUBBASIN



Stratigraphic Cross Section of McCully Field, New Brunswick



Location Map of Petroleum Shows Onshore Nova Scotia



**Organic facies, Source Rock Potential,
Maturation, Hydrocarbon Generation
Timing and Boundaries, and Limited
Mineralogy data**

Mississippian Source Rock shale: Type Section - Horton Bluff Bay of Fundy Section, Windsor Basin, Nova Scotia



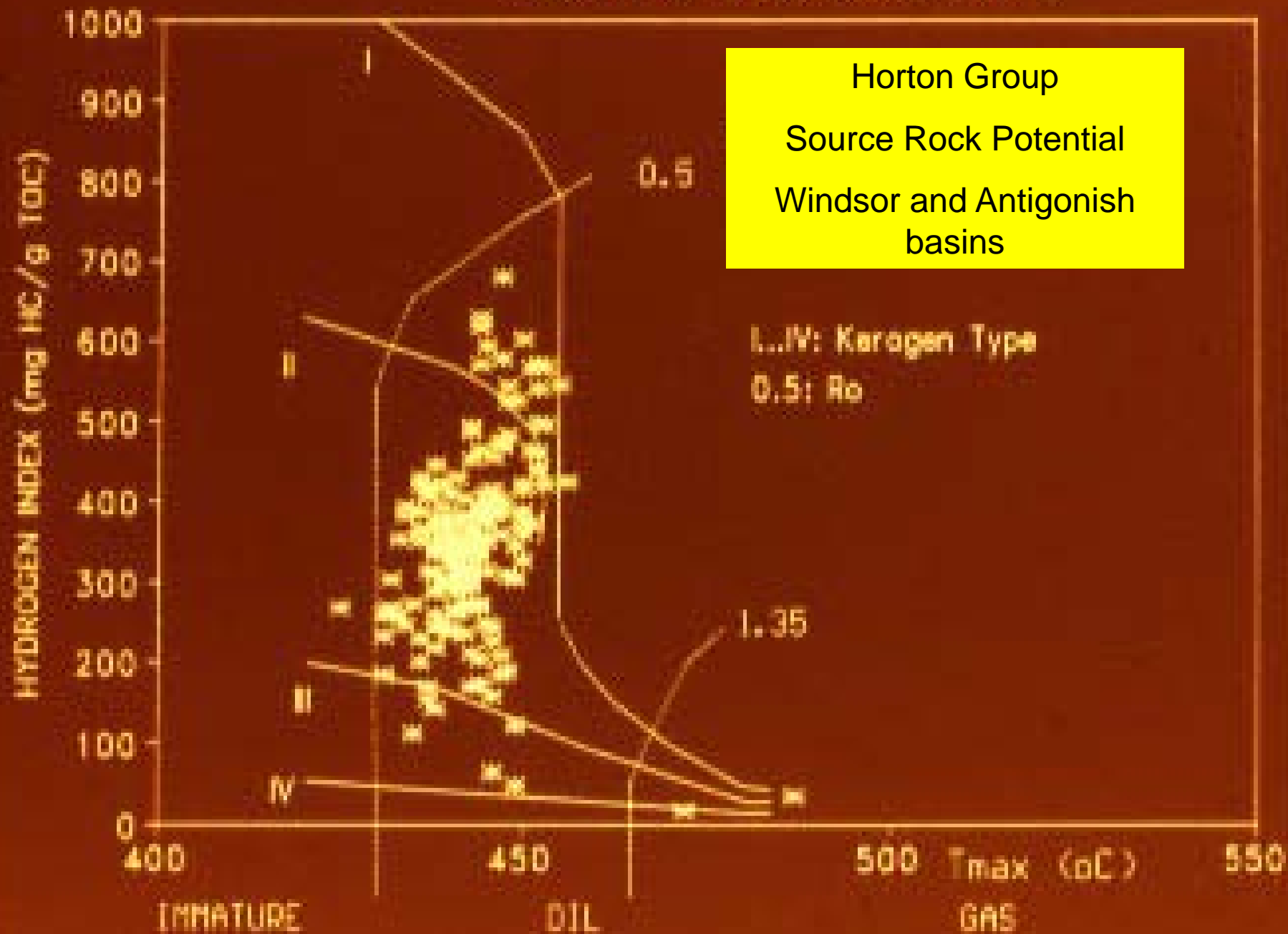
Horton Shale
(Albert Shale in NB)

Type II

Type I

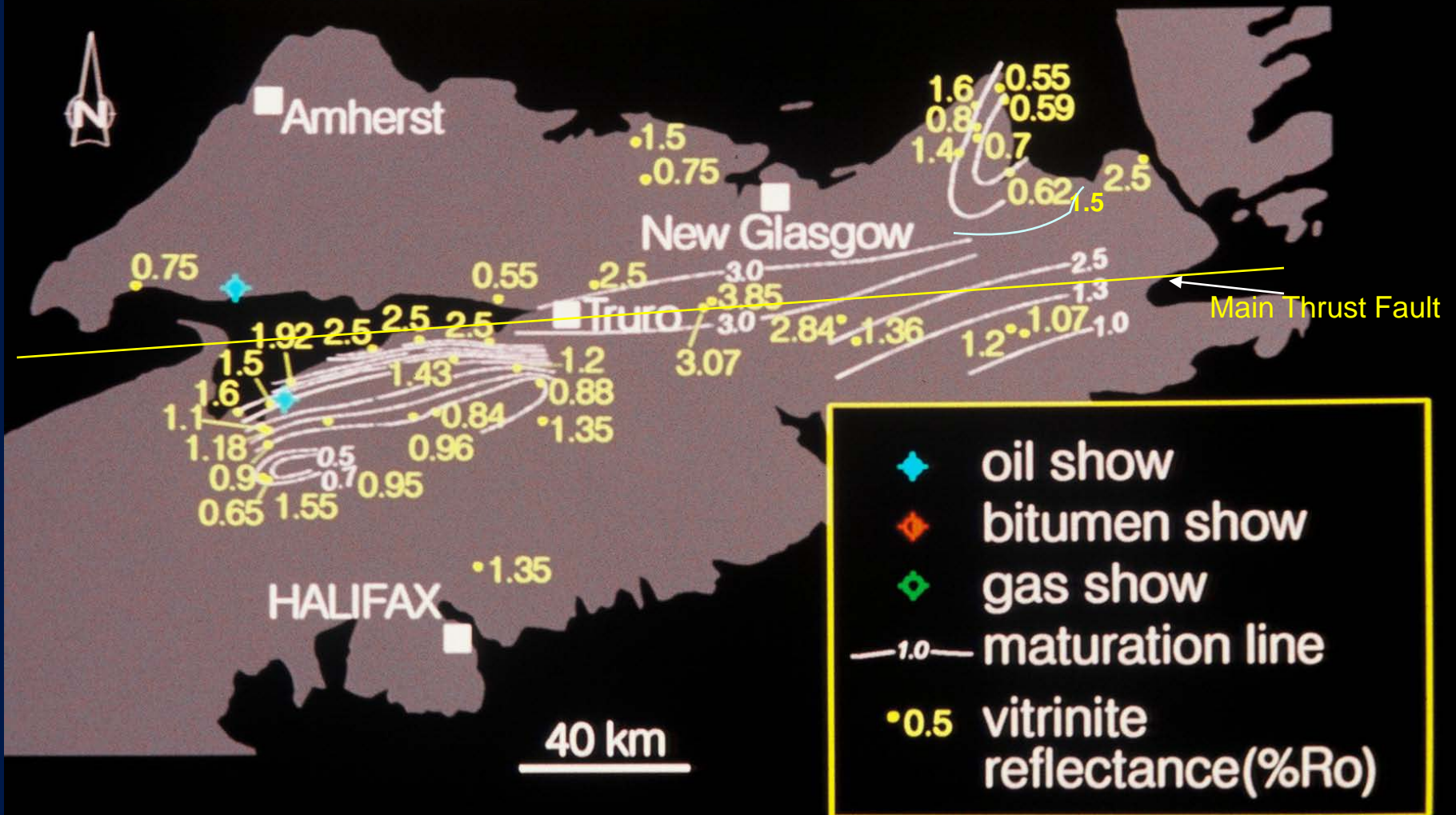
Type II-III

MATURITY vs HYDROCARBON POTENTIAL



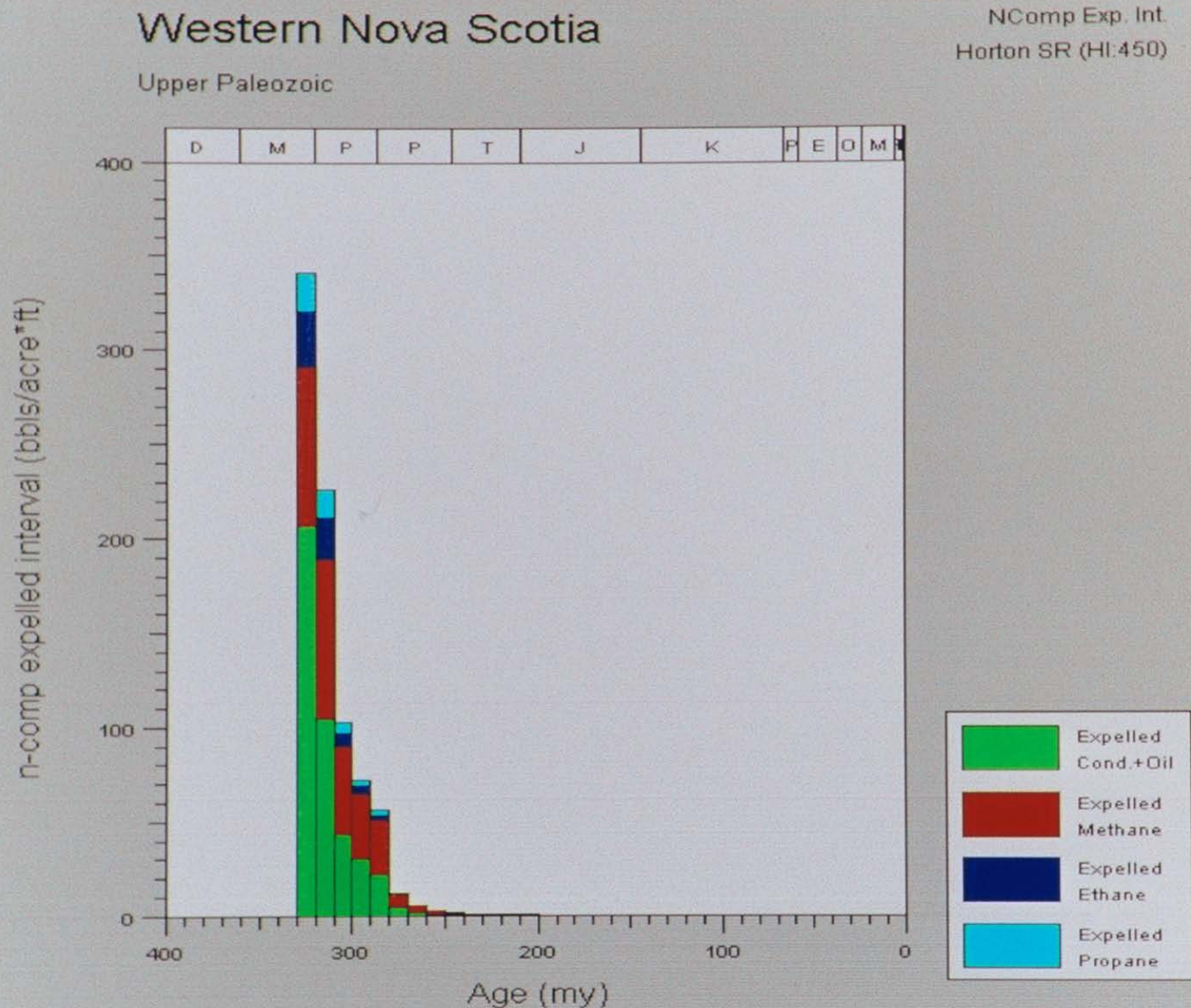
Maturation Contour of the Mississippian Horton Group Onshore Nova Scotia

MATURATION MAP Horton Group





One Dimensional Modelling Showing the Timing of Oil and Gas Expulsion Cumberland Basin, Nova Scotia



Frederick Bk - organic shales, minor sst

New Brunswick

Type II-III
and I

Type III



St. Peter, 2001

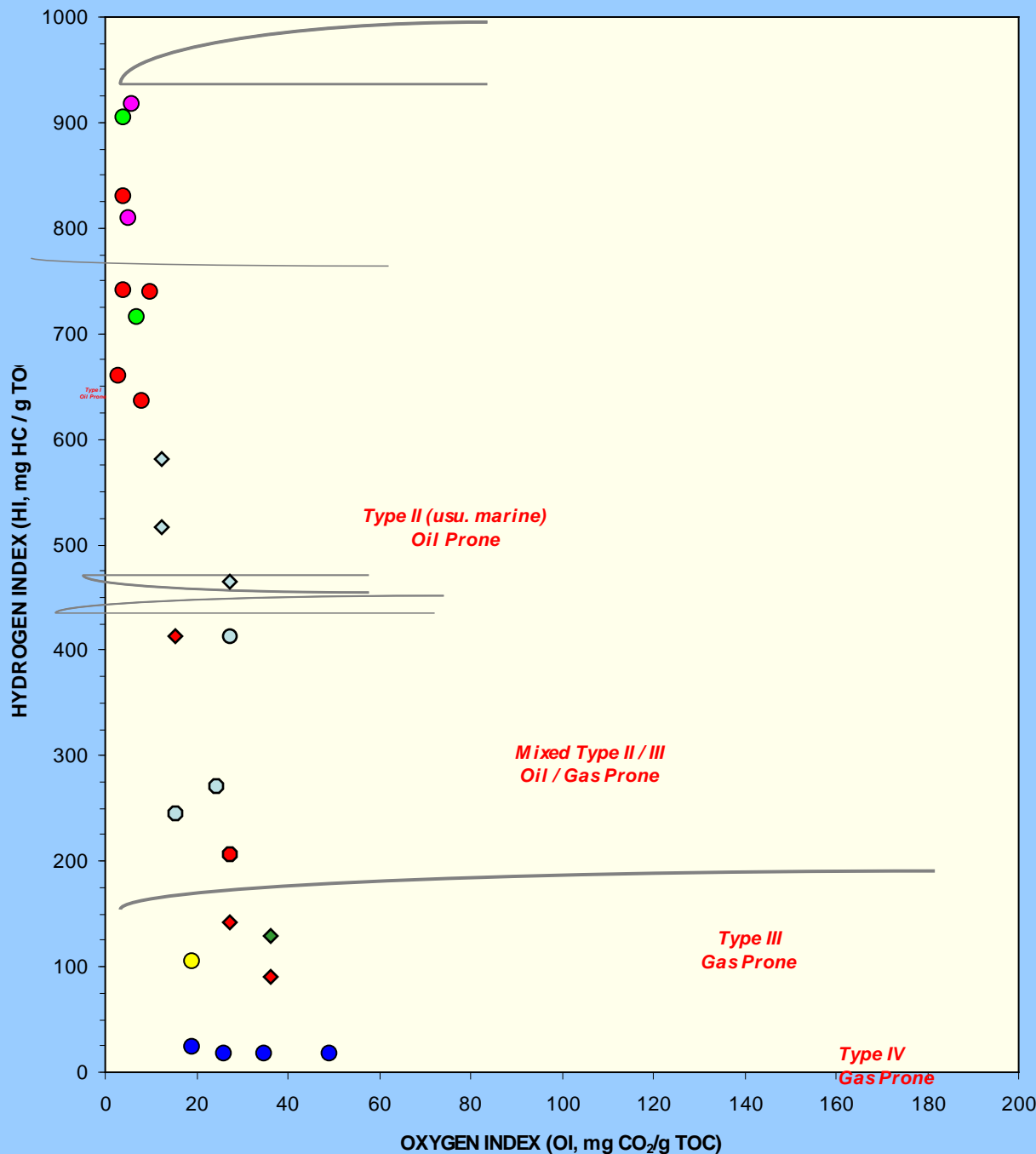
Highway 1
south of Sussex

Courtesy: Clint St. Peter

5. 1. 2001

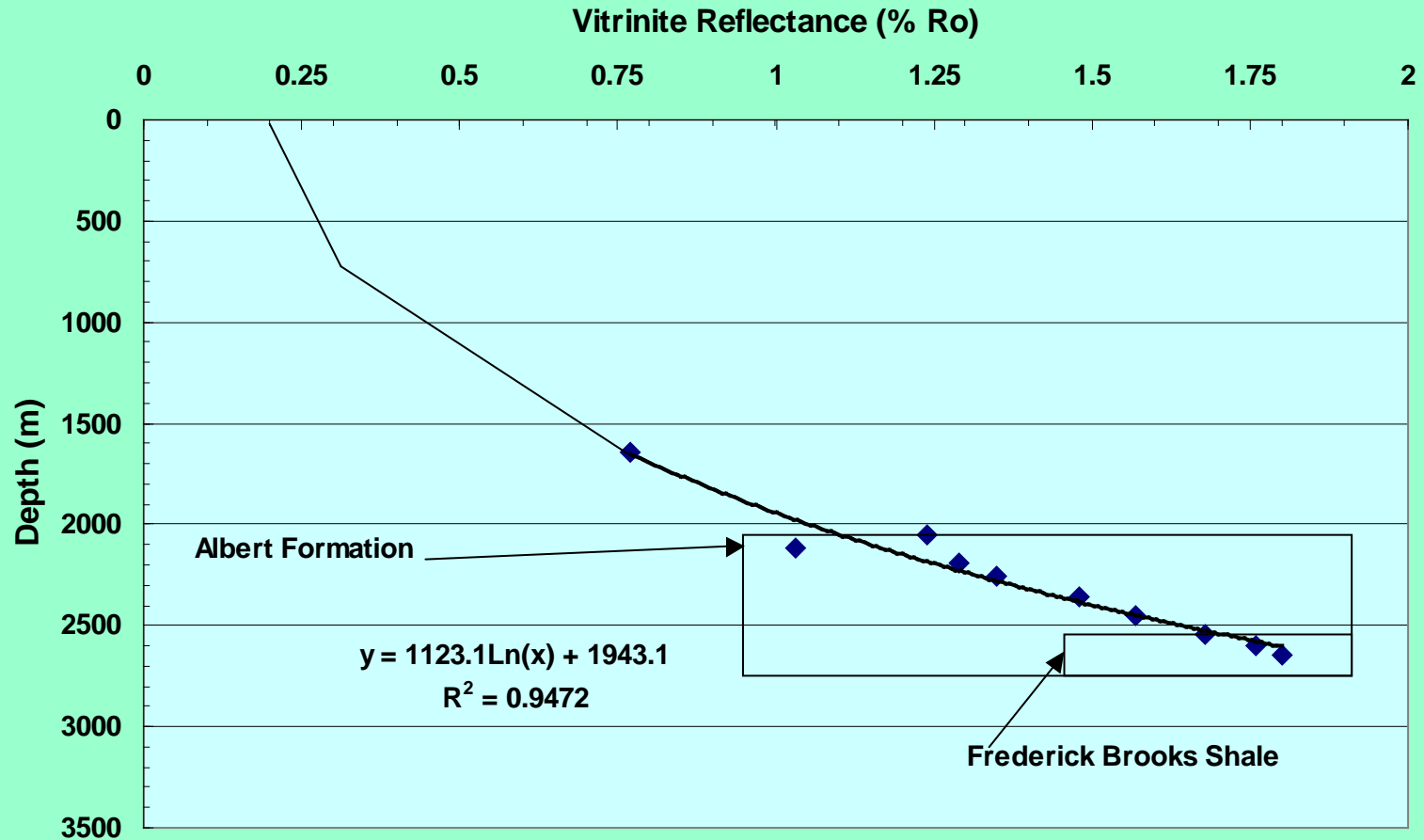
Pseudo van Krevelen Diagram

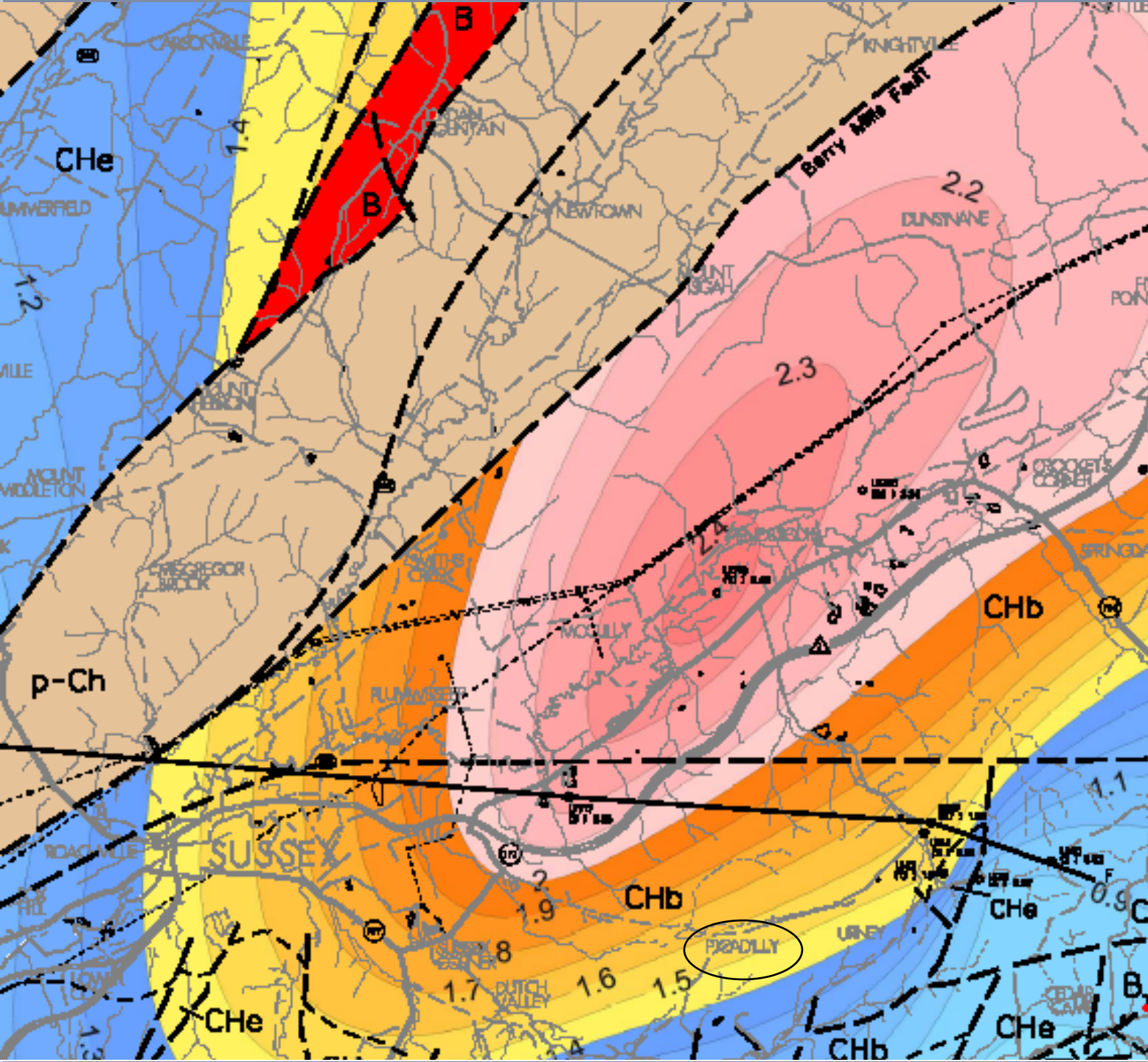
Source Rock Potential of Frederick Brook Shale Stony Creek Field Area



McCully Gas Field: Maturity Plot

Well: McCully D-48, New Brunswick: VRo vs Depth (m)





**Maturation
Contours
of
Part of
Moncton
Subbasin
including
McCully
Gas Field**

Mineralogy

Nova Scotia

Mixture of Quartz,
Carbonate (calcite
and dolomite), < 30 %
clays

New Brunswick

Mixture of Clay, Quartz,
and minor to
moderate Carbonate

Oil Shale and Shale Gas Prospect Areas: Characteristic Parameters

Oil Shale

TOC and Organic facies

5 to 20 wt %; mostly Lamalginite and Telalginite; Sulfur: <1.5%

Hydrocarbon Potential

HI: 650-950 kg HC/Ton, Type I
% Ro: < 0.7%; minor oil expulsion
around 330 Ma

Mineralogy and Fracture Pattern

Dominant Quartz and Clay Minerals.
Minor carbonate. No Visible
Fractures

Area of Interest

Stony Creek and northern part of
Moncton Subbasin, NB and Big
Marsh, Antgonish basin, NS

Shale Gas

TOC and Organic facies

1 to 10 wt %; mostly mixed algal, terrestrial
and AOM; Sulfur: <1.2%

Hydrocarbon Potential

HI: 150-600 mg HC/g TOC, Type II, II-III and III;
main dry gas expelled at 330-310 Ma
(>1.5% Ro)

% Ro: > 1.0%; Adsorption Isotherm data of
Selected Shales from Type II-III Source
Rocks from Nova Scotia have gas
holding capacity of 200-350 Scf/ton

Mineralogy and Fracture Pattern

Dominant Quartz and Clay Minerals.
Dominant Microfracture present

Area of Interest

Western and southern part of Moncton
Subbasin, NB and Windsor and Southern
Antgonish Basin, NS

Thermal Maturity Stages	Kerogen Type I (% R _o)	Kerogen Type II (% R _o)	Kerogen Type II-III (% R _o)	Kerogen Type III (% R _o)
Onset of Oil Generation	0.7	0.5	0.55	0.65
Main Phase of Oil Generation	0.8 to 1.1	0.65-0.9	0.7 to 1.0	0.7 to 0.9
Main Phase of Wet Gas and Condensate Generation	1.1 to 1.5	0.9 to 1.25	1.0 to 1.4	0.9 to 1.1
Start of Dry Gas Generation	1.4	1.2	1.3	1.1
Main Phase of Dry Gas Generation	1.5 to 3.5	1.2 to 2.5	1.3 to 3	1.0 to 2.2

Thermal Maturity Boundaries & Relation to HC Generation Stages

Calculated Gas Content and Gas Desorption data Nova Scotia

Calculated Gas Generation from Kennetcook #1 well, Windsor Basin, Nova Scotia Based on Organic Facies, Hydrocarbon Potential, and Gas Desorption Data

(Data from webpage of Triangle Petroleum Inc - Report of Dan Jarvie based on Report from Muki

TOCo (wt.%)		(S2o- S2p) +S1 (mg HC/g)	Total Generation (mcf/af)	thickness (feet)	Total Generation (bcf/section) (per thickness)
	S2o				
	(mg HC/g)				
2.10	5.57	5.01	232	175.1	26
3.35	7.61	7.10	329	175.1	37
18.02	35.14	28.14	1303	55.2	46
49.00	87.71	75.62	3501	55.2	124
77.14	97.19	82.39	3815	55.2	135
29.40	52.63	46.86	2169	55.2	77
Totals:					571 444

Summary of the Gas Prospect, Kennetcook #1 well, Windsor Basin, Nova Scotia

(Data from webpage of Triangle Petroleum Inc - Report of Dan Jarvie based on Report from Muki)

Thickness:	571	ft.
TOC (average):	10%	
Average density:	2.39	g/cc
Initial pressure:	1800	psi
Initial temperature:	92	°F
TOC (average):	10%	
Porosity (average):	3%	
Gas Saturation (average):	62%	
Gas Formation Volume Factor:	0.01	
<i>Sorbed GIP:</i>	46.1	bcf/section
<i>Free GIP:</i>	26.3	bcf/section
<i>Total GIP:</i>	72.4	bcf/section
Recovery (10% of total GIP):	7.2	bcf/section

CONCLUSIONS

- Potential for hybrid tight gas, oil Shale and shale gas projects exists within Mississippian Lacustrine/Fluvial Sediments from NB and NS
- **Moncton Subbasin in NB and Antigonish/Windsor Basins in NS have the major shale potential**
- Laminated Organic Rich (1-20% TOC) and 150-850 HI in Mississippian Shale with both NB and NS
- Source rock maturity is dependent on thermal gradients related to closeness of major thrust faults
- **Fracture patterns are dependent on maturity and mineralogy of the source rocks.**
- About 35-44% of the gases are retained within the shale matrix as adsorbed gases beyond a maturity of 1.5% Ro
- **The ratios of free and adsorbed gases and fracture pattern within the shale matrix is related to organic facies, mineralogical variations, maturity and kinetics of gas generation.**