# Hydrocarbon Potential of the Paleozoic basins of eastern Canada: An assessment of conventional resources

Denis Lavoie[1] (delavoie@nrcan.gc.ca), Jim Dietrich[2], Nicolas Pinet[1], Peter Hannigan[2], Sébastien Castonguay[1], Peter Giles[3] and Tony Hamblin[2]

Geological Survey of Canada, [1] Quebec City, [2] Calgary, [3] Halifax

GeoConvention 2012:Vision

## Summary

In 2009, the Geological Survey of Canada released its evaluation of the conventional hydrocarbon potential of the Paleozoic basins of eastern Canada (Lavoie et al., 2009). The hydrocarbon resource assessment was based on over 20 years of collaborative research by the GSC and provincial partners. Fifteen petroleum plays were recognized in the Paleozoic basins in eastern Canada, with six having sufficient exploration or production data for quantitative assessments. The assessed plays have a combined P50 in place potential of $1170*10^9$ $m^3$ (41 Tcf) of natural gas and $403*10^6$ $m^3$ (2.5 BBO) of oil. Most of the potential for the assessed plays occurs in the Carboniferous Maritimes Basin.

## Introduction

The Cambrian-Permian successions in eastern Canada belong to two major morphological elements, 1) the St. Lawrence Platform of Cambrian to Lower Silurian rocks which extends from southern Quebec to Western Newfoundland and 2) the Appalachians formed by Cambrian to Permian rocks, south and east of the St. Lawrence Platform, extending to the Atlantic Ocean. Within these two domains, sedimentary basins of different ages and origin are recognized (Fig. 1) and can be divided into three tectonostratigraphic domains: 1) the Cambrian-Ordovician, 2) the Silurian-Devonian and 3) the Carboniferous-Permian. In 1984, a preliminary assessment of the hydrocarbon potential of some of these successions was derived from a “minimum of geological data” (Procter et al., 1984).

Figure 1: Main tectonostratigraphic domains in eastern Canada and location of producing or discovered fields

## Hydrocarbon systems and plays in the Cambrian-Ordovician succession

Potential hydrocarbon source rocks occur in organic-rich shales deposited in the Lower Ordovician passive margin, Middle Ordovician deep ocean basin and Upper Ordovician foreland basin successions (Lavoie et al, 2011). The best known quality reservoirs in the Cambrian-Ordovician are hydrothermal dolomites (HTD). Secondary potential reservoirs consist of nearshore and fluvial sands, and thick successions of turbidites and slope channel-fill sands (Lavoie et al., 2009). The carbonate and clastic reservoirs are involved in stratigraphic and tectono-diagenetic traps in the St. Lawrence Platform and in foothill-style traps at the Appalachian structural front (Lavoie et al., 2009). Of the 7 conventional petroleum plays identified (Fig. 2), only three have sufficient production or exploration data to produce quantitative estimates of resource potential: the Lower Ordovician and Middle-Upper Ordovician HTD plays and the carbonate thrust slice play (plays 2, 3 and 4; Fig. 2).

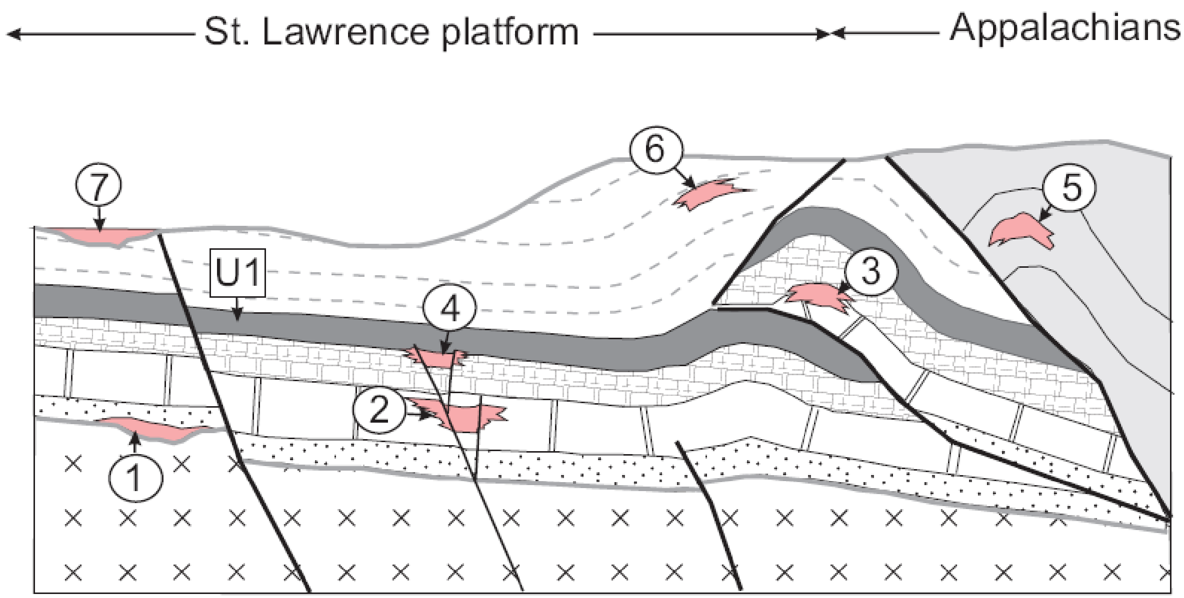


Figure 2: Schematic cross-section of the Cambrian-Ordovician St. Lawrence Platform and coeval Appalachian Humber Zone. The 7 conventional and one unconventional (U1) plays are presented. The plays 2, 3 and 4 are quantitatively assessed. See Lavoie et al. (2009) for discussion of all plays.

Both the Ordovician HTD plays have gas and oil components with the oil play occurring in the northern part of the Gulf of St. Lawrence. An HTD gas reservoir was discovered in southern Quebec by Talisman in 2006. The most significant risk factor in the Ordovician HTD plays is trap preservation. The carbonate thrust slices at the Appalachian structural front (play 3 on Fig. 2) have been seismically identified in a ca. 30 km wide zone from the international border to Quebec City. Extension of this zone is postulated from Quebec City to western Newfoundland. This carbonate play is mainly a gas play with oil potential limited to a small area in western Newfoundland (Port-au-Port Peninsula). The 5 Bcf Saint-Flavien gas field in southern Quebec is a type example of this play (Bertrand et al., 2003). The Garden Hill oil-gas discovery in western Newfoundland (Cooper et al., 2001) is another example of the carbonate play at the Appalachian structural front, but unlike those of the Quebec Reentrant, the trap is associated with a thick-skinned Acadian tectonic wedge. The most significant risk factor for the carbonate thrust slice play is trap preservation. The P50 evaluation of in-place resources for these three plays is $41.4*10^9$ $m^3$ (1.5Tcf) natural gas and $116*10^6$ $m^3$ (730 MBO) oil.

## Hydrocarbon systems and plays in the Silurian-Devonian succession

Fair to poor source rocks in the Silurian-Devonian succession of the Gaspé Belt are limited to Lower Devonian shaly limestones and thin coals (Lavoie et al., 2011). Oil-source rock correlation indicates that oil in Lower Devonian reservoirs in Gaspé can best be tied to either Middle or Upper Ordovician shales, with some contribution from these Devonian sources. Maturation data for the Silurian-Devonian domain indicate both oil and gas potential (Lavoie et al., 2009). The Silurian-Devonian succession is deformed into major folds cut by faults, with a complex kinematic history (Pinet et al., 2008). Six conventional plays are recognized (Fig. 3) with production currently established in Lower Devonian fractured carbonate breccia (Galt field) and in fluvial sandstones (Haldimand field) (plays 5 and 6, respectively on Fig. 3). The Lower Devonian sandstones are highly porous and are very prospective shallow targets (Lavoie et al., 2009). Given the limited modern sub-surface information and the unpredictable nature of the fracture carbonate play (play 5 on Fig. 3), only the Lower Devonian sandstone play (play 6 on Fig. 3) was quantitatively assessed.

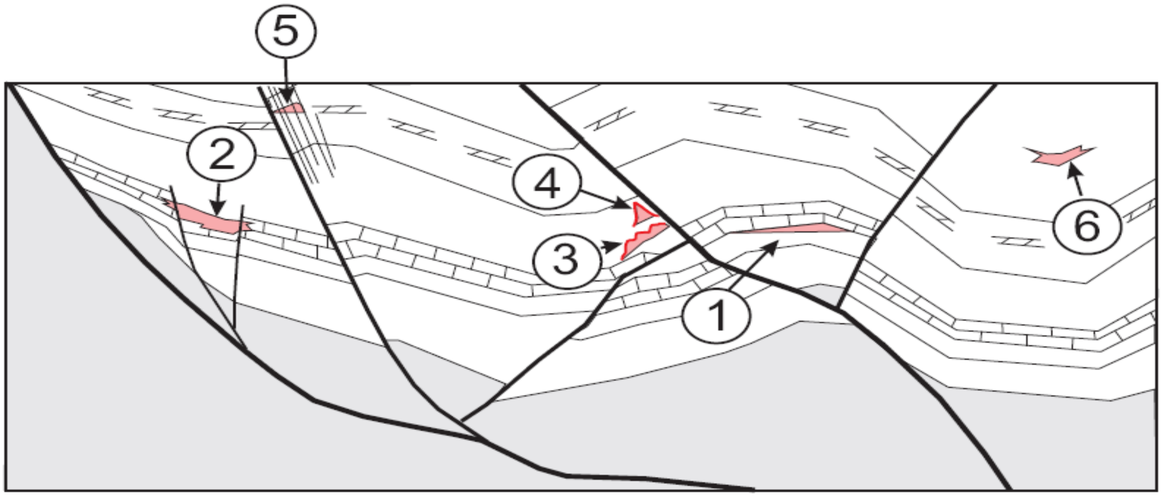


Figure 3: Schematic cross-section of the Silurian-Devonian Gaspé Belt. The 6 conventional plays are presented. Only the Lower Devonian sandstone (#6) was quantitatively assessed. See Lavoie et al (2009) for discussion for all plays.

The map distribution of the Lower Devonian sandstones of the York River Formation is well documented and regional maturation data indicate that this play is oil-prone. Some production data are available from the discovery at Haldimand near Gaspé (34 BOE/d; 47° API oil). At this locality, the hydrocarbon pay zone is 22 metres thick with reservoir porosity ranging between 5 to 15%. The porous sandstones are recognized in the petrophysical summary for wells in the Gaspé (Hu and Lavoie, 2008). The main risk factor is trap seal. The P50 evaluation of the oil-in-place is $16.2*10^6$ $m^3$ (100 MBO).

## Hydrocarbon systems and plays in the Carboniferous-Permian succession

Hydrocarbon source rocks in the Carboniferous-Permian succession of the Maritimes Basin include Lower Carboniferous lacustrine shales (Type I-II organic matter) and Upper Carboniferous coal measures (Type II-III organic matter). The gas prone coal measures are the most widespread source rocks (Lavoie et al., 2009). Basin structures are associated with rift faulting, strike-slip related inversion tectonics, and salt diapirism (Figure 4).The primary exploration plays in the Maritimes Basin involve Lower Carboniferous sandstones or conglomerates in combined structural-stratigraphic traps, Windsor Group carbonate reefs, and Upper Carboniferous fluviatile sandstones in fault block and salt structure traps (salt withdrawal anticlines, salt pillows, salt-diapir flanks, and sub-salt traps; Figure 4). The Upper Carboniferous salt-structure play contains the largest number of known prospects in the basin. The sub-salt play locally includes Horton Group reservoir strata. The Windsor play is the most conceptual, as little is currently known about the regional distribution or sizes of carbonate reefs.

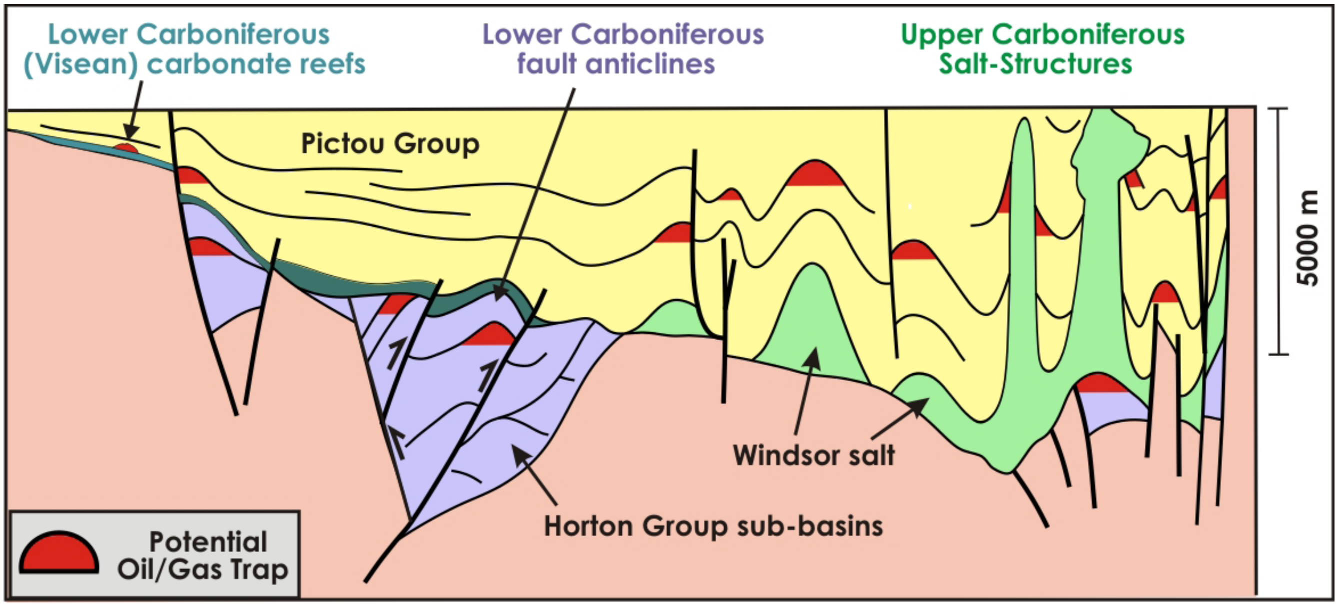


Figure 4: Schematic cross-sections of the Carboniferous Maritimes Basin. The 3 conventional plays are presented. The two Carboniferous clastic plays were assessed. See Lavoie et al. (2009) from the other play.

There are two producing hydrocarbon fields in Lower Carboniferous strata in the onshore portion of the southwestern Maritimes Basin: the Stoney Creek oil field and the McCully gas field. There is one offshore gas field in Upper Carboniferous strata (East Point) that has not been developed but is designated with significant discovery status. Several other exploration wells have recovered natural gas in drill-stem tests, albeit at low reported flow rates. The main exploration risks for the Carboniferous clastic plays are associated with reservoir quality and trap preservation. The P50 evaluation of in-place resource for the two Carboniferous clastic plays is $1108 \times 10^9$ $m^3$ (39 Tcf) natural gas and $235 \times 10^6$ $m^3$ (1.5 BBO).

**References**


Bertrand, R., Chagnon, A., Duchaine, Y., Lavoie, D., Malo, M., and Savard, M.M., 2003. Sedimentologic, diagenetic and tectonic evolution of the Saint-Flavien gas reservoir at the structural front of the Québec Appalachians. Bulletin of Canadian Petroleum Geology, v., 51, p. 126-154.

Cooper, M., Weissenberger, J., Knight, I., Hostad, D., Gillespie, D., Williams, H., Burden, E., Porter-Chaudhry, J., Rae, D., and Clark, E., 2001. Basin evolution in western Newfoundland: new insights from hydrocarbon exploration: American Association of Petroleum Geologists Bulletin, **85**, 393-418.

Hu, K., and Lavoie, D., 2008. Porosity and permeability evaluation and geological interpretations from core data and geophysical logs for 18 wells in the Paleozoic successions of Eastern Canada and implications for hydrocarbon exploration. Geological Survey of Canada, Open File 5485

Lavoie, D., Obermajer, M. and Fowler, M.G., 2011. Rock-Eval/TOC Data from Cambrian-Ordovician of the Saint Lawrence Platform and Humber Zone, and Silurian-Devonian of the Gaspé Belt Successions, Quebec; Geological Survey of Canada, Open File 6050, 1 CD-Rom.

Lavoie, D., Pinet, N., Dietrich, J., Hannigan, P., Castonguay, S., Hamblin, A.P. and Giles, P. 2009**.** Petroleum resource assessment, Paleozoic successions of the St. Lawrence Platform and Appalachians of eastern Canada, Geological Survey of Canada, Open File 6174, 273 pages..

Pinet N., Lavoie D., Keating, P., Brouillette, P., 2008. Gaspé belt subsurface geometry in the northern Québec Appalachians as revealed by an integrated geophysical and geological study. 1- Potential field mapping. Tectonophysics, **460**, 34-54.

Proctor, R.M., Taylor, G.C. and Wade, J.A. 1984. Oil and natural gas resources in Canada. Geological Survey of Canada, Paper 83-31, 59 pages.