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POROSITY AND PERMEABILITY MEASUREMENTS FOR SELECTED PALEOZOIC SAMPLES IN QUEBEC

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Summary

A total of 167 field samples were collected in 2005 and 2006 in order to provide some porosity and permeability data for Paleozoic rocks in Quebec. Samples were collected in the three major tectonostratigraphic domains of the Paleozoic of Quebec; namely the Cambrian-Ordovician shallow marine St. Lawrence Platform (southern Quebec and Anticosti Island), the coeval deep-water sediments preserved in the Taconian Humber Zone (eastern Quebec) and the late Ordovician to Middle Devonian Gaspé Belt (Gaspé Peninsula). Two samples were taken from the thin Carboniferous veneer in southern Gaspé Peninsula. Porosity and permeability measurements were realized at the AGAT laboratories in Calgary. In all domains, some sandstones have relatively high porosity and permeability values. Carbonates are generally characterized by low porosity and permeability values, except for hydrothermal dolomites.

Sommaire

Un total de 167 échantillons de terrain furent récoltés en 2005 et 2006 dans le but de générer des données de porosité et de perméabilité pour les roches du Paléozoïque du Québec. Les échantillons proviennent des trois principaux domaines tectono-stratigraphiques du Paléozoïque du Québec ; la Plate-forme du Saint-Laurent du Cambrien-Ordovicien (sud du Québec et Île d'Anticosti), les sédiments contemporains d'eau profonde préservés dans la Zone taconienne de Humber (est du Québec) et la Ceinture de Gaspé de l'Ordovicien tardif – Dévonien Médian (péninsule de Gaspésie). Deux échantillons proviennent de la mince zone d'affleurements du Carbonifère dans le sud de la Gaspésie. Les mesures de porosité et de perméabilité furent réalisées au laboratoire AGAT à Calgary. Dans tous les domaines, certains grès ont des valeurs de porosité et de perméabilité relativement élevées. Les carbonates ont généralement caractérisés par des valeurs de porosité et de perméabilité faibles, à l'exception des dolomies hydrothermales.

Experimental

167 samples were sent in 2005 and 2006 to the AGAT laboratory in Calgary. Values of porosities were obtained using a pressure chamber, whereas permeability values (K_{max} which represents the addition of the horizontal and vertical components of K) were estimated using water injection on 2.5 to 3.8 cm diameter plugs drilled from field samples. These are usual procedures for the oil and gas industry.

While sampling, great care was taken in taking the least altered samples. However, the values presented in this report should be evaluated with great care as sub-aerial weathering did affect these samples. These values are nevertheless considered useful as they present some qualitative and relative ideas on the reservoir potential of identified hydrocarbon plays.

Regional geological setting of the Paleozoic successions in Quebec

The Paleozoic successions of eastern Canada represent hydrocarbon frontier basins. The successions consist of three major tectonostratigraphic packages that are bounded by tectonically-controlled unconformities. The rock packages which have unique source rocks and reservoir units and specific trap types include 1) the Cambrian-Ordovician autochthonous St. Lawrence shallow marine platform and coeval allochthonous deep water facies preserved in the Taconian thrust belt of the Humber Zone, 2) the Silurian-Devonian shallow to deep marine Gaspé Belt and 3) the Devonian-Permian mostly terrestrial Maritimes Basin (Fig. 1).

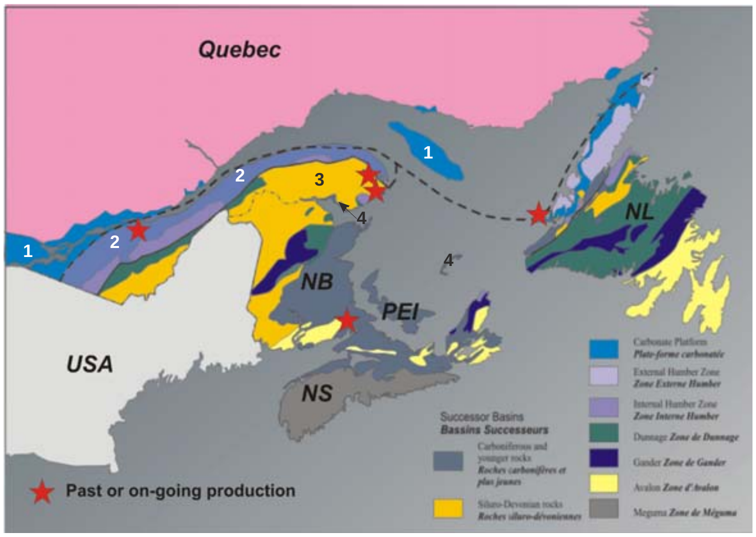

Fig 1: Simplified geological map of eastern Canada. The Paleozoic basins in Quebec consists of the Cambrian-Ordovician St. Lawrence Platform (1) and Humber Zone (2) as well as the Silurian-Devonian Gaspé Belt (3) and the Carboniferous Maritimes basin (4).

The Taconian unconformity separates the Cambrian-Ordovician from the Silurian-Devonian whereas the Acadian unconformity occurs at the base of the Late Devonian-Permian rock package.

Over the past five years the Geological Survey of Canada and its partners have acquired new hydrocarbon systems data, to produce the first ever regional hydrocarbon play assessment for Paleozoic basins in eastern Canada. A total of 13 conventional and 1 unconventional (shale gas) plays have been identified in Cambrian-Devonian strata (Lavoie et al., 2009a and b). The conventional plays include six plays in Cambrian-Ordovician strata (Fig. 2): 1) Cambrian rift sandstones, 2) Lower Ordovician hydrothermal dolomite (HTD), 3) carbonate thrust slices at the Appalachian structural front, 4) Middle-Upper Ordovician HTD, 5) passive margin slope clastics, 6) foreland sandstones and carbonates. A seventh play in southern Quebec (7 on Fig. 2) overlies the Cambrian-Ordovician strata and consists of unconsolidated Quaternary sediments. The unconventional play (U1; Fig. 2) corresponds the Upper Ordovician Utica Shale and correlative units (Lavoie et al., 2008a).

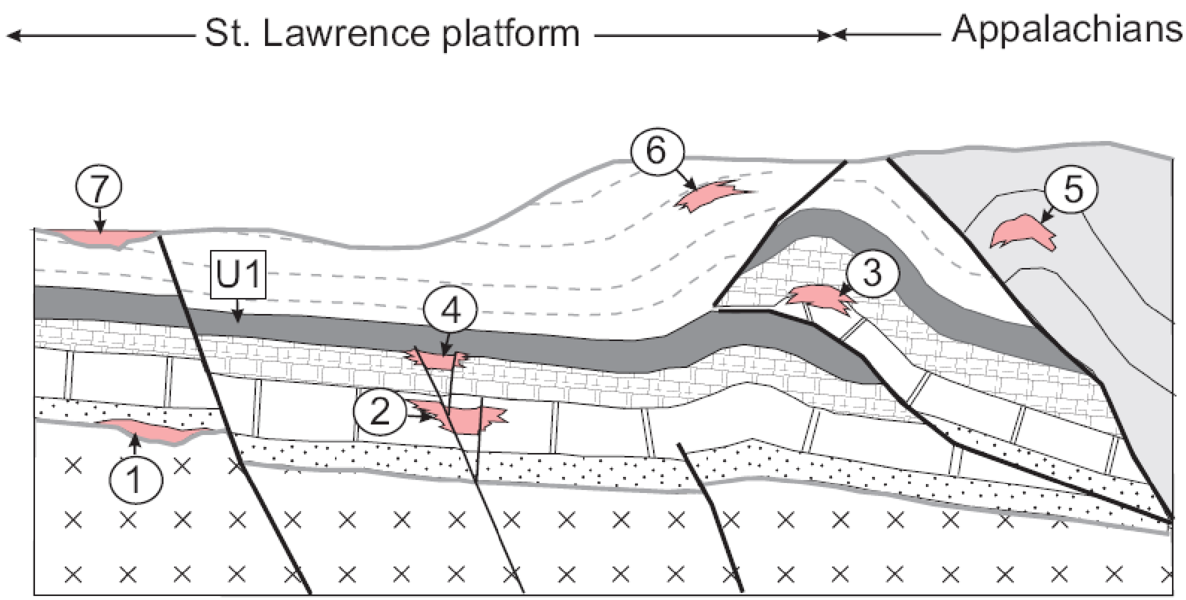

Figure 2: Schematic cross-section of the Cambrian-Ordovician St. Lawrence Platform and coeval Appalachian Humber Zone. The 7 conventional and one unconventional (U1) plays are presented.

Six plays in Silurian-Devonian strata have been identified (Fig. 3): 1) Lower Silurian sandstones, 2) Lower Silurian HTD, 3), Upper Silurian HTD reefs, 4) lowermost Devonian HTD reefs, 5) Lower Devonian fractured carbonates, and 6) Lower Devonian nearshore sandstones.

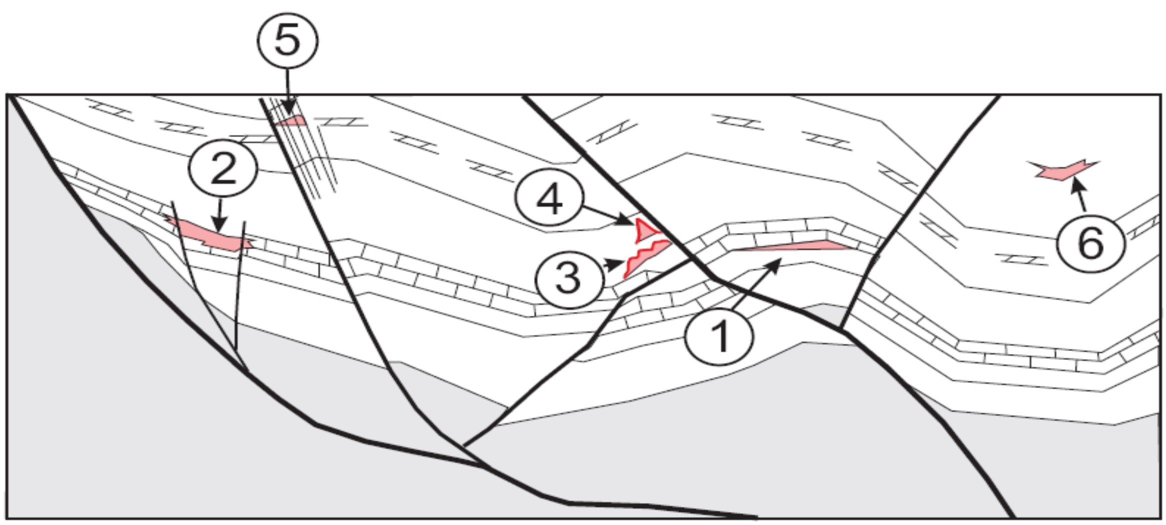

Figure 3: Schematic cross-section of the Silurian-Devonian Gaspé Belt. The 6 conventional plays are presented.

Amongst the new data generated by the eastern Canada Paleozoic project, samples for evaluation of porosity and permeability were collected in all these sedimentary belts. Field samples are not commonly used by the industry, because of surface weathering. However, this information provides an early appraisal of potential for reservoir rocks in the Paleozoic successions of Québec. This contribution reports 165 new porosity and permeability values for the Lower Cambrian to Middle Devonian of Quebec and 2 from the Carboniferous. Some units with significant subsurface information (e.g., the Lower Ordovician dolomites of the Beekmantown Group that hosts the St. Flavien gas field) were not sampled.

In the following sections, a brief summary of current exploration plays for the Cambrian-Ordovician and Silurian-Devonian will be presented and complemented with discussions on the new porosity-permeability data (Tables 1 and 2).

Hydrocarbon plays in the Cambrian-Ordovician of Quebec

In the Quebec Cambrian-Ordovician successions, potential hydrocarbon source rocks are found in organic-rich shales deposited in Lower Ordovician passive margin, Middle Ordovician deep ocean basin and Upper Ordovician foreland basin (Lavoie et al., 2009c). Geochemical analyses suggest that hydrocarbons from Cambrian-Ordovician rocks in southern Quebec were sourced from Upper Ordovician foreland basin black shales (Lavoie et al., 2009a and b). High quality reservoirs in the Cambrian-Ordovician are recognized in hydrothermal dolomites (HTD) in Lower Ordovician passive margin and in the Middle/Upper Ordovician foreland basin carbonates. This potential is supported by production (Saint-Flavien gas field in Lower Ordovician dolostones of the Beekmantown Group; Bertrand et al., 2003) and by recent discovery (Gentilly #1 well in Middle/Upper Ordovician dolostones of the Black River Group; Lavoie et al., 2009a). Other significant potential reservoirs consist of nearshore and fluvial sands, and thick successions of turbidites and slope channel-fill sands (Lavoie et al., 2009a). 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., 2009a).

Porosity-permeability data. Table 1 presents the porosity and permeability values for various units of the St. Lawrence Platform and Humber Zone. Clastic-dominated units are in black characters whereas carbonate-dominated units are in red.

St. Lawrence Platform

In the St. Lawrence Platform of southern Quebec, clastics are found at or near the base of the Paleozoic successions (Cairnside Formation or basal sandstone unit) or overlying the Sauk-Tippecanoe unconformity (La Gabelle Formation). Both intervals show relatively high porosity and permeability values. The Cairnside Formation at the top of the Potsdam Group consists of well-sorted and texturally mature quartz arenite. The La Gabelle Formation and the unnamed basal sandstone near Quebec City are coarse-grained, relatively impure and poorly cemented.

For carbonates in southern Quebec, the dolostones of the Beekmantown Group have the highest porosity – permeability values. In the St. Flavien gas field, the secondary porosity of the reservoir dolostone ranges from 3 to 15% with permeabilities up to 70 mD (Béland and Morin, 2000; Bertrand et al., 2003), although the distribution of porous intervals is highly irregular. No efforts were made in sampling more Beekmantown dolostones. One of the main exploration targets in southern Quebec is hydrothermal dolomites in the Trenton-Black River interval. For these units, there are few hydrothermally dolomitized intervals recognized in outcrops. Along the Sainte-Anne River, the samples LKA-2006-69 and 70 (Leray Formation of the Black River Group) as well as samples LKA-2006-71 and 72 (Sainte-Anne Formation of the Trenton Group) are diffusely dolomitized and interpreted to reflect distal hydrothermal alteration. They have slightly higher than average porosity and permeability compared to unaltered Ordovician limestones. High porosity and permeability values for Lower and Middle/Upper Ordovician hydrothermal dolomites on Anticosti Island were petrophysically and core-documented in Hu and Lavoie (2008).

Along the southwestern coast of Anticosti Island, Lower Silurian (late Llandoverian) carbonates of the Chicotte Formation are dominated by nearshore encrinite facies (Desrochers, 2006). The Chicotte Formation samples (Table 1) have very high porosity and permeability values, the origin of which is still not documented.

The Humber Zone

In the Humber zone, some relatively significant reservoir potential is known from the Lower Cambrian Green Sandstone informal unit (Lavoie et al., 2003) with number of core and petrophysical porosity – permeability values (Parke wells, Hu and Lavoie, 2008). The porosity is of secondary origin and is largely derived from fractures with subordinate leaching of alumino-silicates (Lavoie et al., 2009a). New field samples from the Green Sandstones show low to moderate porosity and permeability (Table 1).

The higher porosity field samples are found in the Lower Cambrian Saint-Nicolas Formation near Quebec City and in the Upper Cambrian Kamouraska Formation in eastern Quebec. The Saint-Nicolas Formation (Lavoie et al., 2003) is roughly time equivalent with the Green Sandstone and consists of coarse-grained, mineralogically and texturally immature sandstone. At some localities, these sandstones are host to significant volume of bitumen and impsonite (Lavoie et al., 2009a). Porosity results primarily from microfractures and from subordinate secondary leaching of metastable alumino-silicates (Lavoie et al., 2009a); however, even with relatively good porosity values (up to 5.1%; Table 1), permeability is very low. The Kamouraska Formation is a well-sorted, medium-grained quartz arenite succession of Late

Cambrian to earliest Ordovician age (Lavoie, 2008); locally the Kamouraska host small pockets of natural gas that were encountered during shallow aquifer-drilling (Lavoie et al., 2009a). In thin section, some secondary dissolution is visible with various amount of bitumen in the pore space (Hubert, 1973) and given its brittle nature, significant open fractures are visible in field outcrops. Some porosity values are relatively high (up to 3.3%; Table 1) although as with the Saint-Nicolas Formation, permeability values are minimal.

In the Humber Zone, carbonates are subordinate deep water deposits that consist of resedimented material from the shallow marine St. Lawrence Platform (Lavoie, 2008; Lavoie et al., 2009a).

Hydrocarbon systems and plays in the Silurian-Devonian

Rock-Eval analyses identify fair to poor source rocks in the Silurian-Devonian succession of the Gaspé Belt, limited to Lower Devonian foreland basin shaly limestone and thin Lower Devonian coals (Lavoie et al., 2009c). Oil-source rock correlation indicates that oil in Lower Devonian reservoirs in Gaspé can best be tied with either Middle or Upper Ordovician shales with some contributions from these Devonian sources (Roy, 2008). Good quality reservoir has been known for decades in the Lower Devonian Gaspé Sandstone (York River Formation) with this play being plagued by inadequate seal; nevertheless, some production is now established in the Haldimand field (40 BOE/day; operator press releases and Lavoie et al., 2009a). The Lower Devonian sandstones are highly porous and are very prospective shallow targets (Lavoie et al., 2009a). For carbonates, the Lower Devonian fractured and hydrothermally altered Upper Gaspé Limestones are reservoirs of small gas and condensate accumulations in the Galt field (Kirkwood et al., 2005; Lavoie et al., 2009a). The Lower Devonian HTD formed in association with significant fracture networks, a prerequisite for enhanced permeability and reservoir potential

(Lavoie et al., 2009a). Hydrothermal dolomites in the Silurian succession have been recently documented (Lavoie and Morin, 2004; Lavoie and Chi, 2006 and in press) and have never been tested in the subsurface. The Silurian-Devonian succession is involved in major folds and cuts by faults that exhibit a variable cinematic (Pinet et al., 2008). A significant number of seismic anomalies and bright spots (hydrocarbon indicators?) are observed in the untested Silurian succession. Maturation data for the Silurian-Devonian domain indicate both oil and gas potential (Roy, 2008; Lavoie et al., 2009a).

Porosity-permeability data. Table 2 presents the porosity and permeability values for various units of the Gaspé Belt. Clastic-dominated units are in black characters whereas carbonate-dominated units are in red.

Within the Gaspé belt, sandstones are characterized by higher average and maximum porosity and permeability values (Table 2). The best values are found in the immature, coarse-grained and little cemented alluvial sandstones of the Battery Point (Gaspé Sandstones Group, Lavoie, 2008); these sandstones yielded higher porosity values, with an average close to 10% although a high clay content results in low connectivity of the primary pore space (Kmax usually less than 0.2 mD). Similarly, the nearshore sandstones of the York River Formation (Gaspé sandstone Group, Lavoie, 2008) yield high porosity values (average of 6.3%) but again with relatively low permeability (Kmax less than 0.1 mD). These good porosity and fair to poor permeability intervals are recognized in electric logs from wells that intercept these units (Hu and Lavoie, 2008)

Lower Silurian nearshore sandstones are also characterized by some high porosity and permeability values (Table 2). For these, the higher values can be found in the coarse-grained and immature litharenite of the Weir Formation (maximum of 9.2%). Slightly younger sandstone units (Val Brillant and Anse Cascon formations) correspond to mineralogically more mature quartz arenite, that yielded relatively high porosity values (2.8 and 2.6%, respectively) although all these Lower Silurian sandstones are characterized by low permeability (highest values less than 0.1mD). The porosity of the Lower Silurian sandstones is poorly documented in wells as only one electric log is available (Hu and Lavoie, 2008).

The petrophysical characteristics of the fractured and hydrothermally altered carbonates of the Lower Devonian Upper Gaspé Limestones (Indian Cove and Forillon formations) have been documented at Galt (Hu and Lavoie, 2008) with subsurface porosity and permeability values up to 7% and 600 mD. These high values were not replicated by our limited field sample dataset (Table 2).

The recognition of hydrothermal dolomites in Lower Silurian (Sayabec and La Vieille formations), Upper Silurian (West Point Formation) and lowermost Devonian (West Point Formation) has generated new ideas on prospective plays for the Silurian-Devonian Gaspé Belt (Lavoie et al., 2009a and b). However, these specific dolomites have never been tested in the subsurface. Some specific sampling was done in order to preliminarily characterize the significant porosity visible in hand specimens.

The Lower Silurian hydrothermal dolomites are represented by samples LKA-2005-71, 72 and 146 (Table 2); these are characterized by high porosity values (up to 5.6%) and fair to poor permeability (up to 1.22 mD). Interestingly, a fracture and brecciated sample from the reef facies of the Sayabec Formation (LKA-2005-85) has yielded one of the highest porosity (6.6%) and permeability value (4.68 mD) for the Lower Silurian succession, this sample is totally impregnated with bitumen.

The Upper Silurian Anse-à-la-Barbe Member of the West Point Formation (Bourque et al., 1986; Lavoie, 2008) is locally fractured and slightly dolomitized (sample LKA-2005-113); porosity and permeability values are low (Table 2). The lowermost Devonian pinnacle reefs of the West Point Formation are intensely brecciated and dolomitized at one locality in northern Gaspé, very high temperature and massive dolomitization is documented (Lavoie et al., 2008b). One sample from this locality (LKA-2005-63) has yielded the highest porosity (7.5%) and one of the highest permeability value (1.79 mD) for the carbonate dataset.

Conclusions

Porosity and permeability measurements on 167 samples from the Paleozoic rocks of Quebec were done in order to generate preliminary and qualitative estimates of potential reservoir units. It should be cautioned that the most permeable and porous field samples for these Cambrian to Carboniferous units might not be indicative of conditions in the subsurface. Therefore, the values presented here should be evaluated with this limitation.

Some sandstones have yielded relatively high porosity and permeability values for the Cambrian-Ordovician (St. Lawrence Platform and Humber Zone), the Silurian-Devonian (Gaspé Belt) and the Carboniferous (Maritimes Basin) successions. For carbonates, with the exception of the porous coarse-grained limestones of the Chicotte Formation, high values are only obtained for demonstrated and hypothesized hydrothermal dolomites. For all these cases, besides the Lower Devonian sandstones, porosity is of various secondary origin and the higher permeability values relate to more or less intense (micro)fracturing.

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References

Béland, P., et Morin, C., 2000. Le gisement de gaz naturel de Saint-Flavien, Québec. Ministère des Ressources Naturelles du Québec, 19 p.

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.

Bourque, P.-A., Amyot, G., Desrochers, A., Gignac, H., Gosselin, C., Lachambre, G., and Laliberté, J.Y., 1986. Silurian and Lower Devonian reef and carbonate complexes of the Gaspé Basin, Québec – a summary: Bulletin of Canadian Petroleum Geology, v. 34, p. 452-489.

Desrochers, A., 2006. Rocky shoreline deposits in the Lower Silurian (upper Llandovery, Telychian) Chicotte Formation, Anticosti Island, Quebec. Canadian Journal of Earth Sciences, v. 43, p. 1205-1214.

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.

Hubert, C. 1973. Kamouraska, La Pocatière, and Saint-Jean-Port-Joli area. Ministère des Richesses Naturelles, Québec, Geological Exploration Service, Geological Report 151

Kirkwood, D., Lavoie, M., and Marcil, J.-S., 2005. Structural style and hydrocarbon potential in the Acadian foreland thrust and fold belt, Gaspé Appalachians, Canada: in Swennen, R., Roure, F., and Granath, J., eds., Deformation, fluid flow and reservoir appraisal in foreland fold-and-thrust belts: American Association of Petroleum Geologists, Hedberg Series, No. 1, p. 412-430.

Lavoie, D., 2008. Appalachian foreland basins, 1. Canada. In K.J. Hsü (series ed.) Sedimentary basins of the World Sedimentary basins of the World – USA and Canada, Miall, A., (ed.). Elsevier Science, p. 63-105.

Lavoie, D., and Morin, C., 2004. Hydrothermal dolomitization in the Lower Silurian Sayabec Formation in Northern Gaspé – Matapédia: Constraint on timing of porosity and regional significance for hydrocarbon reservoirs: Bulletin of Canadian Petroleum Geology, v. 52, p. 256-269.

Lavoie, D., and Chi, G., 2006. Hydrothermal dolomitization in the Lower Silurian La Vieille Formation in northern New Brunswick: geological context and significance for hydrocarbon exploration: Bulletin of Canadian Petroleum Geology, v. 54, p. 380-395

Lavoie, D., and Chi, G., in press. Lower Paleozoic foreland basins in eastern Canada: tectono-thermal events recorded by faults, fluids and hydrothermal dolomites. Bulletin of Canadian Petroleum Geology.

Lavoie, D., Burden, E., and Lebel, D., 2003. Stratigraphic framework for the Cambrian-Ordovician rift and passive margin successions from southern Québec to western Newfoundland: Canadian Journal of Earth Sciences, v. 40, p. 177-205.

Lavoie, D., Hamblin, A.P., Thériault, R., Beaulieu, J., and Kirkwood, D., 2008a. The Upper Ordovician Utica Shale and Lorraine Group flysch in southern Québec. Tectonostratigraphic setting and significance for unconventional gas. Geological Survey of Canada Open File 5900.

Lavoie, D., Urbatsch, M., Chi, G., 2008b. Fault-controlled hydrothermal dolomitization of pinnacle reefs of the Lower Devonian West Point Formation in Northern Gaspé, GAC-MAC Annual Meeting , Québec, Canada, Program with Abstracts

Lavoie, D., Pinet, N., Castonguay, S., Dietrich, J., Giles, P., Fowler, M., Thériault, R., Laliberté, J.-Y., St. Peter, C., Hinds, S., Hicks, L., and Klassen, H., 2009a. Hydrocarbon systems in the Paleozoic basins of eastern Canada – Presentations at the Calgary 2007 workshop. Geological Survey of Canada, Open File 5980, 1 DVD.

Lavoie, D., Pinet, N., Castonguay, S., Hannigan, P., Dietrich, J., Hamblin, T., and Giles, P., 2009b. The Cambrian – Devonian frontier basins in eastern Canada: Assessment of hydrocarbon potential of the most promising plays. Canadian Society of Petroleum Geologists, Annual Meeting, Calgary 2009. Program with abstracts.

Lavoie, D., Obermajer, M., and Fowler, M., 2009c. Rock Eval data for Paleozoic rocks of Quebec. Geological Survey of Canada, Open File 6050, 1 CD.

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, v. 460, p. 34-54.

Roy, S., 2008. Maturation thermique et potential pétroligène de la Ceinture de Gaspé, Gaspésie, Québec, Canada. Ph.D. thesis, Institut National de la Recherche Scientifique – Eau, Terre et Environnement, Québec, Canada. 471 p

Table 1: Porosity and Permeability data for Cambrian-Ordovician units of the St. Lawrence Platform and the Taconian Humber Zone

Sample	Formation / unit	Age of unit	east	north	Po (%)	Kmax (mD)
St. Lawrence Platform						
LKA-2006-48	**Cairnside**	Upper Cambrian	610738	5096152	3,6	0,1
LKA-2006-49	**Cairnside**	Upper Cambrian	610750	5096145	3,8	0,01
LKA-2006-50	**Cairnside**	Upper Cambrian	610750	5096145	6,2	0,02
Average					**4,5**	**0,4**
LKA-2006-60	**La Gabelle**	Middle Ordovician	671146	5147825	7,4	0,04
LKA-2006-61	**La Gabelle**	Middle Ordovician	671146	5147825	3,6	0,01
LKA-2006-62	**La Gabelle**	Middle Ordovician	671146	5147825	6,8	0,56
Average					**5,9**	**0,2**
LKA-2006-25A	**Basal sandstone**	Middle Ordovician	355768	5216251	9,2	1,09
LKA-2006-26	**Basal sandstone**	Middle Ordovician	355768	5216251	0,8	0,01
Average					**5**	**0,6**
LKA-2006-35	**Leray**	Middle Ordovician	293747	5181956	2,5	0,03
LKA-2006-36	**Leray**	Middle Ordovician	293745	5181951	1,7	0,03
LKA-2006-63	**Leray**	Middle Ordovician	689491	5152472	0,7	0,01
LKA-2006-64	**Leray**	Middle Ordovician	689502	5152433	1,1	0,01
LKA-2006-65	**Leray**	Middle Ordovician	689575	5152160	1,7	0,01
LKA-2006-66	**Leray**	Middle Ordovician	690223	5151511	0,6	0,01
LKA-2006-69	**Leray**	Middle Ordovician	723171	5177000	2,1	0,03
LKA-2006-70	**Leray**	Middle Ordovician	723171	5177000	1,7	0,04
Average					**1,5**	**0.02**
LKA-2006-51	**Ouareau**	Upper Ordovician	615484	5093866	0,7	0,01
LKA-2006-71	**Sainte Anne**	Upper Ordovician	723171	5176998	1,3	0,01
LKA-2006-72	**Sainte Anne**	Upper Ordovician	723175	5176990	1,7	0,1
LKA-2006-37	**Pont-Rouge**	Upper Ordovician	293735	5181913	1,8	0,06
LKA-2006-38	**Pont-Rouge**	Upper Ordovician	293769	5181776	1,3	0,01
Average					**1,4**	**0,04**
LKA-2006-28	**Deschambault**	Upper Ordovician	355801	5216253	4,1	0,01
LKA-2006-39	**Deschambault**	Upper Ordovician	294002	5180308	0,6	0,01
LKA-2006-43	**Deschambault**	Upper Ordovician	294162	5179938	1	0,03
LKA-2006-44	**Deschambault**	Upper Ordovician	304468	5177047	0,4	0,14
LKA-2006-45	**Deschambault**	Upper Ordovician	304469	5177049	1,6	0,05
LKA-2006-53	**Deschambault**	Upper Ordovician	615526	5093822	3	0,01
LKA-2006-54	**Deschambault**	Upper Ordovician	609169	5089436	2,1	0,04
LKA-2006-57	**Deschambault**	Upper Ordovician	665445	5142044	0,7	0,01
LKA-2006-59	**Deschambault**	Upper Ordovician	665445	5142044	0,7	0,01
LKA-2006-68	**Deschambault**	Upper Ordovician	690223	5151511	1,4	0,03
LKA-2006-73	**Deschambault**	Upper Ordovician	723195	5177027	1,6	0,01

LKA-2006-74	**Deschambault**	Upper Ordovician	723286	5177120	1,8	0,01
Average					**1,6**	**0,03**
LKA-2006-29	**Neuville**	Upper Ordovician	355832	5216239	2	0,01
LKA-2006-32	**Neuville**	Upper Ordovician	355635	5215248	1,2	0,01
LKA-2006-34	**Neuville**	Upper Ordovician	359155	5214982	2,5	0,04
LKA-2006-41	**Neuville**	Upper Ordovician	294283	5180216	0,8	0,01
LKA-2006-46	**Neuville**	Upper Ordovician	304588	5177079	0,9	0,01
LKA-2006-75	**Neuville**	Upper Ordovician	726893	5163603	1,5	0,05
Average					**1,5**	**0,02**
AN-1	**Chicotte**	Lower Silurian	470450	5471000	8,1	3,64
AN-2	**Chicotte**	Lower Silurian	470450	5471000	6,7	2,21
128	**Chicotte**	Lower Silurian	492750	5453100	9,5	11,4
Average					**8,1**	**5,75**

Humber Zone

LKA-2005-8	**Green Sandstone**	Lower Cambrian	460320	5271948	0,5	0,01
LKA-2005-13	**Green Sandstone**	Lower Cambrian	406537	5233498	0,5	0.01
LKA-2005-17	**Green Sandstone**	Lower Cambrian	379534	5203049	0,6	0,01
LKA-2005-18	**Green Sandstone**	Lower Cambrian	325425	5179942	1,6	0,02
LKA-2005-29	**Green Sandstone**	Lower Cambrian	328129	5178934	2,2	0,01
LKA-2005-30	**Green Sandstone**	Lower Cambrian	326956	5178750	1,6	0,02
LKA-2005-38	**Green Sandstone**	Lower Cambrian	323735	5178255	1,1	0,02
Average					**1.2**	**0.02**
LKA-2005-12	**Saint-Roch**	Lower Cambrian	406588	5233567	1,6	0,01
LKA-2005-16	**Saint-Roch**	Lower Cambrian	391181	5208435	0,7	0,02
LKA-2005-21	**Saint-Roch**	Lower Cambrian	363906	5191262	0,9	0,01
LKA-2005-33	**Saint-Nicolas**	Lower Cambrian	325442	5176297	0,9	0,02
LKA-2005-34	**Saint-Nicolas**	Lower Cambrian	311251	5165553	5,1	0,01
LKA-2005-35	**Saint-Nicolas**	Lower Cambrian	310126	5163997	1,2	0,01
LKA-2005-36	**Saint-Nicolas**	Lower Cambrian	325423	5177978	3,4	0,01
LKA-2005-37	**Saint-Nicolas**	Lower Cambrian	325423	5177978	2,5	0,01
LKA-2005-42	**Saint-Roch**	Lower Cambrian	464350	5305879	0,5	0,01
LKA-2005-43	**Saint-Roch**	Lower Cambrian	464336	5305870	0,5	0,02
Average					**1.7**	**0.01**
LKA-2005-10	**Saint-Damase**	Upper Cambrian	438657	5265292	0,5	0,02
LKA-2005-14	**Saint-Damase**	Upper Cambrian	407858	5218132	2,3	0,01
LKA-2005-20	**Saint-Damase**	Upper Cambrian	369377	5188474	0,5	0,01
LKA-2005-23	**Saint-Damase**	Upper Cambrian	366085	5187367	0,7	0,01
LKA-2005-25	**Saint-Damase**	Upper Cambrian	363629	5182235	0,5	0,02
LKA-2005-31	**Breakeyville**	Upper Cambrian	327786	5163926	0,9	0,01
LKA-2005-32	**Breakeyville**	Upper Cambrian	326600	5173835	2,1	0,01
LKA-2005-41	**Saint-Damase**	Upper Cambrian	457670	5296378	0,8	0,01
LKA-2005-46	**Saint-Damase**	Upper Cambrian	496420	5341750	2,4	0,01
LKA-2005-66	**Saint-Damase**	Upper Cambrian	600537	5401140	0,7	0,01

LKA-2005-68	**Saint-Damase**	Upper Cambrian	609743	5405329	0,7	0,01
LKA-2005-69	**Saint-Damase**	Upper Cambrian	608220	5402982	0,5	0,01
Average					**1.1**	**0,01**
LKA-2005-9	**Kamouraska**	Upper Cambrian	436831	5265285	1,4	0,01
LKA-2005-11	**Kamouraska**	Upper Cambrian	434405	5259104	3,1	0,01
LKA-2005-15	**Kamouraska**	Upper Cambrian	407637	5218818	1,3	0,01
LKA-2005-19	**Kamouraska**	Upper Cambrian	372422	5192417	1,3	0,01
LKA-2005-22	**Kamouraska**	Upper Cambrian	366982	5186005	1,9	0,01
LKA-2005-24	**Kamouraska**	Upper Cambrian	364135	5182589	2,6	0,01
LKA-2005-26	**Kamouraska**	Upper Cambrian	361904	5181571	0,5	0,01
LKA-2005-27	**Kamouraska**	Upper Cambrian	361005	5180878	2,5	0,01
LKA-2005-28	**Kamouraska**	Upper Cambrian	357811	5179854	1	0,01
LKA-2005-44	**Kamouraska**	Upper Cambrian	481434	5310559	0,5	0,01
LKA-2005-45	**Kamouraska**	Upper Cambrian	489318	5328121	3,3	0,01
LKA-2005-70	**Kamouraska**	Upper Cambrian	611166	5395690	1,5	0,01
LKA-2005-86	**Kamouraska**	Upper Cambrian	311877	5439706	2,1	0,02
average					**1.8**	**0,01**
LKA-2005-40	**Rivière-Ouelle**	Lower Ordovician	459456	5295795	0,5	0,01
LKA-2005-47	**Rivière-Ouelle**	Lower Ordovician	537138	5361570	0,5	0,01
LKA-2005-67	**Rivière-Ouelle**	Lower Ordovician	607697	5408657	1,1	0,01
average					**0.7**	**0,01**
LKA-2005-39	**Tourelle**	Middle Ordovician	454471	5274416	0,5	0,01
LKA-2005-56	**Tourelle**	Middle Ordovician	686702	5447338	0,5	0,01
average					**0,5**	**0,01**

Table 2: Porosity and permeability values for the Late Ordovician-Middle Devonian Gaspé Belt and two values for the Carboniferous Maritimes Basin

Sample	Formation	Age of unit	east	north	Po (%)	Kmax (mD)
Gaspé Belt						
LKA-2005-138	**Garin**	Upper Ordovician	301029	5342184	1,2	0,01
LKA-2005-144	**Garin**	Upper Ordovician	306482	5349162	0,5	0,01
average					**0,9**	**0,1**
LKA-2005-107	**White Head**	Upper Ordovician	400099	5378585	0,6	0,01
LKA-2005-110	**White Head**	Upper Ordovician	364783	5382961	1,1	0,01
average					**0,9**	**0,01**
LKA-2005-48	**Cabano**	Lower Silurian	547750	5349037	0,9	0,01
LKA-2005-49	**Cabano**	Lower Silurian	548295	5350244	2,4	0,05
average					**1.7**	**0,3**
LKA-2005-51	**Val Brillant**	Lower Silurian	550886	5350830	2,4	0,01
LKA-2005-62	**Val Brillant**	Lower Silurian	297268	5424195	0,9	0,01
LKA-2005-73	**Val Brillant**	Lower Silurian	583830	5370496	2,8	0,05
average					**2**	**0.2**
LKA-2005-127	**Weir**	Lower Silurian	349551	5337969	1	0,01
LKA-2005-128	**Weir**	Lower Silurian	349541	5337989	9,2	0,09
LKA-2005-142	**Weir**	Lower Silurian	307425	5348000	0,5	0,01
LKA-2005-143	**Weir**	Lower Silurian	307896	5348509	2,7	0,01
average					**3.4**	**0,03**
LKA-2005-129	**Anse Cascon**	Lower Silurian	349514	5338071	0,5	0,01
LKA-2005-130	**Anse Cascon**	Lower Silurian	349543	5338142	1,7	0,01
LKA-2005-131	**Anse Cascon**	Lower Silurian	349501	5338285	1,9	0,01
LKA-2005-140	**Anse Cascon**	Lower Silurian	301029	5342184	1,9	0,01
LKA-2005-141	**Anse Cascon**	Lower Silurian	306272	5345748	2	0,1
LKA-2005-145	**Anse Cascon**	Lower Silurian	308516	5341827	2,6	0,01
average					**1.8**	**0,03**
LKA-2005-52	**Sayabec**	Lower Silurian	551452	5350067	0,5	0,01
LKA-2005-54	**Sayabec**	Lower Silurian	544139	5346171	1,3	0,01
LKA-2005-57	**Sayabec**	Lower Silurian	290720	5420058	0,5	0,01
LKA-2005-58	**Sayabec**	Lower Silurian	290354	5419912	0,6	0,01
LKA-2005-60	**Sayabec**	Lower Silurian	299594	5425395	0,7	0,01
LKA-2005-64	**Sayabec**	Lower Silurian	711613	5417802	0,8	0,01
LKA-2005-71	**Sayabec**	Lower Silurian	591090	5368721	4,8	0,01
LKA-2005-72	**Sayabec**	Lower Silurian	591090	5368721	5,6	1,22
LKA-2005-74	**Sayabec**	Lower Silurian	584790	5370615	0,5	0,01
LKA-2005-76	**Sayabec**	Lower Silurian	584927	5370733	0,5	0,01

LKA-2005-77	**Sayabec**	Lower Silurian	585929	5371747	0,6	0,01
LKA-2005-78	**Sayabec**	Lower Silurian	587533	5372258	0,5	0,1
LKA-2005-84	**Sayabec**	Lower Silurian	584578	5367360	0,5	0,04
LKA-2005-85	**Sayabec**	Lower Silurian	584578	5367360	6,6	4,68
LKA-2005-115	**La Vieille**	Lower Silurian	364412	5340437	0,6	0,06
LKA-2005-121	**La Vieille**	Lower Silurian	354327	5338397	0,6	0,12
LKA-2005-132	**La Vieille**	Lower Silurian	349391	5338424	0,5	0,01
LKA-2005-133	**La Vieille**	Lower Silurian	349376	5338431	0,6	0,01
LKA-2005-136	**La Vieille**	Lower Silurian	332637	5331508	4	0,05
LKA-2005-139	**La Vieille**	Lower Silurian	301770	5341838	2,7	0,01
LKA-2005-146	**La Vieille**	Lower Silurian	288871	5335940	3,9	0,02
LKA-2005-148	**La Vieille**	Lower Silurian	701510	5335979	0,7	0,01
LKA-2005-149	**La Vieille**	Lower Silurian	701508	5335992	1,4	0,01
LKA-2005-152	**La Vieille**	Lower Silurian	701062	5336910	0,8	0,01
Average					**1.7**	**0,3**
LKA-2005-53	**St-Léon**	Upper Silurian	552536	5348765	0,8	0,01
LKA-2005-55	**St-Léon**	Upper Silurian	543320	5347301	2,8	0,02
LKA-2005-79	**St-Léon**	Upper Silurian	601802	5377834	0,7	0,02
LKA-2005-137	**Gascon**	Upper Silurian	332238	5330619	4	0,11
Average					**2.1**	**0,04**
LKA-2005-92	**West Point**	Upper Silurian	376083	5427570	0,7	0,01
LKA-2005-93	**West Point**	Upper Silurian	376102	5427523	0,6	0,01
LKA-2005-113	**West Point**	Upper Silurian	357390	5386251	1	0,01
LKA-2005-117	**West Point**	Upper Silurian	362846	5339291	0,5	0,01
LKA-2005-118	**West Point**	Upper Silurian	355035	5337929	0,5	0,03
LKA-2005-119	**West Point**	Upper Silurian	355328	5339549	0,8	0,01
LKA-2005-120	**West Point**	Upper Silurian	355245	5339708	1	0,01
LKA-2005-122	**West Point**	Upper Silurian	352336	5333674	0,7	0,18
LKA-2005-123	**West Point**	Upper Silurian	352375	5333680	3,6	0,47
LKA-2005-124	**West Point**	Upper Silurian	352325	5333665	1,4	0,09
LKA-2005-126	**West Point**	Upper Silurian	352560	5333297	2,4	0,18
average					**1,2**	**0,09**
LKA-2005-59	**West Point**	Lower Devonian	299875	5425207	1,5	0,02
LKA-2005-63	**West Point**	Lower Devonian	286663	5418119	7,5	1,79
average					**4.5**	**0,9**
LKA-2005-111	**Indian Point**	Lower Devonian	365268	5384988	1,9	0,06
LKA-2005-81	**Forillon**	Lower Devonian	600776	5368555	0,6	0,01
LKA-2005-104	**Forillon**	Lower Devonian	400761	5381055	0,6	0,01
average					**0.6**	**0.01**
LKA-2005-80	**Indian Cove**	Lower Devonian	600692	5368010	0,7	0,01
LKA-2005-91	**Indian Cove**	Lower Devonian	375623	5426315	1,4	0,01
average					**1.1**	**0,01**

LKA-2005-112	**Fortin**	Lower Devonian	365185	5385176	0,8	0,01
LKA-2005-87	**York River**	Lower Devonian	326473	5422162	0,6	0,01
LKA-2005-89	**York River**	Lower Devonian	352764	5408708	5,5	0,01
LKA-2005-90	**York River**	Lower Devonian	364642	5410932	3,8	0,01
LKA-2005-99	**York River**	Lower Devonian	386699	5402190	9,6	0,04
LKA-2005-101	**York River**	Lower Devonian	405003	5397511	12,1	0,08
average					**6.3**	**0,03**
LKA-2005-94	**Battery Point**	Lower Devonian	387427	5415654	17,2	4,3
LKA-2005-95	**Battery Point**	Lower Devonian	393933	5409162	7,1	0,06
LKA-2005-96	**Battery Point**	Lower Devonian	391247	5410263	8,2	0,17
LKA-2005-98	**Battery Point**	Lower Devonian	391329	5410354	6,8	0,15
LKA-2005-100	**Battery Point**	Lower Devonian	405067	5397277	7,6	0,1
average					**9,4**	**1**

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LKA-2005-106	**Bonaventure**	Carboniferous	386251	5375698	6,6	0,05
LKA-2005-109	**Cannes-de-Roches**	Carboniferous	406263	5377745	15,9	14,5
average					**11.3**	**7.3**