

A conventional play in the Lower St. Lawrence River area (Québec, Canada): the silurian Sayabec Formation

Stéphanie Larmagnat¹, Alexandre Aubiès-Trouilh², Michel Malo¹, Jasmin Raymond¹

¹INRS - Centre Eau Terre Environnement

²Ressources & Énergie SQUATEX Inc.

Summary

The hydrocarbon potential of the Gaspé Peninsula and adjacent Lower St. Lawrence River area has been established for several years but little is known about the specific sector of the St. Lawrence River area partly because of its structural complexity. The presence of hydrocarbons notably within the silurian carbonate Sayabec Formation (Fm) has already been documented in the NW part of the Peninsula. A joint research project with Oil and gas operator in St. Lawrence River sector allow us to access a large set of subsurface data and investigate the reservoir quality of carbonate sedimentary facies in a prospective play, the Massé structure. The detailed stratigraphy of the Sayabec Fm revealed four distinct interval with promising reservoir facies. Three of them are associated with natural fractures. Pore type is diverse and include intergranular, intragranular, modicl and vuggy porosity. In fine-grained facies, microporosity could also play a significant role in reservoir quality. A highly fractured 40 m thick interval is associated with dolomitic cement within Massé No.1 well but this interval is absent in the adjacent Massé No. 2 well. This interval is interpreted as a typical example of hydrothermal dolomite interval (HTD). Based on similar sedimentary facies and the occurrence of HTD, the Sayabec Fm could represent an analog to the Ladyfern gas field reservoir.

Introduction

Hydrocarbons occurrences are well documented within the Sayabec Fm in the northwestern area of the Gaspésie Peninsula (e.g. Bourque, 2001; Lavoie et Chi, 2001; Lavoie et Morin, 2004). However, little is known about the specific sector located between the Matapedia lake at the NE and the Temiscouata lake at the SO, partly because of its structural complexity. This area is part of the Gaspé Belt (sensu Bourque et al., 1995) and is known to expose shallow-water to deep-water carbonate platform deposits, silurian to early devonian in age. These sediments have been deposited after the taconian deformation stage, during the filling stages of the basin and its subsequent uplift phase (Lavoie et al., 1992 ; Bourque et al., 2000 ; Lavoie, 2008). Industry partner (Energie Squatex Inc.) has demonstrated its interest for developing the oil and gas potential of the area and has drilled about 6000 meters of stratigraphic wells over the past six years. While drilling, several of them revealed oil or gas shows associated with naturally fractured zones in a prospective play the Massé structure. The Massé structure belongs to the northern part of the Connecticut Valley-Gaspé synclinorium. In this area, the Taconian unconformity separates the Cambro-Ordovician strata (to the north) and the Siluro-Devonian succession (to the south; Malo and Bourque, 1993; Bourque et al., 1995). The Massé structure is limited by two normal faults and its sedimentary sequence was preserved with little amount of deformation and only local brecciation and/or fracturing occurrences.

Fine-scale stratigraphy of the Sayabec Formation

The Sayabec Fm, lower Silurian in age, corresponds to peritidal carbonates deposited at the end of a regressive cycle initiated in the late Ordovician. In the Massé structure area, the average thickness of the

Sayabec Fm is 300 meters. Overall, the upper part of the Sayabec Fm displays fine-grained carbonate facies, ranging from well sorted peloidal packstone to poorly sorted packstone with crinoids and bioturbated mudstones. These carbonate facies are interbedded with plurimetric layers of siltstones. Locally, metric units are made of corals, stromatoporoids and bryozoan baffestones and/or framestones where intraparticules porosity is often preserved. The size of individual fossil could reach up to 8 cm in diameter and appear much larger at the outcrop scale (up to several tens of centimeters).

In Massé No. 2 well, the Sayabec Fm interval revealed at least four intervals with reservoir quality potential. Those intervals correspond to: (1) bioclastic packstone, (2) bryozoan bounstone forming decimetric thickets (Fig. 1B), (3) bioclastic grainstone (Fig. 1C) and (4) coarse intervals with crinoids and brachiopods packstones (Fig. 1D). Among these four intervals, three are associated with fractures occurring in three distinctive phases. In addition, pores are variable in nature and correspond to intergranular, intragranular, moldic and vuggy porosity.

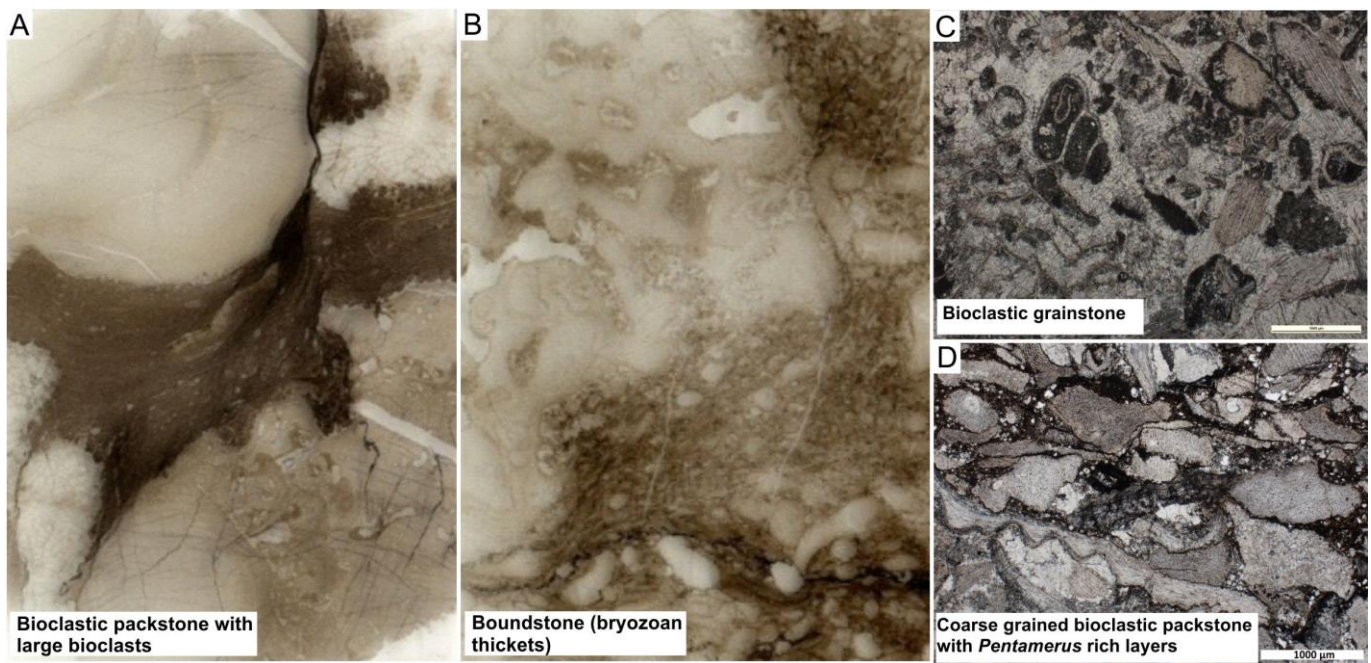


Figure 1: Within the Sayabec Formation, four facies have interesting reservoir quality. These intervals are associated with variable porosity types (intergranular, intragranular, moldic and vuggy) and fractures.

Lateral variation

Massé no.1 well has a distinctive 40 m thick interval of hydrothermal dolomite (HTD) where highly connected porosity is common (Fig. 2A-B). Pores are associated with fractures, dissolved bioclasts and vugs. Size of voids ranges from millimetric to pluricentimetric and shape varies from circular/pseudo circular to lenticular. In the Gaspé peninsula, lower silurian carbonates displaying hydrothermal dolomites are known at the outcrop scale, at various locations notably at Ruisseau Isabelle section in northern Gaspé (Lavoie and Chi, 2001). At Saint-Cleophas the Sayabec Fm is exposed in a quarry on the southern flank of the Lac Matapedia Syncline (Fig. 2C). The 20 m thick brecciated dolostone section consists of replacive and pore-filling saddle dolomite of hydrothermal origin (Lavoie and Chi, 2001; Lavoie and Morin, 2004). The presence of nearby mafic to ultramafic rock units is often mentioned as a possible significant source of Mg to explain extensive dolomitization (Lavoie and Morin, 2004; Lavoie and Chi, 2001).

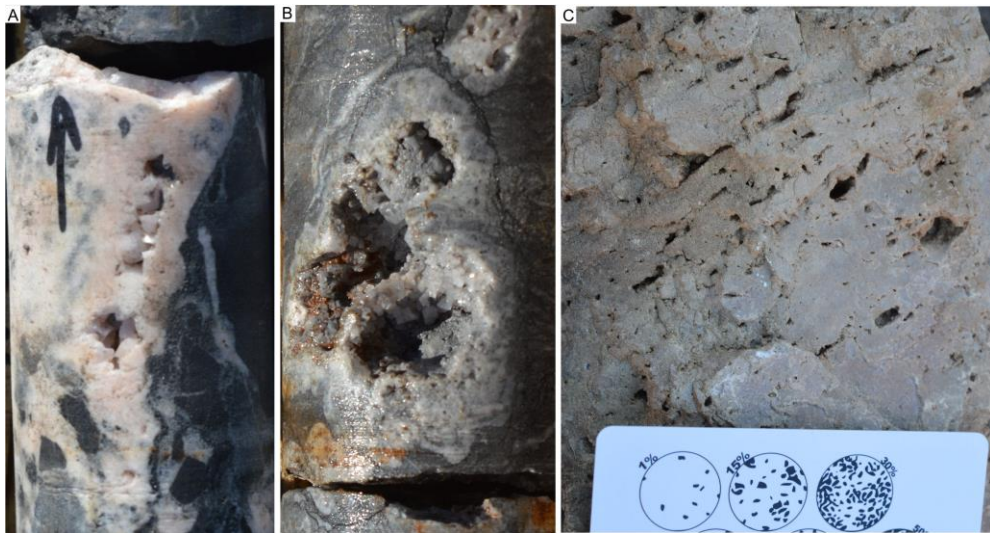


Figure 2 : (A) Fractured and vug-bearing intervals within Massé No.1 well. Width of the picture is approx. 30 mm. (B-C) Highly porous dolostone from the Sayabec Fm at the Saint-Cleophas quarry.

Reservoir analogs

Carbonate reservoirs associated with structurally-controlled hydrothermal dolomites correspond to an economically important play type in North America and notably in the Ordovician strata of the Michigan basin or Devonian sequences in western Canada (Lavoie et al., 2005; Davies et Smith, 2006). Detailed petrographic analyses revealed that the Sayabec Fm facies can be considered as analogous of hydrothermal dolomite reservoir facies of the Albion-Scipio (Fig. 3A-B) and Stony Point fields in the Trenton–Black River Fms (Ordovician, Michigan basin, USA) or the Ladyfern gas field (Fig. C-D) (Devonian, Slave Point Reservoir, British Columbia; Boreen and Colquhoun, 2001; Smith, 2006).

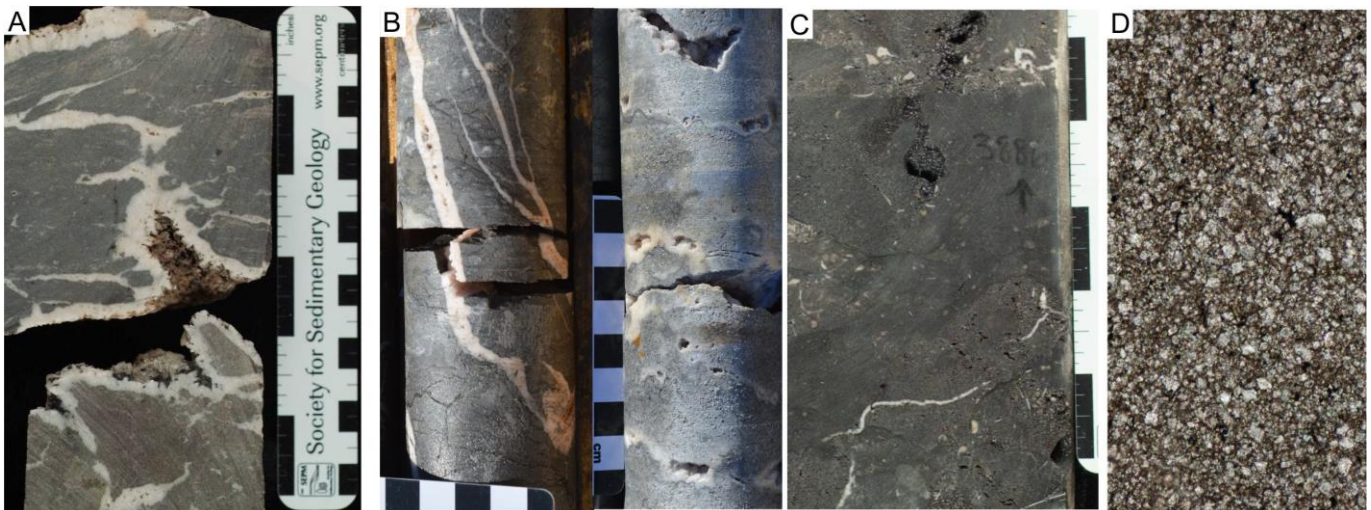


Figure 3 : (A) Albion-Scipio HTD reservoir facies (from Thornton and Grammer, 2011). (B) Fractured and vugs with non colmated porosity within the Sayabec Fm carbonate facies. (C) Albion-Scipio burrowed reservoir facies with variable permeability at the cm-scale (from Thornton and Grammer, 2011). (D) Similar fine-grained burrowed facies with matrix locally replaced by microdolomite in the Sayabec Fm.

Conclusions and future works

The diagenetic evolution of the Sayabec carbonate facies is complex and further work is needed. To improve our understanding of the Sayabec Fm reservoir potential, future works will focus on:

- geochemistry analyses of fractures-filling mineral phases;
- wireline log re-interpretations with the new refined stratigraphic framework of the Sayabec Fm;
- acquisition and interpretation of new seismic lines within the Massé structure;
- and finally building a 3D geological model of the Sayabec Fm integrating all subsurface data available for the Massé structure.

Acknowledgements

Financial support of the project was provided by both Mitacs and Ressources and Energie Squatex Inc. through a Mitacs Acceleration postdoctoral fellowship (IT06251). We are grateful to K. Bedard and F.A. Comeau (INRS-ETE) for their technical support throughout the project.

References

Bourque, P.A., Brisebois, D., and Malo, M., 1995. Gaspé belt, In : Geology of the Appalachian-Caledonian Orogen in Canada and Greenland. H. Williams (ed). Geological Society of America, Geology of North America, v.F-1, p. 316-351.

Boreen, T., and Colquhoun, K. (2001). Ladyfern, NEBC: major gas discovery in the Devonian Slave Point Formation.

Davies, G. R., and Smith Jr, L. B. (2006). Structurally controlled hydrothermal dolomite reservoir facies: An overview. AAPG bulletin, 90(11), 1641-1690.

Lavoie, D., and Chi, G. (2001). The Lower Silurian Sayabec Formation in northern Gaspé: carbonate diagenesis and reservoir potential. Bulletin of Canadian Petroleum Geology, 49(2), 282-298.

Lavoie, D., and Morin, C. (2004). Hydrothermal dolomitization in the Lower Silurian Sayabec Formation in northern Gaspé-Matapédia (Québec): Constraint on timing of porosity and regional significance for hydrocarbon reservoirs. Bulletin of Canadian Petroleum Geology, 52(3), 256-269.

Malo, M., and Bourque, P. A. (1993). Timing of the deformation events from Late Ordovician to Mid-Devonian in the Gaspé Peninsula. Geological Society of America Special Papers, 275, 101-122.

Thornton, J. E., and Grammer, G. M. (2011). Prediction of Petrophysical Properties of Trenton-Black River (Ordovician) Reservoirs by Comparing Pore Architecture and Permeability to Sonic Velocity. ESAAPG abstract, AAPG Search and Discovery, 90142.