# Upper Ordovician shale gas and oil in Quebec: Sedimentological, geochemical and thermal frameworks

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## Summary

In eastern USA, significant industry interest has recently focused on Upper Ordovician black shales in Ohio that is the liquid-rich Utica Shale. As in Ohio and New York, the Upper Ordovician black shales in Quebec (Utica and Macasty) form a thick marine clastic succession that overlies the predominantly shallow marine carbonate facies of the Cambrian-Ordovician St. Lawrence Platform. Over the years, the hydrocarbon exploration targets in southern Quebec consisted primarily of the dolomitized facies of the carbonate platform (e.g., Beekmantown, Trenton-Black River), a small field (St. Flavien) was exploited and some sub-economic discoveries made.

When drilling for the deep targets, gas kicks and/or oil shows, sometimes very significant, were almost invariably reported when intercepting the Utica and Macasty shales. Geochemical analyses of the typical dark shales of both units led to the recognition of their significant hydrocarbon source rock potential as well as preliminary mapping of thermal maturation.

For the Utica Shale, extensive testing of its potential to release natural gas through high pressure hydraulic fracturing started a few years ago. It has been shown that the calcareous shales of the Utica have the capacity to release significant volume of natural gas, whereas a liquid-rich window has been identified near Quebec City; a situation in line with our current understanding of regional thermal maturation in southern Quebec. On Anticosti Island, preliminary data from the industry indicate that the Macasty shales are, at least locally, oil-rich. However, the potential of these shales to release economic volume of oil is still unknown.

## Introduction

The Utica (50 to 300 m thick) and Macasty (20 to 175 m thick) shales are known from surface outcrops and cores between Montréal and Quebec City and from cores on Anticosti Island (Lavoie et al., 2009), respectively (Fig. 1). In the subsurface, drilling and seismic data allows extending the known presence of the Utica Shale to significant distances to the southeast where it is eventually overlain by the Appalachians east of Logan's Line. Over the years, these two units have sporadically been studied, primarily for their biostratigraphy and for their hydrocarbon source rock potential (Bertrand and Lavoie, 2006; Dietrich et al., 2011). There is no regional stratigraphic or sedimentologic framework for these units and depositional facies as well as variations in the sedimentary basin are largely unknown.

## Geological setting

The Utica Shale overlies the Ordovician carbonate platform in southern Quebec (Fig. 2); the calcareous shales started to accumulate when, because of rapid increase of relative sea level, the backstepping carbonate producing zone was partially shutdown, leaving siliciclastic with

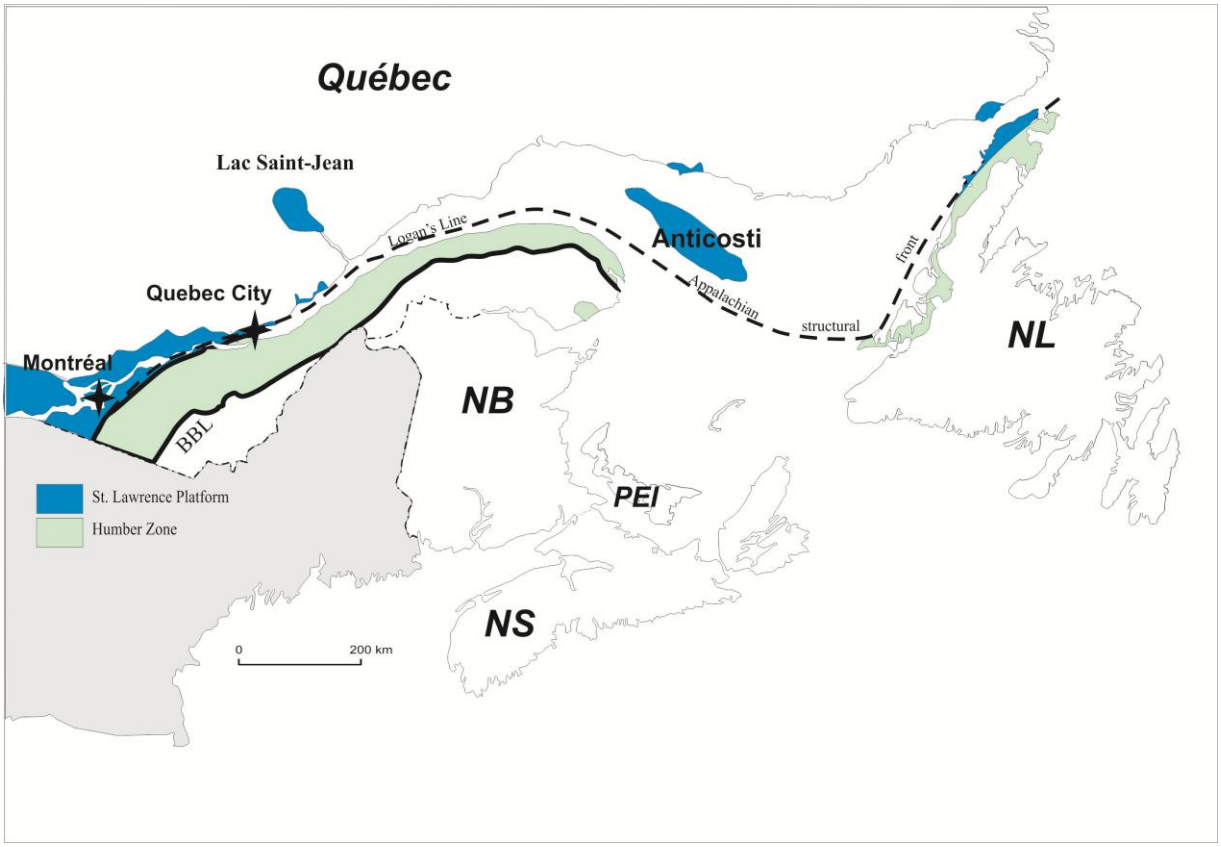


Figure 1. Distribution of the St. Lawrence Platform, from Southern Quebec (Utica Shale) to Anticosti Island (Macasty Shale) and Western Newfoundland.

subordinate carbonate muds to accumulate in an interpreted marine, poorly oxygenated setting. Irregular basin configuration resulted in variation in thickness and lateral character of the sedimentary accumulations, whereas variations in the vertical succession resulted from higher frequency sea-level fluctuations in a larger scale eustatic sea level fall in Late Ordovician. The Utica Shale is rapidly overlain by Taconian-derived flysch (Lorraine Group), the base of which is assumed to have some potential for unconventional hydrocarbons.

The Macasty Shale on Anticosti Island also overlies the Ordovician passive margin to foreland carbonates (Fig. 2). However, the deposition of the Macasty is slightly older compared to the Utica. In Late Ordovician time, the Anticosti Basin was more outboard, at the St. Lawrence Promontory compared to southern Quebec where sediments accumulated in the Quebec Reentrant (Lavoie et al. 2009). The Anticosti Basin recorded first the tectonic foundering of the carbonate margin and the transition to foreland clastics. Moreover, to the contrary of the Utica Shale, the Macasty is overlain by a thinner mixed carbonate-clastic flysch (Vauréal Formation), which rapidly gives way to uppermost Ordovician to Lower Silurian shallow marine carbonates (Lavoie et al. 2009).

Both the Utica and the Macasty shales have been deformed during the Late Ordovician Taconian Orogeny. Over the St. Lawrence Platform, the degree of deformation of the Utica has long been considered minor and recorded by extensional faulting and by the regional Chambly-Fortierville syncline. However, recent work suggests that some significant compressive events are recorded well within the St. Lawrence Platform (Castonguay et al., 2010). In both the transitional parautochthonous and allochthonous Appalachians domains, the deformation significantly increases and the Utica is involved in thrust-bounded tectonic stacks. The Anticosti Basin was little affected by the Taconian Orogeny; on the island only extensional to transtensional faults are recorded (Lavoie et al., 2009).

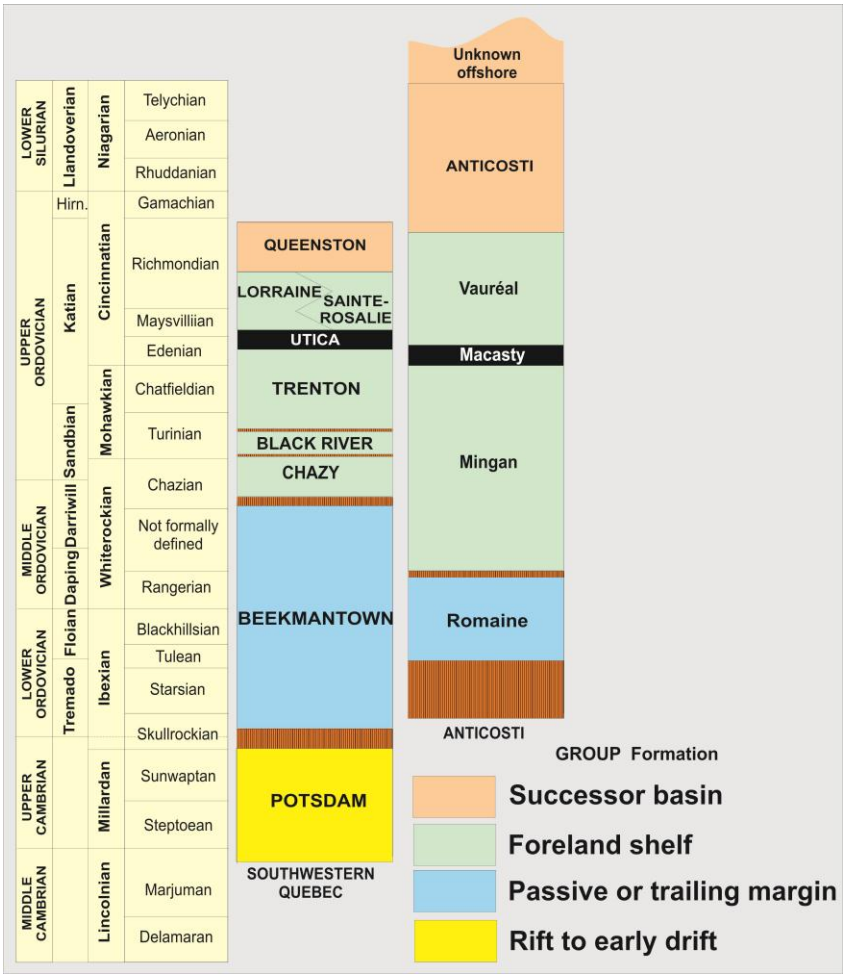


Figure 2: Stratigraphic framework for the St. Lawrence Platform of southern Quebec and Anticosti Island. Modified from Lavoie et al. (2009).

Previous work on the source rock potential of the Utica Shale in southern Quebec has led to a regional understanding of the distribution of thermal domains at the surface of the St. Lawrence platform (Bertrand and Lavoie, 2006; Lavoie et al., 2009). A regional SW-oriented increase in thermal conditions from the condensate zone near Quebec City to the dry gas zone in the Montréal area is known (Fig. 3), whereas a significant increase of maturation is observed at the Platform-Appalachians boundary. In the subsurface, the Bertrand and Lavoie (2006) data has been complemented by Thériault (in press) and allows to identify general NW-SE oriented increase in thermal conditions of the Utica whereas domains with contrasting TOC and/or HI are now mapped in the Utica (Fig. 4). Because of limited sub-surface information for the Macasty Shale on Anticosti Island, the thermal and geochemical characters of the Macasty are less understood. Current available data indicate that the northeastern half of the island is in the oil-condensate window, the remaining southwestern part being in the dry gas zone (Fig. 5) (Lavoie et al., 2009). The average and maximum TOC and HI values in the Macasty are usually higher compared to those of the Utica (Lavoie et al., 2009), the data for the Macasty indicate an oil-prone Type I and II organic matter (Fig. 6).

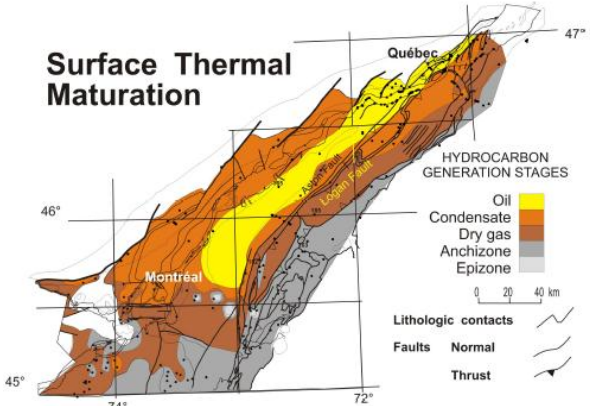


Figure 3. Surface maturation map of the St. Lawrence Platform. Modified from Bertrand and Lavoie (2006)

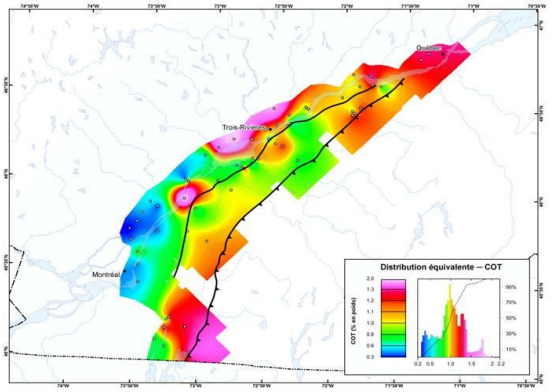


Figure 4: Map of TOC values in the upper section of the Utica Modified from Thériault (in press).

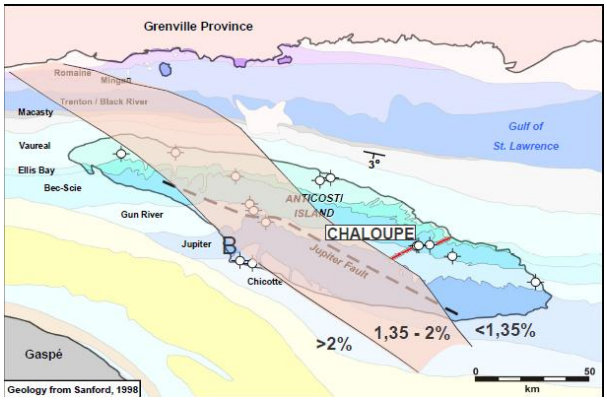


Figure 5. Sub-surface maturation of the Macasty Shale

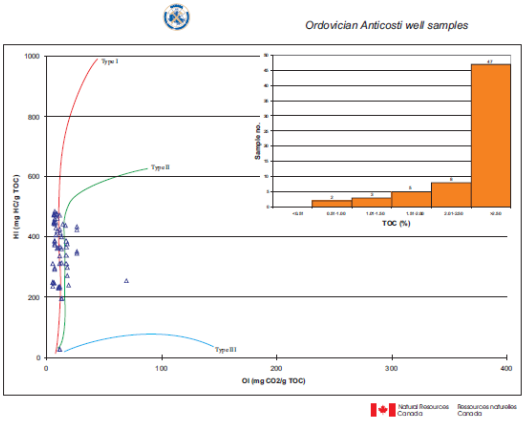


Figure 6. HI vs OI for the Macasty Shale

## Conclusions

The Utica Shale in southern Quebec has potential for yielding significant volume of natural gas after multistage fracturing. Preliminary geological and geochemical data suggest that the Macasty Shale on Anticosti Island, even if thinner compared to the Utica, might have a significant oil-rich domain.

### References

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