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The Upper Ordovician Utica and Lorraine Shales in Southern Quebec: Sedimentological and Geochemical Frameworks

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Summary

The Upper Ordovician Utica and Lorraine shales in southern Quebec form a thick, deep-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, sometimes very significant, were almost invariably reported when intercepting the lower part of the Lorraine Group and the underlying Utica 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.

Extensive testing of their potential to release natural gas through high pressure hydraulic fracturing started a few years ago. It has been recently documented that the calcareous shales of the Utica have the capacity to release significant volume of natural gas, whereas the gas-rich but more argillaceous shales of the Lorraine have yet to be significantly tested.

Introduction

The Utica Shale (50 to 300 m thick) and Lorraine Group (500 to 2000 m thick) are known from surface outcrops between Montréal and Quebec City (Globensky, 1987) (Fig. 1). In the subsurface, drilling and seismic data allows extending their known presence to significant distances to the southeast where they are 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 the Utica, for its hydrocarbon source rock potential. There is no regional stratigraphic or sedimentologic framework for these units and depositional facies as well as variations in the depositional basin are largely unknown.

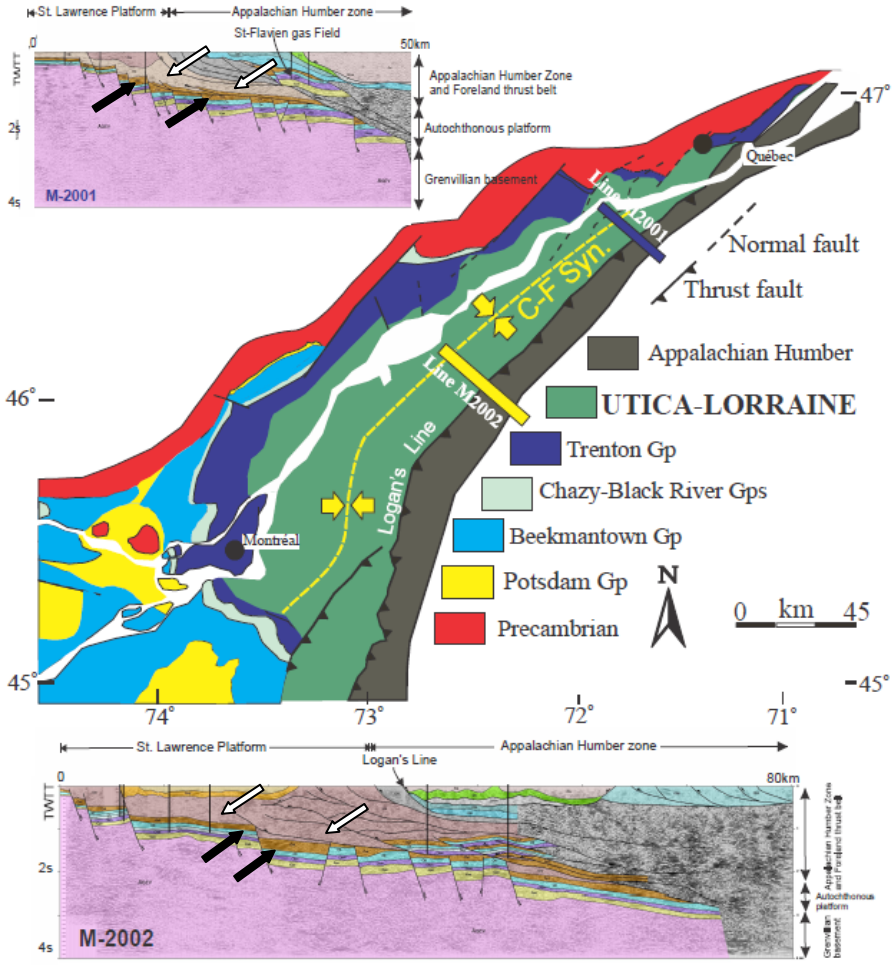

Figure 1. Simplified geological map of the St. Lawrence Platform in southern Quebec showing the surface distribution of the Utica Shale and Lorraine Group. Seismic profiles are from Castonguay et al. (2010), black arrows point to the Utica Shale and white arrows to the Lorraine..

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 rise, the backstepping carbonate producing zone was partially shutdown leaving siliciclastic muds with subordinate carbonate mud to accumulate in an interpreted deep marine, poorly oxygenated setting. Largely unknown basin configuration resulted in variation in thickness and lateral character of the sedimentary accumulations whereas the variations in the vertical succession resulted from yet to demonstrate, higher frequency sea-level fluctuations in a larger scale eustatic sea level fall in Late Ordovician.

The Lorraine Group overlies the Utica Shale (Fig. 2), the nomenclature of that stratigraphic package varies in southern Quebec depending of the geological domain where those sediments are present (St. Lawrence Platform or Appalachians domains; e.g. Sainte-Rosalie Group, Fig. 2). The Lorraine is an Upper Ordovician flysch succession dominated by mudstones and siltstones with local thicker bedded sandstones. Available limited paleocurrent data suggest that these sediments were derived from the southeast, from the rapidly encroaching Appalachians allochthons. The distribution of thicker sandstone beds likely relates to some feeder system although no sedimentological analysis is available at the regional scale to reconstruct the deep Taconian foreland basin geometry.

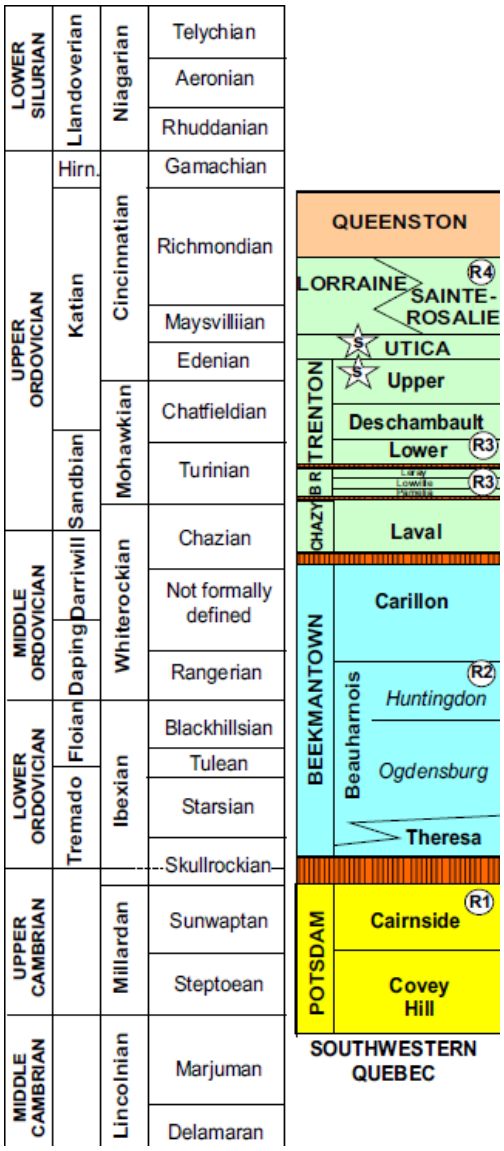

Figure 2: Stratigraphic framework for the St. Lawrence Platform of southern Quebec. Modified from Lavoie et al. (2009).

Both the Utica and the Lorraine have been deformed during the Late Ordovician Taconian Orogeny. Over the St. Lawrence Platform, the degree of deformation has long been considered minor and recorded by extensional faulting and by the regional Chambly-Fortierville syncline (Fig. 1). However, recent work suggests that some significant compressive events are recorded well within the St. Lawrence Platform (Fig. 1, seismic line 2002) (Castonguay et al., 2010). In both the transitional parautochthonous and allochthonous Appalachians domains, the deformation significantly increases and both units are commonly involved in multiple thrust-bounded tectonic stacks (Fig. 1, seismic lines 2001 and 2002).

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 (2008, 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 and lower Lorraine (Fig. 4).

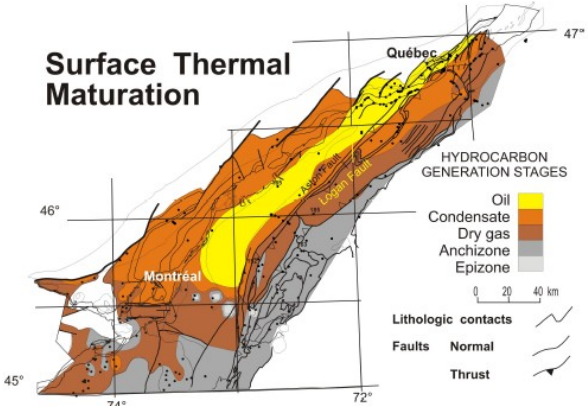

Figure 3. Surface maturation map of the St. Lawrence Platform. Modified from Bertrand and Lavoie (2006)

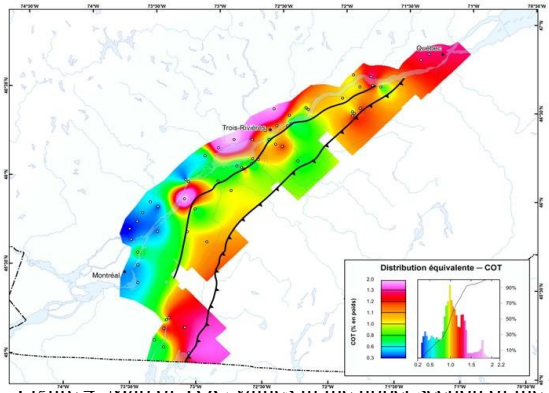

Figure 4. Map of TOC values in the upper section of the Utica Modified from Thériault (in press).

Conclusions

The Utica Shale in southern Quebec has demonstrated potential for yielding significant volume of natural gas after multistage fracturing. Pre-commercial production pilot projects are in the planning stage. Preliminary geological data suggest that the overlying shales of the Lorraine Group contains significant volume of in-place gas, although the state-of-knowledge is definitively less advanced compared to that of the Utica Shale and is not the actual target for development.

Acknowledgements

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