The Offshore Part of the Anticosti Basin: A Major Gap in the Understanding of Early to Middle Paleozoic Basins of Eastern Canada in a Promising Hydrocarbon Setting

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The current knowledge of the offshore part of the Anticosti basin is fragmentary and the age and lithology of its sedimentary infill as well as its geometrical relationship with coeval deeper marine sediments preserved in the Appalachian tectonic wedge are hypothetical. However, geological and geophysical evidences found both on land and offshore support the hydrocarbon potential of this Paleozoic platform and are key elements for increase efforts in this area.

The Anticosti basin covers the onshore and offshore area between Anticosti/Mingan islands and Newfoundland/Labrador to the east, the Gaspé Peninsula to the southwest and an imprecise location in the Gulf of St. Lawrence to the south. In the Anticosti/Mingan islands, the base of the sedimentary succession corresponds to a passive margin, peritidal-dominated, limestone and dolostone assemblage (Lower Ordovician Romaine Formation). This assemblage is unconformably overlain by a Taconian shallow marine foreland-basin succession in which unconformity-overlying basal siliciclastics were succeeded by predominantly open marine carbonates (Middle Ordovician Mingan Formation). The overlying Upper Ordovician to Lower Silurian units include: 1) a relatively thin (< 175 m) dark marine mudstone and shale (Macasty Formation); 2) a siltstone-dominated interval overlain by outer ramp shallowing-upward foreland carbonate (Vauréal Formation); 3) subtidal carbonate with local bioherms (Ellis Bay Formation); 4) various carbonate facies with minor siliciclastics deposited on a storm-dominated carbonate ramp (Anticosti Group).

The offshore part of the Anticosti basin has been the focus of seismic surveys in the ’70 and early ‘80. However, due to seismic acquisition and processing problems, most of vintage industry seismic lines located between the Gaspé Peninsula and the Anticosti Island failed to depict the internal geometry of the upper part of the platform succession and its relationship with the Appalachian frontal units. The main result of seismic hydrocarbon-targeted exploration was the mapping of the lower part of the platform domain which is marked by a seismic marker imaged on most profiles. This marker defines a slightly south-dipping plan crosscuts by normal faults (Fig. 1). This plan is clearly imaged up to around 20 km of the northern shore of the Gaspé Peninsula.

Despite their low penetration (1/2 s twt), high resolution seismic data collected between Anticosti Island and the Gaspé Peninsula provide additional images of the top of the Paleozoic succession. Seismic lines show that a 2.5 to 3 km thick monoclinal succession overlies the upmost sedimentary units traced to Anticosti Island (Fig. 1). To the south this succession is involved in broad open folds (Fig. 1) that must postdate the main deformation event in northern Gaspé Peninsula (Middle Ordovician Taconian orogeny) as rocks younger than the Early Silurian are involved.

Additional information is provided by potential field data which have been recently used to constrain the geometry of the Anticosti basin and its relationship with the Appalachian tectonic wedge. Of particular significance is a wide (90 km N-S) positive (10 to 32 mGal) gravity anomaly that covers the eastern part of the Gaspé peninsula and surrounding offshore areas. Forward gravity modelling suggests that this anomaly is associated with high-density allochtonous volcanic rocks of the Taconian tectonic wedge extending offshore beneath the Gulf of St. Lawrence (Fig. 1). This interpretation implies that the Ordovician deformation front is not located on-land at the southern contact of syn-orogenic units (Cloridorme Formation) has classically considered (St-Julien and Hubert, 1975), but is 20 to 30 km further to the north, where it is covered either unconformably or tectonically by Silurian (or younger) autochthonous rocks belonging to the St. Lawrence platform (Fig. 1). This interpretation agrees with structural data that indicate more than 40% of tectonic shortening within the Cloridorme Formation and with its inferred maximum burial depth (Islam et al, 1982), which is significantly greater compared with the nearby autochonous platform domain. This interpretation is also consistent with the match between the gravity anomaly and a deep (~ 3.5 s twt) domal structure recognized on vintage seismic (Fig. 1).

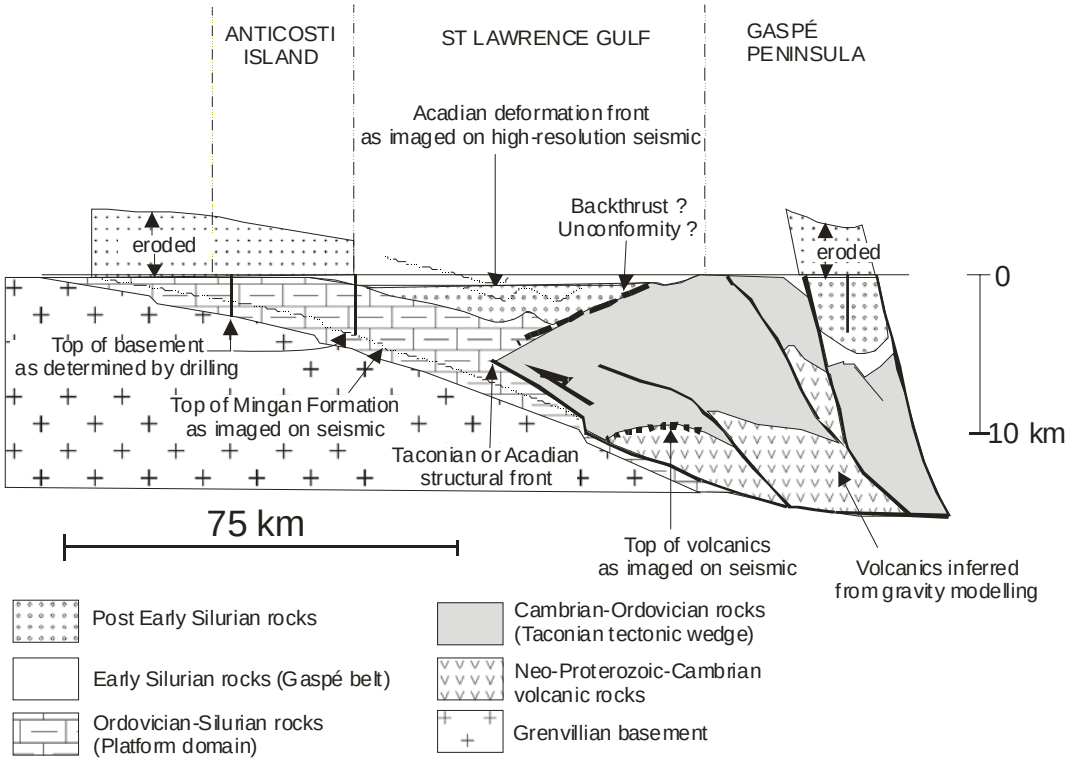

Figure 1. Schematic cross-section illustrating key geological and geophysical features

Stand alone, geophysical data do not allow a clear characterization of the Appalachian structural front but discard the classical interpretation in which the contact between the platform and the orogenic wedge is a Middle Ordovician thrust. Alternative hypothesis include a triangular zone geometry, an unconformable relationship between the upper part of the platform succession and the Appalachians and a thick-skinned (Middle Devonian ?) reactivation of Appalachians structures.

The Hydrocarbon System

A quantitative evaluation of the hydrocarbon potential of the offshore Anticosti basin is beyond the present-day level of geological knowledge. However, several indirect evidence or interpretations are supportive arguments for the hydrocarbon prospectivity of the offshore segment of this Paleozoic platform (Fig. 2).

On Anticosti Island, detailed organic matter petrography and Rock Eval analyses indicate that the Late Ordovician Macasty Formation had significant potential for oil and gas generation (Bertrand, 1987). This unit which contains Type II and a subordinate Type I organic matter yielded high total organic carbon (TOC) values that range from 1.5 to 4.9 wt% with HI up to 360. The presence of coeval potential source rocks in the Gaspé Peninsula reinforces the possibility of finding such high TOC value rocks in the offshore part of the Anticosti basin. Moreover, the potential contribution of older source rocks involved in the Taconian orogenic wedge (such as the Lower Ordovician Rivière-Ouelle Formation) should also be considered as Lower Ordovician shales are the source rocks of oil in western Newfoundland fields.

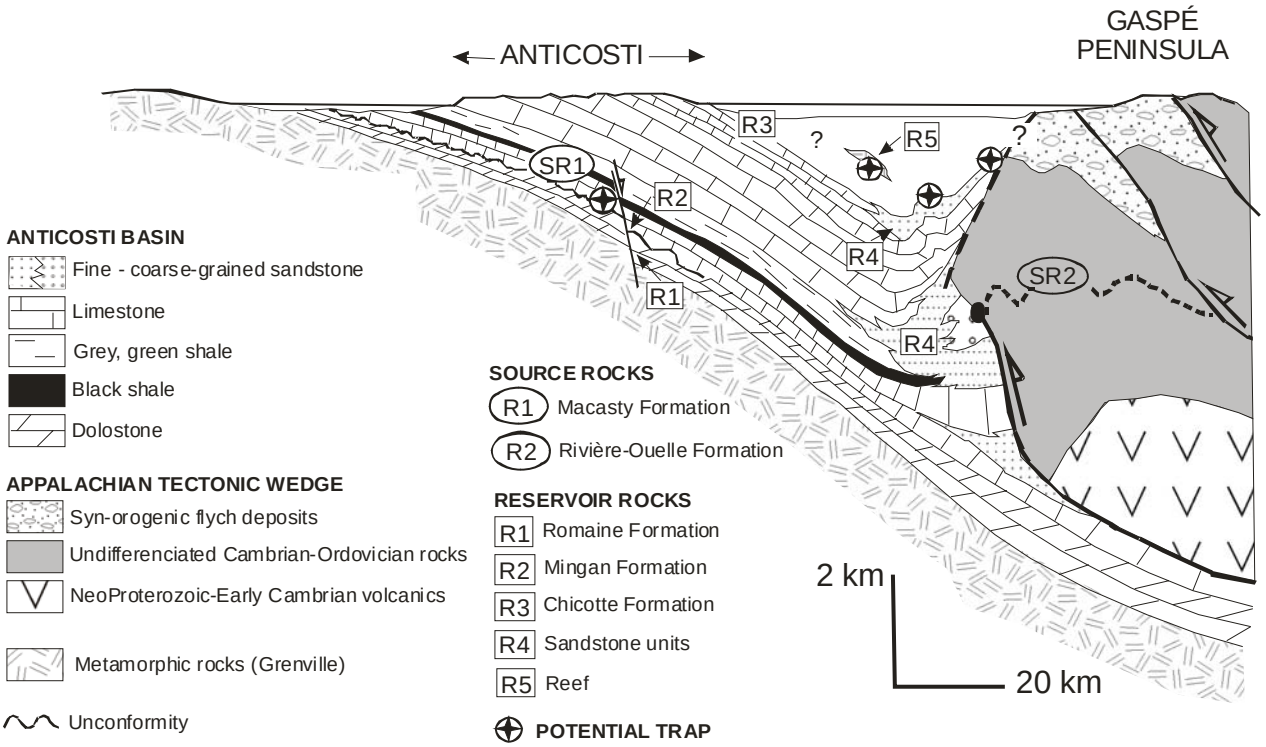

Figure 2. Schematic cross-section illustrating some key-elements of the hydrocarbon system

On Anticosti Island, maturation increases southwesterly and positively correlates with depth (Bertrand, 1987). The Macasty Formation source rock is within the oil window in the northeastern half of the island and in the condensate zone in the southwestern segment of the island. An obvious parameter that must control the maturation state of the offshore succession is the thickness of the post- Early Silurian (Llandoverian) rocks. The thickness of the offshore monoclinal succession that overlies the sedimentary units recognized on Anticosti Island (2.5 to 3 km) is in close agreement with the assumed thickness of eroded strata on the island itself, based on thermal maturation data and basin modelling (Bertrand, 1987). This may be a supportive argument for the late tilting of a sedimentary pile characterized by a relatively uniform thickness. Moreover, the presence in the St. Lawrence estuary of gas seeps characterized by vertical seismic chimneys that root into the top of the offshore Paleozoic succession and that are located far from biogenic-rich sedimentary influx, suggests a thermogenic origin for the gas. If true, this indicates that a mature and quality source rock exists within the offshore geological system.

As suggested by petrographic and geochemical studies, porous Ordovician units formed through early burial extensional (or transtensional) fault-controlled hydrothermal dolomitization may be potential reservoirs (Lavoie et al., 2005). Another potential reservoir type corresponds to the very shallow subtidal to nearshore bioclastic limestone facies (with up to 30% of visible pore space) of the Lower Silurian Chicotte Formation (Desrochers, 2006), at the top of the preserved succession on Anticosti Island. The reservoir potential of sedimentary units younger than the Chicotte Formation and identified on marine seismic data is unknown. However, due to its foreland setting, the offshore part of the Anticosti basin may be characterized by sandstone units that intertongue with shale or carbonate units. Moreover, the possible occurrence of Upper Ordovician and Lower Silurian reefs that may have formed along the outer rapidly subsiding margins of the Anticosti basin in transition zones to deeper water facies should not be neglected as these bioconstructions are known on Anticosti (Ordovician) and Gaspé (Silurian). In this scheme, potential traps may include structural (closures associated with open folds; triangular zone at the Appalachian front), mixte (normal fault bounded block that may focus hydrothermal fluids), and stratigraphic (sandstone and reef units) types.

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