Hydrocarbon Reservoir Potential in Carboniferous Sandstones in the Maritimes Basin, Eastern Canada

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Summary

There are several producing or discovered oil and gas fields in Carboniferous sandstones in the Maritimes Basin in eastern Canada, and the potential for additional discoveries is high. Carboniferous strata in the basin are generally characterized by low porosity and permeability, with reservoir quality a significant exploration risk. In this study we present detailed core and log-analysis based evaluations of sandstone reservoir quality in six wells in the western Maritimes Basin. The wells include Bradelle L-49, Brion Island No.1, Irishtown No.1, Cable Head E-95 and East Point E-49 in the Magdalen Basin and North Sydney F-24 in the Sydney Basin. Reservoir properties evaluated include lithology, porosity, permeability, and water saturation. Integrated geological data and interpretations include clay mineralogy, drill-stem test data, and identification of potential hydrocarbon-bearing zones. Porosity-depth trends are derived and discussed in terms of stratigraphic and geographic variations. The analyses indicate there is good hydrocarbon reservoir potential in sandstones in the Upper Carboniferous Pictou and Mabou groups and the Lower Carboniferous Horton Group. Upper Carboniferous sandstones in the northern Magdalen Basin appear to have the best overall reservoir quality in the region.

Introduction

The Carboniferous Magdalen and Sydney basins underlie the southern Gulf of St. Lawrence, Cabot Strait, and adjacent onshore areas, encompassing an area of about 250,000 km^2. The Magdalen, Sydney and St. Anthony basins are part of the composite Maritimes Basin, a broad successor basin that developed over a collage of Lower Paleozoic rocks of the Appalachian Taconian- and Acadian-deformed tectonic domains (Fig. 1). One of the long recognised exploration risks in the Magdalen and Sydney basins is related to reservoir quality. Exploration wells drilled to date have encountered many log-indicated hydrocarbon zones in low porosity and low permeability sandstone reservoirs. Most conventional drill-stem tests in these reservoirs have resulted in no hydrocarbon recovery or very low (sub-economic) hydrocarbon flow rates. The only commercial oil or gas production from Carboniferous reservoirs in the region occurs in the onshore New Brunswick portion of the Magdalen Basin (Stoney Creek and McCully fields; Fig. 1). The one significant gas discovery in the offshore region (East Point E-49; Fig. 1) has not been developed.

Previous reports on Carboniferous reservoir quality include the multi-well study of Bibby and Shimeld (2000) and a single-well core study of Chi and others (2003). The present study advances the observations in the previous reports by deriving a more comprehensive suite of reservoir parameters, identifying potential hydrocarbon-bearing zones, and evaluating both stratigraphic and geographic variations in reservoir quality.

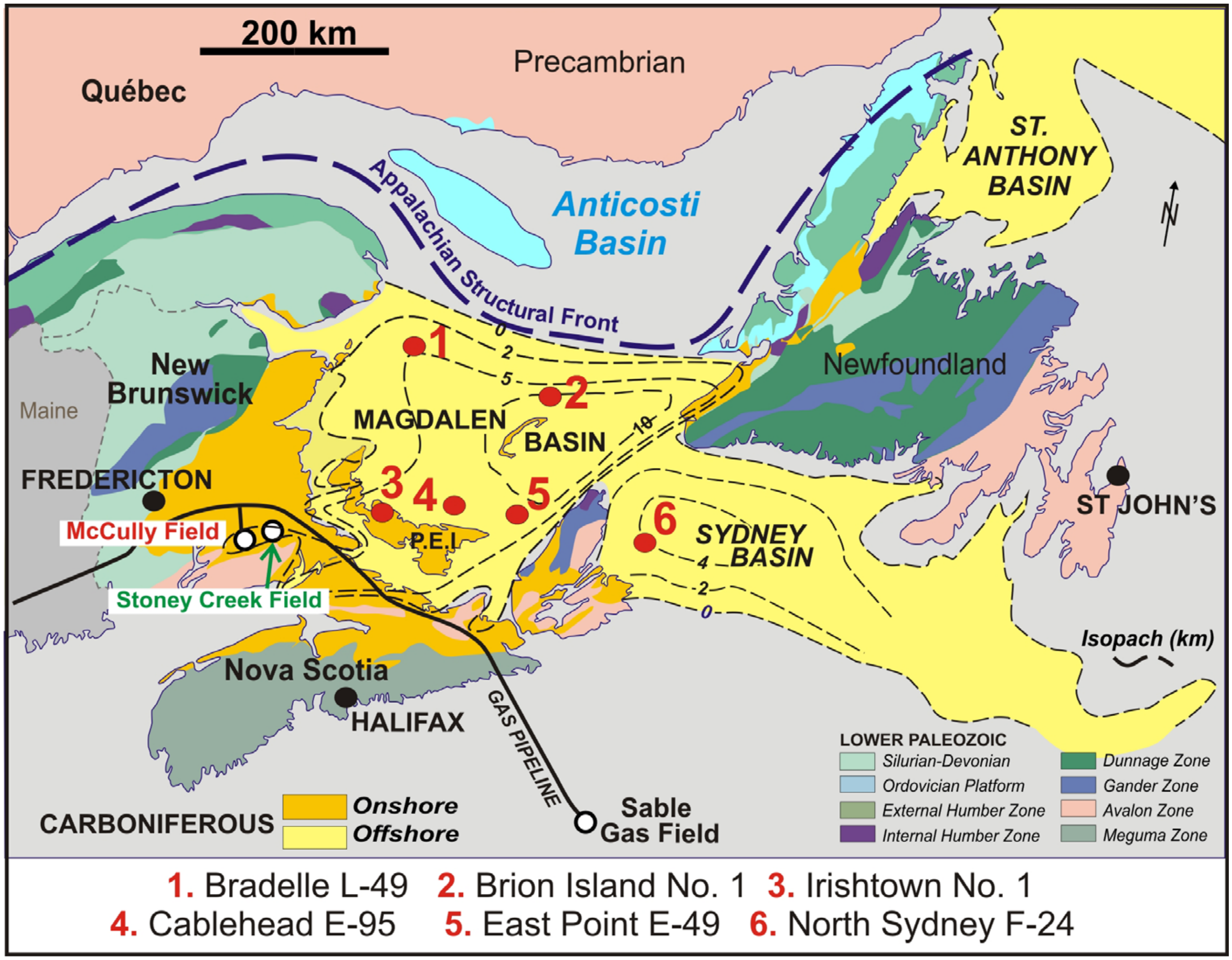

Figure 1: Tectonic assemblage map of eastern Canada with Carboniferous basin outlines and locations of the six wells analysed in this study.

Petrophysical Data

Compiled core petrophysical data include porosity, permeability, grain density and residual water and oil saturation from 255 sandstone core samples from Bradelle L-49, Cable Head E-95, East Point E-49 and North Sydney F-24 wells. Based on the core data, the best reservoir quality sandstones occur in the Bradelle well (highest average porosity and permeability), while the poorest reservoir characteristics occur in the East Point well. Sandstones in the Upper Carboniferous Green Gables Formation have the highest porosity and permeability values (18% and 100md), while the upper Carboniferous Bradelle Formation is characterised by lower porosity and permeability. Sandstones in the middle Carboniferous Mabou Group have very low permeability (less than 0.16 mD) but relatively high porosity, in part comparable to the Green Gables Formation. Lower Carboniferous Horton Group strata have the lowest porosity and permeability.

Petrophysical Analyses

To complement core analysis data, petrophysical analyses of conventional wireline logs in six wells were undertaken using the log-analysis program PRIZM. The well-log analyses included determinations of lithology, porosity, permeability, and water saturation, as well as identification of possible hydrocarbon zones. Log-derived porosity-depth trends were calculated and compared for the six wells (Fig.2).

The highest log-calculated porosity values are 22% in the North Sydney well, and 25 to 30% in the five Magdalen basin wells. All well plots show the trend of rapidly decreasing porosity with depth (Fig. 2) Average porosity values are 15% to 20% at shallow depths (above 1000 m), decreasing to 10% or less below depths of about 2000 m. However, in several wells, there are intervals with above average porosity values (10 to 20%) at depths of up to 3500 m. The porosity-depth profiles for the six wells indicate 1) The Brion Island well has the highest (average) sandstone porosity in the upper Carboniferous Pictou Group, followed by the Bradelle and East Point wells (intermediate porosity values), and the Cable Head and Irishtown wells (relatively low porosity values); 2) In general, the northern Magdalen Basin wells (Brion Island and Bradelle) have better reservoir potential in the upper Carboniferous Pictou Group strata (more sandstone intervals with porosity above 10%) compared to the same stratigraphic interval in the southern Magdalen Basin wells; 3) The poorest reservoir characteristics in Pictou Group strata occur in the North Sydney well (Sydney Basin); 4) In the lower Carboniferous Horton Group, there is little difference in observed porosity patterns between the northern and southern Magdalen Basin wells (Bradelle and Irishtown, respectively). The Horton Group in both wells contains several sandstone intervals with above average porosity (10 to 20%). There is insufficient data to evaluate regional porosity trends or variations for the middle and lower Carboniferous Cumberland, Mabou, or Windsor groups; 5) The best quality sandstone reservoirs (porosity >10%) in this part of the succession are observed in the Brion Island well (Windsor Group) and the North Sydney well (Mabou Group).

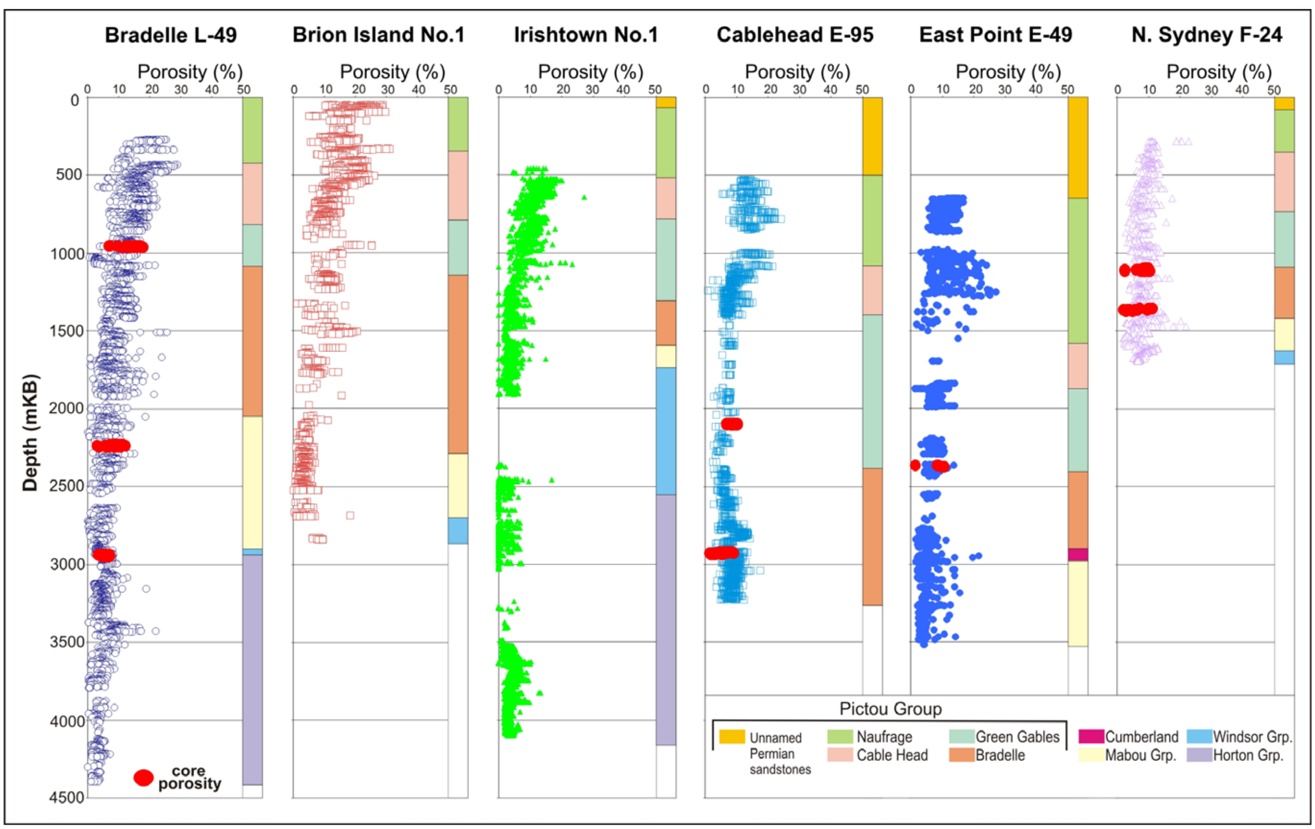

Figure 2: Porosity-depth plots, core data, and stratigraphic units for 6 wells in the Maritimes Basin.

Hydrocarbon Reservoir Potential

The log analyses indicate the possible presence of hydrocarbon zones in all wells, based on variable porosity and water saturation cut-off values. Many potential hydrocarbon zones occur in Upper Carboniferous sandstones with fair to good porosity and permeability. An example of an untested prospective hydrocarbon reservoir in the offshore Magdalen Basin is illustrated in Figure 3.

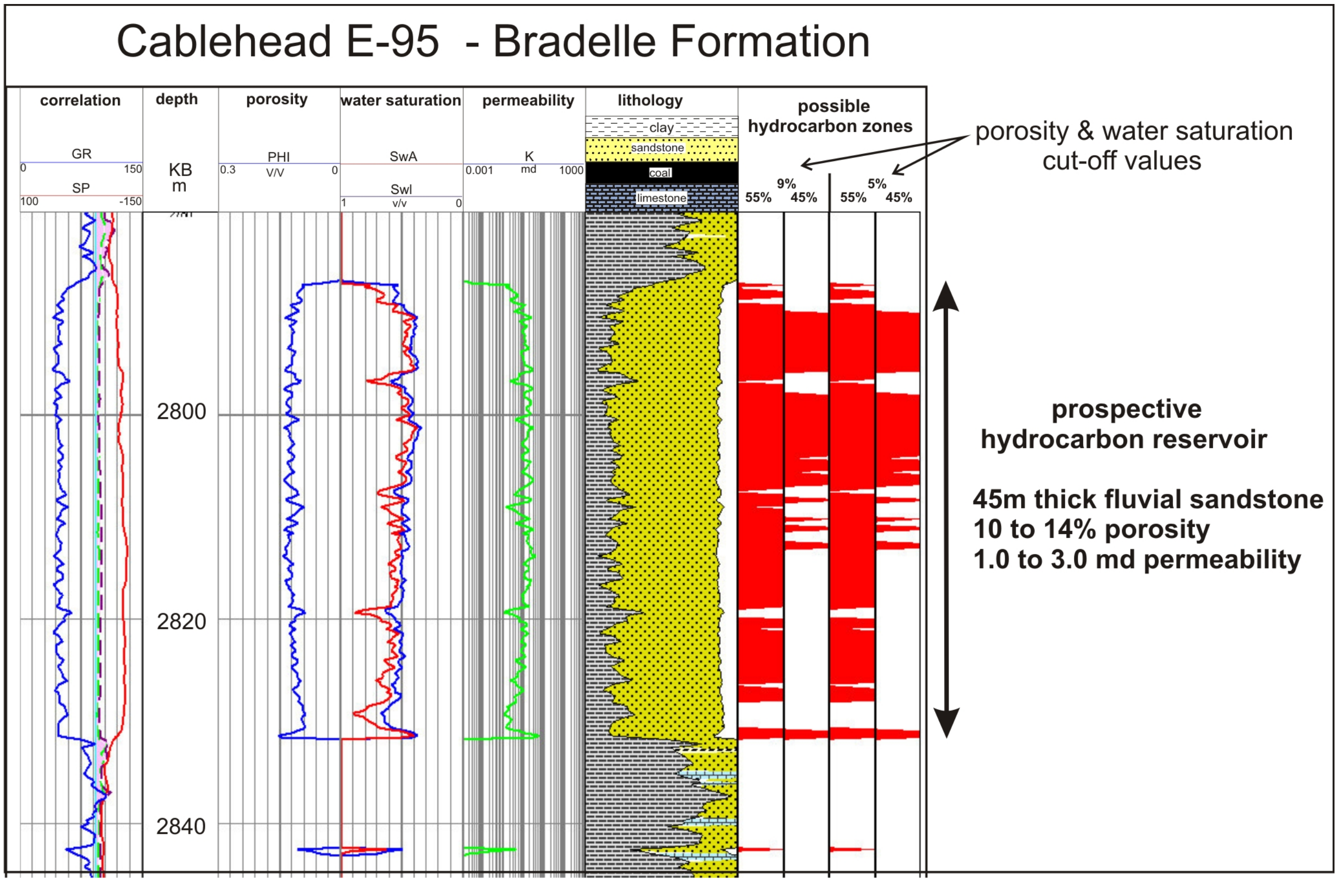

Figure 3: Log analysis plot of segment of Cablehead E-95 well, indicating a possible hydrocarbon-charged sandstone in the Upper Carboniferous Bradelle Formation.

Conclusions

The Carboniferous Maritimes Basin contains large volumes of sandstone reservoirs, displaying a wide range of porosity and permeability characteristics. Based on known hydrocarbon source rocks, observed reservoir parameters, and log-indicated hydrocarbon shows, there appears to be considerable potential for the discovery of high productivity natural gas zones in Carboniferous sandstones in the basin. In terms of overall reservoir quality, the northern Magdalen Basin (central Gulf of St. Lawrence) may be the most prospective area in the study region.

References

Bibby, C. and J. Shimeld, 2000. Compilation of reservoir data for sandstones of the Devonian-Permian Maritimes Basin, Eastern Canada, GSC open file 3895.

Chi, G., Giles, P.S., Williamson, M.A., Lavoie, D., and Bertrand, R., .2003. Diagenetic history and porosity evolution of Upper Carboniferous sandstones from the Spring Valley #1 well, Maritimes Basin, Canada - implications for reservoir development. Journal of Geochemical Exploration, Volume 80, Number 2, pp. 171-191.