Tight Oil Play of the Upper Devonian Torquay Formation in Southeastern Saskatchewan, Canada

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Summary

This paper summarizes the stratigraphy, and oil reservoir and production characteristics of the Upper Devonian Torquay Formation in southeastern Saskatchewan, gleaned from examination of geophysical well logs from over 2000 wells, cores from 7 wells and 11 thin sections from 3 wells. The study area encompasses Townships 1 to 15, Ranges 30W1 to 30W2 (Figure 1).

Stratigraphically, the Torquay Formation overlies the Birdbear Formation and is underlain unconformably by the Big Valley and Bakken formations. The Torquay is subdivided into six units (Christopher, 1961), Unit 1 to Unit 6 in ascending order, which can be correlated across much of the Williston Basin (LeFever and Nordeng, 2012; Nicolas, 2012). Unit 1 consists of an oxidized, rusty brown to tan argillaceous dolostone, with grey-green dolomitic shale to silty shale interbeds and anhydrite nodules. Unit 2 has a lithology similar to Unit 1, but is less argillaceous, contains more soft sediment clasts and anhydrite nodules, and is distinguished by a lower gamma ray signature. Unit 3 is a massive, oxidized, chocolate brown dolomitic mudstone, with a distinct high gamma ray signature. Unit 4 is characterized by interbeds of beige dolomitic siltstone, very fine sandstone, silty dolostone and grey-green dolo-mudstone. Unit 5 consists of grey-green dolomitic mudstone and tan dolostone. Unit 6 is dominated by grey or beige to tan silty fine crystalline dolostone, with dolo-mudstone occurring as laminae and matrix material.

The subdivisions defined by examination of geophysical well logs and cores provided the stratigraphic framework for mapping all units in this study. All six units can be traced throughout much of the study area, except on the eastern side, where units 5 and 6 are absent.

In Saskatchewan, the average oil production from the Torquay Formation, which is a tight oil play, has increased sharply, from 110 m^3/day (700 bbls/d) in 2006 to near 1900 m^3/day (12 x 10^3 bbls/d) in 2017. This increase is ascribed to the application of horizontal drilling techniques, coupled with multi-stage hydraulic fracturing. Productive wells show a predominant horizontal leg length of 1200 to 1600 metres, with the longest length reaching nearly 4000 metres. The current oil wells are concentrated in two sweet spots (Figure 1): west and southeast of Estevan, along the US border; and in the Ryerson area, near the Saskatchewan–Manitoba border.

In the area along the US border, a total of 435 oil wells in Torquay Formation have produced about 2.7 x 10^6 m^3 (17 mmbbl) of oil up to July, 2018, from depths of 2200 to 2400 m. Of these, 391 are fracked horizontal wells. Here, the reservoir rocks are dominantly Unit 6 silty dolostone, with porosities ranging from 4 to 8% and very low permeabilities, ranging from 0.01 to 1 mD. The Big Valley Formation is absent in this area, placing the Torquay tight reservoirs directly beneath and in contact with Lower Bakken shale

that, in this area, are mature, based on reported T_{max} and vitrinite reflectance (%Ro) values up to 435ºC and 0.68, respectively (Aderoju, 2016; Stasiuk, 1994). Oil generated from the Lower Bakken source rock has most likely migrated vertically down from the shales into the top (Unit 6) of the Torquay Formation although lateral oil migration from south are not completely excluded.

In the area near the Manitoba border, a total of 269 oil wells produce from the Torquay, of which 130 are fracked horizontal wells producing from depths of 1000 to 1200 metres. These wells have produced a total of 1.3 x 10^6 m^3 (8.4 mmbbl) of oil up to the end of July, 2018. Absent from this area are most of the Middle Bakken, all of the Lower Bakken shale, the Big Valley Formation, and units 5 and 6 of the Torquay Formation. Oil is produced from Unit 4, the dolomitic siltstone to very fine sandstone. The reservoirs have good porosities, mostly from 10 to 18%, and low permeabilities, from 0.1 to 10 mD. Because the Bakken shale is not mature in this area, lateral oil migration from the south was necessary to accumulate oil at the Torquay subcrop, where long-term exposure improved porosity. The subcrop was sealed by the Upper Bakken shale in up-dipping direction to form the effective trap.

The different geological and stratigraphic conditions identified in this study suggest different trapping mechanisms for the two main areas of production from the Torquay Formation in southeastern Saskatchewan.

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References

Aderoju, T.E. (2016) Organic geochemical assessment of the Upper and Lower Members of the Bakken Formation, southern Saskatchewan; University of Regina, Ph. D. thesis, 228p.

Christopher, J. (1961) Transitional Devonian-Mississippian Formations of Southern Saskatchewan; Saskatchewan Mineral Resources, Report No. 66, 103p.

LeFever, J. and Nordeng, S. (2012) Preliminary report on the Bakken Formation, north-central North Dakota (poster); North Dakota Geological Survey, Geological Investigation 156.

Nicolas, M.P.B. (2012) New insights into the Three Forks Group, southwestern Manitoba: stratigraphic changes and new sedimentological model; Canadian Society of Petroleum Geologists Geoconvention, May 14–18, 2012, Calgary, Alberta, oral presentation; http://www.geoconvention.com/uploads/2012abstracts/073_GC2012_New_Insights_into_the_Three_Forks_Group.pdf [date of access: June 19, 2012].

Stasiuk, L.D. (1994) Petrographic thermal maturity assessment of Winnipegosis (Middle Devonian) and Bakken (Devonian-Mississippian) formations, southeastern Saskatchewan; Bulletin of Canadian Petroleum Geology, v.42, no.2, p.178-186.

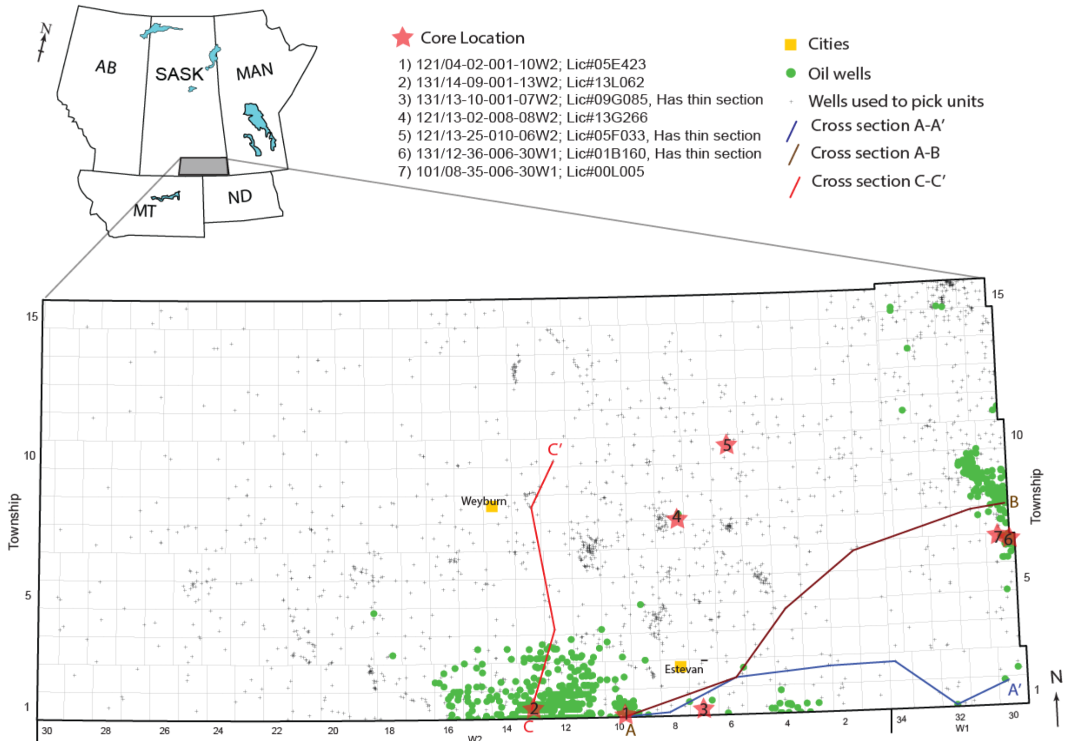

Figure 1 - *Outline of the study area in southeastern Saskatchewan, with the locations of the 7 wells whose core was examined, and the over 2200 subsurface wells with geophysical logs that were used to pick stratigraphic units in this study. Also shown are the locations of 3 cross-sections and Torquay Fm oil wells. Abbreviations on inset map: AB = Alberta, SASK = Saskatchewan, MAN = Manitoba, MT = Montana, ND = North Dakota.*