Synthesis of Hydrocarbon Systems and Conceptual Plays for the Intracratonic Hudson Bay Basin, Arctic Canada*

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Abstract

The Phanerozoic Hudson Bay Basin is the least studied sedimentary basin in Canada despite the fact that it is one of the largest sedimentary accumulations in North America. Of all these basins, the Hudson Bay Basin is the only intracratonic basin in North America completely encircled by the Precambrian craton (Figure 1) and the mechanism responsible for its formation is yet to be fully understood. As part of the 2008-2013 Geo-mapping for Energy and Minerals (GEM) program, the Geological Survey of Canada and its partners initiated a research project aimed at generating a better understanding of the geological evolution of the basin that will lead to a modern appraisal of its hydrocarbon potential. Reevaluation of historical geoscience information and new data are being synthesized. The integration of geoscience information will shed new light on the evolution of this basin and lead to the proposition of conceptual hydrocarbon plays in this oil-prone basin.

Introduction

The Hudson Bay Basin encompasses parts of northeastern Manitoba, northern Ontario and Nunavut, with two thirds of the area covered by waters of Hudson Bay with, to the north and south, the smaller Moose River and Foxe satellite basins, respectively (Figure 1). The surface of the Hudson Bay Basin rivals that of other intracratonic basins, although it has a thinner preserved sedimentary succession.

Geological Setting

The Hudson Bay Basin unconformably rests on the Canadian Shield. The succession of the Hudson Bay Basin consists of Ordovician to recently documented Mid-Tertiary strata (Figure 2; Hu et al., 2011; Galloway et al., 2011), with a maximum preserved thickness of about 2500 m in Hudson Bay. The Paleozoic succession includes Upper Ordovician to Upper Devonian shallow marine carbonates, reefs and thin mudstones with thick Lower Devonian evaporites in structural lows. Paleozoic strata are unconformably overlain by thin remnants of Mesozoic and Cenozoic clastics.

An updated stratigraphic framework for the central Hudson Bay has been achieved through the reappraisal of well logs and new biostratigraphic data (Figure 2). A detailed knowledge of the geometry of the Hudson Bay Basin is hampered by the low quality of vintage seismic data. The main structural feature is an array of north-northwest-trending fault blocks in the central part of the basin. Onlapping relationships indicate that these faults were mainly active during the Silurian to earliest Devonian, with no clear evidence for younger movement (Figure 2). Another major structural feature is a west-northwest-trending fault array that forms the northern boundary of the basin. This fault array parallels the Hudson Strait that connects the Hudson Bay to the Atlantic Ocean and limits structural imbricated basins characterized by preserved sedimentary successions much thicker (~2 km) than those preserved on neighbouring islands (<0.6 km).

Hydrocarbon Systems

The hydrocarbon potential of the Hudson Bay Basin is poorly constrained and the area is currently viewed as a frontier prospect. During the first phase of exploration (1970-1980), more than 46,000 line-km of seismic reflection data were acquired and 5 offshore exploration wells drilled in Hudson Bay. Bitumen and minor gas and oil shows have been reported in offshore and onshore wells (Hu and Dietrich, 2012).

Outcrops of high quality Upper Ordovician source rocks (TOC up to 35%) have been known for many years (Macauley, 1986, 1987; Zhang, 2008) and new occurrences have been recently identified in northern Ontario (Armstrong and Lavoie, 2010). An organic matter reflectance study (Bertrand and Malo, 2012) of offshore well and a re-evaluation of Tmax data (Lavoie et al., 2013) indicate that, for all offshore and onshore wells, the oil window threshold is near the base of the succession, close to the Ordovician-Silurian contact (Figure 3). Analyses of offshore well data indicate that many carbonate and clastic units within the Paleozoic succession have sufficient porosity and permeability to form good quality reservoirs. By-passed hydrocarbon zones are also identified (Figure 4).

Preliminary interpretation of apatite fission tracks data suggest that the offshore wells entered the oil window. High resolution seafloor bathymetry and RADARSAT images document the presence of seafloor pockmarks and the possible presence of oil slicks at the surface of Hudson Bay.

Conceptual Plays

Based on field, seismic and petrophysical data, conceptual plays are proposed (Figure 5). Fault-controlled plays consist of tilted basement blocks and hydrothermal dolomites, stratigraphic plays are represented by the sub-Devonian unconformity and Ordovician, Silurian and Devonian reefs, finally a salt dissolution structures play is also proposed.

Conclusions

The Hudson Bay Basin is a major frontier sedimentary basin with coeval basins to the south (Michigan and Illinois) being world-class hydrocarbon producers. The Geological Survey of Canada and partners reassessed historical data and acquired new hydrocarbon-related information. Outcrops of high-quality Ordovician source rocks are identified on all sides of the basin. New thermal maturation data suggest that the Ordovician source rocks are within the oil window. Five conceptual hydrocarbon plays are proposed based on field, seismic and petrophysical data.

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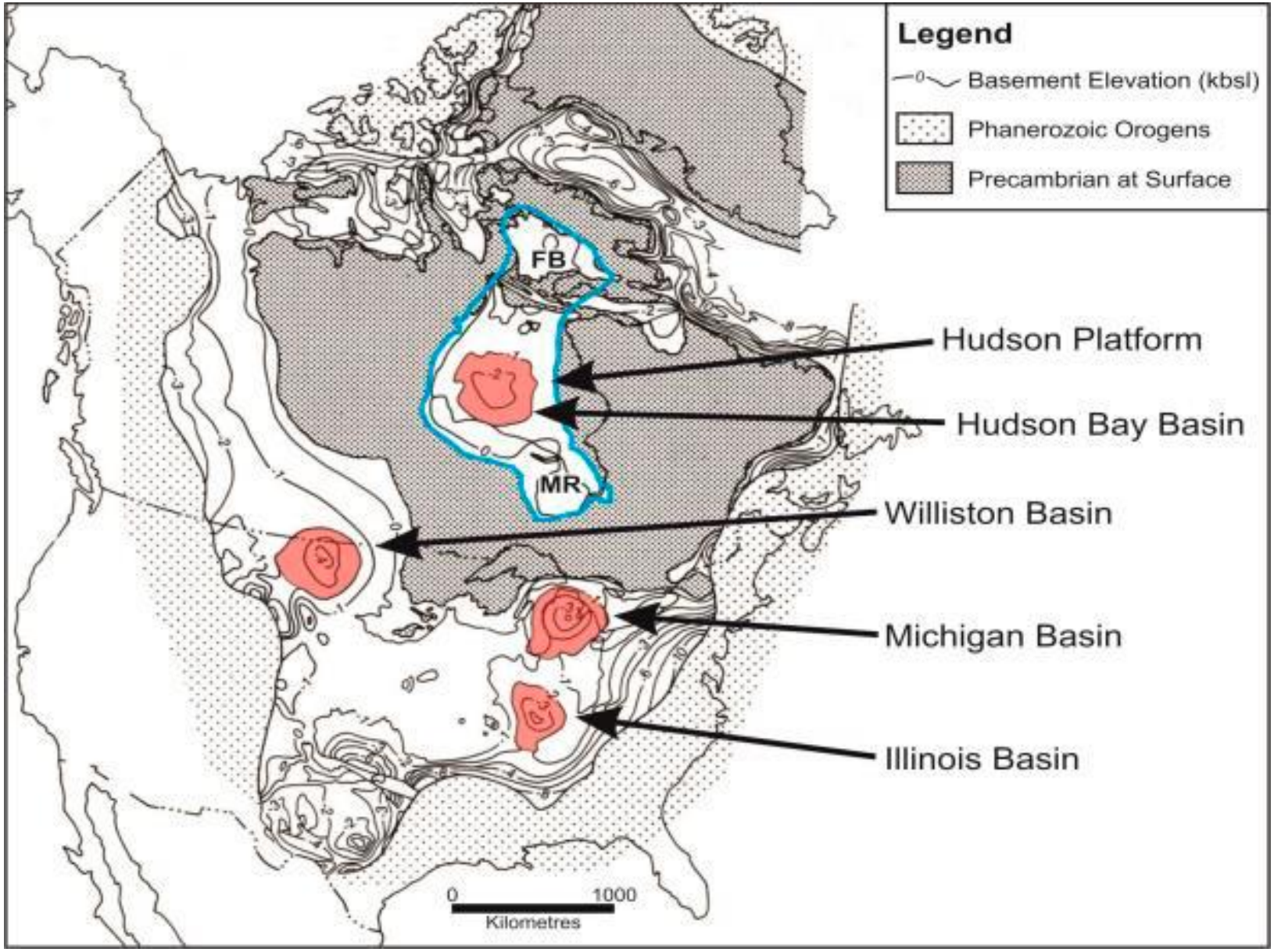


Figure 1. General setting of the Hudson Bay Basin in North America. MR is Moose River Basin and FB is Foxe Basin.

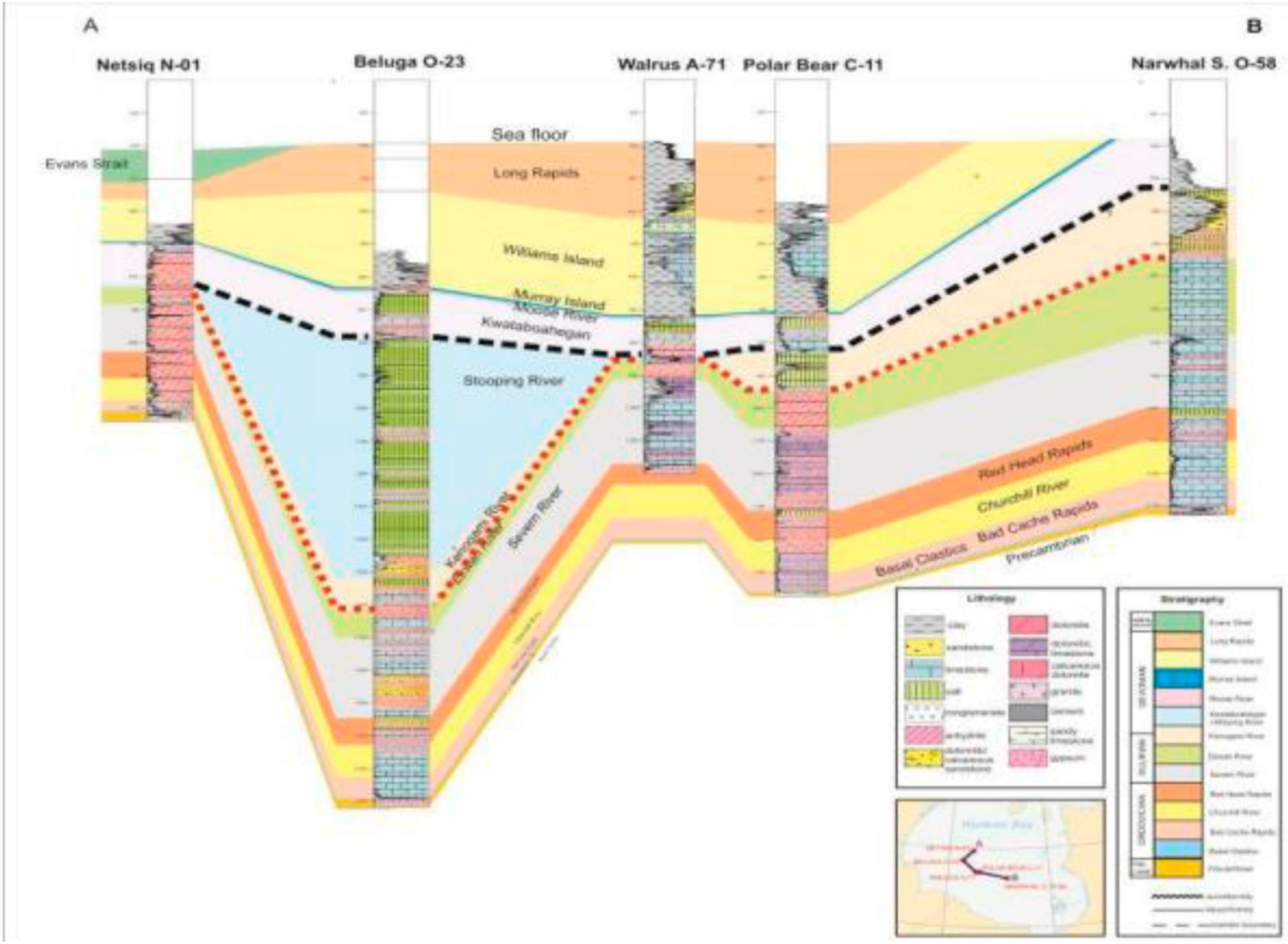


Figure 2. Stratigraphic framework based on new biostratigraphic data and correlation of offshore well logs. Red dotted line is at a major Lower Silurian – Lower Devonian unconformity, black dotted line is positioned at the upper most reach of active fault movement in the basin. Modified from Hu et al. (2011).

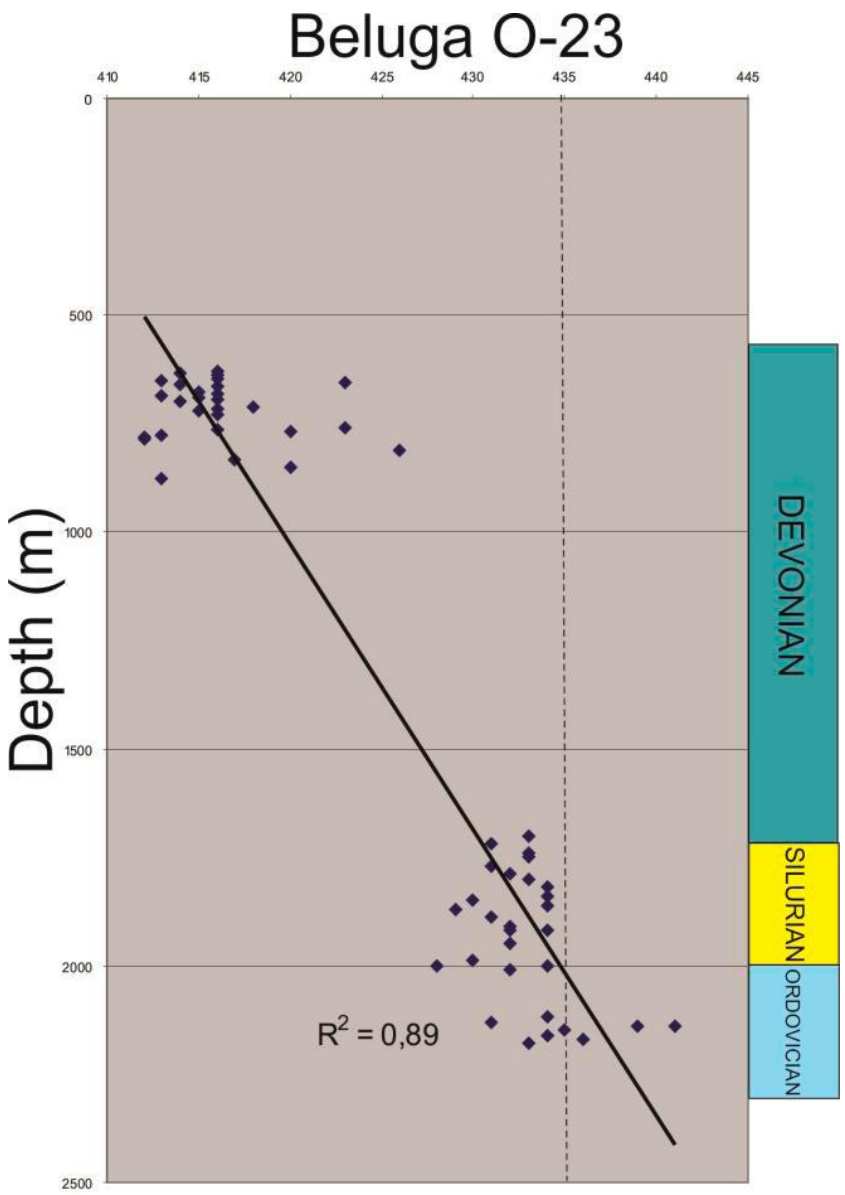
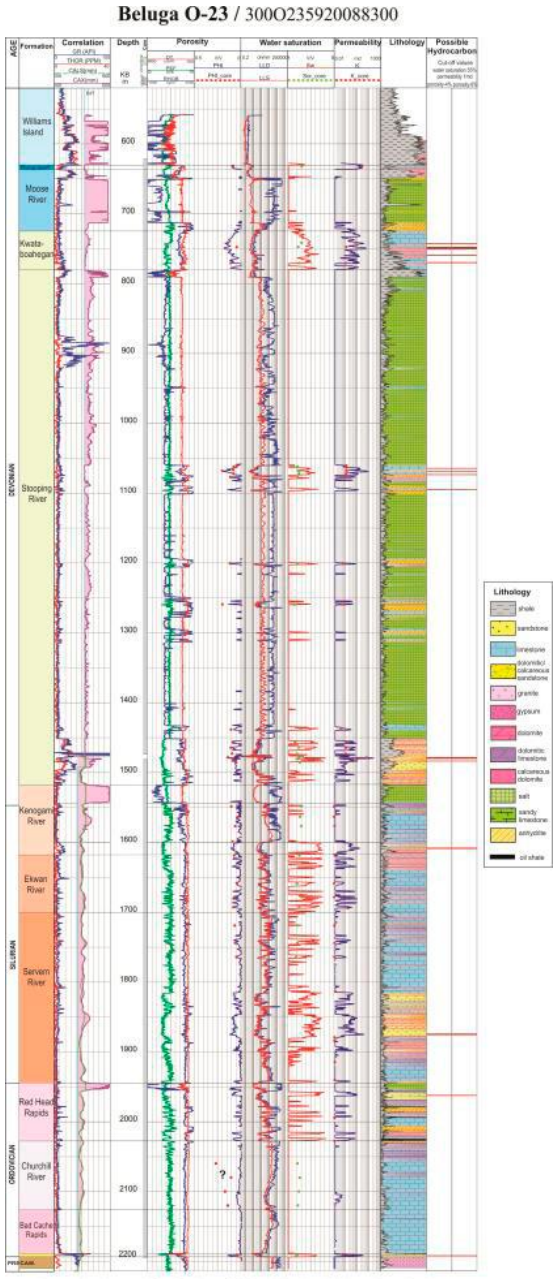


Figure 3. Tmax vs depth, for Beluga 0-23 well. The oil window is reached at the Ordovician-Silurian contact (Lavoie et al., 2013).



Log analysis result for Beluga O-23 well in the Hudson Bay Basin.

Figure 4. Petrophysical analyses of Beluga 0-23 well, the red lines are by-passed HC zones (Hu and Dietrich, 2012).

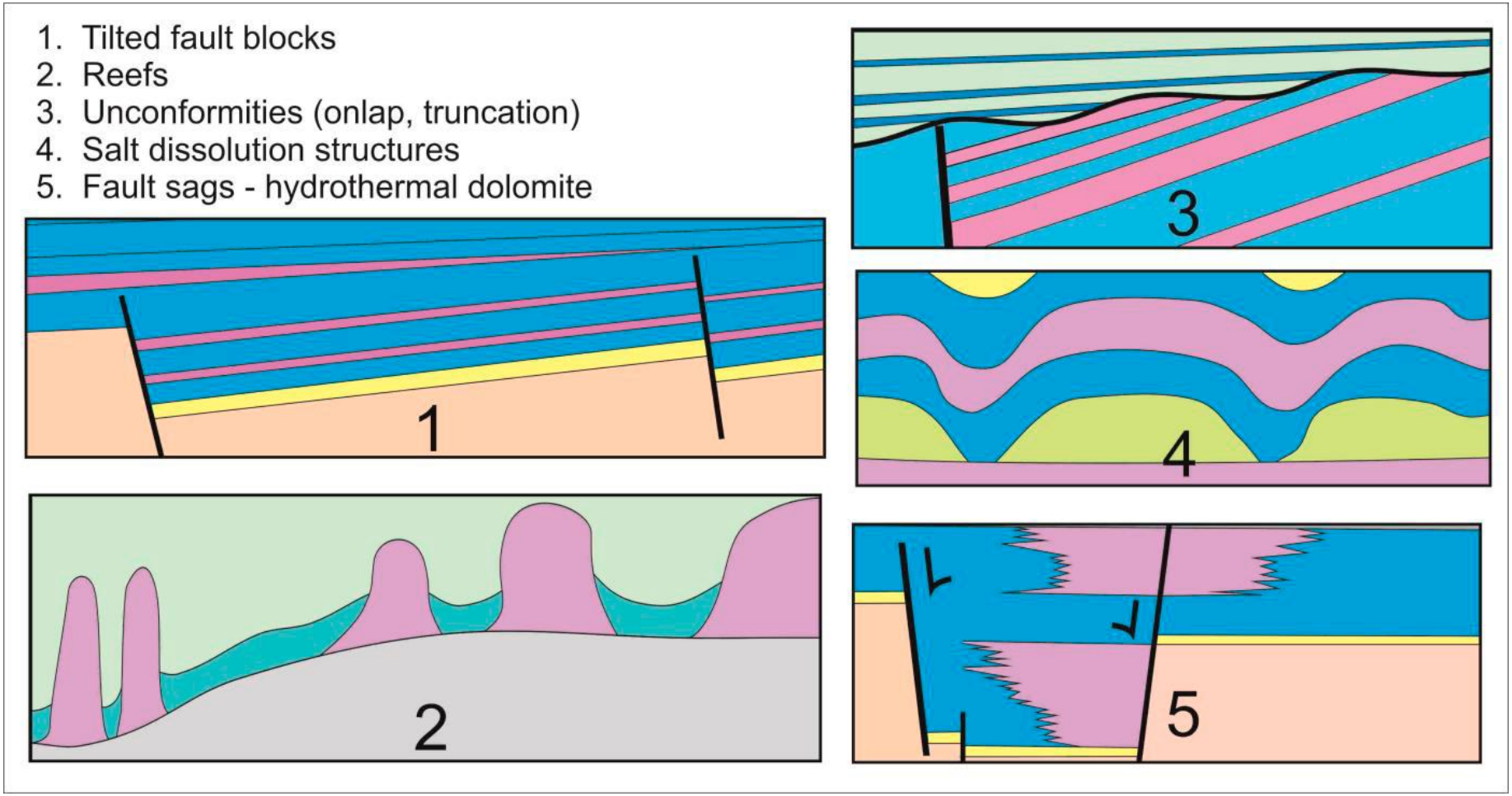


Figure 5. Conceptual plays in the Paleozoic succession of the Hudson Bay Basin. These plays are suggested from field, seismic and petrophysical data.