Basin Analysis Points to New Plays in the Arctic Islands

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Introduction

Generating new exploration ideas in a frontier area, where drilling is widely spaced and petroleum systems poorly known, requires the best possible understanding of the basin history to estimate the areas in which source rocks were likely to produce hydrocarbons, the timing of hydrocarbon generation, the timing of trap formation, and the potential for hydrocarbon preservation. This information can be used to predict which plays are the most prospective.

In anticipation of renewed interest in hydrocarbon exploration in the Canadian Arctic Islands, the Geological Survey of Canada (GSC) has reviewed the thermal maturity, geochemistry and stratigraphic data from the Canadian Arctic to better constrain the known petroleum systems and identify petroleum systems beyond those that have been previously postulated. Five plays are identified as being the most prospective.

There were 185 wells drilled, resulting in the discovery of 20 major petroleum fields, during the 1960 to 1986 oil and gas exploration of the Arctic Islands. Most discoveries in the Sverdrup Basin were found in structural traps in Jurassic strata. While this play will be continue to be important in the next round of exploration, other stratigraphic intervals and other traps may prove to be just as attractive targets.

Geological History of the Arctic Islands

Strata from three geological provinces have petroleum potential: Ediacaran to Devonian passive to convergent margin sedimentary strata (including undeformed Arctic Platform, and Boothia and Ellesmerian foldbelts); Carboniferous to Cretaceous rift basin sediments and volcanic rocks of the Sverdrup Basin; and Cretaceous–Tertiary rift and passive margin sediments of the Polar Continental Margin and Banks Basin.

The geological episodes that control the hydrocarbon potential of the Arctic Islands are (Fig. 1): 1) deposition of Cambrian to Ordovician shelf carbonates, clastics, and evaporites on the Franklinian trailing margin; 2) step-back of the shelf margin and deposition of widespread Upper Ordovician source beds; 3) west-directed folding and thrusting of the Early Devonian Boothia Uplift in the central Arctic Islands; 4) progradation of the Mid to Late Devonian clastic wedge in front of the advancing Ellesmerian orogenic belt; 5) southerly-directed folding and thrusting of the Late Devonian—Early Carboniferous Ellesmerian Orogeny; 6) rifting and deposition of the Carboniferous to Cretaceous Sverdrup Basin; 7) rifting and opening of the Canada Basin and Banks Graben in the Mid-Jurassic to Early Cretaceous; 8) widespread intrusion of igneous rocks related to Alpha Ridge spreading in the Early Cretaceous; 9) burial by the sediments of the clastic wedge derived from the Eurekan Orogeny; 10) Eurekan folding in the Eocene.

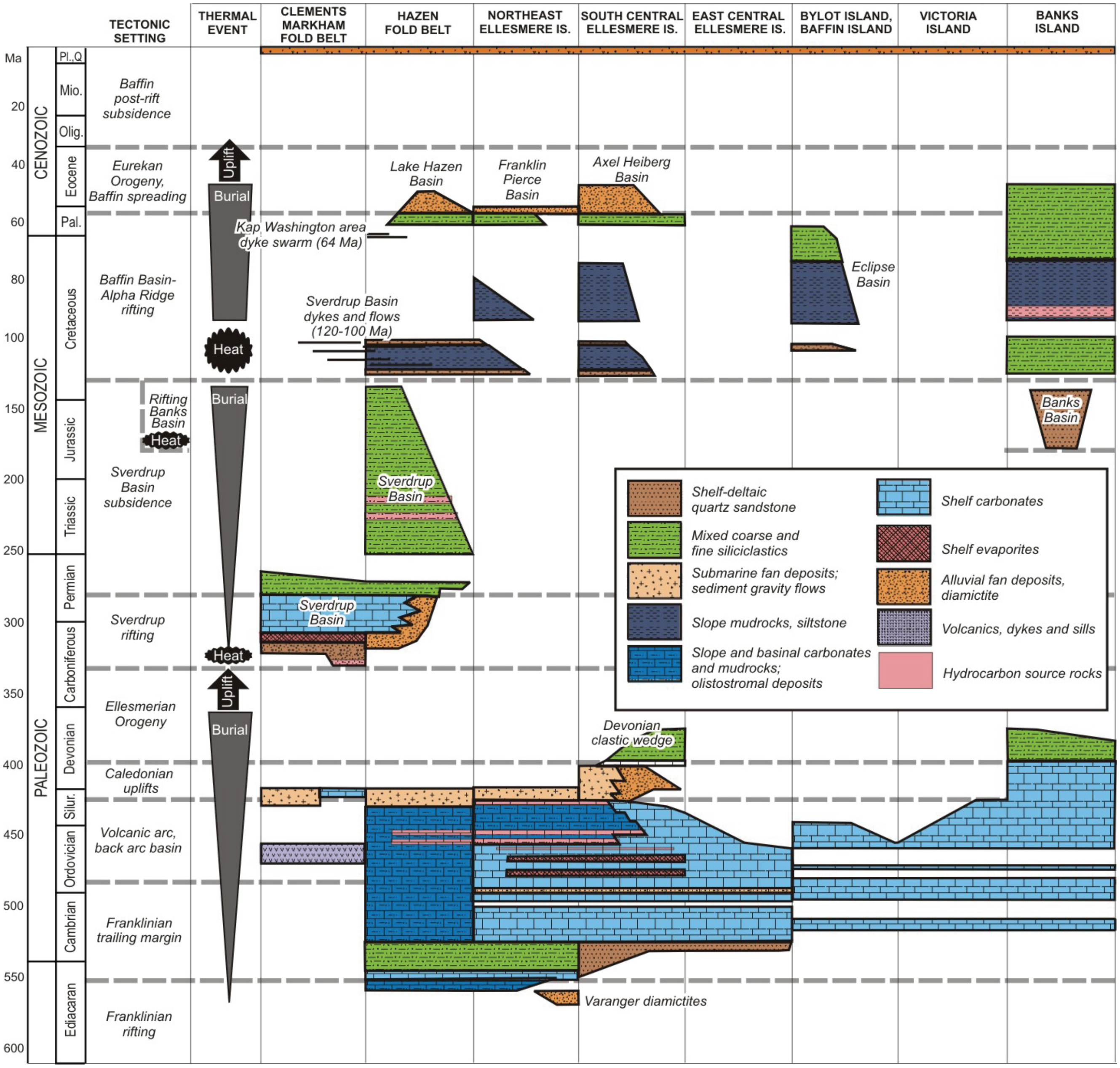

Figure1: Tectono-stratigraphic elements of the Canadian Arctic Islands

Lower Paleozoic-sourced Hydrocarbon Plays

The thermal maturity of the lower Paleozoic is high in the west, central, and northeast parts of the islands, but areas of low thermal maturity occur over the northern Boothia Uplift and between Sabine Peninsula and Cameron Island. Three thermal events produced this pattern: burial by the Mid to Late Devonian clastic wedge over much of the Arctic Islands, Jurassic-Cretaceous rifting of the Canada Basin in the western Arctic, and burial of the northern part of the lower Paleozoic succession by the Sverdrup Basin in the Cretaceous.

Burial by the Devonian clastic wedge matured most of the lower Paleozoic source rocks at about 380Ma. The prospectivity of these rocks is hampered by maximum burial and hydrocarbon migration occurring before the folding and thrust faulting that created the Parry Islands and

Ellesmere fold belts. Also, the old age of hydrocarbon generation means that most hydrocarbons have likely been lost due to leakage or degradation. Preservation in some traps may be possible where salt or anhydrite have acted as a seal.

A hydrocarbon play can be envisaged on eastern Bathurst Island and adjacent water bodies. In this area, the Lower Ordovician Eleanor River Formation was folded into N-S trending anticlines during the Early Devonian Boothia Uplift. The Eleanor River Formation is overlain by thick evaporites of the Bay Fiord Formation. If porosity occurs within the Eleanor River Formation, then hydrocarbons generated during Late Devonian burial of Silurian shales on western Bathurst Island could have migrated into these pre-existing folds on the flanks of the Boothia Uplift and been preserved by the salt seal.

The second play occurs on the Sabine Peninsula and elsewhere on northeastern Melville Island, Cameron Island, and an unknown distance below the Sverdrup Basin to the north. The Devonian clastic wedge was thin in these areas and the Silurian shale remained immature with most of its hydrocarbon-generating potential intact. Later burial by sediments of the Sverdrup Basin may have been sufficient to drive Silurian strata back into the oil or gas window. This hydrocarbon charge could be held in traps within the lower Paleozoic succession (e.g., Bent Horn) or in upper Paleozoic and Mesozoic traps.

A third play involving lower Paleozoic source rocks may occur in the western Arctic. Thermal maturity (a proxy for temperature) and sonic velocity (a proxy for compaction) correlate well in most shale units from the Canadian Arctic Islands. This implies that the thermal response relative to the depth of burial is consistent over most of the islands. Samples from the lower Paleozoic in the western Arctic consistently plot below the maturity-velocity curve indicating that the lower Paleozoic strata attained a much higher temperature than would be expected from their burial compaction. Given the location of these wells in the western Arctic, in the area of Jurassic-Early Cretaceous rifting of the Canada Basin, it seems likely that the elevated vitrinite reflectance was due to increased heat flow during rifting rather than burial during the Ellesmerian Orogeny. Lower Paleozoic source rocks may have re-entered the gas window during this time, charging reservoirs in Devonian to Jurassic strata.

Sverdrup Basin-Sourced Hydrocarbon Plays

Comparison of vitrinite reflectance to sonic velocity indicates a uniform response of thermal maturity with depth for Mesozoic strata within the Sverdrup Basin. Given that vitrinite reflectance cannot decrease after is it set, it is possible to determine which samples have been uplifted by comparing the depth inferred by the vitrinite reflectance to the current depth of burial. The thermal maturity at the level of the Upper Triassic Gore Point Member of the Roche Point Formation was established for each well. The Gore Point Member is the only widespread limestone in the Sverdrup Basin so it can be consistently picked in wells, as well as being a good seismic reflector and close to the two main oil-prone source rocks in the Sverdrup Basin.

A normal burial curve is established using boreholes drilled in areas with no structural complexity (Fig. 2). Low amplitude structures, including the Drake, Hecla and Whitefish fields, show little or no uplift following maximum burial in the Late Cretaceous, indicating that these structures formed prior to the Eurekan Orogeny. Because they were present at the time of maximum burial, they were charged during hydrocarbon migration. High amplitude structures show large uplifts following maximum burial. They formed in the Eocene during the Eurekan Orogeny, and hence post-date most hydrocarbon migration.

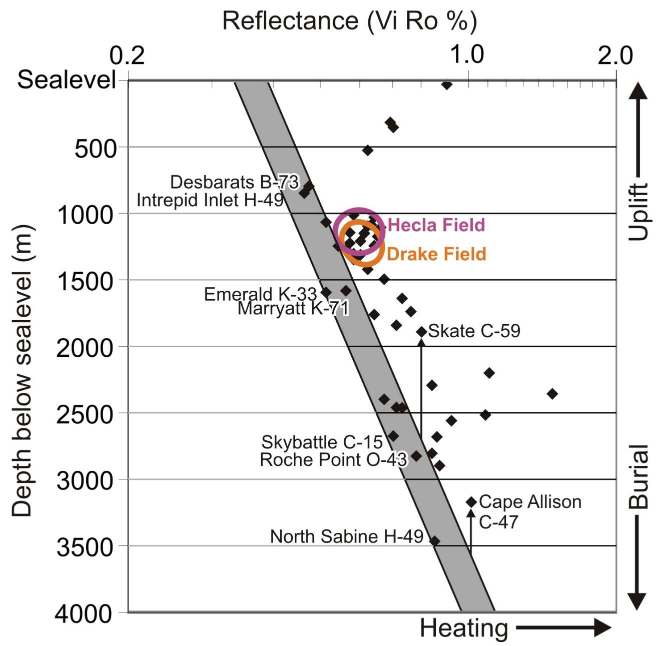

Figure2: Depth of burial vs. reflectance for the Triassic Gore Point Member

Discovery of salt canopies on Axel Heiberg Island by Jackson and Harrison (2006) opens the possibility of a wide range of sub-canopy plays. Traps would have been established by the Early Cretaceous were present at the time of maximum burial. Although Triassic source beds in the area were likely cooked by igneous activity, younger gas-prone shales may have generated hydrocarbons due to burial by the Eurekan clastic wedge.

Analysis of the thermal maturity in the western Sverdrup Basin indicates that the Triassic Schei Point Group source units are in the oil window. The abundant gas at Drake, Hecla, and Whitefish must have come from a deeper source in the Triassic, Permian or older strata. Deeper traps may be prospective.

Acknowledgements

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References

Jackson, M.P.A., and Harrison, J.C., 2006. An allochthonous salt canopy on Axel Heiberg Island, Sverdrup Basin, Arctic Canada. Geology, v. 34 (12), p. 1045-1048.