Petroleum Potential of the Peel Plain and Plateau in the Yukon Territory, Canada.

Kirk Osadetz*, Don Cook, Bernie Maclean and Jim Dixon
Geological Survey of Canada: Calgary,
3303 - 33rd St. N.W., Calgary, AB T2L 2A7
kosadetz@nrcan.gc.ca

and

Riona Freeman and Tammy Allen
Oil and Gas Management Branch, Department of Energy, Mines and Resources
Government of Yukon, Whitehorse, Yukon

ABSTRACT

The Peel Plateau and Plain in the Yukon is a prospective petroleum province that lies north of the Mackenzie Mountains and east of the Richardson Mountains up to the inter-territorial boundary. The region contains a Lower Cambrian to Upper Cretaceous stratigraphic succession up to approximately 4.5 km thick that overlies a poorly described Proterozoic succession that is currently ascribed as "economic basement". The assessment region is contiguous with the Mackenzie-Peel Shelf/Platform in the N.W.T. and it lies entirely west of the Mackenzie Peel Arch. To the west and south the limit of Phanerozoic prospectivity is defined by the Richardson and Mackenzie mountains where Paleozoic and older strata are exposed.

Nineteen exploratory wells have been drilled within the region. None of these wells have established economic reserves or production, but there have been several shows. One surface natural gas seepage occurs in the NWT in the contiguous Mackenzie-Peel Shelf geological province. Assessment of this region suggests that there is a significant potential for natural gas throughout the region with a summed mean play potential of approximately 83.428 X 10^9 m^3 initial raw gas in place (~3 TCF) in approximately 88 pools. The largest expected pool of 3.36 X 10^9 m^3 initial raw gas in place is expected to occur in Mesozoic clastics of the Peel Plain. In general the small size of gas pools will be an impediment to their development because of their location. No crude oil potential can be estimated due to an inferred lack of oil prone sources in strata of suitable maturity. In general, petroleum potential is inferred to decrease both westward and with increasing depth and stratigraphic age.

The result of this study, while differing in detail from previous work, for gas, is generally similar in aggregate potential. This study differs significantly from previous with respect to crude oil potential. This difference occurs primarily because of a lack of hard data that could be obtained from the available wells if there were time and resources to perform suitable analysis (Rock-Eval/TOC pyrolysis). Where previous work speculated that the history of petroleum

systems in the Peel Plain and Plateau was distinctive from that of surrounding regions that are suitably characterized, this work finds no justification for such a distinctive petroleum system history.

The geological outcrop structure of the region is obscured by the monotonous topography and poor outcrop of the Peel Plain physiographic region. Seismic surveys are incomplete and cover only a small portion of the region, with wide spacing. Many of the wells were drilled without the benefit of or prior to the existing seismic surveys. To some degree this means that the lack of exploratory success is not diagnostic of the potential of the region. None of these wells have been characterized geochemically, so that the potential and maturity of petroleum sources must be inferred from regional data and functioning of the petroleum systems is not known.

The unfavorable results of exploratory drilling in the Yukon are part of a larger unsuccessful effort in the adjacent N.W.T. Most notable has been the lack of success in the Paleozoic carbonate successions of the Mackenzie Peel Platforms. The lack of additional exploration during the last quarter century while largely due to economic considerations, must also consider lack of previous success and the unfavorable geological characteristics, including the following. These successions are dominated by carbonate ramp deposition that results in large stratiform porosity zones following a predominantly vertical succession of facies. While internal stratigraphic traps exist, most carbonate ramp settings rely on a structural component of entrapment. Two features invoked by a previous assessment, an abrupt margin carbonate depositional model and a hydrothermal dolomitization event were examined and evaluated. There is a small probability for an abrupt carbonate margin play that could be provided by isolated carbonate build-ups growing off the drowned Hume platform, like the Horn Plateau reefs of in the N.W.T. Such reefs, generally limestone, lack porosity because burial compaction by a thick and largely eroded later Paleozoic succession. However, there is no reasonable expectation that the region was affected by hydrothermal dolomitization events during the Paleozoic, as the limit of the Manetoe Facies is about 63 degrees north, on the Mackenzie-Peel Shelf. Deep burial in limestone dominated Paleozoic successions reduces porosity by compaction destroying reservoir potential. The same deep late Paleozoic burial appears, regionally to have matured potential Paleozoic source rocks and destroyed any Paleozoic oil potential prior to the latest Cordilleran deformation. What proportion of the succession and petroleum resource that was lost accompanying the formation of the sub-Mesozoic erosion surface is unknown.

The Mesozoic succession is shale and siltstone dominated, except for the basal Martin House Formation Sandstone. While the timing for petroleum generation from these strata is favorably related to the timing of the Cordilleran deformation of a foreland succession wherein depositional processes provide many opportunities for internal stratigraphic traps, the sedimentary facies and inferred sources are inferred to be gas-prone. Therefore it is not reasonable to attribute a

crude oil potential to any plays within this region without the provision of new, currently missing, organic geochemical data. Such data could be obtained from the existing wells if they were suitably analyzed. Both thermogenic and biogenic natural gas generation may have occurred within the Mesozoic succession during the Cordilleran orogeny. The basal Mesozoic sandstone might also have been charged by gas re-migrated from Paleozoic strata by the effects of the Cordilleran deformation.

The combination of depositional and tectonic history indicate that the petroleum potential of the region will be gas-prone, largest in the highest stratigraphic levels and, by analogy to other thrust and fold-belt to foreland basin settings, greatest in the undeformed portion of the foreland basin. These geological framework considerations influence the definition of plays and assessment regions. Despite the negative characteristics and features of the geological setting and history the inferred natural gas potential is significant, with initial raw gas in place of ~3 TCF in approximately 88 pools. In comparison the proven initial in place reserve of the Mackenzie-Delta and Beaufort Sea are about 12 TCF.

The Peel Plateau and Plain assessment region is divided into three structural and stratigraphic belts that do not coincide with the physiographic boundaries. From the outcrop of the Richardson and Mackenzie mountains west to the Trevor Fault is the first Assessment Region. This region lies primarily in the Peel Plain, but it is underlain by east verging Cordilleran thrust and fold structures that are similar to those of that underlie the Peel Plateau. This assessment region is referred to as the Peel Plateau – West of Trevor Fault. Most of the Peel Plateau and contiguous portions of the Peel Plain lying east of the Trevor Fault but west of the Peel River are also part of the east and north verging Cordilleran thrust and fold belt. This assessment area, from the surface trace of the Trevor Fault to the eastern limit of Cordilleran thrusting is referred to as the Peel Plateau, regardless of the physiography of the region. The carbonate to shale transition of a persistent Paleozoic paleotopographic feature, the Richardson Trough, occurs with the region between the Trevor Fault and the eastern limit of the Cordilleran deformation. East and north of the region affected by Cordilleran diastrophism are the undeformed successions of the Mackenzie-Peel Paleozoic carbonate shelf, also known as the Mackenzie-Peel Platform. This region, to the inter-territorial boundary constitutes the third assessment region of this study.

Peel Plateau – West of Trevor Fault: In this region dominated by Paleozoic outcrops the Cambrian to Devonian succession is composed of Road River and Imperial Formation and equivalents. Dominantly shales, no potential is inferred for the sub-Imperial succession. There is some potential for gas occurrence in the sandy intercalations within the post-Hume equivalent succession, although many of these units are near the surface and the preservation of this potential is a high risk. A single pool of 105 million cubic metres initial in place resource is assessed for the upper Paleozoic (Imperial-Tuttle-Ford Lake succession) in this region.

The total petroleum potential of the Peel Plateau – West of Trevor Fault is small to negligible, as would be expected from it geological history and characteristics. This region is the least attractive for petroleum potential in the assessment area.

Peel Plateau – East of Trevor Fault to the Eastern Limit of Cordilleran Deformation: This region contains the temporally and geographically persistent Platform to Basin facies transition that marks the eastern margin of the Richardson trough. This facies transition is unfavorably oriented with respect to the Cordilleran structure to provide a distinctive trapping mechanism. Neither is there strong evidence to support a distinctive diagenetic history or events that would help to preserve reservoir quality by way of hydrothermal dolomitization. Therefore, the plays in Paleozoic carbonates of this region will be in Cordilleran structural culminations where vestigial limestone porosity and minor dolostones will constitute potential reservoirs in a petroleum system that experienced its peak generation during the late Paleozoic. The remaining potential is for dry, over mature gas generated by combinations of Foreland and tectonic burial, or for Paleozoic gas to be re-migrated into Cordilleran structures. The western margin of the Mackenzie-Peel Shelf constitutes a single play within Cordilleran structures. It is expected that the Peel Plateau Cambrian to Devonian Carbonate Margin will consist of about 7 gas pools with a mean potential of approximately 4.460 X 10^9 m^3 initial raw gas in place. The largest expected pool is 1.337 X 10^9 m^3 initial raw gas in place.

Paleozoic clastics, although comprising a thinner succession dominated by non-reservoir facies, have a greater potential for a favorable stratigraphic component of entrapment. Therefore they have an improved potential for the preservation of the petroleum generated in the Paleozoic. It is expected that the Peel Plateau Upper Paleozoic Clastic Play will consist of about 2 gas pools with a mean potential of approximately 7.799 X 10^9 m^3 initial raw gas in place. The largest expected pool is 5.517 X 10^9 m^3 initial raw gas in place. This is the single largest projected pool in this assessment. It is likely to occur as a turbiditic sandstone body. This play resembles deep-water sandstone plays on current oceanic margins, similar to Shell's current successful exploration on the margin of the African continent.

Mesozoic sandstones in the Martin House and Arctic Red formations constitute the third play in the Peel Plateau Cordilleran thrust and fold belt. Although less likely to have large and thick extent, the timing of hydrocarbon generation relative to structure is much more favorable for Mesozoic hosted petroleum systems compared to those in Paleozoic strata. It is expected that the Peel Plateau Mesozoic Clastic Play will consist of about 12 gas pools with a mean potential of approximately 13.157 X 10^9 m^3 initial raw gas in place. The largest expected pool is 2.861 X 10^9 m^3 initial raw gas in place.

The total potential of the Peel Plateau assessment region between the Trevor Fault and the eastern limit of Cordilleran deformation is about 25.4 X 10^9 m^3 (~0.9 TCF) initial raw gas in place. This potential is significant, but moderated compared to that of the Peel Plain to the east. It is significant to compare the thrust and fold belt in the Peel region with that of the Southern Cordillera. In the southern Cordillera only about 15% of the conventional petroleum potential occurs in the thrust and fold belt, as compared to the undeformed Plains, not accounting for the tar sands and heavy oils. In the Peel region about 30% of the inferred potential is attributed to the thrust and fold belt. This, however, does not represent a real difference, once it is remembered that only a portion of the Peel Plain petroleum potential occurs within the Yukon portion of the region.

Peel Plain East of the Cordilleran Deformation: The remaining, and most prospective region of this assessment is the Peel Plain, east of the Cordilleran Deformation Front to the inter-territorial boundary. Five plays were defined here. The Cambrian to Devonian Carbonate platform, all the units of which are dominated by carbonate ramp deposition, constitutes the largest volume of rock in any single play. Factors that adversely affect this play include: the style of porosity development and the lack of lateral seals in carbonate ramps, the preservation of limestone reservoir porosity in the absence of pervasive dolomitization, and the timing of hydrocarbon generation relative to structure formation, Throughout the northern Interior Platform there has been a most notable lack of success drilling to the Hume Formation and the Ronning Group. It is expected that the Peel Plain Carbonate Platform Play will consist of a single pool of about 0.218-0. X 10^9 m^3 initial raw gas in place.

Manetoe dolostones do not extend north of 63 degrees in the Mackenzie-Peel Shelf. This means that there is no potential in the previous defined Devonian Fractured Arnica Dolomite (Bird, 1999). Most of the Devonian is in a carbonate ramp setting in the Peel Plain. The one significant opportunity for an abrupt carbonate margin facies model accompanies the persistence of carbonate deposition following the drowning of the Hume Platform. This is identical in configuration to the Horn Plateau Play of the southern NWT. While, this play is not known to exist, neither can it be entirely discounted. A major problem with this play is the lack of reservoir, something that should also depreciate the play potential in the Peel Plain. It is expected that the Peel Plain Post-Hume Reef play will consist of about single gas pool with a mean potential of approximately 0.888 X 10^9 m^3 initial raw gas in place.

Clastic plays in the Upper Paleozoic and Mesozoic section are the equivalent of plays in the same succession of the thrust and fold belt, but within the Interior Platform setting. The Upper Paleozoic clastic play of the Peel Plain is expected to consist of about 9 gas pools with a mean potential of approximately 7.26 X 10^9 m^3 initial raw gas in place. The largest expected pool is 1.352 X 10^9 m^3 initial raw gas in place. The smaller size here reflects both the small available structures of the Plains, but also the more distal setting of this play area relative to the

apparent source of these clastics. The Mesozoic Clastic play of the Peel Plain is expected to consist of about 55 gas pools with a mean potential of approximately 49.487 X 10^9 m^3 initial raw gas in place. The largest expected pool is 3.356 X 10^9 m^3 initial raw gas in place.

In total the Peel Plain region, east of the limit of Cordilleran deformation constitutes the most attractive exploration region within the Peel Plain and Plateau. In total this 57.907 X 10^9 m^3 initial raw gas in place, or about 70% of the potential in place resource.