The Significance of Oil in the Sverdrup Basin

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Summary

The discovery history of the Sverdrup Basin includes two well-defined exploration cycles. In the first, onshore, cycle only one well tested oil in the western Sverdrup Basin. In the later offshore cycle seven of the discovered fields contain oil in varying quantities and quality. This paper will address some of the issues that arise from the occurrence and distribution of oil in the Sverdrup Basin and the impact this may have on economic development of resources in the basin.

Introduction

Exploration in the Arctic proceeded quite differently from many exploration areas. Discovered in-place resources include 19.8 trillion cubic feet of gas (CGPC 2005) and 1.9 billion barrels of oil (Chen et al. 2000). In the latest discussion of role of Panarctic Oils Ltd. Meneley (2007) illustrated how and why onshore exploration proceeded first, followed by offshore exploration. Offshore exploration could not proceed until Panarctic had deveveloped the technology to drill wells from artificially thickened ice islands. This exploration pattern produced two distinct creaming curves that define the discovery history in the Sverdrup Basin.

Discovered Gas and Oil Fields

Hydrocarbon discoveries in the Sverdrup Basin are contained in Mesozoic beds. While most of the accumulated hydrocarbons are found in the Late Triassic to Early Jurassic aged Heiberg sand and its lateral equivalents, gas and oil accumulations and shows are present .in reservoirs ranging from the Triassic Bjorne Formation to the Late Cretaceous Hassel Formation. The main source rocks are prolific shales in the Middle to Late Triassic. Recent geochemical studies discussed by Keith Dewing (2007) suggest that the Triassic source rocks are still largely in the oil-window, even in the basin axis. This raises interesting issues such as where is all the oil and why is the dominant hydrocarbon in the basin extremely dry gas. There is evidence that gas has flushed oil from at least some reservoirs. The source of such gas may be found in the Upper Paleozoic section. Jurassic Jameson Bay shale is the main regional top seal, but fracturing of this seal has permitted charging of younger reservoirs.

Results of exploration in the Sverdrup Basin are shown on Figure 1. This map shows the outcrop and subcrop limits of the Heiberg sands (Okulitch, 1991) and the limit defined where intrusives penetrate Heiberg and younger beds. These limits define the prospective area for Mesozoic hydrocarbon accumulations in the Sverdrup Basin.

- Discovered gas and/or oil fields are shown in red, fields where oil has been tested are ringed in green,
- Dry structures are in blue,
- Undrilled prospects are in yellow.
- Carboniferous diapirs and salt walls that penetrate the sediments and rise to the surface or sea floor are shown in grey.

In the western Sverdrup Basin seventeen gas and oil fields have been found, discovered resources include 19.8 trillion cubic feet of gas in place (CGPC 2005) and 1.8 billion barrels of oil in place (Chen et al., 2000). The two largest gas fields, Drake Point and Hecla, are located on broad low relief, wrench fault related anticlines close to the southern limit of Heiberg sand. These fields have thin gas pays but cover very large areas.

The remaining discoveries in the basin have been made on unpierced salt structures of varying amplitudes. A dominant characteristic of such discoveries is that the gas column is limited to about 600 feet or less. This gas column appears to be the maximum that can be retained by the Jameson Bay top seal. As a result, the structural traps are dramatically underfilled and in many cases only 10% of the trap capacity is occupied by hydrocarbons. Evidence for hydrocarbon loss has been demonstrated in a number of fields where residual oil is present in water-saturated sands (Waylett and Embry 1993). Leaky traps characterize the hydrocarbon system in the Sverdrup Basin.

Discovered oil resources in the Sverdrup Basin are confined to the axis of the basin and are highlighted on Figures 1 and 2. Oil is housed in Heiberg, Awingak and Isachsen sands and there is no apparent trend to the discovery history. Oil gravities vary from 41°API in the Awingak at Cisco to about 10°in the Heiberg at Balaena. With the exception of those two fields the remaining oil zones are associated with gas reservoirs.

The 100 million barrel tar sand deposit at Marie Bay (Trettin and Hills, 1966) on western Melville Island is held in a possible stratigraphic trap in the Bjorne Formation where conventional oil has been highly degraded by exposure at surface. The trapping mechanism includes an overlap of Jurassic shale in a manner analogous to the stratigraphic trap component in the Hecla gas field. Oil was also tested from Bjorne on the culmination of the Hecla structure and a smaller oil show occurred in the Bjorne at the culmination of the Drake Point structure as well.

Live oil was recovered in the sulphur test holes drilled by King Resources around the Barrow Dome on the Sabine Peninsula. Oil was seen in the Late Cretaceous Hassel and Kanguk sands as well as in the Otto Fiord carbonates associated with the salt dome (reported in Osadetz, 1979).

Given the requirement for areally large traps to house large gas deposits demonstrated by the exploration history of the basin (Meneley, 2006a), the undiscovered gas resources will be found mainly in small structural and stratigraphic traps, many of which may be found on piercement salt structures. As oil utilizes trap capacity much more efficiently than gas any oil bearing smaller traps may be more economically attractive. In any event the presence of combined oil and gas reservoirs will complicate the production of gas until such time as an oil delivery system is available to produce the oil. Another potential complication lies in the presence of residual oil in the Heiberg gas reservoirs at Drake Point (Waylett, 1990,Waylett and Embry, 1993) and Hecla (Gentzis and Goodarzi, 1993). While the presence of degraded residual oil does not appear to have affected the permeability as demonstrated by consistent high gas flow rates achieved (Waylett, 1990 any residual oil volume will need to be considered when calculating the amount of gas contained in those fields.

Climate change has already impacted the ice cover in the Sverdrup Basin. It may be no longer feasible to conduct seismic surveys on the ice or to construct ice-drilling platforms. Reasonably open-water conditions will be required to conduct detailed 2D and 3D seismic surveys that will be needed to define small, complex traps. There may be a period of time when ice conditions preclude both the ice-friendly techniques used by Panarctic and conventional marine exploration.

Conclusions

The presence of oil in the Sverdrup Basin needs to be considered both as an economic target in its own right and also as a factor impacting the volume and deliverability of gas. Smaller salt dome related traps might present attractive exploration targets for oil.

Acknowledgements

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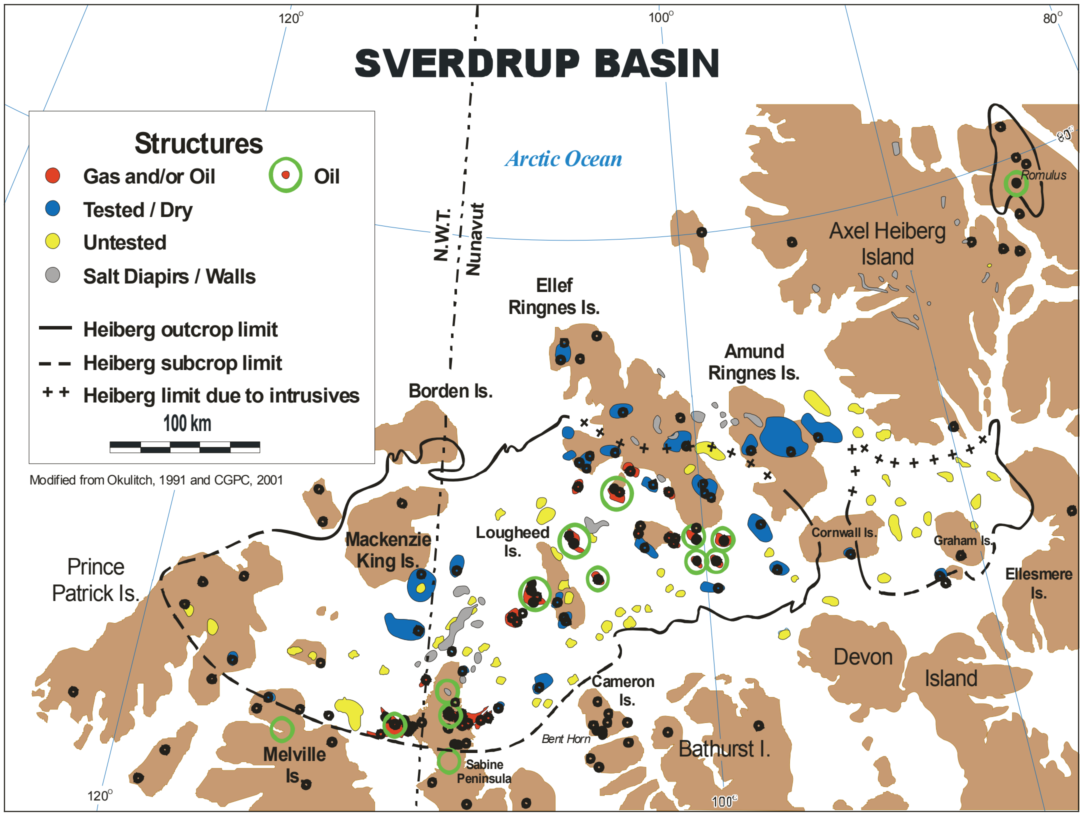
SVERDRUP BASIN
Structures
Gas and/or Oil
Oil
Tested / Dry
Untested
Salt Diapirs / Walls
Heiberg outcrop limit
Heiberg subcrop limit
Heiberg limit due to intrusives
100 km
Modified from Okulitch, 1991 and CGPC, 2001
Arctic Ocean
N.W.T.
Nunavut
Axel Heiberg Island
Romulus
Ellef Ringnes Is.
Amund Ringnes Is.
Borden Is.
Prince Patrick Is.
Mackenzie King Is.
Lougheed Is.
Cornwall Is.
Graham Is.
Ellesmere Is.
Devon Island
Cameron Is.
Bent Horn
Bathurst I.
Melville Is.
Sabine Peninsula
120°
100°
80°

Fig. 1

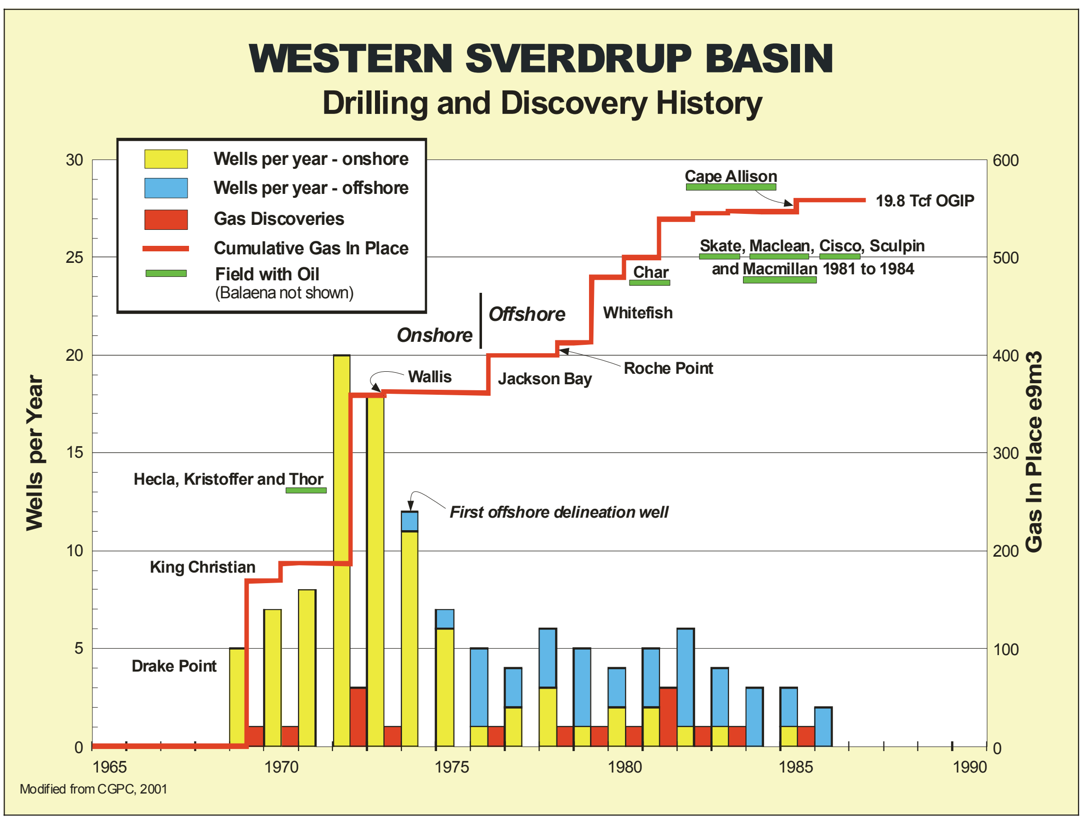
WESTERN SVERDRUP BASIN
Drilling and Discovery History
Wells per year - onshore
Wells per year - offshore
Gas Discoveries
Cumulative Gas In Place
Field with Oil
(Balaena not shown)
Wells per Year
Gas In Place e9m3
Cape Allison
19.8 Tcf OGIP
Skate, Maclean, Cisco, Sculpin
and Macmillan 1981 to 1984
Char
Whitefish
Offshore
Onshore
Roche Point
Jackson Bay
Wallis
Hecla, Kristoffer and Thor
First offshore delineation well
King Christian
Drake Point
1965
1970
1975
1980
1985
1990
Modified from CGPC, 2001

Fig. 2