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Petroleum Exploration on the Scotian Margin

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Summary

Seeps of oil, associated with Paleozoic salt systems, and oil-bearing shales were the target of early exploration in New Brunswick and Cape Breton in the 19th Century, but petroleum exploration of the Scotian margin (Fig. 1) did not begin until the 1960's (Wach et al. 2020). Perhaps the paucity of Mesozoic outcrops and the harsh weather offshore Atlantic Canada dampened enthusiasm for exploration. Perhaps it was an exploration mindset driven by head office, and more conventional exploration in the Western Canadian Sedimentary Basin.

The Scotian Margin encompasses the continental shelf and slope offshore Nova Scotia, a classic passive margin formed during the Triassic and Early Jurassic with the breakup of Pangaea (Fensome *et al.* 2008). The Scotian Margin represents over 250 million years of continuous sedimentation, from the initial opening of the Atlantic Ocean to the present (Brown 2008). The Scotian basin and subbasins encompass 300,000 km^2 with a maximum sediment thickness of 24 km (Wade and MacLean 1990).

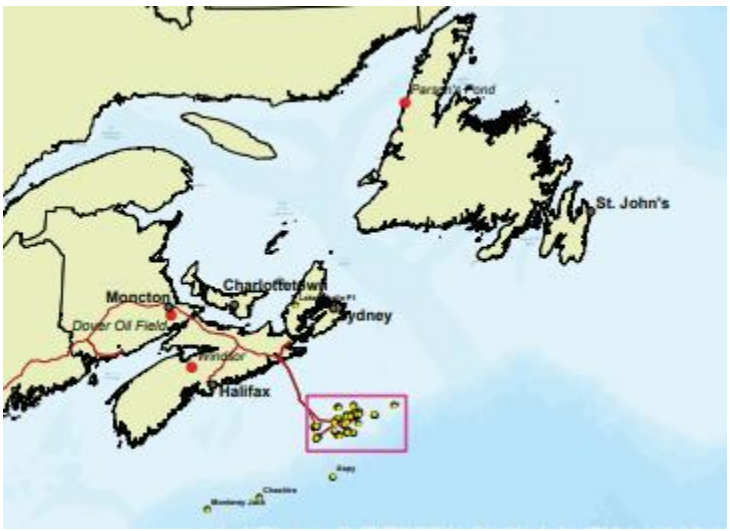

Figure 1: Scotian margin field developments and pipelines. (modified from Wach et al. 2020).

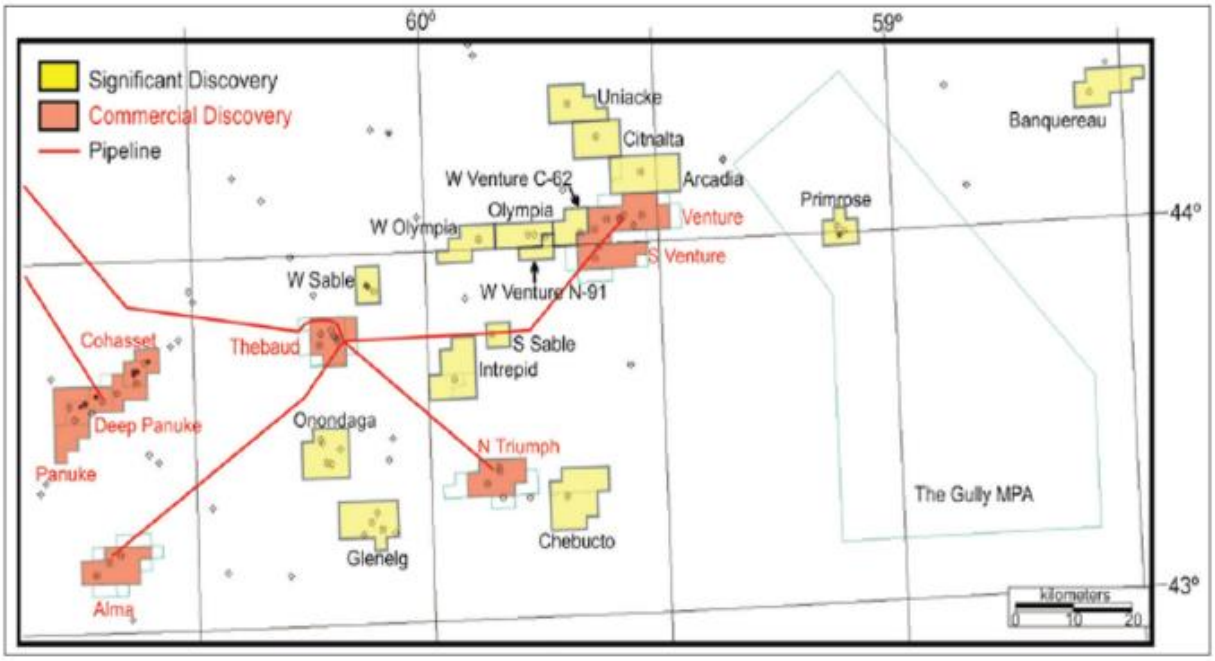

Figure 2: The map shows the Significant Discovery and Commercial Discovery blocks offshore Nova Scotia (from Smith et al. 2014).

Discussion

Don Axford and the First Exploration Cycle- Don Axford of Mobil Oil Canada firmly believed offshore Atlantic Canada could be prospective for exploration. He studied the geology and investigated the petroleum exploration history and production in the region, including the Hillsborough No.1 well. The dry hole drilled offshore Prince Edward Island in 1943, was in Don's view, too close to shore to accurately infer the petroleum potential further offshore. Offshore Nova Scotia, fisherman occasionally reported bringing Jurassic rocks up in their nets. In early seismic data from Woods Hole Laboratories a very thick succession of sediment was identified with evidence of structures that Axford believed were salt, similar to the increasingly prospective Gulf of Mexico. Axford recommended that Mobil lease one million offshore acres. He also believed Sable Island could be used as a low-cost drilling platform to test the exploration strategy. Don Axford's tenacity and belief in his homework began four phases of exploration that has lasted for five decades. By 1962, interest in the area had increased, and Shell acquired licenses for 20 million acres surrounding the Mobil's holdings. In 1967 Mobil's Sable Island No.1 was drilled to 4,604m with many oil shows in the Cretaceous sands (1950 to 2134m) and bottomed in overpressured gas sands. Sable Island, 300km offshore from Halifax, did indeed prove to be an excellent drilling platform to test the subsurface geological structures. Between 1967 and 1978, 71 wells were drilled offshore in this area of the Scotia Shelf (Figs. 1 & 2). Mobil and Shell estimated the offshore could match the magnitude of the North Sea. Small discoveries were made at Onondaga (1969), Citnalta (Atlantic spelled backwards), and Intrepid, while the 1972 discovery at Thebaud, 10km south of Sable was more significant, with ½ trillion cubic feet (Tcf) reserves. Light oil was also discovered at Cohasset (1973), oil and gas were discovered at West Sable (1971) and Primrose.

The second exploration cycle- The second cycle was initiated by the major gas discovery at the Venture field east of Sable Island. A large rollover anticline was targeted by the Venture D-23 well, off the eastern end of Sable Island, by Mobil and PetroCanada. This discovery in 1979 was the largest, with reserves nearly equaling the total discovered volumes of the Sable subbasin. This ignited a second wave of exploration in the offshore between 1979 and 1989, leading to further significant gas discoveries in similar roll-over anticlinal structures including South Venture, West Venture, Olympia, West Olympia, Arcadia, South Sable, Glenelg, Alma, North Triumph, Uniacke, Eagle, Banquereau and Chebucto. There were also oil discoveries during this period at Penobscot and Panuke (1986) for total of 15 significant discoveries. The governments of Canada and Nova Scotia in 1988 determined, “a significant discovery is defined by the first well on a geologic feature that demonstrates the existence of hydrocarbon in the feature by flow testing and suggests the existence of an accumulation of hydrocarbons that has potential for sustained production”. Further, the Resource Act defines a commercial discovery as “a significant discovery that has been demonstrated to contain quantities of petroleum that justifies the investment of capital and effort to bring into production” (Smith et al. 2014).

Currently, this remains the most successful exploration cycle with 15 significant discoveries designated, from 54 wells drilled. But near the end of the 1980s with decreasing energy prices and high development costs, and successes in other basins such as the Gulf of Mexico and North Sea, exploration interest waned (Fig.3).

The Development Phase

Cohasset Panuke (COPAN)- By the early 1990s, development plans began to emerge for the exploration discoveries on the Scotian margin. Nova Scotia native Norman Miller was a key figure leading the effort to bring the first offshore oil project to production. Miller suggested combining the development of two known oil fields, Cohasset (Mobil) and Panuke (Shell), into a single project, COPAN. In late 1989, the London & Scottish Marine Organization (LASMO) and Nova Scotia Resources (Ventures) Limited announced the COPAN project to develop the light oil discoveries at Cohasset and Panuke. LASMO Nova Scotia was formed with Miller as the Vice President, and from 1990 through 1993, he led the Nova Scotia team in the development and initial production of the Cohasset/Panuke oilfields offshore Nova Scotia, with the project later purchased by PanCanadian (later Encana). The COPAN project started production in late 1992 and continued until 1999, with a total of 44.5 million barrels (MMBbls) of light oil produced and shipped by tanker. Despite its relatively small scale, the COPAN project was a major achievement for Nova Scotia and Canada, as it represents the first commercial petroleum production from the Scotian Margin and Canada’s offshore (Miller et al. 1992)

Sable Offshore Energy Project- By 1996, a joint venture among ExxonMobil Canada, Shell Canada Limited, Imperial Oil Resources, Cona Resources Ltd. and Mosbacher Operating Ltd. was formed with plans to develop six gas condensate fields (Thebaud, North Triumph, Venture, Alma, South Venture and Glenelg) in the Sable Island area, creating the Sable Offshore Energy Project (SOEP). In December 1999, the SOEP project began flowing gas and eventually five of the six fields were in production. Delineation drilling at Glenelg failed to confirm commercial quantities of gas in the largest undrilled fault closure. A key component of the SOEP was the construction of the Maritimes & Northeast Pipeline; natural gas was transported onshore though 200 km of submerged pipeline to a processing plant in Goldboro, Nova Scotia, and then

transported via the pipeline to the New England markets. SOEP was decommissioned in 2018, producing more than 2.09 trillion cubic feet (Tcf) over the span of the project.

Deep Panuke- In late 1999 PanCanadian decided to test a seismic anomaly beneath the Panuke field by re-drilling and deepening an un-used water disposal well. Panuke PI-1A encountered a thick gas column in highly porous reefal limestones of the Abenaki Formation. An entirely new play! After the Cohasset Panuke fields' abandonment, Encana drilled four exploration wells to delineate the Deep Panuke field. Reserves were initially considered insufficient for development but in 2007, the Canada-Nova Scotia Offshore Petroleum Board approved development of Deep Panuke. The four delineation wells were designed as potential development wells, and natural gas production began in 2013. The production lifetime of Deep Panuke was originally estimated at 13 years; however, due to unexpected water influx and declining yield, production ceased in 2018. A total of 145.6 billion cubic feet (Bcf) of slightly sour (0.2% H2S) gas was produced at Deep Panuke. Deep Panuke was decommissioned with the abandonment stage completed in 2020 (Fig. 4).

The Third Exploration Cycle- Success around the globe of projects targeting deepwater depositional systems such as basin floor fans, downdip from large deltaic complexes, witnessed exploration focus on the outer shelf, slope and deepwater regions. The acquisition of large regional 2D and especially 3D seismic volumes during this exploration cycle has had minimal influence on the success rate to date. Further exploration of rollover anticlines (notably the Adamant and Cree structures) resulted in gas discoveries but were deemed non-commercial by ExxonMobil.

The Fourth Exploration Cycle- The fourth exploration cycle was focused exclusively on salt-related targets in the deepwater Scotian Slope. Significant volumes of extensive 3D seismic lines were acquired beginning in 2013. Between 2015-2018 three exploration wells have been drilled offshore Nova Scotia (CNSOPB 2019). The Cheshire L-97 and Monterey Jack E-43 wells, drilled as part of the Shelburne Basin Venture Exploration Drilling Project operated by Shell Canada Ltd., were plugged, and abandoned along with their sidetracks (CNSOPB 2019). The third exploration well (Aspy D-11, also sidetracked) operated by BP Canada Energy Group was reported to be devoid of commercially viable volumes of hydrocarbon.

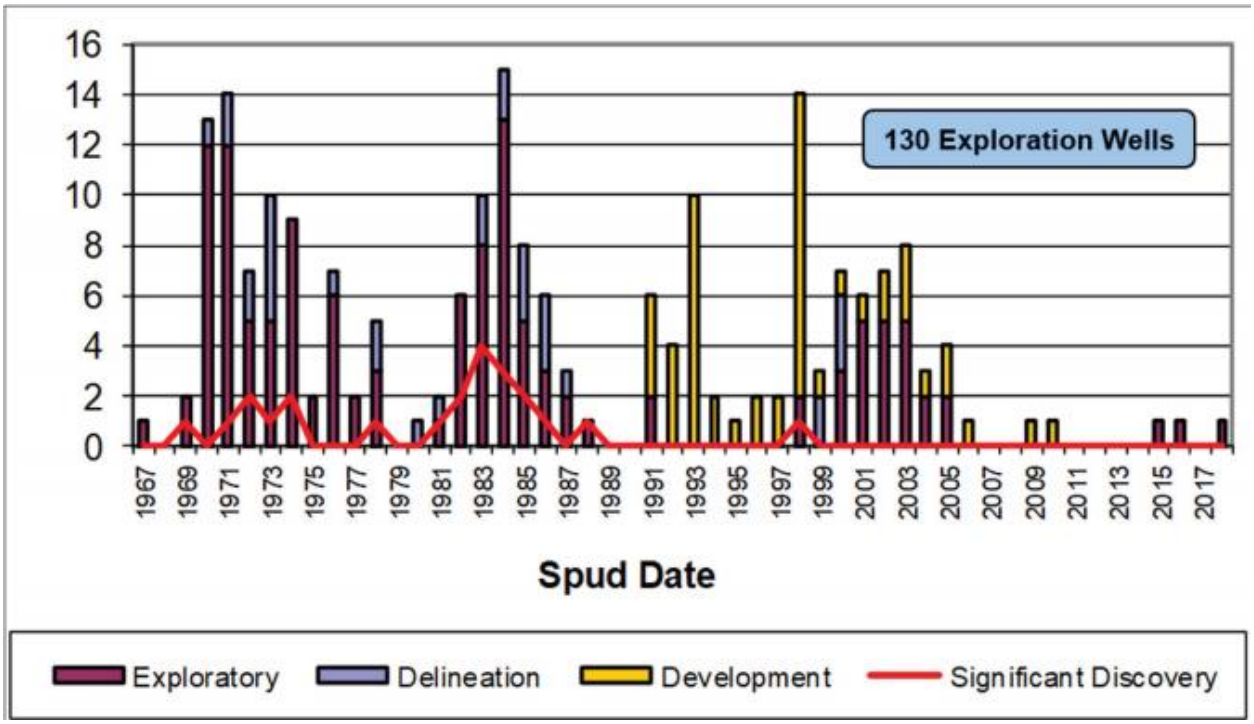

Figure 3: A bar graph of the wells drilled offshore Nova Scotia. The curve in red illustrates the significant discoveries and phases of exploration (CNSOPB 2019).

Conclusions

There has been a half century of exploration and development offshore Nova Scotia since 1959. There have been 210 wells drilled, with the majority in the Sable Subbasin, and most before 1986 (CNSOPB 2019). Prior to 2000, a 1 in 5 exploration success rate on the Scotian Margin was achieved despite using relatively poor quality 2D seismic data.

The fourth round of exploration has ended, testing play concepts in the challenging deep water Scotian Slope region, with no significant hydrocarbon discoveries. In 2005, Enachescu and Wach asked *Quo vadis (where do we go from here)?* and there was soon another exploration cycle. Driven by the World's insatiable demand for energy, with daily consumption of 100 million bbls of oil (IEA, 2019), will it be long before the next exploration cycle begins in these proven petroleum basins?

Figure 4: The decommissioned Deep Panuke field production platform in Halifax Harbour August 2020 (Photo credit Kristie McVicar).

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