

EXPLORATION & PRODUCTION HISTORY of the NOVA SCOTIA OFFSHORE AREA - December 2018

Hydrocarbon exploration offshore Nova Scotia began in 1959, with four distinct cycles of activity since that time. To date, 210 wells have been drilled since the first in 1967, with 124 being exploration, 29 delineation, and 57 development. To date, twenty-three significant and eight commercial hydrocarbon discoveries have been made with additional wells encountering numerous oil and gas shows (CNSOPB, 2000, Smith et al., 2014). Total 2D and 3D seismic data acquired from 1960-2018 is 401,651.2 km and 48,376.9 km² respectively.

Exploration Cycle 1 – 1960-1978

The initial exploration cycle commenced with the awarding of exploration licences to Mobil Oil Canada for the Sable Island region on the shallow water Scotian Shelf in 1959. Subsequent magnetic, gravity and seismic surveys lead to the drilling of the first well Sable Island C-67 on Sable Island in 1967 confirming the existence of a thick Tertiary-Mesozoic stratigraphic succession (Sable Delta) with gas and oil shows. Further licences were awarded to industry, specifically Shell, and the seismic coverage expanded rapidly to cover most of the margin. Between 1967 and 1978, 71 wells were drilled of which 57 were wildcats and 14 delineation, and over 140,000 km of 2D seismic acquired. A number of play concepts were tested, focusing on easily imaged salt structures using the successful Gulf of Mexico analogues, as well as rollover anticlines, drape over basement features and the carbonate bank margin structures. Of the 28 wells drilled in the salt structure play, three significant discoveries were made: Onondaga E-84 (Shell, 1969 - gas), Primrose A-41 (1972, Shell - oil & gas), and on the western end of Sable Island at Sable 1H-58 (Mobil, 1971 - oil & gas).

In 1972, Mobil tested a new play concept involving rollover anticlines associated with down-to-the-basin listric faults in the Sable Subbasin, thus far the most prolific depocentre in the basin. The Thebaud P-84 well made a major gas discovery in the fluvial-deltaic sandstones of the Early Cretaceous Missisauga and Late Jurassic Mic Mac formations. The next year, Mobil tested another play concept, with their Cohasset D-42 well discovering light oil in a subtle drape structure of Logan Canyon Formation fluvial and marine sandstones above the Late Jurassic Abenaki Formation carbonate bank margin. At the end of this exploration cycle, additional exploration of the rollover anticline play resulted in significant gas discoveries by Mobil at Citnalta I-59 (1974) and Intrepid L-80 (1974). Hydrocarbon shows in various play types were recorded by Shell in their Cree E-35 (1970, gas), Mic Mac J-77 (1970, oil), Triumph P-50 (1971, gas), Wyandot E-53 (1970, oil), Erie D-26 (1971, oil), Marmora C-34 (1972, gas), and Eagle D-21 (Shell, 1972 - gas) wells. Mobil had a gas show in its Bluenose G-47 well (1973).

Exploration Cycle 2 – 1979-1988

Sparking the second exploration cycle was the major gas discovery in 1979 at Venture by Mobil and Petro-Canada in very shallow waters just east of Sable Island. This was a continuation of the increasingly successful rollover anticline play with the Venture D-23 well encountering multiple Early Cretaceous Missisauga Formation sandstone reservoirs

with very high flow rates (e.g. Sand 3a: 22.2 MMscf/d, 278 Bbls/d condensate). The Venture well discovered in a single well about the same total amount of gas that had been found to date in the Sable Subbasin.

Throughout the 1980s, Mobil, its partners, and other companies delineated existing discoveries, drilled deeper to new gas-charged highly overpressured siliciclastic reservoirs and other anticlinal structures (e.g., Venture B-13, B-43, B-52 and H-22, and Thebaud I-94, I-93 and C-74). A number of companies and their partners made major gas discoveries in the Sable Subbasin in rollover anticlines along several northeast-southwest striking major growth faults trends north and south of Sable Island with Early Cretaceous productive zones stepping up stratigraphically towards the basin's outer margin:

- Mobil: Arcadia J-16 (1983), South Venture O-59 (1983), Olympia A-12 (1983), West Venture C-62 and N-91 (1985), West Olympia O-51 (1985), and South Sable B-44 (1988)
- Shell: Glenelg J-48 (1983), Uniacke G-72 (1984), Alma F-67 (1984), and North Triumph G-43 (1986)
- Petro-Canada: Banquereau C-21 (1982)
- Husky-Bow Valley: Chebucto K-90 (1984)

Shell's light oil (ca. 55°API) find in Early Cretaceous Missisauqua Formation transgressive sands within a shallow drape structure at Panuke B-90 (1986), and earlier in the shallow rollover anticline at Penobscot L-80 (1976), confirmed the on-trend extension of this basin hingeline margin oil fairway first discovered in 1973 by Mobil at their Cohasset D-42 well.

Stepping out of the Scotian Basin, Murphy and Shell drilled a very large fault-bounded basement horst with drape closure incorporating presumed Early Permian to earliest Mississippian age sediments in the Carboniferous Sydney Basin. Targeted reservoirs were postulated to exist within two successions: Early Mississippian Windsor Group porous shallow marine carbonates, and Horton Group latest Devonian-Early Mississippian lacustrine and fluvial sandstones. The North Sydney P-05 well (1974) drilled through a succession of Pennsylvanian fluvial sandstones, shales and coals with many gas peaks on mud-gas logs, though none were tested. Two years later, Shell and Murphy drilled the North Sydney F-24 well (1976) close to P-05 and slightly off the crest of the structure to flow test the sandstone F-24 pay zones. Gas was found throughout the pay section though the sands had low porosity and gas was likely from coals. Two sands were tested that included acidizing and fracking but no gas flowed to surface.

Following acquisition of new 2D seismic along the deep water Scotian Slope, the Shubenacadie H-100 (Shell, 1983), Evangeline H-98 (Husky, 1984), and Tantallon (Shell, 1986) deepwater wells were drilled to test possible Tertiary and Cretaceous turbidite fan plays but were unsuccessful. At the end of this second cycle that ended due to the fall of oil and gas prices, 39 exploration and 13 delineation wells were drilled resulting in 15 significant discoveries and a number of oil and gas shows.

Exploration Cycle 3 – 1990-2005

The third exploration cycle was a two-prong campaign with drilling on the shallow Scotian Shelf and deepwater Scotian Slope, and, the development of several significant oil and gas discoveries. In late 1989, LASMO and partner Nova Scotia Resources (Ventures) Limited announced plans to develop the light oil discoveries at Cohasset and Panuke (Cohasset-Panuke 'COPAN' Project), and in 1996 and Mobil, Shell, and partners filed a development plan to produce six gas-condensate fields in the Sable Island area (Sable Offshore Energy Project) (SOEP, 1997). LASMO initiated the exploration cycle with the drilling of two wells to test related shallow drape structures near the Cohasset and Panuke discoveries, with more light oil found at Balmoral M-32 adjacent to the Cohasset field in 1991.

In 1998, production at the COPAN fields was nearing the end of production due to high water production, ultimately producing 44.5 MMBbls (7.1 E6M3) of high gravity light oil from 1992-1999. During that year, PanCanadian (now EnCana), the operator of the COPAN project since January 1996, sought additional oil reserves and drilled an amplitude anomaly beneath the Panuke field. The Panuke PP3C well made a significant discovery of slightly sour (0.2% H₂S) gas in dolomitized and leached limestones of the Late Jurassic Abenaki reef margin. From 1999-2005 they drilled a number of follow-up wells to define the areal extent of the Deep Panuke gas field. In November 2006, EnCana in their Development Plan Application stated that the Deep Panuke field contained 28.9 E9M3 (1027 Bcf) of mean in-place gas with mean recoverable reserves of 18.6 E9M3 (659 Bcf) (EnCana, 2006). In 2001, EnCana drilled an exploration well (Queensland M-88) near Deep Panuke to test for by-pass sands in front of the carbonate bank and encountered a thin low quality gas-charged sand that demonstrated the potential viability of this play concept. In 2001, EnCana drilled Southampton A-25 to test for hydrocarbons in Missisauga sands trapped in a fault dependent closure near Shell's Onondaga E-84 (1970) discovery. Southampton encountered reservoir quality sands but all zones were wet. In partnership with Marauder Energy, the Dominion J-14 well (2016) sought to extend the Deep Panuke field along strike northeast of the field's limit towards Cohasset. The prospect was a significant seismic amplitude interpreted as a highly porous reservoir interval that turned out to be a shale plug within an intra-margin channel. The well was deviated (Dominion J-14A) to seek an adjacent porous zone but was unsuccessful.

Following the December 1999 start of production at their Sable Offshore Energy Project, Mobil (now ExxonMobil) and partners initiated an exploration program to test a number of large rollover anticlinal structures near their producing fields. Adamant N-97 (2001) and Cree I-34 (2004) encountered gas pay in a number of the fluvial deltaic sands of the Missisauga and Mic Mac formations, however these zones' total recoverable reserves were not deemed to be commercial. In 2001, Shell drilled Onondaga B-84 primarily to test for deeper lower Missisauga deltaic sands trapped against the flank of the Onondaga salt dome. In the target interval, only a few poor quality gas-bearing zones were present. Other explorers such as Canadian Superior and El Paso tested a Deep Panuke Abenaki carbonate analogue at Marquis L-35/L-35A (2002) but were unsuccessful. At Mariner I-85 (2004) the companies drilled a rollover anticline northeast of Sable Island and discovered several low to modest quality gas-bearing zones in the Jurassic Mic Mac Formation deltaic sandstones.

In the late 1990s, large areas of the deepwater Scotian Slope were licenced by industry. Six deepwater wells were drilled between 2002 and 2004 with four targeting large anticlinal features related to salt withdrawal. The initial well results were encouraging, with Marathon discovering a total of 27 m of net gas pay over three Logan Canyon Formation sandstone intervals in Annapolis G-24 (2002). Chevron's Newburn H-23 (2002) encounter several thin, gas-bearing reservoir sands in upper Missisauga and lower Logan Canyon formation equivalents. The other two wells targeting salt withdrawal features - Balvenie B-79 (Imperial, 2003) and Crimson F-81 (Marathon, 2004) – with both failing to encounter any significant gas-bearing reservoir sands. EnCana drilled an interpreted Tertiary fan on the western portion of the Scotian Slope at Torbrook C-15 (2003) that was determined to be a slump feature. They later drilled a large anticlinal subsalt closure at Weymouth A-45 (2004) but failed to find any Missisauga Formation reservoir sands. Kidston et al., (2007) provide details on the results of deepwater drilling up to 2004.

Exploration Cycle 4 – 2006-present

In 2012, Shell was awarded four large Exploration Licences (ELs) in the southwestern portion of the Scotian Slope and the following year Shell acquired two additional deepwater ELs and two ELs in the Sable Subbasin. In 2013, BP acquired four large ELs east of Shell's deepwater licences on the Scotian Slope. Two deepwater ELs east of Georges Bank were awarded to Equinor (formerly Statoil) in January 2016. Both Shell (2013) and BP (2014) completed large 3D Wide Azimuth seismic programs over their deepwater ELs covering 10,850 km² and 8,502 km² respectively.

Shell and partners ConocoPhillips Canada and Suncor Energy Canada spudded the Cheshire L-97 well in 2,141 metres of water about 250 km southwest of Sable Island. The well was designed to test lower Cretaceous turbidites equivalent to the productive Missisauga Formation deltaic successions in the Sable Subbasin. Secondary targets were upper and middle Jurassic sandstones, with the structure related to salt withdrawal and onlap and closure of reservoirs against Argo Formation salt. No significant reservoir sands or shows were present in the targeted interval. Drilling issues resulted in sidetracking the wellbore (L-97A) that reached a total depth of 7068 m MD in Middle Jurassic Abenaki Formation equivalent limestones. Following completion of the Cheshire L-97/L-97A well, Shell moved its drilling unit approximately 120 km to the west to drill Monterey Jack E-43. The well was subsequently sidetracked (E-43A) and was plugged and abandoned on January 21, 2017. On April 22, 2018, BP and partner Hess spudded the Aspy D-11 well in 2771 m of water.

Gas production from the five SOEP fields began in December 1999 and up to November 2018 had produced 2.09 Tcf (59 E9M3) of gas. By early December 2018, the production wells in the Thebaud and North Triumph fields have been abandoned. At present, well abandonment operations are underway at the Venture field while Alma and South Venture are expected to remain on production until the end of December 2018. Deep Panuke gas production began in August 2013 and terminated in May 2018. Deep Panuke produced a total of 145.6 Bcf of gas (CNSOPB website).

REFERENCES

Canada-Nova Scotia Offshore Petroleum Board, 2013

Call for Bids NS13-1 Information Package.

<http://www.callforbids.cnsopb.ns.ca/2013/01/>

Canada-Nova Scotia Offshore Petroleum Board, 2000

Technical Summaries of Scotian Shelf Significant and Commercial Discoveries.

Canada-Nova Scotia Offshore Petroleum Board, Halifax, 257p. Available online at www.cnsopb.ns.ca

EnCana Corporation, 2006

Deep Panuke Offshore Gas Development – Development Plan Application - Volume 2

Canada-Nova Scotia Offshore Petroleum Board, Halifax, Nova Scotia, 293p. Available online at www.cnsopb.ns.ca

Kidston, A.G., Brown, D.E., Smith B.M. and Altheim, B., 2005

The Upper Jurassic Abenaki Formation Offshore Nova Scotia: A Seismic and Geologic Perspective.

Canada-Nova Scotia Offshore Petroleum Board, Halifax, 165p. Available online at www.cnsopb.ns.ca

Kidston, A.G., Brown, D.E., Smith B.M. and Altheim, B., 2002

Hydrocarbon Potential of the Deep-Water Scotian Slope.

Canada-Nova Scotia Offshore Petroleum Board, Halifax, 111p. Available online at www.cnsopb.ns.ca

Kidston, A.G., Smith, B., Brown, D.E., Makrides, C. and Altheim, B., 2007

Nova Scotia Deep Water Offshore Post-Drill Analysis - 1982-2004.

Canada-Nova Scotia Offshore Petroleum Board, Halifax, Nova Scotia, 181p. Available online at www.cnsopb.ns.ca

LASMO Nova Scotia Limited, 1990

Cohasset-Panuke Development Project – Development Plan Part I.

Canada-Nova Scotia Offshore Petroleum Board, 985p. Available online at www.cnsopb.ns.ca

Sable Offshore Energy Project (SOEP), 1997

Development Plan Application – Volume 2: Sable Offshore Energy Project.

Canada-Nova Scotia Offshore Petroleum Board, 245p. Available online at www.cnsopb.ns.ca

Smith, B.M., Makrides, C., Altheim, B. and Kendell, K., 2014

Resource Assessment of Undeveloped Significant Discoveries on the Scotian Shelf.

Canada Nova Scotia Offshore Petroleum Board, 182p. Available online at www.cnsopb.ns.ca