Success and Failure in the Deepwater Norphlet Play, United States Gulf of Mexico

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GCAGS Explore & Discover Article #00391*
http://www.gcags.org/exploreanddiscover/2018/00391_smith.pdf
Posted September 29, 2018.

*Article based on an extended abstract published in the *GCAGS Transactions* (see footnote reference below), which is available as part of the entire 2018 *GCAGS Transactions* volume via the GCAGS Bookstore at the Bureau of Economic Geology (www.beg.utexas.edu) or as an individual document via AAPG Datapages, Inc. (www.datapages.com), and delivered as an oral presentation at the 68th Annual GCAGS Convention and 65th Annual GCSSEPM Meeting in Shreveport, Louisiana, September 30–October 2, 2018.

EXTENDED ABSTRACT

The deepwater Norphlet play is active in the Mississippi Canyon (MC) and DeSoto Canyon (DC) protraction areas (Fig. 1) in the Outer Continental Shelf (OCS) of the United States Gulf of Mexico (GoM). At present, there have been 6 companies that have drilled 19 wildcats including 7 discoveries (Table 1). Resources estimated at the Appomattox and Vicksburg fields alone are 650 million barrels of oil equivalent (Shell, 2015) with first production scheduled for 2020 (Offshore, 2018). The petroleum system contains Oxfordian-aged source, reservoir, and seal, with Late Jurassic–Early Cretaceous trap formation and mid-Cenozoic oil generation and expulsion (Fig. 2).

The deepwater Norphlet Sandstone is reworked alluvium from terranes to the north and east as determined from detrital zircon analysis (Weislogel et al., 2015). The sand sheets were reworked into ergs, dunes, and inter-dune wadis, often overlaying the finer-grained alluvium. The diverse paleogeography results in a range of reservoir characteristics from excellent in the west to poor in the southeast where sediments are finer-grained (Fig. 1). Chemical precipitates (primarily quartz, halite, and magnesium chlorite cements) and solid hydrocarbons (SHCs) clog pore throats where present, greatly reducing permeability and effective porosity. The Norphlet pore pressure being underpressured may also enhance the precipitation of SHCs. Wireline logs in the Norphlet wells indicate very low formation water resistivity (Rw), interpreted by the Bureau of Ocean Energy Management (BOEM) to be salt dissolution from the Louann Salt that is in contact with the bottom of the Norphlet. The Louann was a syn-rift, likely sag phase evaporite, deposited during thermal contraction of the basin (Fig. 2).

Post-Norphlet marine transgression quickly buried the dunes leaving the geomorphology well preserved (Godo, 2017). The play is sourced by the overlying Oxfordian-aged Smackover carbonate (Fig. 2). BOEM often refers to a separate basal unit interpreted on a strong wireline log signature, from the rest of the Smackover. Source potential is present from the upper section of the Basal Smackover through the lower section of the Smackover (Fig. 3). The laminated marls deposited during maximum flooding are organically the richest. Kerogens are predominately an oil-prone, type IIS as determined from hydrogen index (HI), pseudo van Krevelen diagrams, S_2 vs. TOC plots, and S_2/S_3 ratios (Figs. 4 and 5). T_{max} (Fig. 4) and vitrinite reflectance are in the oil window

Originally published as: Smith, D. J., 2018, Success and failure in the deepwater Norphlet play, United States Gulf of Mexico: Gulf Coast Association of Geological Societies Transactions, v. 68, p. 635–642.

for much of the play. Thermal maturity may be inadequate however, in the southeast area (Fig. 1) where overburden thicknesses decrease.

Differential loading from hundreds of feet of Norphlet and Smackover deposited on the Louann, led to the formation of salt rollers. Extensional faulting separated these salt-cored structures into "rafts" as they moved tens of miles basinward. The gravitational sliding created thin-skinned, thrust faulting downdip as rafted material came into contact with emplaced sediment. This allowed hydraulic communication between the stratigraphically younger Smackover source and the older Norphlet reservoir. Movement was greatest during the Late Jurassic and Early Cretaceous, as observed in the sediment growth structures on the seismic and as published by Pilcher et al. (2014). To the west where salt volume increases, diapirism occurs and growth structures continue into the Cenozoic. Geohistory modeling of geochemical data from select wells indicates hydrocarbon generation and expulsion peaking during the Miocene on average, ~100+ Ma after structures were emplaced. With the Smackover source self-sealing and shales of the overlying Haynesville Formation providing an additional seal, lack of migration pathways are suspected for the absence of hydrocarbons in wells penetrating reservoir quality Norphlet. The lower Basal Smackover does not generate significant hydrocarbons based on modeled geochemical data. Therefore this non-source, low porosity section, separates the source and reservoir, obstructing a direct downward charge. The minimal fluorescence and solid hydrocarbons observed make a breached seal interpretation unlikely.

Data available to BOEM and used in this assessment included seismic data, cores, cuttings, scanning electron microscope (SEM) images, X–ray diffraction (XRD), pore throat diameter histograms, and electronic wireline logs including nuclear magnetic resonance (NMR). Analogues including the Gulf Coast onshore Norphlet and Smackover plays and the Mexican Campeche play were used in our analysis.

The Deepwater Norphlet play has the sixth largest undiscovered technically recoverable resources (UTRRs) of any GoM play as of BOEM's most recent assessment (Fig. 6). Determined from data through the end of 2013, 60 undiscovered pools with a mean of 5.1 billion barrels of oil equivalent were projected for its UTRR (Fig. 6). Four discoveries and several hundred feet of net pay on average have since been reported in public press releases. Available data demonstrates reservoir quality and hydrocarbon migration pathways as the limiting conditions for success. Familiarity with the depositional environment of the Norphlet and good seismic coverage are consequential to mitigating geologic exploration risk.

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