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National and Global Petroleum Assessment

Assessment of Undiscovered Conventional Oil and Gas Resources in the Norphlet Formation, U.S. Gulf Coast Region, 2023

*U*sing a geology-based assessment methodology, the U.S. Geological Survey (USGS) estimated undiscovered, technically recoverable mean resources of 16 million barrels of oil and 348 billion cubic feet of gas in conventional reservoirs of the Norphlet Formation in the U.S. Gulf Coast region.

Introduction

Sediments of the Norphlet Formation were deposited in the Late Jurassic (Oxfordian) and are composed predominantly of sandstones, conglomerates, and associated fine-grained continental sediments. In the U.S. Gulf Coast region, the Norphlet is only present in the subsurface in a linear northwest–southeast fairway across the eastern half of the Louisiana-Mississippi Salt Basins Province, primarily in Mississippi, Alabama, and Florida, in an area with the same general bounds as the assessment units (AUs) shown in figure 1. Continental sediments coeval with the Norphlet are present across the Gulf Coast rim into Arkansas and Texas (Newkirk, 1971; Budd and Loucks, 1981). Updip, the Norphlet onlaps onto Paleozoic basement, and downdip, the Norphlet grades into time-equivalent marine rocks of the Smackover Formation.

As many as 400 wells have been drilled in the Norphlet to date, resulting in cumulative production of approximately 66 million barrels of oil (MMBO) and 6 trillion cubic feet of gas (TCF; Nehring Associates, Inc., 2018; S&P Global Commodity Insights, 2023).

The USGS has assessed the petroleum potential (undiscovered resources contained in fields greater than minimum size) of the Norphlet in the 1990s and 2010s. As part of a wider Gulf Coast assessment, Schenk and Viger (1995a, b) divided the Norphlet into five AUs in Alabama, Mississippi, and Florida. A sixth AU spanning the Louisiana–Arkansas border into Texas was not quantitatively assessed. Pearson (2011) assessed the Norphlet as containing means of 87 MMBO and about 3.5 TCF gas in three quantitatively assessed AUs, including a new AU in south Texas that was proposed to contain gas and natural gas liquids (NGL). Continued exploration and development, including offshore discoveries far from onshore production, have necessitated a reevaluation of the Norphlet Formation.

Geologic Model for Assessment

The Norphlet Formation is between 10,000 and 27,000 feet (ft) deep in the Gulf Coast area, and is underlain by Paleozoic basement, discontinuous clastics of the Triassic to Early Jurassic Eagle Mills Formation, and the Jurassic Louann Salt (Salvador, 1987). In the Late Jurassic during Norphlet deposition, the Gulf of Mexico was an incipient rift basin that was formed as Gondwana separated from the rest of Pangaea (Lovell and Weislogel, 2010; Scotese, 2013). Erosion of the southern Appalachian Mountains led to the deposition of lithologically immature conglomeratic alluvial fans onshore on the northern margin of the rift basin. Arid conditions, combined with favorable wind directions and topography, resulted

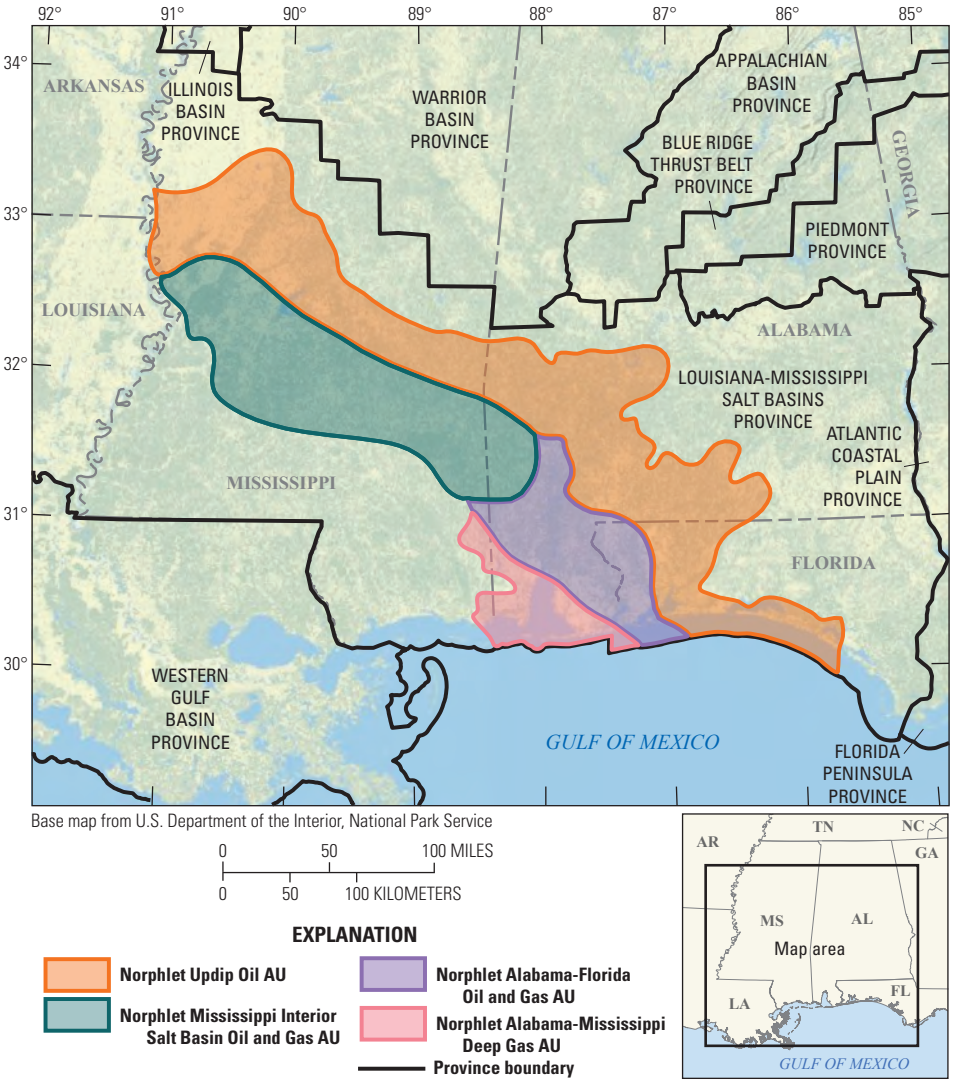

Figure 1. Map showing the location of four Norphlet Formation assessment units (AUs) in the Louisiana-Mississippi Salt Basins Province, U.S. Gulf Coast region.

in the development of a large eolian sand sea (erg) at the foot of the mountain chain (Hunt and others, 2017), comparable to ergs in modern desert environments (for example, Namibia). Within the erg, sand dunes and associated continental dryland environments formed the part of the Norphlet that contains modern petroleum reservoirs. Sabkhas and marginal-marine environments formed at the southern edge of the erg adjacent to the restricted marine environment of the incipient Gulf of Mexico where carbonates were deposited (Snedden and others, 2021). Climate change, latitudinal shifts in continental positions, and a global transgression led to reworking of sands in places in the upper part of the Norphlet. Clastic deposition ultimately ended and deposition began of a thick sequence of carbonates of the Smackover Formation (Peterson, 1988).

Erg sandstones in the Norphlet are highly variable in thickness, ranging from less than 100 ft to greater than 700 ft (Marzano and others, 1988). Thickness of the unit is affected by basement topography; areas of thinning or nondeposition are present on arches and basement highs, and thicker depocenters occur in lower areas. Movement of the Louann Salt has also locally affected the structure and thickness of the Norphlet, where diapiric rises of salt have created three- and four-way closures that form important trapping components of the petroleum system. Reservoir quality is considered best in erg and reworked sandstones where porosity is maintained by early chlorite overgrowths that inhibited later cementation. Updip conglomeratic and alluvial facies outside of the erg system are generally not considered prospective. There are no eolian dune sandstones reported in the Norphlet dune sands in the Norphlet west of the present Mississippi River. Descriptions of Norphlet-equivalent rocks from the Louisiana-Arkansas-Texas region indicate the presence of conglomeratic, muddy, or lithologically immature sands that likely lack the characteristics required for porosity creation and preservation (Newkirk, 1971; Snedden and others, 2021). Additionally, the Norphlet thins to the west to less than 100 ft in some places. Thus, areas outside of the fairway in the eastern part of the Gulf Coast, including those portions of past assessments, were not considered here because of the lack of evidence as being part of a viable petroleum system.

Oil and gas in porous erg sandstones of the Norphlet are sourced from the overlying organic-rich shales of the Smackover Formation, which has the appropriate organic content and thermal maturity to have produced oil and gas (Claypool and Mancini, 1989; Sassen, 1990; Godo, 2019). The Norphlet produces oil, natural gas, and natural gas liquids (NGL) across the fairway and has a clear gradient in thermal maturity increasing to the southwest with a related change in petroleum type from oil to NGL to dry gas as the formation becomes deeper and hotter toward its southwestern margin. Thermal maturity modeling for the Norphlet in the Norphlet Mississippi Interior Salt Basin Oil and Gas AU indicates petroleum generation began in the Early Cretaceous (Mancini and others, 2003), and migration likely occurred shortly thereafter into areas of underpressured, porous sandstones of the Norphlet. Oil and gas fields are presently concentrated along regional strike-parallel normal fault systems, where fault-bounded salt anticlines provide the mechanism for conventional hydrocarbon trapping.

In the 2000s, oil was discovered in the Norphlet in the Federal waters offshore (Godo, 2019), and continued development resulted in the highest producing oil wells in the Norphlet (S&P Global Commodity Insights, 2023). Norphlet facies in this offshore area are also eolian, but lie on top of large, rafted blocks of salt that have moved laterally for 25–30 kilometers (Pilcher and others, 2014). Because this type of salt-tectonic movement is not present within the onshore assessment area, these discoveries do not change the geologic model used for the assessment.

Assessment Units

The USGS defined four conventional AUs for the Norphlet Formation. Potential numbers and sizes of undiscovered fields are shown in table 1 and in Counts (2024).

The Norphlet Updip Oil AU primarily contains proximal continental facies that generally lack reservoir potential. The facies change between alluvial fan conglomerates and eolian sandstones is gradational and occurs approximately at the southwest AU boundary; interfingering cleaner sands with less clay content may be present and productive near this AU boundary, as is the case for the large Flomaton gas field. Additionally, cleaner sands may be present elsewhere within the AU as small fluvial bodies surrounded by lower quality rock, as Dean (1998) hypothesized to be the case for the Excel and Excel North fields. The northwest boundary of this AU is defined by the depositional limits of the Norphlet where alluvial sediments onlap onto Appalachian bedrock. The downdip boundary roughly coincides with the change in facies to an erg environment, and approximately overlies the peripheral fault system that runs along strike. The northwest and southeast boundaries of the AU mark the limits of the erg and the 3-mile State water boundary,

Table 1. Key input data for four conventional assessment units in the Norphlet Formation.

[Gray shading indicates not applicable. AU, assessment unit; MMBO, million barrels of oil; BCFG, billion cubic feet of gas]

Assessment input data—Conventional AUs	Norphlet Updip Oil AU				Norphlet Mississippi Interior Salt Basin Oil and Gas AU			
	Minimum	Median	Maximum	Calculated mean	Minimum	Median	Maximum	Calculated mean
Number of oil fields	1	2	8	2.2	1	3	30	3.9
Number of gas fields					1	3	30	3.9
Size of oil fields (MMBO)	0.5	1	10	1.3	0.5	1	60	2.1
Size of gas fields (BCFG)					3	6	400	12.8
AU probability	0.9				1.0			
Assessment input data—Conventional AUs	**Norphlet Alabama-Florida Oil and Gas AU**				**Norphlet Alabama-Mississippi Deep Gas AU**			
	Minimum	Median	Maximum	Calculated mean	Minimum	Median	Maximum	Calculated mean
Number of oil fields	1	2	10	2.3				
Number of gas fields	1	2	10	2.3	1	6	18	6.4
Size of oil fields (MMBO)	0.5	1	60	2.1				
Size of gas fields (BCFG)	3	6	400	12.8	3	12	2,000	40.8
AU probability	1.0				1.0			

respectively. Because most of this AU is updip, is in the least thermally mature area of the play, and is in the oil maturity window (gas production from Flomaton field is on the downdip edge of the AU), this AU was not assessed for nonassociated gas fields.

The Norphlet Mississippi Interior Salt Basin Oil and Gas AU overlaps with the northern part of the Mississippi Interior Salt Basin. This basin is characterized by the presence of mobile salt, which may form diapiric structures that intrude overlying stratigraphy into shallow levels. At deeper depths, salt movement may also occur to a lesser degree, potentially forming structures affecting the Norphlet. Linear salt stocks separated by anticlines (turtle structures) are also present within the AU. These features all have the potential to trap hydrocarbons in the Norphlet. The northwest boundary of this AU is the border with the Norphlet Updip Oil AU, corresponding to the erg margin and the peripheral fault system. The southeast boundary approximately corresponds to the Mississippi Interior Salt Basin boundary, and downdip, the erg transitions into marine sediments, forming the southeast boundary of the AU. Both oil and gas potential were assessed in this AU.

The Norphlet Alabama-Florida Oil and Gas AU lies adjacent to and approximately along strike with the Norphlet Mississippi Interior Salt Basin Oil and Gas AU and has a similar updip boundary. The southeast boundary is the limit of the State waters boundary, and the southwest boundary is coincident with the Norphlet Alabama-Mississippi Deep Gas AU. This unit lies between areas dominated by oil and gas production, and contains Hatters Pond Field, which produces primarily natural gas liquids. Potential traps include salt-cored, faulted anticlines, although salt structures are likely to be less abundant than in the adjacent Mississippi Interior Salt Basin Province.

The Norphlet Alabama-Mississippi Deep Gas AU is relatively small and is primarily located in Baldwin and Mobile Counties, Alabama. This AU is the site of significant natural gas production from some of the deepest Norphlet wells, many of which are located offshore in the shallow State waters of Mobile Bay. Production from this area is almost exclusively dry gas, and can be traced to linear dune forms that subsided into the Louann Salt and are preserved in the subsurface (Ajdukiewicz and others, 2010). The boundaries of this AU are the State waters boundary to the south, the updip boundary with the Norphlet Alabama-Florida Oil and Gas AU to the north, and the limits of the erg environment to the west.

Undiscovered Resources Summary

The USGS quantitatively assessed four conventional AUs for undiscovered oil and natural gas resources in the Norphlet Formation. The estimated mean total resources in all four AUs are 16 million barrels of oil (MMBO), 348 billion cubic feet of gas (BCFG), and 19 million barrels of natural gas liquids (MMBNGL) (tables 1, 2; Counts, 2024). These numbers are smaller than previous estimates of the undiscovered resources in the unit, primarily due to the reduced size of the overall AU area and the lower estimates of both field numbers and mean field sizes in each AU.

Table 2. Results for four conventional assessment units in the Norphlet Formation.

[Results shown are fully risked estimates. F95 represents a 95-percent chance of at least the amount tabulated; other fractiles are defined similarly. Gray shading indicates not applicable. MMBO, million barrels of oil; BCFG, billion cubic feet of gas; NGL, natural gas liquids; MMBNGL, million barrels of natural gas liquids]

Assessment units (AUs)	AU probability	Accumulation type	Total undiscovered resources											
			Oil (MMBO)				Gas (BCFG)				NGL (MMBNGL)			
			F95	F50	F5	Mean	F95	F50	F5	Mean	F95	F50	F5	Mean
Norphlet Updip Oil AU	0.9	Oil	0	2	6	3	0	1	1	1	0	0	0	0
		Gas												
Norphlet Mississippi Interior Salt Basin Oil and Gas AU	1.0	Oil	1	5	26	8	1	2	13	4	0	0	1	0
		Gas					7	30	163	50	1	5	26	8
Norphlet Alabama-Florida Oil and Gas AU	1.0	Oil	1	3	14	5	0	1	7	2	0	0	0	0
		Gas					4	17	94	29	2	7	36	11
Norphlet Alabama-Mississippi Deep Gas AU	1.0	Oil												
		Gas					41	172	798	262	0	0	0	0
Total undiscovered conventional oil and gas resources			**2**	**10**	**46**	**16**	**53**	**223**	**1,076**	**348**	**3**	**12**	**63**	**19**

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For More Information

Assessment results are also available at the USGS Energy Resources Program website at https://www.usgs.gov/programs/energy-resources-program.

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