Assessment of Undiscovered Conventional Oil and Gas Resources in the Offshore Salt Basin Area of Morocco, 2021

Using a geology-based assessment methodology, the U.S. Geological Survey estimated undiscovered, technically recoverable mean resources of 3.8 billion barrels of oil and 20.7 trillion cubic feet of gas offshore of Morocco.

Introduction

The U.S. Geological Survey (USGS) quantitatively assessed the potential for undiscovered, technically recoverable conventional oil and gas resources in the offshore of Morocco (fig. 1). Rift basins in this area were initiated in the Triassic as Africa began to separate from North America, forming northeast-southwest and north-south oriented horsts and grabens (Guiraud, 1998; Hafid, 2000; Ait Brahim and others, 2002; Zühlke and others, 2004). By the Late Triassic, up to 5 kilometers of clastic sediment accumulated in the rifts, which were succeeded by as much as 1.5 kilometers of late synrift salt. With the initiation of seafloor spreading in the Sinemurian (Duval-Arnould and others, 2021), thermal subsidence and subsequent transgression led to the formation of extensive post-rift carbonate platforms and adjacent deep-water basins that persisted through the Early Cretaceous (Hafid, 2000). Organic-rich calcareous shales were deposited in these basins. Continued thermal subsidence caused submergence of the platforms and the progradation of clastic sediments to the deep offshore, forming slope and basin floor clastic systems with potential oil and gas reservoirs (Neumaier and others, 2019). The accumulation of clastic sediments provided the burial necessary to thermally mature Triassic and Jurassic source rocks and generate oil and gas (Davison, 2005). Burial also mobilized and deformed Triassic salts, potentially forming structural traps for migrating oil and gas. In the Late Cretaceous and Paleogene, the opening of the South Atlantic Ocean caused Africa to rotate counterclockwise while moving north, resulting in the diachronous collision of Africa with Europe and closing the western Tethys Ocean. Triassic rifts, including the Atlas rifts of onshore northern Africa, were inverted during this and subsequent phases of collision and contractional deformation as Africa impinged upon an irregular European margin. Erosion during uplift and inversion caused clastic sediments to prograde offshore in the Paleogene and Neogene. These sediments not only form potential reservoirs but may have provided sufficient burial for the thermal maturation of Cenomanian–Turonian source rocks and the generation of oil and gas. Salt mobilization continued through the Neogene (Tari and Jabour, 2008), which may have caused loss of some oil and gas from existing accumulations.

Total Petroleum System and Assessment Unit

The USGS defined a Mesozoic Composite Total Petroleum System (TPS) sourced by Triassic, Lower and Upper Jurassic, and Cenomanian–Turonian organic-rich shales (Morabet and others, 1998). Geochemical data are not available to characterize the source-rock potential of Triassic synrift subsalt lacustrine shales. Lower Jurassic basinal calcareous shales are up to 100 meters (m) thick, contain Type II marine organic matter, and have total organic content (TOC) up to 8 weight percent and hydrogen index (HI) values up to 511 milligrams of hydrocarbon per gram of total organic carbon (mg HC/g TOC), making them the most viable petroleum source rock offshore of Morocco (Davison, 2005). Middle Jurassic shales contain mixed Type II/III (marine/terrestrial) organic matter with TOC values up to 6 weight percent, and HI values as high as 260 mg HC/g TOC, but the shales are less than about 2 m thick and may be too thin to be a viable source rock (Davison, 2005). Oxfordian shales have TOC values as high as 6 weight percent and HI values up to 200 mg HC/g TOC, but they are less than 10 m thick (Herbin and others, 1986; Offshore Energy Research Association, 2016). Cenomanian–Turonian shales in the offshore basin have TOC values as high as 10 weight percent, HI values up to 500 mg HC/g TOC, and thicknesses up to 50 m (Kolonic and others, 2002). Modeling suggests that generation of oil and gas from Triassic, Jurassic, and Lower Cretaceous source rocks may have begun in the Late Cretaceous, and that Cenomanian–Turonian shales may have begun to generate in the offshore during the Neogene (Davison, 2005; Offshore Energy Research Association, 2016).

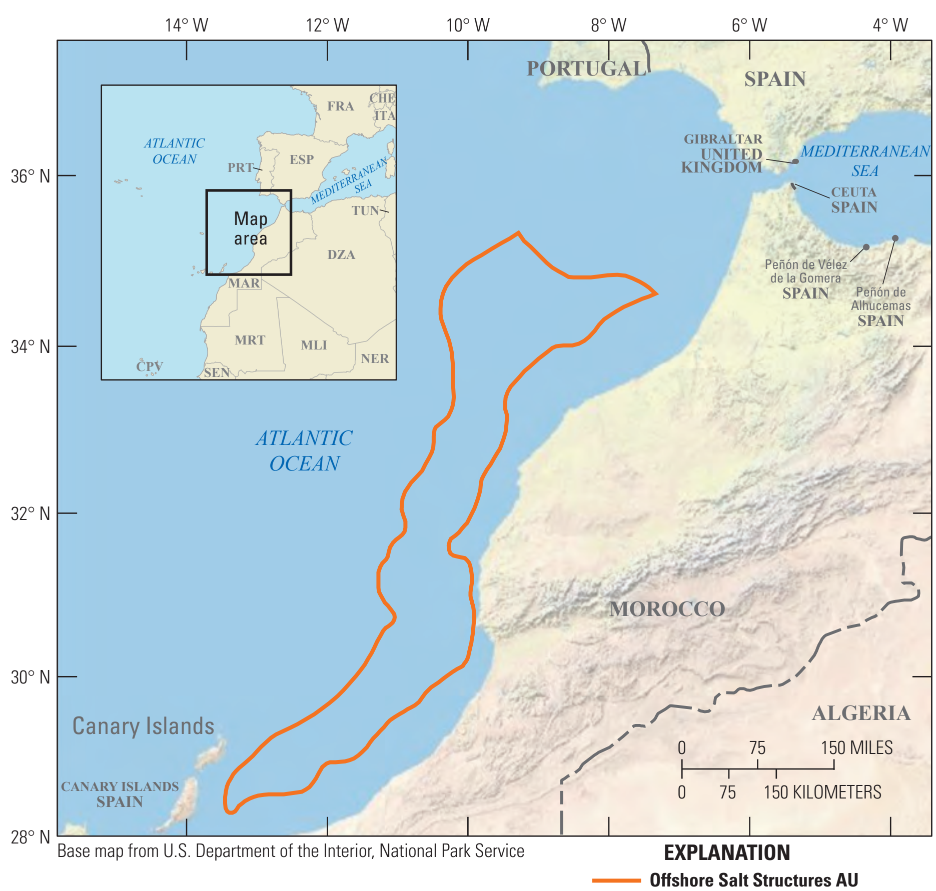

Figure 1. Map showing the location of the Offshore Salt Structures AU offshore of Morocco.

The Offshore Salt Structures Assessment Unit (AU) was defined to encompass oil and gas likely generated from Triassic, Jurassic, Lower Cretaceous, and Cenomanian–Turonian source rocks and migrated into reservoirs within structural and stratigraphic traps. Triassic synrift reservoirs may include alluvial fluvial, deltaic, and lacustrine sandstones within structural and stratigraphic traps, possibly sealed by salt. Lower Jurassic to Lower Cretaceous reservoirs may include carbonate platform-margin reefs, karst zones, off-platform debris flows, and slope-channel and basin-floor sandstones where clastics have bypassed the carbonate shelf margin (Neumaier and others, 2019). The margins of salt diapirs and other structures may be sites for sandstone reservoirs sealed by salt. Basin-floor sandstones, slope-channel sandstones, and sandstones within salt-withdrawal basins may provide reservoirs that are sealed by shales (Neumaier and others, 2019; Duval-Arnould and others, 2021). Contractional deformation in the Neogene caused the formation of anticlines, folds, faults, and faulted anticlines, which may have caused re-migration or loss of previously reservoired and trapped oil and gas. Assessment input data are summarized in table 1 and presented in Schenk (2023).

Table 1. Key input data for the Offshore Salt Structures AU offshore of Morocco.

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

Assessment input data—Conventional AUs	Offshore Salt Structures AU			
	Minimum	Median	Maximum	Calculated mean
Number of oil fields	1	60	180	63.8
Number of gas fields	1	40	120	42.5
Size of oil fields (MMBO)	5	10	6,000	59.7
Size of gas fields (BCFG)	30	60	36,000	358.4
AU probability	0.99			

Undiscovered Resources Summary

The USGS quantitatively assessed undiscovered conventional oil, gas, and natural gas liquid (NGL) resources within the Offshore Salt Structures AU of Morocco (table 2). The fully risked mean totals are 3,776 million barrels of oil (MMBO) or 3.8 billion barrels, with an F95–F5 fractile range from 1,014 to 8,518 MMBO; 20,743 billion cubic feet of gas (BCFG), or 20.7 trillion cubic feet, with an F95–F5 range from 4,952 to 50,363 BCFG; and 1,047 million barrels of natural gas liquids (MMBNGL), or 1.0 billion barrels, with an F95–F5 range from 244 to 2,576 MMBNGL.

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Table 2. Results for the Offshore Salt Structures AU in the offshore of Morocco.

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

Total petroleum system and assessment units (AUs)	AU probabiliy	Accumulation type	Total undiscovered resources											
			Oil (MMBO)				Gas (BCFG)				NGL (MMBNGL)			
			F95	F50	F5	Mean	F95	F50	F5	Mean	F95	F50	F5	Mean
Mesozoic Composite Total Petroleum System														
Offshore Salt Structures AU	0.99	Oil	1,014	3,193	8,518	3,776	1,520	4,784	12,784	5,665	38	120	321	142
		Gas					3,432	12,041	37,579	15,078	206	722	2,255	905
Total undiscovered conventional resources			**1,014**	**3,193**	**8,518**	**3,776**	**4,952**	**16,825**	**50,363**	**20,743**	**244**	**842**	**2,576**	**1,047**

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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