National and Global Petroleum Assessment

Assessment of Undiscovered Conventional Oil and Gas Resources of Offshore East Africa and the Seychelles, 2022

*U*sing a geology-based assessment methodology, the U.S. Geological Survey estimated undiscovered, technically recoverable mean resources of 5.1 billion barrels of oil and 79.1 trillion cubic feet of gas in offshore East Africa and the Seychelles.

Introduction

The U.S. Geological Survey (USGS) assessed the potential for undiscovered, technically recoverable conventional oil and gas resources of offshore East Africa and the Seychelles as part of an ongoing assessment of conventional resources in priority provinces of the world (fig. 1). The tectonic evolution of the East Africa continental margin began in the late Paleozoic with rifting of east Gondwana (Antarctica, Australia, New Zealand, Madagascar, India, Seychelles) from west Gondwana (Africa, South America; Etheve and others, 2021), leading to eventual breakup of east Gondwana into several microcontinents during the Mesozoic (Mahanjane, 2012; Macgregor, 2018; Reeves, 2018; Davison and Steel, 2018; Senkans and others, 2019; Dofal and others, 2021). The following summary of the tectonic evolution of the East African margin is based on these cited references. The evolution of rifting and breakup was influenced by the activity of several mantle plumes or hot spots (Davison and Steel, 2018). The first major phase of rifting lasted from the latest Carboniferous to the Triassic and formed the regionally extensive northeast-trending Karoo rifts, some of which may contain Triassic organic-rich synrift lacustrine shales (Macgregor, 2018). The second phase of rifting was oblique to the Karoo rifts and lasted from Early to Middle Jurassic. Rift basins formed in the second phase may contain organic-rich synrift shales overlain by Upper Jurassic organic-rich shales deposited during a subsequent phase of thermal subsidence (Davison and Steel, 2018). Jurassic organic-rich shales may be the most important petroleum source rocks in the East Africa continental margin (Davison and Steel, 2018). This phase of rifting preceded final breakup and initial seafloor spreading in the Middle Jurassic and formation of oceanic crust in the offshore of Mozambique, with Madagascar separating from West Gondwana along the regional Davies and Mozambique fracture zones. Madagascar ceased moving in the Early Cretaceous (Aptian) and became part of the East Africa continental margin as seafloor spreading shifted to the east of Madagascar. The Karoo and Jurassic rifts are associated with extensive sills, lava flows, and seaward-dipping seismic reflectors interpreted as volcanic rocks that are known to occur throughout the East Africa continental margin.

The third phase of rifting in the Late Jurassic to Early Cretaceous (Oxfordian to Valanginian) was centered on the South Africa continental margin, although it also had expression

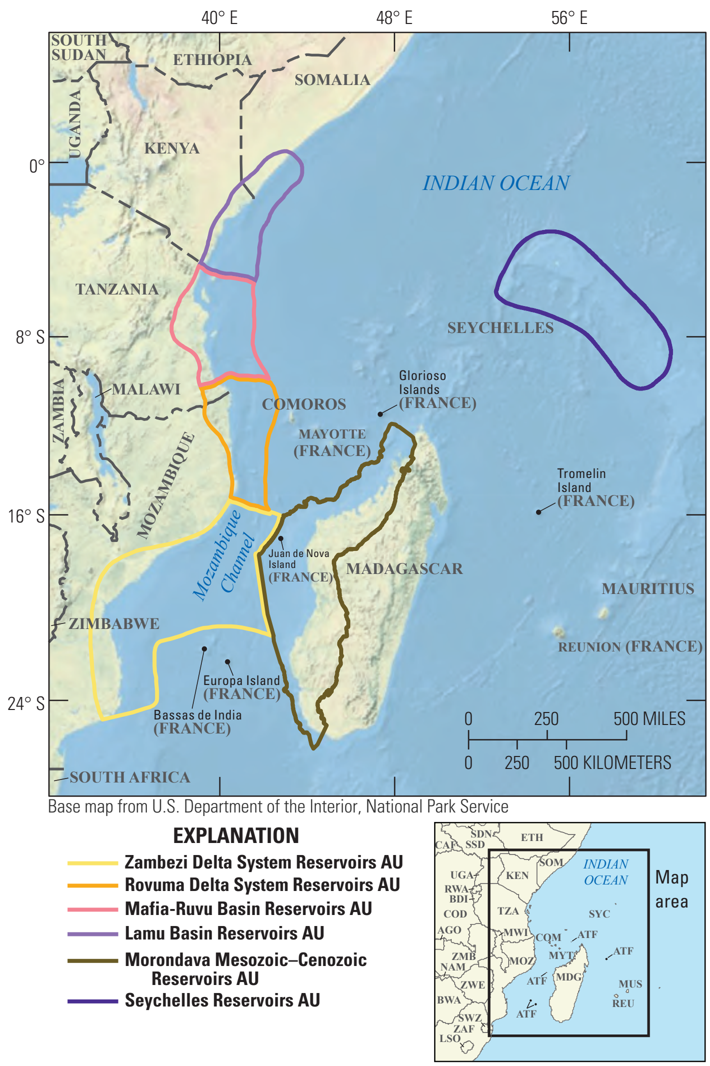

Figure 1. Maps showing location of six conventional assessment units (AUs) of offshore East Africa and Seychelles.

in the formation of the Anza Basin in the northern part of the assessment area. The final phase of rifting began in the Paleogene (Oligocene) and resulted in the East African rift system. From the Cretaceous to the Neogene, extensive eastward prograding deltas formed along the margin because of large fluvial catchment areas in East Africa, forming the Zambezi, Rovuma, Mafia-Ruvu, and Lamu delta systems. These clastic wedges are from 5 to 11 kilometers thick and may have buried potential Mesozoic source rocks into the thermal generation windows for oil and gas.

Total Petroleum System and Assessment Units

The USGS defined the Mesozoic–Cenozoic Composite Total Petroleum System (TPS) in the offshore East Africa and Madagascar area. The Zambezi Delta System Reservoirs Assessment Unit (AU), Rovuma Delta System Reservoirs AU, Mafia-Ruvu Basin Reservoirs AU, Lamu Basin Reservoirs AU, and the Morondava Mesozoic–Cenozoic Reservoirs AU were geologically defined within this TPS. The AUs encompass large fluvial-deltaic to deep-water clastic depositional systems formed along the East African continental margin (Castelino and others, 2015). Petroleum source rocks within this composite TPS are poorly known largely because of deep burial and limited sampling (Butt and Gould, 2018). Available geochemical data for most source rocks were summarized by Brownfield (2016). Triassic source rocks are important for the Morondava Basin in western Madagascar, and Jurassic source rocks are commonly cited as the most important along the East Africa margin (Davison and Steel, 2018). Reservoirs in the composite TPS are typical for clastic deltaic systems, including sandstones deposited in fluvial-deltaic, nearshore marine, slope-channel, and basin-floor fan environments (Castelino and others, 2015; Fierens and others, 2022). Recent gas discoveries in the Rovuma Delta System Reservoirs AU are in stacked basin-floor, deep-water sandstones with excellent reservoir properties (Fletcher, 2017). Similar sandstone reservoirs occur in the Zambezi Delta System Reservoirs AU, Mafia-Ruvu Basin Reservoirs AU, and Lamu Basin Reservoirs AU. Traps span the spectrum from stratigraphic traps in deep-water sandstones to combination traps with a structural component, to structural traps such as those in the gravity-driven extension-contraction features in the Rovuma delta system (Fletcher, 2017; Cai and others, 2020; Fierens and others, 2022). The Rovuma Delta System Reservoirs AU has been the site of most exploration efforts and gas discoveries.

The Mesozoic Composite TPS was defined for the Seychelles area, and the Seychelles Reservoirs AU was defined within this composite TPS. Petroleum source rocks in this TPS may include Triassic synrift lacustrine shales and possible Upper Jurassic to Lower Cretaceous marine shales (Plummer, 1994; Brownfield and Schenk, 2016). Reservoirs range from synrift alluvial-fluvial sandstones to marginal lacustrine and deep-water lacustrine sandstones. Sandstones deposited during the thermal subsidence phase include fluvial-deltaic to marginal marine sandstones. Reservoirs may also include Cretaceous carbonate platform-margin reef and karst reservoirs. The assessment input data for six conventional AUs are summarized in table 1 and in Schenk (2024).

Table 1. Key input data for six conventional assessment units of offshore East Africa and Seychelles.

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

Assessment input data—Conventional AUs	Zambezi Delta System Reservoirs AU				Rovuma Delta System Reservoirs AU			
	Minimum	Median	Maximum	Calculated mean	Minimum	Median	Maximum	Calculated mean
Number of oil fields	1	30	90	31.9	1	20	40	20.5
Number of gas fields	1	100	300	106.3	1	70	210	74.4
Size of oil fields (MMBO)	5	8	2,500	31.3	5	8	2,000	28.0
Size of gas fields (BCFG)	30	60	10,000	185.7	30	60	20,000	260.1
AU probability	1.0				1.0			

Assessment input data—Conventional AUs	Mafia-Ruvu Basin Reservoirs AU				Lamu Basin Reservoirs AU			
	Minimum	Median	Maximum	Calculated mean	Minimum	Median	Maximum	Calculated mean
Number of oil fields	1	20	60	21.3	1	20	80	22.1
Number of gas fields	1	80	240	85.1	1	20	80	22.1
Size of oil fields (MMBO)	5	8	2,500	31.3	5	8	1,000	20.5
Size of gas fields (BCFG)	30	60	10,000	185.7	30	48	6,000	123.3
AU probability	1.0				1.0			

Assessment input data—Conventional AUs	Morondava Mesozoic–Cenozoic Reservoirs AU				Seychelles Reservoirs AU			
	Minimum	Minimum	Median	Calculated mean	Minimum	Median	Maximum	Calculated mean
Number of oil fields	1	60	180	63.8	1	20	60	21.3
Number of gas fields	1	60	180	63.8	1	20	60	21.3
Size of oil fields (MMBO)	5	8	2,500	31.3	5	8	1,000	20.5
Size of gas fields (BCFG)	30	60	12,000	202.0	30	48	6,000	123.3
AU probability	1.0				0.9			

Undiscovered Resources Summary

The USGS quantitatively assessed undiscovered conventional oil and gas resources in six AUs of offshore East Africa and the Seychelles (table 2). Estimated mean resources are 5,071 million barrels of oil (MMBO), or 5.1 billion barrels of oil, with an F95–F5 range from 1,401 to 11,828 MMBO; 79,133 billion cubic feet of gas (BCFG), or 79.1 trillion cubic feet of gas, with an F95–F5 range from 28,606 to 157,242 BCFG; and 451 million barrels of natural gas liquids (MMBNGL), or 0.5 billion barrels, with an F95–F5 range from 159 to 906 MMBNGL.

Table 2. Results for six conventional assessment units of offshore East Africa and Seychelles.

[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]

Total petroleum system and 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
Mesozoic–Cenozoic Composite Total Petroleum System														
Zambezi Delta System Reservoirs AU	1.0	Oil	270	799	2,423	995	351	1,040	3,154	1,293	3	7	22	9
		Gas					8,309	18,191	36,226	19,700	67	145	290	158
Rovuma Delta System Reservoirs AU	1.0	Oil	180	444	1,426	573	198	489	1,574	630	2	4	13	5
		Gas					6,643	17,283	39,225	19,385	13	34	80	39
Mafia-Ruvu Basin Reservoirs AU	1.0	Oil	157	497	1,776	662	173	545	1,955	729	1	4	16	6
		Gas					6,456	14,561	29,672	15,821	13	29	60	32
Lamu Basin Reservoirs AU	1.0	Oil	124	370	1,085	455	136	407	1,192	501	1	3	10	4
		Gas					734	2,212	6,446	2,714	3	9	26	11
Morondava Mesozoic–Cenozoic Reservoirs AU	1.0	Oil	670	1,739	4,154	1,992	871	2,263	5,418	2,590	18	48	114	54
		Gas					4,735	11,621	25,358	12,890	38	93	203	103
Mesozoic Composite Total Petroleum System														
Seychelles Reservoirs AU	0.9	Oil	0	337	964	394	0	437	1,255	512	0	9	26	11
		Gas					0	2,015	5,767	2,368	0	16	46	19
Total undiscovered conventional resources			**1,401**	**4,186**	**11,828**	**5,071**	**28,606**	**71,064**	**157,242**	**79,133**	**159**	**401**	**906**	**451**

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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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