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National and Global Petroleum Assessment

Assessment of Undiscovered Conventional Oil and Gas Resources in the Santos Basin, Campos Basin, and Espírito Santo Basin Provinces of Brazil, 2024

Using a geology-based assessment methodology, the U.S. Geological Survey estimated undiscovered, technically recoverable mean conventional resources of 10.4 billion barrels of oil and 53.3 trillion cubic feet of gas in the Santos Basin, Campos Basin, and Espírito Santo Basin provinces of Brazil.

Introduction

The U.S. Geological Survey (USGS) assessed the potential for undiscovered, technically recoverable conventional oil and gas resources in the Santos Basin, Campos Basin, and Espírito Santo Basin provinces of Brazil (fig. 1*A*, *B*). These three offshore geologic provinces along the eastern margin of South America share a similar tectonic evolution, which is briefly summarized as follows for this report (Davison, 2007; Contreras and others, 2010; Beglinger, Doust, and Cloetingh, 2012; Beglinger, Wees, and others, 2012; Alves and others, 2017; Amarante and others, 2020). In the Late Jurassic, Gondwana began to fragment because of mantle hotspot activity, and by the Early Cretaceous, rifts formed as South America began to separate from Africa. From the Berriasian to Barremian, synrift lacustrine-fluvial to deep-lacustrine sandstones and organic-rich lacustrine mudstones accumulated in the rifts. As extension and rifting waned in the early Aptian, postrift thermal subsidence formed a sag basin in which a spectrum of lacustrine carbonate reservoir rocks, mudstones, and minor sandstones were deposited. Topographic relief on the Florianopolis Fracture Zone formed a volcanic sill immediately south of the Santos Basin that was periodically crossed by marine waters. Evaporation in the silled basin led to as much as 2,000 meters (m) of salt and anhydrite from the late Aptian Ariri Formation. Shortly after deposition, differential loading produced by postsalt deposition caused the salt to deform, forming diapirs, rollers, turtles, and other salt structures that affected the distribution, trapping, and sealing of postsalt carbonate and clastic reservoirs. Seafloor spreading and the continued opening of the South Atlantic Ocean in the early Albian led to the inundation of the evaporite basin by normal marine waters and the formation of extensive carbonate platforms. Transgression in the Late Cretaceous led to drowning of the carbonate platforms, deposition of Cenomanian to Turonian organic-rich source rocks, and progradation of clastic sequences shed from the Serra do Mar. Several phases of uplift from the Late Cretaceous to the Miocene, possibly related to mantle hotspot activity, led to the progradation of several clastic sequences. These sequences comprise fluvial, deltaic, shelf, and slope to deep-marine sandstones and mudstones and are important postsalt reservoirs in the three provinces. The Paleogene emplacement of volcanic rocks of the Abrolhos Bank in the eastern Espírito Santo Basin may have covered presalt and postsalt source rocks, reservoir rocks, and traps (Estrella and others, 1984).

Total Petroleum System and Assessment Units

The Mesozoic Composite Total Petroleum System (TPS) was defined for this assessment to encompass oil and gas generated from organic-rich Aptian presalt lacustrine source rocks and postsalt Albian to Turonian marine mudstones. Presalt lower Aptian lacustrine mudstones are generally interpreted as the major source rocks in the three provinces and consist of Type I organic matter, have total organic carbon (TOC) values as much as 10 weight percent (wt. pct.), have hydrogen indices (HI) as much as 900 milligrams of hydrocarbon per gram of TOC (mg HC/g TOC), and are as much as 300 m thick (Guardado and others, 2000; Buckley and others, 2015; Sabato Ceraldi and Green, 2017; Farias and others, 2019; Oliveira and others, 2019; Mello and others, 2021; Freitas and others, 2022; Fragoso and others, 2023; Terra and others, 2023; Carvalho Antunes and others, 2024). Burial-history modeling has indicated that presalt source rocks in the Santos and Campos Basins are in the thermal generative windows for oil and gas (Cole, 2021).

Albian to Turonian mudstones have been cited as possible postsalt source rocks related to deep-marine marls deposited in basins adjacent to carbonate platforms, and possibly to deposition of shales during Late Cretaceous oceanic anoxic events (Venancio and others, 2022). These potential source rocks contain Type II marine organic matter, have TOC values as much as 8 wt. pct., have HI values as much as 700 mg HC/g TOC, and are as much as 90 m thick (Contreras and others, 2010; Beglinger, Wees, and others, 2012; Delgado and others, 2018; Venancio and others, 2022).

The geologic model for the assessment of the three provinces is for oil and gas generated from presalt Aptian lacustrine mudstones to have migrated into presalt lacustrine reservoirs, mainly in structural traps, and then to have migrated, where salt was not present, into postsalt carbonate platform margin reservoirs and fluvial to deep-marine sandstone reservoirs. Oil and gas generated from Albian to Turonian shales migrated into postsalt sandstone and carbonate reservoirs.

Twelve assessment units (AUs) were defined within the Mesozoic Composite TPS in the three provinces (fig. 1*A*, *B*). The assessment input data for the AUs are summarized in table 1 and Schenk (2026).

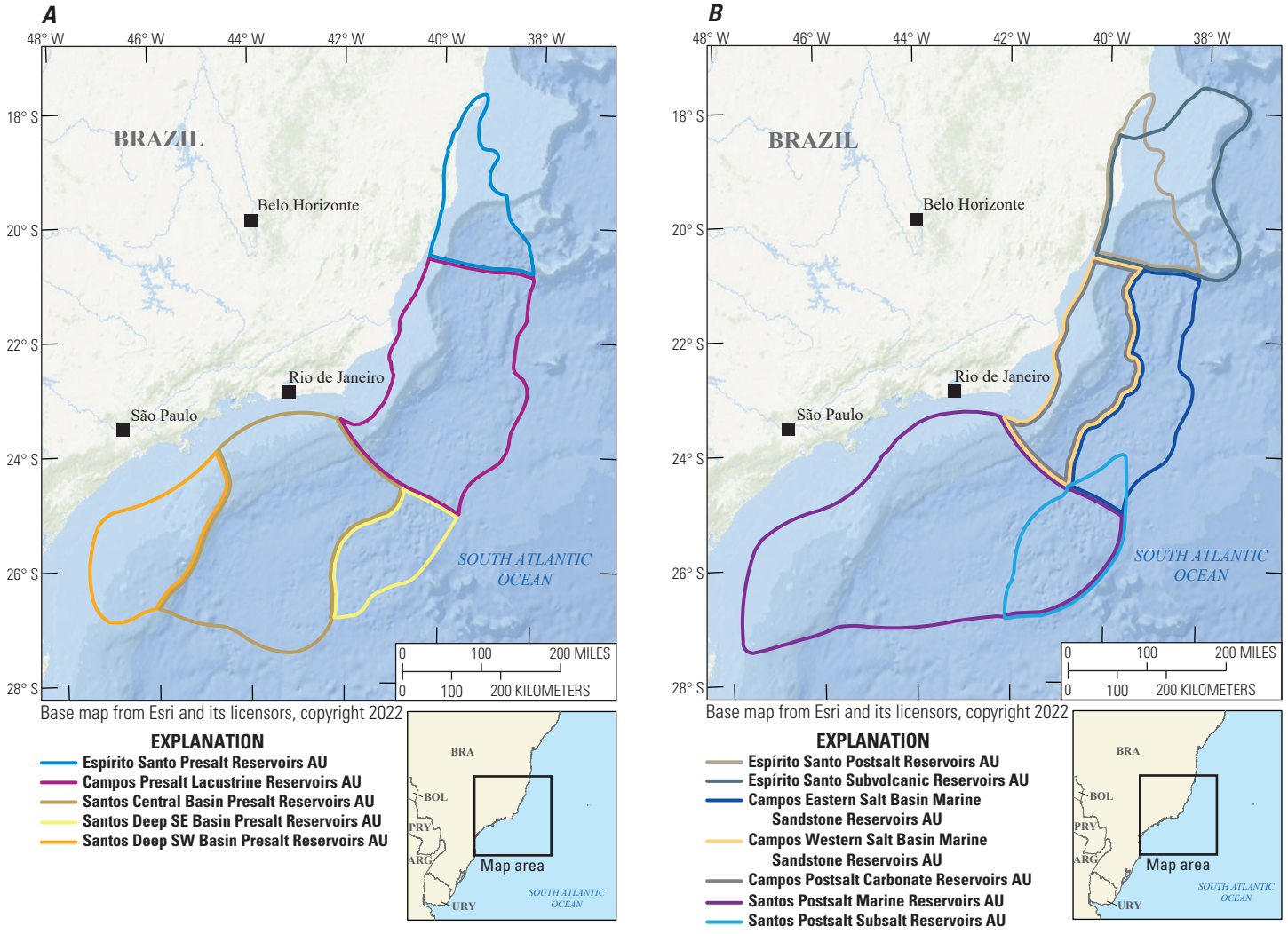

Figure 1. Maps showing the location of (*A*) five conventional assessment units (AUs) in the presalt section and (*B*) seven conventional AUs in the postsalt section of the Santos Basin, Campos Basin, and Espírito Santo Basin provinces of Brazil.

Table 1. Key input data for 12 conventional assessment units in the Santos Basin, Campos Basin, and Espírito Santo Basin provinces of Brazil.

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

Assessment input data—Conventional AUs	Espírito Santo Presalt Reservoirs AU				Campos Presalt Lacustrine Reservoirs AU			
	Minimum	Median	Maximum	Calculated mean	Minimum	Median	Maximum	Calculated mean
Number of oil fields	1	40	120	42.5	1	50	150	53.2
Number of gas fields	1	40	120	42.5	1	30	90	31.9
Size of oil fields (MMBO)	0.5	0.8	1,500	9.0	5	8	10,000	68.9
Size of gas fields (BCFG)	3	24	14,000	164.2	30	48	12,000	168.0
AU probability	1.0				1.0			
Assessment input data—Conventional AUs	**Santos Central Basin Presalt Reservoirs AU**				**Santos Deep SE Basin Presalt Reservoirs AU**			
	Minimum	Median	Maximum	Calculated mean	Minimum	Median	Maximum	Calculated mean
Number of oil fields	1	60	180	63.8	1	5	20	5.5
Number of gas fields	1	15	45	16.0	1	20	80	22.1
Size of oil fields (MMBO)	5	8	5,000	45.4	5	8	1,500	24.5
Size of gas fields (BCFG)	30	48	20,000	217.8	30	48	12,000	168.0
AU probability	1.0				0.8			

Table 1. Key input data for 12 conventional assessment units in the Santos Basin, Campos Basin, and Espírito Santo Basin provinces of Brazil.—Continued

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

Assessment input data—Conventional AUs	Santos Deep SW Basin Presalt Reservoirs AU				Espírito Santo Postsalt Reservoirs AU			
	Minimum	Median	Maximum	Calculated mean	Minimum	Median	Maximum	Calculated mean
Number of oil fields	1	5	20	5.5	1	40	80	41.0
Number of gas fields	1	20	80	22.1	1	40	120	42.5
Size of oil fields (MMBO)	5	8	2,000	28.0	0.5	0.8	450	4.3
Size of gas fields (BCFG)	30	48	20,000	217.8	3	24	700	42.0
AU probability	0.8				1.0			
Assessment input data—Conventional AUs	**Espírito Santo Subvolcanic Reservoirs AU**				**Campos Eastern Salt Basin Marine Sandstone Reservoirs AU**			
	Minimum	**Median**	**Maximum**	**Calculated mean**	**Minimum**	**Median**	**Maximum**	**Calculated mean**
Number of oil fields	1	25	75	26.6	1	40	120	42.5
Number of gas fields	1	25	75	26.6	1	15	45	16.0
Size of oil fields (MMBO)	5	8	1,200	22.2	5	8	400	14.8
Size of gas fields (BCFG)	30	48	20,000	217.8	30	48	3,000	95.3
AU probability	0.8				1.0			
Assessment input data—Conventional AUs	**Campos Western Salt Basin Marine Sandstone Reservoirs AU**				**Campos Postsalt Carbonate Reservoirs AU**			
	Minimum	**Median**	**Maximum**	**Calculated mean**	**Minimum**	**Median**	**Maximum**	**Calculated mean**
Number of oil fields	1	40	80	41.0	1	30	60	30.7
Number of gas fields	1	15	45	16.0	1	10	30	10.6
Size of oil fields (MMBO)	5	8	600	16.9	5	8	300	13.6
Size of gas fields (BCFG)	30	48	1,000	69.9	30	48	1,000	69.9
AU probability	1.0				1.0			
Assessment input data—Conventional AUs	**Santos Postsalt Marine Reservoirs AU**				**Santos Postsalt Subsalt Reservoirs AU**			
	Minimum	**Median**	**Maximum**	**Calculated mean**	**Minimum**	**Median**	**Maximum**	**Calculated mean**
Number of oil fields	1	40	120	42.5	1	10	30	10.6
Number of gas fields	1	60	180	63.8	1	20	60	21.3
Size of oil fields (MMBO)	5	8	350	14.2	5	8	2,000	28.0
Size of gas fields (BCFG)	30	48	3,500	100.4	30	48	6,000	123.3
AU probability	1.0				0.8			

Undiscovered Resources Summary

The USGS quantitatively assessed undiscovered, technically recoverable conventional oil and gas resources in 12 AUs in the Santos Basin, Campos Basin, and Espírito Santo Basin provinces of Brazil (table 2). The estimated mean resources are 10,381 million barrels of oil (MMBO), or 10.4 billion barrels of oil, with an F95 to F5 range from 2,814 to 24,965 MMBO; 53,289 billion cubic feet of gas (BCFG), or 53.3 trillion cubic feet of gas, with an F95 to F5 range from 12,137 to 133,055 BCFG; and 1,926 million barrels of natural gas liquids (MMBNGL), or 1.9 billion barrels of natural gas liquids, with an F95 to F5 range from 454 to 4,780 MMBNGL.

Table 2. Results for 12 conventional assessment units in the Santos Basin, Campos Basin, and Espírito Santo Basin provinces of Brazil.

[Gray shading indicates not applicable. Results shown are fully risked estimates. F95 represents a 95-percent chance of at least the amount tabulated; other fractiles are defined similarly. 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 Composite Total Petroleum System														
Espírito Santo Presalt Reservoirs AU	1.0	Oil	61	257	1,152	380	30	129	573	190	1	4	16	5
		Gas					1,750	5,761	16,610	7,005	35	115	332	140
Campos Presalt Lacustrine Reservoirs AU	1.0	Oil	758	2,759	9,766	3,653	906	3,313	11,674	4,384	41	149	526	197
		Gas					1,570	4,408	12,386	5,348	60	168	471	203
Santos Central Basin Presalt Reservoirs AU	1.0	Oil	803	2,396	6,663	2,890	1,364	4,072	11,268	4,914	113	338	935	408
		Gas					665	2,307	10,397	3,452	20	69	312	104
Santos Deep SE Basin Presalt Reservoirs AU	0.8	Oil	0	60	383	107	0	125	802	225	0	10	67	19
		Gas					0	2,195	9,215	2,972	0	66	276	89
Santos Deep SW Basin Presalt Reservoirs AU	0.8	Oil	0	62	463	124	0	129	974	260	0	11	81	22
		Gas					0	2,567	12,807	3,862	0	77	384	116
Espírito Santo Postsalt Reservoirs AU	1.0	Oil	54	141	427	176	32	84	257	106	1	3	8	3
		Gas					805	1,666	3,173	1,782	21	43	83	46
Espírito Santo Subvolcanic Reservoirs AU	0.8	Oil	0	413	1,234	471	0	247	745	283	0	8	24	9
		Gas					0	3,428	14,482	4,655	0	89	376	121
Campos Eastern Salt Basin Marine Sandstone Reservoirs AU	1.0	Oil	278	582	1,135	627	152	320	625	345	4	9	18	10
		Gas					552	1,316	3,216	1,523	22	53	129	61
Campos Western Salt Basin Marine Sandstone Reservoirs AU	1.0	Oil	357	649	1,180	694	196	357	651	382	6	10	19	11
		Gas					500	1,027	2,035	1,116	20	41	81	45
Campos Postsalt Carbonate Reservoirs AU	1.0	Oil	231	396	670	416	183	316	539	333	5	9	16	10
		Gas					319	675	1,405	744	13	27	56	30
Santos Postsalt Marine Reservoirs AU	1.0	Oil	272	560	1,081	604	297	617	1,193	664	13	27	51	29
		Gas					2,816	5,948	11,576	6,400	79	166	325	179
Santos Postsalt Subsalt Reservoirs AU	0.8	Oil	0	154	811	239	0	169	893	263	0	7	38	11
		Gas					0	1,803	5,559	2,081	0	50	156	58
Total undiscovered conventional oil and gas resources			**2,814**	**8,429**	**24,965**	**10,381**	**12,137**	**42,979**	**133,055**	**53,289**	**454**	**1,549**	**4,780**	**1,926**

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For More Information

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

Brazil Assessment Team

Christopher J. Schenk, Sarah E. Gelman, Jane S. Hearon, Tracey J. Mercier, Phuong A. Le, Andrea D. Cicero, Benjamin G. Johnson, Jenny H. Lagesse, and Heidi M. Leathers-Miller

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