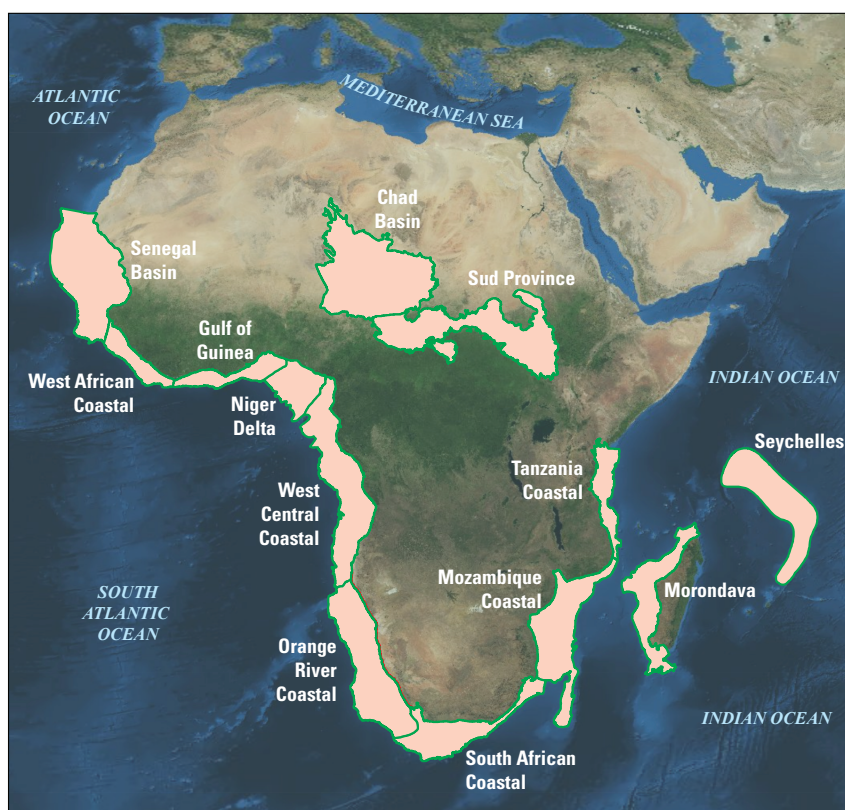


Executive Summary—Geologic Assessment of Undiscovered Hydrocarbon Resources of Sub-Saharan Africa

By Michael E. Brownfield, Ronald R. Charpentier, Troy A. Cook, Donald L. Gautier, Debra K. Higley, Mark A. Kirschbaum, Timothy R. Klett, Janet K. Pitman, Richard M. Pollastro, Christopher J. Schenk (Task Leader), Marilyn E. Tennyson, and Craig J. Wandrey



Click here to return to
Volume Title Page

Chapter 1 of **Geologic Assessment of Undiscovered Hydrocarbon Resources of Sub-Saharan Africa**

Compiled by Michael E. Brownfield

Digital Data Series 69—GG

U.S. Department of the Interior
U.S. Geological Survey

U.S. Department of the Interior
SALLY JEWELL, Secretary

U.S. Geological Survey
Suzette M. Kimball, Director

U.S. Geological Survey, Reston, Virginia: 2016

For more information on the USGS—the Federal source for science about the Earth, its natural and living resources, natural hazards, and the environment—visit <http://www.usgs.gov> or call 1–888–ASK–USGS.

For an overview of USGS information products, including maps, imagery, and publications, visit <http://www.usgs.gov/pubprod/>.

Any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

Although this information product, for the most part, is in the public domain, it also may contain copyrighted materials as noted in the text. Permission to reproduce copyrighted items must be secured from the copyright owner.

Suggested citation:

Brownfield, M.E., Charpentier, R.R., Cook, T.A., Gautier, D.L., Higley, D.K., Kirschbaum, M.A., Klett, T.R., Pitman, J.K., Pollastro, R.M., Schenk, C.J., Tennyson, M.E., and Wandrey, C.J., 2016, Executive summary—Assessment of undiscovered oil and gas resources of the Sub-Saharan region, Africa, *in* Brownfield, M.E., compiler, Geologic assessment of undiscovered hydrocarbon resources of Sub-Saharan Africa: U.S. Geological Survey Digital Data Series 69–GG, chap. 1, 9 p., <http://dx.doi.org/10.3133/ds69GG>.

ISSN 2327-638X (online)

Contents

Introduction.....	1
Resource Summary of Sub-Saharan Africa	4
For Additional Information.....	9
World Conventional Resources Assessment Team	9
References.....	9

Figures

1. Map of African provinces assessed as part of the U.S. Geological Survey World Petroleum Resources Project.....	2
2. Map of 18 African assessment units assessed as part of the U.S. Geological Survey World Petroleum Resources Project	3
3. Map of African provinces with mean undiscovered, technically recoverable oil resources	7
4. Map of African provinces with mean undiscovered, technically recoverable gas resources.....	8

Table

1. Assessment results for assessed provinces of Sub-Saharan Africa	5
--	---

Executive Summary—Assessment of Undiscovered Hydrocarbon Resources of the Sub-Saharan Region, Africa

By Michael E. Brownfield, Ronald R. Charpentier, Troy A. Cook, Donald L. Gautier, Debra K. Higley, Mark A. Kirschbaum, Timothy R. Klett, Janet K. Pitman, Richard M. Pollastro, Christopher J. Schenk (Task Leader), Marilyn E. Tennyson, and Craig J. Wandrey

Introduction

The main objective of the U.S. Geological Survey's (USGS) National and Global Petroleum Assessment Project is to assess the potential for undiscovered, technically recoverable oil and natural gas resources of the United States and the world (U.S. Geological Survey World Conventional Resources Assessment Team, 2012). The USGS updated assessments that were completed during the USGS World Petroleum Assessment 2000 (U.S. Geological Survey World Energy Assessment Team, 2000) and conducted new assessments in areas around the world that were not previously examined (U.S. Geological Survey World Conventional Resources Assessment Team, 2012). These assessments used the latest geology-based assessment methodology for conventional oil and gas resources. The new assessments are available at the USGS website, (<http://energy.usgs.gov/OilGas/AssessmentsData/WorldPetroleumAssessment.aspx>).

As part of this project, the USGS assessed 13 geologic provinces located in sub-Saharan Africa (U.S. Geological Survey World Conventional Resources Assessment Team, 2012). Coastal provinces were extended offshore to water depths ranging from 2,000 to 4,000 meters (m). Within these 13 geologic provinces 18 assessment units (figs. 1, 2) were identified.

The west Africa provinces are (1) the Senegal, containing the passive-margin Senegal Basin of Middle Jurassic to Holocene age; (2) the West African Coastal, characterized by rift, passive-margin, and transform tectonics; (3) the Gulf of Guinea, characterized by transform tectonics; (4) the Niger Delta, containing more than 9,100 m of sedimentary rock and recent sediments; (5) the West-Central Coastal, which contains the Aptian salt basin, is dominated by both rift and sag tectonics, and includes the Congo Basin; and (6) the Orange River Coastal, containing more than 7,000 m of syn-rift and post-rift sedimentary rock. The West African Coastal Province was assessed for the first time, whereas the other five west Africa provinces were reassessed for the 2012 World Oil and

Gas Resource Assessment (fig. 1 of U.S. Geological Survey World Conventional Resources Assessment Team, 2012). More than 275 new oil and gas fields have been discovered in the six west Africa provinces (IHS Energy, 2008, 2009) since the USGS World Petroleum Assessment in 2000 (U.S. Geological Survey World Energy Assessment Team, 2000). These provinces were assessed because of increased energy exploration activity and new oil and gas discoveries within the provinces.

Seven provinces not assessed as part of the World Petroleum Assessment 2000 (U.S. Geological Survey World Energy Assessment Team, 2000) were assessed by the USGS as part of the World Assessment 2012 (U.S. Geological Survey World Conventional Resources Assessment Team, 2012). These provinces are (1) the Chad Province, containing Cretaceous and Cenozoic-age lacustrine, continental, and minor marine rocks; (2) the Sud Province, containing Cretaceous and Paleogene age lacustrine, continental, and minor marine rocks; (3) the South Africa Coastal Province, which contains rift, transform, and passive-margin rocks; (4) the Mozambique Coastal Province, containing rift, drift, and passive-margin rocks; (5) the Morondava Province, which contains failed rift, drift, and passive-margin rocks; (6) the Tanzania Coastal Province, containing rift, drift, and passive-margin rocks; and (7) the Seychelles Province, which contains rift and drift rocks. At the time of this assessment 157 oil and gas fields had been discovered in the seven provinces (IHS Energy, 2009). These provinces were assessed because of increased interest and new oil and gas discoveries within the provinces.

The assessment was geology-based and used the total petroleum system (TPS) concept. The geologic elements of a TPS are hydrocarbon source rocks (source rock maturation and hydrocarbon generation and migration), reservoir rocks (quality and distribution), and traps where hydrocarbon accumulates. Using these geologic criteria, 16 conventional total petroleum systems and 18 assessment units in the 13 provinces were defined. The undiscovered, technically recoverable oil and gas resources were assessed for all assessment units (figs. 1, 2).

2 **Executive Summary—Assessment of Undiscovered Hydrocarbon Resources of the Sub-Saharan Region, Africa**

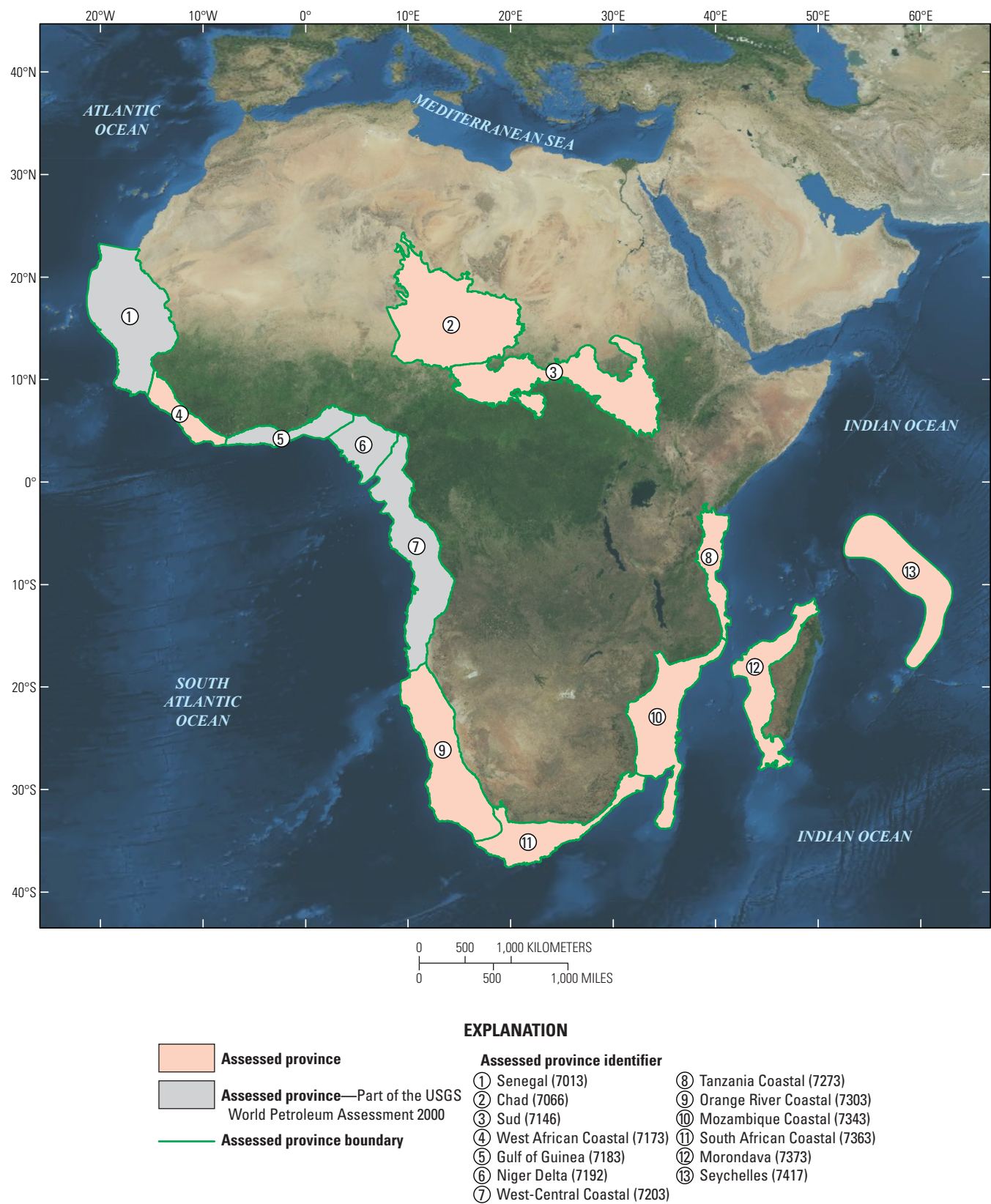
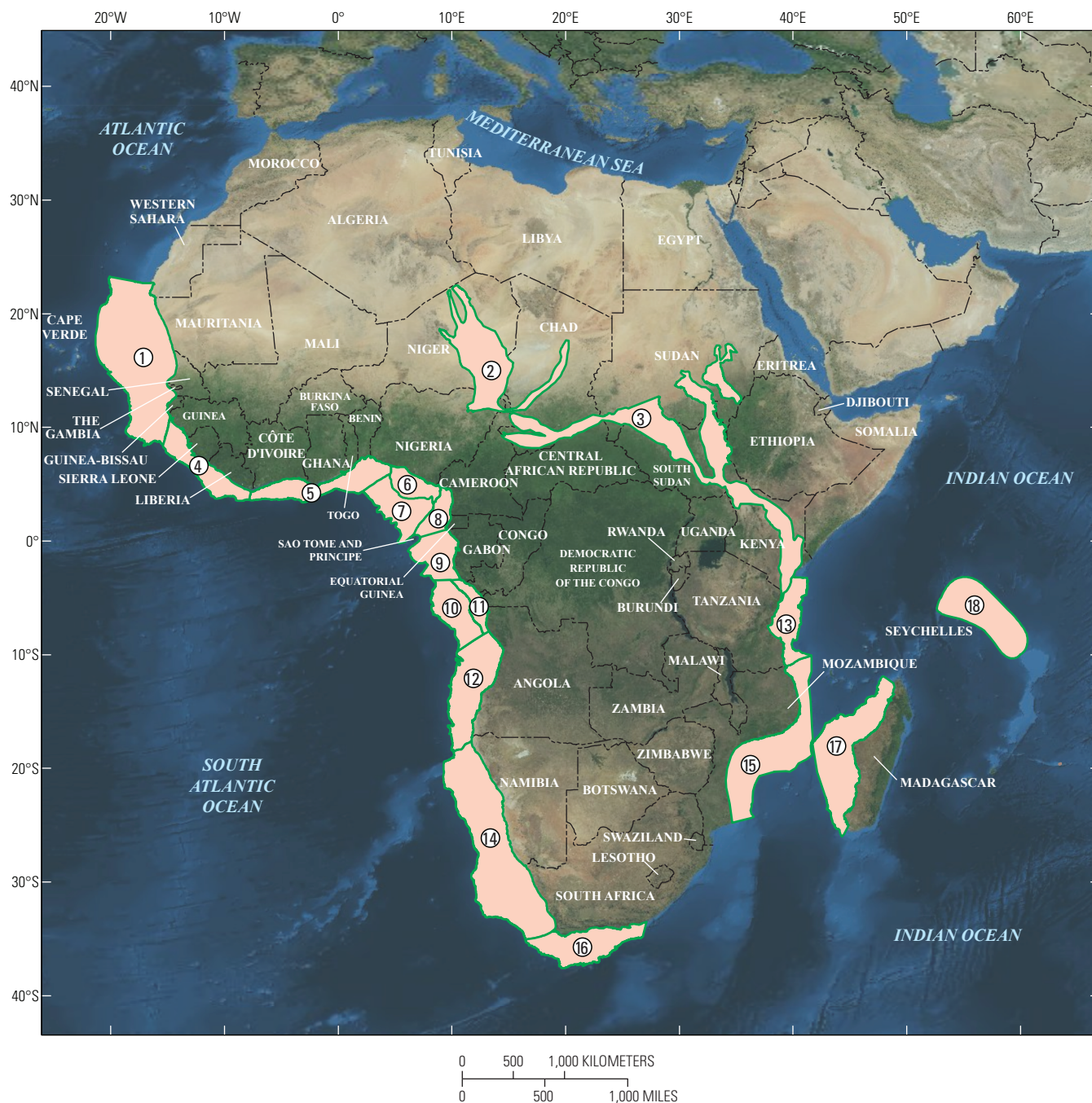


Figure 1. Thirteen assessed provinces in Sub-Saharan Africa. Gray areas, provinces assessed as part of the USGS World Petroleum Assessment 2000 (U.S. Geological Survey World Energy Assessment Team, 2000) and reassessed for the 2012 assessment (U.S. Geological Survey World Conventional Resources Assessment Team, 2012).



EXPLANATION



 Assessment unit	Assessment unit identifier		
 Assessment unit boundary	① Coastal Plain and Offshore (70130101)	⑦ Agbada Reservoirs (71920102)	⑬ Mesozoic-Cenozoic Reservoirs (72730101)
	② Cretaceous-Tertiary Rifts (70660101)	⑧ Gabon Subsalt (72030101)	⑭ Offshore (73030101)
	③ Central African Rifts (7146)	⑨ Gabon Suprasalt (72030201)	⑮ Mesozoic-Cenozoic Reservoirs (73430101)
	④ Mesozoic-Cenozoic Reservoirs (71730101)	⑩ Central Congo Delta and Carbonate Platform (72030301)	⑯ Mesozoic-Cenozoic Reservoirs (73630101)
	⑤ Coastal Plain and Offshore (71830101)	⑪ Central Congo Turbidites (72030302)	⑰ Mesozoic-Cenozoic Reservoirs (73730101)
	⑥ Akata Turbidite Reservoirs (71920101)	⑫ Cuanza-Namibe (72030401)	⑱ Seychelles Rifts (74170101)

Figure 2. Eighteen assessment units in Sub-Saharan Africa assessed for this report.

Resource Summary of Sub-Saharan Africa

The results of this U.S. Geological Survey assessment of undiscovered, technically recoverable conventional oil and gas resources for 13 provinces and 18 assessment units in sub-Saharan Africa (figs. 1, 2) are given in table 1. Mean volumes of west Africa provinces (fig. 1, provinces 1, 4, 5, 6, 7) are estimated as follows:

- Senegal Province (7013): 2,350 million barrels of oil, 18,706 billion cubic feet of gas, and 567 million barrels of natural gas liquids
- West African Coastal Province (7173)—Mesozoic-Cenozoic Reservoirs Assessment Unit: 3,200 million barrels of oil, 23,629 billion cubic feet of gas, and 721 million barrels of natural gas liquids
- Gulf of Guinea Province (7183)—Coastal Plain and Offshore Assessment Unit: 4,071 million barrels of oil, 34,461 billion cubic feet of gas, and 1,145 million barrels of natural gas liquids
- Niger Delta Province (7192)—Agbada Reservoirs and Akata Reservoirs Assessment Unit: 15,534 million barrels of oil, 58,221 billion cubic feet of gas, and 6,326 million barrels of natural gas liquids
- West-Central Coastal Province (7203)—Gabon Subsalt, Gabon Suprasalt, Central Congo Delta and Carbonate Platform, Central Congo Turbidites, and Kwanza-Namibe Assessment Units: The estimated mean volumes for these five assessment units are 49,736 million barrels of oil, 75,790 billion cubic feet of gas, and 2,877 million barrels of natural gas liquids.

Along the southwestern coast of Africa (fig. 1, provinces 9, 11), the mean volumes of conventional oil and gas are estimated as follows (fig. 2; table 1):

- Orange River Coastal Province (7303)—Offshore Assessment Unit: 1,057 million barrels of oil, 27,839 billion cubic feet of gas, and 700 million barrels of natural gas liquids

- South Africa Coastal Province (7363)—Mesozoic-Cenozoic Reservoirs Assessment Unit—2,129 million barrels of oil, 35,964 billion cubic feet of gas, and 1,145 million barrels of natural gas liquids.

Three provinces along the eastern part of the African coast and one more than 900 miles east of the African coast were assessed (fig. 1, provinces 8, 10, 12, 13; fig. 2; table 1). From north to south the mean volumes are estimated as follows:

- Tanzania Coastal Province (7273)—Mesozoic-Cenozoic Reservoirs Assessment Unit: 2,806 million barrels of oil, 71,107 billion cubic feet of gas, and 2,212 million barrels of natural gas liquids
- Seychelles Province (7417)—Seychelles Rift Assessment Unit: 2,394 million barrels of oil, 20,376 billion cubic feet of gas, and 739 million barrels of natural gas liquids
- Morondava Province (7373)—Mesozoic-Cenozoic Reservoirs Assessment Unit: 10,750 million barrels of oil, 167,219 billion cubic feet of gas, and 5,176 million barrels of natural gas liquids
- Mozambique Coastal Province—Mesozoic-Cenozoic Reservoirs Assessment Unit: 11,682 million barrels of oil, 182,349 billion cubic feet of gas, and 5,645 million barrels of natural gas liquids.

Two central African Cretaceous rift provinces were assessed (fig. 1, provinces 2, 3; fig. 2, table 1), and their oil and gas volumes are as follows:

- Chad Province (7066)—Cretaceous-Tertiary Rifts Assessment Unit: 2,315 million barrels of oil, 14,648 billion cubic feet of gas, and 391 million barrels of natural gas liquids
- Sud Province (7146)—Central African Rifts Assessment Unit: 7,310 million barrels of oil, 13,218 billion cubic feet of gas, and 353 million barrels of natural gas liquids.
- Mean estimates for undiscovered, technically recoverable conventional oil and gas in sub-Saharan Africa are shown in figures 3 and 4.

Table 1. Assessment results for assessed oil and gas provinces of Sub-Saharan Africa.

[For location information, see fig. 1 (provinces), fig. 2 (assessment units). MMBO, million barrels of oil; BCFG, billion cubic feet of gas; MMBNGL, million barrels of natural gas liquids. Results shown are fully risked estimates. For gas accumulations, all liquids are included as NGL (natural gas liquids). Undiscovered gas resources are the sum of nonassociated and associated gas. F95 represents a 95 percent chance of at least the amount tabulated; other fractiles are defined similarly. AU, assessment unit. AU probability is the chance of at least one accumulation of minimum size within the AU. TPS, total petroleum system. Fractiles are additive under the assumption of positive correlation. Gray shading indicates not applicable]

Provinces, Total petroleum systems (TPS), and assessment units (AU)	Field type	Largest expected mean field size	Total undiscovered resources											
			Oil (MMBO)				Gas (BCFG)				NGL (MMBNGL)			
			F95	F50	F5	Mean	F95	F50	F5	Mean	F95	F50	F5	Mean
Senegal Province—Cretaceous-Tertiary Composite TPS														
Coastal Plain and Offshore AU	Oil	579	720	2,073	4,914	2,350	1,343	3,914	9,519	4,465	35	105	261	121
	Gas	3,505					4,353	12,563	29,747	14,241	134	391	942	446
Province total conventional resources			720	2073	4,914	2,350	5,696	16,477	39,266	18,706	169	496	1,203	567
West African Coastal Province—Cretaceous Composite TPS														
Mesozoic-Cenozoic Reservoirs AU	Oil	783	801	2,713	7,305	3,200	1,047	3,662	10,847	4,492	27	98	297	121
	Gas	4,695					4,862	16,202	43,437	19,137	149	506	1,374	600
Province total conventional resources			801	2,713	7,305	3,200	5,909	19,864	54,284	23,629	176	604	1,671	721
Gulf of Guinea Province—Cretaceous Composite TPS														
Coastal Plain and Offshore AU	Oil	1,737	563	2,966	11,409	4,071	1,347	7,224	29,054	10,126	88	365	1,466	513
	Gas	10,409					3,382	17,704	68,094	24,335	87	457	1,782	632
Province total conventional resources			563	2,966	11,409	4,071	4,729	24,928	97,148	34,461	155	822	3,248	1,145
Niger Delta Province—Tertiary Niger Delta TPS														
Agbada Reservoirs AU	Oil	274	526	1,437	3,326	1,616	1,904	5,387	13,011	6,139	65	245	904	339
	Gas	981					751	2,742	7,817	3,315	30	120	397	155
Akata Reservoirs AU	Oil	4,119	4,321	12,271	29,129	13,918	5,432	16,270	45,864	19,779	143	433	1,253	535
	Gas	13,355					5,862	21,723	78,443	28,988	1,030	3,886	14,491	5,297
Province total conventional resources			4,847	13,708	32,455	15,534	13,949	46,122	145,135	58,221	1,268	4,684	17,045	6,326
West-Central Coastal Province—Melania-Gamba TPS														
Gabon Subsalt AU	Oil	2,559	2,042	6,492	16,805	7,589	1,134	3,783	12,115	4,863	57	191	617	247
	Gas	7,384					1,883	9,196	43,246	13,891	83	410	1,934	620
Total conventional resources			2,042	6,492	16,805	7,589	3,017	12,979	55,361	18,754	140	601	2,551	867
West-Central Coastal Province—Cretaceous-Tertiary Composite TPS														
Gabon Suprasalt Au	Oil	2,550	2,047	6,446	16,710	7,548	941	3,250	11,378	4,385	24	83	302	115
	Gas	6,583					1,241	7,356	39,177	11,822	38	227	1,224	370
Total conventional resources			2,047	6,446	16,710	7,548	2,182	10,606	50,555	16,207	62	310	1,526	485
West-Central Coastal Province—Congo Delta Composite TPS														
Central Congo Delta and Carbonate Platform AU	Oil	1,249	1,111	3,379	8,514	3,917	841	2,758	8,541	3,492	42	139	431	176
	Gas	3,305					645	4,009	20,577	6,307	33	208	1,091	334
Central Congo Turbidites AU	Oil	2,148	3,186	8,133	17,597	8,967	1,850	4,885	11,567	5,567	94	247	589	282
	Gas	2,014					215	1,304	10,437	2,814	9	58	466	126
Total conventional resources			4,297	11,512	26,111	12,884	3,551	12,956	51,122	18,180	178	652	2,577	918
Kwanza-Namibe AU	Oil	5,093	6,417	19,201	45,677	21,715	2,789	8,406	20,537	9,613	74	224	566	260
	Gas	7,729					1,306	7,640	44,892	13,036	34	199	1,198	347
Total conventional resources			6,417	19,201	45,677	21,715	4,095	16,046	65,429	22,649	108	423	1,764	607
Province total conventional resources			14,803	43,651	105,303	49,736	12,845	52,587	222,467	75,790	488	1,986	8,418	2,877
Chad Province—Cretaceous-Tertiary Composite TPS														
Cretaceous-Tertiary Rifts AU	Oil	387	794	2,082	4,637	2,315	228	657	1,665	766	6	18	46	21
	Gas	2,321					4,786	12,443	28,002	13,882	125	330	751	370

6 Executive Summary—Assessment of Undiscovered Hydrocarbon Resources of the Sub-Saharan Region, Africa

Table 1. Assessment results for assessed oil and gas provinces of Sub-Saharan Africa.—Continued

[For location information, see fig. 1 (provinces), fig. 2 (assessment units). MMBO, million barrels of oil; BCFG, billion cubic feet of gas; MMBNGL, million barrels of natural gas liquids. Results shown are fully risked estimates. For gas accumulations, all liquids are included as NGL (natural gas liquids). Undiscovered gas resources are the sum of nonassociated and associated gas. F95 represents a 95 percent chance of at least the amount tabulated; other fractiles are defined similarly. AU, assessment unit. AU probability is the chance of at least one accumulation of minimum size within the AU. TPS, total petroleum system. Fractiles are additive under the assumption of positive correlation. Gray shading indicates not applicable]

Provinces, Total petroleum systems (TPS), and assessment units (AU)	Field type	Largest expected mean field size	Total undiscovered resources											
			Oil (MMBO)				Gas (BCFG)				NGL (MMBNGL)			
			F95	F50	F5	Mean	F95	F50	F5	Mean	F95	F50	F5	Mean
Province total conventional resources			794	2,082	4,637	2,315	5,014	13,100	29,667	14,648	131	348	797	391
Sud Province—Cretaceous-Cenozoic Composite TPS														
Central African Rifts AU	<i>Oil</i>	1,112	3,141	6809	13,222	7,310	531	1,321	3,169	1,522	14	35	87	41
	<i>Gas</i>	3,677					2,824	9,822	26,776	11,696	73	259	732	312
Province total conventional resources			3,141	6809	13,222	7,310	3,355	11,143	29,945	13,218	87	294	819	353
Tanzania Coastal Province—Mesozoic-Cenozoic Composite TPS														
Mesozoic-Cenozoic Reservoirs AU	<i>Oil</i>	594	1,223	2,608	5,064	2,806	1,583	3,555	7,571	3,933	42	95	208	106
	<i>Gas</i>	6,162					35,902	64,054	108,925	67,174	1,118	2,006	3,433	2,106
Province total conventional resources			1,223	2,608	5,064	2,806	37,485	67,609	116,496	71,107	1,160	2,101	3,641	2,212
Orange River Coastal Province—Mesozoic Composite TPS														
Offshore AU	<i>Oil</i>	247	410	955	2,044	1,057	937	2,209	4,806	2,458	57	134	293	149
	<i>Gas</i>	2,693					11,988	23,771	44,329	25,381	257	516	970	551
Province total conventional resources			410	955	2,044	1,057	12,925	25,980	49,135	27,839	314	650	1,263	700
Mozambique Coastal Province—Mesozoic Composite TPS														
Mesozoic-Cenozoic Reservoirs AU	<i>Oil</i>	1,041	6,268	11,174	18,857	11,682	8,423	15,615	27,238	16,425	225	421	744	444
	<i>Gas</i>	7,976					93,486	158,654	263,301	165,924	2,915	4,978	8,270	5,201
Province total conventional resources			6,268	11,174	18,857	11,682	101,909	174,269	290,539	182,349	3,140	5,399	9,014	5,645
South Africa Coastal Province—Mesozoic Composite TPS														
Mesozoic-Cenozoic Reservoirs AU	<i>Oil</i>	340	924	1,984	3,851	2,129	1,209	2,728	5,657	2,995	32	74	155	81
	<i>Gas</i>	2,937					15,915	30,931	57,024	32,969	496	968	1,794	1,034
Province total conventional resources			924	1,984	3,851	2,129	17,124	33,659	62,681	35,964	528	1,042	1,949	1,115
Morondava Province—Mesozoic Composite TPS														
Mesozoic-Cenozoic Reservoirs AU	<i>Oil</i>	1,016	5,701	10,255	17,455	10,750	7,686	14,325	25,323	15,123	205	386	693	409
	<i>Gas</i>	7,837					85,291	145,683	242,887	152,096	2,667	4,569	7,618	4,767
Province total conventional resources			5,701	10,255	17,455	10,750	92,977	160,008	268,210	167,219	2,872	4,955	8,311	5,176
Seychelles Province—Mesozoic-Cenozoic Composite TPS														
Seychelles Rifts AU	<i>Oil</i>	793	585	1,984	5,574	2,394	1,328	4,760	15,038	6,044	28	100	324	129
	<i>Gas</i>	4,765					3,538	11,781	33,360	14,332	146	496	1,467	610
Province total conventional resources			585	1,984	5,574	2,394	4,866	16,541	48,398	20,376	174	596	1,791	739
Total conventional resources			40,780	102,962	232,090	115,334	318,783	662,287	1,453,371	743,527	10,662	23,977	59,170	27,967

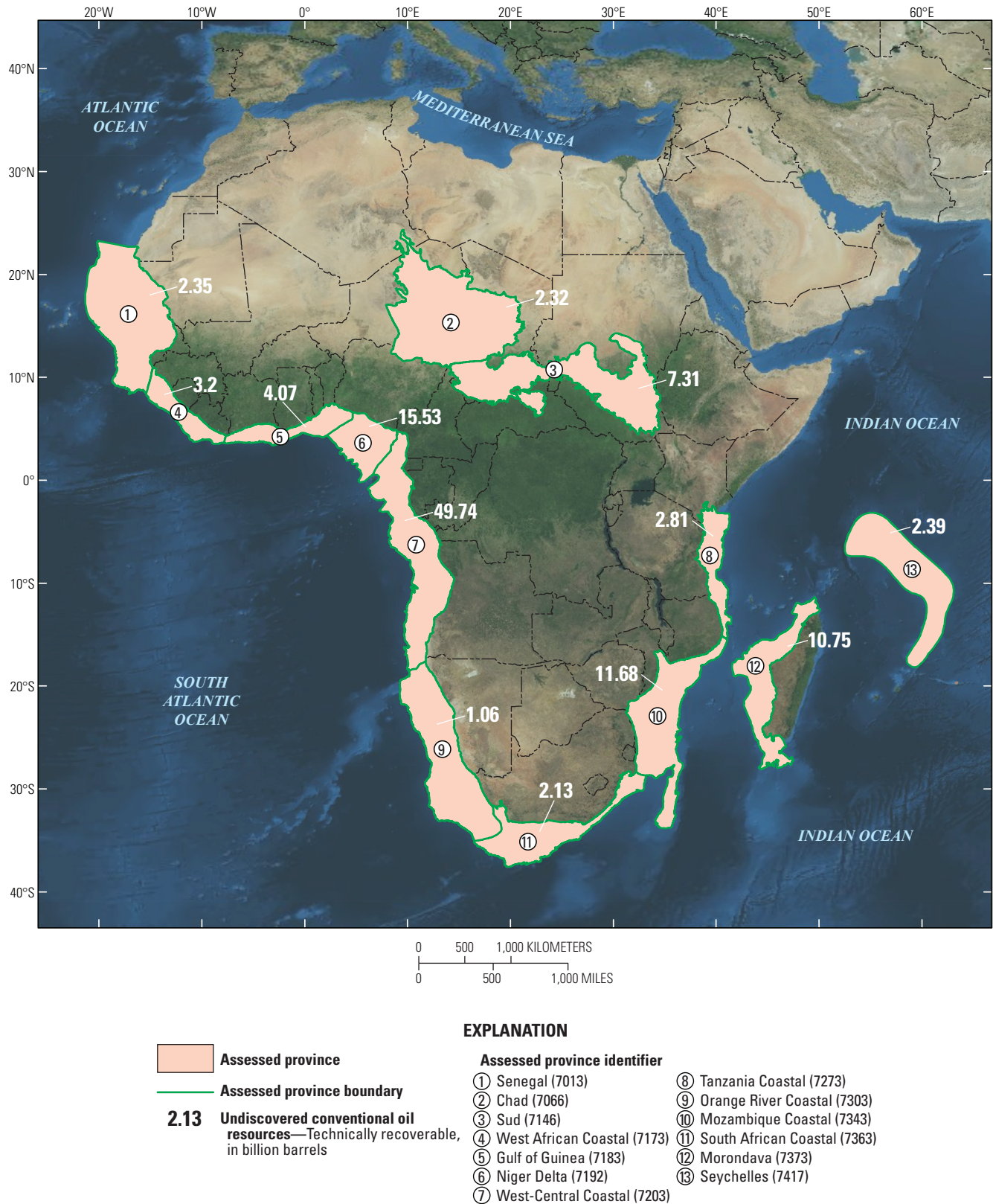


Figure 3. Mean undiscovered, technically recoverable conventional oil resources in Sub-Saharan Africa. BBO, billion barrels of oil.

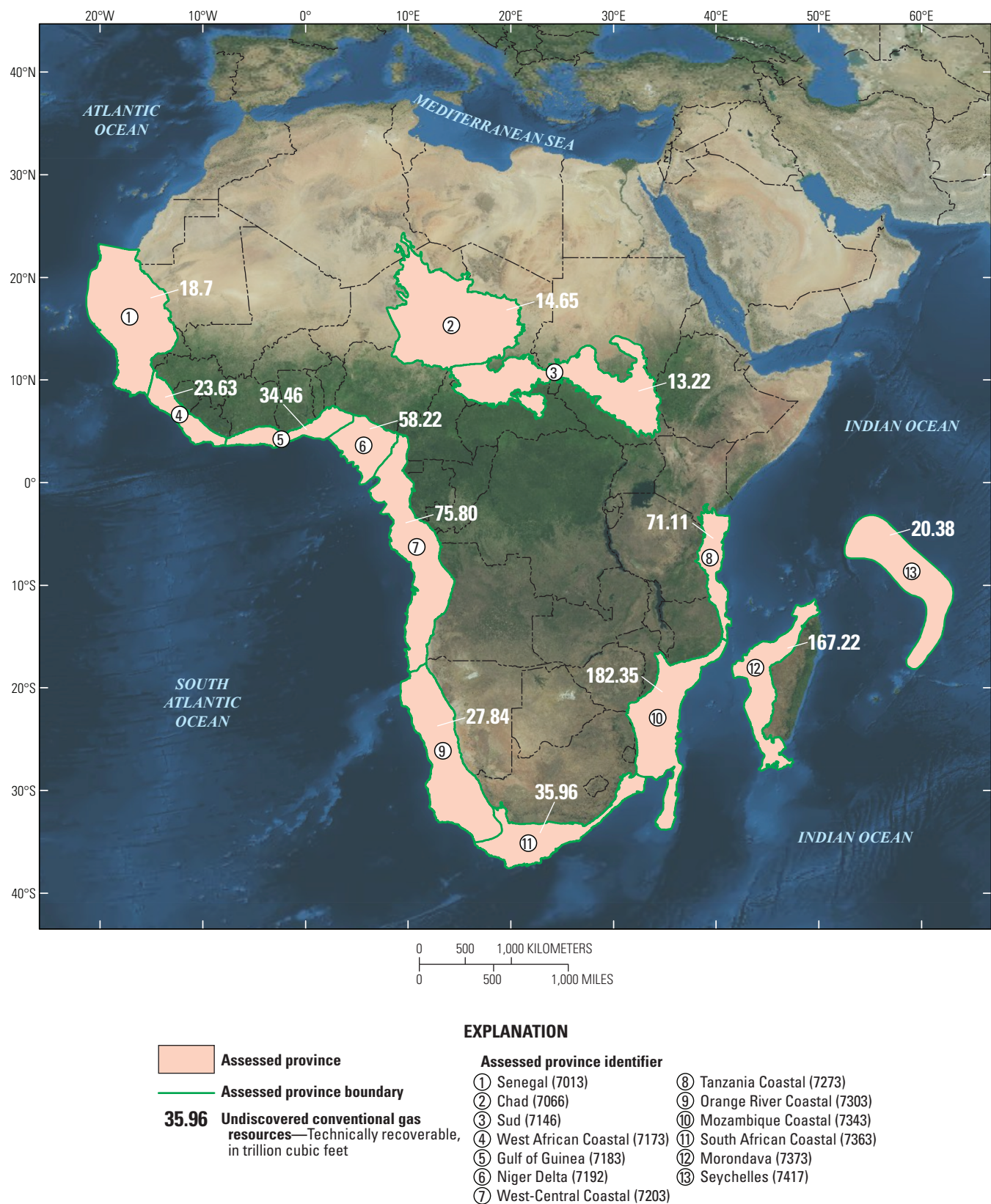


Figure 4. Mean undiscovered, technically recoverable conventional gas resources in Sub-Saharan Africa. TCF, trillion cubic feet.

For Additional Information

Supporting studies of the geologic provinces assessed and the methodologies used in the assessments are included in this CD-ROM. Assessment results are available at the USGS Energy Program website, <http://energy.cr.usgs.gov/oilgas/>. Contact Christopher J. Schenk, Task Leader (schenk@usgs.gov) or Michael E. Brownfield (mbrownfield@usgs.gov), U.S. Geological Survey, MS 939, Box 25046, Denver, Colorado, USA 80225.

World Conventional Resources Assessment Team

Michael E. Brownfield, Ronald R. Charpentier, Troy A. Cook, Donald L. Gautier, Debra K. Higley, Mark A. Kirschbaum, Timothy R. Klett, Janet K. Pitman, Richard M. Pollastro, Christopher J. Schenk (Task Leader), Marilyn E. Tennyson, and Craig J. Wandrey.

References

- IHS Energy, 2008, International petroleum exploration and production database [current through December 2008]: Available from IHS Energy, 15 Inverness Way East, Englewood, Colo. 80112 USA.
- IHS Energy, 2009, International petroleum exploration and production database [current through December 2009]: Available from IHS Energy, 15 Inverness Way East, Englewood, Colo. 80112 USA.
- U.S. Geological Survey World Energy Assessment Team, 2000, U.S. Geological Survey World Petroleum Assessment 2000—Description and results: U.S. Geological Survey Digital Data Series DDS-60, 4 CD-ROMs.
- U.S. Geological Survey World Conventional Resources Assessment Team, 2012, An estimate of undiscovered conventional oil and gas resources of the world, 2012: U.S. Geological Survey Fact Sheet 2012-3042, 6 p. Available at <http://pubs.usgs.gov/fs/2012/3042/>.



**Click here to return to
Volume Title Page**

