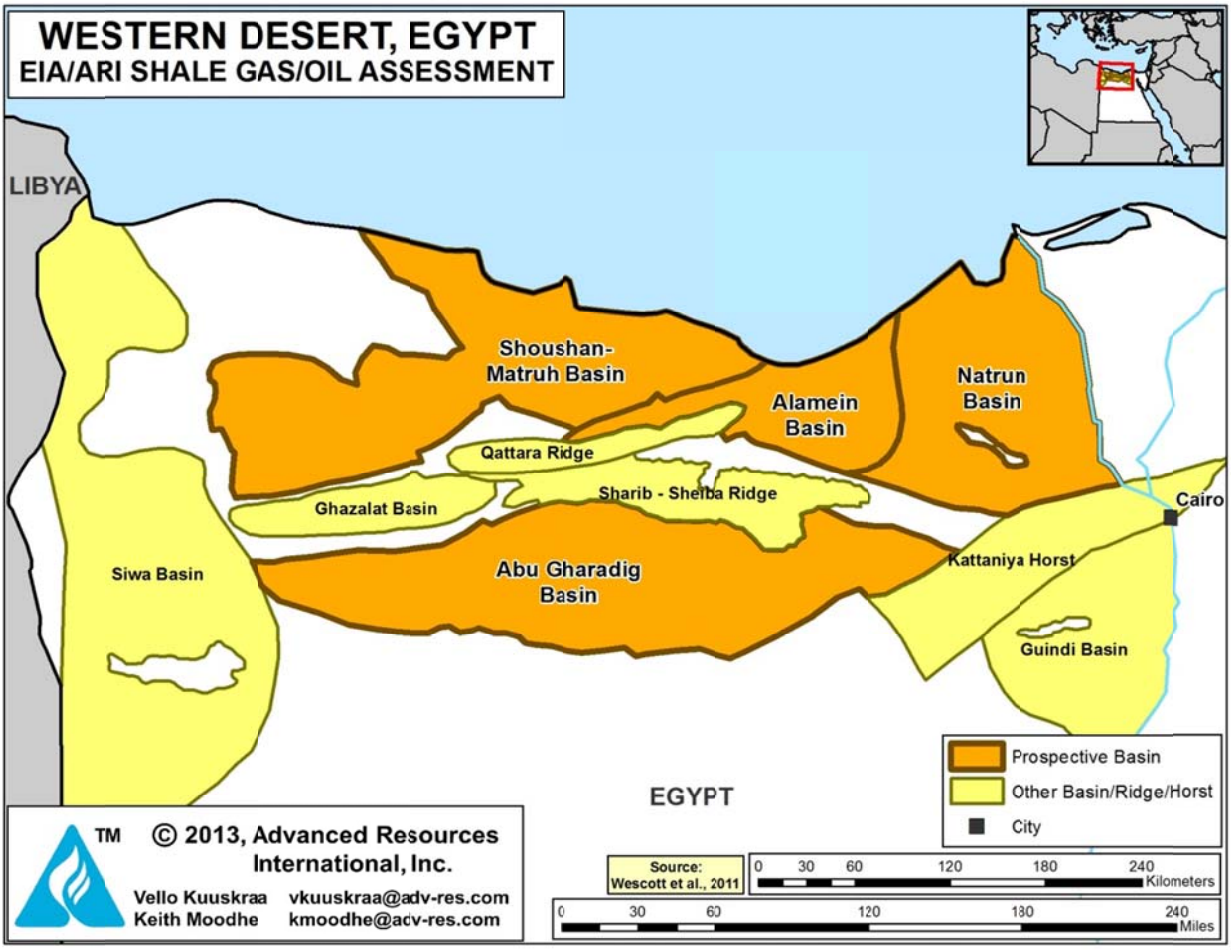
XVIII. EGYPT

SUMMARY

Egypt has four basins in the Western Desert with potential for shale gas and shale oil - - Abu Gharadig, Alamein, Natrun and Shoushan-Matruh, Figure XVIII-1.[1] The target horizon is the organic-rich Khatatba Shale, sometimes referred to as the Kabrit Shale or Safa Shale, within the larger Middle Jurassic Khatatba Formation.

Figure XVIII-1. Hydrocarbon Basins of the Western Desert, Egypt



Source: ARI, 2013.

Our assessment is that the Khatatba Shale contains approximately 535 Tcf of risked shale gas in-place, with 100 Tcf of risked, technically recoverable shale gas resources, Table XVIII-1. In addition, we estimate that the Khatatba Shale contains about 114 billion barrels of risked shale oil in-place, with 4.6 billion barrels of risked, technically recoverable shale oil resources, Table XVIII-2.

Table XVIII-1. Shale Gas Reservoir Properties and Resources of Egypt

			Abu Gharadig (7,670 mi^2)	Alamein (2,340 mi^2)	Natrun (4,860 mi^2)	Shoushan-Matruh (7,080 mi^2)
Basic Data	Basin/Gross Area					
	Shale Formation		Khatatba	Khatatba	Khatatba	Khatatba
	Geologic Age		M. Jurassic	M. Jurassic	M. Jurassic	M. Jurassic
	Depositional Environment		Marine	Marine	Marine	Marine
Physical Extent	Prospective Area (mi^2)		6,840	2,340	4,860	4,420
	Thickness (ft)	Organically Rich	1,500	1,000	1,200	1,000
		Net	300	200	240	200
	Depth (ft)	Interval	11,000 - 13,000	13,000 - 15,000	13,000 - 15,000	10,000 - 15,000
		Average	12,000	14,000	14,000	13,000
Reservoir Properties	Reservoir Pressure		Normal	Normal	Normal	Normal
	Average TOC (wt. %)		4.0%	4.0%	4.0%	4.0%
	Thermal Maturity (% Ro)		1.15%	0.85%	0.85%	1.15%
	Clay Content		Low/Medium	Low/Medium	Low/Medium	Low/Medium
Resource	Gas Phase		Wet Gas	Assoc. Gas	Assoc. Gas	Wet Gas
	GIP Concentration (Bcf/mi^2)		99.2	29.1	35.0	71.3
	Risked GIP (Tcf)		325.7	16.7	41.6	151.2
	Risked Recoverable (Tcf)		65.1	1.3	3.3	30.2

Table XVIII-2. Shale Oil Reservoir Properties and Resources of Egypt

			Abu Gharadig (7,670 mi^2)	Alamein (2,340 mi^2)	Natrun (4,860 mi^2)	Shoushan-Matruh (7,080 mi^2)
Basic Data	Basin/Gross Area					
	Shale Formation		Khatatba	Khatatba	Khatatba	Khatatba
	Geologic Age		M. Jurassic	M. Jurassic	M. Jurassic	M. Jurassic
	Depositional Environment		Marine	Marine	Marine	Marine
Physical Extent	Prospective Area (mi^2)		6,840	2,340	4,860	4,420
	Thickness (ft)	Organically Rich	1,500	1,000	1,200	1,000
		Net	300	200	240	200
	Depth (ft)	Interval	11,000 - 13,000	13,000 - 15,000	13,000 - 15,000	10,000 - 15,000
		Average	12,000	14,000	14,000	13,000
Reservoir Properties	Reservoir Pressure		Normal	Normal	Normal	Normal
	Average TOC (wt. %)		4.0%	4.0%	4.0%	4.0%
	Thermal Maturity (% Ro)		1.15%	0.85%	0.85%	1.15%
	Clay Content		Low/Medium	Low/Medium	Low/Medium	Low/Medium
Resource	Oil Phase		Condensate	Oil	Oil	Condensate
	OIP Concentration (MMbbl/mi^2)		14.3	25.1	30.1	7.9
	Risked OIP (B bbl)		47.1	14.4	35.9	16.8
	Risked Recoverable (B bbl)		1.88	0.58	1.43	0.67

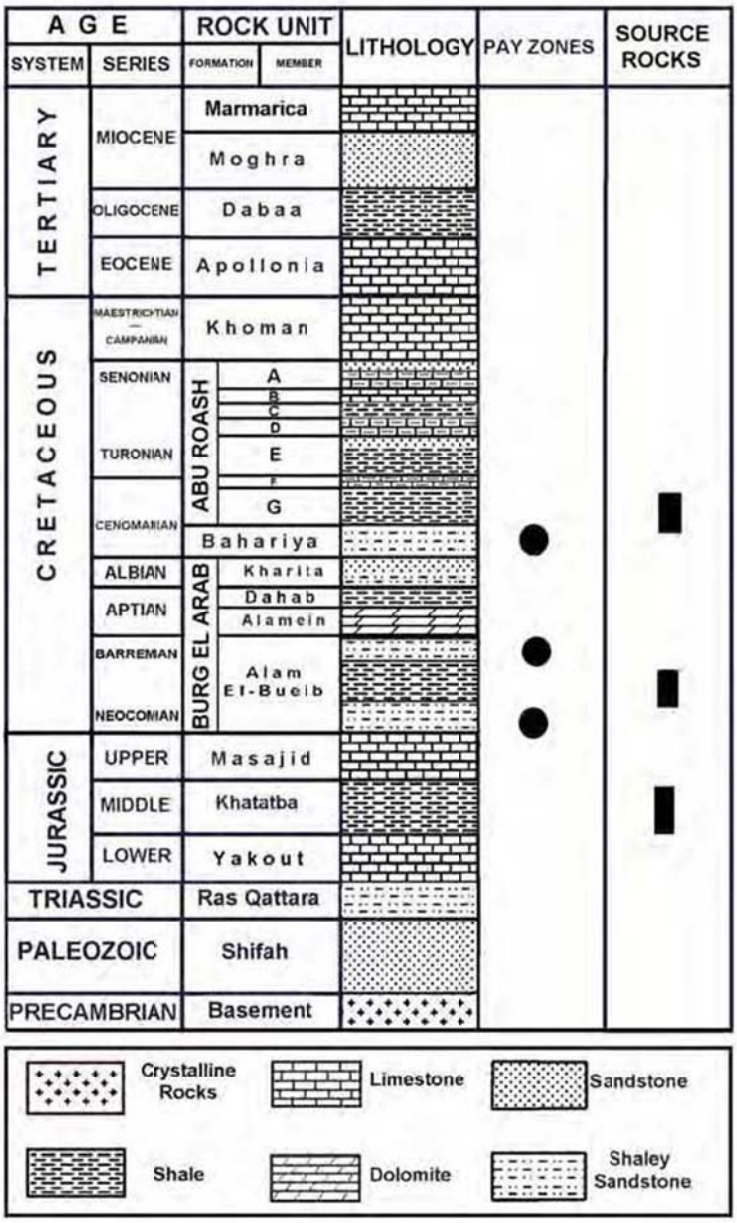
INTRODUCTION

The northern portion of the Western Desert of Egypt contains a series of basins underlain by organic-rich shales that have provided the source for the conventional hydrocarbons production from these basins. The primary hydrocarbon basins in the Western Desert include Abu Gharadig, Alamein, Natrun and Shoushan-Matruh. The Western Desert is the location of many of the major oil and gas fields of Egypt, including the more recently discovered, large Jurassic fields of Kanayes (discovered in 1992), Obayeid (discovered in 1993) and Shams (discovered in 1997).[2]

The basins have a thick sedimentary sequence comprising Paleozoic through Tertiary strata that exceed 15,000 feet, Figure XVIII-2.[3] Despite many years of successful discovery of conventional oil and gas deposits, the large Western Desert hydrocarbon basins of Egypt are still only lightly explored, particularly for their deeper formations.

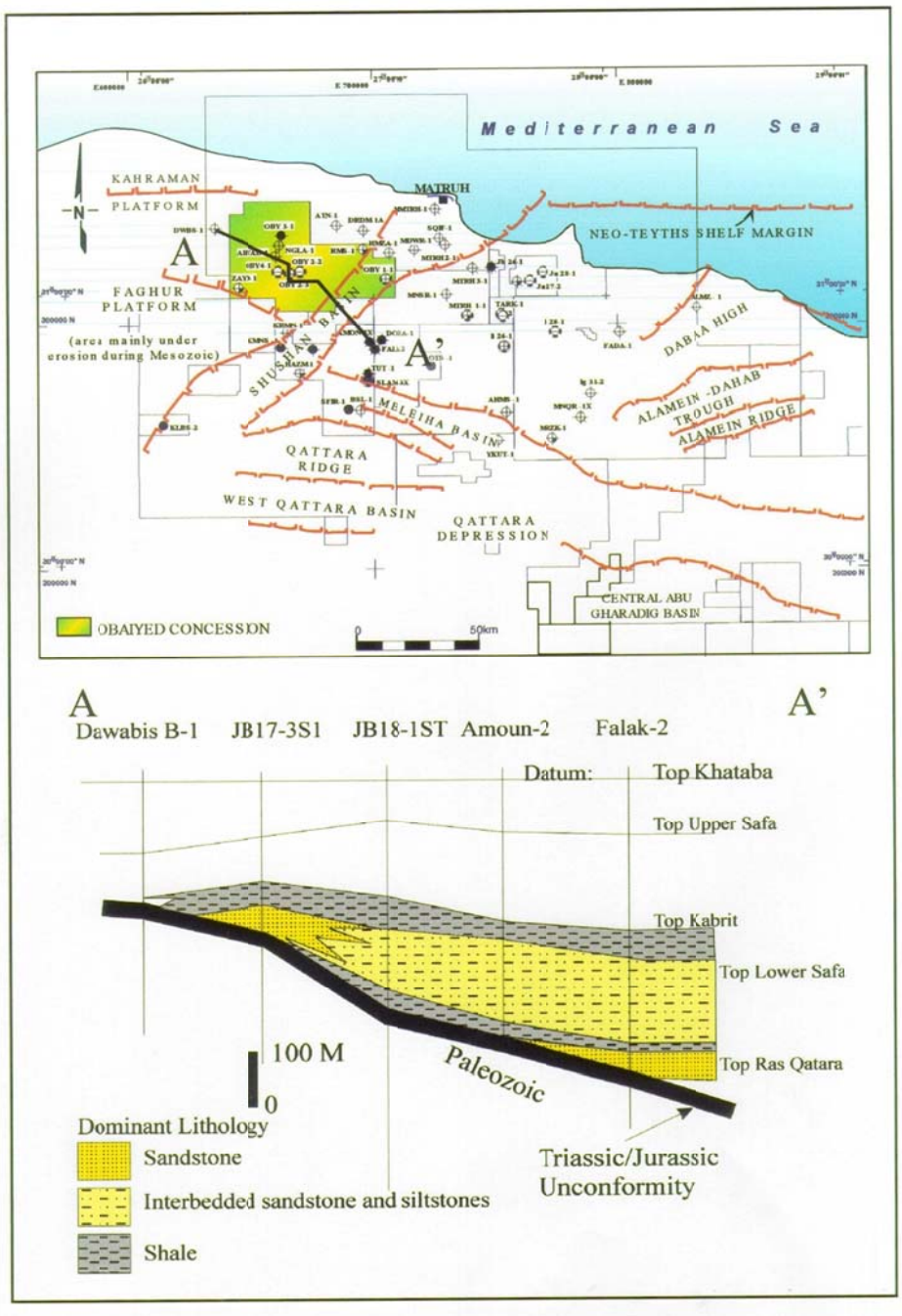
The focus of our shale resource study is the Khatatba Shale within the Middle Jurassic Khatatba Formation, also called the Kabrit Shale and the Safa Shale, Figure XVIII-3.[4]

Figure XVIII-2. Generalized Lithostratigraphic Column of the Western Desert of Egypt.



Source: Younes, 2012 (Modified after Abdou,1998).

Figure XVIII-3. Khatatba Formation and Kabrit (Safa) Shale, Shoushan-Matruh Basin, Western Desert.



Source: Dolson, 2000.

Egypt's geologic history is complex and a full discussion of its geology and tectonics is beyond the scope of this resource assessment. However, this chapter provides an overview that is intended to help place the shale oil and gas resources of the Western Desert into context. As such, the study examined three major shale source rocks in the Western Desert of Egypt before establishing the Middle Jurassic Khatatba Shale as the primary target.

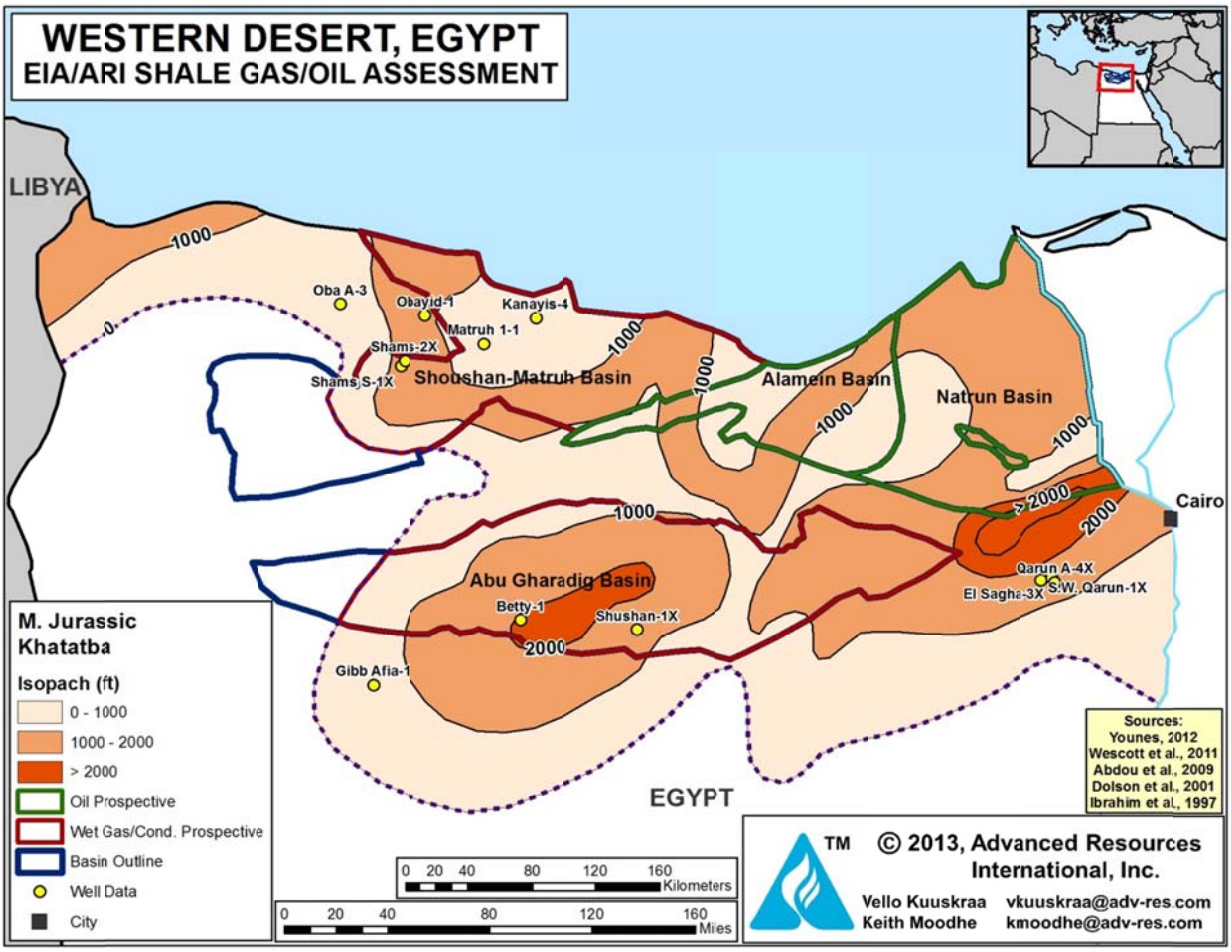
Silurian. A thick sequence of Silurian siltstone, estimated at about 200 to 300 m in the Basur-1 and Kohka-1 wells, exists in the northwestern portion of the Western Desert.[5] These sandstones and siltstones thin to the south and east as shown by the Foram-1 and Sheiba-1 wells.[6] The sandstone and siltstone units appear to rest directly on Upper Ordovician glacial deposits without any evidence of Silurian organic-rich shales.[8] The Western Desert of Egypt lacks a Silurian Tannezuft ("Hot Shale") source rock equivalent due to a paleo-basement high and erosion of Silurian sediments.[7]

Cretaceous. Cretaceous-age shale source rocks within the Alam El-Bueib and Abu Roash formations exist across much of the Western Desert. However, these shales have been classified as marginal to moderate source rock quality for oil and gas generation, with TOC values generally reported at less than 2%. In addition, the Cretaceous-age source rocks are thermally immature in significant portions of the Western Basin study area.[8] Due to these less favorable reservoir properties and limited data, we have not included these Cretaceous-age source rocks in our shale oil and gas resource assessment.

Jurassic. During the late Triassic and Jurassic, a series of rift basins formed in the Western Desert. These rift basins and their subsequent extension during the Cretaceous provided the setting for the important Khatatba Formation and its thick, black shale deposition. The Khatatba Shale (also called the Safa Shale) has served as the source rock for much of the oil and gas found in the Western Desert.[2,3]

The larger Khatatba Formation ranges from 1,000 feet to over 2,000 feet thick in the Western Desert. The type section of the Kabrit (Safa) Shale Member within the Khatatba Formation ranges in thickness from 0 to over 600 feet in the Western Desert, with an estimated net pay of 200 to 300 feet, XVIII-Figure 4.[3,9,2,10]

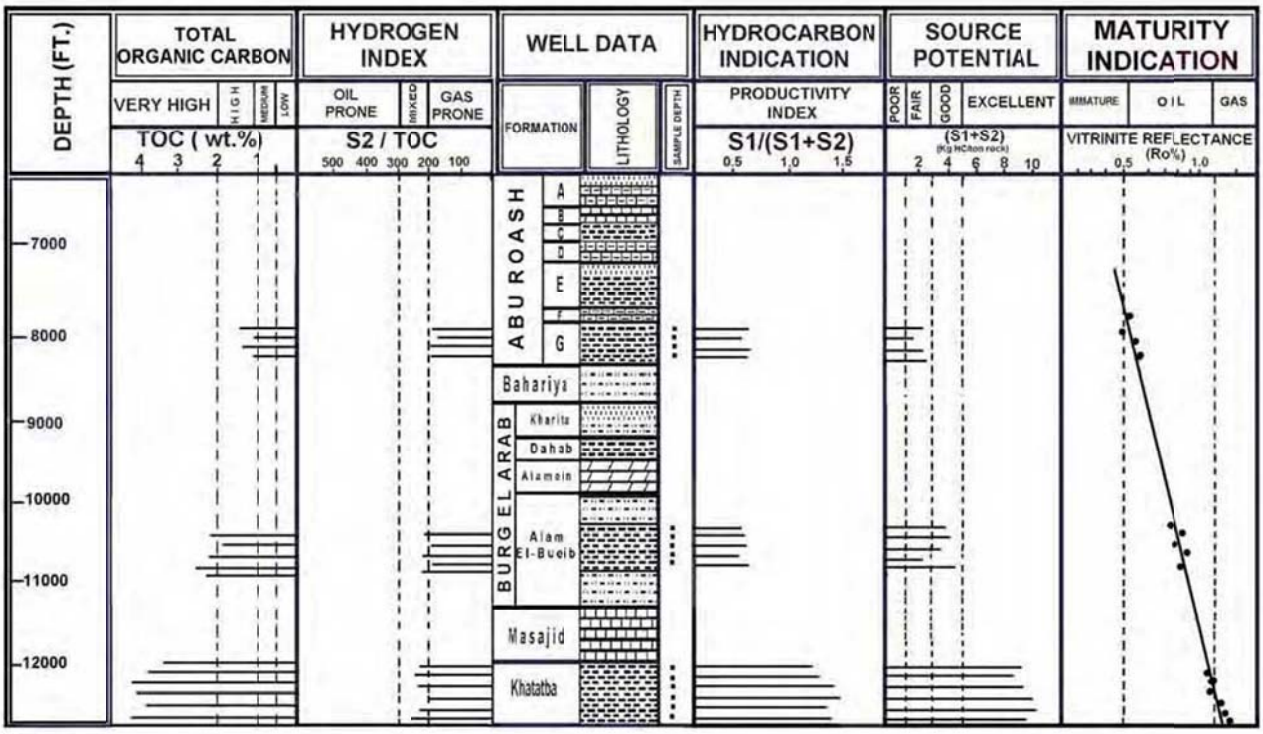
Figure XVIII-4. Middle Jurassic Khatatba Formation Gross Isopach



Source: ARI, 2013.

Detailed source rock evaluations of core samples from the Shushan-1X well in the southern portion of the Abu Gharadig Basin provided important data on the reservoir properties of the Khatatba Shale. The TOC of the shale varied from 3.6% to 4.2% with a vitrinite reflectance (R_o) of 1.0% to 1.3%, placing the shale primarily in the wet gas and condensate window, Figure XVIII-5.[3] The shale contains mixed vitrinite-inertinite kerogen derived from land plants and algae, implying a mixture of marginal marine and continental organic matter.[11] The combination of maximum temperature and kerogen type places the Khatatba Shale primarily in the wet gas/condensate and volatile oil windows with significant associated plus free gas in the pore space.

Figure XVIII-5. TOC and Maturity Data, Jurassic- and Cretaceous-Age Source Rocks, Western Desert, Egypt



Source: Younes, 2012

ABU GHARADIG BASIN

Geologic Setting. The 7,670-mi^2 Abu Gharadig Basin is an east-west trending half graben with a depth to basement that exceeds 30,000 feet. The basin is bounded on the north by the Qattara Ridge and on the south by the Sitra Platform. The Jurassic-age Khatatba Shale is considered the major hydrocarbon source rock in this basin.[2] We have identified a 6,840-mi^2 prospective area in this basin after excluding the western portion of the basin which lacks Middle Jurassic deposits, Figure XVIII-4.

Reservoir Properties (Prospective Area). Within the 6,840-mi^2 prospective area, the depth of the Khatatba Shale in the Abu Gharadig Basin ranges from 11,000 to 13,000 feet, averaging 12,000 feet. The gross interval of the Khatatba Formation ranges from near 0 to over 2,000 feet, averaging about 1,500 feet thick. The net shale, using a net to gross ratio of 0.2, is estimated at 300 feet. Based on grain and bulk density data from the Betty-1 well, drilled in the south central portion of the basin, the porosity ranges from 2.4% to 8.4%, averaging 5.7% for six

core samples. The TOC of the shale, using data from the Shushan-1X well, ranges from 3.6% to 4.2%, averaging 4%, with thermal maturity (Ro) values of 1.0% to 1.3%.

Resource Assessment. Within the 6,840-mi^2 prospective area of the Abu Gharadig Basin, the Khatatba Shale has a resource concentration of 99 Bcf of wet gas and 14 million barrels of oil/condensate per mi^2. The risked resource in-place for wet gas in the prospective area is estimated at 326 Tcf, with 65 Tcf as the risked, technically recoverable shale gas resource, Table XVIII-1. The risked resource in-place for oil/condensate in the prospective area is estimated at 47 billion barrels with 1.9 billion barrels of the risked, technically recoverable shale oil resource, Table XVIII-2.

ALAMEIN BASIN

Geologic Setting. The Alamein Basin is a large Jurassic rift basin in the northwestern portion of the Western Desert which was further extended during the Cretaceous. The onshore portion of the basin is bounded on the north by the Mediterranean Sea and on the south by the Qattara Ridge. The Jurassic-age Khatatba Shale, which contains mixed Type II and III kerogen, appears to be the main shale oil and gas target in this basin. Remarkably, the entire basin appears to be prospective for the Khatatba Shale.

Reservoir Properties (Prospective Area). Within the 2,340-mi^2 prospective area, the depth of the Khatatba Shale in the Alamein Basin ranges from 13,000 to 15,000 feet, averaging 14,000 feet. The gross interval of the Khatatba Formation averages 1,000 feet with a porosity of 5.7%. Organic content ranges up to 10%, with an average of 4%, and the shale is in the oil thermal maturity window (R_o of 0.8% to 1.0%).[12]

Resource Assessment. Within the 2,340-mi^2 prospective area of the Alamein Basin, the Khatatba Shale has a resource concentration of 25.1 million barrels of oil/condensate per mi^2 plus associated gas. The risked resource in-place for oil/condensate in the prospective area is estimated at 14 billion barrels, with 0.6 billion barrels as the risked, technically recoverable resource, Table XVIII-2. The basin also has associated gas estimated at 17 Tcf of risked in-place, with about 1 Tcf as risked technically recoverable, Table XVIII-1.

NATRUN BASIN

Geologic Setting. The Natrun Basin, covering an area of 4,860 mi^2, is a poorly defined basin located between the major oil and gas fields of the Nile Delta and the Western Desert.[13] The basin is bounded on the north by the Mediterranean Sea and on the south by the Kattaniya Horst. The Natrun Basin appears to hold a favorable conventional petroleum system of source rock, reservoir-seal, and timing of thermal maturity. The Jurassic-age Khatatba Shale is considered the major hydrocarbon source rock in this basin.[2] The entire basin appears to be prospective for the Middle Jurassic Khatatba Shale, Figure XVIII-4.

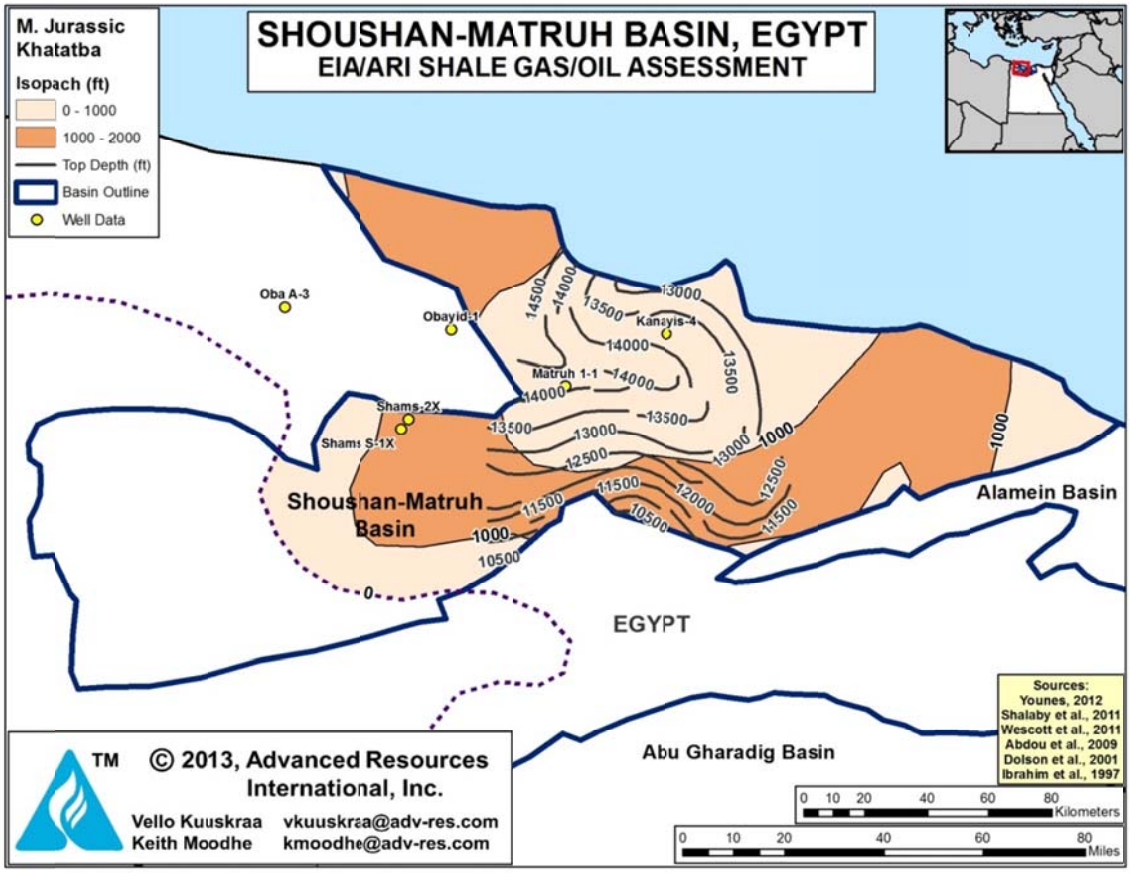
Reservoir Properties (Prospective Area). Within the 4,860-mi^2 prospective area, the depth of the Khatatba Shale in the Natrun Basin ranges from 13,000 to 15,000 ft, averaging 14,000 ft. The gross interval of the Khatatba Formation ranges from near 0 to over 2,000 ft, averaging about 1,200 ft thick. The net shale, using a net to gross ratio of 0.2, is estimated at 240 ft, with a porosity averaging 5.7%. The TOC averages 4% with thermal maturity (R_o) values of 0.7% to 1.0%, placing the shale in the oil window. (Although thermal modeled vitrinite reflectance values indicated over-mature Jurassic source rocks, borehole data from intra-basinal sediments showed a thermal maturity in the oil window).**Error! Bookmark not defined.**

Resource Assessment. Within the 4,860-mi^2 prospective area of the Natrun Basin, the Khatatba Shale has a resource concentration of 30.1 million barrels of oil/condensate per mi^2. The risked resource in-place for oil/condensate in the prospective area is estimated at 36 billion barrels, with 1.4 billion barrels as the risked, technically recoverable resource, Table XVIII-2. The basin also has associated gas estimated at 42 Tcf of risked in-place, with 3 Tcf of risked technically recoverable resources, Table XVIII-1.

SHOUSHAN-MATRUH BASIN

Geologic Setting. The Shoushan-Matruh Basin is a large Jurassic rift basin in the northwestern portion of the Western Desert which also was further extended during the Cretaceous. The basin is bounded on the north by the Mediterranean Sea and on the south by the Qattara Ridge. The Jurassic-age Khatatba Shale is the focus of our shale oil and gas resource assessment in this basin. We have identified a prospective area of 4,420 mi^2 in this basin after deleting the western portion of the basin beyond the limits of Middle Jurassic deposition, Figure XVIII-6.[3,14,1,9,2,10]

Figure XVIII-6. Shoushan-Matruh Basin, Khatatba Shales Depth and Gross Isopach



Source: ARI, 2013.

Reservoir Properties (Prospective Area). Within the 4,420-mi^2 prospective area, the depth of the Khatatba Shale in the Shoushan-Matruh Basin ranges from 10,000 to 15,000 ft, averaging 13,000 ft. The gross interval of the Khatatba Formation ranges from near zero to over 1,500 ft averaging 1,000 ft. The Khatatba Shale has an organic content averaging 4% and a thermal maturity of R_o 1.0% to 1.3%, placing the shale in the wet gas/condensate window. Core analysis indicates a porosity of about 5.7%.

Resource Assessment. Within the 4,420-mi^2 prospective area of the Shoushan-Matruh Basin, the Khatatba Shale has a resource concentration of 71 Bcf of wet gas and 7.9 million barrels of oil/condensate per mi^2. The risked resource in-place for wet gas in the prospective area is estimated at 151 Tcf, with 30 Tcf as the risked technically recoverable resource, Table XVIII-1. The risked resource in-place for oil/condensate in the prospective area is estimated at 17 billion barrels, with 0.7 billion barrels as the risked, technically recoverable resource, Table XVIII-2.

RECENT ACTIVITY

Much of the past exploration drilling in the Western Desert has targeted the Cretaceous and shallower sediments. Recently, however, Apache has begun to successfully explore the deeper Jurassic sediments, such as the Safa Sandstone in the Faghur Basin of the Western Desert. In 2010, Apache announced that an unidentified shale formation below the East Bahariya Field holds "between 700 million and 2.2 billion barrels of oil". The company stated that, "We have two wells planned to test the idea here later this year."[15] However, no further information is publically available as to activity or results involving the exploration for oil from these shales.

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