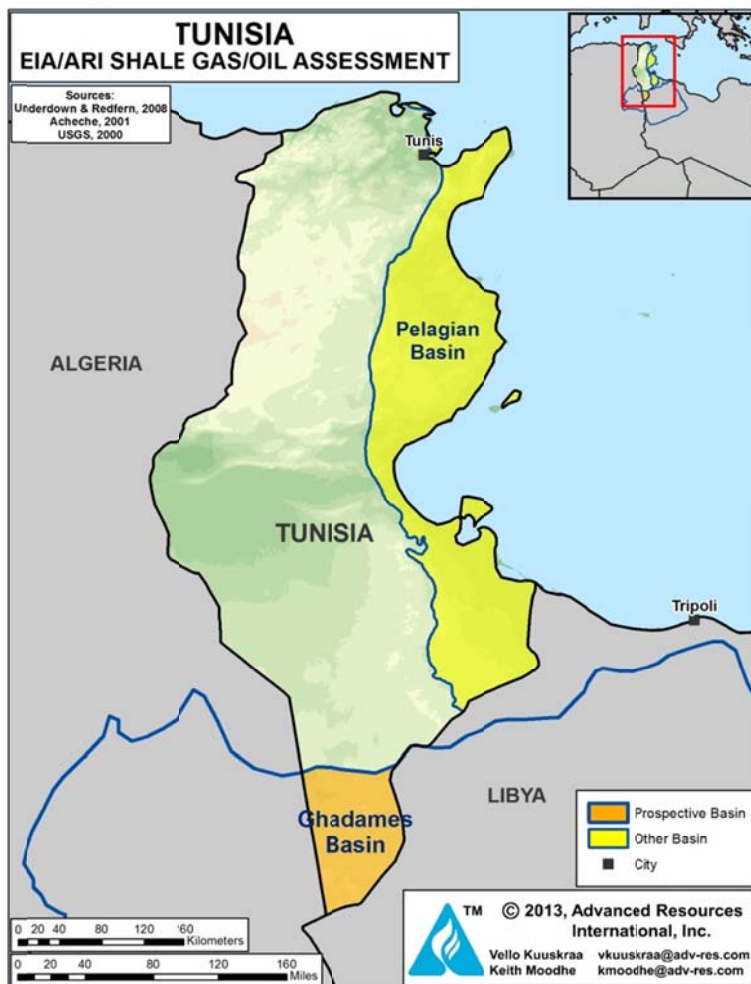


XVI. TUNISIA

SUMMARY

Tunisia has two significant formations with potential for shale gas and shale oil - - the Silurian Tannezuft “Hot Shale” and the Upper Devonian Frasnian Shale. These shale formations are in the Ghadames Basin, located in southern Tunisia. Additional shale gas and oil potential may exist in the Jurassic-Cretaceous and Tertiary petroleum systems in the Pelagian Basin of eastern Tunisia, as discussed further in this Chapter, Figure XVI-1.

Figure XVI-1. Tunisia’s Shale Gas and Shale Oil Basins



Source: ARI, 2013.

Our assessment is that the Tannezuft and Frasnian shale formations in the Ghadames Basin contain 114 Tcf of risked shale gas in-place, with 23 Tcf as the risked, technically recoverable shale gas resource, Table XVI-1. In addition, these two shale formations contain 29 billion barrels of risked shale oil in-place, with 1.5 billion barrels as the risked, technically recoverable shale oil resource, Table XVI-2.

Table XVI-1. Shale Gas Reservoir Properties and Resources of Tunisia.

Basic Data	Basin/Gross Area		Ghadames (117,000 mi ²)				
	Shale Formation		Tannezuft		Frasnian		
	Geologic Age		Silurian		U. Devonian		
	Depositional Environment		Marine		Marine		
Physical Extent	Prospective Area (mi ²)		410	940	1,210	850	80
	Thickness (ft)	Organically Rich	115	115	197	197	197
		Net	104	104	177	177	177
	Depth (ft)	Interval	10,000 - 11,000	11,000 - 14,500	8,000 - 10,000	9,000 - 10,000	10,000 - 11,000
Average		10,500	13,000	8,500	9,500	10,500	
Reservoir Properties	Reservoir Pressure		Mod. Overpress.	Mod. Overpress.	Mod. Overpress.	Mod. Overpress.	Mod. Overpress.
	Average TOC (wt. %)		5.7%	5.7%	6.0%	6.0%	6.0%
	Thermal Maturity (% Ro)		1.15%	1.60%	0.85%	1.15%	1.35%
	Clay Content		Medium	Medium	Medium	Medium	Medium
Resource	Gas Phase		Wet Gas	Dry Gas	Assoc. Gas	Wet Gas	Dry Gas
	GIP Concentration (Bcf/mi ²)		42.9	54.5	25.4	79.8	100.7
	Risked GIP (Tcf)		11.4	33.3	20.0	44.1	5.2
	Risked Recoverable (Tcf)		2.3	8.3	2.0	8.8	1.3

Table XVI-2. Shale Oil Reservoir Properties and Resources of Tunisia.

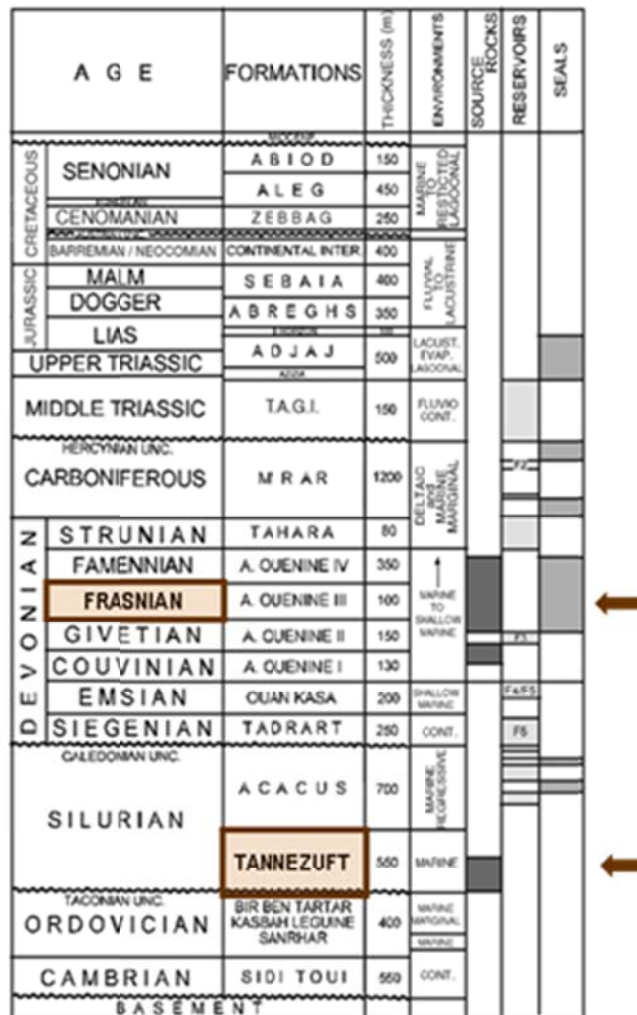
Basic Data	Basin/Gross Area		Ghadames (117,000 mi ²)		
	Shale Formation		Tannezuft	Frasnian	
	Geologic Age		Silurian	U. Devonian	
	Depositional Environment		Marine	Marine	
Physical Extent	Prospective Area (mi ²)		410	1,210	850
	Thickness (ft)	Organically Rich	115	197	197
		Net	104	177	177
	Depth (ft)	Interval	10,000 - 11,000	8,000 - 10,000	9,000 - 10,000
Average		10,500	8,500	9,500	
Reservoir Properties	Reservoir Pressure		Mod. Overpress.	Mod. Overpress.	Mod. Overpress.
	Average TOC (wt. %)		5.7%	6.0%	6.0%
	Thermal Maturity (% Ro)		1.15%	0.85%	1.15%
	Clay Content		Medium	Medium	Medium
Resource	Oil Phase		Condensate	Oil	Condensate
	OIP Concentration (MMbbl/mi ²)		3.1	31.3	7.0
	Risked OIP (B bbl)		0.8	24.6	3.9
	Risked Recoverable (B bbl)		0.04	1.23	0.19

1. GHADAMES BASIN

1.1 Introduction and Geologic Setting

The Silurian-age Tannezuft “Hot Shale” (called “hot” because of its high uranium content; gamma-ray values >150 API units) is present in much of North Africa and the Middle East. This organic-rich shale has served as a major source rock for many of the conventional oil and gas fields in the region. The Upper Devonian-age Frasnian Shale is deposited above the deeper Tannezuft Shale. It has also served as an important source rock for the Devonian and Triassic conventional reservoirs in the region, Figure XVI-2.¹

Figure XVI-2. Ghadames Basin Stratigraphic Column



Source: Acheche, M.H, 2001.

Prior geological and source rock studies by Acheche (2001),¹ Yahi (2001),² and Klett (2000),³ as well as more recent information from oil and gas production companies operating in Tunisia^{4,5,6,7} have provided valuable information on the geologic setting and reservoir properties of the shale formations of Tunisia.

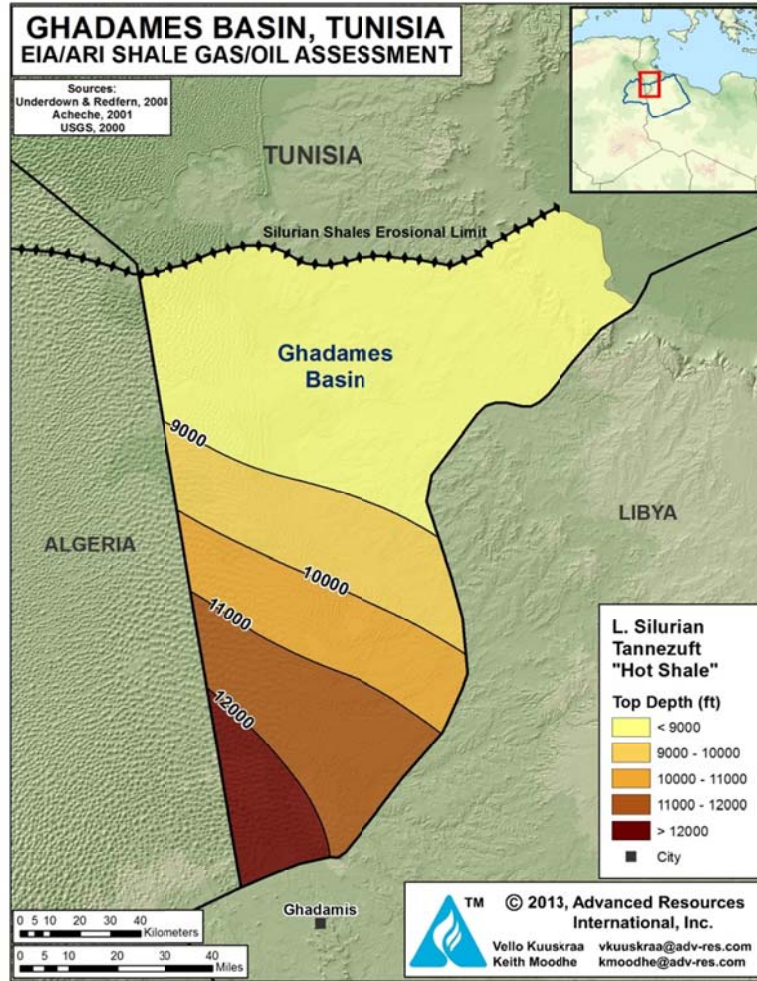
The Ghadames Basin and its two significant shale formations are located in the southern portion of Tunisia. Figures XVI-3 and XVI-4 provide the Ghadames Basin's shale outline and depth contours for the Silurian Tannezuft "Hot Shale"¹ and the Upper Devonian Frasnian Shale.

In Tunisia's portion of the Ghadames Basin, the Tannezuft Formation contains a organic-rich marine shale that grades from immature on the north to post-mature on the south. We have mapped a 1,350-mi² higher quality prospective area for the Tannezuft "Hot Shale" in the Ghadames Basin giving considerable emphasis to the recently assembled data on the mineralogy of the shale. The western and northern boundaries of the prospective area are defined by a change in shale deposition from higher quartz, lower clay to lower quartz, higher clay mineralogy. The eastern and southern borders of the prospective area are defined by the Tunisia and Libya border.

The northern portion of the Tannezuft "Hot Shale" prospective area covers 410 mi² and has thermal maturity of 1.0% to 1.3% R_o, placing this area in the wet gas and condensate window. The remaining prospective area of 940 mi² for the Tannezuft "Hot Shale", with R_o greater than 1.3%, is in the dry gas window, Figure XVI-5.

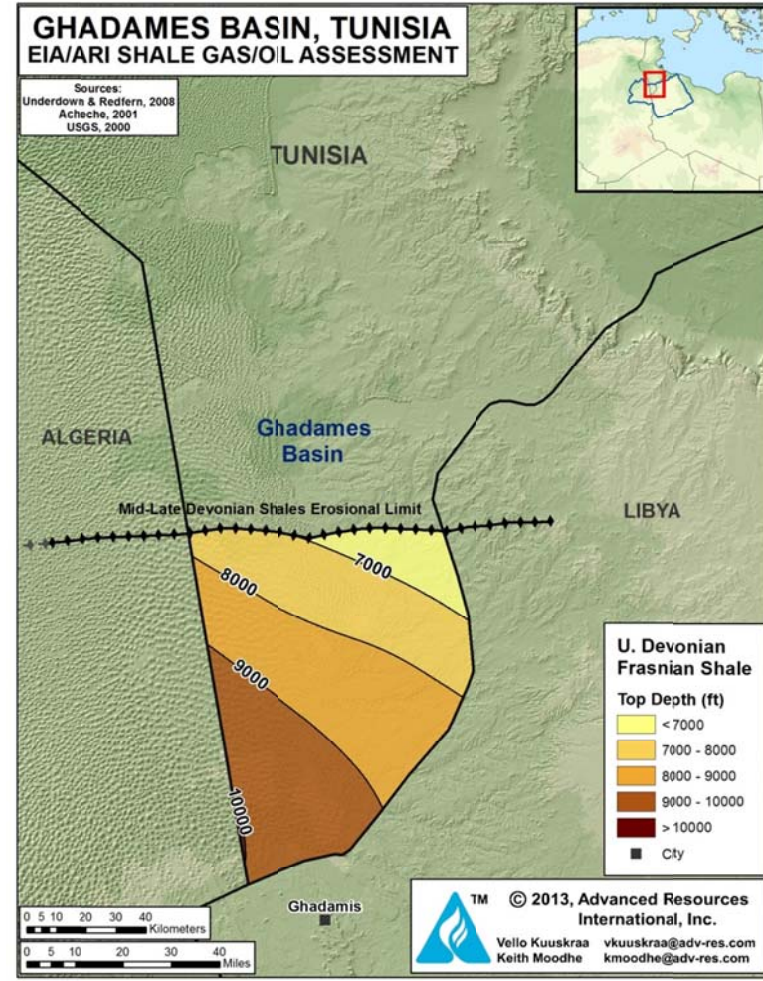
Deposited above the Tannezuft "Hot Shale" is the thermally less mature Frasnian Shale. We have mapped a 2,140-mi² prospective area for the Frasnian Shale in Tunisia's portion of the Ghadames Basin. The northern boundary of the Frasnian Shale prospective area is the minimum oil maturity criterion of 0.7% R_o. The western boundary of the prospective area is the Tunisia and Algeria border. The eastern and southern boundary of the Frasnian Shale prospective area is the Tunisia and Libya border.

Figure XVI-3. Ghadames Basin Silurian Tannezuft Shale Outline and Depth Contours



Source: ARI, 2013.

Figure XVI-4. Ghadames Basin Upper Devonian Frasnian Shale Outline and Depth Contours



Source: ARI, 2013.

The 1,210-mi² northern and eastern portion of the Frasnian Shale prospective area is in the oil window, with R_o between 0.7% and 1.0%. The 850-mi² central portion of the prospective area is in the wet gas and condensate window, with R_o between 1.0% and 1.3%. A relatively small 80-mi² area in the southwestern portion of the Frasnian Shale prospective area is in the dry gas window, with R_o above 1.3%, Figure XVI-6.

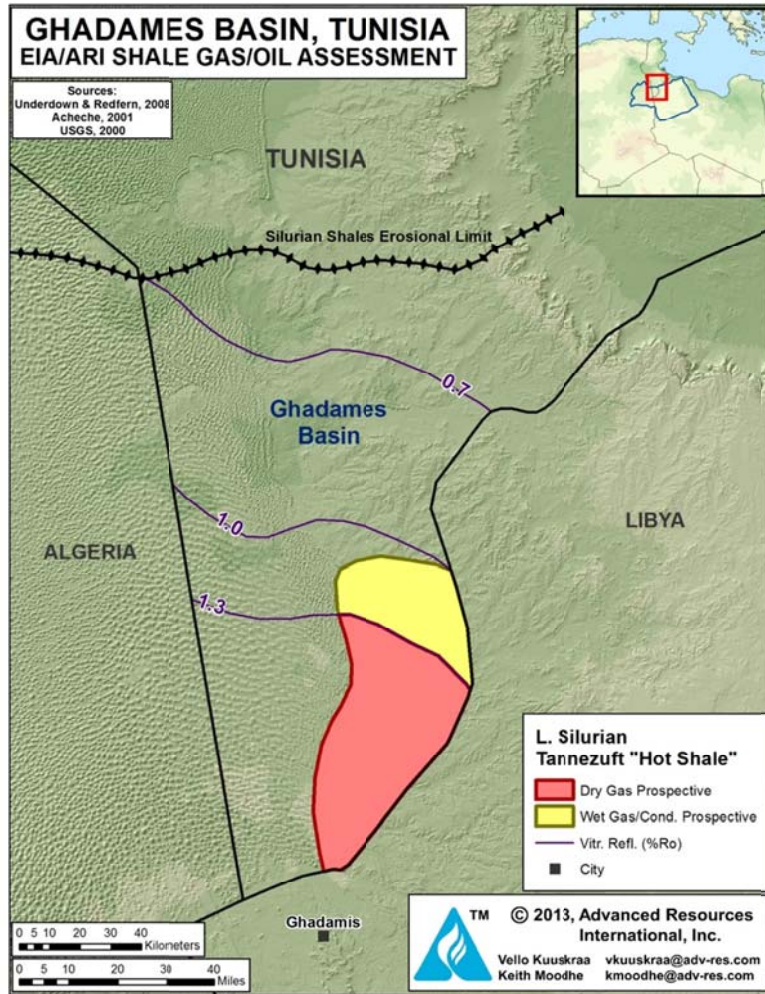
1.2 Reservoir Properties (Prospective Area)

Silurian Tannezuft Shale. The depth of the Silurian Tannezuft “Hot Shale” in the prospective area ranges from 10,000 ft along the northern and eastern basin edge to 14,500 ft in the basin center, averaging 10,500 ft in the wet gas area and 13,000 ft in the dry gas area, Figure XVI-3. The gross thickness of the Tannezuft “Hot Shale” is 115 ft, with an organic-rich average net thickness of 104 ft. (A thick package of Wenlockian silty sands overlies the Llandoveryan “Hot Shales” within the Silurian Tannezuft Formation. These high porosity, potentially gas-charged silty sands are not included in our shale gas resource assessment.)

The TOC of the Tannezuft “Hot Shale” averages 5.7%. The lower portion of the formation is particularly organic-rich, with TOC values of up to 15%.⁴ The thermal maturity of the Tannezuft “Hot Shale” ranges from wet gas (R_o of 1.0% to 1.3%) in the northern portion of the prospective area to dry gas ($R_o > 1.3%$) in the southern portion of the prospective area in the Ghadames Basin, Figure XVI-5.

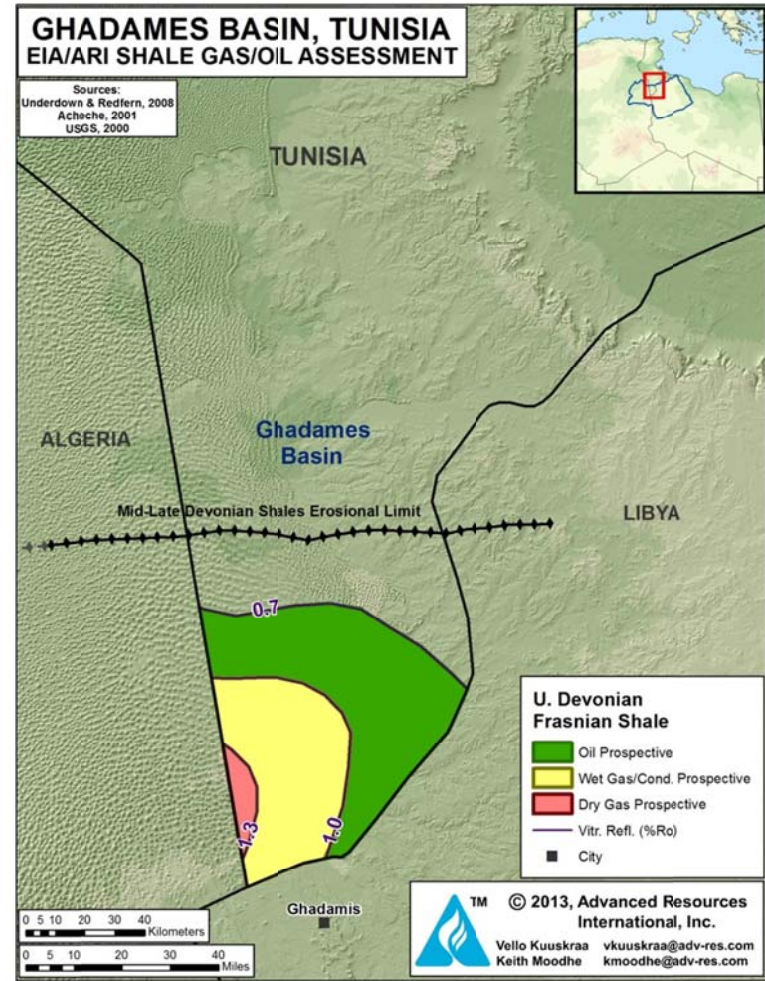
Upper Devonian Frasnian Shale. The depth of the overlying Upper Devonian Frasnian Shale in the prospective area ranges from 8,000 ft to 11,000 ft, averaging 8,500 ft in the oil-prone area, 9,500 ft in the wet gas/condensate area, and 10,500 ft in the dry gas area, Figure XVI-3. The Frasnian Shale has a gross thickness of 197 ft with an organic-rich net thickness of 177 ft. The Frasnian Shale has TOC values that range from 1% to 10% with an average of 6%.³ The thermal maturity in the Frasnian Shale in the prospective area ranges from 0.7% in the north to over 1.3% R_o in the southwest, placing the shale in the oil, wet gas/condensate and dry gas windows, Figure XVI-5.

Figure XVI-5. Ghadames Basin Silurian Tannezuft "Hot Shale" Prospective Area



Source: ARI, 2013.

Figure XVI-6. Ghadames Basin Upper Devonian Frasnian Shale Prospective Area



Source: ARI, 2013.

1.3 Resource Assessment

Silurian Tannezuft Shale. The Tannezuft “Hot Shale”, within its 410-mi² wet gas and condensate prospective area, has resource concentrations of 43 Bcf/mi² of wet gas and 3.1 million barrels/mi² of condensate. Within its 940-mi² dry gas prospective area, the Tannezuft “Hot Shale” has a resource concentration of 54 Bcf/mi².

The risked resource in-place for the overall 1,350-mi² wet gas/condensate and dry gas prospective area is 45 Tcf of shale gas and 0.8 billion barrels of shale oil. Based on moderate reservoir properties, particularly the medium level of clay content, we estimate risked, technically recoverable resources from the Tannezuft “Hot Shale” of 11 Tcf of shale gas and less than 0.1 billion barrels of shale oil, Tables XVI-1 and XVI-2.

Upper Devonian Frasnian Shale. The Frasnian Shale, within its overall 2,140-mi² prospective area has resource concentrations of 31 million barrels/mi² of oil (plus associated gas) in the 1,210-mi² oil window, 7 million barrels/mi² of condensate and 80 Bcf/mi² of wet gas in the 850-mi² wet gas/condensate window, and 101 Bcf/mi² of dry gas in the 80-mi² dry gas window.

The risked resource in-place within the overall 2,140-mi² prospective area is 69 Tcf of shale gas and 28.5 billion barrels of shale oil. Based on moderate reservoir properties, we estimate risked, technically recoverable resources from the Frasnian Shale of 12 Tcf of shale gas and 1.4 billion barrels of shale oil, Tables XVI-1 and XVI-2.

1.4 Recent Activity

Considerable exploration activity is underway in the Ghadames Basin, with much of the activity still devoted to conventional oil and gas resources. Cygam Energy has acquired four permits in the Ghadames Basin totaling 1.6 million net acres.⁴ Cygam’s exploration program involves 200 km of 3D seismic and two deep exploration wells. The company reportedly conducted a hydraulic stimulation in March 2010 on Well No. 1, completed in the Tannezuft Shale at a depth of 13,000 ft in their Sud Tozeur permit area. No information has been provided on test results. Cygam is seeking a JV partner to further develop its four Tunisia permit areas.

Chinook Energy Inc. has acquired a series of lease blocks in the Ghadames Basin, totaling 1.3 million net acres. The large Sud Remada block totals 1.2 million acres and targets

the Tannezuft Shale as well as conventional formations.⁵ The company plans to drill a deep exploration well in the Sud Remada lease block during 2013, targeting conventional Ordovician and Silurian resources. Previous drilling into the deeper, oil bearing “TT” Ordovician reservoir showed hydrocarbon potential in the Silurian Tannezuft Formation.

In early 2010, Perenco Tunisia reportedly drilled and hydraulically stimulated a deep Silurian well (Well #5) to test the shale gas potential in their El Franig Field. The company has not released data on the well’s performance. In late 2012, Perenco reported that their gas production in Tunisia was all from conventional reservoirs and the company was not producing any shale gas. Winstar Resources, a small Canadian E&P company active in Tunisia, has sponsored an evaluation of the Silurian Tannezuft Shale in the Ghadames Basin of southern Tunisia. Winstar has acquired a series of concession areas in the basin and, with participation of ETAP (the state company), has committed to drilling a deep, test well (Sabria 12) in 2013.

2. OTHER BASINS

In addition to the shale gas and oil potential in the Ghadames Basin, Tunisia may also have shale resource potential in the less defined Pelagian Basin, located in the eastern portion of the country and extending into the offshore.

The Pelagian Basin contains two hydrocarbon systems with established shale source rocks. The first is the Jurassic-Cretaceous Petroleum System and its shale source rocks, particularly the Jurassic Nara Formation and the Early Cretaceous (Albian) Fahdene Formation contains Type II and III kerogen. The third potential shale source rock is the Late Cretaceous (Cenomanian to Turonian) Bahloul Formation containing Type II kerogen that underlies a limited portion of the basin. The thermal maturity of these source rocks ranges from early mature to late mature with TOCs that range from 0.5% to 14%, generally 1% to 3%. The oil generated from these Jurassic-Cretaceous source rocks is generally light, averaging 33° API.

The second hydrocarbon system in the Pelagian Basin is the Tertiary Petroleum Systems and its Early Eocene Bou Dabbous Formation shale. The Bou Dabbous Shale contains Type I and II kerogen with TOC that ranges from 0.4% to 4%. The thermal maturities of the shale ranges from early mature to mature, providing a variety of oil gravities, ranging from 18° to 53° API.

A number of companies have begun exploration efforts in the Pelagian Basin, including a small Canadian-listed company, African Hydrocarbons and super-major Shell Oil. African Hydrocarbons has a minority interest in the 130,000-acre Bouhajla and Ktititir carbonate-chalk reservoir. While the company acknowledges that its lease acreage many also hold an unconventional shale play, it plans to target the “low hanging fruit” first.⁸

Shell Oil acquired a large lease position in the Pelagian Basin and has announced a \$150 million exploration program to target conventional reservoirs as well as shale gas and shale oil potential on its lease acreage.

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-
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 - ⁵ Chinook Energy, Incorporated, 2012.
 - ⁶ Perenco Tunisia, 2012.
 - ⁷ Winstar Resources, 2012
 - ⁸ Stafford, J., 2013. “Is Tunisia the New Hot Spot for Energy Investors?” www.rigzone.com accessed April 10, 2013.