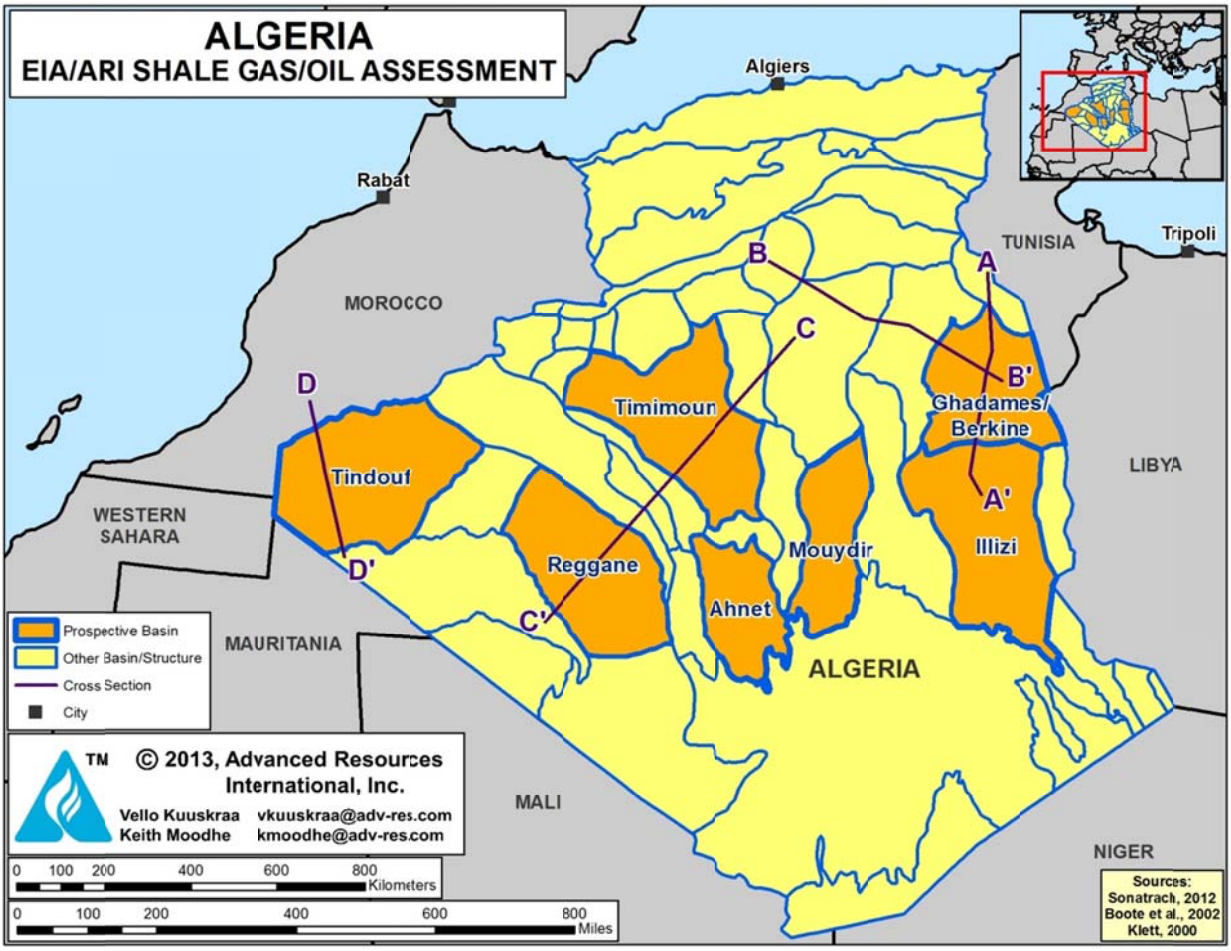
XV. ALGERIA

SUMMARY

Algeria's hydrocarbon basins hold two significant shale gas and shale oil formations, the Silurian Tannezuft Shale and the Devonian Frasnian Shale. This study examines seven of these shale gas and shale oil basins: the Ghadames (Berkine) and Illizi basins in eastern Algeria; the Timimoun, Ahnet and Mouydir basins in central Algeria; and the Reggane and Tindouf basins in southwestern Algeria, Figure XV-1.

Figure XV-1. Shale Gas and Shale Oil Basins of Algeria



Source: ARI, 2013.

Our assessment is that these seven basins contain approximately 3,419 Tcf of risked shale gas in-place, with 707 Tcf as the risked, technically recoverable shale gas resource, Table XV-1A, 1B and 1C. In addition, six of these basins hold 121 billion barrels of risked shale oil and condensate in-place, with 5.7 billion barrels as the risked, technically recoverable shale oil resource, Table XV-2.

Table XV-1A. Shale Gas Reservoir Properties and Resources of Algeria.

Basic Data	Basin/Gross Area		Ghadames/Berkine (117,000 mi^2)					Illizi (44,900 mi^2)	
	Shale Formation		Frasnian			Tannezuft		Tannezuft	
	Geologic Age		U. Devonian			Silurian		Silurian	
	Depositional Environment		Marine			Marine		Marine	
Physical Extent	Prospective Area (mi^2)		2,720	3,840	3,490	6,050	22,080	9,840	16,760
	Thickness (ft)	Organically Rich	275	275	275	115	115	180	180
		Net	248	248	248	104	104	162	162
	Depth (ft)	Interval	8,000 - 10,500	9,000 - 10,000	10,000 - 16,000	10,000 - 14,500	11,000 - 16,000	3,300 - 8,000	3,300 - 8,000
		Average	8,500	9,500	13,000	10,500	13,000	5,000	5,000
Reservoir Properties	Reservoir Pressure		Mod. Overpress.	Mod. Overpress.	Mod. Overpress.	Mod. Overpress.	Mod. Overpress.	Mod. Overpress.	Mod. Overpress.
	Average TOC (wt. %)		6.0%	6.0%	6.0%	5.7%	5.7%	5.7%	5.7%
	Thermal Maturity (% Ro)		0.85%	1.15%	1.70%	1.15%	1.90%	1.15%	1.70%
	Clay Content		Medium	Medium	Medium	Medium	Medium	Medium	Medium
Resource	Gas Phase		Assoc. Gas	Wet Gas	Dry Gas	Wet Gas	Dry Gas	Wet Gas	Dry Gas
	GIP Concentration (Bcf/mi^2)		35.4	111.4	133.9	42.9	54.5	50.9	60.7
	Risked GIP (Tcf)		48.2	213.8	233.7	129.9	601.3	100.1	203.6
	Risked Recoverable (Tcf)		4.8	42.8	58.4	26.0	150.3	15.0	40.7

Table XV-1B. Shale Gas Reservoir Properties and Resources of Algeria.

Basic Data	Basin/Gross Area		Timimoun (43,700 mi^2)		Ahnet (20,200 mi^2)			Mouydir (22,300 mi^2)
	Shale Formation		Frasnian	Tannezuft	Frasnian		Tannezuft	Tannezuft
	Geologic Age		U. Devonian	Silurian	U. Devonian		Silurian	Silurian
	Depositional Environment		Marine	Marine	Marine		Marine	Marine
Physical Extent	Prospective Area (mi^2)		32,040	41,670	1,650	5,740	11,730	12,840
	Thickness (ft)	Organically Rich	200	100	275	60	330	60
		Net	180	90	248	54	297	54
	Depth (ft)	Interval	3,300 - 9,000	5,000 - 15,000	3,300 - 6,600	5,000 - 9,500	6,000 - 10,500	5,000 - 10,000
		Average	6,000	10,000	5,000	7,000	8,000	6,500
Reservoir Properties	Reservoir Pressure		Mod. Overpress.	Mod. Overpress.	Mod. Overpress.	Mod. Overpress.	Mod. Overpress.	Mod. Overpress.
	Average TOC (wt. %)		4.0%	2.8%	4.0%	3.0%	2.8%	3.0%
	Thermal Maturity (% Ro)		1.70%	2.00%	1.15%	1.70%	2.00%	2.20%
	Clay Content		Medium	Medium	Medium	Medium	Medium	Medium
Resource	Gas Phase		Dry Gas	Dry Gas	Wet Gas	Dry Gas	Dry Gas	Dry Gas
	GIP Concentration (Bcf/mi^2)		72.9	35.5	77.6	21.6	109.0	18.5
	Risked GIP (Tcf)		467.1	295.5	25.6	24.8	255.7	47.6
	Risked Recoverable (Tcf)		93.4	59.1	3.8	5.0	51.1	9.5

Table XV-1C. Shale Gas Reservoir Properties and Resources of Algeria.

Basic Data	Basin/Gross Area		Reggane (40,000 mi^2)				Tindouf (77,000 mi^2)	
	Shale Formation		Frasnian		Tannezuft		Tannezuft	
	Geologic Age		U. Devonian		Silurian		Silurian	
	Depositional Environment		Marine		Marine		Marine	
Physical Extent	Prospective Area (mi^2)		2,570	2,110	10,150	24,600	5,340	23,800
	Thickness (ft)	Organically Rich	330	260	130	230	60	60
		Net	297	234	117	207	54	54
	Depth (ft)	Interval	5,500 - 14,500	6,600 - 16,000	5,000 - 9,500	7,500 - 16,000	6,600 - 13,000	6,600 - 14,000
		Average	10,000	11,000	8,000	12,000	10,000	11,000
Reservoir Properties	Reservoir Pressure		Mod. Overpress.	Mod. Overpress.	Mod. Overpress.	Mod. Overpress.	Mod. Overpress.	Mod. Overpress.
	Average TOC (wt. %)		3.0%	3.0%	4.0%	4.0%	4.0%	4.0%
	Thermal Maturity (% Ro)		1.15%	1.70%	1.15%	1.80%	1.15%	2.50%
	Clay Content		Medium	Medium	Medium	Medium	Medium	Medium
Resource	Gas Phase		Wet Gas	Dry Gas	Wet Gas	Dry Gas	Wet Gas	Dry Gas
	GIP Concentration (Bcf/mi^2)		103.9	97.3	38.3	94.4	18.9	24.2
	Risked GIP (Tcf)		53.4	41.0	77.8	464.5	20.2	115.2
	Risked Recoverable (Tcf)		8.0	8.2	11.7	92.9	3.0	23.0

Table XV-2. Shale Oil Reservoir Properties and Resources of Algeria.

Basic Data	Basin/Gross Area		Ghadames/Berkine (117,000 mi^2)			Illizi (44,900 mi^2)	Ahnet (20,200 mi^2)	Reggane (40,000 mi^2)		Tindouf (77,000 mi^2)
	Shale Formation		Frasnian		Tannezuft	Tannezuft	Frasnian	Frasnian	Tannezuft	Tannezuft
	Geologic Age		U. Devonian		Silurian	Silurian	U. Devonian	U. Devonian	Silurian	Silurian
	Depositional Environment		Marine		Marine	Marine	Marine	Marine	Marine	Marine
Physical Extent	Prospective Area (mi^2)		2,720	3,840	6,050	9,840	1,650	2,570	10,150	5,340
	Thickness (ft)	Organically Rich	275	275	115	180	275	330	130	60
		Net	248	248	104	162	248	297	117	54
	Depth (ft)	Interval	8,000 - 10,500	9,000 - 10,000	10,000 - 14,500	3,300 - 8,000	3,300 - 6,600	5,500 - 14,500	5,000 - 9,500	6,600 - 13,000
		Average	8,500	9,500	10,500	5,000	5,000	10,000	8,000	10,000
Reservoir Properties	Reservoir Pressure		Mod. Overpress.	Mod. Overpress.	Mod. Overpress.	Mod. Overpress.	Mod. Overpress.	Mod. Overpress.	Mod. Overpress.	Mod. Overpress.
	Average TOC (wt. %)		6.0%	6.0%	5.7%	5.7%	4.0%	3.0%	4.0%	4.0%
	Thermal Maturity (% Ro)		0.85%	1.15%	1.15%	1.15%	1.15%	1.15%	1.15%	1.15%
	Clay Content		Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium
Resource	Oil Phase		Oil	Condensate	Condensate	Condensate	Condensate	Condensate	Condensate	Condensate
	OIP Concentration (MMbbl/mi^2)		43.7	9.7	3.1	6.5	14.4	11.4	3.9	1.7
	Risked OIP (B bbl)		59.4	18.7	9.5	12.8	4.8	5.9	8.0	1.8
	Risked Recoverable (B bbl)		2.97	0.93	0.47	0.51	0.19	0.24	0.32	0.07

INTRODUCTION

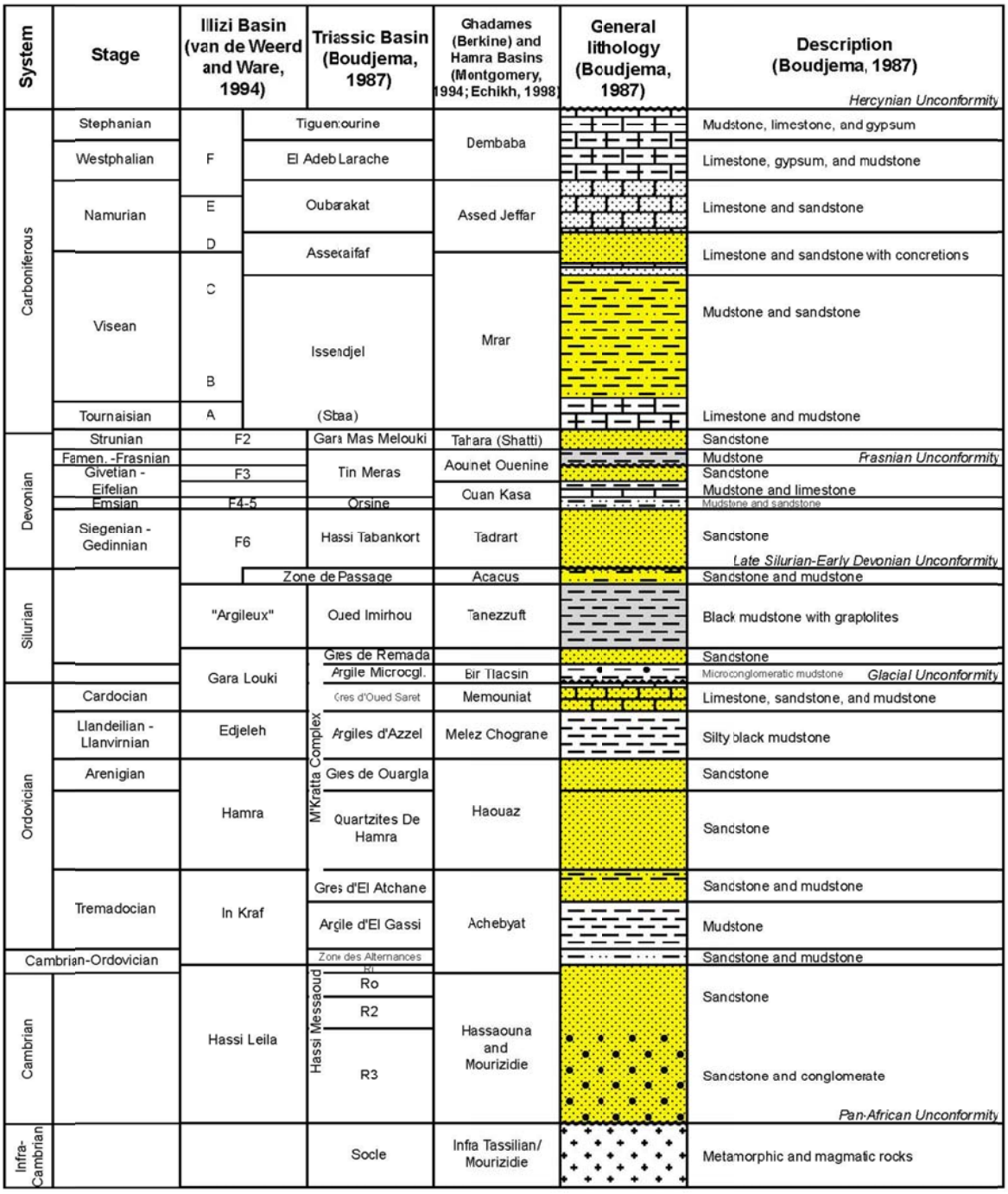
For most of Paleozoic time, North Africa (including Algeria) was a single massive depositional basin.[1] The separation and subsequent collision of Laurasia and Gondwana (the Hercynian event) established the seven individual basin outlines and uplift structures of present day Algeria.[2] Two major transgressions, first in the Silurian and the second in the Late Devonian, provided the deposition of the organically rich marine (generally Type I and II) source rocks in these basins. Subsequent transpressional movements reactivated the older structures. These events, plus additional compression and movement, caused the local uplifts and erosion that today define and characterize these basins.[3]

The stratigraphic column for the shale basins of Algeria is provided in Figure XV-2,[4] identifying the Silurian Tannezuft black mudstone interval and the Upper Devonian Frasnian mudstone that are the principal shale source rocks for the conventional oil and gas discovered to date in Algeria. The stratigraphy of the Silurian section is generally more continuous than of the Devonian section, which has been influenced by more localized deposition[5].

Geochemical modeling indicates that these shales may have generated over 26,000 Tcf of gas (including secondary cracking of generated oil), with some portion of this gas still retained in the shales. The present day total organic content (TOC) of the Silurian Tannezuft Shale ranges from 2% to 4%. However, the TOC of the shale has been reduced by as much as one-half due to the thermal maturation process.[6] The present day TOC of the Upper Devonian Frasnian Shale ranges more widely, from 1% to 8%, decreasing westward across the region.

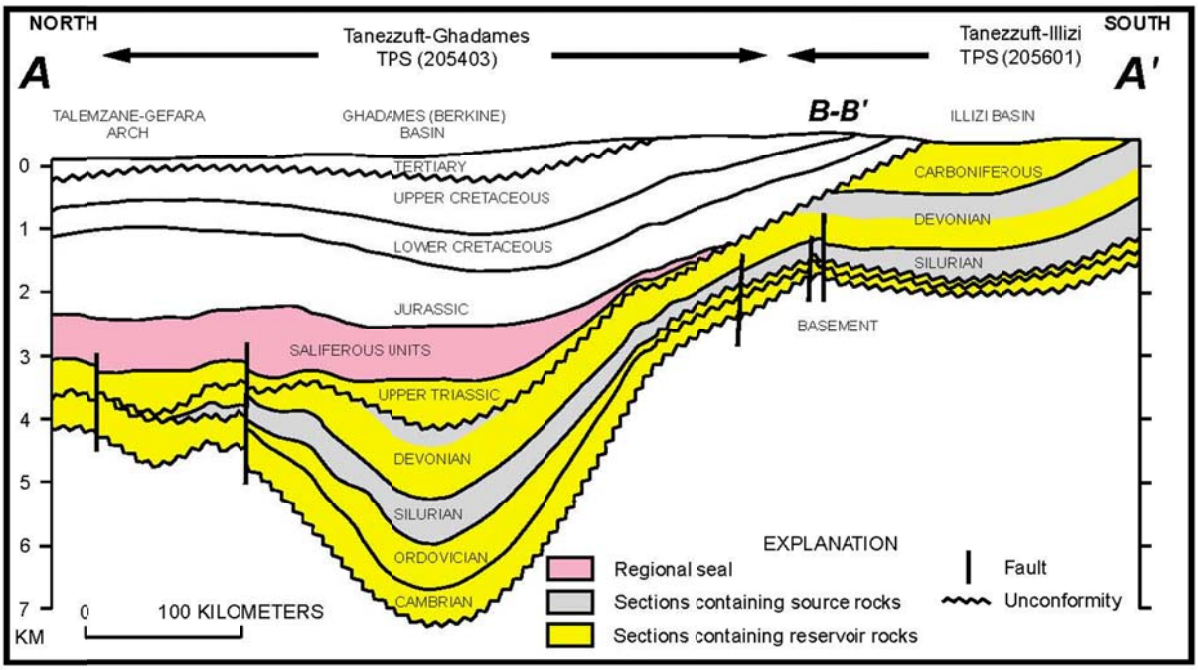
The following series of three regional cross-sections provides a useful perspective of the depositional and structural setting for six of these basins, Figures XV-3,[4] XV-4[4] and XV-5.[1] Figure XV-1(provided previously) shows the location of these three cross-sections.

Figure XV-2. Stratigraphic Column and Nomenclature for Illizi and Ghadames (Berkine) Basins. (Major reservoir rocks are shown in yellow and source rocks in gray.)



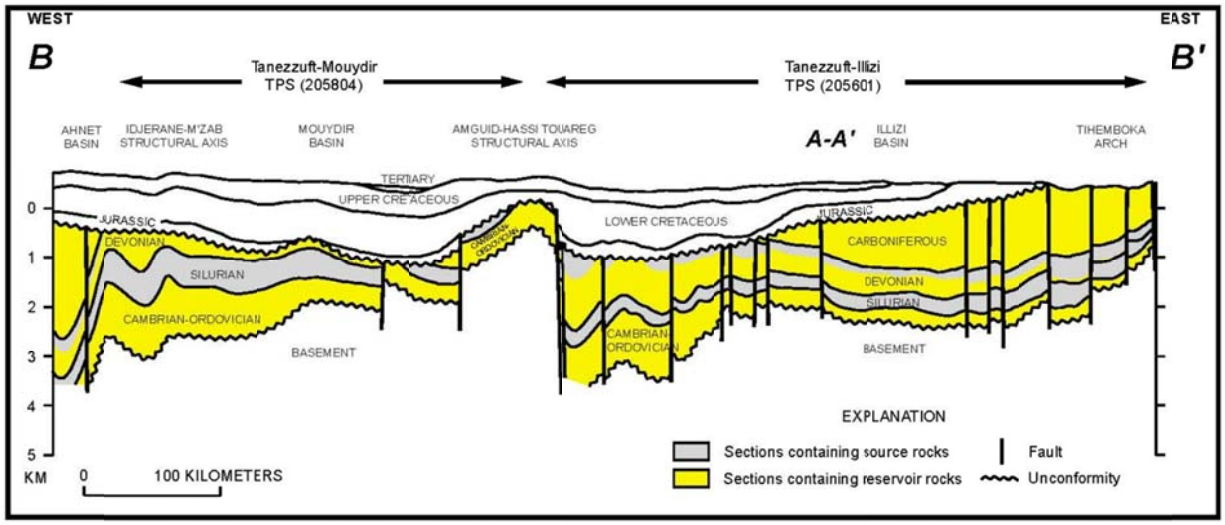
Source: Klett, 2000A.

Figure XV-3. Cross Section A-A': Ghadames (Berkline) and Illizi Basins



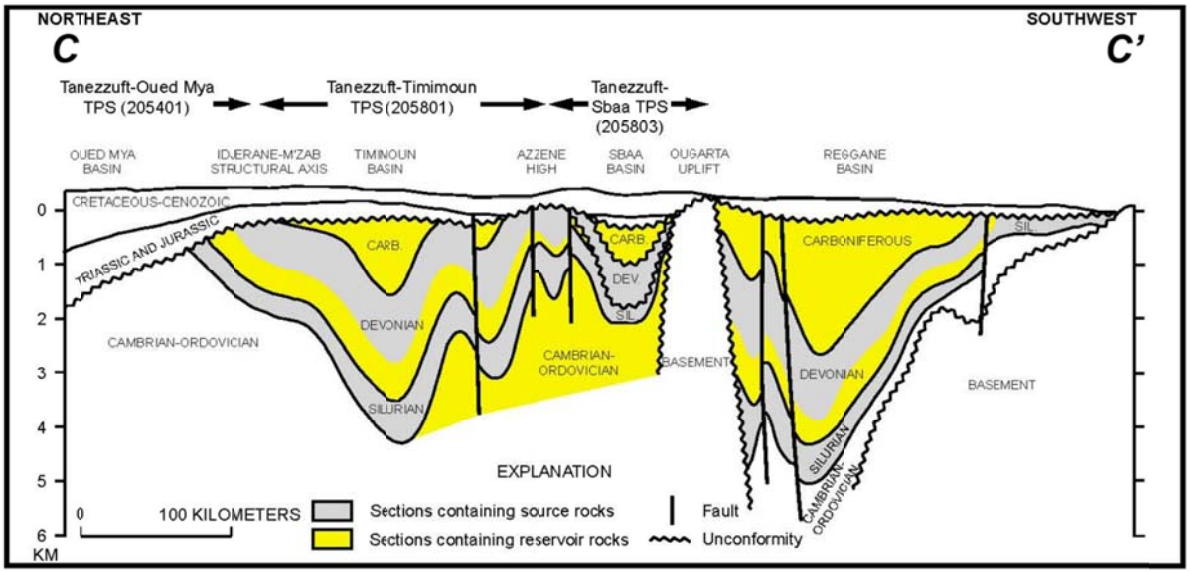
Source: Klett, 2000A.

Figure XV-4. Cross Section B-B': Ahnet, Mouydir and Illizi Basins



Source: Klett, 2000A.

Figure XV-5. Cross-Section C-C': Timimoun and Reggane Basins



Source: Klett, 2000B.

1. GHADAMES (BERKINE) BASIN

1.1 Geologic Setting

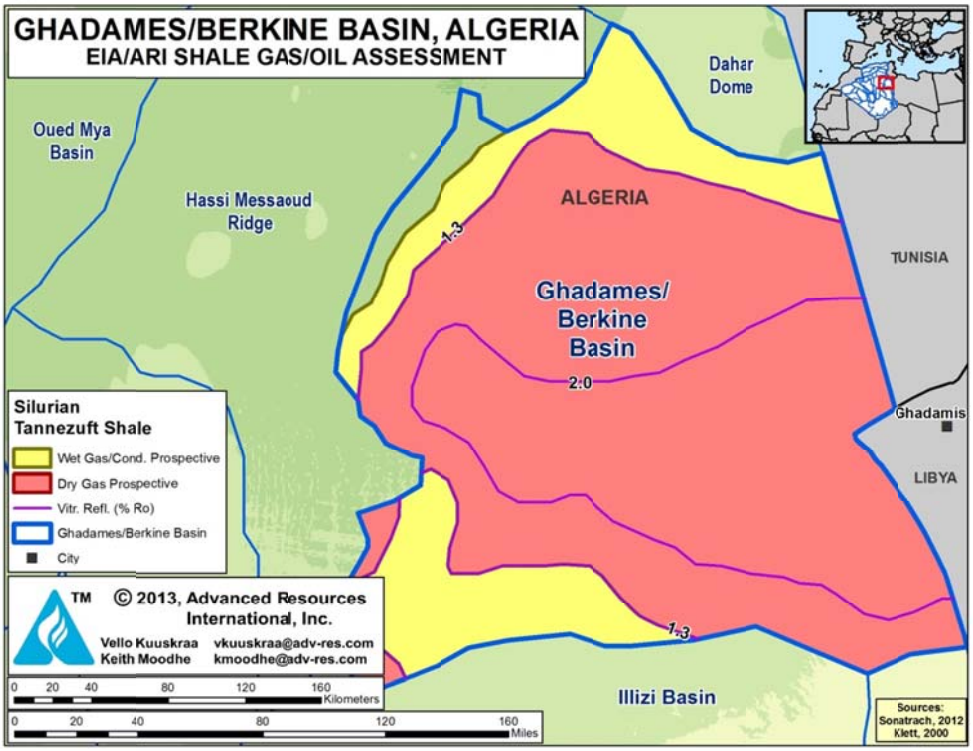
The Ghadames (Berkine) Basin is a large intra-cratonic basin underlying eastern Algeria, southern Tunisia and western Libya. The basin contains a series of reverse faults, providing structural traps for conventional oil and gas sourced from Devonian- and Silurian-age shales. The central, deep portion of the basin contains uplifted fault blocks formed during the Cambrian-Ordovician.[7] The Ghadames Basin and its two significant shale formations, the Silurian Tannezuft and the Upper Devonian Frasnian, are located in the eastern portion of Algeria. Figures XV-6 and XV-7 provide the basin outline and shale thermal maturity contours for these two shale formations.

In Algeria's portion of the Ghadames Basin, the Silurian Tannezuft Formation contains an organic-rich marine shale that increases in maturity toward the basin center. We have mapped a 28,130-mi^2 higher quality prospective area for the Tannezuft Shale in this basin. The western and northern boundaries of the Tannezuft Shale prospective area are defined by the erosional limits of the Silurian and by minimum thermal maturity. The eastern border of the prospective area is defined by the Tunisia and Algerian border.

The central, dry gas portion of the Tannezuft Shale prospective area in the Ghadames Basin, covering 21,420 mi^2, has thermal maturity (R_o) of 1.3% to over 2%. The remaining portion of the prospective area of 6,710 mi^2 has an R_o between 1.0% and 1.3%, placing this area in the wet gas and condensate window.

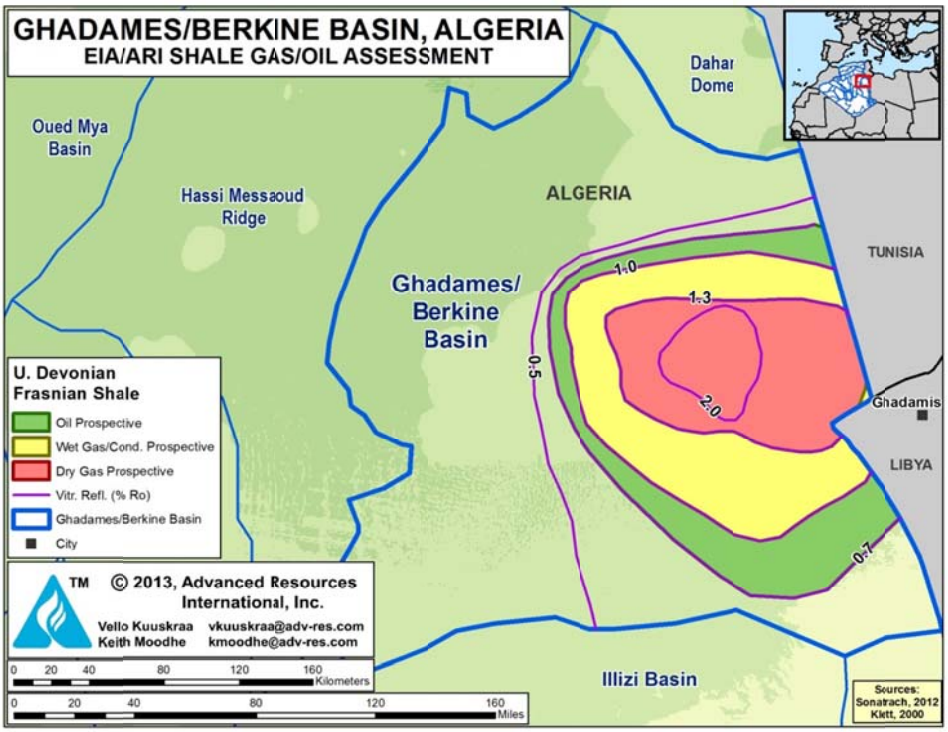
Deposited above the Tannezuft is the areally more limited and thermally less mature Upper Devonian Frasnian Shale. We have mapped a 10,040-mi^2 higher quality prospective area for the Frasnian Shale in the Ghadames Basin of Algeria. The western, northern and southern boundaries of the Frasnian Shale prospective area are set by the minimum thermal maturity criterion of 0.7% R_o. The eastern boundary of the prospective area is the Tunisia and Algeria border. The northern, eastern and southern outer ring of the Frasnian Shale prospective area in the Ghadames Basin, encompassing an area of 2,720 mi^2, is in the oil window with R_o between 0.7% and 1.0%. The central 5,010-mi^2 portion of the Frasnian Shale prospective area is in the dry gas window, with R_o of 1.3% to over 2%. In between is the 2,310-mi^2 wet gas and condensate window for the Frasnian Shale, with R_o between 1.0% and 1.3%.

Figure XV-6. Ghadames Basin Silurian Tannezuft Shale Outline and Thermal Maturity



Source: ARI, 2013.

Figure XV-7. Ghadames Basin Upper Devonian Frasnian Shale Outline and Thermal Maturity



Source: ARI, 2013.

1.2 Reservoir Properties (Prospective Area)

Silurian Tannezuft Formation. The depth of the gas prospective area of the Silurian Tannezuft Shale in the Ghadames (Berkine) Basin of Algeria ranges from 10,000 ft along the northern and eastern edge of the basin to 16,000 ft in the basin center, averaging 10,500 ft in the wet gas prospective area and 13,000 ft in the dry gas prospective area. The gross thickness of the Tannezuft Shale ranges from 30 to 200 ft, with an organic-rich average net thickness of 104 ft. The TOC of the Tannezuft Shale averages 5.7%. The lower portion of the formation is particularly organic-rich, with TOC values of up to 15%.[8]

Upper Devonian Frasnian Formation. The depth of the prospective area of the overlying Upper Devonian Frasnian Shale ranges from 8,000 ft to 16,000 ft, averaging 8,500 ft in the oil-prone area, 9,500 ft in the wet gas/condensate area, and 13,000 ft in the dry gas area. The Frasnian Shale has a gross thickness of 50 to 500 ft, with an average organic-rich net thickness of 248 ft. The Frasnian Shale has TOC values ranging from 3% to 10%, with an average of 6%.[10]

1.3 Resource Assessments

Silurian Tannezuft Shale. The Tannezuft Shale, within its 6,050-mi^2 wet gas and condensate prospective area, has resource concentrations of 43 Bcf/mi^2 of wet gas and 3 million barrels/mi^2 of condensate. Within its larger 22,080-mi^2 dry gas prospective area, the Tannezuft Shale has a resource concentration of 55 Bcf/mi^2. The risked resource in-place for the 28,130-mi^2 wet gas/condensate and dry gas prospective areas of the Tannezuft Shale is 731 Tcf of wet and dry gas and 10 billion barrels of condensate. Based on presence of clays but otherwise favorable reservoir properties, we estimate a risked, technically recoverable resource of 176 Tcf of wet/dry shale gas and 0.5 billion barrels of shale condensate.

Upper Devonian Frasnian Shale. The Frasnian Shale has resource concentrations of 44 million barrels/mi^2 for oil in the 2,720-mi^2 oil window; 10 million barrels/mi^2 of condensate and 111 Bcf/mi^2 of wet gas in the 3,840-mi^2 wet gas/condensate window; and 134 Bcf/mi^2 of dry gas in the 3,490-mi^2 dry gas window. The risked resource in-place within the overall 10,050-mi^2 prospective area is 496 Tcf of shale gas and 78 billion barrels of shale oil/condensate, with risked, recoverable of 106 Tcf for shale gas and 3.9 billion barrels for shale oil.

2. ILLIZI BASIN

2.1 Geologic Setting

The Illizi Basin is located south of the Ghadames (Berkine) Basin, separated by a hinge line in the slope of the basement rocks. This hinge line controls much of the differing petroleum generation, migration and accumulation histories of these two basins.[4] The Illizi Basin is bounded on the east by the Tihemboka (Garoaf) Arch, on the south by the Hoggar Massif, and on the west by the Amguid-Hassi Touareg structural axis which separates the Illizi Basin from the Mouydir Basin, Figure XV-8.[4] The Illizi Basin is located on a basement high and thus its shale formations are shallower than in the Ghadames (Berkline) Basin. We have mapped an overall shale gas and oil prospective area of 26,600 mi^2 for the Illizi Basin.

2.2 Reservoir Properties (Prospective Area)

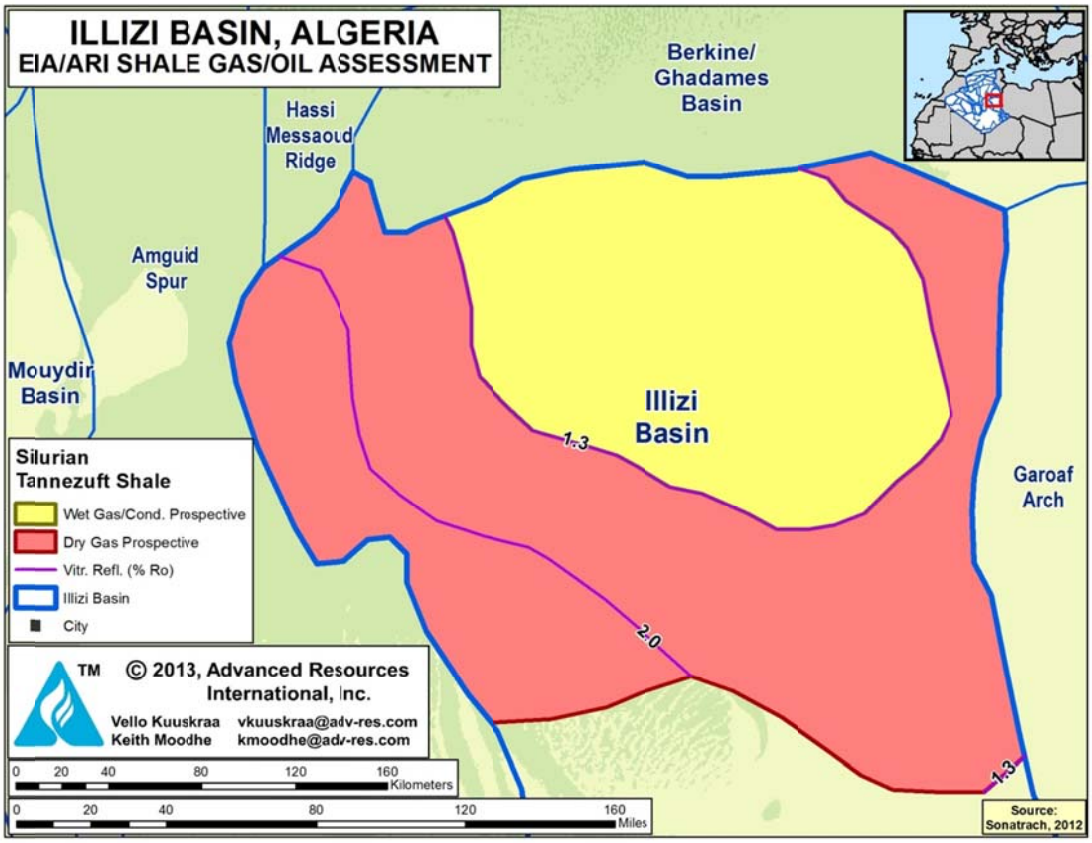
Only the Silurian Tannezuft Shale is assessed as prospective in the Illizi Basin. (The Upper Devonian Frasnian Shale in the Illizi Basin has been excluded because of insufficient thickness and low thermal maturity.) The depth of the Tannezuft Shale ranges from 3,000 to 8,000 ft, averaging 5,000 ft in the northern prospective area of the basin. The gross thickness of the Tannezuft Shale ranges from 30 to 330 ft, with an average net pay of 162 ft. The TOC of this Type II kerogen marine shale ranges from 2% to 10%, with an average of 5.7%. The basin has a thermal maturity (R_o) of 1% to over 2%. This places the Tannezuft Shale in the wet gas and condensate window (R_o of 1% to 1.3%) in the north-central portion of the basin and places the shale in the deeper surrounding area of the Illizi Basin in the dry gas window.

2.3 Resource Assessment

Within its 9,840-mi^2 prospective area for wet gas and condensate, the Silurian Tannezuft Shale of the Illizi Basin has resource concentrations of 51 Bcf/mi^2 of wet shale gas and 6 million barrels/mi^2 of shale oil and condensate. Within its 16,760-mi^2 prospective area for dry gas, the shale has a resource concentration of 61 Bcf/mi^2.

The risked resource in-place in the total prospective area is estimated at 304 Tcf of wet/dry shale gas plus 13 billion barrels of shale oil/condensate. Of this, 56 Tcf of wet/dry shale gas and 0.5 billion barrels of shale oil/condensate are estimated as the risked, technically recoverable resource.

Figure XV-8. Illizi Basin Silurian Tannezuft Shale, Outline and Thermal Maturity



Source: ARI, 2013.

3. TIMIMOUN BASIN

3.1 Geologic Setting

The Timimoun Basin, located in central Algeria, is bounded on the north and east by structural uplifts, on the west by the Beni Abbes Saddle, and on the south by the Djoua Saddle that separates the Timimoun Basin from the Ahnet Basin. The depth and deposition of the Timimoun Basin varies greatly due to erosion along the structural highs during the Hercynian. The Paleozoic section is thickest in the center of the Timimoun Basin, thinning to the north and east. The major shale source rocks in this basin are the Silurian Tannezuft Shale and the Upper Devonian Frasnian Shale.

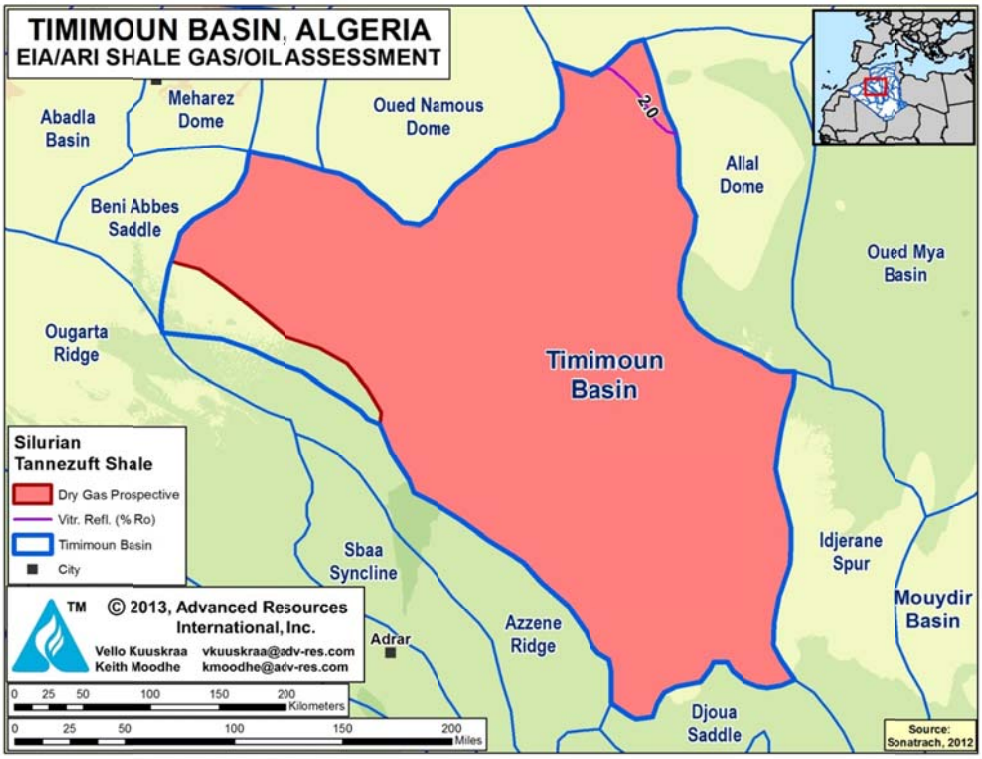
We mapped a 41,670-mi^2 dry gas prospective area for the Tannezuft Shale that covers essentially all of the Timimoun Basin, excluding a small area along the north-western portion of the basin where the Silurian is absent, Figure XV-9. In addition, we mapped a 32,040-mi^2 Frasnian Shale dry gas prospective area that covers the eastern two-thirds of the basin, excluding the low (<2%) TOC area along the western portion of the basin, Figure XV-10.

3.2 Reservoir Properties (Prospective Area).

Silurian Tannezuft Formation. The depth of the dry gas prospective area of the Tannezuft Shale in the Timimoun Basin ranges from 5,000 ft on the edges of the basin to nearly 15,000 ft in the basin center, averaging 10,000 ft. The thickness of the gross shale interval is 100 ft, with a net organic-rich pay of 90 ft. The TOC of the Tannezuft Shale averages 2.8% in the prospective area.

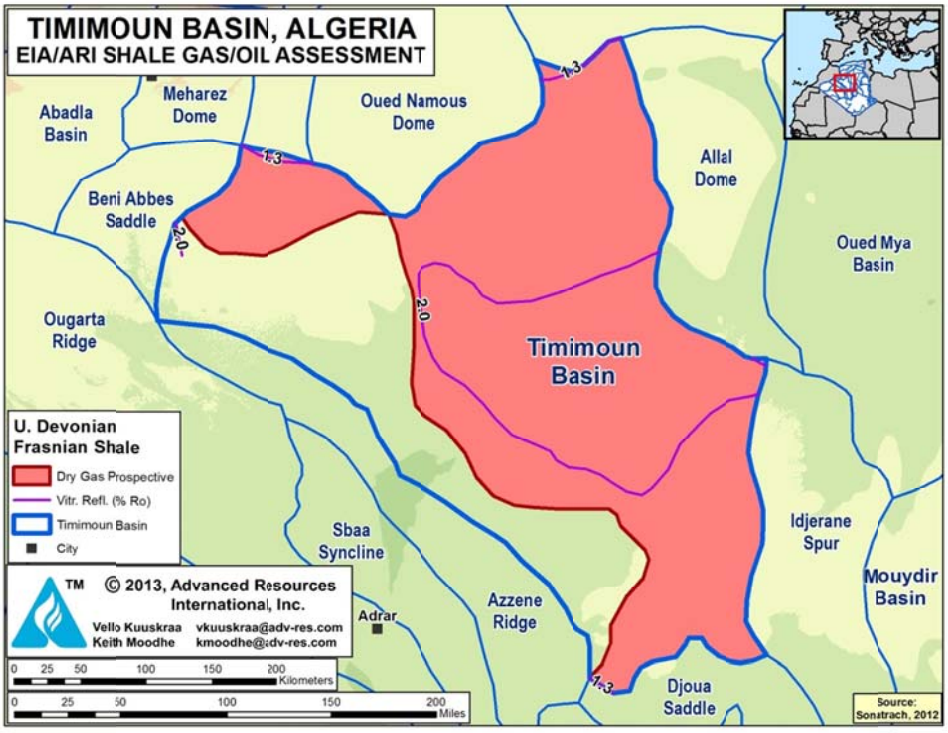
Upper Devonian Frasnian Formation. The depth of the dry gas prospective area of the Upper Devonian Frasnian Shale in the Timimoun Basin ranges from about 3,300 ft along the basin edge to about 9,000 ft in the basin center, averaging 6,000 ft. The thickness of the gross shale interval is 200 ft, with a net organic-rich pay of 180 ft. The TOC of the Frasnian Shale averages 4% in the prospective area.

Figure XV-9. Timimoun Basin Silurian Tannezuft Shale, Outline and Thermal Maturity



Source: ARI, 2013.

Figure XV-10. Timimoun Basin Upper Devonian Frasnian Shale, Outline and Thermal Maturity



Source: ARI, 2013.

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3.3 Resource Assessment

Silurian Tannezuft Shale. The Tannezuft Shale, within the 41,670-mi^2 dry gas prospective area of the Timimoun Basin, has a resource concentration of 36 Bcf/mi^2. The risked shale gas resource in-place in the prospective area is 296 Tcf, with 59 Tcf as the risked, technically recoverable shale gas resource.

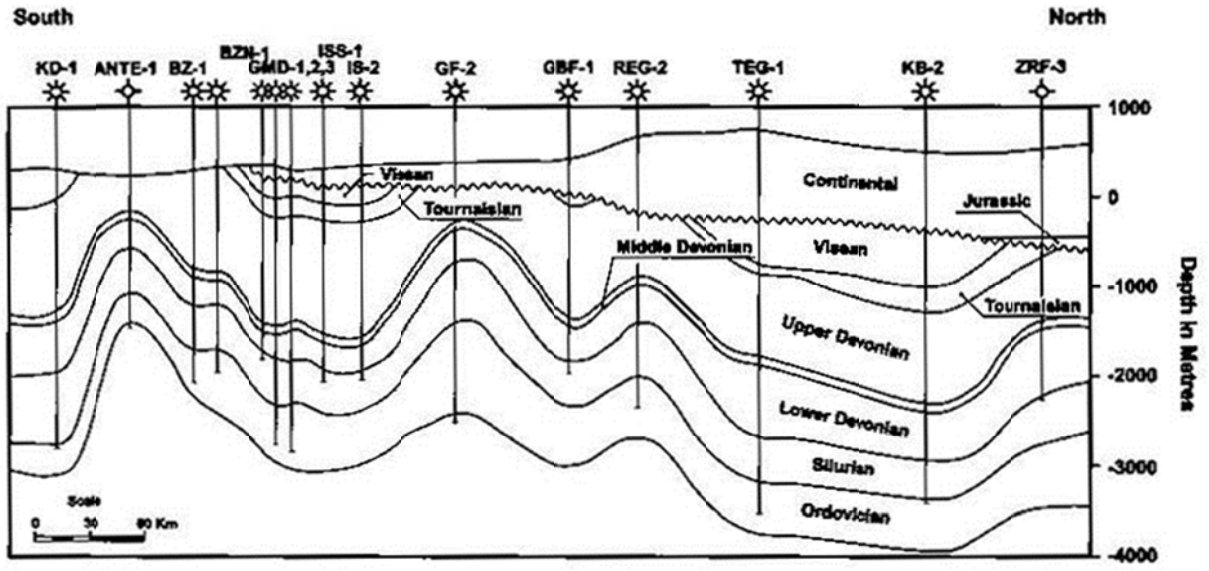
Upper Devonian Frasnian Shale. The Frasnian Shale, within the 32,040-mi^2 dry gas prospective area of the Timimoun Basin, has a resource concentration of 73 Bcf/mi^2. The risked shale gas resource in-place in the prospective area is 467 Tcf, with 93 Tcf as the risked, technically recoverable shale gas resource.

4. AHNET BASIN

4.1 Geologic Setting

The Ahnet Basin is located in the Sahara Desert Platform, south of the large Timimoun Basin, west of the Mouydir Basin, and north of the Hoggar Shield. The Ahnet Basin is a north-south trending basin that contains thick (over 3,000 ft) of Paleozoic sediments including organic-rich Silurian and Devonian shales. The structures in the basin take the form of large, elongate anticlines and domes formed as a result of tectonic compression, as shown on the north to south cross-section, Figure XV-11.[9]

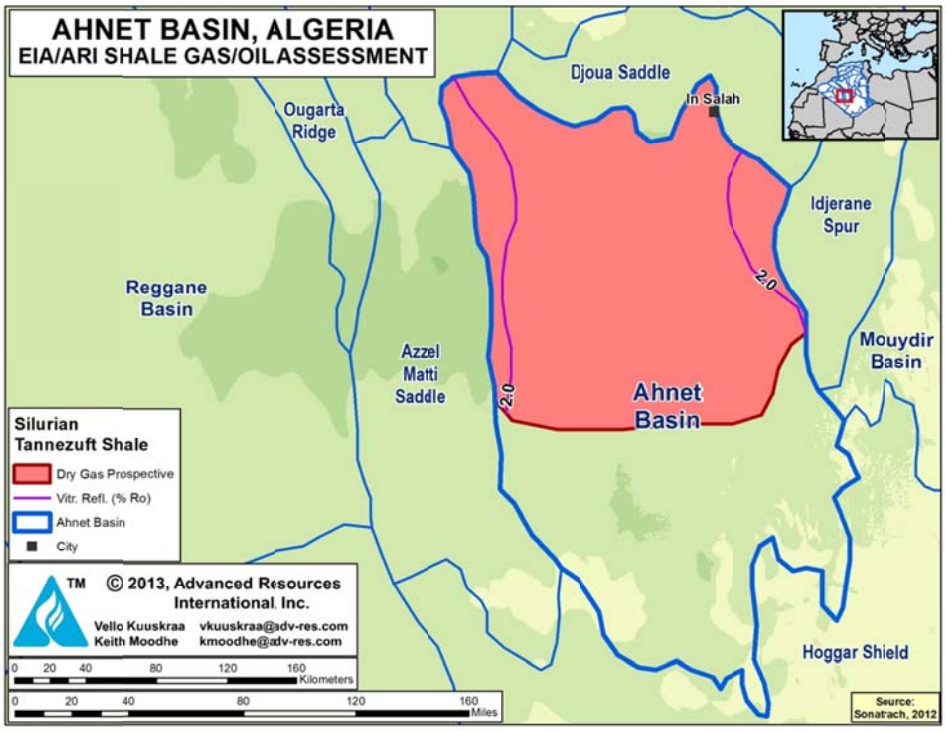
Figure XV-11. Schematic Cross Section of the Ahnet Basin, Algeria



Source: Logan, P. and Duddy, I., 1998.

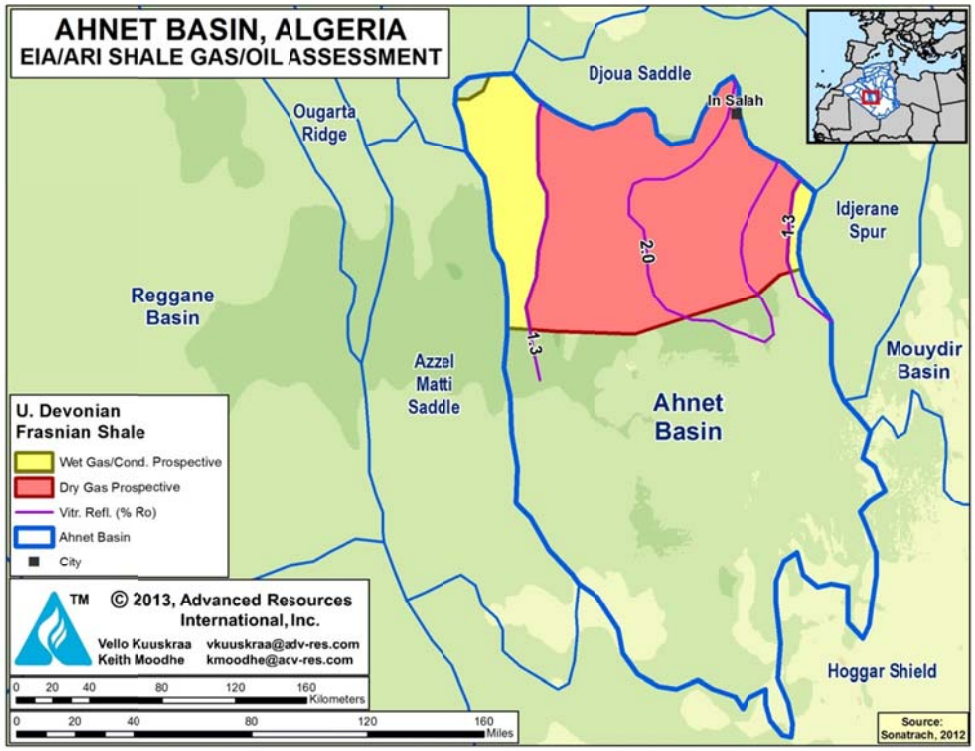
The Ahnet Basin contains the Silurian Tannezuft and Upper Devonian Frasnian formations and their organic-rich shale intervals. In some portions of the basin, the Paleozoic section was eroded during Hercynian deformation. However, up to 4 km of Paleozoic deposits remain intact in the center of the basin.[9] We have defined prospective areas of 11,730 mi^2 for the Silurian Tannezuft Shale and 7,390 mi^2 for the Devonian Frasnian Shale in the northern portion of the Ahnet Basin, Figures XV-12 and XV-13.

Figure XV-12. Ahnet Basin Silurian Tannezuft Shale, Outline and Thermal Maturity



Source: ARI, 2013.

Figure XV-13. Ahnet Basin Upper Devonian Frasnian Shale, Outline and Thermal Maturity



Source: ARI, 2013.

4.2 Reservoir Properties (Prospective Area).

Silurian Tannezuft Formation. The depth of the Tannezuft Shale in the prospective area of the Ahnet Basin ranges from 6,000 to 10,500 ft, averaging 8,000 ft. The thickness of the shale ranges from 150 to 500 ft, averaging 330 ft with a high net to gross ratio. The TOC of the shale ranges from 1.5% to 4% and contains Type III gas-prone kerogen. The thermal maturity places the prospective area of the Tannezuft Shale of the Ahnet Basin in the dry gas window (R_o > 1.3%).

Devonian Frasnian Formation. The depth of the Frasnian Shale in the prospective area of the Ahnet Basin ranges from about 3,300 to 9,500 ft, averaging 6,000 ft, with the wet gas/condensate area shallower and the dry gas area deeper. The gross thickness of the shale ranges from 60 to 275 ft, with a net pay of approximately 54 ft in the dry gas area and 248 ft in the wet gas/condensate area. The TOC ranges from 3% to 4% and is mostly Type III gas-prone kerogen. The thermal maturity of the prospective area of the Frasnian Shale is in the wet gas/condensate and dry gas windows (R_o > 1.0%). Petrophysical evaluations of the Frasnian Shale indicate porosity of 6% and low water saturation in the deeper, prospective area of the Ahnet Basin.

4.3 Resource Assessments (Prospective Area).

Silurian Tannezuft Shale. Within its 11,730-mi^2 dry gas prospective area, the Tannezuft Shale in the Ahnet Basin has a resource concentration of 109 Bcf/mi^2. The risked shale gas resource in-place in the dry gas prospective area is 256 Tcf, with 51 Tcf estimated as the risked, technically recoverable shale gas resource.

Devonian Frasnian Shale. Within its 5,740-mi^2 dry gas prospective area, the Frasnian Shale in the Ahnet Basin has a resource concentration of 22 Bcf/mi^2. Within its 1,650-mi^2 wet gas/condensate prospective area, the Frasnian Shale has resource concentrations of 15 million barrels/mi^2 of shale oil/condensate and 78 Bcf/mi^2 of wet shale gas.

The risked shale gas resource in-place in the overall 7,390-mi^2 wet/dry gas prospective area is 50 Tcf, with 9 Tcf as the risked technically recoverable shale gas resource. The risked shale oil resource in-place in the 1,650-mi^2 oil/condensate prospective area is 5 billion barrels, with 0.2 billion barrels as the risked, technically recoverable shale oil resource.

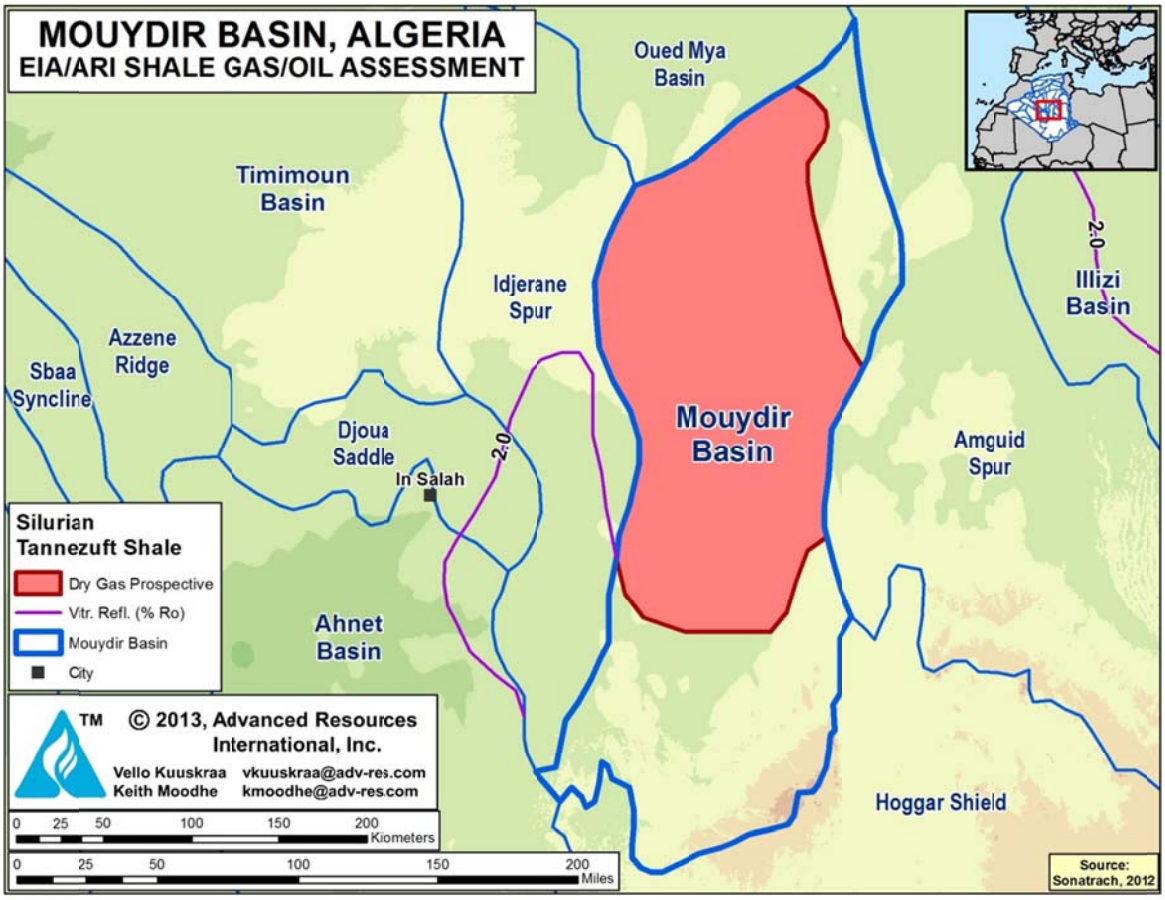
5. MOUYDIR BASIN

5.1 Geologic Setting.

The Mouydir Basin is located in central Algeria, west of the Illizi Basin and east of the Timimoun and Ahnet basins. A variety of upthrusted structural ridges separate these basins. The Paleozoic Silurian and Devonian sediments, which include the important Silurian Tannezuft Shale and the Upper Devonian Frasnian Shale, are deepest in the northern portion of the basin and crop out in the southern portion of the basin.

We have mapped a prospective area of 12,840 mi^2 in the northern portion of the basin, limited on the south by the depth of the shale, Figure XV-14.

Figure XV-14. Mouydir Basin Silurian Tannezuft Shale, Outline and Thermal Maturity



Source: ARI, 2013.

5.2 Reservoir Properties (Prospective Area).

Only the Silurian Tannezuft Shale is assessed as prospective in the Mouydir Basin. (The Devonian Frasnian Shale, although thick and organically rich, is mostly too shallow, less than 3,300 ft, excluding the shale from further assessment.) The depth of the Tannezuft Shale ranges from 5,000 to 10,000 ft, averaging 6,500 ft in the prospective area. The gross thickness of the shale ranges from 20 to 120 ft, averaging 60 ft with a high net to gross ratio. The Tannezuft Shale in the Mouydir Basin has TOC ranging from 2% to 4%, with a thermal maturity above 1.3% R_o, placing the shale in the dry gas window.

5.3 Resource Assessment.

Within its 12,840-mi^2 dry gas prospective area, the Silurian Tannezuft Shale of the Mouydir Basin has a resource concentration of 19 Bcf/mi^2. The risked resource in-place in the dry gas prospective area is estimated at 48 Tcf, with 10 Tcf as the risked, technically recoverable shale gas resource.

6. REGGANE BASIN

6.1 Geologic Setting.

The Reggane Basin, located in the Sahara Desert portion of central Algeria, is separated from the Timimoun Basin by the Ougarta Ridge. The basin is an asymmetric syncline, bounded on the north by a series of reserve faults and on the south by shallowing outcrops, Figure XV-15.[9] This basin may contain over 800 m of Silurian section, although well control in the deep northern portion of the basin is limited. The basin also contains the Upper Devonian Frasnian Formation which is reported to reach a maximum thickness of 400 m.

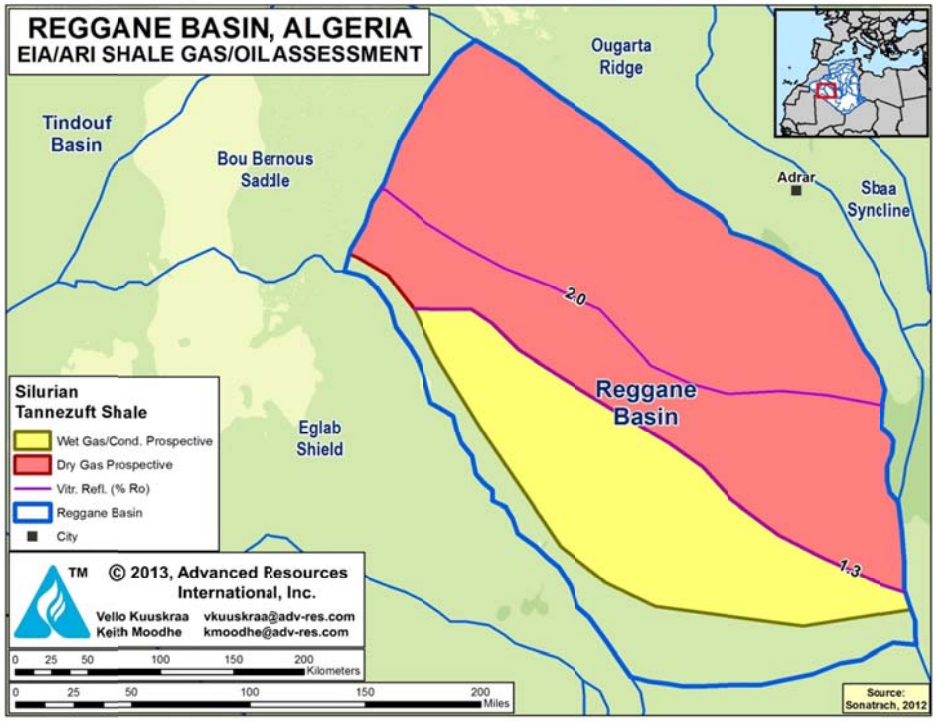
We have mapped prospective areas of 34,750 mi^2 for the Silurian Tannezuft Shale and 4,680 mi^2 for the Upper Devonian Frasnian Shale in the eastern portions of the Reggane Basin, Figures XV-16 and XV-17.

6.2 Reservoir Properties (Prospective Areas).

Silurian Tannezuft Formation. The depth of the prospective area for the Silurian Tannezuft Shale ranges from 16,000 ft on the north to 5,000 ft on the south, averaging 10,000 ft. The wet gas/condensate prospective area is slightly shallower than this average, while the dry gas prospective area is deeper.[9] The gross thickness of the organic-rich section in the prospective area ranges from about 130 to 230 ft, with a high net to gross ratio.[9] TOC is favorable, ranging from 3% to 5%. The thermal maturity places the prospective area of the Tannezuft Shale into the wet gas and condensate window (R_o of 1.0 to 1.3%) in the shallower south and into the dry gas window (R_o > 1.3%) in the deeper north, as illustrated by the north to south cross-section on Figure XV-17.[10]

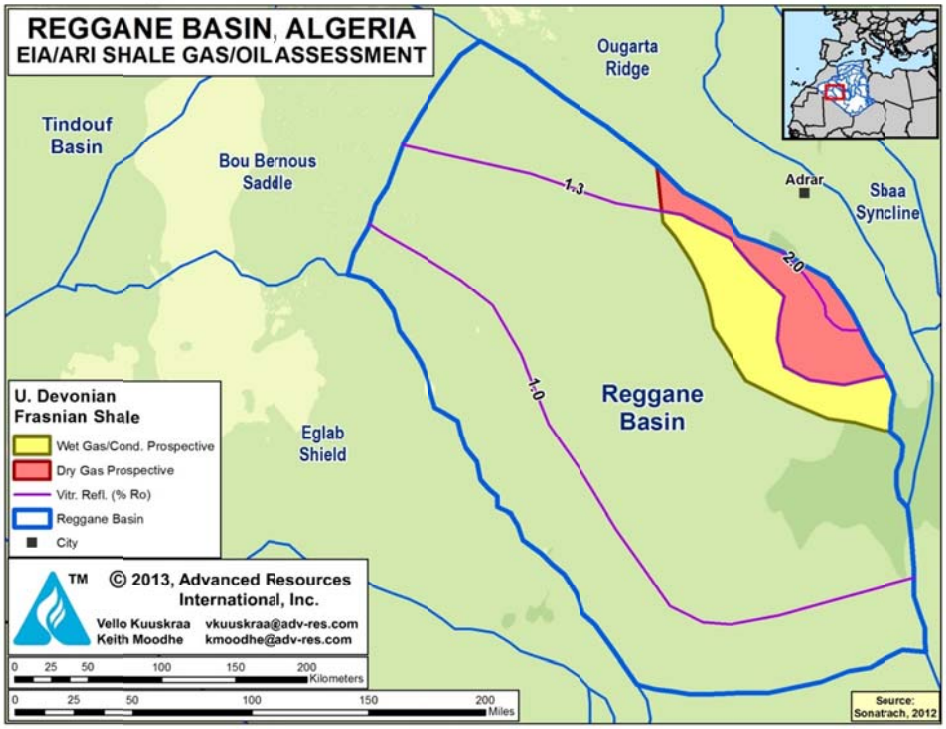
Upper Devonian Frasnian Formation. The depth of the shallower Upper Devonian Frasnian Shale in the Reggane Basin ranges from 5,500 ft to 16,000 ft, averaging about 10,500 ft in the prospective area, with the wet gas/condensate area shallower and the dry gas area somewhat deeper.[9] The thickness of the organic-rich portion of the shale ranges from 260 to 330 ft, with a high net to gross ratio.[9] The TOC of the shale ranges from 2% to 4%.[10] The thermal maturity places the prospective area of the Frasnian Shale in the wet/condensate and dry gas windows (R_o > 1%). The Frasnian Shale is judged to have good porosity of about 6% with low water saturation, based on petrophysical evaluations of the Frasnian Shale in the adjoining Ahnet Basin.[10,11]

Figure XV-15. Reggane Basin Silurian Tannezuft Shale, Outline and Thermal Maturity



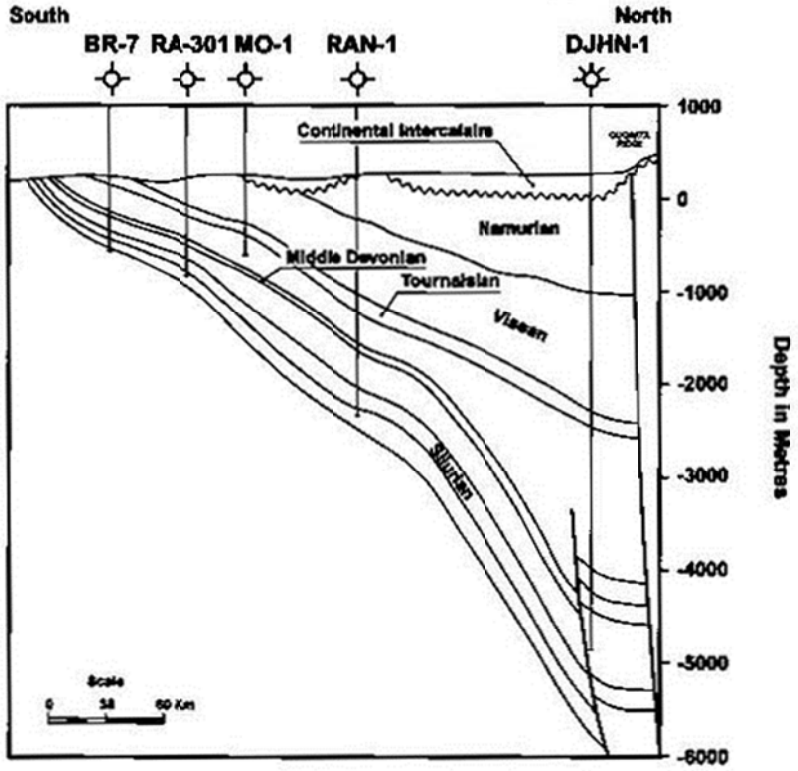
Source: ARI, 2013.

Figure XV-16. Reggane Basin Upper Devonian Frasnian Shale, Outline and Thermal Maturity



Source: ARI, 2013.

Figure XV-17. Schematic Cross Section of the Reggane Basin, Algeria



Source: Logan, P. and Duddy, I., 1998.

6.3 Resource Assessment

Silurian Tannezuft Shale. Within its 24,600-mi^2 dry gas prospective area, the Tannezuft Shale in the Reggane Basin has a resource concentration of 94 Bcf/mi^2. Within its 10,150-mi^2 wet gas and condensate prospective area, the shale has resource concentrations of 38 Bcf/mi^2 of wet gas and 4 million barrels/mi^2 of oil/condensate.

The risked resource in-place for the overall 34,750-mi^2 Silurian Tannezuft Shale prospective area in the Reggane Basin is 542 Tcf of wet/dry shale gas plus 8 billion barrels of shale oil/condensate. Of this, 105 Tcf of wet/dry shale gas plus 0.3 billion barrels of shale oil/condensate are estimated as the risked, technically recoverable resource.

Devonian Frasnian Shale. Within its 2,110-mi^2 dry gas prospective area, the Frasnian Shale in the Reggane Basin has a resource concentration of 97 Bcf/mi^2. Within its 2,570-mi^2 wet gas and condensate prospective area, the shale has resource concentrations of 104 Bcf/mi^2 of wet gas and 11 million barrels/mi^2 of oil and condensate.

The risked resource in-place for the overall 4,680-mi^2 Devonian Frasnian Shale prospective area in the Reggane Basin is estimated at 94 Tcf of wet/dry shale gas plus 6 billion barrels of shale oil/condensate. Of this, 16 Tcf of wet/dry shale gas plus 0.2 billion barrels of shale oil/condensate are estimated as the risked, technically recoverable resource.

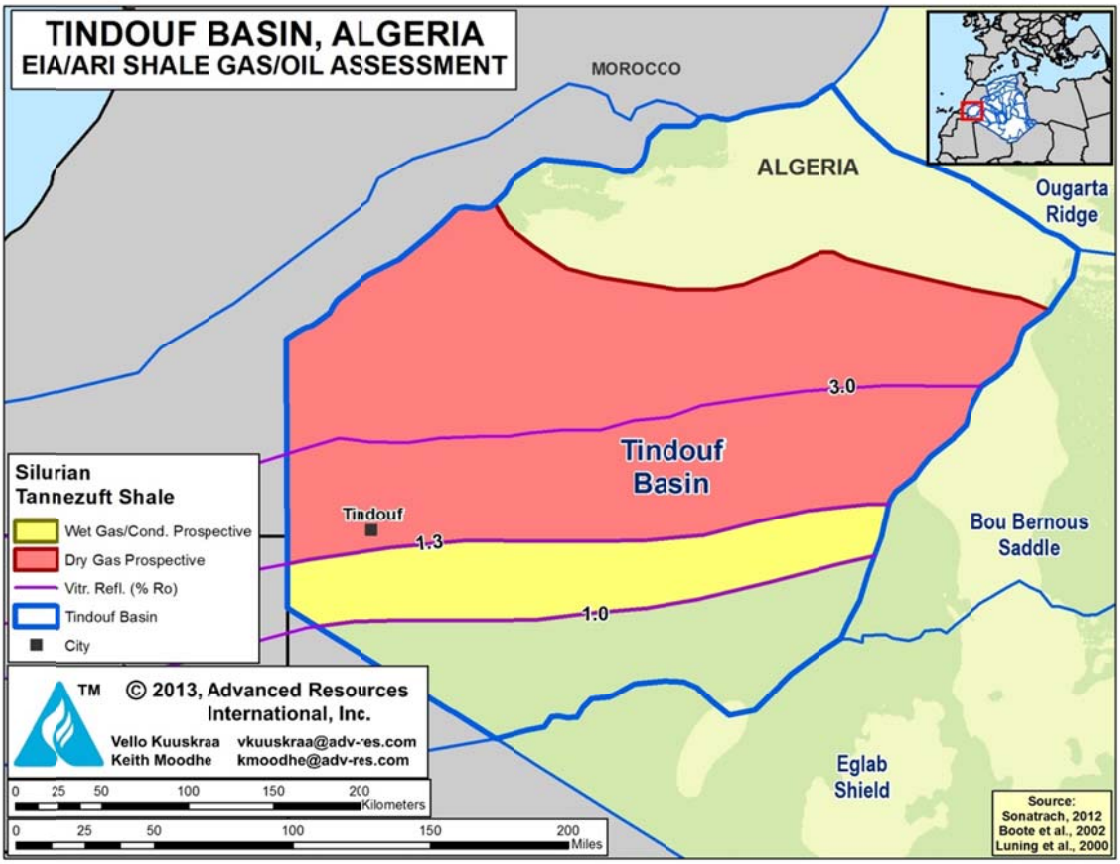
7. TINDOUF BASIN

7.1 Geological Setting.

The Tindouf Basin is located in the far southwestern portion of Algeria, bordered on the west by Morocco and on the south by Mauritania. This large basin, the least explored basin in the Sahara Desert Platform, covers an area of over 45,000 mi^2 just within the Algeria.

Because of limited well penetrations, considerable uncertainty surrounds the shale gas and oil potential of the Tindouf Basin. Based on recent data from Sonatrach, the Devonian Frasnian Shale is relatively thin (average of 10 m) with a TOC of only about 1%.[10] As such, this shale unit has been excluded from further quantitative assessment. However, the Silurian Tannezuft Shale appears to be more promising. We have established a dry and wet gas prospective area of 29,140 mi^2 for the Silurian Tannezuft Shale in the northern portion of the Tindouf Basin where the TOC is 2% or higher, Figure XV-18.

Figure XV-18. Tindouf Basin Silurian Tannezuft Shale Outline and Thermal Maturity

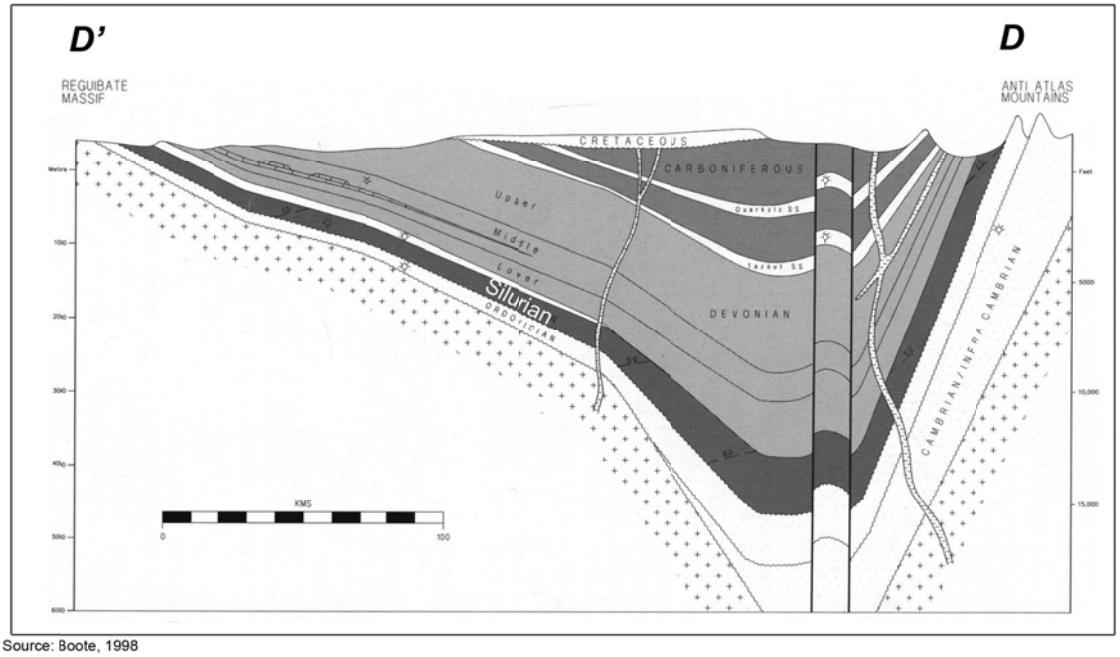


Source: ARI, 2013.

7.2 Reservoir Properties (Prospective Area).

The depth of the Silurian Tannezuft Shale in the prospective area ranges from 6,600 to 14,000 ft, averaging about 10,500 ft. While the total Upper Silurian section can be several thousand feet thick, the organic-rich portion of the Silurian Tannezuft Shale has a net thickness of only 54 ft where the TOC exceeds 2%. In the prospective area, the Tannezuft Shale is in both the wet gas/condensate and the dry gas windows (R_o > 1.0%) and has gas-prone Type III kerogen.[10,12] Figure XV-19 provides a cross-section for this frontier hydrocarbon basin.[13]

Figure XV-19. Tindouf Basin Cross Section



Source: Boote, 1998

Source: Boote, 1998.

7.3 Resource Assessment.

Within its 23,800-mi^2 dry gas prospective area, the Silurian Tannezuft Shale in the Tindouf Basin has a resource concentration of 24 Bcf/mi^2. Within its 5,340-mi^2 wet gas and condensate area, the shale has resource concentrations of 19 Bcf/mi^2 for wet gas and 1.7 million barrels/mi^2 for oil/condensate.

Within its overall 29,140-mi^2 prospective area, the risked resource in-place for the Tannezuft Shale in the Tindouf Basin is estimated at 135 Tcf of wet/dry shale gas and 2 billion barrels of shale oil/condensate. Of this, 26 Tcf of wet/dry shale gas and 0.1 billion barrels of shale oil/condensate are estimated as the risked, technically recoverable resource.

ACTIVITY

Algeria's natural gas and gas company, Sonatrach, has undertaken a comprehensive effort to define the size and quality of its shale gas (and oil) resources. To date, the company has established a data base of older cores, logs and other data and complemented this with information from new shale well logs in the main shale basins of Algeria. Next in the plan is to drill a series of pilot wells to test the productivity of the high priority basins, targeting shale formations with high TOC (>2%) and thick pay (>20m) at moderate depths (<3,000 m). The first pilot well within this comprehensive shale resource assessment program is scheduled for the Berkine (Ghadames) Basin, followed by test wells in the Illizi, Timimoun, Ahnet and Mouydir basins.[10] International energy companies, Statoil and Repsol, have also undertaken geological and reservoir characterization studies of Algeria's shales.[11]

Over the past year, Algeria has passed amendments to its federal legislation covering the hydrocarbon sector improving investment climate in anticipation of an expanded hydrocarbon licensing round due in 2013. However, the position of its stated-owned company Sonatrach is expected to remain dominant in this sector.

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