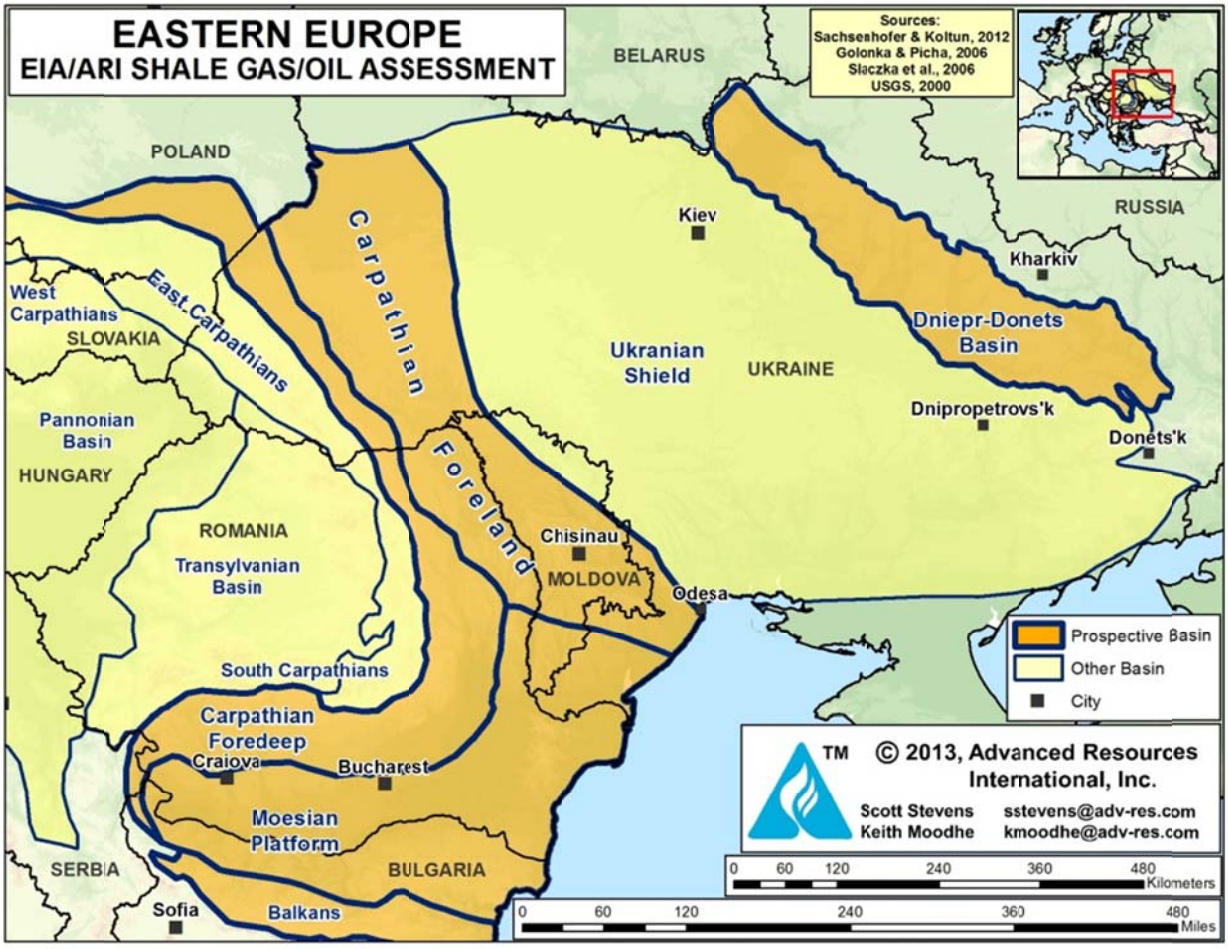
X. EASTERN EUROPE (BULGARIA, ROMANIA, UKRAINE)

SUMMARY

Eastern Europe (ex. Poland, assessed separately) has significant prospective shale gas and oil resources in three sedimentary basins: the Dniepr-Donets Basin, the Carpathian Foreland Basin, and the Moesian Platform, Figure X-1. Shale exploration is underway in Ukraine and Romania, while Bulgaria currently has a moratorium on shale development.

Figure X-1: Prospective Shale Basins of Eastern Europe



Source: ARI, 2013.

The total risked, technically recoverable shale resource potential for the three basins is estimated at 195 Tcf of shale gas and 1.6 billion barrels of shale oil and condensate, Tables X-1 and X-2. Our new, larger interpretation of the shale resource is based on recent shale leasing, drilling, and seismic activities that were stimulated in part by the 2011 EIA/ARI study.

Table X-1: Shale Gas Reservoir Properties and Resources, Eastern Europe.

Basic Data	Basin/Gross Area		Carpathian Foreland (70,000 mi^2)	Dniepr-Donets (23,200 mi^2)			Moesian Platform (45,000 mi^2)		
	Shale Formation		L. Silurian	L. Carboniferous			L. Silurian		Etropole
	Geologic Age		L. Silurian	L. Carboniferous			L. Silurian		L. Jurassic
	Depositional Environment		Marine	Marine			Marine		Marine
Physical Extent	Prospective Area (mi^2)		16,080	1,460	2,680	6,010	840	760	7,940
	Thickness (ft)	Organically Rich	1,000	700	700	700	600	600	650
		Net	400	350	350	350	450	450	260
	Depth (ft)	Interval	3,300 - 16,400	3,300 - 16,400	3,300 - 16,400	3,300 - 16,400	6,600 - 16,400	13,000 - 16,400	5,000 - 16,400
		Average	10,000	11,000	12,000	13,000	11,000	14,000	10,000
Reservoir Properties	Reservoir Pressure		Normal	Normal	Mod. Overpress.	Mod. Overpress.	Normal	Normal	Highly Overpress.
	Average TOC (wt. %)		2.0%	4.5%	4.5%	4.5%	3.0%	3.0%	3.0%
	Thermal Maturity (% Ro)		2.50%	0.90%	1.15%	2.00%	1.15%	2.00%	1.15%
	Clay Content		Medium	Low	Low	Low	Medium	Medium	Medium
Resource	Gas Phase		Dry Gas	Assoc. Gas	Wet Gas	Dry Gas	Wet Gas	Dry Gas	Wet Gas
	GIP Concentration (Bcf/mi^2)		112.7	49.2	118.5	195.2	121.9	154.4	106.7
	Risked GIP (Tcf)		362.5	14.4	63.5	234.6	22.5	25.8	148.2
	Risked Recoverable (Tcf)		72.5	1.4	15.9	58.6	4.5	5.2	37.1

Source: ARI 2013.

Table X-2: Shale Oil Reservoir Properties and Resources, Eastern Europe.

Basic Data	Basin/Gross Area		Dniepr-Donets (23,200 mi^2)		Moesian Platform (45,000 mi^2)	
	Shale Formation		L. Carboniferous		L. Silurian	Etropole
	Geologic Age		L. Carboniferous		L. Silurian	L. Jurassic
	Depositional Environment		Marine		Marine	Marine
Physical Extent	Prospective Area (mi^2)		1,460	2,680	840	7,940
	Thickness (ft)	Organically Rich	700	700	600	650
		Net	350	350	450	260
	Depth (ft)	Interval	3,300 - 16,400	3,300 - 16,400	6,600 - 16,400	5,000 - 16,400
		Average	11,000	12,000	11,000	10,000
Reservoir Properties	Reservoir Pressure		Normal	Mod. Overpress.	Normal	Highly Overpress.
	Average TOC (wt. %)		4.5%	4.5%	3.0%	3.0%
	Thermal Maturity (% Ro)		0.90%	1.15%	1.15%	1.15%
	Clay Content		Low	Low	Medium	Medium
Resource	Oil Phase		Oil	Condensate	Condensate	Condensate
	OIP Concentration (MMbbl/mi^2)		45.3	18.1	8.9	5.0
	Risked OIP (B bbl)		13.2	9.7	1.6	7.9
	Risked Recoverable (B bbl)		0.66	0.48	0.08	0.40

Source: ARI 2013.

The main shale targets in Eastern Europe are marine-deposited black shales within the Lower Carboniferous of the Dniepr-Donets Basin (TRR of 76 Tcf and 1.2 billion barrels); the Silurian of the Carpathian Foreland Basin (73 Tcf); and the Silurian and Jurassic Etropole shale deposits of the Moesian Platform (47 Tcf and 0.5 billion barrels). By country, the estimates are Ukraine (128 Tcf and 1.2 billion barrels); Romania (51 Tcf and 0.3 billion barrels); and Bulgaria (17 Tcf and 0.2 billion barrels). Compared with North America, the shale geology of Eastern Europe is more complex, although faulting appears less prevalent than in other parts of Europe.

Shale resource assessments are reported to be underway in Ukraine, Romania, and Bulgaria but no official assessments have been published yet. To date only one shale-focused exploration core well has been drilled in the region (Bulgaria); no production testing has occurred. In Ukraine, Shell recently signed a Production Sharing Agreement in the Dniepr-Donets Basin, committing at least $200 million for exploration, while Chevron reportedly has been negotiating for a block in the Ukraine portion of the Carpathian Foreland Basin. Chevron's previously awarded shale blocks in Romania and Bulgaria have been put on hold.

INTRODUCTION

Since EIA/ARI's initial shale assessment first defined the potential in 2011, several Eastern European countries have begun to investigate their shale gas/ and shale oil resource potential. International oil and gas companies, including Chevron and Shell, have negotiated shale exploration licenses in Bulgaria, Romania, and Poland. The countries of Eastern Europe are taking various approaches to shale exploration. Ukraine currently welcomes shale investment. On the other hand, Bulgaria and Romania have placed shale exploration on hold, after initially proceeding with shale leasing.

Ukraine. The Ukraine State Service of Geology and Mineral Resources (Gosgeonedra) has announced shale gas resources in the country of 7 trillion m^3 (Tm^3) or 247 Tcf.[1] However, the basis for this estimate has not been released and the figure includes some tight gas resources. The newly created Geological Research and Production Center in Poltava plans to coordinate shale gas studies in Ukraine, while monitoring water quality in drilling areas. Ukraine's current Production Sharing Agreement (PSA) involves a 5-year exploration period and up to 45 years for development. Tender fees are modest: $60,000 for the tender and $10,000 for the geologic information package.

On February 23, 2012 the Ukraine government announced a tender for shale exploration and development in the Oleska and Yuzovska blocks of western and eastern Ukraine, respectively. Shell, ExxonMobil, Chevron, ENI, and TNK-BP initially responded to the tender. In January 2013, Ukraine awarded the first shale gas PSA, signing with Shell at the World Economic Forum in Davos, Switzerland. Shell's 50-year PSA permit at Yuzovska in the eastern Dniepr-Donets Basin covers an area of 7,886 km^2 and assigns oil and gas rights to all strata to a depth of 10 km, including tight and basin-centered gas. The contract allows for 70% investor recovery and a 16.5% government revenue share.

Chevron has been in negotiations with the government for a PSA at the Oleska field in western Ukraine. This block is along strike with Poland's Lublin basin, where Chevron already holds shale licenses. Duration and terms likely would be similar to those granted to Shell.

Bulgaria. While the country lacks a shale-specific investment regime, Bulgaria's conventional oil and gas production terms are attractive. Production licenses extend for 35 years, with royalties ranging from 2.5% to 30% on a sliding scale, with a 10% corporate income tax. The Economy and Energy Minister has suggested that Bulgaria's shale gas resources could be in the range of 0.3 to 1.0 Tm^3 (11 to 35 Tcf), but no supporting study has been released. The Shale Gas Research Group, a newly formed consortium of Sofia University and Bulgaria's Institutes of Geology and Organic Chemistry, is conducting long-term studies of organic-rich shale deposits in Bulgaria.[2]

However, during the past year public opposition to shale gas development has increased dramatically in Bulgaria. This opposition has been led by environmental organizers, with no effective counter-balancing information campaign offered by the petroleum industry or the government, such as exists in Poland. In January 2012 the government banned all shale gas exploration and production, whether or not it involves hydraulic fracturing. The performance of the shale industry in Poland and the UK is expected to influence the future political acceptance and government policies in Romania and Bulgaria.[3]

Romania. Romania also recently banned shale gas exploration and production, although some local observers believe its ban would be easier to reverse than Bulgaria's. In May 2012 the newly elected Romanian government began an informal (i.e., not legislated) ban on shale gas exploration activities, pending the outcome of European-level studies on the health, safety, and environmental aspects of shale gas development.

Romania lacks specific regulations for shale gas development, thus shale applications fall under the country's conventional petroleum terms. In 2011 the National Agency for Mineral Resources, which regulates petroleum operations in Romania, initiated a study of the country's shale gas deposits, in cooperation with the national research institute GeoEcoMar and three universities (Bucharest, Iasi and Cluj). No further details are available.

More than a dozen companies have expressed interest in shale gas exploration in Romania. Beginning in March 2012 Chevron was awarded four shale gas exploration licenses totaling 9,000 km^2, three blocks located in Dobruja and one in the Moldova region. Hungary's MOL was awarded three shale gas permits in northwestern Romania (Voivozi, Adea, and Curtici). Sterling Resources and partner TransAtlantic Petroleum jointly hold the 5,800-km^2 Sud Craiova license of southwest Romania. Finally, state-owned energy firm Romgaz reported that it discovered shale gas resources in 5 out of 20 of its exploration wells in Transylvania, noting that it had applied hydraulic fracturing technology in Romania as early as the mid-1990's. All of these projects are on hold due to Romania's shale ban.

GEOLOGIC OVERVIEW

Eastern Europe has three distinct shale-prospective areas with shale gas and oil potential in Paleozoic and Mesozoice marine-deposited black shales. Within the Paleozoic, the Carboniferous and Silurian black shales are most prospective, while the mid-Jurassic shales are most prospective for oil and gas within the Mesozoic. Other organic-rich shales exist locally but these tend to be less widespread and/or are thermally less mature, and thus were not assessed.

- **Carpathian Foreland Basin.** The moderately complex Lviv-Volyn Basin of western Ukraine is similar to the Lublin Basin in southeast Poland. However, the Silurian black shale belt becomes structurally simpler as it trends towards the southeast across southwestern Ukraine and northern Romania until it reaches the Black Sea. This deep Paleozoic belt north of the Carpathian Foldbelt is called the Carpathian Foreland Basin.
- **Dniepr-Donets Basin.** This well-defined Late Paleozoic basin in eastern Ukraine and southern Belarus contains prospective organic-rich L. Carboniferous black shales.
- **Moesian Platform.** Silurian and Jurassic black shales are present across Romania and Bulgaria. Note that the Moesian Platform shale plays are less well defined than the previous two plays and may be considerably larger than assessed here.

Other basins in Eastern Europe contain organic-rich source rock shales but these were deemed to be less prospective. The large Pannonian-Transylvanian basin of Hungary, Romania, Serbia and Montenegro, Slovenia, and Bosnia and Herzogovina has Paleozoic shale which appears too deep for shale development. The Carpathian, Balkan, and related fold belts appear much too structurally complex to be prospective.

1. CARPATHIAN FORELAND BASIN (UKRAINE-ROMANIA-MOLDOVA)

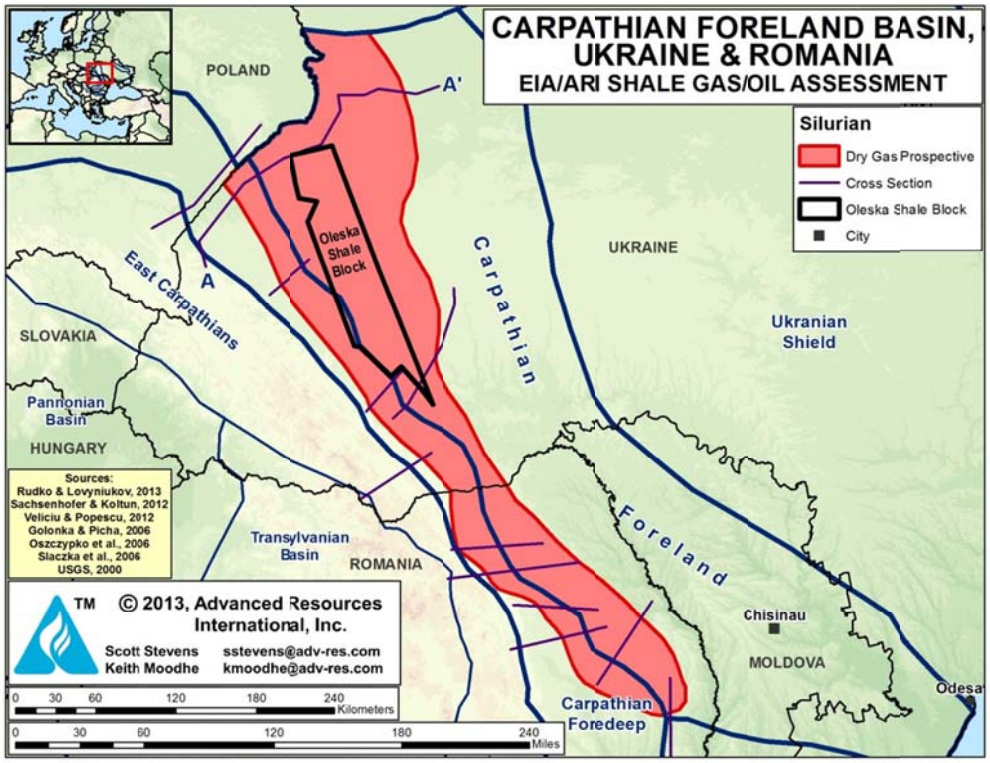
1.1 Introduction and Geologic Setting

Prospective marine black shales of Silurian age extend continuously within a 50- to 200- km wide Paleozoic belt, from Poland all the way to the Black Sea. In western Ukraine, Silurian deposits of southeast Poland's Lublin Basin continue into the adjoining Lviv-Volyn Basin, where 62 conventional oil and gas fields have been developed. Much of the Lviv-Volyn Basin appears to be too deep and faulted for shale development.

However, the Silurian belt becomes wider and structurally simpler as it continues further to the southeast across western Ukraine and northern Romania, Figure X-2. After some tectonic disturbance, the Silurian belt re-enters southern Ukraine and eastern Romania in the Scythian Platform before heading out into the Black Sea. It then briefly re-emerges onto land on the Crimean Peninsula near Odessa before continuing offshore. The North Dobrogea Orogen separates this belt from the Silurian of the Moesian Platform to the south[4], which was separately assessed. We refer to the Silurian belt as the Carpathian Foreland Basin, but other researchers have named it the Lviv-Moldava Slope.[5]

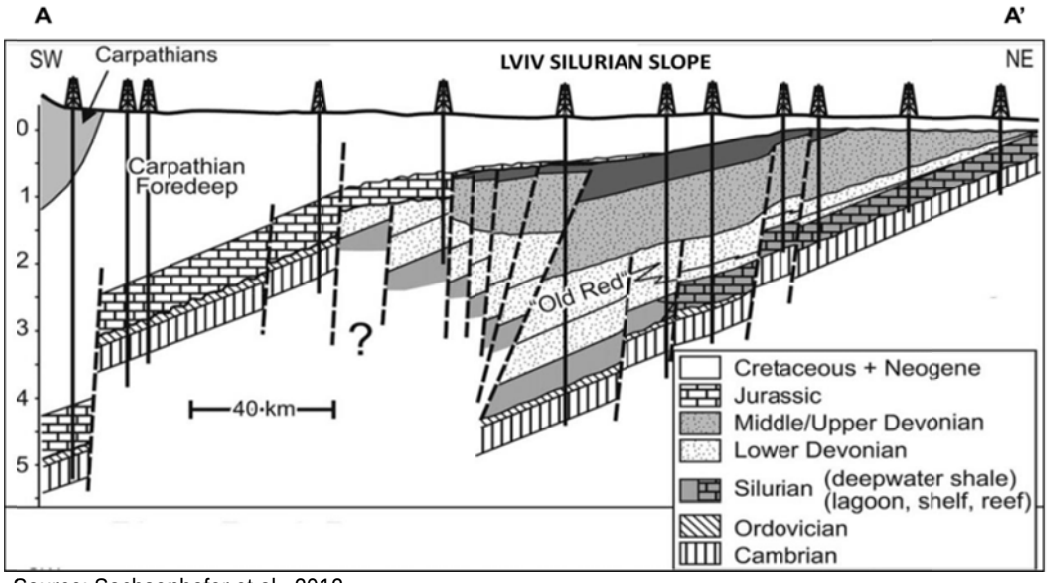
The Carpathian Foreland Basin has good shale gas development potential in Silurian black shales. As the foreland basin to the Carpathian thrust belt, this shale belt dips gently to the southwest and is characterized by mostly simple structure with few faults, Figure X-3. Further to the south, the structurally complex Carpathian region also contains multiple rich marine source rocks. These include the 500-m thick Jurassic Kokhanivka Formation with up to 12% TOC, the 200-m thick L. Cretaceous Spas and Shypot formations with 2-7% TOC, and the Oligo-Miocene Lower Menilite Formation with up to 20% TOC. However, the Carpathian region is intensely faulted with complex nappe tectonics, Figure X-4,[6,7] and was not assessed.

Figure X-2: Carpathian Foreland Basin Showing Shale-Prospective Areas.



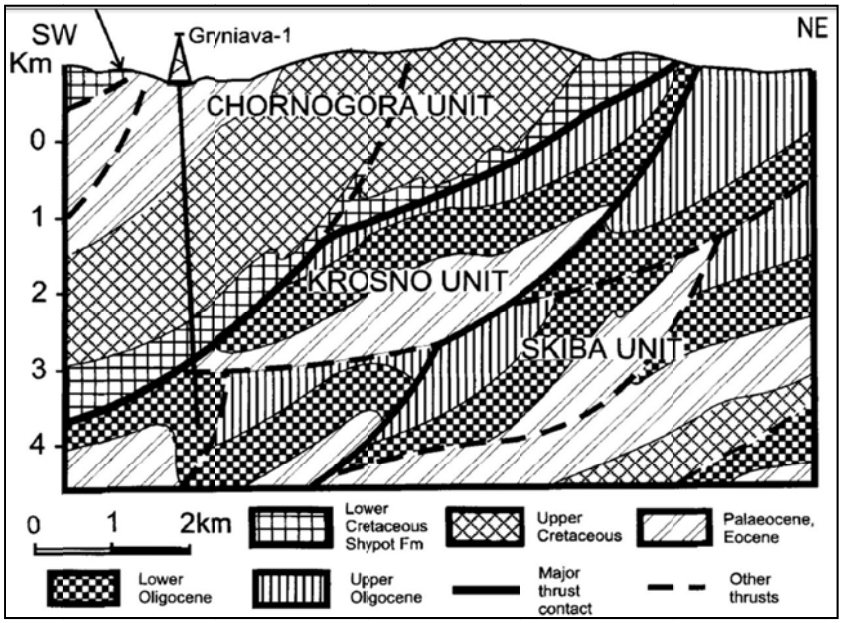
Source: ARI 2013

Figure X-3: Cross-Section of Lviv Slope Portion of the Carpathian Foreland Basin in Western Ukraine



Source: Sachsenhofer et al., 2012

Figure X-4: Cross-Section of a Nappe Structure in the Carpathian Thrust Belt

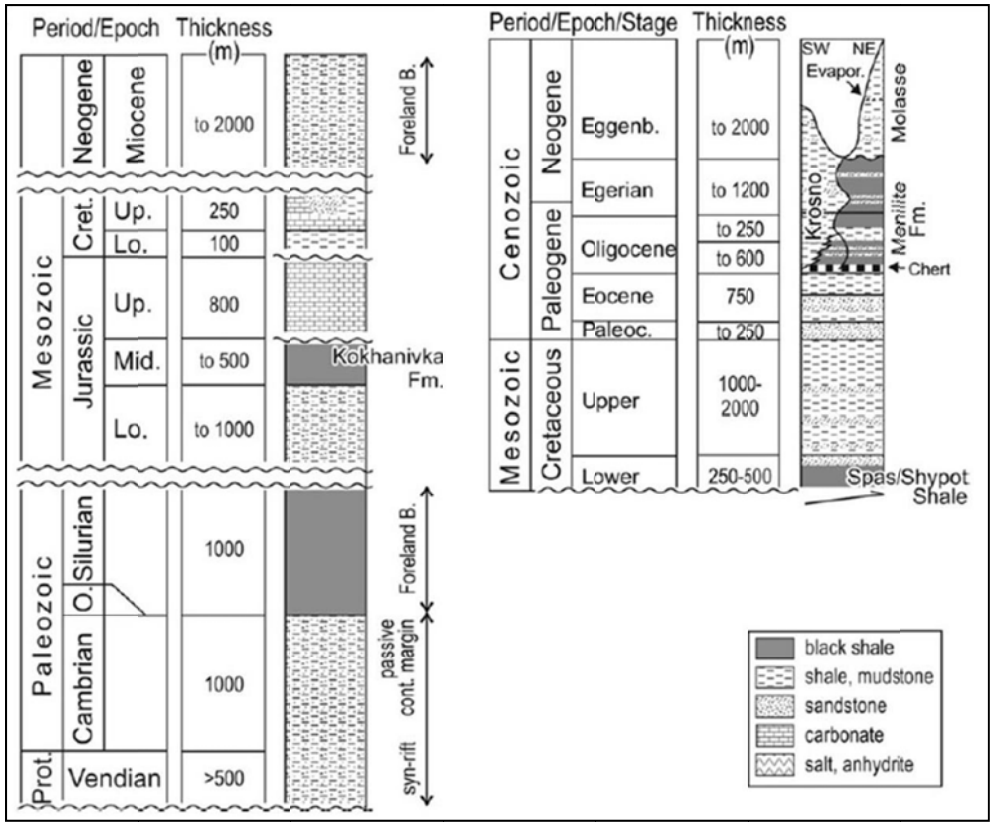


Source: Koltun et al., 1998

The Silurian is the main petroleum source rock and shale gas exploration targets in the Carpathian Foreland Basin, Figure X-5. Compared with Poland, the reservoir characteristics of the Silurian shale in western Ukraine are less certain. About 400 to 1,000 m of deep-water Silurian shale is present, transitioning eastward into thinner, shallow-water carbonates. The Ludlow member of the Silurian is considered the most prospective interval. The Ludlow ranges from 400 to 600 m thick and occurs at depths of 2 to 3 km in western Ukraine.

Silurian shale TOC may be lower in Ukraine than in Poland, at least based on the single well data point available (IS-1). Most TOC measurements at a depth range of 1,400 to 1,592 m in this well were less than 1%. However, the original TOC is estimated at 3% prior to thermal alteration. Given the depositional environmental of the Silurian, it is likely that higher TOC exists in places. Thermal maturity mapping, calculated from conodant alternation index, indicates the Silurian is entirely in the dry gas window (R_o of 1.3% to 3.5%). Several (possibly spurious) over-mature values of 5% R_o also were measured. Maturation is believed to have occurred prior to the Mesozoic. As Sachsenhofer and Koltun (2012) noted: “additional investigations are needed to investigate lateral and vertical variations of TOC contents and refine the maturity patterns in Lower Paleozoic rocks.”

Figure X-5: Stratigraphy of Carpathian Foreland Basin Showing Thick Black Shales of Silurian and Mid-Jurassic-Age (left). L. Cretaceous and Paleogene Source Rocks Occur in the Carpathians (right).



Source: Sachsenhofer et al., 2012

The Kovel-1 petroleum well is a key stratigraphic test drilled during the late 1980s in western Volynia, northwestern Ukraine. The well is located along the transition between the structurally complex Lublin-Lviv basins on the west and the less deformed Volynia region of the Slope. The Kovel-1 well cored Ordovician at a depth of about 250 m; Silurian apparently had been eroded in this uplifted location.[8]

1.2 Reservoir Properties (Prospective Area)

Based on geologic control from regional cross-sections, the total estimated shale gas prospective area in the Carpathian Foreland Basin is estimated to be approximately 16,080 mi^2, of which 11,520 mi^2 is in Ukraine and 4,560 mi^2 in Romania. The target organic-rich portion of the 500-m thick Ludlow Member of the Silurian is estimated to average 1,000 ft thick gross and 10,000 ft deep within the prospective region, and have 4% porosity. TOC averages a relatively

low 2.0% and is in the dry gas window (R_o average 2.5%). The pressure gradient is assumed to be hydrostatic (0.43 psi/ft).

1.3 Resource Assessment

Risked, technically recoverable resources from Silurian black shale in the Carpathian Foreland Basin are estimated to be 73 Tcf (52 Tcf in Ukraine and 21 Tcf in Romania), out of a risked shale gas in-place of 363 Tcf, Table X-1. The play has a moderately high resource concentration of about 113 Bcf/mi^2, reflecting the significant thickness of the organic-rich shale that is present.

Ukraine's State Commission on Mineral Resources has estimated that the Oleska shale gas license area in the Lviv-Volyn Basin has about 0.8 to 1.5 trillion m^3 (28 to 53 Tcf) of shale gas resources. Whether this estimate reflects in-place or recoverable resources was not specified.

An independent assessment of Silurian shale gas resources in the Romanian portion of the Carpathian Foreland Basin arrived at a Mean Estimate of 5.6 Tcf technically recoverable out of 279 Tcf of gas in-place. This estimate utilized EIA/ARI's 2011 methodology, but key assumptions (thickness, porosity, risk) were not specified, nor was Ukraine evaluated.[9]

1.4 Recent Activity

Chevron reportedly is in negotiations with the government to develop a shale gas project in the Oleska block of western Ukraine. The government recently removed its self-imposed deadline of May 2013 for completing this deal. Chevron also initially acquired the 6,257-km^2 Barlad shale gas permit in northeastern Romania close to Moldova, but the status of this block is unclear following the shale ban in Romania.

In 2012 ENI acquired half of LLC WestGasInvest, which controls nine unconventional gas licenses totaling 3,800-km^2 in the Lviv Basin of western Ukraine, which may include shale gas potential. The company and its partners, including UK-based Cadogan Petroleum, plan to spend about $55 million exploring for shale gas in the Lviv basin from 2012 through 2015.

2. DNIEPR-DONETS BASIN (EAST UKRAINE)

2.1 Introduction and Geologic Setting

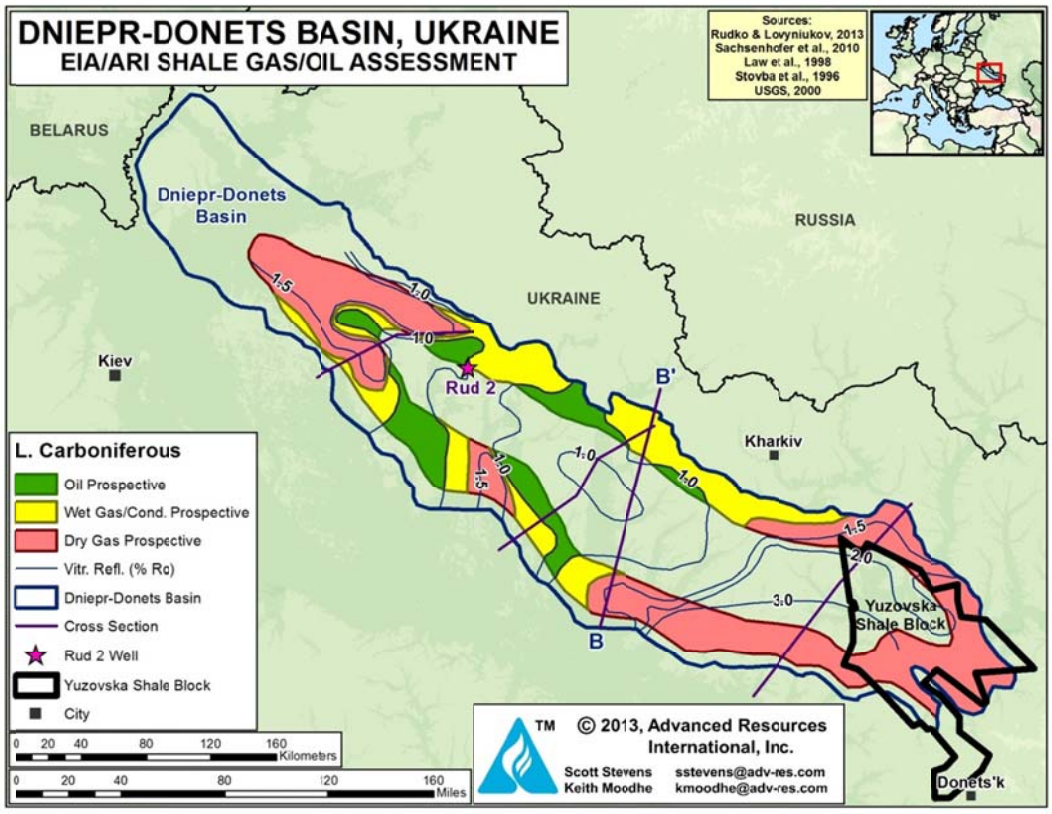
The Dniepr-Donets Basin (DDB) in eastern Ukraine is a Mid-to Late-Devonian failed rift basin on the Eastern European Craton, Figure X-6. The basin contains a thick sequence of Lower Carboniferous black shale which may be prospective for oil and gas development. Economically important Carboniferous coal deposits and tight sands of the Moscovian overlie these shales,[10] but this coaly sequence does not appear to be a prospective shale target.

The DDB accounts for most of Ukraine's onshore petroleum reserves and is comparatively well understood, with several thousand oil and gas wells, some of which reached depths of over 5 km. Lower Carboniferous black shales and coal seams are the main source rocks, while overlying clastic Carboniferous sandstones provide conventional reservoirs within mainly structural traps. To the northwest the DDB continues into the Pripyat Trough of southern Belarus, which appears to be too shallow and low in TOC for shale development. To the southeast the basin continues into the Donbas Foldbelt of southwestern Russia.

Roughly symmetrical, the DDB is about 700 km long, 40 to 70 km wide, and trends northwest-southeast.[11] It comprises a series of half grabens bounded by large-displacement faults (h= 100 m to 2 km). The individual blocks are quite sizeable (50-100 km by 20-40 km), although numerous smaller faults are locally present. The basin contains as much as 15 km of Devonian and younger sedimentary rocks, which includes 1 to 2 km of mostly Devonian (Frasnian) salt deposited under restricted rift conditions. Figure X-7 is a structural cross-section showing depth to the L. Carboniferous (L. Visian) black shale as well as salt flows in the basin.[12]

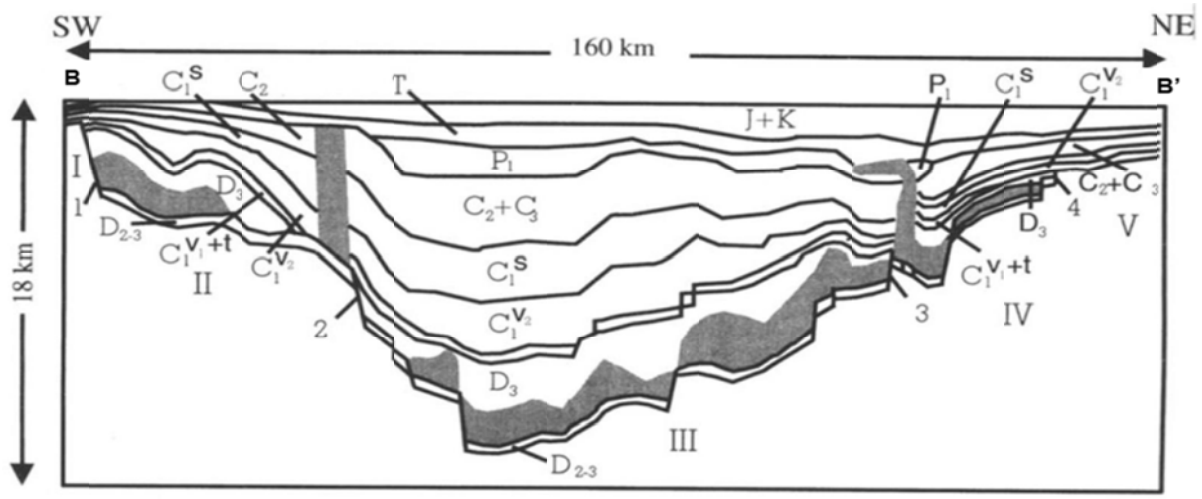
L. Carboniferous black shale overlies the Devonian salt interval. This black shale and the overlying coal seams sourced most of the conventional oil and gas fields in the basin. The entire Carboniferous section ranges up to 11 km thick in the DDB and is up to 15 km deep near its base along the basin axis. In the northwest portion of the DDB the Carboniferous is continental in origin, but transitions into partly shallow marine depositional cycles, each of which is typically 50 m thick and contains an organic-rich shallow marine shale layer.

Figure X-6: Dniepr-Donets Basin Showing Shale-Prospective Areas



Source: ARI, 2013

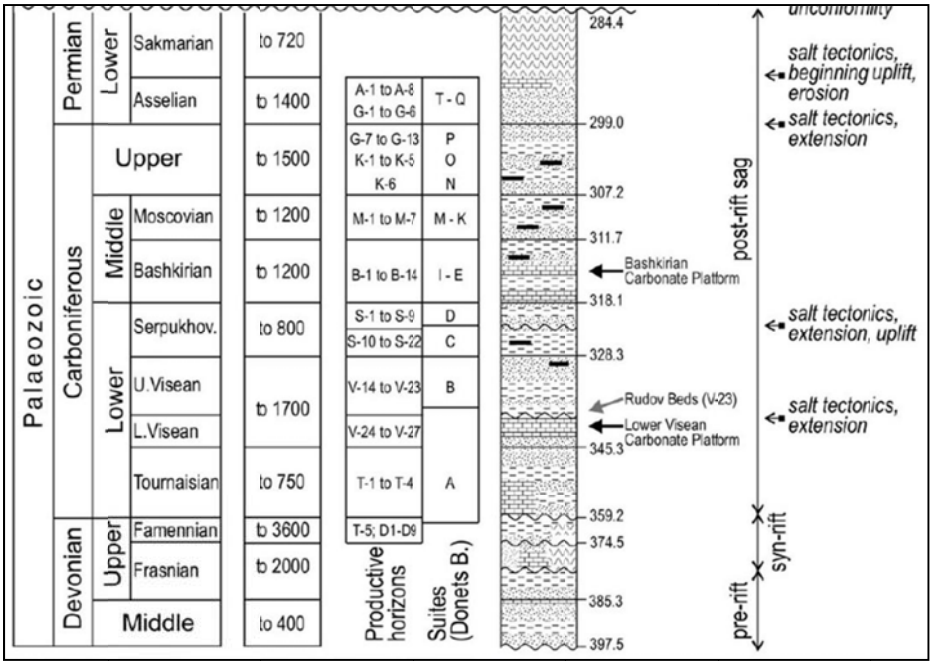
Figure X-7: Cross-Section of Dneipr-Donets Basin Showing Depth to the L. Carboniferous (L. Visian) Black Shale



Source: Stovba et al., 1996

Several black shale targets occur within the L. Carboniferous sequence, Figure 8.[13] The Upper Visean Rudov Beds are considered the best quality source rock and shale gas target. These black shales are up to 70 m thick, but more typically 30-40 m, and particularly well developed in the Srebnen and Zhdanivske depressions where they are quite deep and dry gas prone. The Rudov Beds are rich in siliceous radiolaria, making them potentially brittle, while the lower part of the formation is high in calcite as well as clay. The organic-rich middle section of the Rudov Beds has 3.0% to 10.7% TOC (average 5%), mostly Type III with some Type II kerogen. Additional slightly leaner (TOC of 3.0% to 3.5%) but still quite prospective source rocks occur in the Upper Visean above the Rudov Beds, while the lower Serpukhovian contains black shales with up to 5% TOC.

Figure X-8: Stratigraphy of Dniepr-Donets Basin. Black shales Occur in L. Carboniferous Rudov and U. Visean.

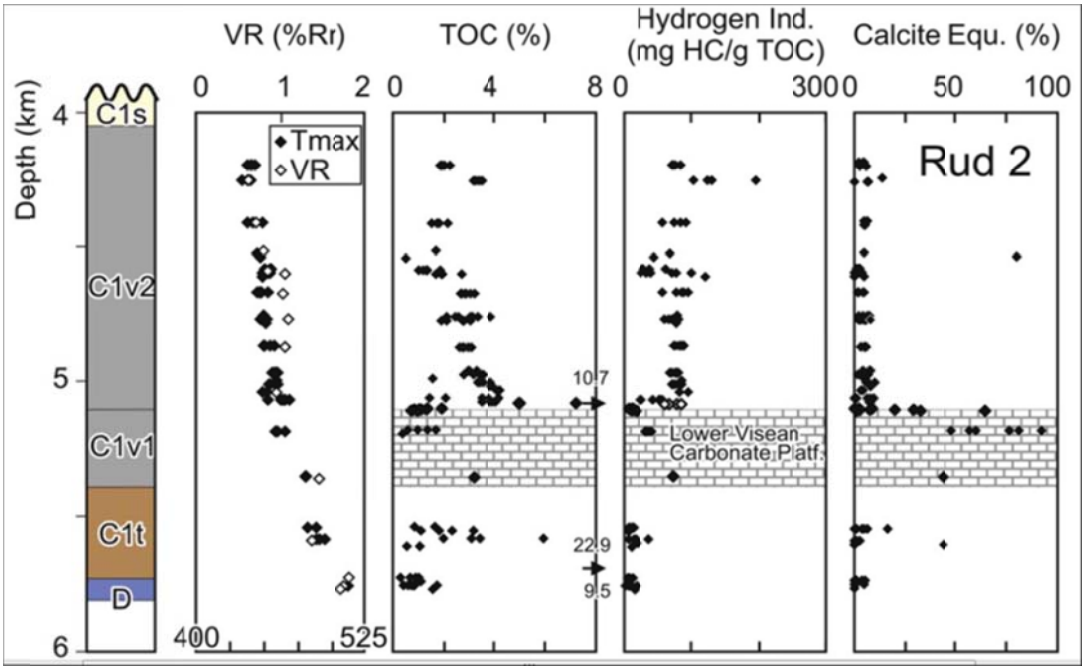


Source: modified from Sachsenhofer et al., 2010

Thermal maturity of the Rudov Beds and the overlying Upper Visean is mainly in the oil window (R_o 0.8-1.0%) in the central and northwestern DDB, increasing to dry gas maturity (R_o 1.3-3.0%) in the southeast. For example, the Rud-2 petroleum well in the Dniepr-Donets Basin penetrated a nearly 1-km thick Carboniferous Upper Visean shale interval at a depth of 4 to 5 km, **Figure X-9**. TOC of up to 4% in this interval is within the oil thermal maturity window (R_o 0.8-1.0%). The oil window in this basin appears to be normally to under-pressured, while the

dry gas window is likely to be over-pressured due to ongoing gas generation, although pressure data control is poor.[14]

Figure X-9: Rud-2 Well in the Dniepr-Donets Basin, Showing the Carboniferous Upper Visean Shale (C1v2) with TOC up to 4% in the Oil Window (Ro 0.8 to 1.0%).



Source: Sachsenhofer et al., 2012

The southwest flank of the Dneipr-Donets Basin is characterized by a structurally simple dip slope, where thick L. Carboniferous black shale tilts gently to the NNE towards the basin axis. The L. Carboniferous is at ideal depth for shale development (1-5 km) over a broad belt. The northeast flank of the DDB has thinner L. Carboniferous that is structurally more complex. Lacking a detailed depth map on the Carboniferous, we constrained the depth-prospective area using basement contours and multiple published cross-sections, yielding good control on the prospective area. Note that salt intrusions up to 15 km thick may negatively impact shale potential along various parts of the slope.

2.2 Reservoir Properties (Prospective Area)

Lower Carboniferous black shales (Rudov Beds, Lower Visean, and Lower Serpukhovian) are prospective within a 10,150-mi^2 depth-controlled belt that surrounds the axis of the Dneipr-Donets Basin. These shales are estimated to total about 1 km in thickness but are relatively deep (3-5 km). They largely consist of siliceous or calcareous lithologies rich in

radiolarian and thus are expected to be brittle with high porosity (6%). Gas recovery rates also should be favorable (30%) due to the inferred frackability of the shale. TOC appears favorable, averaging about 4.5%. Thermal maturity ranges from oil to dry gas. On the negative side, salt intrusions may sterilize some of the mapped prospective area (10%).

2.3 Resource Assessment

Dry Gas Window. The mapped prospective area for the dry shale gas window in southeastern Dniepr-Donets Basin is estimated at 6,010 mi^2. Lower Carboniferous shale (comprising the Rudov Beds and portions of the overlying Upper Visean) has a highly favorable resource concentration of approximately 195 Bcf/mi^2. Risked, technically recoverable shale gas resources are estimated to be 59 Tcf, out of a risked shale gas in-place of 235 Tcf.

Wet Gas Window. The wet gas prospective area of the DDB extends over about 2,680 mi^2. Risked, technically recoverable resources are estimated at 16 Tcf of shale gas and 0.5 billion barrels of condensate from in-place shale gas and shale oil resources of 63 Tcf and 10 billion barrels.

Oil Window. The smaller oil window in the northwestern Dniepr-Donets Basin covers a prospective area of about 1,460 mi^2. Risked technically recoverable resources are estimated to be about 0.7 billion barrels of shale oil and condensate and 1 Tcf of associated shale gas, out of risked in-place shale oil resources of 13 billion barrels.

Ukraine's State Commission on Mineral Resources has estimated that the Yuzovska shale gas license in the eastern Dniepr-Donets Basin has 2-3 Tm^3 (71-107 Tcf) of shale gas and tight gas resources. Whether this estimate reflects in-place or recoverable resources was not specified.

2.4 Recent Activity

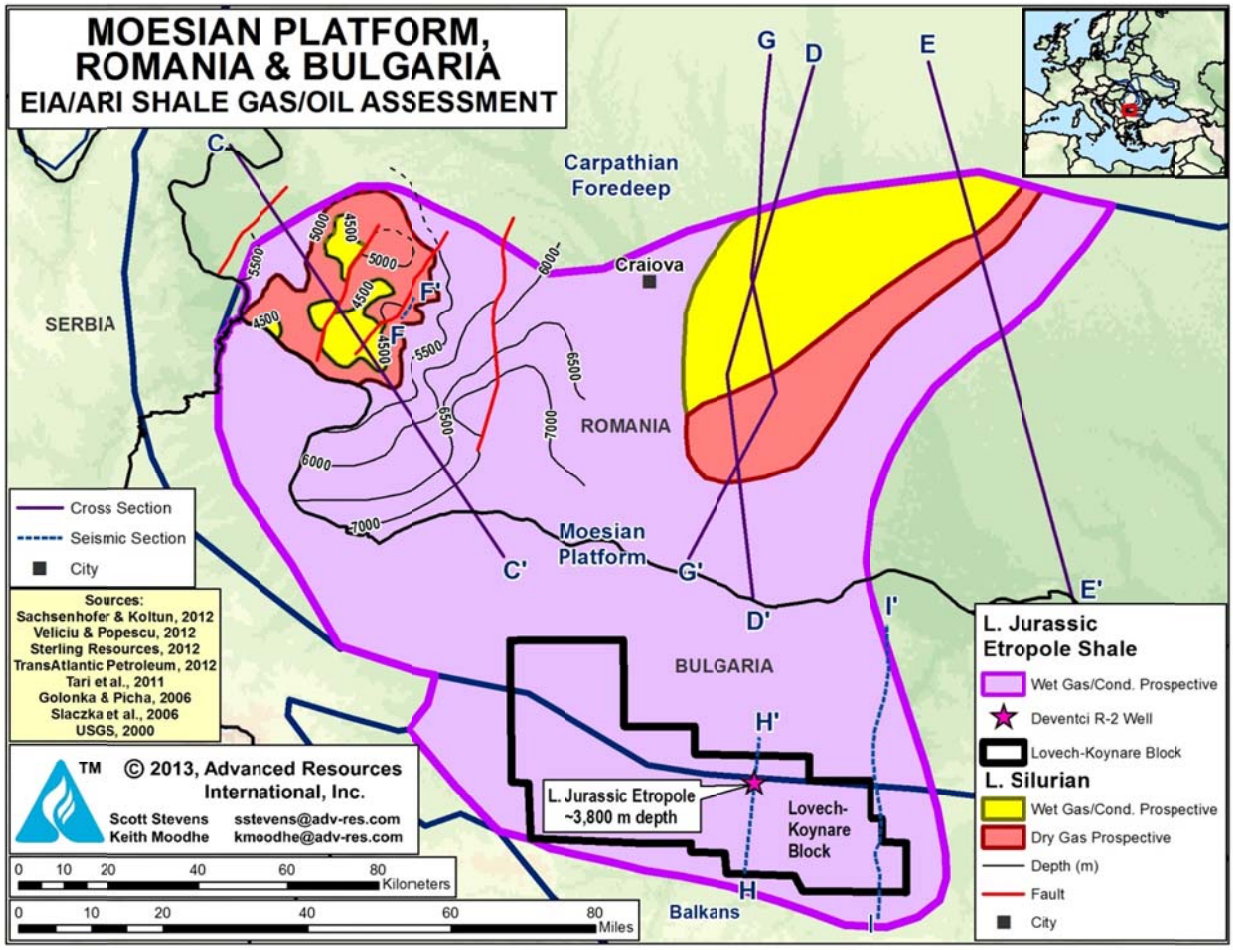
In early 2013 Shell was awarded Ukraine's first formal shale gas exploration license, the 7,800-km^2 Yuzovska PSA located on the south flank of the Dniepr-Donets Basin. Shell's first-stage investment commitment is $200 million. Previously in 2011, ENI acquired from Cadogan Petroleum portions of the Zagoryanska and Pokroskoe conventional licenses in the DDB, which may include shale potential.

3. MOESIAN PLATFORM (ROMANIA, BULGARIA)

3.1 Introduction and Geologic Setting

The Moesian Platform is a comparatively simple (for Europe) foreland basin that stretches across southern Romania and north-central Bulgaria, Figure X-10. The Platform is overthrusted by the Balkan thrust system to the south, while the Carpathian thrust system forms the northern boundary; both are Cenozoic features related to Alpine tectonics. To the east, the Moesian Platform is separated from the Carpathian Foreland Basin and on the north by the North Dobrogea Orogen. The adjacent Getic Basin of Romania, the foreland of the South Carpathians, contains similar source rocks but is more deformed by Tertiary tectonic events and considered less prospective.

Figure X-10: Moesian Platform Region Showing Shale-Prospective Areas.



Source: ARI 2013

Up to 12 km of mostly flat-lying, carbonate-rich Paleozoic and Mesozoic sedimentary rocks are present on the Moesian Platform, Figure X-11. The relatively few conventional oil and gas fields that have been discovered in this region produce mainly from mid-Triassic dolomite and occasionally from basal Jurassic sandstone. [15,16]

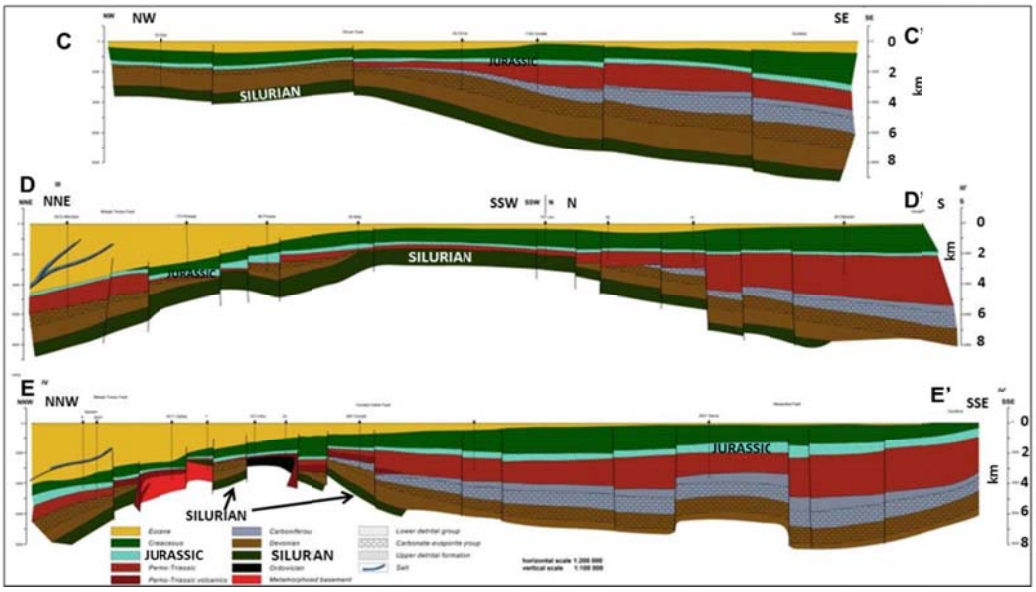
The Moesian Platform contains multiple organic-rich source rock shales that are prospective for shale gas development, Figure X-12. These include the Ordovician to Upper Carboniferous Tandarei, Vlasin, and Calarasi formations, including Silurian shales; the Jurassic Etropole Shale; the Bathonian (Dogger) shales (Bals Formation); and Mid-Miocene marls and shales (Badenian to Sarmatian). The main targets for shale gas exploration are the Silurian shale and Jurassic Etropole Shale.

The Silurian shale in the Moesian Platform is broadly similar to that targeted in Poland and the Carpathian Foreland Basin further to the north. Regional cross-sections show the Silurian ranges from 2 to over 5 km deep across the Moesian Platform. At the South Craiova Block in southwest Romania, the Silurian Llandovery Shale is at least 160 m thick, 4,050 to 4,200 m deep, and has about 3% TOC, Figures X-13 and X-14.[17] At the Bulgarian Arch in eastern Bulgaria, thick (650-m), organic-rich Silurian shales reportedly are at prospective depths of 1 to 5 km, but data were not sufficient to map this portion of the play.

The other main target in the Moesian Platform is the Jurassic Etropole Shale, considered the main petroleum source rock in northwest Bulgaria, Figure X-15. In particular its organic-rich lower portion, the Stefanetz Member, contains thick, carbonate-rich (40-50%) black shale with interbeds of marl and limestone that was deposited in a marine environment, not dissimilar to the Upper Jurassic Haynesville Shale.[18] TOC ranges from 1.0% to 4.6%,[19] with Type II kerogen predominating.[20] The Etropole Shale generally ranges from 2.5 to >5 km deep[21] and is over-pressured in much of the region, with an elevated pressure gradient of 0.78 psi/ft. Thermal maturity falls in the oil window in the north, increasing to wet and dry gas in the south near the Balkan thrust belt (R_o 1.0% to 1.5%).[22]

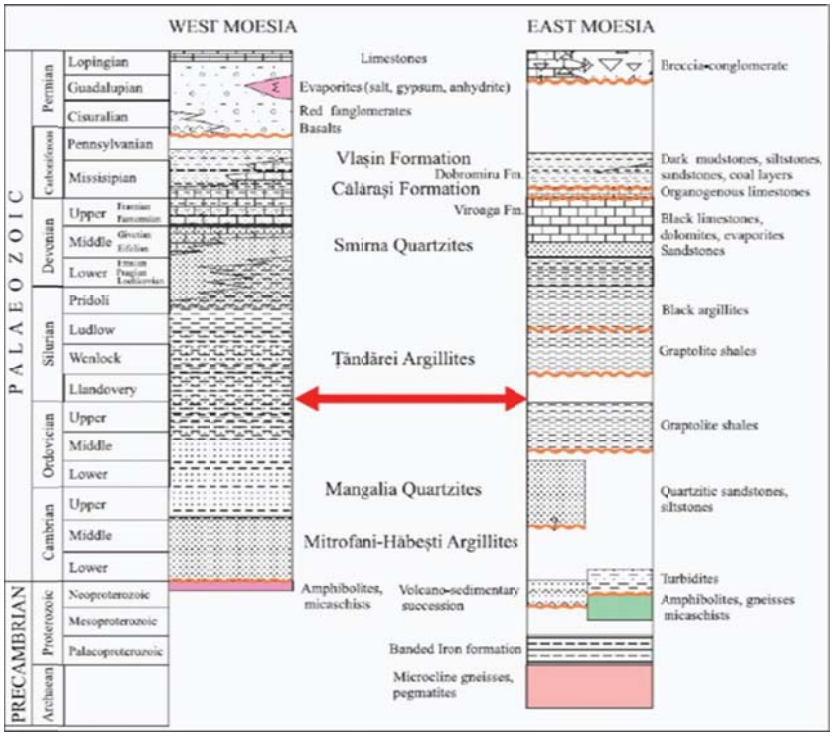
Oil and gas has been produced from conventional silty, sandy, and carbonate intervals within the Etropole Formation, such as the Peshtene R-5 well which reportedly flowed gas at an unstimulated rate of 530,000 ft^3/d. In addition, oil produced from the Jurassic Dolni Lukovit and Mid-Triassic Dolni Dabnik fields has been chemically linked back to the Etropole Shale.

Figure X-11: Regional Cross-Sections in of the Moesian Platform In Romania Showing Jurassic and Paleozoic Shale at Mostly Moderate Depth with Relatively Simple Structure.



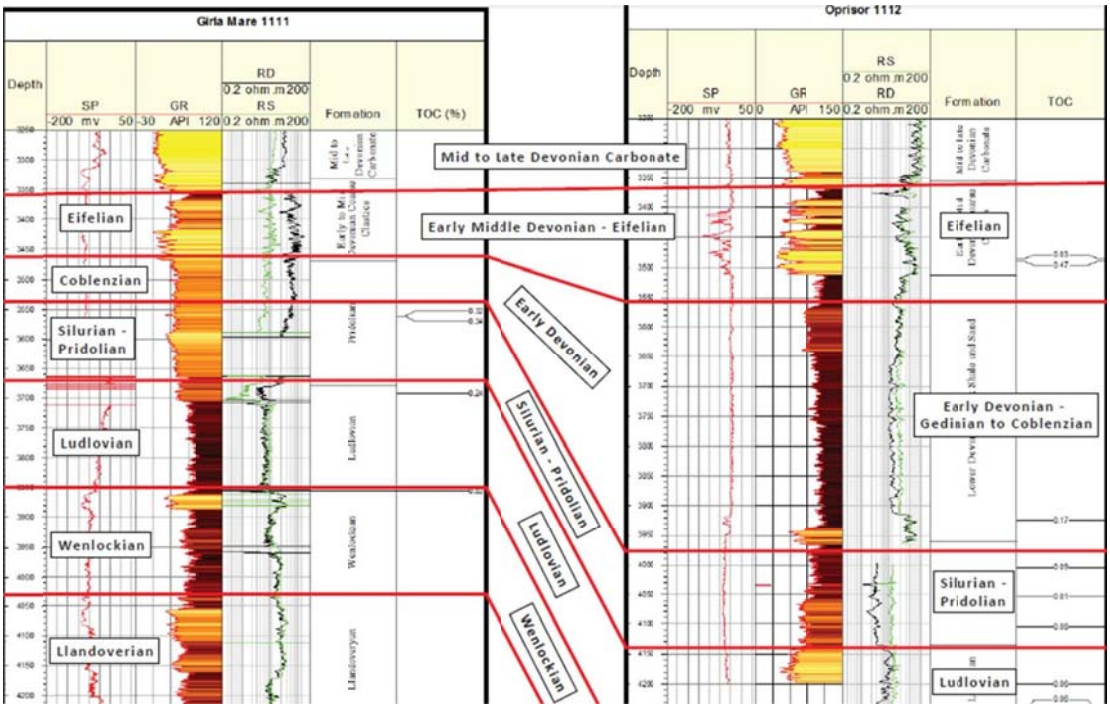
Source: Veliciu and Popescu, 2012

Figure X-12: Stratigraphic Column Showing L. Silurian Llandovery Shales in Southwest Romania.



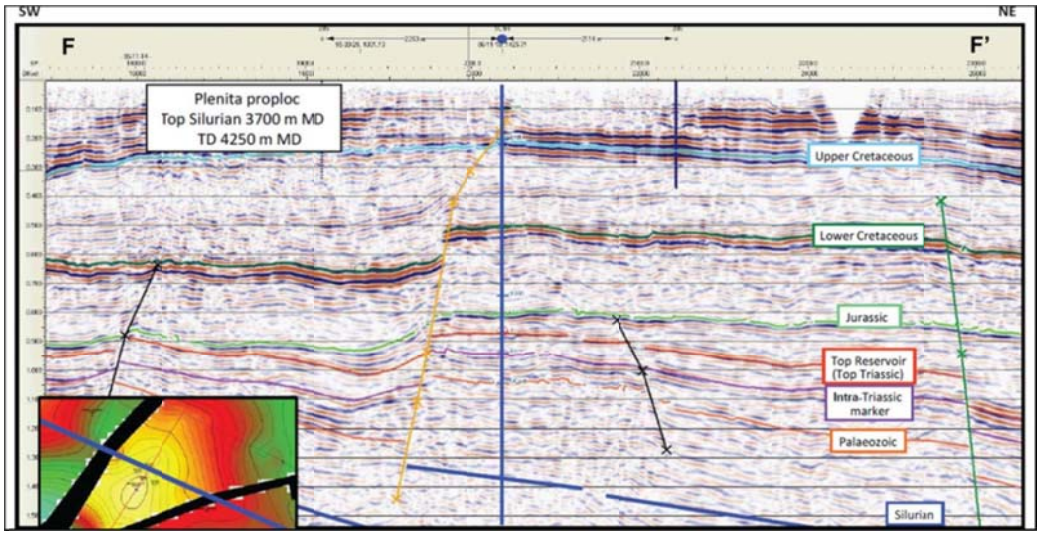
Source: Sterling Resources, 2013

Figure X-13: Well Logs Showing Paleozoic Section Including L. Silurian Llandovery Shales at the South Craiova Block (EIII-7) in Southwest Romania.



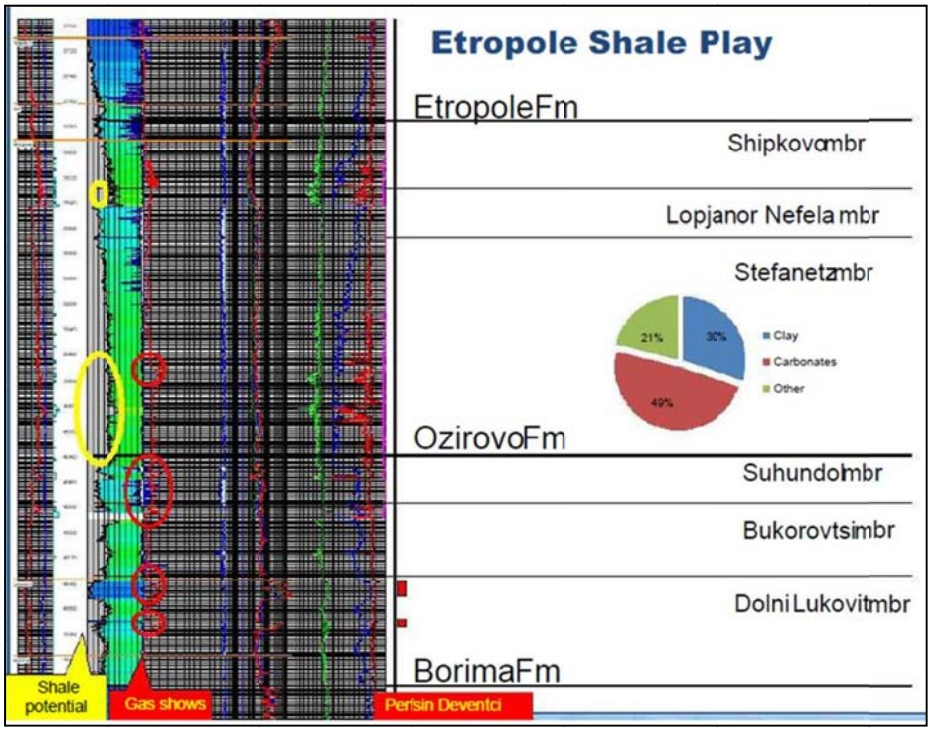
Source: Sterling Resources, 2013

Figure X-14: SW-NE Trending Seismic Line Showing Paleozoic Section Including L. Silurian Llandovery Shales at the South Craiova Block in Southwest Romania. Structure is Relatively Simple But Faults are Present.



Source: Sterling Resources, 2013

Figure X-15: Well log across the Jurassic Etropole Shale in Bulgaria

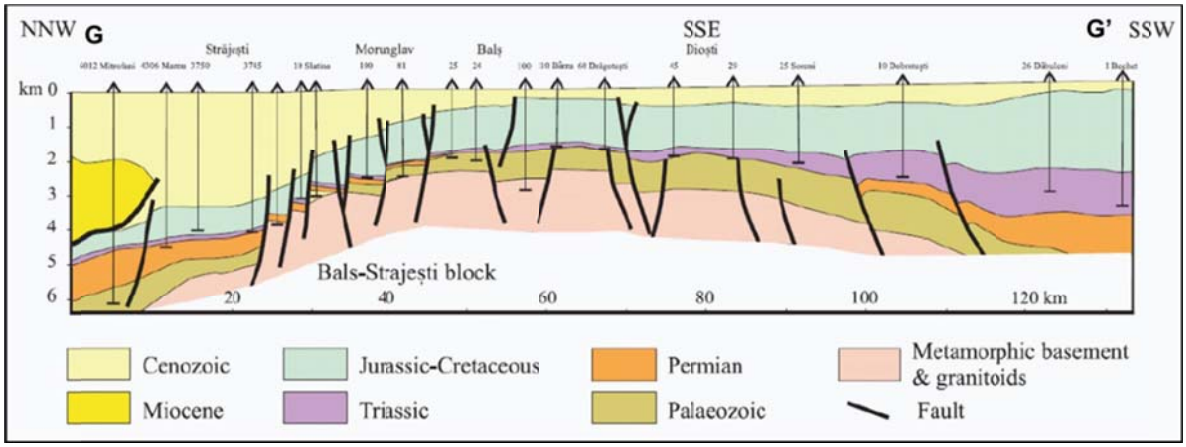


Source: TransAtlantic Petroleum Ltd, February 2011

At the Sud Craiova license in southwest Romania, operated by Sterling and TransAtlantic, the Etropole Shale ranges from 115 to over 700 m thick and 3,700 to 4,500 m deep across the block, Figure X-16. At the Lovech block in northwest Bulgaria the Etropole Shale is about 3,800 m deep, Figure X-17. Structure is fairly simple in this region, with flat lying dips cut by several faults. Other portions of the Moesian Platform lacking data control also were assumed to have relatively similar structure.

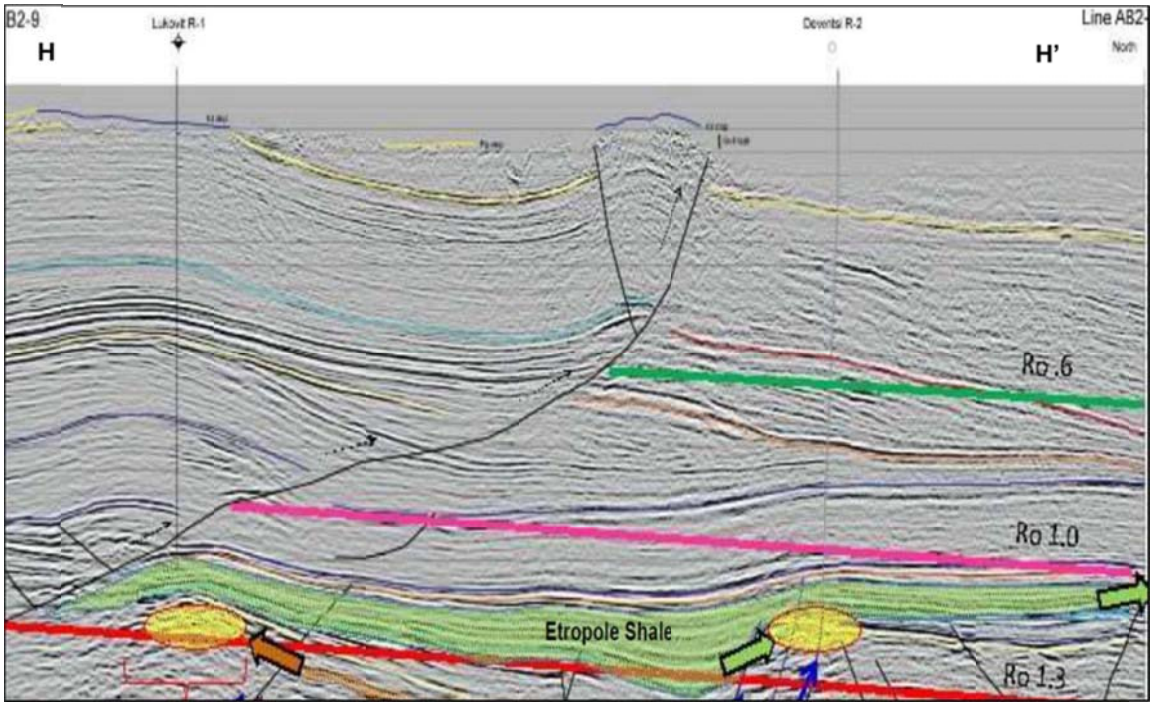
The eastern continuation of the Jurassic Etropole Shale is unclear and could not be rigorously mapped. Two time-structure transects suggest the Etropole may be present in eastern onshore Bulgaria at two-way seismic times of 0.5 to 3.0 seconds, deepening to the east into the Black Sea, Figure X-18. The Central Dobrogea Green Schist Zone, comprising uplifted blocks of Proterozoic basement blocks north of the Palazu Fault, has only a thin or no Jurassic sequence. On the other hand, the North Bulgarian Arch -- where Chevron initially was awarded a shale gas license – holds preserved Jurassic to Tertiary sedimentary sequences.[23]

Figure X-16: Regional Seismic Section Showing Jurassic and L. Silurian Llandovery Shales at the South Craiova Block in Southwest Romania. The Structural Dip is Relatively Gentle but Numerous Faults are Present.



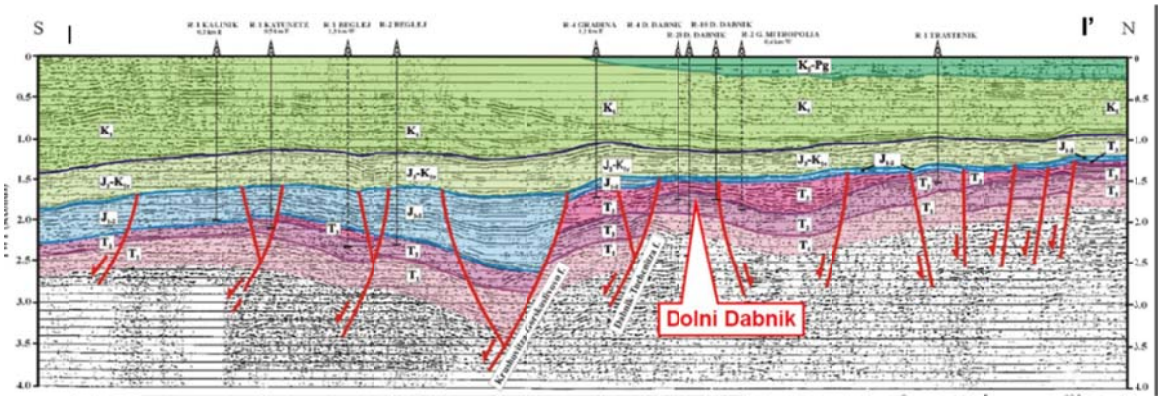
Source: Sterling Resources, 2013

Figure X-17: Jurassic Etropole Shale is about 3,800 m Deep with 1.0% to 1.3% Ro at TransAtlantic Petroleum's Lovech Block in Northwest Bulgaria.



Source: TransAtlantic Petroleum, 2011

Figure X-18: Regional Cross-Section Showing Thick Jurassic Lias and Dogger Shale Deposits in Northern Bulgaria Which Thin Markedly to the North into Romania.



Source: Tari et al., 2011

3.2 Reservoir Properties (Prospective Area)

L. Silurian Shale. The mapped prospective area for black shales in the L. Silurian totals 1,600 mi^2, all of which is located in Romania. No prospective area was identified in Bulgaria due to data limitations, although there could be prospective Silurian areas in northeast Bulgaria. Depth ranges from 2 to 5 km. Organic-rich thickness averages about 600 ft (gross). Thermal maturity ranges from wet to dry gas. TOC is estimated at 3%, porosity at about 4%.

Jurassic Etropole Shale. Black shales in the Mid-Jurassic Etropole Shale are prospective within an estimated 7,940-mi^2 area of the Moesian Platform, in northwest Bulgaria and southwest Romania. The most organic-rich shales are estimated to total about 250 m thick (gross) at moderate depth of about 10,000 ft. Porosity is assumed to be moderately high (5%). Gas recovery rates also could be favorable based on the inferred brittle lithology. TOC appears moderate, averaging about 3% in the more prospective intervals. Thermal maturity is wet gas (R_o 1.0% to 1.3%). The pressure gradient is estimated at 0.7 psi/ft.

3.3 Resource Assessment

Risked, technically recoverable shale resources in the Moesian Platform region of Romania and Bulgaria are estimated to be 47 Tcf of shale gas and 0.5 billion barrels of shale condensate, out of a risked shale gas and shale oil in-place of 196 Tcf and 10 billion barrels, respectively. Romania's share is approximately 30 Tcf and 0.3 billion barrels while Bulgaria's share is estimated at 16 Tcf and 0.2 billion barrels.

Silurian Llandovery Shale. Risked, technically recoverable shale gas resources in the Silurian shale of the Moesian Platform of Romania and Bulgaria are estimated to be 10 Tcf, out of a risked shale gas in-place of 48 Tcf.

Jurassic Etropole Shale. Risked, technically recoverable shale resource in the Jurassic Etropole Shale within the Moesian Platform of Romania and Bulgaria are estimated to be 37 Tcf out of a risked shale gas in-place of 148 Tcf, while shale oil/condensate resources are estimated at 0.4 billion barrels of condensate out of 7.9 billion barrels of risked oil in-place.

Separately, in northeastern Bulgaria, the government has estimated the 4,400-mi^2 Novi Pazar block has 0.3 to 1.0 Tm^3 (11 to 35 Tcf) of shale gas resource potential in the Devonian-Silurian silty shale. The Devonian-Silurian was reported in the study to be up to 2 km thick, 800 to 2,800 m deep, and have 3.5% sapropelic organic matter with TAI from 2 to 5.[24] However, it was not possible to map this play due to lack of data.

At the 1,500-mi^2 Sud Craiova license in southwest Romania, Sterling and TransAtlantic have estimated that the Silurian shale has gross recoverable prospective resources of approximately 3 Tcf (Best Estimate). Including the Jurassic Etropole, TransAtlantic has estimated its blocks hold a total of 0.3 Tm^3 (11 Tcf) of unrisked, recoverable shale gas prospective resources (gross; Best Estimate).[25]

Independent researchers in Romania recently estimated the technically recoverable resources in the Silurian shale of the southern Romanian portion of the Moesian Platform to be 26 Tcf, out of 1,295 Tcf of OGIP (Mean Estimate). The Jurassic was not assessed, nor was the Silurian potential in Bulgaria.[26]

3.4 Recent Activity

Several companies have pursued shale gas leasing in Bulgaria but only one shale test well has been drilled. In June 2011, Chevron received a 5-year shale gas exploration permit for the 4,400-km^2 Novi Pazar block of northeastern Bulgaria. However, since the shale ban of January 2012 Chevron can only pursue conventional targets in the block without hydraulic fracturing.

US-based TransAtlantic Petroleum, through its subsidiary Direct Petroleum Bulgaria, holds a shale gas exploration license at the 2,300-km^2 Lovech block, located in the southern Moesian Platform north of the Balkan forelands in northwest Bulgaria. TransAtlantic recently was also awarded the adjacent 648-km^2 Koynare block.

In November 2011 TransAtlantic and Canada-based partner LNG Energy drilled the 3,190-m deep Goljamo Peshtene R-11 exploration well at Lovech to core and test the Mid-Jurassic Etropole Shale. The R-11 well was drilled in 56 days and cost $7.5 million. It was located near the Peshtene R-5 well, which had flowed 530,000 ft^3/d from a conventional interval in the Jurassic Etropole. The R-11 well penetrated 354 m of Etropole argillite with numerous gas shows (C1-C3) and cored 289 m of the Jurassic Etropole and Ozirovo formations. LNG described rock properties as similar to those of productive US shale plays. The well was not fracture stimulated as Bulgaria has a ban in place. TransAtlantic plans to test the Etropole Shale elsewhere on the Lovech block where it is about 3,800-m deep.[27]

Canada's Park Place Energy received an exploration permit in northwest Bulgaria's Dobruja province (blocks Vranino 1 to 11). In June 2011 Chevron won a tender to explore for shale gas at the Novi Pazar field, also located in Dobruja, but the permit was cancelled in January 2012 when the shale gas ban came into effect. Bulgaria's state gas company Bulgargaz has not disclosed any shale-related activity.

REFERENCES

[1] Rudko, G. and Lovyniukov, V.I., 2013. "State Classification of Mineral Resources and Reserves of Ukraine as an Evaluation Instrument of Investment Proposals on Energy Resources." Black Sea and Caspian Sea Energy Conference, London, February 14, 32 p.

[2] Shale Gas Research Group, 2011. "Hydrocarbon Potential and Prospects of NE Bulgaria and Offshore Black Sea – An Overview." Sofia, Bulgaria, 26 January, 41 p.

[3] Daborowski, T. and Groszkowski, J., 2012. "Shale Gas in Bulgaria, the Czech Republic and Romania: Political Context, Legal Status, and Outlook." Centre for Eastern Studies, Warsaw, Poland, 30 p.

[4] Seghedi, A., 2012. "Palaeozoic Formations from Dobrogea and Pre-Dobrogea – An Overview." Turkish Journal of Earth Sciences, vol. 21, p. 669-721.

[5] Sachsenhofer, R.F. and Koltun, Y.V., 2012. "Black Shales in Ukraine – A Review." Marine and Petroleum Geology, vol. 31, p. 125-136.

[6] Koltun, Y., Espitalie, J., Kotarba, M., Roure, F., Ellouz, N., and Kosakowski, P., 1998. "Petroleum Generation in the Ukrainian External Carpathians and the Adjacent Foreland." Journal of Petroleum Geology, vol. 21, p. 265-288.

[7] Ionescu, L., Ionescu, B., Marinescu, D., Nedelcu, M.I., Balint, I., Livanov, O., Pomarjanschi, D., and Pomarjanschi, O. "Hydrocarbons Prospecting Using Integrated Geophysical Methods (Magnetotelluric Soundings, Gravity and Magnetics) in the

External Flysch Zone (Eastern Carpathians, Northern Moldavia)." AAPG Search and Discovery Article 90109 (Abstract), American Association of Petroleum Geologists, European Region Annual Conference, Kiev, Ukraine, October 17-19.

[8] Saadre, T., Einasto, R., Nolvak, J., and Stouge, S., 2004. "Ordovician Stratigraphy of the Kovel-1 Well (Volkhov-Haljala) in the Volynia Region, Northwestern Ukraine." Bulletin of the Geological Society of Denmark, vol. 51, p. 47-69.

[9] Veliciu, S. and Popescu, B., 2012. "Are the Paleozoic Plays the Future of Unconventional Gas in Romania? An Attempt of Assessing the Resource." Petroleum Club, 26 p.

[10] Izart, A., Briand, C., Vaslet, D., Vachard, D., Coquel, R., and Maslo, A., 1996. "Stratigraphy and Sequence Stratigraphy of the Moscovian in the Donets Basin." Tectonophysics, vol. 268, p. 189-209.

[11] Stephenson, R.A. et al., 1993. "Continental Rift Development in Precambrian and Phanerozoic Europe: EUROPROBE and the Dnieper-Donets Rift and Polish Trough Basins." Sedimentary Geology, vol. 86, p. 159-175.

[12] Stovba, S., Stephenson, R.A., and Kivshik, M., 1996. "Structural Features and Evolution of the Dniepr-Donets Basin, Ukraine, from Regional Seismic Reflection Profiles." Tectonophysics, vol. 268, p. 127-147.

[13] Sachsenhofer, R.F., Shymanovskyy, V.A., Bechtel, A., Gratzer, R., Horsfield, B., and Reischenbacher, D., 2010. "Paleozoic Source Rocks in the Dniepr-Donets Basin, Ukraine." Petroleum Geoscience, vol. 16, p. 377-399.

[14] Law, B.E., Ulmishek, G.F., Clayton, J.L., Kabyshev, B.P., Pashova, N.T., and Krivosheya, V.A., 1998. "Basin-Centered Gas Evaluated in Dnieper-Donets Basin, Donbas Foldbelt, Ukraine." Oil and Gas Journal, November.

[15] Barbuliceanu, N., Oterdoom, H., and Tulucan, A., 2010. "Identification of Petroleum Systems in a Complex Geological Framework, Moesian Platform and the Getic Basin, Romania." AAPG Search and Discovery Article 90109 (Abstract), American Association of Petroleum Geologists, European Region Annual Conference, Kiev, Ukraine, October 17-19.

[16] Tari, G., Ciudin, D., Kostner, A., Raileanu, A., Tulucan, A., Vacarescu, G., and Vangelov, D., 2011. "Play Types of the Moesian Platform of Romania and Bulgaria." AAPG Search and Discovery Article #10311, Adapted from AAPG European Region Annual Conference, Kiev, Ukraine, October 17-19, 2010.

[17] Sterling Resources, 2012. "Onshore Romania – Craiova: UCG Silurian Shale Gas." Poster.

[18] TransAtlantic Petroleum Ltd, 2011. SEC Form 8-K, February 4, 2011, 26 p.

[19] Shale Gas Research Group, 2011.

[20] TransAtlantic Petroleum Ltd, 2011. SEC Form 8-K, February 4, 2011, 26 p.

[21] Zilinski, R.E., Nelson, D.R., Ulmishek, G.F., Tonev, K., Vladov, J., and Eby, D.E., 2010. "Unconventional Plays in the Etropole Petroleum System, Southern Moesian Plate, Bulgaria." AAPG Search and Discovery Article 90109 (Abstract), American Association of Petroleum Geologists, European Region Annual Conference, Kiev, Ukraine, October 17-19.

[22] LNG Energy Ltd, Preliminary Short Form Prospectus, August 29, 2011, 16 p.

[23] Georgiev, G., 2012. "Geology and Hydrocarbon Systems in the Western Black Sea." Turkish Journal of Earth Sciences, vol. 21, p. 723-754.

[24] Shale Gas Research Group, 2011.

[25] TransAtlantic Petroleum Ltd., 2012. Corporate Presentation, January, 31 p.

[26] Veliciu and Popescu, 2012.

[27] TransAtlantic Petroleum Ltd., 2011. "A-Lovech License, Bulgaria." August, 8 p.