[PS]Cambrian Rogersville Shale in the Rome Trough, Kentucky and West Virginia: A Potential Unconventional Oil and Gas Reservoir in the Appalachian Basin*

John Hickman[1], David Harris[1], and Cortland Eble[1]

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Editor's note: This article is closely related to Search and Discovery Article #10787 (2015) and Search and Discovery Article #10809 (2015).
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Abstract

Research by the Kentucky, Ohio, and West Virginia Geological Surveys has refined the stratigraphic framework of a Cambrian extensional basin underlying the Appalachian Basin. This graben, called the Rome Trough, is filled with up to 9,000 ft of pre-Knox Group sedimentary rocks. Well log correlations extended the Cambrian Conasauga Group north from outcrops along the eastern Tennessee overthrust, across parts of eastern Kentucky, and into the Rome Trough. Regional distribution of these formations and the underlying Rome Formation is controlled by extensional faults that were active during and after Conasauga deposition. Stratigraphic correlation of these units reveals the presence of a west-prograding carbonate ramp and distal intrashelf shale basin in the Rome Trough. To identify the source of hydrocarbons produced from various Cambrian completions in eastern Kentucky and southern West Virginia, numerous Cambrian shale samples were analyzed from across the Rome Trough. Total organic carbon content of these shales was less than 1 percent for all samples, except for a core of Rogersville Shale from the Exxon No. 1 Smith well in Wayne County, W.Va. TOC for the Rogersville Shale in this core ranges from 1.2 to 4.4 percent, with Tmax values of 460 to 469°C. Six additional Rock-Eval analyses from the Smith core confirmed the original data, with TOC of 1.2 to 4.75 percent, and Tmax of 446–460°C. Low hydrogen indices and Tmax data indicate a thermal maturity in the wet gas-condensate window. The Rogersville Shale is a dark gray fissile shale, interbedded with thin laminated and bioturbated siltstone. Hydrocarbon extracts from the No. 1 Smith core are geochemically very similar to produced condensate from Elliott and Boyd County, Ky., and suggest the Rogersville was the source of gas and condensate in the Homer Field. The Rogersville Shale has suitable thickness, mineralogy, and organic content to potentially produce gas or liquids if fractured to improve permeability. Challenges in developing a Rogersville Shale play include interpreting structure and stratigraphy in the deeper fault-segmented parts of the Rome Trough and predicting the distribution of organic-rich intervals. The Rogersville Shale ranges in thickness from 200 to over 1,200 ft, and in depth from approximately 7,000 to 10,000 ft below surface. Interest in the unconventional resource potential of the Rogersville is increasing, with two new deep tests permitted in the last year.

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Research by the Kentucky, Ohio, and West Virginia Geological Surveys has refined the stratigraphic framework of a Cambrian extensional basin underlying the Appalachian Basin. This graben, called the Rome Trough, is filled with up to 9,000 ft of pre-Knox Group sedimentary rocks. Well log correlations extended the Cambrian Conasauga Group north from outcrops along the Eastern Tennessee Overthrust, across parts of eastern Kentucky, and into the Rome Trough. Regional distribution of these formations and the underlying Rome Formation is controlled by extensional faults that were active during and after Conasauga deposition. Stratigraphic correlation of these units reveals the presence of a westward-prograding carbonate ramp and distal intrashelf shale basin in the Rome Trough.

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The Rogersville Shale has suitable thickness, mineralogy, and organic content to potentially produce gas or liquids if fractured to improve permeability. Challenges in developing a Rogersville Shale play include interpreting structure and stratigraphy in the deeper fault-segmented parts of the Rome Trough and predicting the distribution of organic-rich intervals. The Rogersville Shale ranges in thickness from under 100 to over 1,100 ft, and in depth from approximately 5,000 to 18,000 ft below surface. Interest in the unconventional resource potential of the Rogersville is increasing. Seven deep tests have been permitted in the last year.

Introduction

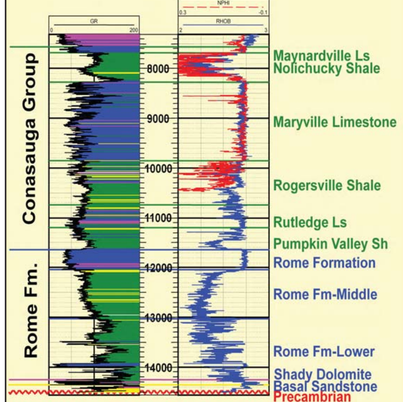
Research by the Rome Trough Consortium (RTC) at the Kentucky, Ohio, and West Virginia Geological Surveys from 1999-2002 refined the stratigraphic framework of a Cambrian-age extensional basin underlying the Appalachian Basin. This fault-bounded graben, called the Rome Trough, is filled with up to 10,000 ft of Cambrian sedimentary rocks. The Rome Trough formed during opening of the lapetan ocean, on the southeastern margin of the North American craton. Faults were active during deposition, with significant thickening of Middle and Upper Cambrian sediments downthrown of bounding faults.

Middle Cambrian paleogeography with Rome Trough superimposed (modified from Blakey, cpgeosystems.com)

Stratigraphic Framework

Stratigraphic correlation of these units reveals the presence of a westward prograding carbonate ramp and distal intrashelf shale basin in the Rome Trough in eastern Kentucky. The Conasauga formations record several cycles of progradation and transgression from east to west into this basin.

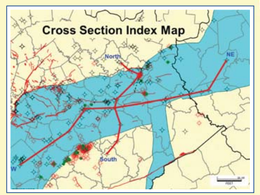
Type Log, US Signal #1 Elkhorn well Johnson County, Kentucky

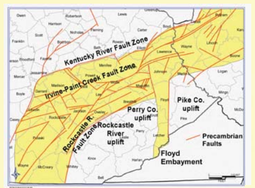


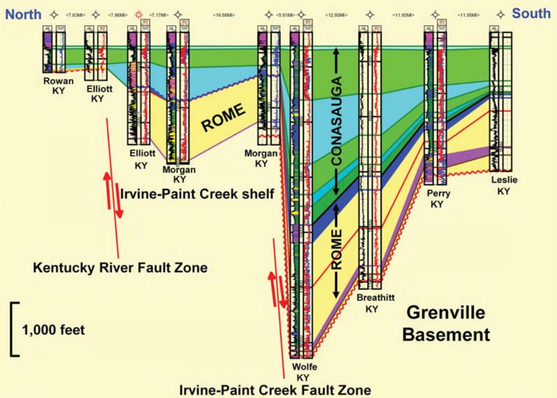
Well log correlations indicate formations comprising the Cambrian Conasauga Group extend across parts of eastern Kentucky, and include in ascending order the Pumpkin Valley Shale, Rutledge Limestone, Rogersville Shale, Maryville Limestone, Nolichucky Shale, and Maynardville Limestone.

Most fault movement had ceased, and the trough was filled by the end of Conasauga time. The trough is overlain by the Cambrian-Ordovician Knox Group, a thick regional carbonate platform sequence. Regional distribution of these formations and the underlying Rome Formation is controlled by extensional faults that were active during Conasauga deposition.

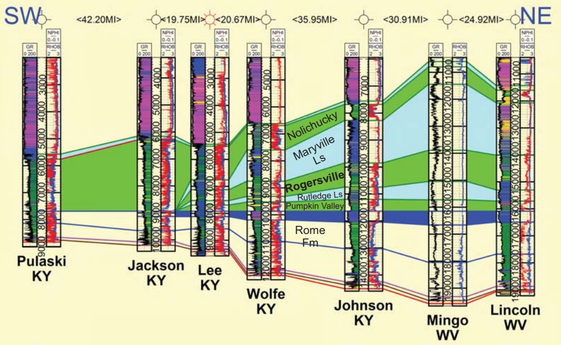
Rome Trough structural features



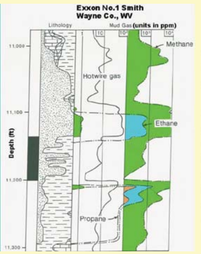




The full sequence of Conasauga formations is restricted to areas south of the Irvine-Paint Creek Fault. North of this fault the Pumpkin Valley Shale, Rutledge Limestone and Rogersville Shale are missing, and the Maryville Limestone overlies the Rome Formation. The Rome Formation is restricted to areas south of the Kentucky River Fault, but the Maryville and Nolichucky extend father north. Maryville and Rutledge carbonate units thin and pinchout to the west into an intrashelf basin in central Kentucky. The Rogersville Shale cannot be recognized in this area.

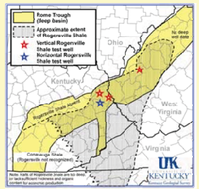


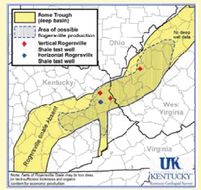
Unconventional Reservoir Potential



The Rogersville Shale has sufficient organic carbon, is thermally mature, and has generated gas and condensate. The mud log from the Exxon Smith well indicates shows of gas were encountered during drilling of the Rogersville interval. This suggests the shale contains hydrocarbons, in nanoscale pores and adsorbed to organic matter. (Cored interval indicate by black bar)

X-ray diffraction analyses of Rogersville Shale samples show mineralogy that is lower in clay, and higher in brittle minerals, such as carbonate and quartz. This indicates the Rogersville will be more susceptible to fracture stimulation than the Nolichucky Shale, which is higher in ductile clays and lower in carbonate.





These maps show the approximate extent of the Rogersville Shale (left) and a speculative map of the potential productive area in the Rome Trough (right). The Rogersville extends into southwest Virginia and northeast Tennessee but is likely too thin, or lacks organic content outside the trough. Newly permitted well locations targeting the Rogersville Shale are also shown.

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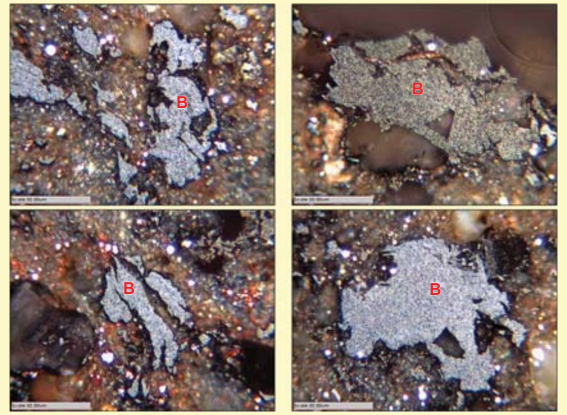
Geochemical analysis and source rock potential of the Rogersville Shale.

Organic Petrography

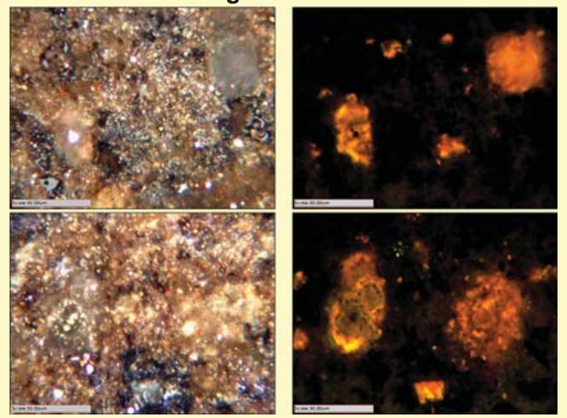
Solid bitumen (B) is common in the Rogersville Shale, and reflectance of this material can be measured and used to estimate thermal maturity.



Bitumen reflectance increases (becomes brighter) as thermomaturity increases. In practice, a microscope equipped with a photomultiplier is first calibrated using a glass standard of known reflectance, and monochromatic light (546 nm). Measurements are then collected on multiple grains of bitumen in a given sample. The average of the measurements (usually 50 to 70) is considered to represent the level of thermomaturity.

In the Exxon Smith core, organic matter in the Rogersville Shale consists of amorphous marine algal macerals and solid bitumen. No identifiable *Gloeocapsomorpha prisca* microfossils were observed. Fluorescent liptodetrinite is present, despite the depth and thermal maturity of the shale in the Exxon Smith core.

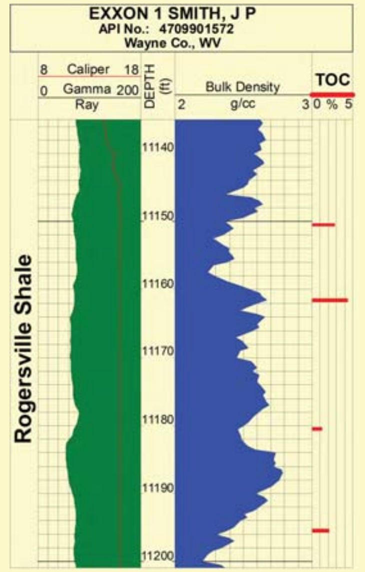
Reflected white light **UV fluoresence**



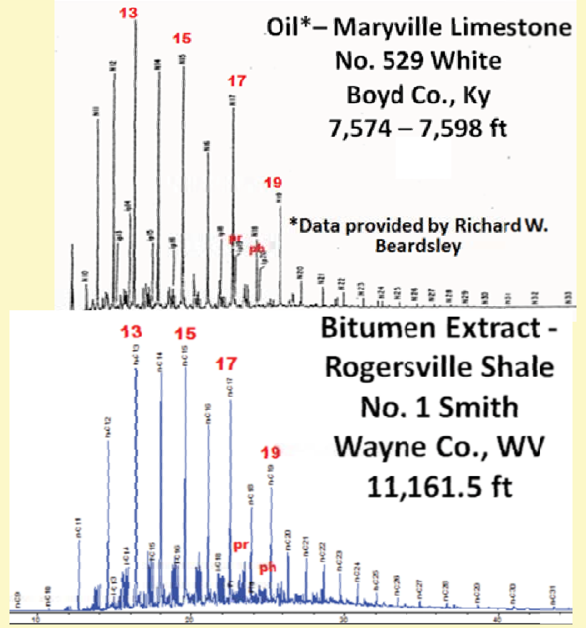
API# 4709901572	Exxon #1 Smith, J P	Wayne Co, WV		
Rogersville core "discovery" well				
Bitumen Reflectance				
Core Depth (ft, md)	11167	11178	11191	11197
Average R_o random	1.76	1.80	1.80	1.84
Maximum R_o random	2.11	2.11	2.04	2.10
Minimum R_o random	1.50	1.47	1.53	1.59
Standard deviation	0.14	0.16	0.13	0.13
Observations/sample	50	50	50	50
Calculated R_o equivalent	1.49	1.51	1.51	1.54
(R_o random * 0.618) + 0.4				
(Jacobs, 1989)				
Indicated T_{max} from calculated R_o equiv.	480	482	482	484
Spectral Fluorescence				
Core Depth (ft, md)	11167	11178	11191	11197
Lambda maximum	638	648	648	645
Indicated R_o	1.35	1.45	1.45	1.45
Indicated T_{max} from Lambda max.	473	479	479	479

% Ro	Level of Petroleum Generation
<0.6	Thermally immature
0.6 – 1.1	Oil window
1.1 – 1.4	Wet gas window
1.4 – 2.0	Dry gas window
>2.0	Catagenic gas generation

Hydrocarbons and Source Rock

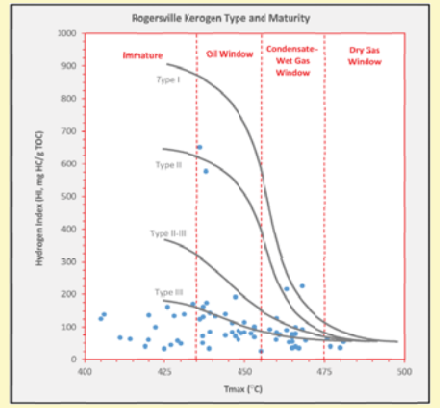


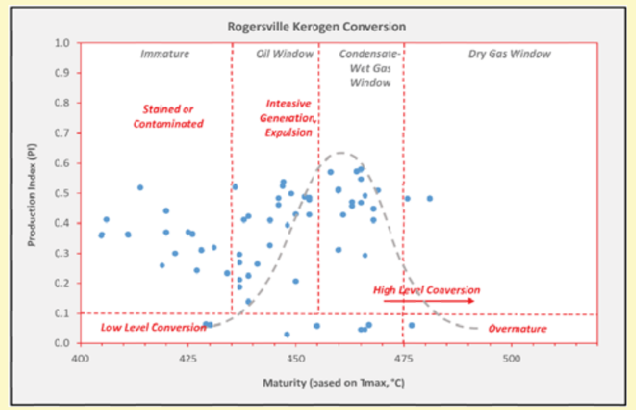
The key core was found in the Exxon #1 Smith well in Wayne County, WV, where the Rogersville Shale was cored from 11,135 to 11,201 ft. This dark gray fissile shale has up to 4.8% total organic carbon. The mud log from this well recorded shows of gas in the Rogersville interval.

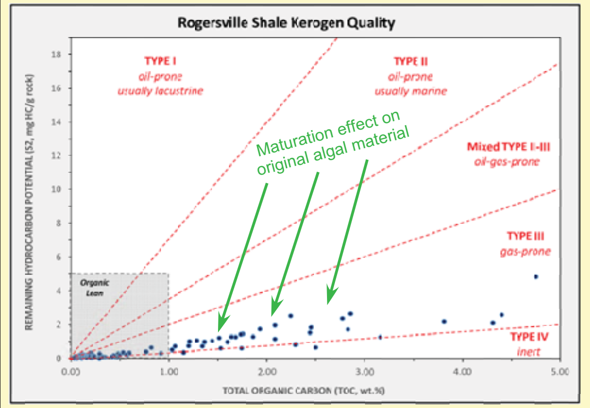


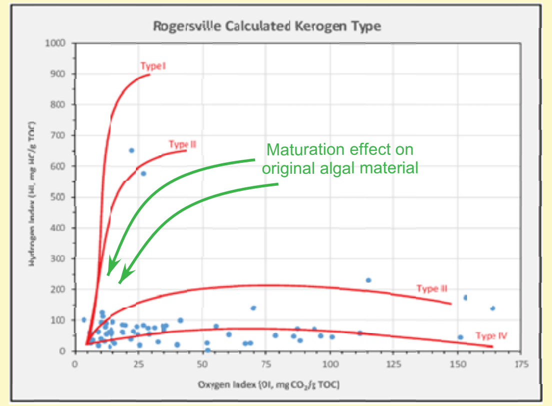
Oil and condensate from Cambrian reservoirs in Ky. have a unique composition characteristic of Ordovician (and older?) source rocks containing the alga *G. prisca*. Gas chromatographs show odd-carbon normal alkanes (C13-C19) are more abundant than even alkanes. This odd-carbon predominance was also seen in bitumen extracted from the Rogersville in the Exxon Smith core. This strong similarity allows correlation of the Rogersville with produced hydrocarbons, and defines a Cambrian petroleum system in the Rome Trough.

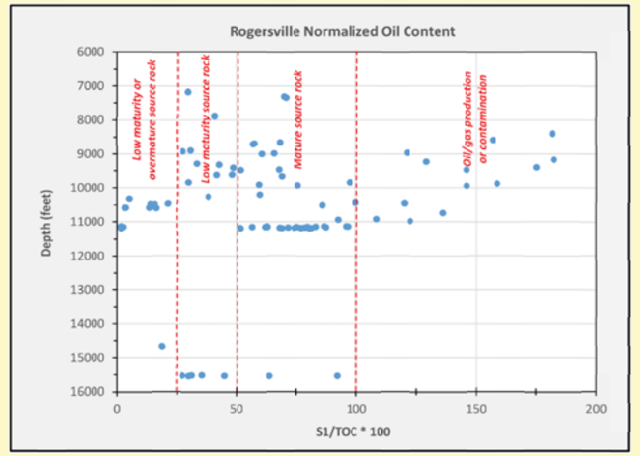
TOC and Rock-Eval Analyses











Current wells with Rogersville Shale data

	API #	Well Name	County	State	Formation @ TD	Lat	Lon	KBElev	TVD	Rogersville (md)	Rogersville (sstvd)	RGRV Isopach
Existing Wells the Penetrate the Rogersville Shale	16025007450000	United Fuel Gas 86131 Williams, S.	Breathitt	KY	Precambrian Basement	37.536584	-83.290302	762	11118	8212	-7450	368
	16043000700000	Inland Gas 546G McDavid, E.	Carter	KY	Rome Formation	38.173835	-82.946759	808	9963	8000	-7192	646
	16063000030000	Monitor Petroleum 1 Ison, Cecil	Elliott	KY	Pumpkin Valley Shale, Conasauga Gp	38.135464	-82.960767	686	9655	8529	-7843	744
	16063000050000	Monitor Petroleum 2 Ison, I.T.	Elliott	KY	Rogersville Shale, Conasauga Gp	38.120510	-82.955832	794	9473	8934	-8140	(base below TD)
	16063005970000	Blue Ridge Group 1 Greene, J.	Elliott	KY	Rogersville Shale, Conasauga Gp	38.135543	-82.927085	696	9032	8806	-8110	(base below TD)
	16063006460000	Ashland Exploration 1 Kazee	Elliott	KY	Precambrian Basement	38.144773	-82.955921	727	11079	7804	-7077	568
	16063009750000	Hay Expl #9A WWP	Elliott	KY	Rogersville Shale, Conasauga Gp	38.090196	-83.013351	810	8409	8468	-7658	(base below TD)
	16063010410000	Hay Expl 41E Simpson, M.&M.	Elliott	KY	Rogersville Shale, Conasauga Gp	38.103305	-82.996560	920	8842	8508	-7588	(base below TD)
	16065007910000	Texaco 1 Tipton, Glyn	Estill	KY	Rome Formation	37.672517	-84.005799	647	6809	5550	-4903	219
	16071017190000	Signal Oil & Gas 1 Hall, M.	Floyd	KY	Precambrian Basement	37.493262	-82.758014	701	13000	9307	-8606	405
	16115002450000	Ashland Exploration 1 Williams, E.	Johnson	KY	Rogersville Shale, Conasauga Gp	37.861278	-83.002591	809	10595	9580	-8771	917
	16115012660000	Columbia Gas Transmission 9714T Evans	Johnson	KY	Rogersville Shale, Conasauga Gp	37.972797	-82.919606	939	9975	9821	-8882	(base below TD)
	16115012680000	ARCO Exploration 1 KY/WV Gas	Johnson	KY	Precambrian Basement	37.743943	-82.672058	687	10950	8853	-8166	316
	16115012700000	U S Signal 1 Elkhorn Coal	Johnson	KY	Precambrian Basement	37.802567	-82.722084	737	14542	10154	-9417	692
	16127018520000	Inland Gas 548 Young, W.	Lawrence	KY	Precambrian Basement	38.226521	-82.744489	884	12693	9203	-8319	724
	16129013030000	Ashland Exploration 1 Cable, M.	Lee	KY	Precambrian Basement	37.689761	-83.744076	1028	9644	7127	-6099	401
	16159010420000	United Fuel Gas 86101 Jasper, James	Martin	KY	Rome Formation	37.856796	-82.521908	659	13160	10676	-10017	703
	16175001960000	Monitor Petroleum 1 Ison, F.&L.	Morgan	KY	Rutledge Limestone, Conasauga Gp	37.987580	-83.039884	821	10002	8951	-8130	736
	16193008720000	ARCO Exploration 1 Duff, J.	Perry	KY	Precambrian Basement	37.365798	-83.324204	1209	9659	8100	-6891	245
	16195037180000	Signal Oil & Gas 1 Straton, H.	Pike	KY	Precambrian Basement	37.482115	-82.462953	1199	12428	10292	-9093	131
	16237008060000	Exxon 1 Banks, Orville	Wolfe	KY	Precambrian Basement	37.708502	-83.367779	1057	12259	8594	-7537	601
	4516720256	Gulf Oil 1 Price, W.	Russell	VA	Precambrian Basement	36.872586	-82.237169	2238	16832	14658	-12420	67
	47013025030000	Exxon 1 Gainer-Lee	Calhoun	WV	Precambrian Basement	38.880717	-81.101780	1238	20222	17408	-16170	635
	47035013660000	Exxon 1 McCoy (Stalnacker)	Jackson	WV	Precambrian Basement	38.727937	-81.572350	943	17675	14608	-13665	940
	47043014690000	Exxon 1 McCormick, D.E.	Lincoln	WV	Precambrian Basement	38.215185	-81.940129	767	19124	13938	-13171	1047
	47059008050000	Columbia Gas 9674T Mineral Tract 10	Mingo	WV	Precambrian Basement	37.903251	-82.170970	958	19537	13891	-12933	1096
	47079015380000	Cabot 50 Amherst Industries	Putnam	WV	Rogersville Shale, Conasauga Gp	38.534115	-81.836249	1005	14000	13855	-12850	(base below TD)
	47099015720000	Exxon 1 Smith, J.P.	Wayne	WV	Precambrian Basement	38.219893	-82.534599	622	14625	10696	-10074	738
New Wells Permitted within last 18 months	16127031000000	Bruin Exploration 1 Young, Silva	Lawrence	KY	Unreported	38.087888	-82.824120	669	PTD=15000	No data released as of 6/1/15		
	47079015380000	Cabot Oil & Gas 50 Amherst Industries	Putnam	WV	Unreported	38.534115	-81.836249	1004	PTD=14000	No data released as of 6/1/15		
	16127031720000	Confidential - Strat Test	Lawrence	KY	Unreported	?	?	?	?	No data released as of 6/1/15		
	16127031790000	Confidential - Strat Test	Lawrence	KY	Unreported	?	?	?	?	No data released as of 6/1/15		
	16127031780000	Confidential - Strat Test	Lawrence	KY	Unreported	?	?	?	?	No data released as of 6/1/15		
	16127031800000	Bruin Exploration 1 Wilbridge Holdings LLC	Lawrence	KY	Unreported	38.013012	-82.616128	620	PTD=15000	No data released as of 6/1/15		
	16115021470000	Horizontal Technology 572360 EQT Production Co.	Johnson	KY	Unreported	37.911750	-82.803907	929	PTD=15000	No data released as of 6/1/15		
	16127031830000	Confidential - Strat Test	Lawrence	KY	Unreported	?	?	?	?	No data released as of 6/1/15		

Conclusions

- A viable Cambrian petroleum system exists in the Southern Appalachian Basin. The Rogersville Shale (Conasauga Group) is the primary source interval.
- The Rogersville Shale is 5,000 to 10,000 ft deep in Kentucky, and up to 1,100 ft thick
- It contains up to 4.8% total organic carbon, and has generated gas and condensate
- Source rock quality in the Rogersville is variable. Controls on TOC distribution are not well understood.
- Shallower, less mature areas likely to be more liquids-prone than deeper areas in WV
- A Rogersville unconventional gas or liquids play should be possible in higher TOC areas, but economics will be a challenge due to depth and low prices.
- Eight new wells have been permitted to test the Rogersville Shale to date; all results remain confidential.

All of the data presented in this poster is available on request from the Kentucky Geological Survey in Lexington, Ky.
http://www.uky.edu/KGS

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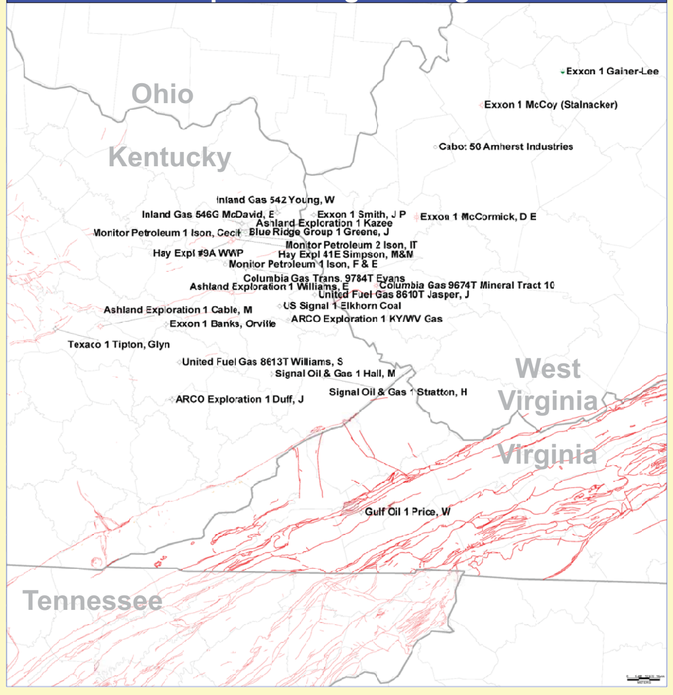
UNIVERSITY OF KENTUCKY Kentucky Geological Survey

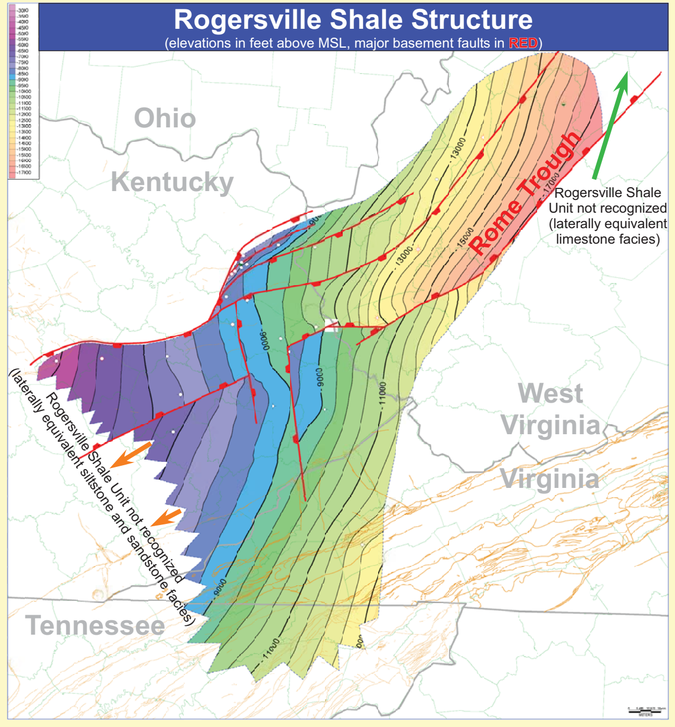
Preliminary maps of the Rogersville Shale interval using publicly available data.

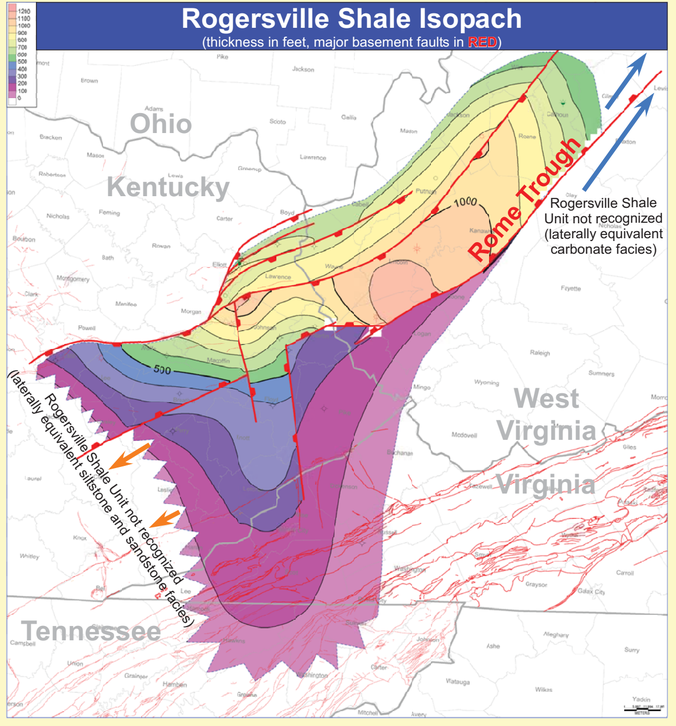
Current wells penetrating the Rogersville Shale



Rogersville Shale Structure

(elevations in feet above MSL, major basement faults in RED)



Rogersville Shale Isopach

(thickness in feet, major basement faults in RED)