[PS]Geologic Overview and Activity Update for the Utica-Point Pleasant Shale Play in Ohio*

Lawrence H. Wickstrom[1], Ronald Riley[1], Matthew Erenpreiss[1], and Christopher Perry[1]

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Abstract

The Ordovician Point Pleasant Formation-Utica Shale interval is shaping up to be the next stop of the “shale gale” in the United States, and Ohio appears to be the primary focus of this play. Leasing activity ramped up in Ohio in late 2010 and still continues at a fevered pitch. The first horizontal exploration wells were drilled and completed in the Utica-Point Pleasant in early 2011.

Within Ohio, the Point Pleasant Formation lies directly above the Trenton Limestone and is, at least in part, equivalent with the thick deposits of the Trenton carbonate platform of northwestern Ohio, famous for the Lima-Indiana oil-and-gas trend, which was the first true giant field produced in North America starting in 1884. As the carbonate platform deposits of the Trenton thin, the interbedded organic-rich carbonates and shales of the Point Pleasant thicken, so that over much of Ohio the Trenton is only about 40-60 feet thick, while the Point Pleasant is 150-200 feet thick. The northwestern-Ohio Trenton carbonate platform represents a distal bulge of the ensuing Taconic Orogeny. As the orogenic activity and subsidence increased, the organic-rich Utica Shale proper transgressed the area from present day east-southeast to west-northwest, eventually overwhelming and drowning the carbonate environments. Thus, in the deeper portions of the present-day basin, the Utica (and Antes) is, in part, laterally equivalent and overlies the Point Pleasant.

Analysis of source rock geochemistry and early drilling results indicate the Utica-Point Pleasant to contain sufficient hydrocarbons to sustain a major drilling play. Oil-source rock pairings indicate the Utica-Point Pleasant has been the primary source for numerous conventional reservoirs in the region. Also, analyses indicate much of the play area in Ohio will be natural gas liquids and oil prone. In fact, a number of historical wells have encountered large shows, and some have produced substantial oil from this interval.

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Development and Activity of the Play

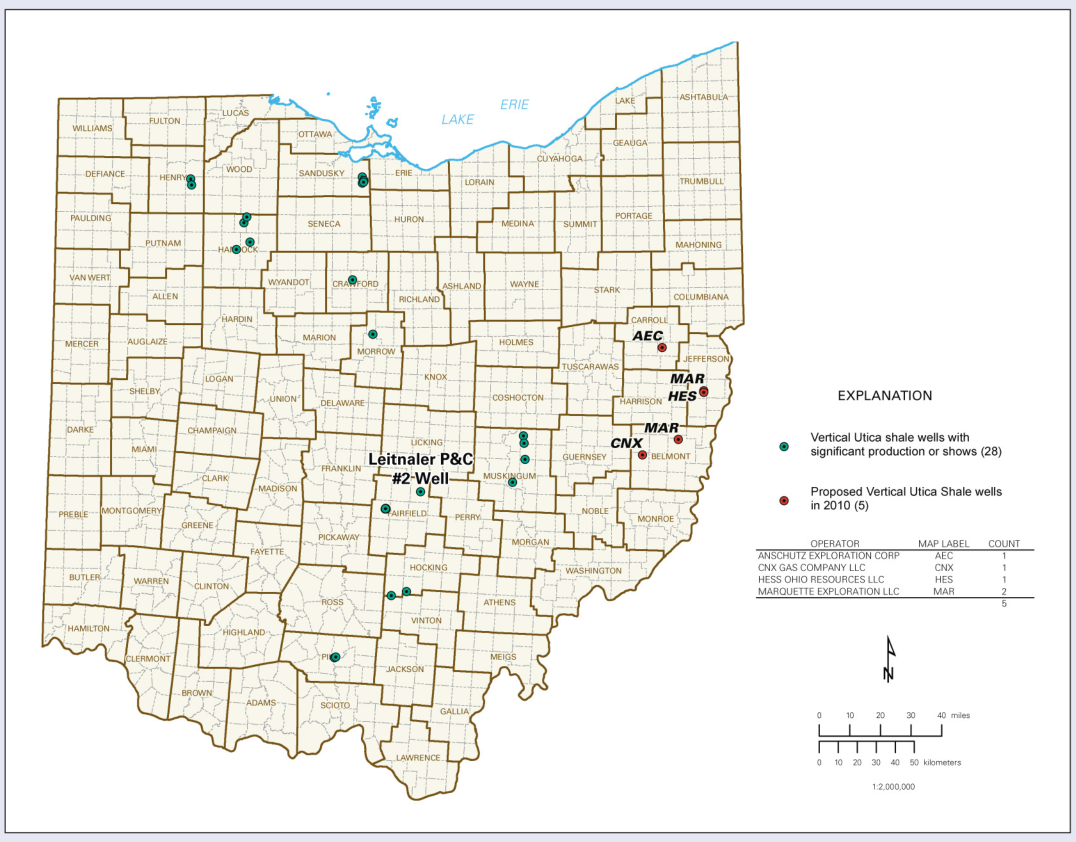

Figure 1.—Exploratory drilling in the Utica-Point Pleasant interval of Ohio began in 2010 with vertical wells. In June 2010 CNX tested 1.5 MMCFGPD in the Utica-Point Pleasant in western Belmont County. Anschutz, Hess and Marquette also had permits for exploratory wells in Ohio by August 2010. Legacy production and shows from this interval are fairly well known in Ohio as shown by wells in green. The most significant of these was the Leitnaker P&C #2 well drilled in Fairfield County in 1998. This well intersected a fault in the Utica-Point Pleasant interval and produced approximately 50,000 barrels of oil naturally during two years.

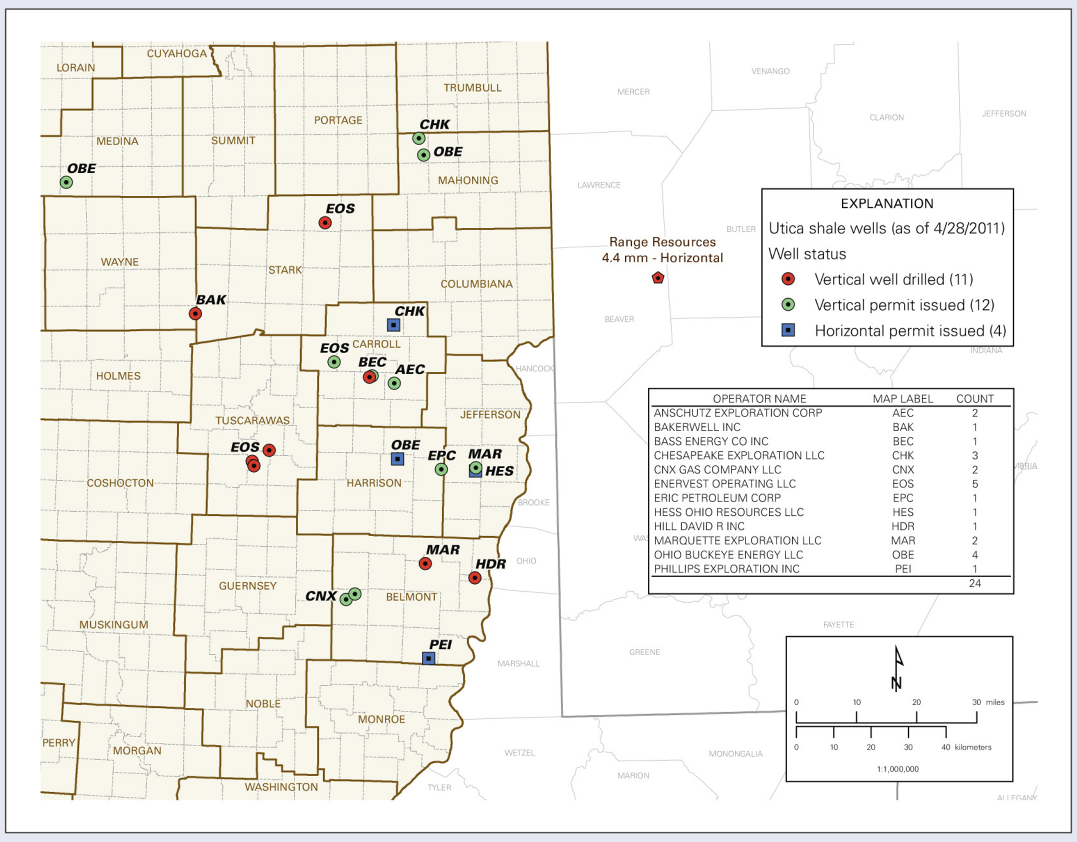

Figure 2.—By early 2011 exploration programs were beginning to take shape via issued permits. Operators were developing drilling pads and drilling an initial vertical test well; many were coring the Utica-Point Pleasant interval. The initial test well would then be plugged back, drilled directionally, and completed as the first horizontal well of the pad. In early 2010 Range Resources announced initial production of 4.4 MMCFGPD from their first horizontal Utica well in Beaver County, Pennsylvania. On March 22, 2011, an 18-stage hydraulic fracture stimulation was completed on the Ohio Buckeye Energy (Chesapeake) Buell #8H well (34067210570100), which was put into production shortly after. This was the first production from a horizontal Utica-Point Pleasant well in Ohio.

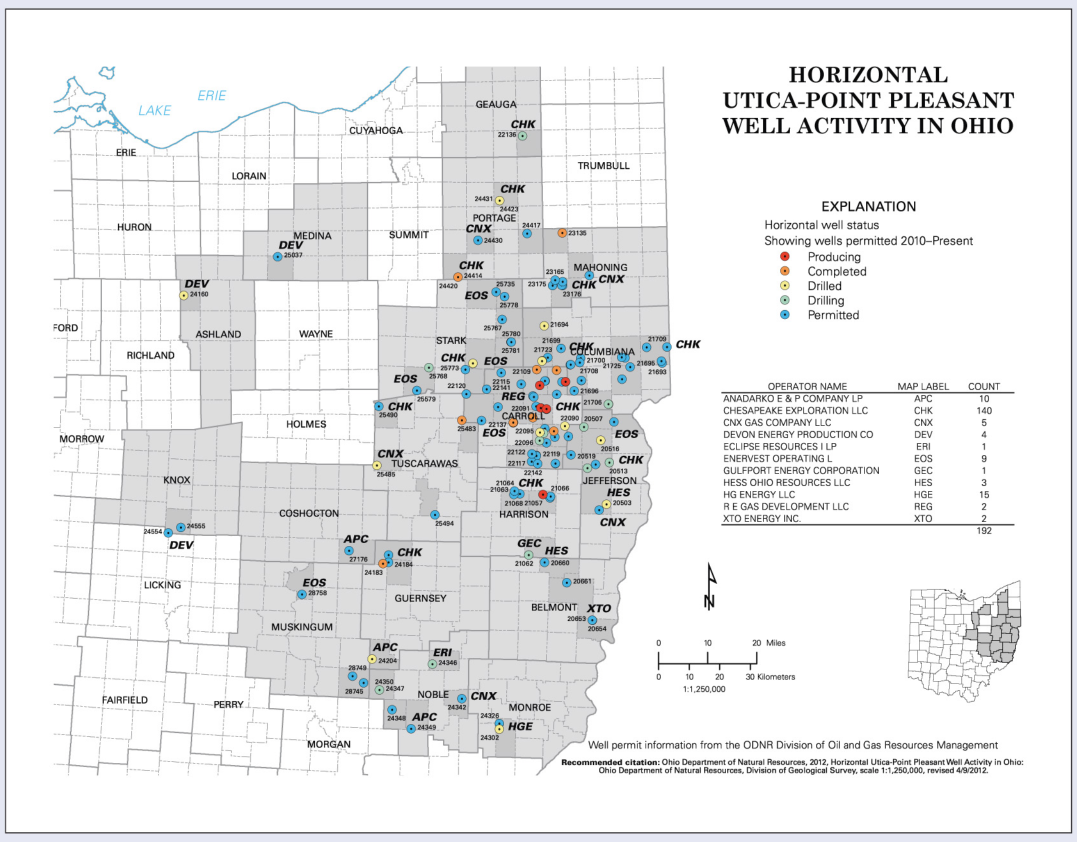

Figure 3.—With more frequent and densely spaced permitting, the Ohio Geological Survey stopped showing vertical (test) wells on its activity maps. This map shows the Utica-Point Pleasant horizontal well-permitting and drilling activity as of April 9, 2012. This map and accompanying spreadsheet are updated monthly on the Survey website at www.OhioGeology.com. As of that date 192 horizontal permits had been issued and 58 drilled. Twenty-one rigs capable of drilling these wells were active in the state.

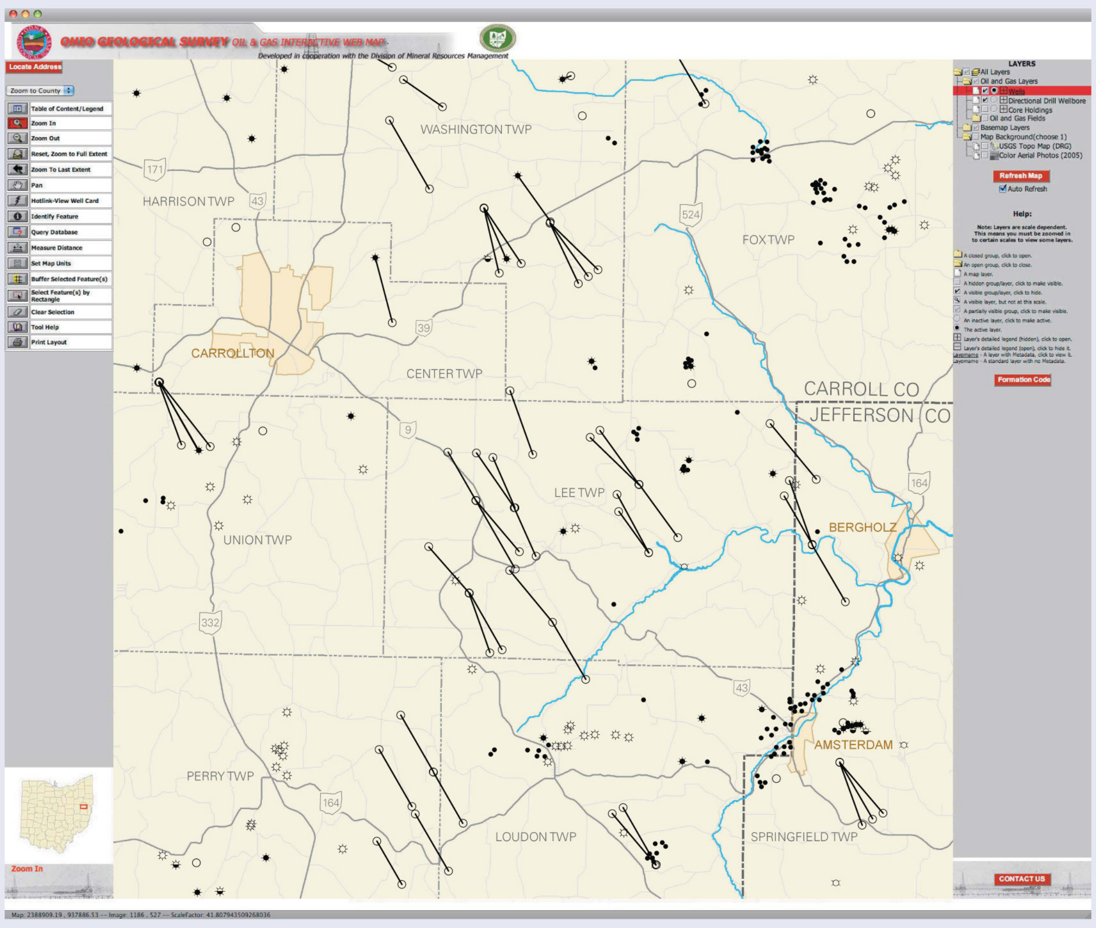

Figure 4.—Thus far, Carroll County in central-eastern Ohio has had the most wells drilled and permitted within the play. This map shows the permitted wells' top and bottom hole locations. Note that wells in this portion of the state are oriented NW-SE to intercept NE-SW-oriented natural fractures. Well maps can be generated using the interactive map service at www.OhioGeology.com.

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Regional Stratigraphy and Structure

During Trenton/Lexington depositional time effects, of the ensuing Taconic Orogeny were manifested by way of a distal bulge developing over the northwest-Ohio area, leading to a clean carbonate platform. Closer inboard to the collision zone the Lexington Platform developed centered over the Kentucky-West Virginia area as well as a central New York platform. Trenton/Lexington carbonate thickness ranges from over 200 ft on the Trenton Platform in northwestern Ohio to more than 300 ft on the Lexington Platform in central Kentucky, and to over 850 ft on the Trenton Platform in central New York (fig. 5). A large, interplatform sub-basin developed between these in which interlayered organic-rich shale and carbonates were deposited (figs. 6–8). Eventually, sea level rise associated with the orogeny overwhelmed all of the carbonate platforms, and the Utica Shale was deposited over most of the carbonate platforms as well as on top of the Point Pleasant within the sub-basin. Analyses indicate the Point Pleasant Formation has higher source rock potential and is less dense and more porous than the overlying Utica Shale. In addition, the interlayered carbonate and shale of the interval allows better fracture generation. Thus the presence of the Point Pleasant is key to the success of this play.

Because of the deposition of shales and limestones between the thicker carbonate platforms, the interval thickness of the Trenton/Lexington Limestone (figure 5) and that of the Utica-Point Pleasant interval (figure 9) are in a somewhat reciprocal relationship and define the sub-basin and the thick carbonate platforms that developed along much of the sub-basin margins. The thickness of the Utica-Point Pleasant interval ranges from approximately 100 ft in southern Ohio, where the Utica is absent, to over 350 ft in western Ohio, adjacent to the platform margin. Thickness of this interval in the northeast and north-central Ohio areas, where current activity is focused, is generally 200–250 ft. In southwestern Pennsylvania, the interval is thought to be composed primarily of Utica Shale and may reach as much as 700 ft thick, based on limited well data. The Trenton/Lexington Limestone grades laterally and upward to dominantly dark-gray to brown-to-black, platy, finely laminated, locally calcareous organic shale and interbedded limestone and calcareous shale of the Point Pleasant Formation. The Point Pleasant becomes more terrigenous and contains less organic carbon to the south as it comes up onto the Lexington Platform. The Utica is defined as dark gray-black, organic-rich shale with only sporadic calcareous-rich layers. The southern boundary is tenuous because of limited data.

The structure map on the top of the Trenton (base of Utica/Point Pleasant; Fig. 10) illustrates the present-day architecture of the northern Appalachian basin and, in western Ohio, Indiana and Ontario, the Cincinnati, Findlay, and Algonquin Arches. Regionally, the top of the Trenton ranges from +500 ft in Kentucky to as much as –14,000 ft in southwestern Pennsylvania. In Ohio the top of the Trenton ranges from –500 ft in western Ohio to –9,500 ft in extreme eastern Ohio.

Areas of historic conventional oil-and-gas production from the Trenton-Black River are found in northwestern and northeastern Ohio, Indiana, south-central New York, West Virginia, and Kentucky and are coincident with the platform margin in these states. These reservoirs and many others are thought to be sourced from the Utica/Point Pleasant interval (Cole and others, 1987). The Lima-Indiana Trend of northwestern Ohio and eastern Indiana alone produced over 350 million barrels of oil and 2 trillion cubic feet of gas (Wickstrom and others, 1992).

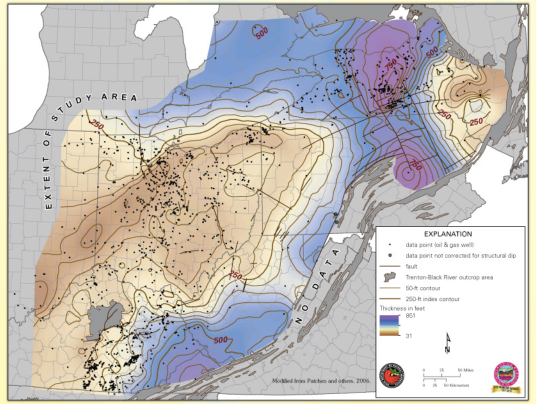


Figure 5.—Interval thickness of the Trenton/Lexington (top of Black River to top of the Trenton/Lexington Limestone).

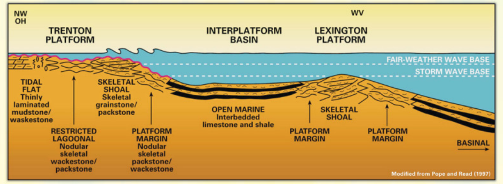


Figure 6.—Idealized platform-to-basin model and major facies.

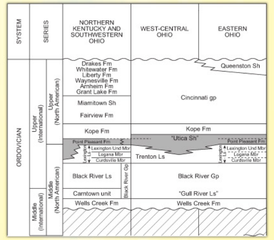


Figure 8.—Stratigraphic nomenclature for the Ordovician interval in Ohio and northern Kentucky.

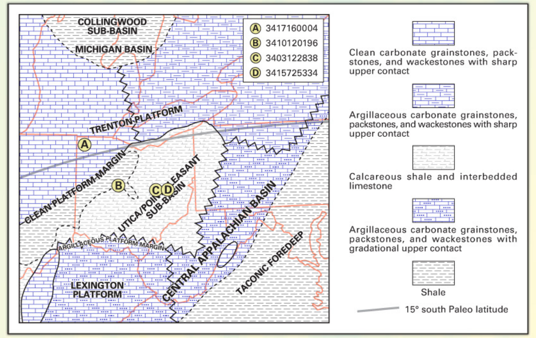


Figure 7.—Facies map of Trenton/Point Pleasant time (modified from Patchen and others, 1996). Paleoclimate is from Scotese and McKerrow (1990). Also shown are locations of selected wells in accompanying figures that illustrate facies changes across the basin.

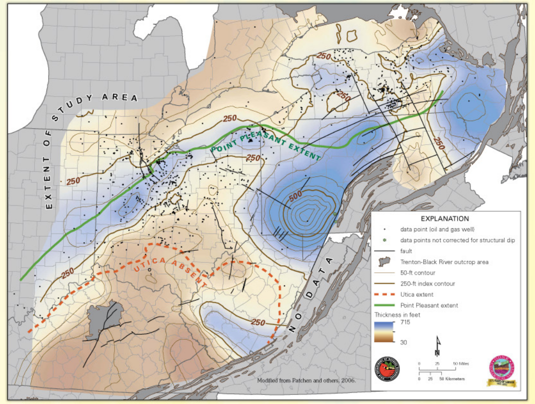


Figure 9.—Thickness map of the Utica-Point Pleasant interval (top of Trenton to top of Utica; includes the Point Pleasant and Antes Shale). The extent of the Utica and the Point Pleasant are also shown. The southern limit of the Utica is tenuous due to a limited amount of data.

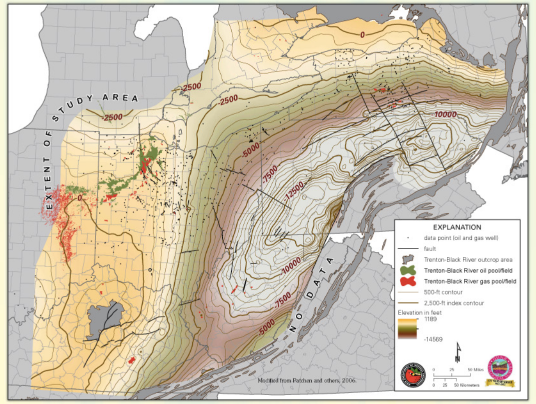


Figure 10.—Structure map on top of the Trenton Limestone.

Ⓐ 3417160004
Stone Co. No. 1
Williams County, Ohio

Trenton Ls and Utica Shale

Ⓑ 3410120196
Prudential No. 1-A
Marion County, Ohio

Point Pleasant Fm

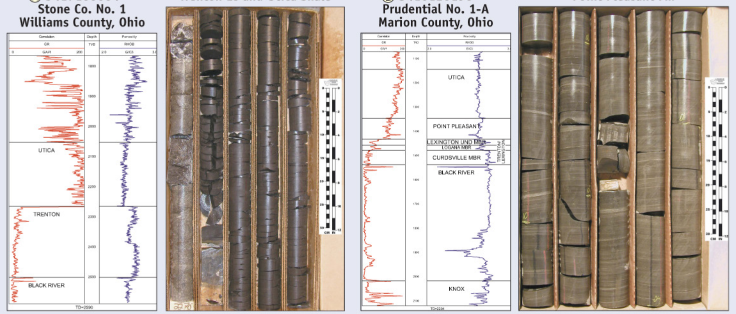
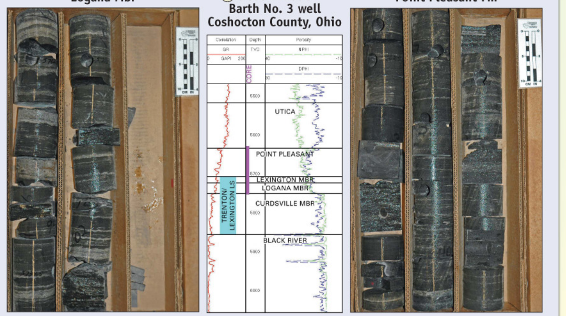


Figure 11.—Representative geophysical logs and core of the Trenton through Utica interval. Letters correspond to locations on figure 7. (A) The Point Pleasant is absent in northwestern Ohio, above the Trenton Platform. Here the Utica Shale is in a sharp contact with the Trenton Limestone. (B) Marion County core illustrates the very gradational sequence from the Trenton/Lexington strata through the Utica. Note the fine calcareous/limestone laminae of the Point Pleasant at this location. The top of the Point Pleasant is placed at the last occurrence of thin, interbedded limestone in the shale interval overlying the Trenton. (C) The Barth well has been the most heavily sampled core in the Ohio Geological Survey archives over the last few years. It contains a complete section from the Lexington through the base of the Utica. The Logana Member is a good marker bed and often contains some of the highest organic-carbon content. Note the crystalline faces within the organic-rich limestone of the Point Pleasant.

Logana Mbr

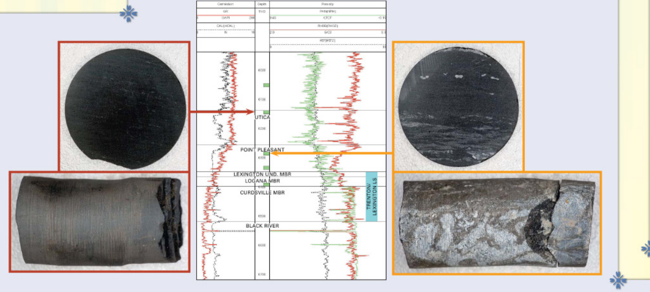
Ⓒ 3403122838
Barth No. 3 well
Coshocton County, Ohio

Point Pleasant Fm

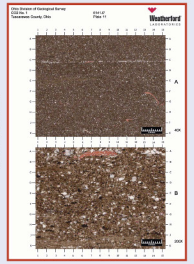


Ⓓ 3415725334
CO_2 No. 1 Well
Tuscarawas County, Ohio

Figure 12.—Geophysical logs, sidewall cores, photomicrographs, analyses, and descriptions from the Ohio Geological Survey, CO_2 No. 1 well in Tuscarawas County, Ohio. Location corresponds to (D) on figure 7. Photos, analyses, and descriptions from Weatherford Laboratories contracted services.

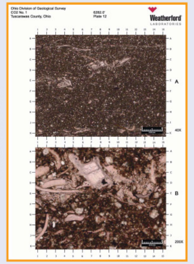


UTICA SHALE



Depth............................6141.0 ft
Permeability (Klink.)....0.0002 mD
Porosity.........................5.1%
Grain Density...............2.70 gm/cc
Lithology.......................Slightly fossiliferous, silty mudstone (silty shale).
Framework Grains........Common fine to medium, silt-sized quartz and mica; scattered chambered calcareous fossil fragments.
Matrix............................Abundant detrital clay.
Cements and Replacement Minerals..Minor amount of calcite cement; scattered ferroan dolomite crystals replacing clay matrix; trace amount of microcrystalline pyrite replacement of shell material, organic material, and mud matrix.

POINT PLEASANT



Depth............................6282.0 ft
Permeability (Klink.)....0.0003 mD
Porosity.........................4.2%
Grain Density...............2.70 gm/cc
Lithology.......................Fossiliferous, slightly dolomitic mudstone (shale) to argillaceous, skeletal wackestone.
Framework Grains........Minor fine, silt-sized to medium silt-sized quartz and mica; abundant calcareous fossil fragments (typically concentrated in layers), including bivalves, echinoderm fragments, ostracods, rare phosphatic shell fragments and brachiopod spines; common organic particles.
Matrix............................Abundant detrital clay.

Basic Source Rock Geochemistry of the Utica-Point Pleasant in Ohio

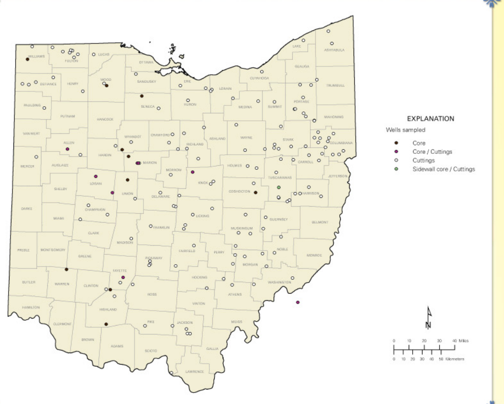
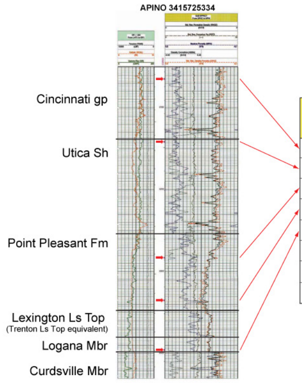


Figure 13.—Location map of wells sampled from holdings of the Ohio Geological Survey for the Logana through Utica interval for source rock analyses and mapping. Analyses performed by multiple labs over a wide range of time; however, a large amount of sampling and analyses have taken place since 2009. The Ohio Geological Survey requires analyses from its archival core and cuttings to be turned in; these can be held confidential for up to 12 months.



Source Rock Analyses

Depth (ft)	Sample Type	TOC	Rock Unit
6064	core	0.48	Cincinnati gp
6141	core	2.72	Utica Sh
6282	core	2.41	Point Pleasant Fm
6336	core	3.73	Point Pleasant Fm
6396	core	1.61	Logana Mbr
7192	core	0.11	Wells Creek Fm
7579	core	0.14	Copper Ridge dol
8274	core	0.23	Conasauga gp

Figure 14.—Type log for eastern Ohio and total organic carbon (TOC) analyses from sidewall cores in the Ohio Geological Survey CO_2 No. 1 well in Tuscarawas County.

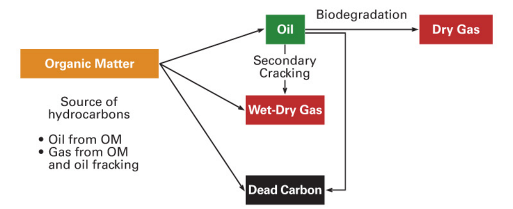


Figure 15.—Diagram illustrating the generation of oil and gas from organic matter.

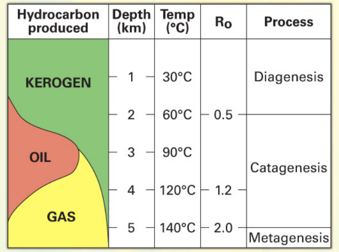


Figure 16.—Graph of subsurface processes, depths, temperatures, and vitrinite reflectance values associated with the conversion of organic matter to hydrocarbons in petroleum source rocks. Modified from Tissot and Welte (1984).

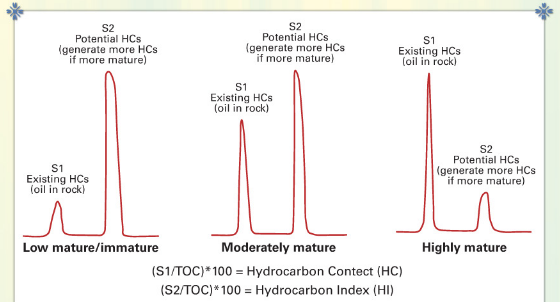


Figure 17.—Comparison of relative S_1 and S_2 values/curves at different levels of hydrocarbon-generation maturity.

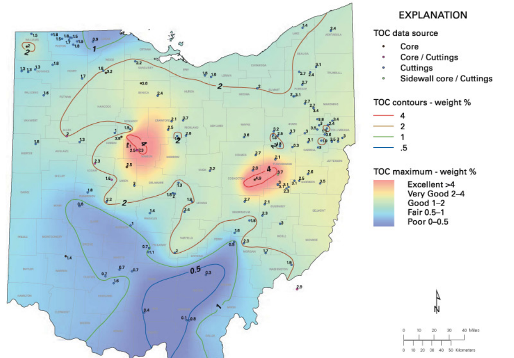


Figure 18.—Map of total organic carbon (TOC) distribution from available Ohio analyses. TOC is a measurement in weight percent of the quantity of organic carbon preserved in a rock sample. Note: For this and subsequent maps, values for core-derived samples and fresh cuttings are generally higher than from older cuttings-derived samples. Values shown are not corrected for type or age.

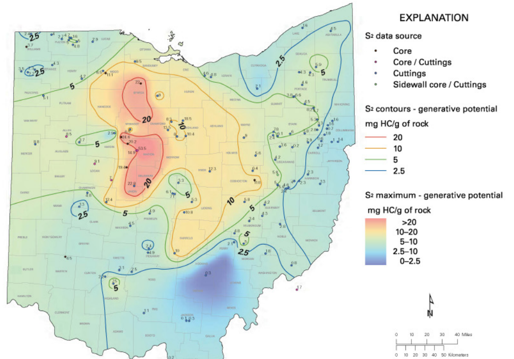


Figure 20.—Map of maximum S_2 values per well. S_2 is a measurement (mg HC/g of rock) of the amount of hydrocarbons generated through thermal cracking of kerogen and heavy hydrocarbons. It represents the existing potential of a rock to generate hydrocarbons and is a measure of remaining source rock potential.

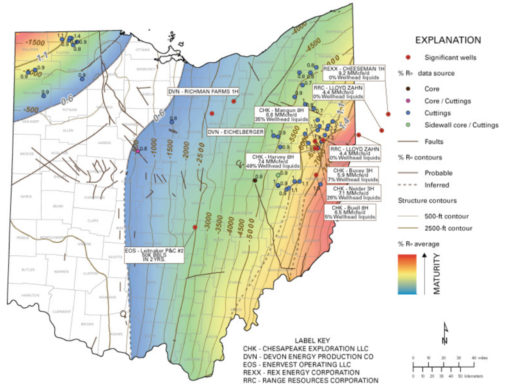


Figure 22.—Preliminary map of equivalent R_o average per well overlain on the Trenton structure contours. Significant wells are labeled with their associated IP (initial potential) or production. The presence of the natural gas liquids and oil windows in Ohio are attracting much of the attention of this play.

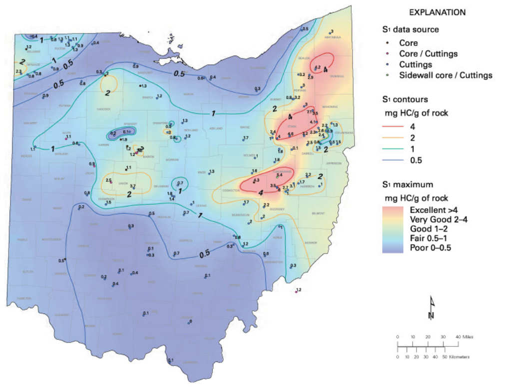


Figure 19.—Map of maximum S_1 values per well (from the Logana-Utica interval). S_1 is a measurement (in mg hydrocarbon/gm of rock) of the free hydrocarbons already generated.

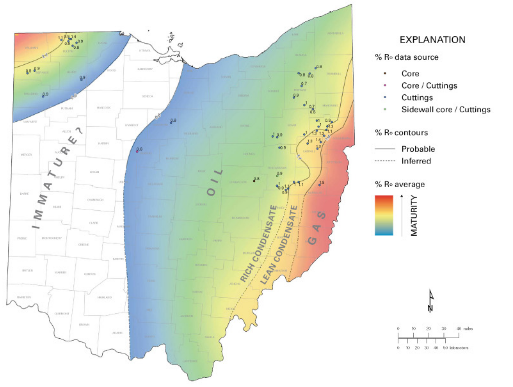


Figure 21.—Map of Average R_o values from available Ohio samples. Vitrinite reflectance (R_o) is a key diagnostic tool for assessing thermal maturity and is based on measuring the reflectivity (R) of vitrinite. Vitrinite is a maceral (plant and animal remains) found in many kerogens. As temperature increases, vitrinite undergoes complex alterations that increase the reflectance. Because vitrinite is only present in sediments with plants, and because there was no plant life yet in the Ordovician, calculations and plots using T_{max} and hydrogen index (HI), or other means of calibrating a given rock's R_o, are used to generate proxy values, or equivalent R_o values.

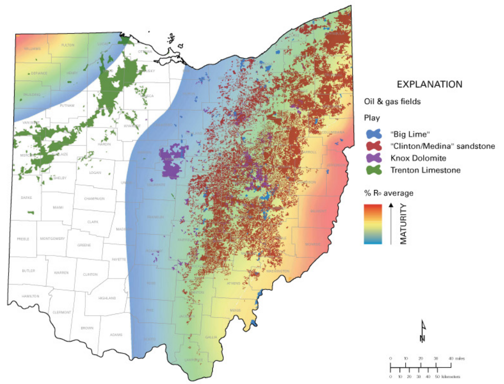


Figure 23.—Map of equivalent R_o average overlain with Cambrian through Silurian oil and gas fields of Ohio. Oil-source rock pairing indicates most of the hydrocarbons from conventional Cambrian-Silurian fields in Ohio were sourced from the Utica-Point Pleasant interval.

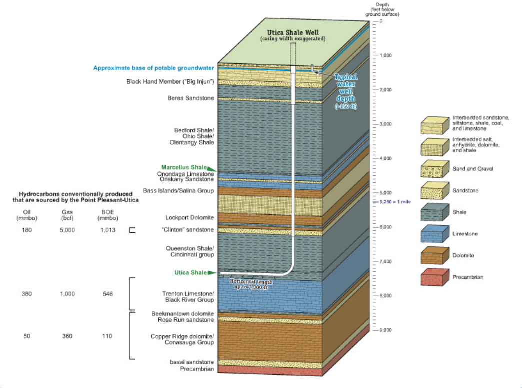


Figure 24.—Diagram to scale in the vertical direction of generalized geology and a horizontal well, based on depths and thicknesses for Portage County area (northeastern Ohio). Also shown are known produced hydrocarbons from Cambrian through Silurian conventional reservoirs in Ohio.

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DISCLAIMER

The maps presented here are based on presently available data. As such, they are preliminary. As additional wells are drilled and analyses conducted, the maps will be updated. No lines on the maps should be considered absolute or final.

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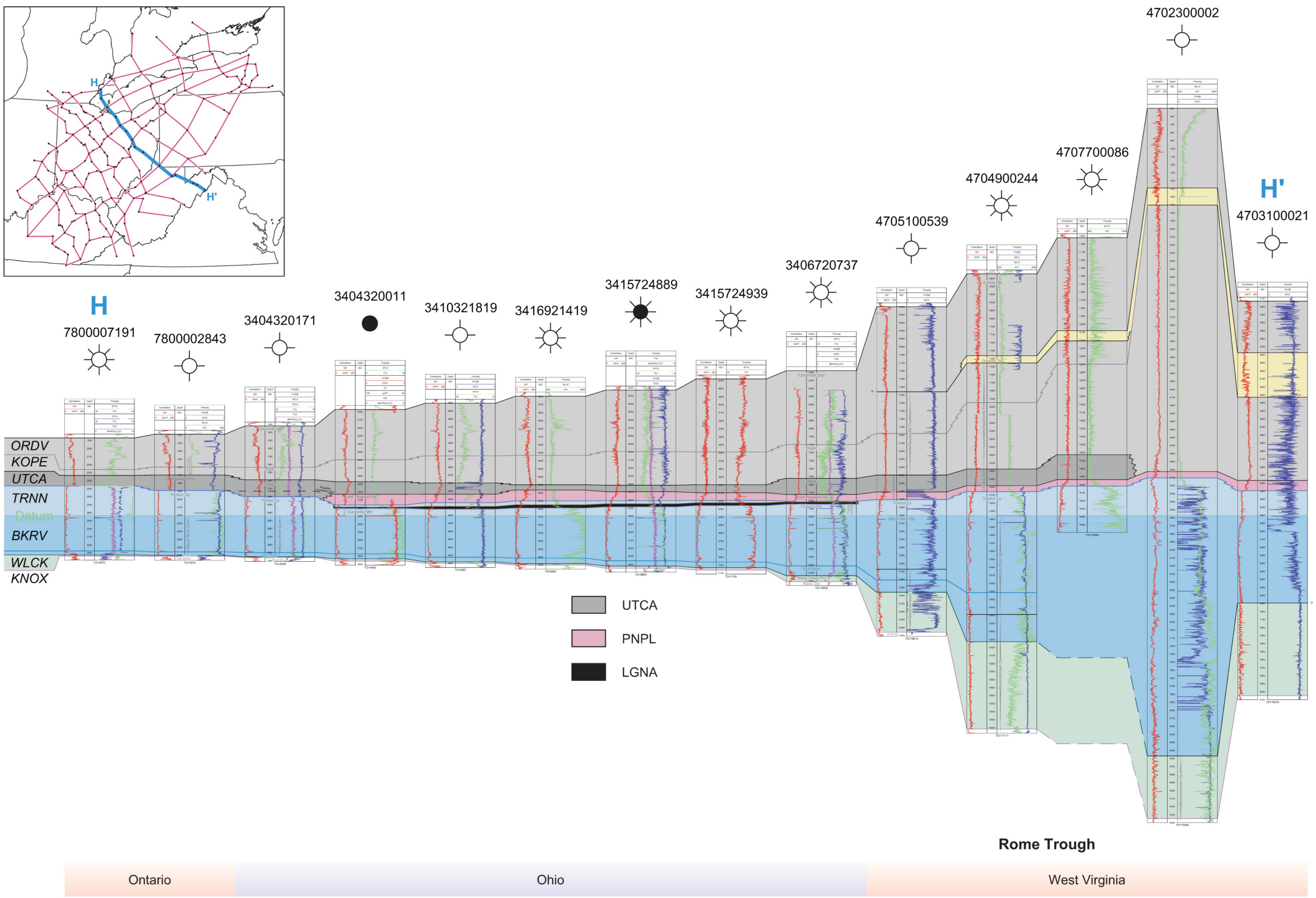

Figure 25.—Stratigraphic cross section of the top of Ordovician to Knox Dolomite from Ontario to West Virginia, illustrating the Utica and Point Pleasant facies. Modified from Patchen and others (2006).

Summary of Core Analyses for the Barth No. 3 (APINO 340312838) in Coshocton County, Ohio

Weight percent	Raw Data NORMALIZED to sum to 100%							
Well name	**FT Barth**							
Sample ID	1	2	3	4	5	6	7	8
Sample depth (ft)	5,655.5	5,661.4	5,675.0	5,678.4	5,681.5	5,684.5	5,708.5	5,747.5
Non-clay fraction								
Quartz	15.9	16.6	14.9	16.7	16.7	18.7	2.1	11.6
K-Feldspar	1.1	1.1	1.3	1.4	1.4	1.3	0.0	1.7
Plagioclase	4.0	5.0	3.8	4.1	5.0	4.8	0.0	3.8
Apatite	1.2	1.2	1.6	1.4	1.9	1.4	0.5	2.4
Pyrite	1.0	1.5	2.7	1.4	2.0	1.0	0.4	1.6
Calcite	41.1	36.2	45.7	41.1	46.7	38.3	92.8	45.9
Dolomite	5.2	3.1	3.5	4.1	5.8	7.9	1.1	3.8
Total	**69.4**	**64.7**	**73.5**	**70.2**	**79.6**	**73.4**	**96.8**	**70.7**
Clay fraction								
Mixed-layer ILLITE/SMECTITE (includes R3)	4.0	7.0	5.2	6.3	3.7	5.9	0.0	7.3
Illite + mica	24.7	26.7	20.5	22.6	16.3	20.1	3.2	21.2
Chlorite	1.9	1.6	0.8	0.9	0.4	0.6	0.0	0.8
Total	**30.6**	**35.3**	**26.5**	**29.8**	**20.4**	**26.6**	**3.2**	**29.3**
Grand total	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**
% Expandable layers in I/S	11.5	28.1	24.9	28.1	27.3	29.7	n/a	26.6
% I/S to Illite in <1.0um fraction	23.4	34.4	38.4	37.8	44.0	41.8	0.0	49.9
% Expandable I/S layers in sample	0.46	1.97	1.30	1.78	1.01	1.76	n/a	1.93
No TOC at time of regression								

api #	Top "Depth," feet	Well	A-R Bulk "Density," gm/cc	Dry Bulk "Density," gm/cc	Dry Grain "Density," gm/cc	Dry Helium "Porosity," % of BV	Dry Press Decay "Permeability," md
34031228380000	5,630.40	Fred T. Barth 3	2.65	2.63	2.74	4.1	2.41E-05
34031228380000	5,640.80	Fred T. Barth 3	2.55	2.53	2.67	5.2	1.09E-04
34031228380000	5,660.00	Fred T. Barth 3	2.55	2.53	2.65	4.7	2.04E-04
34031228380000	5,664.00	Fred T. Barth 3	2.54	2.52	2.64	4.5	5.70E-05
34031228380000	5,674.50	Fred T. Barth 3	2.50	2.48	2.65	6.5	2.19E-04
34031228380000	5,678.50	Fred T. Barth 3	2.53	2.50	2.64	5.2	3.39E-04
34031228380000	5,681.50	Fred T. Barth 3	2.54	2.52	2.66	5.3	1.26E-04
34031228380000	5,682.50	Fred T. Barth 3	2.49	2.46	2.64	6.8	6.63E-05
34031228380000	5,684.50	Fred T. Barth 3	2.50	2.47	2.65	6.6	1.68E-04
34031228380000	5,701.60	Fred T. Barth 3	2.56	2.54	2.65	4.0	4.70E-05
34031228380000	5,704.60	Fred T. Barth 3	2.60	2.59	2.69	3.7	8.96E-05
34031228380000	5,715.50	Fred T. Barth 3	2.60	2.58	2.69	4.1	2.23E-05
34031228380000	5,716.90	Fred T. Barth 3	2.59	2.57	2.67	3.8	4.83E-05
34031228380000	5,734.00	Fred T. Barth 3	2.59	2.57	2.68	4.0	1.60E-04
34031228380000	5,737.00	Fred T. Barth 3	2.56	2.54	2.65	4.1	3.81E-05
34031228380000	5,738.50	Fred T. Barth 3	2.57	2.55	2.66	4.0	1.38E-04
34031228380000	5,745.50	Fred T. Barth 3	2.57	2.56	2.65	3.5	6.98E-05

Weatherford LABORATORIES

WFT Labs HH-45711

SUMMARY OF TRIAXIAL COMPRESSIVE TESTS
Saturated with 2% KCl

Dolan Integration Group
Redman Barth No. 3

Sample No.	Depth (ft)	Confining Pressure (psi)	Pore Pressure (psi)	Compressive Strength (psi)	Static Young's Modulus (x10⁶ psi)	Static Poisson's Ratio
5661VRM	5,661.50	2,500	500	19,493	1.87	0.23
5680VRM	5,680.50	2,500	500	19,921	2.15	0.23
5683VRM	5,683.50	2,500	500	25,790	3.11	0.25
5790VRM	5,790.00	2,500	500	19,397	1.93	0.25

Weatherford LABORATORIES

WFT Labs HH-45711

SUMMARY OF ULTRASONIC VELOCITIES AND DYNAMIC ELASTIC PARAMETERS
Saturated with 2% KCl

Dolan Integration Group
Redman Barth No. 3

Sample No.	Depth (ft)	Confining Pressure (psi)	Bulk Density (g/cc)	Ultrasonic Wave Velocity				Dynamic Elastic Parameter			
				Compressional		Shear		Young's Modulus (x10⁶ psi)	Poisson's Ratio	Bulk Modulus (x10⁶ psi)	Shear Modulus (x10⁶ psi)
				ft/sec	msec/ft	ft/sec	msec/ft				
5661VRM	5,661.50	2,500	2.56	13,418	74.53	7,636	130.96	5.06	0.26	3.52	2.01
5680VRM	5,680.50	2,500	2.55	13,789	72.52	8,172	122.37	5.64	0.23	3.47	2.29
5683VRM	5,683.50	2,500	2.59	15,272	65.48	8,801	113.62	6.78	0.25	4.54	2.71
5790VRM	5,790.00	2,500	2.61	14,293	69.96	8,074	123.85	5.79	0.27	4.12	2.29

Weatherford LABORATORIES

SHALE ROCK PROPERTIES
SUMMARY OF ROUTINE CRUSHED CORE ANALYSES RESULTS
As-received and vacuum dried at 212°F

Dolan Integration Group
Redman Barth No.3
USA

HH-45711
1-05-10

Sample ID	Sample "Depth," feet	A-R Bulk "Density," gm/cc	A-R Grain "Density," gms/cc	A-R Water "Saturation," % of PV	A-R Oil "Saturation," % of PV	A-R Gas "Saturation," % of PV	A-R Gas Filled "Porosity," % of BV	A-R Press Decay "Permeability," md	Dry Bulk "Density," gm/cc	Dry Grain "Density," gm/cc	Dry Helium "Porosity," % of BV	Dry Press Decay "Permeability," md
1SRP	5,661.50	2.54	2.58	11.7	52.3	36.0	1.8	3.68E-05	2.51	2.64	4.9	5.63E-04
2SRP	5,680.50	2.52	2.57	10.4	54.5	35.1	1.8	2.68E-05	2.50	2.63	5.2	4.30E-04
3SRP	5,683.50	2.57	2.61	6.0	67.0	27.0	1.5	2.25E-05	2.54	2.69	5.4	8.20E-04
4SRP	5,740.00	2.59	2.61	14.5	66.6	19.0	0.8	9.00E-06	2.56	2.67	4.1	3.18E-04
Average values:		2.56	2.59	10.7	60.1	29.3	1.5	2.38E-05	2.53	2.66	4.9	5.33E-04

As-received bulk volumes and bulk densities were determined on intact bulk sample material. The bulk material was crushed and all other analysis reported herein were conducted on the crushed material.

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