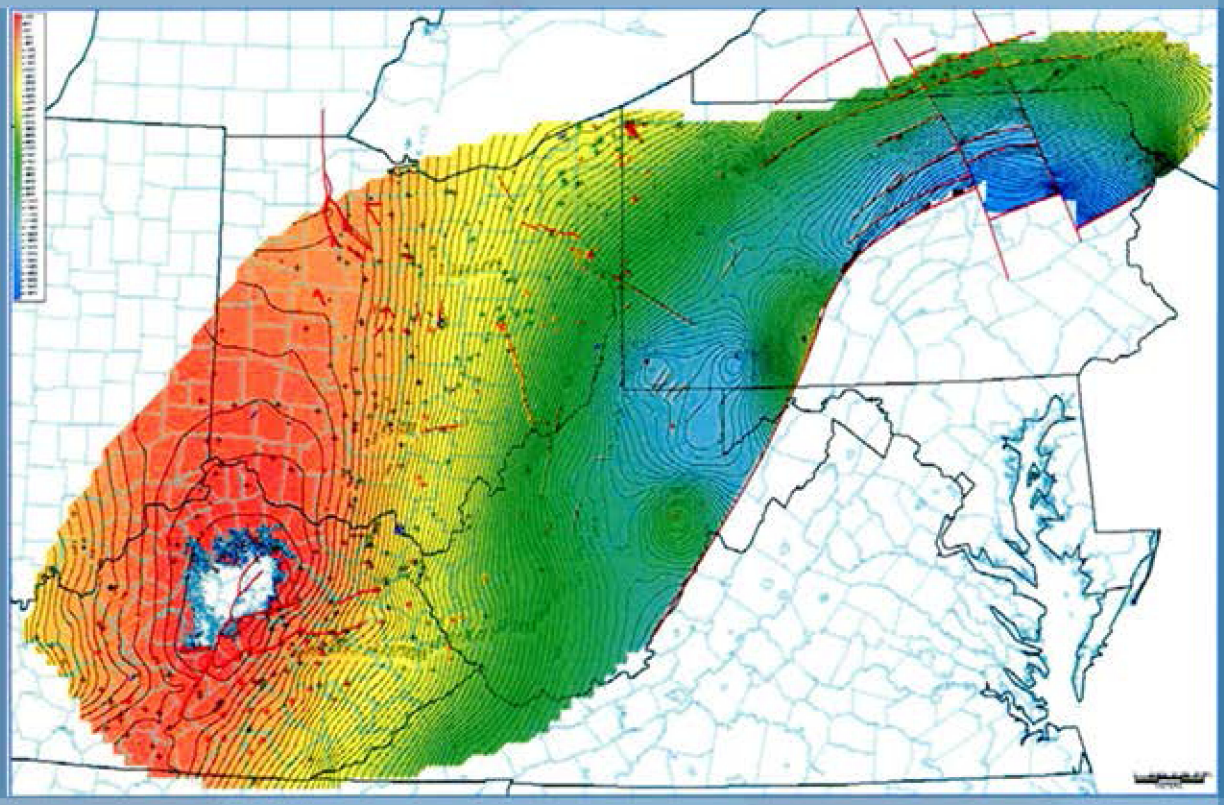
A Geologic Play Book for Utica Shale Appalachian Basin Exploration



FINAL REPORT
April 1, 2012
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(Sections)

3.0 LITHOSTRATIGRAPHY

Utica Shale Appalachian Basin Exploration Consortium

Coordinated by the Appalachian Oil & Natural Gas Consortium at West Virginia University

Table 2-1. Summary of Utica/Point Pleasant production compared to conventional production for 2011 through 2013 in Ohio. Note: Gas includes NGLs.

	Utica/Point Pleasant Production			Conventional Production		
Year	Oil (Barrels)	Gas (Mcf)	No. of Wells	Oil (Barrels)	Gas (Mcf)	No. of Wells
2011	46,326	2,561,524	9	4,809,451	70,728,314	50,192
2012	635,896	12,836,662	87	4,665,167	65,777,332	51,407
2013	3,677,742	100,119,054	359	8,088,599	171,658,608	48,828

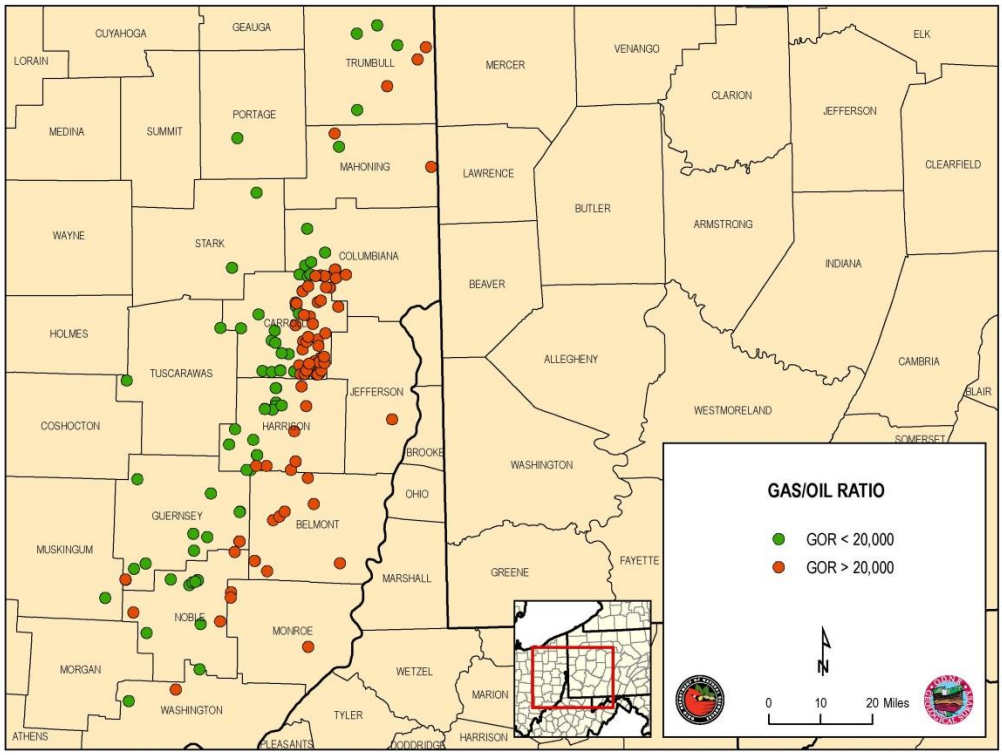

Figure 2-5. GOR map of Ohio using a cutoff of 20,000 scfg/bo. A delineation of the gas to oil window is evident trending northeast-southwest through eastern Ohio.

3.0 LITHOSTRATIGRAPHY

The focus of this particular task is the geology and stratigraphy of the early Late Ordovician strata of the Appalachian basin. These strata include the Kope Formation, Utica Shale, Point Pleasant Formation and Lexington/Trenton Formation (Figure 3-1). Trenton and Lexington are both formal formation names that have been applied to the same interval of rock. Therefore, in keeping with the previously published Trenton/Black River study (Patchen and others, 2006), we are designating this stratigraphic interval the Lexington/Trenton Formation. In some parts of the Study area, it is possible to differentiate individual members of the Lexington/Trenton based on their organic-rich or carbonate-rich but organic-poor characteristics. Formal names have been applied to these members in Kentucky, two of which will be used throughout the report – the basal Curdsville Member (organic-poor) and Logana Member (organic-rich) above. The section between the Logana Member and the Point Pleasant Formation is referred to informally in this

Study as the upper member of the Lexington/Trenton Formation. Of all these Late Ordovician strata, the most productive hydrocarbon source rocks tend to be the Point Pleasant Formation and the upper and Logana members of the Lexington/Trenton Formation. Brief descriptions of each unit's lithostratigraphy are provided below. Detailed Utica/Point Pleasant and equivalent outcrop descriptions have been prepared by each state and are available in Appendix 3-A.

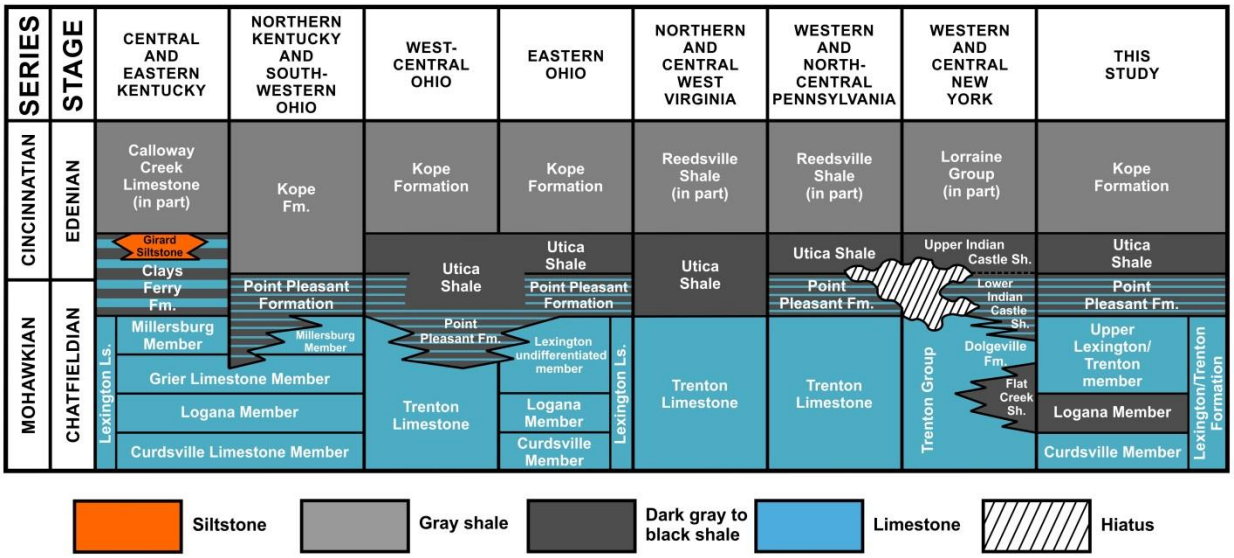

Figure 3-1. Correlation chart for early Late Ordovician strata evaluated by the Utica Shale Play Book Study.

3.1 Kope Formation

The name Kope Formation is used in the Study for the organic-poor shale and siltstone unit above the Utica Shale. It is equivalent to the lower portion of the Calloway Creek Limestone of Kentucky, Lorraine Group of New York, and Reedsville Shale of Pennsylvania and West Virginia (Figure 3-1). The Kope is composed of interbedded shale (about 60 to 80%), limestone (20 to 40%), and minor siltstone; within the Study area it ranges in thickness from about 40 to 1600 ft. The shale commonly occurs in beds 2- to 5-ft thick and is generally very sparsely fossiliferous. Most of the limestone is fossiliferous and commonly occurs in even beds 2- to 6- inches (in) thick that are in places grouped into sets several ft thick. The limestone beds commonly have sharp contacts with the shale beds (McDowell, 1986).

3.2 Utica Shale

For the purposes of this Study, the name Utica Shale is used for all the strata between the Kope and Point Pleasant formations (Figure 3-1). In Kentucky, this interval is equivalent to the upper Clays Ferry Formation, whereas in New York it is called upper Indian Castle Shale. In outcrop in the Appalachian fold belt, the Antes Shale and Martinsburg Formation occupy the stratigraphic level of the Utica. The Utica consists of interbedded dark fissile shale and limey shale (10 to 60% calcite) beds. These beds tend to be bioturbated, and can be fossiliferous in part (Smith, 2013). The Utica Shale pinches out to the south in southern Ohio and West Virginia, but extends to the southwest of the Study area along the "Sebree Trough" (Kolata and others, 2001), roughly coinciding with the Kentucky/Indiana border. The Utica thickens to the northeast to approximately 400 ft in east-central New York.

3.3 Point Pleasant Formation

The Point Pleasant Formation consists of all of the interbedded limestones and black shales between the Utica Shale and the top of the Lexington/Trenton Formation (Figure 3-1). This interval, where it exists, is equivalent to the lower Clays Ferry Formation of Kentucky and the lower Indian Castle Shale of New York. It extends northward beneath the Utica Shale and is comprised of interbedded, fossiliferous limestone, shale and minor siltstone. The limestone and shale occur in roughly equal amounts, whereas the siltstone accounts for only a small percentage of the unit. Within the Study area, this unit ranges in thickness from 0 ft in the northwest to about 240 ft in northern Pennsylvania. The Point Pleasant and Utica intertongue in part with the Lexington/Trenton Formation (Luft, 1972; McDowell, 1986).

3.4 Upper Lexington/Trenton Formation

The upper Lexington/Trenton Formation is equivalent to the Millersburg and Grier Limestone members (undifferentiated) of the Lexington Limestone of Kentucky and the Dolgeville Formation of New York (Figure 3-1). It consists of nodular and irregularly bedded fossiliferous limestone and shale in the upper part of the Lexington Limestone. The limestone consists of very abundant whole and broken fossils in a silt- and clay-sized carbonate matrix. Bryozoans, brachiopods, mollusks and trilobite fragments are particularly abundant, and stromatoporoids and colonial corals are present in some zones. Evidence of bioturbation is common. The limestones were deposited in the infralittoral zone where light, aeration, circulation and the availability of nutrients were at an optimum to foster life (McDowell, 1986).

3.5 Logana Member

The Logana Member is equivalent to the Flat Creek Shale of New York, which is the lowest formation within New York's Utica Group (Figure 3-1). It consists of interbedded calcisiltite and shale, and coquinoid limestone consisting of closely packed shells of the brachiopod *Dalmanella sulcata* (McDowell, 1986). The calcisiltite is generally in even or broadly lenticular beds 0.2- to 0.3-ft thick and is mostly unfossiliferous. The member is about 30-ft thick in western Ohio, and thickens to approximately 220 ft in central New York. The Logana was deposited during the culmination of the initial transgression of Lexington/Trenton time (McDowell, 1986).

3.6 Curdsville Limestone Member

The Curdsville Limestone Member, the basal member of the Lexington/Trenton Formation, consists of 20 to more than 450 ft of bioclastic calcarenite, which is sandy and chert-bearing in part; silicified fossils are common. Near the top of the member, the limestone becomes irregularly bedded, finer grained and more fossiliferous. MacQuown (1967) identified several thin, discontinuous bentonites in the Curdsville. The Curdsville was deposited in shallow, turbulent water during the initial transgression of the Lexington sea. The member is present throughout the outcrop area. The Curdsville conformably overlies the Middle Ordovician Black River Formation (McDowell, 1986).

Utica Shale Play Book

The AONGRC's Utica Shale Appalachian Basin Exploration Consortium includes the following members:

Research Team:
WVU National Research Center for Coal and Energy, Washington University, Kentucky Geological Survey, Ohio Geological Survey, Pennsylvania Geological Survey, West Virginia Geological and Economic Survey, U.S. Geological Survey, Smith Stratigraphic, and U.S. DOE National Energy Technology Laboratory.

Sponsorship:
Anadarko, Chevron, CNX, ConocoPhillips, Devon, EnerVest, EOG Resources, EQT, Hess, NETL Strategic Center for Natural Gas and Oil, Range Resources, Seneca Resources, Shell, Southwestern Energy, and Tracker Resources.

Coordinated by:
Appalachian Oil & Natural Gas Research Consortium at West Virginia University