[PS]Washington - Taylorstown Field - Microcosm of the Oil and Gas Industry in Pennsylvania*

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Abstract

Located in central Washington County, the Washington-Taylorstown field is a fitting example of the ebb and flow of petroleum developments that have occurred throughout the Commonwealth of Pennsylvania since Drake first struck oil in Titusville in 1859. Whether shallow or deep, sandstone or shale, failure or success, this field has seen it all. Underlying the city of Washington and its suburbs, Washington-Taylorstown field was discovered in January 1885 with the completion of the Gantz No. 1. Although exploring for gas, this well struck oil in the shallowest sand of the Upper Devonian Venango Group (aptly named the Gantz sand from that point onward), and spurred extensive drilling activity in the greater Washington area for decades to come. Even though several shallow Pennsylvanian and Mississippian sands were also tapped for oil and gas as part of this activity, it is production from the Venango Group's Hundred Foot/Gantz, Gordon, Fourth, and Fifth sand zones that made Washington-Taylorstown field a prominent fixture in the oil belt of Pennsylvania. Moreover, estimated reserves of roughly 49 MMBLS total oil in place opened Washington-Taylorstown field to various enhanced recovery operations through the years, from gas drive (1923-1970) to waterflooding (1982-present), to extend its livelihood. Such efforts have overwhelmingly been focused on the Gordon sand, due to this zone's particularly favorable reservoir characteristics. With the advent of the modern Marcellus shale gas play, however, the industry has turned its focus to deep gas drilling. Since 2008, cumulative Marcellus shale gas production from several wells in the Richard Foster pool (northern Washington-Taylorstown field) has exceeded four Bcf.

Today, Washington-Taylorstown field has a footprint of about 42,000 acres and includes more than 1,700 wells producing oil and gas from a half dozen reservoirs over a wide range of depths (~1,000-6,500 ft TVD). The oil reserves associated with the Venango Group and the promising production of Marcellus shale gas wells suggest that Washington-Taylorstown field is by no means beyond its prime. Indeed, it could be said that like the petroleum industry in Pennsylvania, Washington-Taylorstown field has re-emerged as a focus of attention with advances in science and technology as well as increases in domestic energy demand.

WASHINGTON-TAYLORSTOWN FIELD - MICROCOSM OF THE OIL AND GAS INDUSTRY IN PENNSYLVANIA

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ABSTRACT

Located in central Washington County, the Washington-Taylorstown field is a fitting example of the ebb and flow of petroleum developments that have occurred throughout the Commonwealth of Pennsylvania since Drake first struck oil in Titusville in 1859. Whether shallow or deep, sandstone or shale, failure or success, this field has seen it all. Underlying the city of Washington and its suburbs, Washington-Taylorstown field was discovered in January 1885 with the completion of the Gantz No. 1. Although exploring for gas, this well struck oil in the shallowest sand of the Upper Devonian Venango Group (aptly named the Gantz sand from that point onward), and spurred extensive drilling activity in the greater Washington area for decades to come. Even though several shallow Pennsylvanian and Mississippian sands were also tapped for oil and gas as part of this activity, it is production from the Venango Group's Hundred Foot/Gantz, Gordon, Fourth, and Fifth sand zones that made Washington-Taylorstown field a prominent fixture in the oil belt of Pennsylvania. Moreover, estimated reserves of roughly 49 MMBLS total oil in place opened Washington-Taylorstown field to various enhanced recovery operations through the years, from gas drive (1923-1970) to waterflooding (1982-present), to extend its livelihood. Such efforts have overwhelmingly been focused on the Gordon sand, due to this zone's particularly favorable reservoir characteristics. With the advent of the modern Marcellus shale gas play, however, the industry has turned its focus to deep gas drilling. Since 2008, cumulative Marcellus shale gas production from several wells in the Richard Foster pool (northern Washington-Taylorstown field) has exceeded 4 Bcf.

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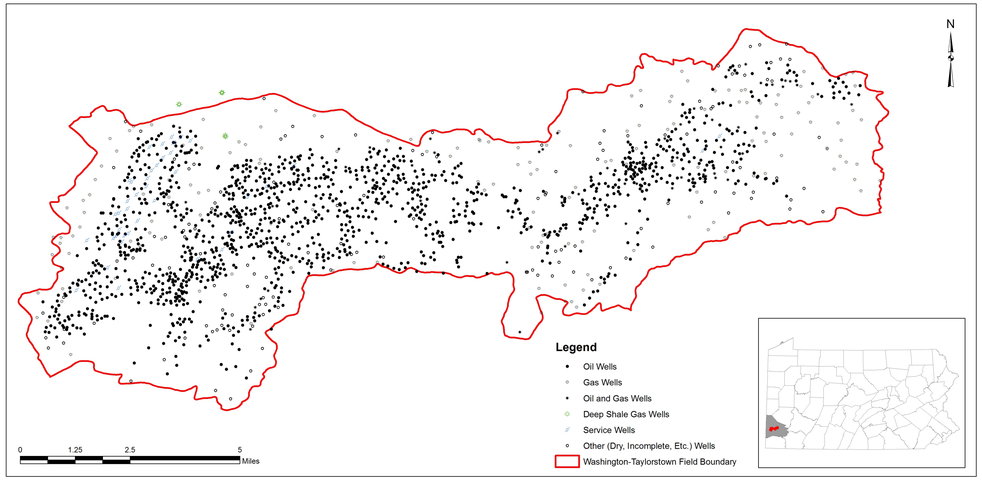
OBJECTIVES

The objectives of this work are as follows:

- Demonstrate the longevity of petroleum production in southwestern Pennsylvania;
- Raise awareness of oil and gas prospects in southwestern Pennsylvania; and
- Identify oppportunities for future potential uses of this region's subsurface geologic reservoirs.

STUDY AREA



FIELD STATISTICS

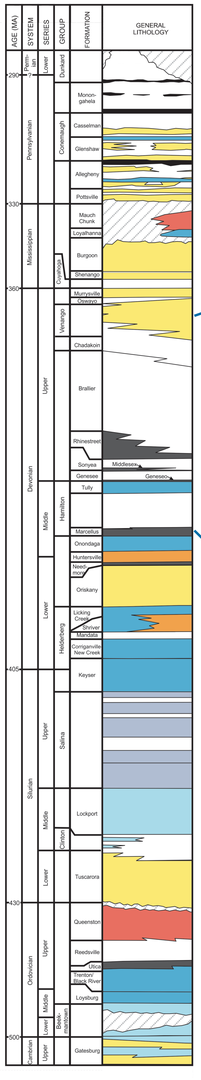
Washington-Taylorstown Field	
Location	central Washington County
Size	~42,000 acres
No. Included Municipalities	12
Discovery Well and Date	Gantz Well/January 1, 1885
Other Notable Discoveries	Gordon Well/August 21, 1885
Total No. Wells	>1,700 (~25% of all wells in the county)
Producing Oil Wells	~1,300
Producing Gas Wells	~180 (11 of which are deep shale gas)
Producing Oil and Gas Wells	~60
Service Wells (Enhanced Recovery)	~40
Other Wells (Dry, Incomplete, Unspecified)	~140
Minimum Depth/Formation Penetrated	367 ft/Monongahela Group
Maximum Depth/Formation Penetrated	12,497 ft TMD (6,490 ft TVD)/Marcellus shale
Estimated Oil Reserves [1]	>49 MMBBLS OIP
Shale Gas Production [2]	>4 BCF
Reservoir Information	
Age	**Unit**
Pennsylvanian	Allegheny Group
	Pottsville Group
Mississippian	Burgoon Sandstone
Devonian	Venango Group
	Brallier Formation
	Chadakoin Formation
	Marcellus shale

(1) - Lytle, W.S., 1950, Crude Oil Reserves of Pennsylvania: Pennsylvania Geological Survey, 4th Series, Mineral Resource Report 32, p. 28.

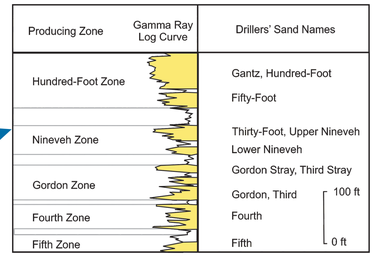
(2) - PA*IRIS/WIS System, 2013, Shale gas production data retrieved from database of the Pennsylvania Geological Survey (production data current as of 2009).

REGIONAL STRATIGRAPHY

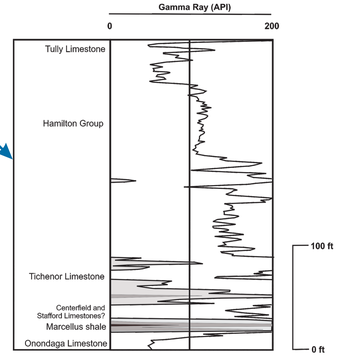
The subsurface geology of Washington County includes more than 10,000 feet of Permian- through Cambrian-age strata. This generalized stratigraphic chart (not to scale) illustrates the relative position, lithology, and nomenclature for multiple layers of sedimentary rock in the southwestern corner of the state.



The Venango Group in Washington County produced from several zones, as shown below. The Gantz sand, discovered here in 1885, is part of the Hundred-Foot Zone, and the Gordon sand, discovered later that same year, comprises the Gordon Zone, which has been associated with several enhanced recovery efforts over the years.



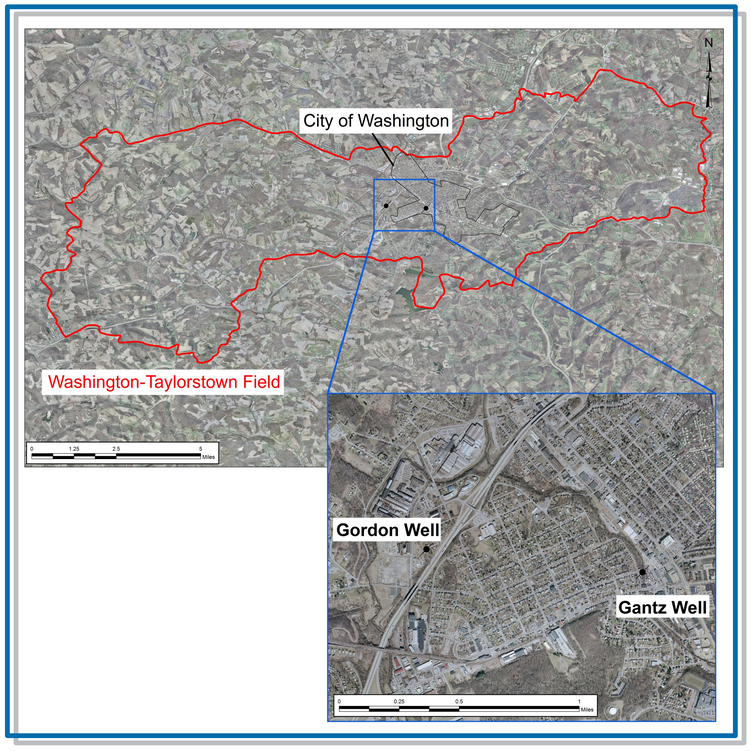
The Marcellus shale, first produced in Washington-Taylorstown Field in 2008, is generally 100 feet or less in thickness and is comprised of "upper" and "lower" productive zones. Well log interpretation efforts by the Pennsylvania Geological Survey have attempted to identify and correlate the limestone layers separating the shale zones, based on New York terminology. In the example below, we have tentatively identified the Tichenor, Centerfield, and Stafford limestones in the lower part of the Hamilton Group. In this area of southwestern Pennsylvania, the Cherry Valley Limestone appears to be absent.



LEGEND

- Sandstone
- Siltstone and shale
- Organic shale
- "Red Beds"
- Coal
- Limestone
- Dolostone
- Chert
- Evaporite
- Unconformity

SHALLOW DISCOVERIES



The Gantz Well

The Washington-Taylorstown Field was discovered with the completion of the Gantz No. 1 by the Citizens Natural Gas Company on January 1, 1885. Drilled to a depth of 2,191 feet, this well reported production of approximately 20 barrels of oil per day from the "coffee-colored" sandstone at the base of the well, named the Gantz sand for the farm on which it was drilled. The Gantz Well was also the first commercially productive oil well in Washington County, as noted by the historical marker near the former site of the well.

The Pennsylvania Railroad Freight Station in Washington, PA. The parking lot of this train station was the former location of the Gantz Well.

Producing the Gordon

The Gordon Sand

Reservoir Statistics

Average Depth	2,608 ft
Average Gross Thickness	25 ft
Average Pay Thickness	6-9 ft [1], [2]
Average Porosity	20% [1], [2]
Permeability	94-130 mD [1], [2]
Reserve Estimate (as of 1947)	15.1 MMBLS OIP [3]

Enhanced Recovery Efforts [1], [2], [3], [4], [5], [6]

Gas Drive Efforts	1923 - 1970
Waterflood Injection Pilot	1982 - 1989
Waterflooding - Line-Drive Pattern	1996 - current day

(1) - Lytle, W.S., 1976, Oil fields of the Greater Pittsburgh Region: Pennsylvania Geological Survey, 4th Series, Mineral Resource Report 70, p. 115.

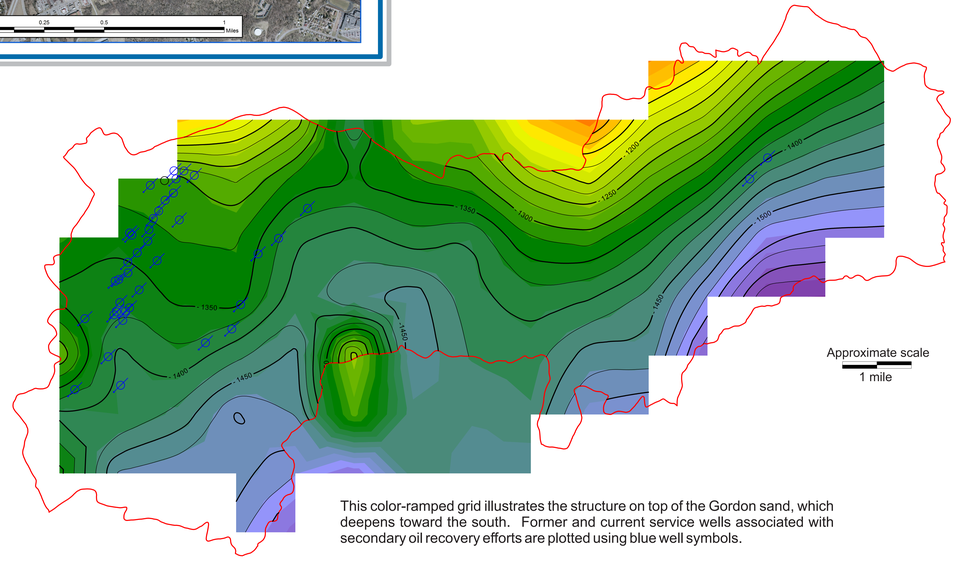
(2) - Farias M., Zaghloul, J., Ertekin, T., and others, 2003, Waterflooding in Gordon sandstone formation - Taylorstown Field, during the period 5/15/2001 to 11/30/2002: Work performed under Prime Award No. DE-FC26-00NT41025, Subcontract No. 2040-TPSU-DOE-1025, 47 p.

(3) - Lytle, W.S., 1950, Crude oil reserves of Pennsylvania: Pennsylvania Geological Survey, 4th Series, Mineral Resource Report 32, 256 p.

(4) - Lytle, W.S., 1960, History, present status and future possibilities of secondary recovery operations in Pennsylvania: Pennsylvania Geological Survey, 4th Series, Mineral Resource Report 41, 42 p.

(5) - Harper, J.A., and Laughrey, C.D., 1987, Geology of the oil and gas fields of southwestern Pennsylvania: Pennsylvania Geological Survey, 4th Series, Mineral Resource Report 87, pp. 112-116.

(6) - McGlade, W.G., 1967, Oil and gas geology of the Amity and Claysville Quadrangles: Pennsylvania Geological Survey, 4th Series, Mineral Resource Report 54, 131 p.

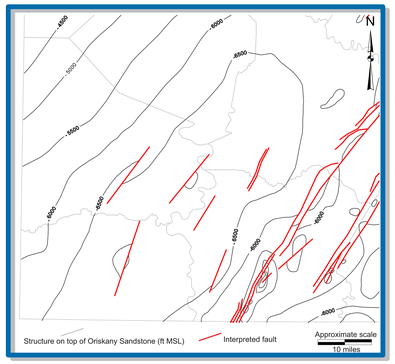


This color-ramped grid illustrates the structure on top of the Gordon sand, which deepens toward the south. Former and current service wells associated with secondary oil recovery efforts are plotted using blue well symbols.

Structure contours on top of the Gordon sand (ft MSL)

OTHER OPPORTUNITIES

Oriskany Sandstone

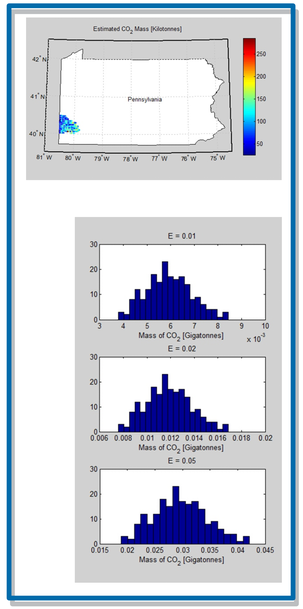


Although the only Oriskany test in Washington-Taylorstown Field was completed as a dry well, other penetrations in southwestern Pennsylvania have been successful in producing gas. This region of the state is part of the fractured Huntersville Chert/Oriskany Sandstone (Dho) play.

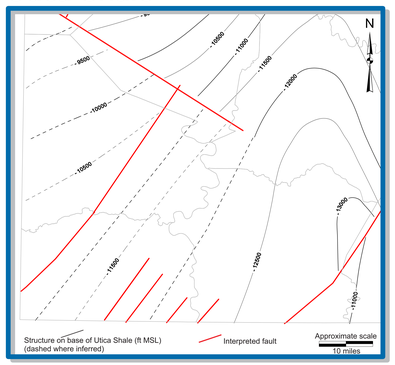
Not only has the Oriskany Sandstone been producing gas since the early 20th century, it has also been used throughout western Pensylvania as a natural gas storage reservoir, generally where structural trapping mechanisms exist.

In addition, the Oriskany Sandstone has been the focus of geologic carbon sequestration research activity in the central Appalachian Basin since 2003. An example of current work, provided by Carnegie Mellon University researchers, and led by Principal Investigator Professor Mitchell Small, is shown to the right.

Utilizing a sequential Gaussian simulation (*see poster presentation by Ms. Olga Popova, Theme 7: Advances in Carbon Capture and Storage, May 21, 1:15-5:00 pm*), estimates of the mass of carbon dioxide that can be permanently stored in the Oriskany Sandstone of Washington County range from ~6 to 30 Megatonnes.



Utica Shale

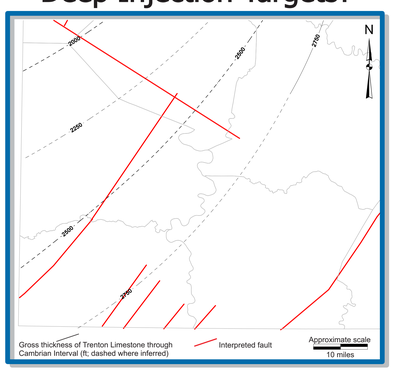


Although Washington County is known as the home of the modern Marcellus shale gas play, the Utica Shale is another deep shale gas reservoir that could pay dividends, given favorable economics.

The Utica Shale of Washington County occurs in the dry gas window and at depths in excess of 10,000 ft, but is estimated to be several hundred feet thick.

The Utica Shale gas play is becoming more popular in Pennsylvania, with recent successes in Beaver and Lawrence counties to the north.

Deep Injection Targets?



The Pennsylvania Geological Survey will soon be participating in a regional study of prospective deep brine injection targets. Several thousand feet of strata exist below the Utica Shale in southwestern Pennsylvania, including the Upper Ordovician Trenton-Black River carbonates and Upper Cambrian Gatesburg Formation. We will be evaluating these deep formations for potential injectivity and reporting our results to the U.S. Department of Energy.

SUMMARY OF FINDINGS

- Washington-Taylorstown Field was the first to produce oil in Washington County (January 1885) and became a mainstay in Pennsylvania's Oil Belt from that point onward.
- Several reservoirs in this field, both shallow and deep, have produced petroleum hydrocarbons since the late 1800s - from Pennsylvanian and Mississippian deposits to various Devonian reservoirs - but it is the Devonian-age rocks that have yielded most of the production (and attention) from the mid-20th century to today.
- The Gordon sand of the Venango Group has undergone enhanced oil recovery efforts since 1923, from gas drive to waterflooding. Even so, the Pennsylvania Geological Survey estimates that >90% of the estimated oil reserves for the Venango Group in Washington-Taylorstown Field (>44 MMBLS) remains in place.
- Much like Pennsylvania's oil and gas industry, activity in Washington-Taylorstown Field is expected to not only continue but also thrive, whether through further enhanced oil recovery work, Marcellus shale gas production, Utica Shale tests, geologic sequestration of greenhouse gases, and/or deep brine injection prospects.

ACKNOWLEDGEMENTS

I sincerely thank the following individuals who offered their technical expertise and provided data relevant to this project; their insight greatly improved the content of this presentation:

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