New York Trenton-Black River Production

- New York is estimated to contain approximately 35 percent of the resources attributed to the Trenton-Black River hydrothermal dolomite play in the Appalachian Basin.
- 98 deep Trenton-Black River tests have been drilled in the State since 1985. Only 8 Trenton-Black River wells were drilled between 1985 and 1998, but Trenton-Black River exploration and field development drilling has increased steadily since 1998. 73 Trenton-Black River wells were drilled in New York in 2004 and 2005.
- Notable Trenton-Black River discoveries in 2006 include the Stoscheck #1 well, Van Etten Township, Chemung County, which was placed on production at a rate of 22 MMcf per day. A second discovery well, the Hartman BJ #1 in Caton Township, Steuben County produced at an initial rate of 12 MMcf per day.
- Since the play was discovered in 1986, attention has focused on developing an exploration model for the play, improving the effectiveness of seismic imaging, and developing efficient drilling and well-completion techniques.
- Fortuna Energy Inc., with New York headquarters in Horseheads, is the largest Trenton-Black River producer in the State. In 2005, Fortuna Energy produced more than 41 Bcf from 50 wells. Chesapeake Energy Corporation, a relatively recent entrant to New York through their 2005 acquisition of Columbia Natural Resources, is also targeting the Trenton-Black River play.
- Most Trenton-Black River production is from Steuben and Chemung Counties, but current activity also includes exploration efforts in Cayuga, Cortland, Schuyler, Tioga and Tompkins Counties.
- Successful Trenton-Black River wells have been drilled using both vertical and horizontal drilling techniques, though recent Trenton-Black River wells are frequently drilled horizontally. A combination of vertical and horizontal drilling may be used. From the vertical hole at about 9,500 to 10,000 feet deep, the well bore is gradually turned 90 degrees and the well continues to be drilled horizontally for another 3,000 feet. This technique has been found to generally increase well productivity and decrease the chance of a dry hole.

Trenton-Black River Hydrothermal Dolomite

In New York and Ontario, the Ordovician age Trenton and Black River Formations produce natural gas from fractured limestone reservoirs and from limestone reservoirs that were altered to more porous and permeable dolomite by hot, mineral-laden fluids. Dolomite is a crystalline sedimentary rock that is formed by the chemical alteration of limestone (calcium carbonate.) Dolomite often makes an excellent reservoir rock for oil and natural gas. Deep Trenton-Black River "hydrothermal dolomite" reservoirs now dominate New York's natural gas production.

Pursuing the Trenton-Black River hydrothermal dolomite play is a high-tech, high-risk enterprise that requires accurate interpretation of 2-D and 3-D seismic imaging data, drilling of deviated or horizontal wells in some areas, and integration of seismic, well logs and geologic and geochemical data into a sophisticated exploration and development model. Deep Trenton-Black River wells may be drilled vertically and then steered horizontally to total depths in the range of 10,000 to more than 12,000 feet.

Recent Trenton-Black River exploration and development drilling in New York may use 2-D seismic for exploration drilling and 3-D seismic for development drilling.

Seismic data has proved to be so effective for mapping Trenton-Black River hydrothermal dolomite reservoirs that recent Trenton-Black River production spacing units are based on bounding faults defined by seismic data. The play continues to generate substantial interest in New York because the potential rewards are great. Individual wells have produced as much as 6 Bcf in a single year; the best well in the play to date has produced 15 Bcf in four years. [20, 21]

Industry's geologic understanding of this play has been aided by a recent multi-state study by the Trenton-Black River Appalachian Basin Exploration Consortium, which has developed and published an integrated stratigraphic, structural and chemical model for the Trenton-Black River hydrothermal dolomite reservoirs in New York.

Shale Gas

Organic-rich black shale formations are found throughout the stratigraphic section in New York. Some are thick and widespread, correlating with shale formations elsewhere in the Appalachian Basin, while some are thin and limited in extent. During the nineteenth century, hundreds of shallow establishment of Lakeshore Field. Naples and Dansville Fields were discovered in the 1880 and 1881. Despite this early history, the shale gas potential of New York remains largely untested. Since 1900, fewer than 100 wells have been purposely drilled to test the potential of New York's Devonian and Silurian-age shale formations, and no wells have tested the Ordovician-age Utica Shale. Several research wells were drilled by NYSERDA and the U.S. Department of Energy in the 1980s, establishing a number of one-well gas fields, some of which are still producing. Until recently, low production rates from shallow shale gas wells limited commercial interest in shale gas.

The recent economic success of other U.S. shale gas plays like the Barnett and Fayetteville shales has renewed industry interest in New York's shale formations. A potential Devonian shale gas resource-in-place of more than 400 Tcf, plus recent advances in shale development concepts and drilling and completion technology, have made New York's fractured shale gas potential more economically attractive. [22] The recompletion potential of New York shale formations currently "behind pipe" in thousands of wells drilled for deeper objectives could potentially allow the economic development of shale reserves that might not otherwise support the drilling of a new well.

Every shale gas play is unique and New York shales are no exception. Exploration strategies should focus on locating areas with high gas content that also have sufficient permeability for economic production. Organic-rich shales, which have a relatively high content of total organic carbon, typically have the best gas-in-place and the most natural fractures. Natural fractures in shale reservoirs are generally supplemented with induced hydraulic fractures so that wells can produce at economic rates.

Horizontal drilling has been applied successfully in other shale gas plays and horizontal drilling could become economically attractive for New York shale formations as drilling and well completion techniques continue to improve, and as the optimal reservoir characteristics of New York shale formations are better understood. [23]

Union Springs Formation, Marcellus Shale, US Rte. 20 near Cherry Valley, NY

Devonian Age Shale

Devonian age formations extend across 22,500 square miles of south-central New York. The organic-rich, gas-bearing shale formations occur in the Middle and Upper Devonian, from the top of the Onondaga Limestone through the Perrysburg Formation of the Canadaway Group. Thickness ranges from less than 100 feet for the Pipe Creek and Genesee Shales to more than 1,200 feet for the Rhinestreet shale. Measured total organic carbon (TOC) values for Upper Devonian black shales range from less than 0.4 percent to as much as 7 percent by weight. The average TOC content of the Rhinestreet shale is 3 percent.

The Rathbone Field, discovered in 1931 in Steuben County, is the only successful Upper Devonian shale gas field since the establishment of Lakeshore field in the late 1800s. Thirty-one wells were drilled in Rathbone Field targeting the Rhinestreet Shale, of which twenty-four wells were producers with initial flow rates ranging up to 2,000 Mcfd.

Marcellus Shale Formation

Much of the renewed interest in New York's Devonian shale gas potential is focused on the Middle Devonian Hamilton Group, the oldest strata of the Devonian gas shale sequence. The Marcellus Shale is the target black shale formation of the Hamilton Group, ranging in thickness from 25 feet in southwestern New York to 180 feet in central New York.[24]

Naples Field, discovered in 1880, produced 32 million cubic feet (MMcf) from the Marcellus Shale. Nearly all of the New York shale gas discoveries after Naples Field were in the Marcellus Shale/ Lower Hamilton Group. A joint NYSERDA and U.S. Department of Energy research program of the 1980s established five productive gas fields in the Marcellus Shale, four of which are still producing.

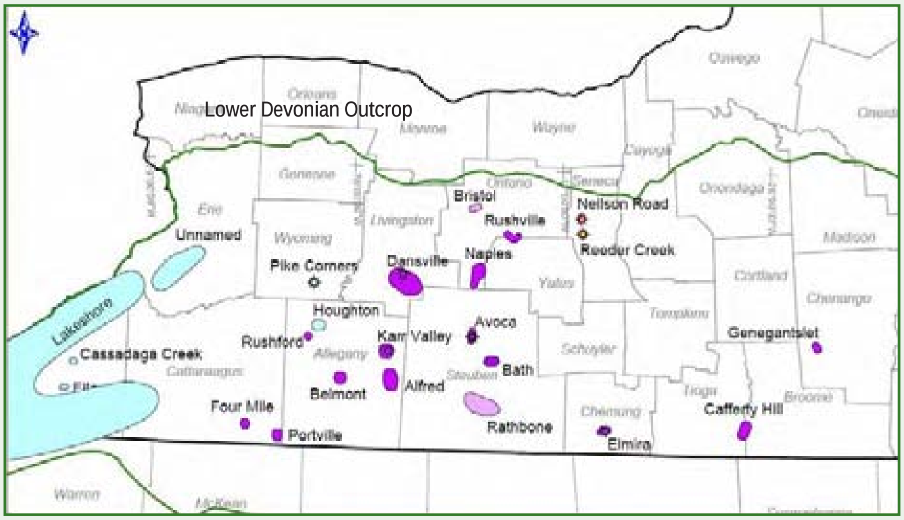
The Genegantslet Field, discovered in 1964 in Chenango County, produced gas from the Marcellus in three wells including the Decker #2 well, which had an initial flow rate of 1,650 Mcfd.

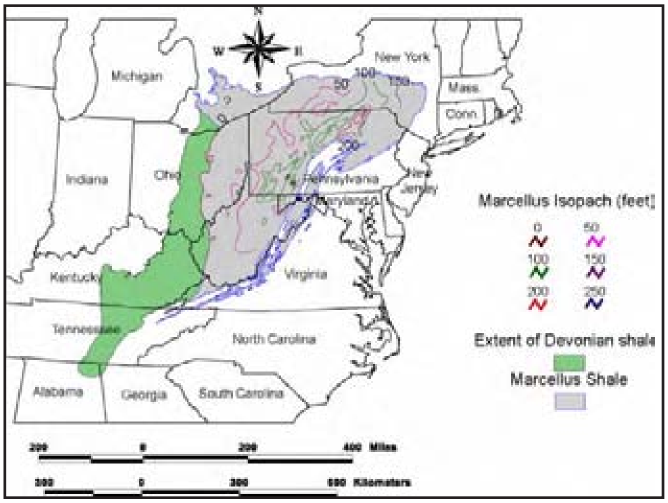
NYSERDA is currently sponsoring research on the Marcellus Shale, providing geochemical and geological analyses of prospective Marcellus zones and identifying the most promising modern well completion techniques. Preliminary results show a wide range in the reservoir quality of the Marcellus Shale. For example, total organic content ranges from 0.3 percent to 11 percent. Work is ongoing to develop a comprehensive understanding of the geologic controls on economic gas production from the Marcellus Shale.

New York Devonian Shale Production

- New York contains approximately 15 percent of the Devonian shale natural gas resources in the Appalachian Basin.
- 100 Shale gas wells have been drilled in NY since 1900; 60 wells have been drilled since 1965.
- 98% targeted Devonian shale; 2% targeted Silurian shale.
- Most New York shale wells currently produce for home or small commercial use.
- Since 1980, most shale R&D activity has targeted the deeper Marcellus Shale.
- Current activity includes testing the Upper Devonian in western New York and western Pennsylvania.

New York Producing Shale Fields





Silurian Age Shale

Lower Silurian Clinton Group shales of potential interest for gas production include the Sodus Shale and the Rochester Shale.[25] Both are primarily gray shales; no data are available on the organic carbon content. Two one-well gas fields produced from Silurian shales. Reeder Creek Field in Seneca County was completed in the Rochester Shale in 1989 and has since been abandoned, and Meridian Exploration discovered the Neilson Road Pool in 1990, which produced 84 MMcf.

Utica Shale

The Ordovician-age Utica Shale is an organic-rich and thermally-mature black to grey-black shale that overlies the Trenton Limestone. The Utica Shale outcrops along the west and south-southeast sides of the Adirondack Mountains but is deeply buried across most of the State. The Utica Shale is considered to be the source rock for lower Devonian through Cambrian oil and gas production. Across much of the State, the Utica Shale is approximately 300 feet thick, thinning to the west and north. Estimated total organic carbon content ranges from 1.5 to 3.0 percent in eastern New York and from 2 to 15 percent in northern New York, Ontario and Quebec.[26]

Significant gas shows have been encountered while drilling through the Utica Shale. NYSERDA is funding detailed geological studies of Utica Shale reservoir properties and resource potential to develop an exploration model that would promote production testing using modern completion technology.

Medina Group 'Tight Gas'

The Lower Silurian age Medina Group sandstones comprise the dominant tight gas sandstone play in western and southwestern New York. The Medina tight gas is trapped in low porosity, low permeability sandstone reservoirs, which require hydraulic fracturing to produce gas at economic rates.[28] Hydraulic fracturing is the practice of pumping fluids into the formation at high pressure to crack the rock so that natural gas can flow more easily to the well bore. Low permeability sandstone reservoirs of the Medina Group were extensively explored in the 1980s as a result of the Federal Energy Regulatory Commission Tight Gas Sand designation. Production from the Medina tight peaked in the mid-1980s. In 2005, the Medina produced more than 8.5 Bcf from 5,223 active wells, contributing 15 percent of New York's total annual gas production and accounting for 76 percent of New York's total non-Trenton-Black River production of 11.2 Bcf.[29]

Despite being a mature play, the Medina tight gas sandstones are estimated to have substantial remaining undiscovered resource potential. The USGS recently estimated more than 4 Tcf of undiscovered Medina resources in New York. Operator interest in the Medina remains strong in response to sustained high gas prices, and relatively low drilling costs, and low drilling risk.

A successful Medina production strategy includes the application of cost-effective new technologies and practices to optimize individual well performance and total field production.

New technologies and operating practices aimed at improving marginal well performance have been developed. Not only does the Medina continue to provide infill drilling and well recompletion opportunities, but the formation has remaining potential for field extension and occasional wildcat drilling. Typical Medina wells in New York recover 80 to 100 MMcf of reserves; seventy Medina wells were drilled in 2005.[30]

New Technology Solutions Help Maintain Well Production and Optimize Performance of Tight Gas Fields

A NYSERDA-funded research project found that a persistent and widespread production problem in New York's Medina wells is the accumulation of produced water in the well bore, which reduces the gas flow rate to below economic levels and may kill gas production altogether. Regular removal of the accumulated water increases average gas production. Conventional water removal techniques such as swabbing and beam pumps are too costly for many of New York's tight gas wells and wells may be prematurely abandoned.

A cost-effective water removal technology has been developed with support of the Stripper Well Consortium and NYSERDA. The Gas-Operated Automatic Lift (GOAL) PetroPump is designed to freely operate within the well casing. The pump rises when gas pressure builds up below the piston, carrying accumulated water to the surface where the water is discharged and the accumulated gas is produced. The pump then descends back downhole as wellhead pressure declines.

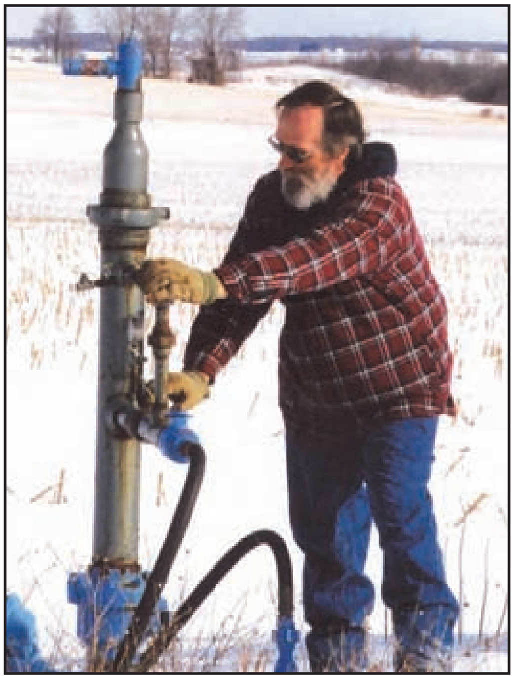
Lenape Resources, one of the larger independent producers in New York State, installed the PetroPump in a 3,200-foot Medina completion that produced about 1,100 Mcf/year and required periodic soaping and swabbing to remove brine. Production after tool installation averaged 3,416 Mcf/year and payout was achieved in eight months. Several other subsequent installations by Lenape Resources resulted in similar increases in production.[27]

New Frontiers in Deep Gas

The Appalachian Basin has been called the "most drilled and least explored" basin in the world. The Appalachian Basin overall is mature in terms of shallow production (at depths less than 5,000 to 6,000 feet), but deeper gas formations offer a new exploration frontier.

What is "deep gas" in New York? Deep gas can be thought of as gas produced from reservoirs located at significant physical depths of 7,500 to 10,000 feet or more below the surface. But "deep gas" in New York can also be thought of as under-explored sedimentary formations in the lowermost portion of New York's stratigraphic section, regardless of physical depth. Such formations are Middle to Late Ordovician to Cambrian in age and include the Trenton, Black River, Theresa and Potsdam. In the Finger Lakes area and Southern Tier, Middle and Lower Ordovician and older formations are quite deep. To the north and west, the Middle Ordovician age and older formations, including the Trenton, the Black River and formations below, are found at much shallower depths.

By either measure, New York has untapped "deep" exploration potential. Of more than 33,000 wells currently in the New York well database, fewer than 600 wells were drilled deeper than 5,000 feet. Only 655 wells in New York's current database were drilled to the Trenton Formation or deeper. (This total may not include recent Trenton-Black River wells, which are confidential.) Fewer than 110 wells have penetrated the entire sedimentary section.[31]



Tending a Medina Gas Well.

Upper Cambrian Theresa Sandstone Play

The Theresa Sandstone play (Galway Formation) consists of Upper Cambrian age sandstone reservoirs that lie at or near the Knox Unconformity. The Theresa Sandstone in New York is equivalent to the active Rose Run Sandstone play in Ohio, and underlies most of western New York at depths ranging from 3,000 to 13,000 feet. The thickness of the formation increases to the south to more than 260 feet; the porosity of the Theresa Sandstone ranges from 6 to 12 percent. Theresa wells are drilled vertically to depths ranging from 5,000 to 7,000 feet.

Although the Upper Cambrian Theresa Sandstone has produced gas from a few small fields in western New York since 1990, the Theresa has not been widely explored. Recent discoveries in the Theresa (notably Ardent Resources' Bockhahn Field in 2004 in Erie County), in addition to many gas shows in the Theresa, have prompted renewed interest in understanding the rock properties and regional distribution of Theresa Sandstone reservoirs. Three wildcat wells were drilled for Theresa objectives in 2004. The Theresa produced more than 430 MMcf from six wells in 2005.

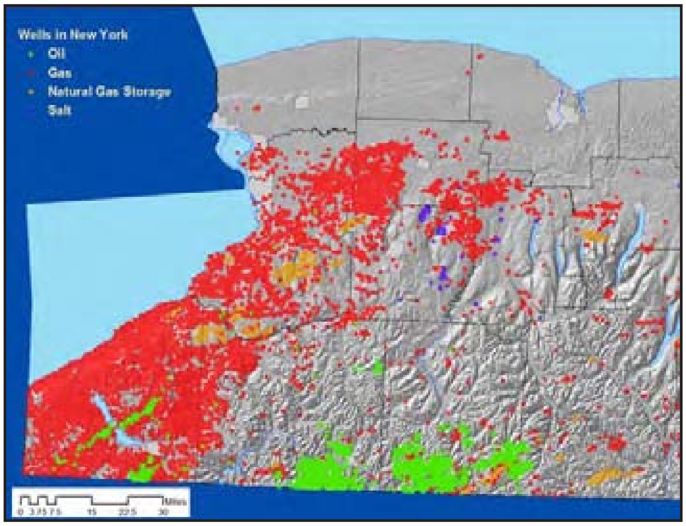
Ardent Resources is updating older studies of the Cambrian-Ordovician stratigraphy in New York using new well log data from wells that have penetrated the Trenton-Black River and deeper formations. Seismic data acquired for Trenton Black River exploration could potentially be used to refine exploration prospects for the Theresa Sandstone. [32, 33]

Extracting More of New York's Crude Oil Potential

New York has produced approximately 245 million barrels of oil since 1880. Today, all of the State's oil production is characterized as stripper well production. New York's stranded oil resources, remaining after traditional primary and secondary oil recovery, are unknown, but are thought to be as much as 255 million barrels.

As the average wellhead price of oil has more than doubled since 2003, New York has seen a surge of interest in the State's remaining oil potential. Annual production of more than 211,000 barrels for 2005 represents a nearly 15 percent increase over 2004 production of 184,000 barrels.

The majority of oil production in New York is from Upper Devonian sandstone reservoirs of the Canadaway Group. Oil is also produced from naturally fractured Bass Island Dolomite and Middle Devonian Onondaga Limestone. The sandstones in the upper part of the Canadaway and the Conneaut Groups in New York correlate to the Bradford sandstones in Pennsylvania. New York's Conewango Group correlates to the Venango sandstones in Pennsylvania. Only recently have modern analytical techniques and concepts been applied to New York's Upper Devonian reservoir sandstones. The goal of current research by the University of Buffalo, funded in part by NYSERDA, is to develop modern models for the Upper Devonian sandstones in western New York State that relate the productive oil fields to sandstone deposition, faulting, folds and basement structure. Such work could result in effective exploration strategies for overlooked or by-passed oil reservoirs, leading to new approaches for extracting the substantial "stranded" oil resources in New York's old producing fields. [36]



Map of Southern Tier and Western New York showing oil producing areas (green) and natural gas producing areas (red). Courtesy of the NY Division of Mineral Resources.

What is a Stripper Well?

Stripper wells (also called marginal wells) are defined as oil wells that produce less than 10 barrels (bbl) of oil per day, or gas wells that produces less than 60 thousand cubic feet (Mcf) of natural gas per day. In 2005, 401,072 stripper oil wells in the United States produced a total of 321 million barrels, which was 17 percent of domestic oil production. That same year 288,898 stripper gas wells produced more than 1.76 Tcf, representing 9 percent of domestic production. The average marginal gas well in the United States produces 16.7 Mcf per day and the average marginal oil well in the U.S. produces 2.2 barrels per day.[34]

All oil production in New York is stripper well production. The average New York oil well produces 0.21 barrels per day, or approximately 76 barrels per year. Average stripper gas production from non-Trenton Black River gas wells in New York is approximately 4.8 Mcf per day, or approximately 1.75 MMcf per year.[35]

CO_2-Enhanced Oil and Natural Gas Recovery and CO_2 Storage

From 50 to 80 percent of oil-in-place and from 20 to 30 percent of natural gas-in-place typically remains trapped in New York's depleted oil and gas fields, not recoverable by traditional primary and secondary recovery techniques. CO_2 flooding is the fastest growing form of enhanced oil recovery (EOR) in the United States, producing an estimated 237,000 barrels per day in 2006. One of the most attractive features of CO_2 injection for EOR is that the CO_2 can be from industrial facilities that may otherwise vent the CO_2 to the atmosphere, contributing to global warming.

CO_2-EOR is most effective if reservoir depth and pressure are great enough to inject CO_2 at sufficient pressure to achieve miscibility with oil contacted in the reservoir. There has been little CO_2-EOR attempted in Appalachian Basin oil fields, and none in New York oil fields. Most New York oil fields have insufficient depth and reservoir pressure for miscible CO_2 floods. Some deeper oil reservoirs might be candidates for less-efficient but still potentially viable immiscible CO_2 floods, and as candidates to permanently store, industrial sourced CO_2.

In addition, CO_2-enhanced gas recovery (EGR), while still in the conceptual stage, is thought to be a likely result of injection of CO_2 into a depleted gas reservoir for the ultimate purpose of sequestering the CO_2. New York's deeper sandstone reservoirs may have potential for substantial CO_2 storage plus incremental gas recovery. CO_2-EGR has yet to be adequately tested. New York's organic-rich shales may also provide an attractive CO_2 sequestration opportunity because the CO_2 can be absorbed onto the shale. CO_2 storage in organic-rich shales is still in the conceptual stage.