New York Fractured Reservoir Project

Phase I - Regional Assessment
Summary Report

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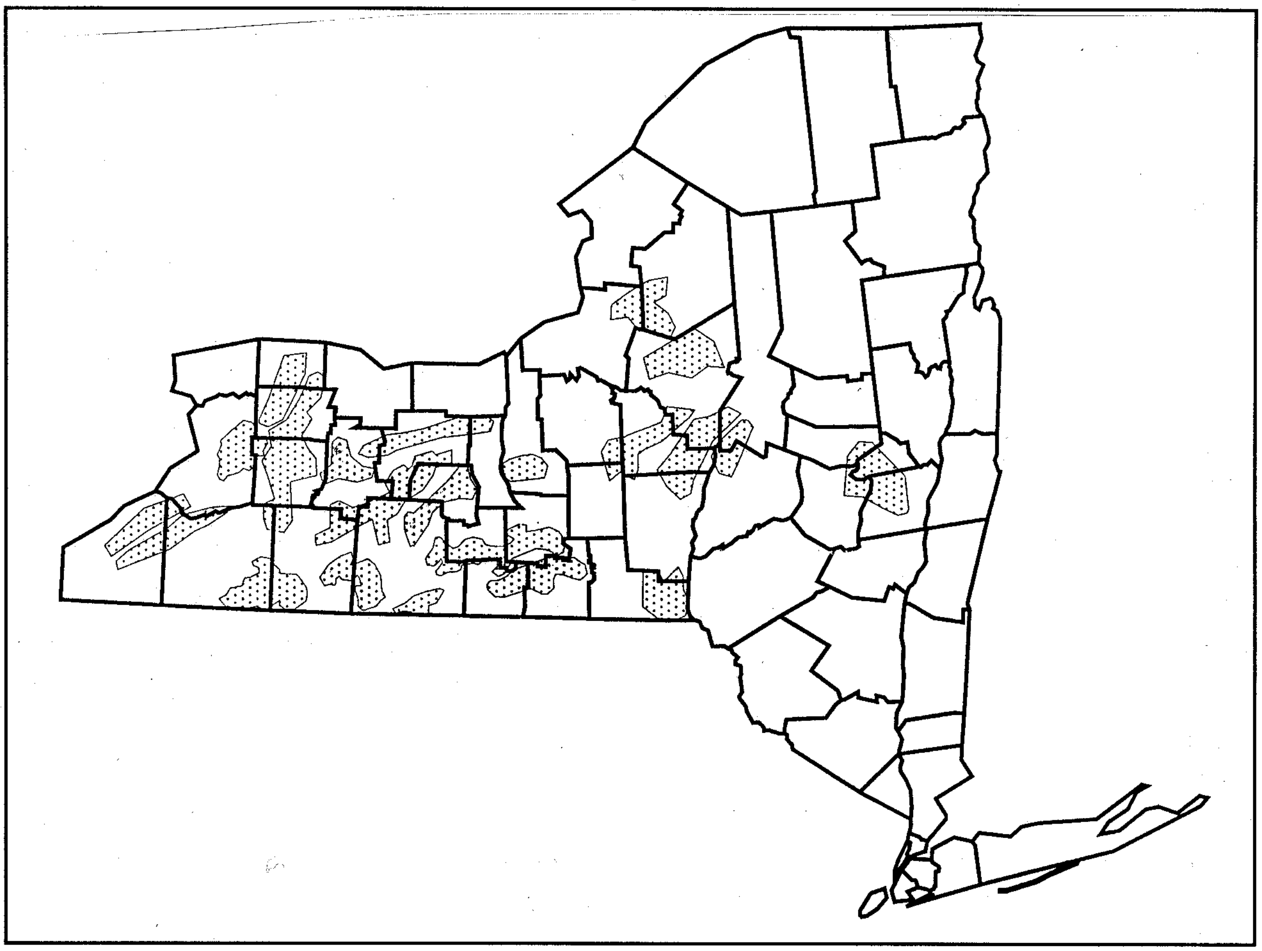
Executive Summary

Current techniques for fractured reservoir detection were applied to middle Devonian shales and associated siltstones/sandstones and to the Ordovician Queenston Formation of New York's Appalachian Basin. The existing literature was reviewed and the data were evaluated and used to determine major geologic influences on fracture development. Production and show data were collected, compiled and analyzed.

A regional geologic analysis was performed using the assembled data and Earth Satellite Corporation's fracture analysis based upon satellite imagery. Promising evidence was found to suggest the existence of a significant fractured reservoir play in the examined geologic intervals. Multiple intervals of potential source rocks appear to be present. Areas with the most potential were identified and mapped as exploration fairways (Exhibit E-1).

Exhibit E-1. Potential Exploration Fairways for Fractured Reservoirs



The Exploration Fairways for the middle Devonian Marcellus Shale through upper Devonian Perrysburg Formation can be divided into two groups. In south-central New York, Exploration Fairways regionally follow structural trends, and hydrocarbons in these fairways will likely be thermally generated. Along the Devonian outcrop, the fairways may be more analogous to the Michigan Basin Antrim Shale with fractures initially created by tectonic forces or natural hydraulic fracturing during hydrocarbon generation. There is the potential, though yet untested, that gas in this area may have a biogenic (bacterial) component.

The Ordovician-aged Exploration Fairways have a different overall trend than the Devonian. The Ordovician-aged fairways in E-1 are those with a predominantly north-south orientation. These fairways may also have reservoir potential in the Devonian sequences but are probably less attractive as Devonian exploration targets.

As a group, the Ordovician orientations are somewhat less favorable for development of fractured reservoirs. Reservoirs may require other additional mechanisms besides fracture systems to create or enhance reservoir permeability. The Ordovician units near their outcrop may also be Antrim-type fractured reservoirs. In south-central New York, surface expression of Ordovician-age structures are muted by the Salina Salt horizon. The subsalt Ordovician-aged trends that do emerge suggest that the potential for fractured reservoirs but the lack of well data points inhibits further interpretation.

More detailed evaluation of the fairways is required to defined their reservoir potential. Additionally, potential recovery is undetermined since existing completion reports indicate that the wells were not appropriately or adequately tested. Technologies and techniques are now available to enable accurate prediction of reservoir location and efficient exploitation of these fractured reservoirs. A systematic, carefully planned exploration program, followed by a state-of-the-art drilling and development plan designed specifically for fractured reservoir recovery could result in the creation of a significant new gas play in New York.

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1. Introduction

Exhibit 1. Stratigraphy of Southwestern New York
(from Isachsen et al., 1991)

PERIOD		GROUP	UNIT	(rock type)	Thickness	Production
Penn.		POTTSVILLE	OLEAN	(ss,cgl)	25-30 m	
Miss.		POCONO	KNAPP	(ss,cgl)	15-30 m	
DEVONIAN	UPPER	CONEWANGO		(sh,ss,cgl)	215 m	
		CONNEAUT	CHADAKOIN	(sh,ss)	215 m	
		CANADAWAY	UNDIFF. +	(sh,ss)	335-425m	Oil, Gas
			PERRYSBURG# DUNKIRK	(sh,ss) (sh)		Oil, Gas
		WEST FALLS	JAVA NUNDA RHINESTREET	(sh,ss) (sh,ss)	115-380m	Oil, Gas
		SONYEA	MIDDLESEX	(sh)	0-120 m	
		GENESEE		(sh)	0-135 m	
	MIDDLE		TULLY	(ls)	0-15 m	Gas
		HAMILTON	MOSCOW LUDLOWVILLE SKANEATELES MARCELLUS	(sh) (sh) (sh) (sh)	60-185 m	Gas
			ONONDAGA	(ls)	10-70 m	Gas, Oil
	LOWER	TRISTATES	ORISKANY	(ss)	0-10 m	Gas
		HELDERBERG	MANLIUS RONDOUT	(ls,dol)	0-3 m	
SILURIAN	UPPER		AKRON	(dol)	0-5 m	Gas, Oil
		SALINA	CAMILLUS SYRACUSE VERNON	(sh,gyp) (dol,sh,salt) (sh,salt)	135-465m	
		LOCKPORT	LOCKPORT	(dol)	45-75 m	
		CLINTON	ROCHESTER IRONDEQUOIT	(sh) (ls)	40 m	Gas
	LOWER		SODUS REYNALES	(sh) (ls)	25 m	
			THOROLD	(ss)	1-2.5 m	
		MEDINA	GRIMSBY WHIRLPOOL	(sh,ss) (ss)	25-45 m 0-10 m	Gas Gas
ORDOVICIAN	UPPER		QUEENSTON OSWEGO	(ss)	335-455m	Gas
			LORRAINE UTICA	(ss,sh) (sh)	275-305m	
	MIDDLE	TRENTON-BLACK RIVER	TRENTON GP. BLACK RIVER GP.		130-190m 70-170m	Gas
	LOWER	BEEKMANTOWN	TRIBES HILL	(ls)	0-170 m	
CAMB.	UPPER		LITTLE FALLS GALWAY POTSDAM	(dol) (dol) (ss)	0-105m 175-410m 25-150m	 Gas Gas
PROTEROZOIC			GNEISS, MARBLE, QUARTZITE, etc.			

\+ Includes Glade, Bradford 1st, Chipmunk, Bradford 2nd, Harrisburg Run, Scio, Penny and Richburg.

\# Includes Bradford 3rd, Humphrey, Clarksville, Waugh & Porter and Fulmer Valley.

New York's Devonian and Ordovician clastic sequences provide a potentially unique opportunity. They have not been carefully examined since the emergence of fractured reservoir gas plays. This study re-evaluated upper Ordovician Utica Shale and Queenston Formation, and middle Devonian Marcellus Shale through the upper Devonian Perrysburg Formation (Exhibit 1). Promising areas and intervals were examined for their potential to contain commercial gas resources.

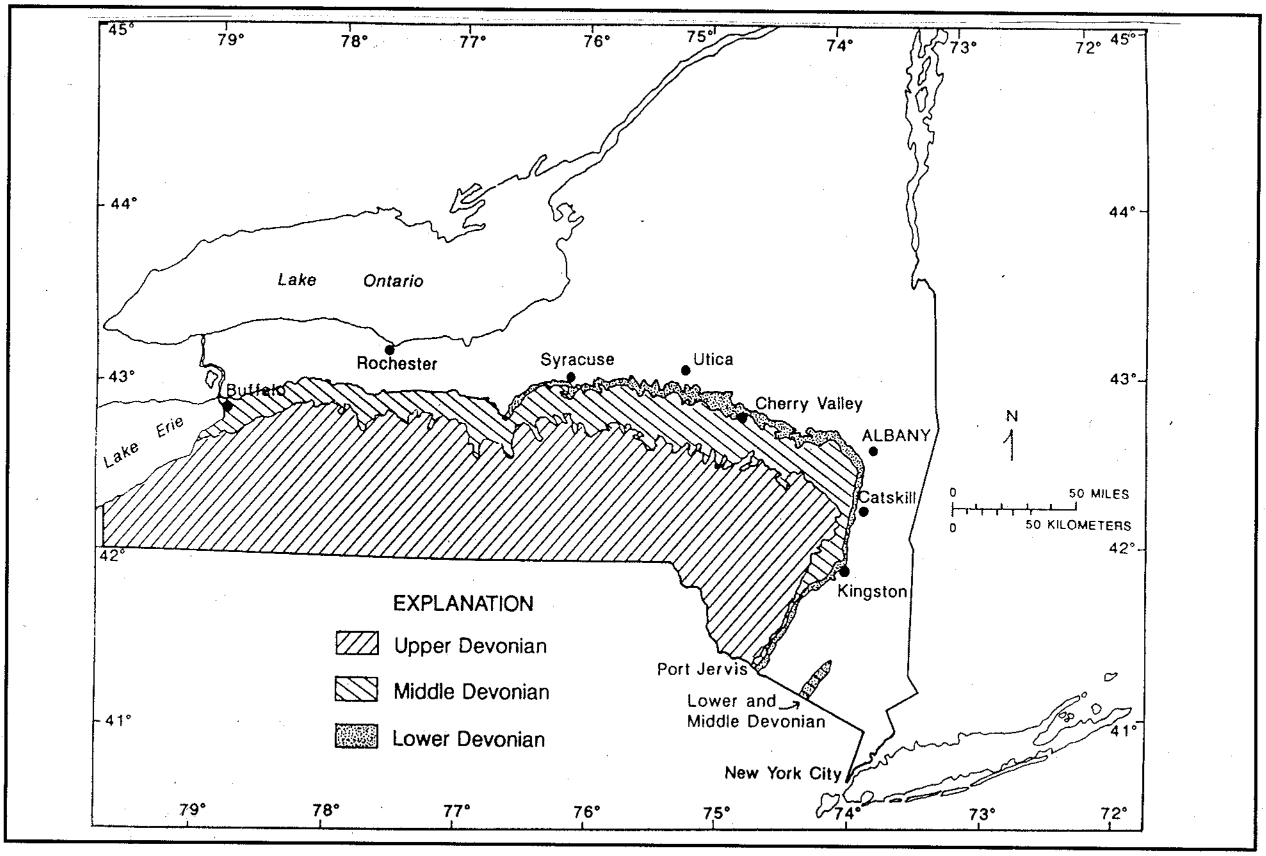
Gas production from New York's Devonian shales dates back to 1891 when a well was drilled near Fredonia to supply gas for street lamps. More recently, minor amounts of gas have been consistently produced in Allegheny County with periodic production reported since 1985 in Cattaraugus, Chautaugua, Ontario and Wyoming Counties. The producing horizons have been the Dunkirk Shale, the Rhinestreet Shale, and horizons in the Hamilton Group. In addition, gas shows have been reported in the Middlesex and Geneseo-Pen Yan Shales.

Historic production has primarily been for home use, although several fields have been briefly exploited commercially. The most recent concerted effort was the jointly funded U.S. Department of Energy (DOE) and N. Y. State Energy Research Authority (NYSERDA) shale-gas project during the late 1970s and early 1980s.

Similar to other recently "rediscovered" shale plays, most of the historic production in New York occurred before the underlying mechanisms that create and sustain fractured reservoirs generally, and shale reservoirs in particular, were understood. Additionally, techniques and technologies that optimize the productivity of these reservoirs have only recently been fully developed. Successful fractured reservoir plays rely on identifying and locating "open" intersecting fracture sets in areas with high hydrocarbon generative and storage capacity. Recent technological advances and better understanding of the geologic conditions that create fractured reservoirs now allow more systematic evaluation and successful exploitation of these plays. Examples include Michigan's Antrim Shale, the Austin Chalk trend in southern Texas, the Williston Basin's Bakkan Shale, and California's Monterey Formation.

Phase I of the New York Fractured Shale Project is a regional assessment that identifies the optimal areas for successfully fractured reservoir development in New York's Appalachian Basin region bounded by the Devonian outcrop (Exhibit 2).

Exhibit 2. Location of Area Studied
(from Isachsen et al., 1991)



2. Methodology

Previous research and data were compiled and critically reviewed. Production data, completion reports and well reports were acquired and evaluated. These data were then combined with Earth Satellite Corporation's regional fracture analysis to delineate Exploration Fairways where the greatest potential exists for successful development of fractured reservoirs.

The areas with the greatest potential for fractured reservoir development in the clastic sequences of New York's Appalachian basin were identified by:

- examining the existing body of research, reviewing their data and conclusions based on current understanding of the most significant factors leading to creation of commercially viable fractured reservoirs.
- confirming or identifying horizons that could potentially contain sufficient hydrocarbons to make a commercial reservoir, including inferences gained from examining existing petroleum geochemistry data and the currently accepted tectono-stratigraphic relationships between the various Queenston Formation and Catskill deltaic sequences.
- collecting and analyzing existing production and show data for indicators of hydrocarbon potential within the identified horizons, including any completion or test data on the few Devonian shale wells that have been drilled or produced.
- identifying paleo-tectonic and ambient stress regimes that dictate orientation and density of fracturing in the horizons of interest which in turn suggest likely orientation and geometry of the potential fractured reservoirs.
- synthesizing these data with Earth Satellite's fracture mapping to identify Exploration Fairways, defined as areas where the data indicate the optimal development of fractured reservoirs.

2.1 Literature Review

Publicly available literature was searched and critical reviewed. References were compiled using AGI's GeoRef database into a bibliography of relevant publications. Using the USGS National Center Library in Reston, Virginia and assistance from the New York State Geological Survey in Albany, New York most of the references were located and obtained for review. Some references dating in the late 1800's were not found but, in most cases, pertinent information from them were reported in later publications. The bibliography concentrated on published references on the geology and production histories of the Ordovician and Devonian sections being evaluated. It is included as Appendix A.

The collected references were critically reviewed in order to determine:

- Structural and tectonic factors. The Devonian and Ordovician sections were examined independently since the Queenston Formation was more affected by the basement and early Paleozoic tectonic events while the Devonian was more affected by later tectonic events. These factors created and continue to define the location of the fractured reservoirs, the fracture density and orientations within the reservoirs which are required to create and maintain reservoir porosity and permeability, and the timing of hydrocarbon generation and expulsion.

- Stratigraphy. The distribution and thicknesses of potential producing horizons were evaluated. The horizons examined were the Ordovician Queenston Formation, and the Devonian Marcellus Shale, Geneseo Shale, Rhinestreet Shale, and Dunkirk Shale. Other potential horizons with documented shows were considered but not examined in detail due to the lack of publicly available information.

- Petroleum geochemistry. Published data on the organic content, the hydrogen content and the thermal maturity of the potential producing horizons were evaluated for preliminary indications of the type and potential quantity of hydrocarbons generated.

- Historical production and shows. Reported production and shows from the horizons, especially for wells drilled before reporting requirements were instituted by the New York Department of Environmental Conservation.

2.2 Data

Primary data sources for the Phase I regional assessment were:

- Well completion reports and production reports from the New York Department of Environment Conservation (NYDEC).

- Well completion reports and geologic data files from the New York Geological Survey (NYGS).

- Devonian shale records from Ardent Resources Inc.'s (Ardent) proprietary production database.

- The Patrick Petroleum well data cards owned by Lomak Petroleum, Inc. (Lomak).

- Maps and data from the U.S. Geological Survey's (USGS) open file reports and oil and gas investigation series.

- Preliminary results from ongoing USGS research on the thermal history of the northern Appalachian Basin and structural mapping of the Queenston Formation in Ohio, Pennsylvania, and New York.

- Data from the Department of Energy's Eastern Gas Shale Project including the Federal Energy Technology Center's revision of the original structural and isopach maps. These maps were reviewed and taken into consideration, primarily to confirm the existence and distribution of stratigraphic intervals of interest.

The well data and production data were reviewed and compiled into a series of data sets that were used to refine the areas and the horizons to be investigated. Electronic copies of the following data sets are provided in EXCEL 5.0 format:

- PRODATA.EXL - Base production data for all wells from designated intervals of the study (Ordovician Queenston Formation and Devonian Marcellus Shale through Perrysburg Formation), compiled from production data collected at the NYDEC and NYGS.

- DPRODATA.EXL - Production data of only Devonian wells which is a further refined subset for the PRODATA.EXL file after reviewing and incorporating data from the Ardent database;

- DWELLS.EXL - Well data on all wells from the Devonian intervals of interest.

- OWELLS.EXL - Well data on all wells penetrating the Queenston Formation.

- SHOWS.EXL - Compilation of all reports of oil and gas shows from the Devonian contained in Lomak's well cards, which was complete through

1977. A representative though less complete survey of wells drilled after 1977 was done with the assistance of the NYGS and using their files and databases.

3. Results

3.1 Geologic Analysis

The Devonian and Ordovician clastic sequences in New York, while not having been as directly impacted by the multiple Appalachian orogenic events were still affected by the stress regimes operating during the three main tectonic events (Taconic, Acadian and Alleganian orogenies). Review of the existing body of literature, and the results of Earth Satellite's fracture analysis suggests that several major fracture trends appear to have been created and periodically reactivated during these tectonic events. Current ambient stress in New York suggests that subsurface fracture orientations in a east-northeast direction will likely be most favorable as the major feeders for hydrocarbons into fractured reservoirs in either the source rocks or conduits to other reservoirs.

Potential for development of fractured reservoirs in the Devonian and/or Ordovician clastic sequences require:

- Areas with promising fracture densities relative to the paleo-tectonic trends and the ambient stress fields. The fracture densities need to be adequate for creating fractured reservoirs but must not be overly developed such that the reservoirs lose their coherence.

- Fracture orientations matching appropriate paleo-tectonic trends so that fracture creation or re-activation coincided with thermal maturation and expulsion of hydrocarbons. The orientations also needed to show intersecting patterns with one prominent orientation that it would serve as a conduit for hydrocarbons under the current ambient stress field and adequate "feeder" fracture orientations to that prominent fracture set.

- Stratigraphic intervals of organic rich shales. Prospective intervals include the Ordovician Utica Shale and Queenston Formation, and the Devonian Marcellus Shale, Geneseo Shale, Rhinestreet Shale, Dunkirk Shale and Perrysburg Formation.

- Correlation with known production and shows including those in the Devonian Marcellus Shale, other Hamilton Group horizons, Rhinestreet

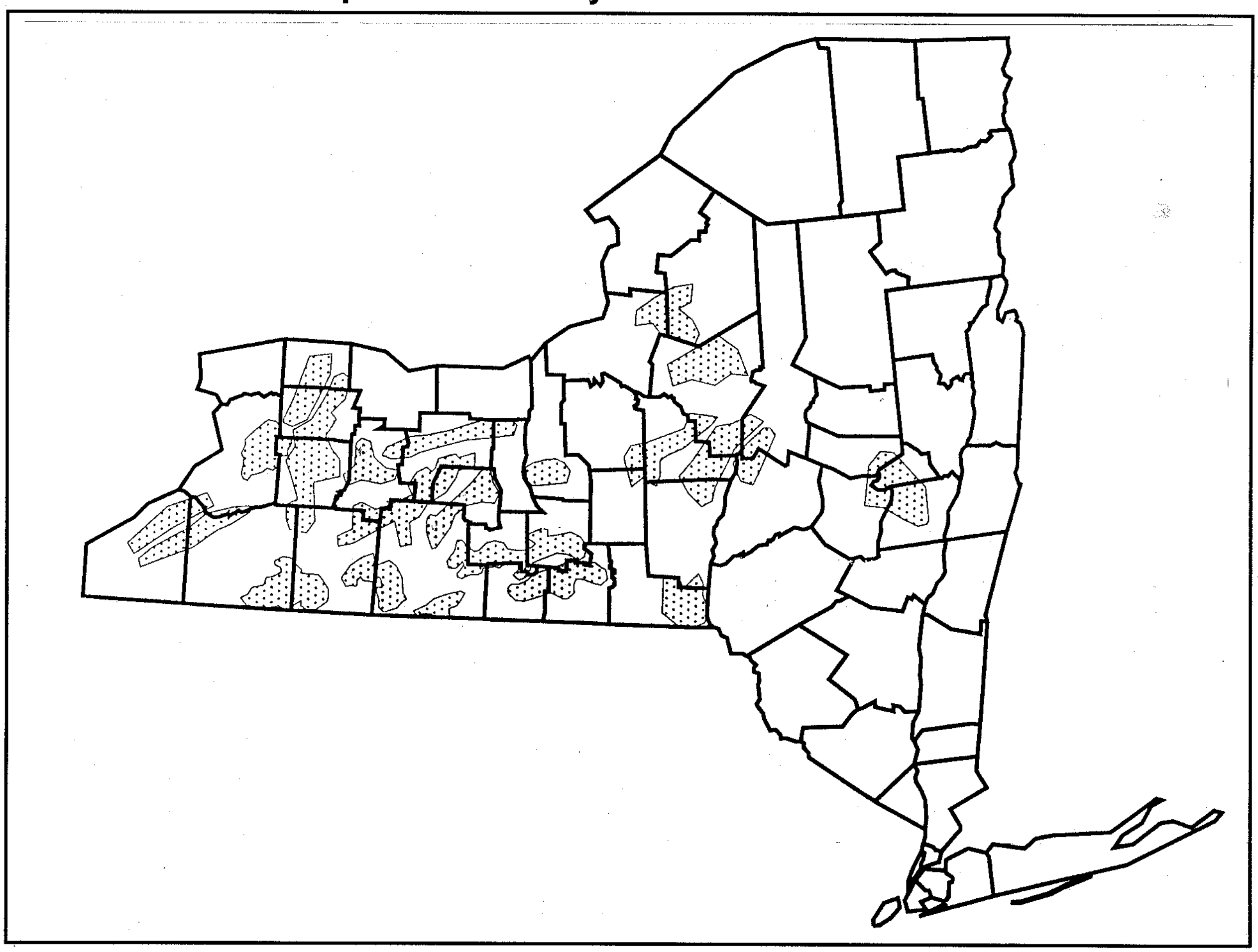
Shale and Perrysburg Formation and in the Ordovician Queenston Formation. In addition, shows were also reported in the Utica Shale, Geneseo Shale, and undifferentiated Devonian shale.

The final map of potential Exploration Fairways (Exhibit 3) summarizes the geologic integration of these factors. Integration of the available well and show data confirmed the geologically based predictions for promising fractured reservoir development. In addition, a few more fairways were added to include major areas of current industry activity that were not initially selected based strictly on the geologic criteria.

The Exploration Fairways consist of areas with shales and interbedded siltstones and sandstones in the Devonian or Ordovician intervals that could potentially contain commercially productive fractured reservoirs. These fairways have several common characteristics:

- Adequate measured thicknesses for source rocks or reservoir rocks.

Exhibit 3. Potential Exploration Fairways of Fractured Reservoirs



- Horizons whose petroleum geochemistry suggested that they could be within the range of other recognized source rocks.

- A geologic history conducive to producing several intersecting fracture orientations.

- Apparent correlation between regional geological trends and available production and show data.

The Devonian and Ordovician Exploration Fairways have different orientations. Fairways with the greatest potential for Devonian-aged fractured reservoirs are oriented predominantly in an east-northeast direction with well developed crosscutting fracture sets. These orientations reflect the influence of the Alleganian Orogeny, a northwest-southeast compressional event. While the Alleganian Orogeny dies out northward towards New York, structural trends of the Valley and Ridge Province can be traced in the fracture patterns and structural orientations of the central portion of New York's Appalachian Basin. Some of the mapped features suggest inversion structures and other fracture patterns similar to those reported for thrust fault frontal regions from other petroleum provinces of the world.

The fracture orientations of the Ordovician Utica Shale and Queenston Formation appear to be in a north-south direction. This is likely due to the Ordovician sequences reflecting structural trends of the basement and the Taconic orogeny. Any subsequent tectonism was, at best, muted vertically by the Salina Salt horizon, which absorbed all but the strongest tectonic forces of post-depositional tectonic activity. Additionally, movement in the Ordovician during later tectonism would have occurred preferentially along pre-existing plane of weaknesses rather than creating new fractures.

Detailed Exploration Fairway maps are found in Appendix B. These maps summarize the integration of the structural and tectonic interpretation, Earth Satellite's fracture analysis, and the production and show data. Also in Appendix B are maps showing the results of Earth Satellites geologic interpretation of lineaments and tonal anomalies and density contour plots of the identified fractures. Additional discussion of specific methodologies and results for these maps are found in their final report.

3.2 Petroleum Geochemistry

Existing data for hydrocarbon generation potential and source rock quality were reviewed by Dr. John Curtis. The data included information on:

- organic carbon content which is an approximate measure of the amount of kerogen, the parent material for hydrocarbons, present in the rock.

- the source rock quality as measured by its hydrogen content, as the generation of liquids and/or gases is limited by the amount of hydrogen available to combine with carbon to form hydrocarbons.

- thermal maturity of the organic matter which is a measure of how far the hydrocarbon-generating reactions have gone, and whether generated liquids have most likely been cracked to gas.

3.2.1 Organic Carbon Content

The bulk of available organic carbon data, reported as TOC (Total Organic Carbon) has been published by the U.S. Department of Energy and the U.S. Geological Survey. The results for western and central New York are sparsely distributed, both geographically and stratigraphically, but indicate that the Angola, Dunkirk, Rhinestreet, Geneseo, and Marcellus shale intervals in Allegheny, Broome, Chautauqua, Cattaraugus, Chemung, Chenango, Cortland, Delaware, Erie, Livingston, Madison, Steuben, Tompkins, Wyoming, and Yates Counties have at least some potential, based solely on TOC. (Leventhal, 1978; Claypool et al., 1980; Zielinski and Moteff, 1981) Please note that the intervals in most of these sampled wells are quite thin, and that they are often confined to the base of the Devonian section.

Upper Ordovician ("Utica Sequence") shale samples from 27 wells in New York were analyzed by the U.S. Geological Survey (Wallace and Roen, 1989). TOC values ranged from 0.01 to 3.19 weight %. Values in excess of 1.0%, which may have at least some hydrocarbon-generating potential, were concentrated in eastern and east-central New York.

3.2.2 Source Rock Quality

Information on source rock quality is rare for New York's Devonian sequence. The predominance of gas production in this portion of the Appalachian basin, gas compositional data and isotopic information indicates a thermogenic (as opposed to bacterial) origin for produced gas in western and central New York (Jenden, et al., 1993).

The hydrogen content of Utica sequence samples is low, based on pyrolysis data. These low present-day values indicate that gas production, not liquids would be expected from further maturation of these shales (Wallace and Roen, 1989). Liquids as well as gas may have been produced in the past, however. There is evidence that some produced Devonian gases were derived from deeper Ordovician shales (Jenden et al., 1993).

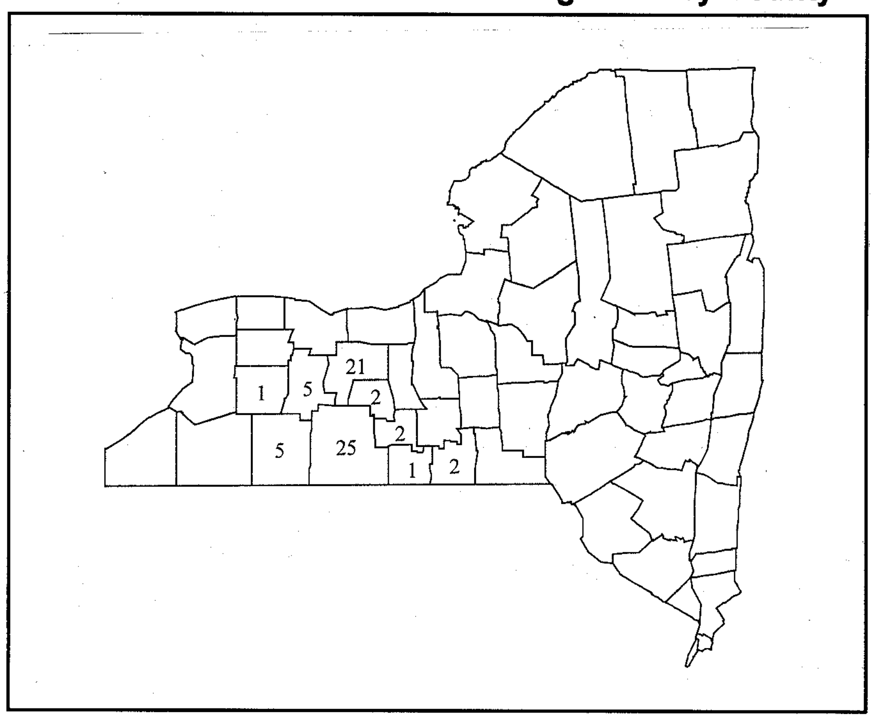
3.2.3 Thermal Maturity

Thermal Maturity information was derived from published conodont alteration indices, pyrolysis Tmax values and minor vitrinite reflectance data. The Devonian sequence in the study area is considered mature for minor liquid and major gas generation (Jenden et al., 1993). The Ordovician rocks in western New York are prone to generate some liquid and gas, while the eastern section of the state is gas-prone (Wallace and Roen, 1989).

3.3 Production History

Examination of production data concentrated on evaluating activity in the Devonian shale sequences from the Marcellus Shale to Dunkirk Shale. Data for the Perrysburg Formation and Queenston Formation were collected and incorporated at the request of the consortium but analysis of these data was minimal based on the scope of this study. Sixty-four wells have produced from Devonian Shale horizons (Exhibit 4). Their exact locations are plotted on the Exploration Fairways maps of Appendix B. Six Hundred and eleven wells also recorded shows or open flow tests in Devonian shales (Exhibit 5). A number of these flow tests were greater than 500 MMcf (Exhibits 6a and 6b). The well locations with shows are also plotted on the Exploration Fairways maps.

Exhibit 4. Devonian Shale Producing Wells by County



While never truly representative, the show data did reveal several interesting trends. First, the Devonian shales were actively drilled and produced in the late 1800s and early 1900s. They appeared to be considered a reliable source of natural gas. Several large discoveries were recorded, most notably the Rathbone Field in central Steuben County. As this was a fractured reservoir play, the wells and field did not behave as traditional fields and was quickly abandoned. Examination

Exhibit 5. Devonian Shale Gas Shows by County

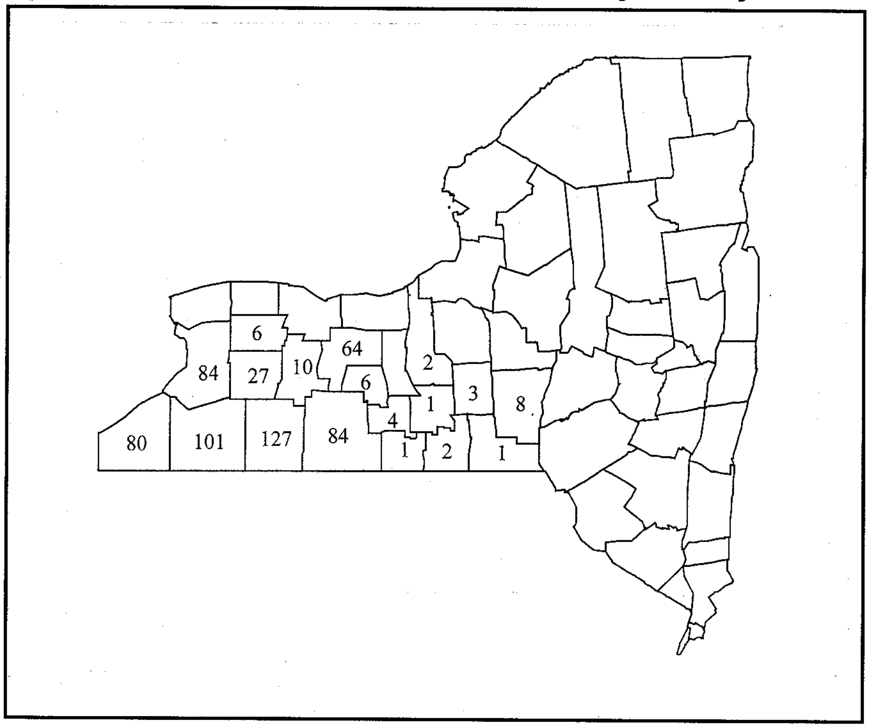
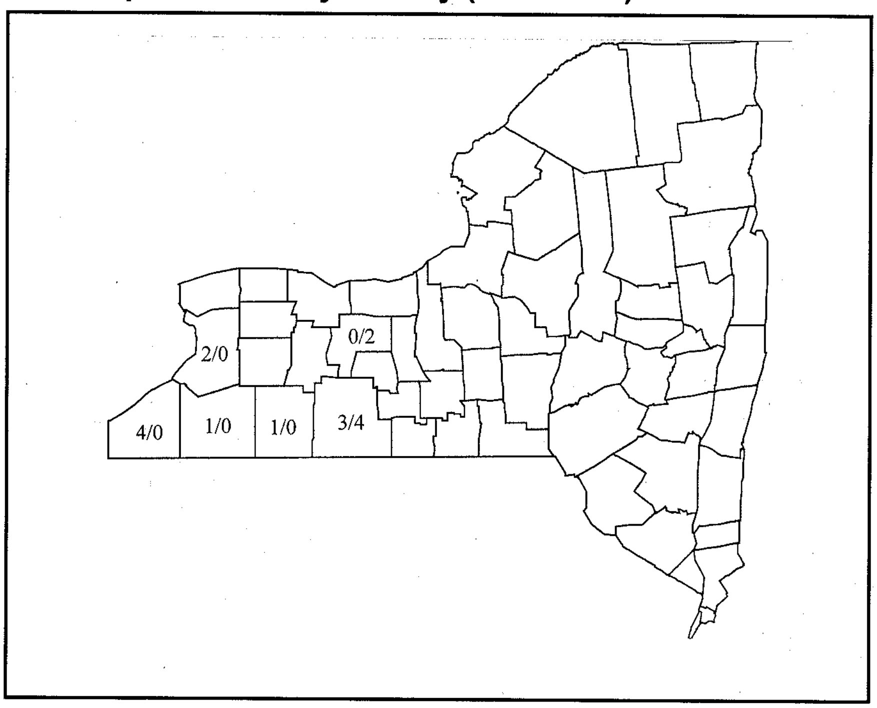


Exhibit 6a. 0.5 to 1 MMcf Devonian Gas Shows and Initial Open Flows by County (Show/IOF)

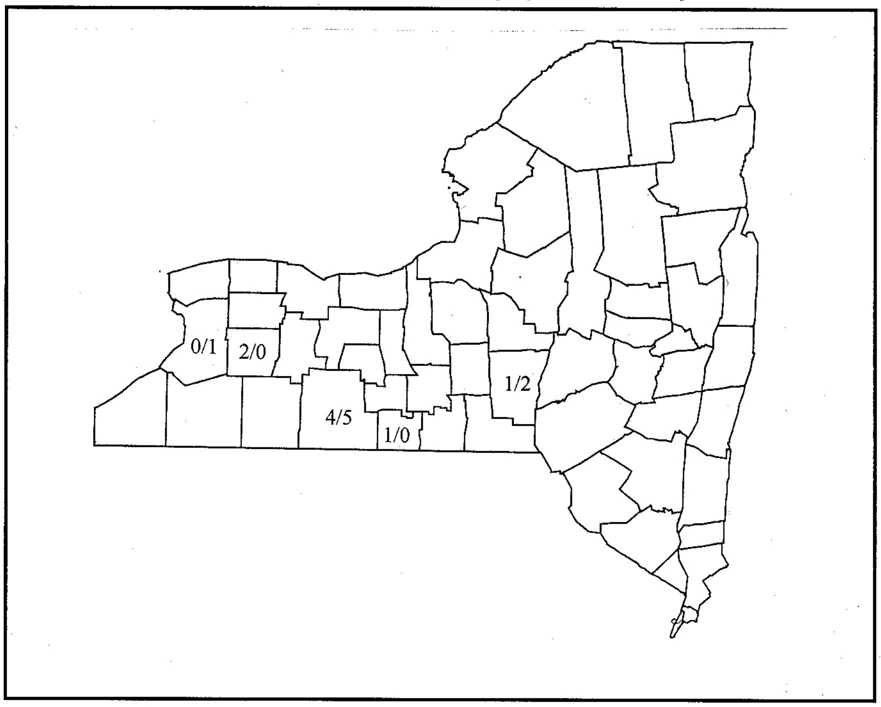


of the historical records bring up several intriguing possibilities

For example, the Rathbone Field discovery well, drilled in April 1931, had a 3.3 MMcf show with water and an initial open flow of 1 MMcf/D which declined to a respectable final open flow of 886 Mcf/D at a reservoir pressure of 225 pounds. All the good wells in the field had shows or initial open flows of greater than 1 MMcf/D. The bad wells were almost completely tight, a common characteristic of data for historic fields that are now considered to be fractured reservoir plays.

Almost all significant reports of shows or initial open flows greater than 1 MMcf/D occurred in the 1940s and 1960s and came from the central portion of the basin. They were from wells drilled in Steuben, Chenango and Chemung Counties. The potential production intervals were located in the range of 1,000 to 3,000 feet of drilled depth. The production intervals were in the Devonian Hamilton Group or the Rhinestreet

Exhibit 6b. Greater than 1 MMcf Devonian Gas Shows and Initial Open Flows by County (Show/IOF)



Shale. These wells are located within some of the more promising Exploration Fairways identified for the south-central area of this study. Successful wells in these fairways have the potential for higher recovery rates and ultimate recoveries than successful wells drilled near the outcrop. However, the reservoirs in these fairways will be predominantly structurally controlled so exploration and subsequent well locations need to carefully consider both regional trends and local geologic factors.

3.4 Historical Well Assessment

Seventy-two wells with historical Devonian shale production were sent to S.A. Holditch & Associates, Inc. (Holditch) for evaluation. Thirty-eight wells, all drilled after 1960, were determined to contain enough information for Holditch to perform a preliminary assessment of the recovery potential for New York's Devonian shale.

3.4.1 Openhole Completions

Seventeen of the wells had openhole completions (Exhibit 7). The operators's state completion reports contained gas and water test rates that appear to represent short-term production tests to atmosphere. The gas rates ranged from 0 to 2,000 Mscf/D. Most of the wells tested the shale at shallow depths. Only two of the wells were stimulated using Judymite. The openhole tests without a sand hydraulic fracture treatment did not adequately test the shale potential. Sand treatments are generally regarded as the best initial method to connect the wellbore with the naturally fractured system compared to using only nitrogen as a stimulation fluid.

Exhibit 7. Openhole Completions by County

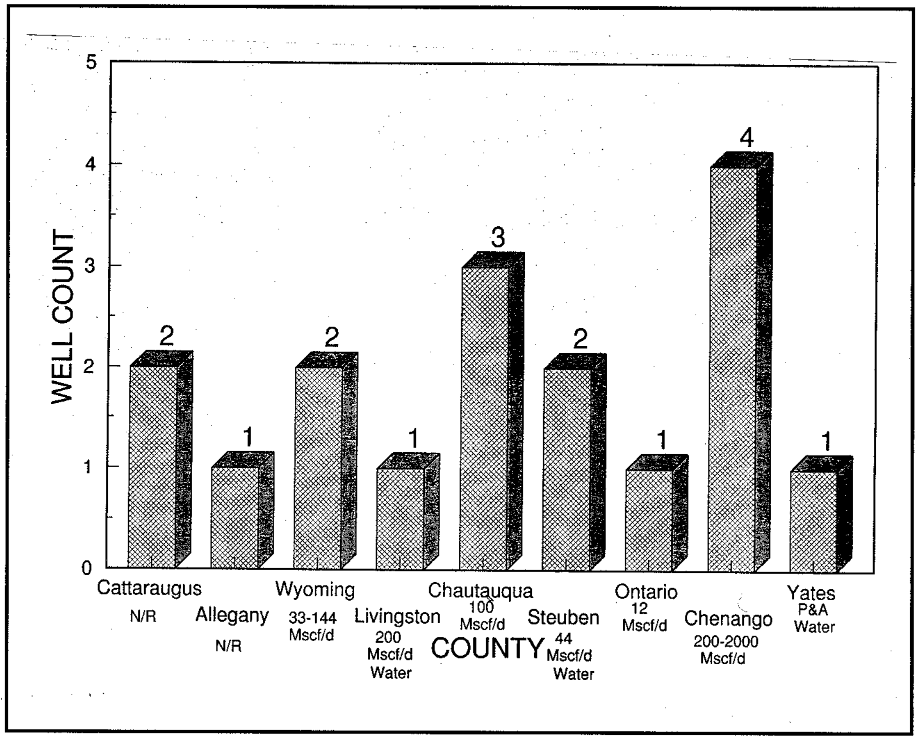
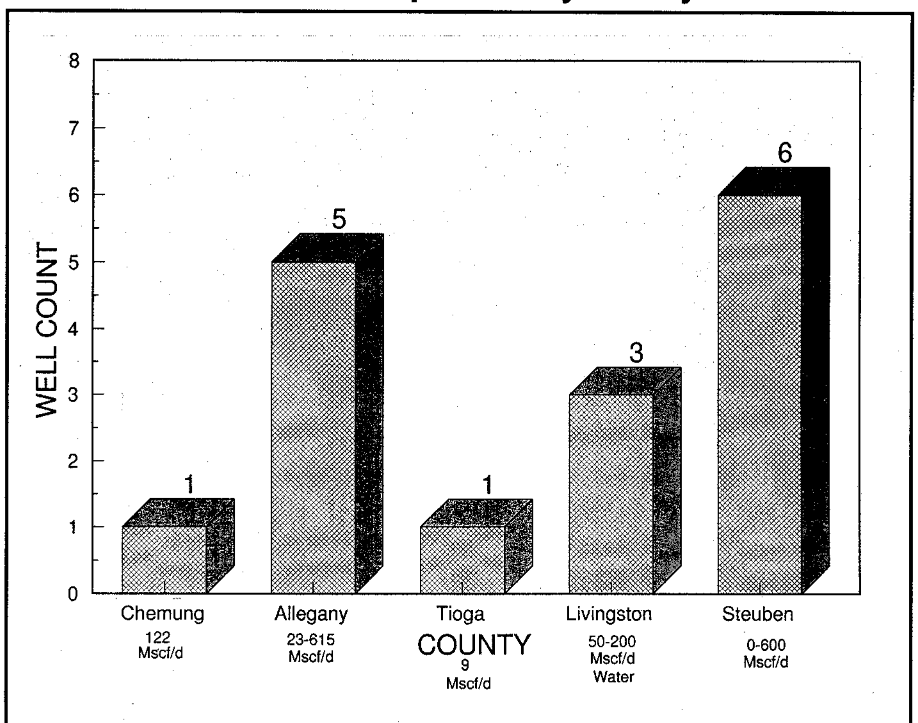


Exhibit 8. Casedhole Completions by County



3.4.2 Casedhole Completions

The remaining twenty-one wells were casedhole completions (Exhibit 8). Shale horizons were tested in both shallow and deep wells. The gas rates ranged from 0 to 600 Mscf/D with water noted in a shallow Livingston County test. Eighteen of the wells were stimulated with single-stage nitrogen foam fracture treatments. The treatment sizes ranged from 25, 000 to 80,000 pounds of proppant. These wells may not have effectively tested all zones if multiple shale intervals are present. In many cases, potentially productive Devonian shales in New York occur as multiple, organic rich units. Like Michigan's Antrim Shale, separate treatments would probably have to be performed on each organic rich shales intervals in order to effectively produce these shales. One well was stimulated with a nitrogen treatment. The well were flowed up 4½ inch casing.

3.4.3 Water Production

Water was noted in openhole completions of Livingston, Steuben and Yates Counties. Water was also reported in a casedhole completion in Livingston County. One shallow openhole shale well was not tested because of water production, presumably originating from the shale. These wells with reported water production cannot be adequately assessed for their true potential. None of the reports indicated installation of pumping units to lift the water. If the shales producing water in New York behave similar to Michigan's Antrim Shale, downhole pumps could be used to dewater the natural fracture system and initiate/or improve gas recovery. They should have been tested by using a downhole pump set below the perforations. Flowing shale wells producing gas and water will not show their production potential due to the additional hydrostatic pressure caused by the water and the gas-water relative permeability effects around the wellbore. Water bearing shales must be dewatered to realize optimal productivity.

4. Conclusions

Regional assessment of New York's Appalachian Basin indicates significant potential for the existence of fractured reservoir plays in the middle Devonian through upper Devonian clastic sequences and some potential exists in the Ordovician Queenston Formation and Utica Shale below the Salina Salt horizon. Good evidence for sufficient reservoir and source rock intervals were found. Natural methane seepage and published hydrocarbon geochemistry suggests that hydrocarbon generation was present.

Four sets of Exploration Fairways were defined. The most promising Devonian-aged fairways are oriented east-northeast. The fairways for the middle Devonian Marcellus Shale through upper Devonian Perrysburg Formation can be divided into two groups. In south-central New York, Appalachian structural trends from the Alleganian Orogeny (i.e. Pennsylvania's Valley and Ridge Province) show a subtle manifestation. The Exploration Fairways in this area of the basin appear to reflect some of these structural trends, and hydrocarbons in these fairways will likely be thermally generated.

The second group of Devonian-aged Exploration Fairways occurs around the basin perimeter near the Devonian outcrop. These may be more analogous to the Michigan Basin Antrim Shale with fractures initially created by tectonic forces or natural hydraulic fracturing during hydrocarbon generation. There is the potential, though yet untested, that gas in this area may have a biogenic component. Available well reports from this area almost always indicate water production in association with gas, another Antrim-like characteristic. None of the wells have been tested using current techniques and understanding of fractured shale reservoirs.

The Ordovician-aged Exploration Fairways have a different overall trend than the Devonian. Movement in the Ordovician during later tectonism probably occurred preferentially along pre-existing planes of weakness (i.e. re-activation of existing fractures or in the overlying Salina Salt). The Ordovician-aged fairways are predominantly oriented north-south. These fairways may also have reservoir potential in the Devonian sequences but are probably less attractive as Devonian exploration targets.

As a group, the Ordovician orientations are somewhat less favorable for development of fractured reservoirs. Reservoirs may require other additional mechanisms besides fracture systems to create or enhance reservoir permeability. Along the rim of the Basin, the Ordovician may exhibit the same characteristics near its outcrop as the middle Devonian horizons. Potential for Antrim-type fractured reservoirs could exist in the Ordovician Utica Shale that underlies the Queenston Formation. In the south-central area, surface expression of Ordovician-age structures are muted by the Salina Salt horizon and publicly available subsurface data were too sparse to gain significant insight into their potential. The subsalt Ordovician-aged trends that do emerge suggest that the potential for fractured reservoirs but the lack of vertical data points preclude further evaluation of their location or potential characteristics

More detailed evaluation of the fairways are required to defined their reservoir potential. Additionally, potential recovery is undetermined since existing completion reports indicate that the wells were not appropriately or adequately tested. Technologies and techniques are now available to enable accurate prediction of reservoir location and efficient exploitation of these fractured reservoirs. A systematic, carefully planned exploration program, followed by a state-of-the-art drilling and development plan designed specifically for fractured reservoir gas recovery could result in the creation of a significant new gas play in New York.

Appendix A
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Appendix B

Maps