RESERVOIR CHARACTERIZATION OF SENECA RESOURCES HUNTLEY #1 WELL
(API# 31-075-23071-0000)
OSWEGO COUNTY, NEW YORK

Final Report Submitted to

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Research and Development Authority

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ABSTRACT

Sidewall cores, logs and drilling information from the Huntley #1 well were analyzed in an effort to better understand the enigmatic Trenton Limestone reservoir in north central New York. Gas has been produced from the Trenton Limestone in this area for more than 120 years. Gas encountered during drilling of these wells is commonly highly overpressured, but rates typically fall dramatically after a few hours or days. This was the case with the Huntley #1 well which encountered overpressures so great that 18-pound mud weight was required to stem the gas flow during drilling. More than 160 sidewall cores were obtained from intervals that had strong shows in the Trenton as well as a few from the underlying formations. Thin sections from the plugs were examined to determine if the intervals are dolomitized or have visible matrix porosity. Neither dolomite nor significant matrix porosity was found in any of the plugs. The Trenton in the area of the production is composed of limestone and interbedded limestone and shale with common bentonite layers. An FMI log from the well did not reveal many significant vertical fractures. The reservoir is interpreted to consist of gas trapped in horizontal bedding planes. The near lithostatic pressures encountered during drilling suggest that the bedding planes are propped open by the high-pressure of the gas. During drilling the gas flows out of the horizontal partings until the fractures slam shut, thereby dropping the rate of production from millions to a few thousand cubic feet per day. The gas may be self sourced from what are likely to be very thin organic rich shale beds interbedded with the limestones. The overpressured play is likely limited by the 2500 or 3000 foot burial depth contour to the south, the pinchout of the capping Steuben Limestone to the east, the outcrop belt to the north and the pinchout of organic rich shale interbeds to the west. At a depth of 2500-3000 feet, the principal compressive stress changes from horizontal to vertical and the bedding planes are no longer likely to be open. There may be greater potential in the Trenton limestone where there are abundant vertical natural fractures or possibly if the formation is subjected to large scale frac jobs like those being performed on shale reservoirs.

Key words: Trenton, natural gas, bedding-plane, Central New York, Huntley #1

ACKNOWLEDGEMENTS

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TABLE OF CONTENTS

Section Page

ORGANIZATION OF THE REPORT

This report contains text and figures and an additional 160 plates. Plate 1 is a map of New York with the locations of all wells with logs that penetrate the Trenton or deeper. Plate 2 shows the mudlog and wireline logs of the Huntley #1 well. Plate 3 displays the FMI, other logs, and interpreted lithology from the Trenton Group. Plate 4 shows the FMI, other logs, and interpreted lithology from the Black River Group. Plate 5 displays the wireline logs along with estimated abundances from the thin sections of the plugs. There are 155 additional plates that show thin section photos and scans of each plug. These are each numbered by the depth of the sample.

The report is available in pdf format with many of the plates and figures internally linked for easier viewing. The report will be available on ESOGIS (www.esogis.com).

FIGURES

FIGURES (continued)

TABLES

PLATES

EXECUTIVE SUMMARY

The Trenton Group Carbonates have produced gas in New York for almost 120 years. Early production from the late 1800s to the present was mainly around Lake Ontario, and most of the gas is thought to have been produced from the Trenton Group carbonates and possibly the uppermost Black River Group. More recently, focus has been on wells drilled in the Southern Tier, where gas is produced at high rates and volumes from the Black River Group. These wells have been studied and are now thought to be hydrothermal dolomite reservoirs (Smith, 2006).

Conventional wisdom has it that the Trenton was not dolomitized in these older fields to the northeast, around Lake Ontario. Most research done on the fields suggests that the natural gas production comes from natural fractures in calcareous shale, shaly limestone, and/or limestone (Orton, 1899; Gillette, 1935; Robinson, 1985; Wallach, 2002). All of this is based on analysis of production data and the few logs that were run in these older fields. This project was undertaken to better understand the production from these fields. Does hydrothermal dolomite have anything to do with this production? Is there any porosity in the limestones that might work as a reservoir for natural gas? Does the gas come from fractured limestone, fractured shale, or both?

Most of these questions have been answered by this study. The studied well is definitely not a hydrothermal dolomite reservoir. No evidence was found of significant hydrothermal dolomitization in any of the producing gas fields around Lake Ontario that are included in the Trenton Limestone play. The Huntley #1 well had several strong shows, but none of the intervals where the gas flowed back contained any significant quantities of dolomite.

Furthermore, there was virtually no visible macroporosity in any of the cores examined in the Trenton or Black River. There appeared to be a small amount of microporosity in the shales, bentonites, and possibly in some limestone that was visible only with a scanning electron microscope. This microporosity may provide some storage for the gas but probably has a very low associated permeability.

There were few, if any, vertical or sub-vertical fractures visible on the FMI log of the well. Horizontal fractures or open bedding plane partings would be extremely difficult to recognize on an FMI log. However, some of the shale-rich samples in intervals that had gas shows were found to have small fractures in them where the plugs fell apart. Microfractures were also revealed by the SEM, although these could have been induced during coring or sample preparation.

It is the conclusion of this study that most of the gas in this well comes from horizontal bedding plane partings between the interbedded tight limestone and shale of the Trenton. The bedding-plane partings are propped open by the high pressure of the gas, which is at near lithostatic values. When they are penetrated, the gas flows back at very high pressure but in most cases quickly blows down, the horizontal fractures are closed, and the rate drops dramatically. In the case of the Huntley #1 well, there may be a few small vertical bed-bound fractures in the shales that also contribute to production in the study well. Storage of the gas may occur in microporosity in the shale beds.

Wells with only horizontal fractures or bedding-plane partings are unlikely to be economic without new completion technology. Hydro-fracturing and propping of fractures may help to increase the production from these wells. The shallow depth of the fields may create problems for performing successful fracture jobs.

Based on discussions with geologists familiar with this play, wells that penetrate significant vertical fractures may have a better chance of producing economic quantities of gas. Zagorski (2005 IOGANY presentation) referred to a seismic line where a Trenton Limestone well had penetrated the downthrown side of a negative flower structure. Zagorski stated that this well had production that held up or at least a test that showed significant reservoir extent. The structure was very similar to the structures that have associated hydrothermal dolomitization in the Black River. Perhaps the fractures induced by this faulting on the downthrown side of the faults are enough to connect many of the bedding plane partings and shale beds filled with gas, creating an economic well.

It also appears that most of the gas shows occur in interbedded shale and limestone just under a clean, well-cemented limestone at the top of the Trenton. This interval is time-equivalent to the organic-rich part of the Utica Shale to the east and is essentially an extension of that play. A good way to explore for economic Trenton gas fields might be to drill horizontal wells in the interbedded limestone and shale along the downthrown side of faults identified on seismic data and then do large-scale frac jobs similar to those done in the Marcellus and Barnett Shales.

Another approach that may help improve results is to expect the high pressures and to flare each zone during drilling. Many of these high-pressure zones will only have minor accumulations of gas that blow down within a few hours. Dick Beardsley, formerly of Columbia Natural Resources, stated that the best way to handle these gas kicks is to stop drilling and flare the gas for a few hours or a day (personal communication, 2004). If the pressure and the rate drop to very low values, continue to drill and assume that this is a gas pocket of limited lateral extent. If the pressure and rate hold up, this may be a zone that could produce economic quantities of gas. One could then continue to drill and come back to perforate this interval later or stop drilling, hook it up, and try to flow gas. This approach will help identify whether one has at least a chance of a good well very early on in the drilling process.

The stratigraphy and burial depth of the formation define the limits of the highly-overpressured play. Horizontal fractures will only form to a depth of about 2500 feet. It is at this depth that the principal compressive stress commonly changes from horizontal to vertical. Once the principal compressive stress is vertical, only vertical or near vertical fractures will form. So the southern limit to the highly-overpressured play occurs where the top of the Trenton Formation is deeper than 2500 or 3000 feet. Laterally, the Trenton play seems to die out to the east where the clean tight limestone at the top, called the Steuben limestone, pinches out. This is mainly because the same interval that is productive in the Trenton is now part of the Utica Shale. This limestone must form a seal that is essential for trapping gas in the interbedded strata below it. The more organic-rich shaly interbeds decrease to the west and it may be the lack of these beds that defines the western limits of the play.

Section 1
BACKGROUND

There are eleven named fields in the Trenton Limestone on the Tug Hill Plateau and to the south that have historically been thought to produce from fractures in tight limestone and shale rather than hydrothermal dolomite (Robinson, 1985) (Figure 1, Plate 1). This interpretation was supported by examination of cuttings (Orton, 1899; Gillette, 1935), logs (Robinson, 1985), and analysis of pressure and production.

These fields were mainly discovered and produced in the late 1800s and early 1900s. What was called the Trenton when most of these wells were drilled is up to 600 feet thick in this part of the state. Some of the lower part of what is commonly called the Trenton Group here may be the equivalent of the Black River Group in the central part of the state. Gas was produced from many parts of the section from near the top to 600 feet or more below the top of the Trenton. The reservoir appears to have been overpressured. One scout card from the Pulaski Field tells this story:

> “When shut in, pressure lifted 633’ of casing and drive pipe out of hole and scattered it about the land. One 80’ length was thrown 600’ from well.”

Another interesting reference is an unpublished report from Tracy Gillette (1935), who studied the Pulaski Field. He obtained much of his information from a manager and a driller for the company that managed Pulaski Field for many years. He states emphatically that, according to the Pulaski Gas Company employees, the productive intervals in the Trenton are not dolomitized and are not even limestones. He believed that the production all came from fractured calcareous shales. He wrote:

> “That the gas is confined to the shale partings and shale layers can be observed at any well during the drilling of the Trenton. The drill first strikes a hard, dense limestone layer which is usually only a few inches thick but is hard to penetrate. As the drill breaks through this layer the gas rushes forth, sometimes under enormous pressure which may even blow the tools out of the hole. When drilling is again resumed it is invariably found that the layer under the hard dense limestone is a calcareous shale. This soft material may persist for six or eight feet or may only be a few inches thick. No increase in volume is realized until another hard dense limestone is reached. Unquestionably the limestone acts as a cap rock.”

This vivid description posed many questions: What type of limestone forms the hard, dense limestone layers that overlie the shales? Are the shales self-sourcing? Are there limestone interbeds in the shales that become fractured and produce, or is it the shales themselves? As it turns out, Gillette’s conclusions are very similar to the conclusions in this report.

Robinson (1985) stated that the best reservoirs in these fields were in beds with interbedded limestone and shale where the limestones were more likely to be fractured. Interestingly, both the Puskarenko and Skranko wells from Herkimer County to the east had shows in the Dolgeville Formation, which is an interbedded limestone and shale. Vertical fractures in the limestone may be essential to making a good well; gas accumulations at bedding-plane partings are probably not enough.

The initial plan was to take a continuous core, but no company was found that was willing to undertake this operation, given the immense pressure kicks that occur while drilling these wells. After a year of trying to solve this problem, it was decided that sidewall cores would be taken instead. This way, the well could be kept under control and the coring intervals could be chosen after it was known where the gas shows occurred.

The cores were taken from the Huntley #1 well in Oswego County (see Figure 2 and Table 1). The well had numerous strong shows and at one point was so over-pressured that 19-pound mud had to be used to prevent a blowout at less than 2200 feet. Personnel at Seneca Resources think that this might be the densest mud ever used in New York, even though the high-pressure zone occurred at less than 2000 feet. This suggests that the Huntley #1 well was in a location that was very similar to the Pulaski, Sandy Creek, and other Trenton Limestone Fields where the pressures were also very high. For these reasons, there is confidence that this well was representative of the play.

When Seneca returned to produce the well, it flowed some gas, but the pressure dropped rapidly. It was deemed to be sub-economic and never hooked up to a pipeline.

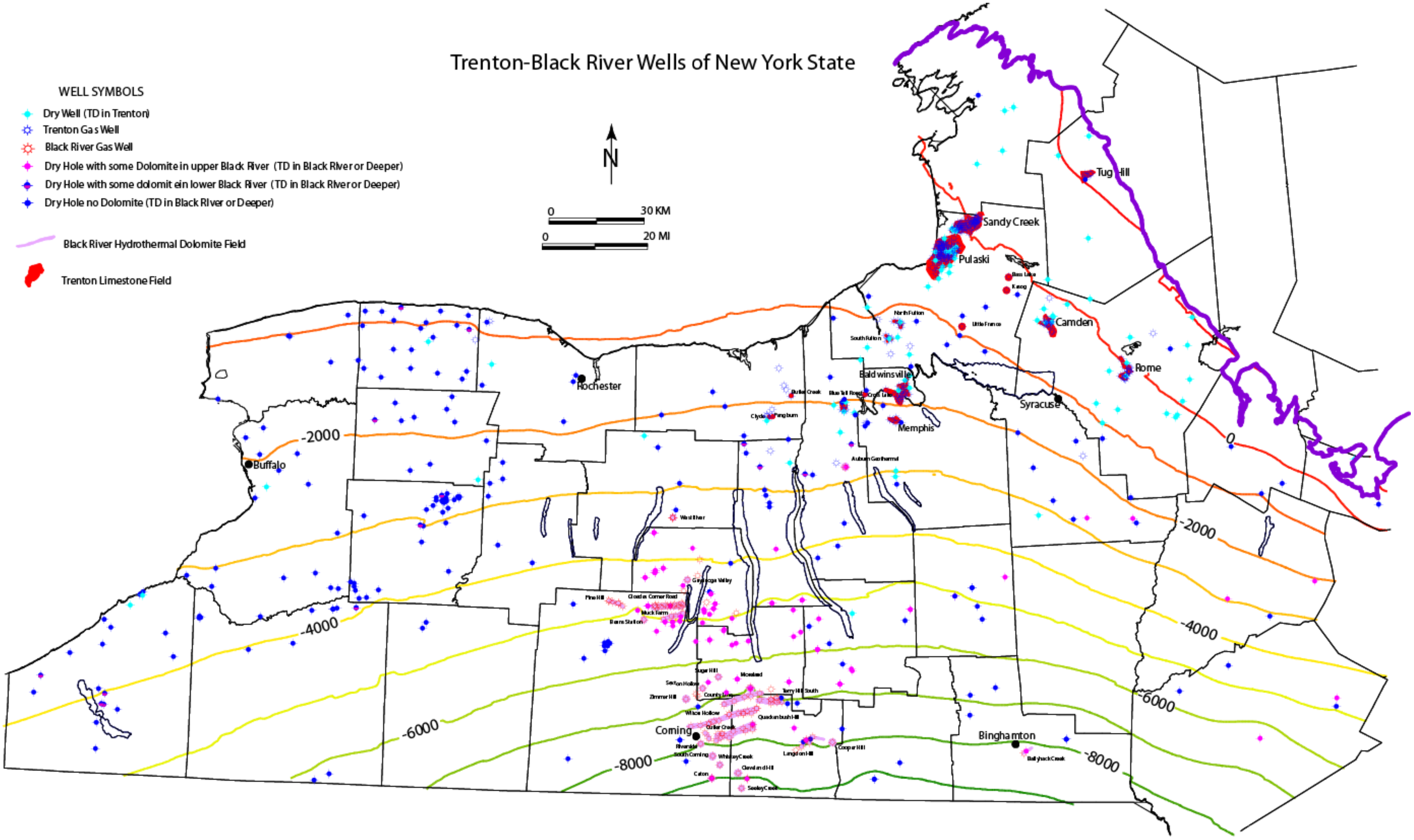


Figure 1. Map of Trenton and Black River Fields and Wells in New York State. There are two plays, the Black River hydrothermal dolomite play nd the Trenton Limestone play. The contours are depth to the top of the Trenton Group in feet subsea.

Section 2
MUDLOG

In the Huntley #1, gas started flowing back at about 1778 feet, approximately 30 feet from the top of the Trenton (Plate 2, Figure 3). This upper gas show was not as strong as gas shows below. The first major gas show occurred at 1812 feet, when the well blew out and the pressure of the gas was 1300 psi. Mud weight was increased to 15.6 pounds/gallon and then to 16.9 pounds/gallon. The well seemed to be under control for about 10 feet, and then the pressure of the gas increased again; the mud weight was increased to 18.0 pounds/gallon and then to 18.4 pounds/gallon. These are very high mud weights, but they still were not able to control the well. Drilling stopped at about 1826 feet, and a different rig was brought in to finish the well. Casing was set and drilling recommenced using 19 pound/gallon mud (S. Gorham, pers.comm); immediately, gas flowed back at a high rate. The gas show stayed above 6000 units and then peaked again at about 1900 feet, where the gas flowing back almost reached 10,000 units.

The gas dropped off to values around 1000 units until a depth of about 2059, when there was another dramatic increase to over 9000 units. The gas flowing back stayed at pretty high values (over 5000 units) from that depth to below the top of the Black River. The mud loggers only put shows between 1778-1812, 1824-1826, and then again from 2061-2071. There may have been many other shows that were not identified by the mudloggers. There was almost certainly a gas show when the drilling recommenced after setting pipe at 1826 as the gas units shot back up to over 8000 units as soon as gas measurement started. Another likely depth for a major gas show is at around 1900 feet.

According to the gamma ray log (Plates 2 and 3; Figure 3), the biggest gas shows come right at or near the base of the two cleanest limestones. This is consistent with conclusions presented in Zagorski's 2005 talk at IOGA-NY.

The difficulty in assessing the locations of the shows comes from the very high mud weight and the fact that gas continued to flow out of overlying beds long after they had been penetrated. Regardless of any debate over the specific depths, there were multiple shows in the Trenton.

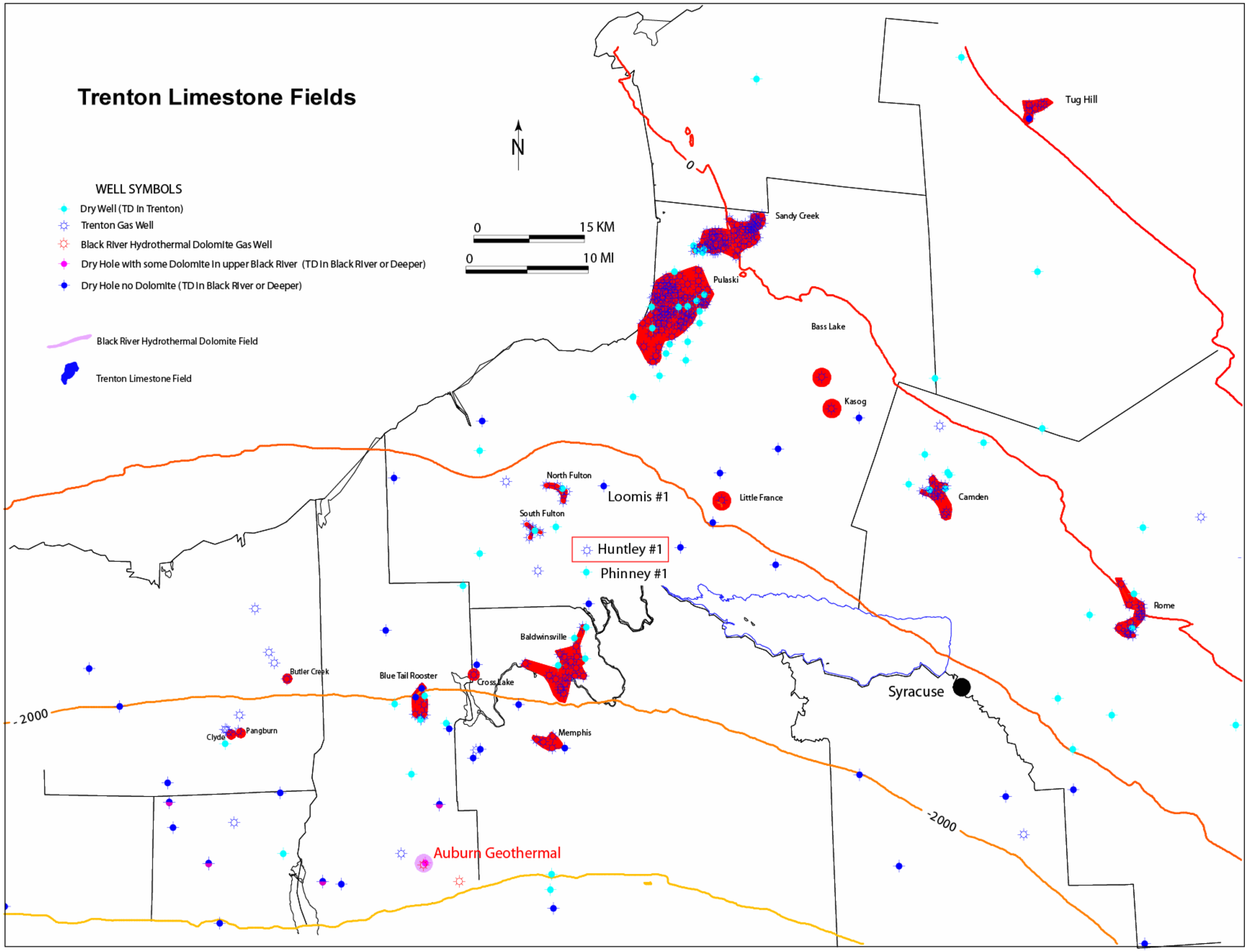


Figure 2. Trenton Limestone Fields and wells with location of Huntley #1 well in red box. Contours are depth to top of Trenton in feet subsea.

Sidewall Core	Depth	Sidewall Core	Depth	Sidewall Core	Depth	Sidewall Core	Depth
1	1761	**41**	1891	**81**	2102	**121**	2372
2	1761.5	**42**	1892	**82**	2103	**122**	2375
3	1762	**43**	1893	**83**	2110	**123**	2377
4	1762.5	**44**	1894	**84**	2140	**124**	2379
5	1775	**45**	1895	**85**	2142	**125**	2389
6	1778	**46**	1895.5	**86**	2144	**126**	2404
7	1791	**47**	1896	**87**	2153.5	**127**	2408
8	1797	**48**	1896.3	**88**	2154	**128**	2413
9	1814	**49**	1897.5	**89**	2154.5	**129**	2432
10	1816.5	**50**	1898	**90**	2155	**130**	2447
11	1825	**51**	1899	**91**	2155.5	**131**	2456
12	1826	**52**	1902	**92**	2156.5	**132**	2466
13	1826.5	**53**	1927	**93**	2157	**133**	2475
14	1827	**54**	1944	**94**	2171	**134**	2532
15	1827.5	**55**	1952	**95**	2189	**135**	2536
16	1828	**56**	1986	**96**	2190	**136**	2549
17	1828.5	**57**	2004	**97**	2191	**137**	2566
18	1829	**58**	2009	**98**	2205	**138**	2570
19	1830	**59**	2023	**99**	2222	**139**	2579
20	1833	**60**	2026	**100**	2231	**140**	2590
21	1837.5	**61**	2031.5	**101**	2261	**141**	2600
22	1840	**62**	2035	**102**	2273	**142**	2609
23	1845	**63**	2041	**103**	2301	**143**	2614
24	1846	**64**	2044	**104**	2328	**144**	2630
25	1846.5	**65**	2046	**105**	2340.5	**145**	2636
26	1847	**66**	2054	**106**	2349	**146**	2645
27	1847.5	**67**	2055	**107**	2349.5	**147**	2656
28	1848	**68**	2057	**108**	2350	**148**	2657
29	1848.5	**69**	2059	**109**	2351	**149**	2663
30	1849	**70**	2061	**110**	2352	**150**	2666
31	1855.5	**71**	2063	**111**	2354	**151**	2669
32	1856.5	**72**	2065	**112**	2356	**152**	2672
33	1857	**73**	2067	**113**	2358	**153**	2675
34	1877.5	**74**	2084	**114**	2360	**154**	2677
35	1878	**75**	2086	**115**	2362	**155**	2684
36	1878.5	**76**	2088	**116**	2364		
37	1879	**77**	2090	**117**	2366		
38	1879.5	**78**	2092	**118**	2367		
39	1880	**79**	2096	**119**	2368		
40	1890	**80**	2097	**120**	2369		

Table 1. Sample numbers and depths for plugs acquired from Huntley #1.

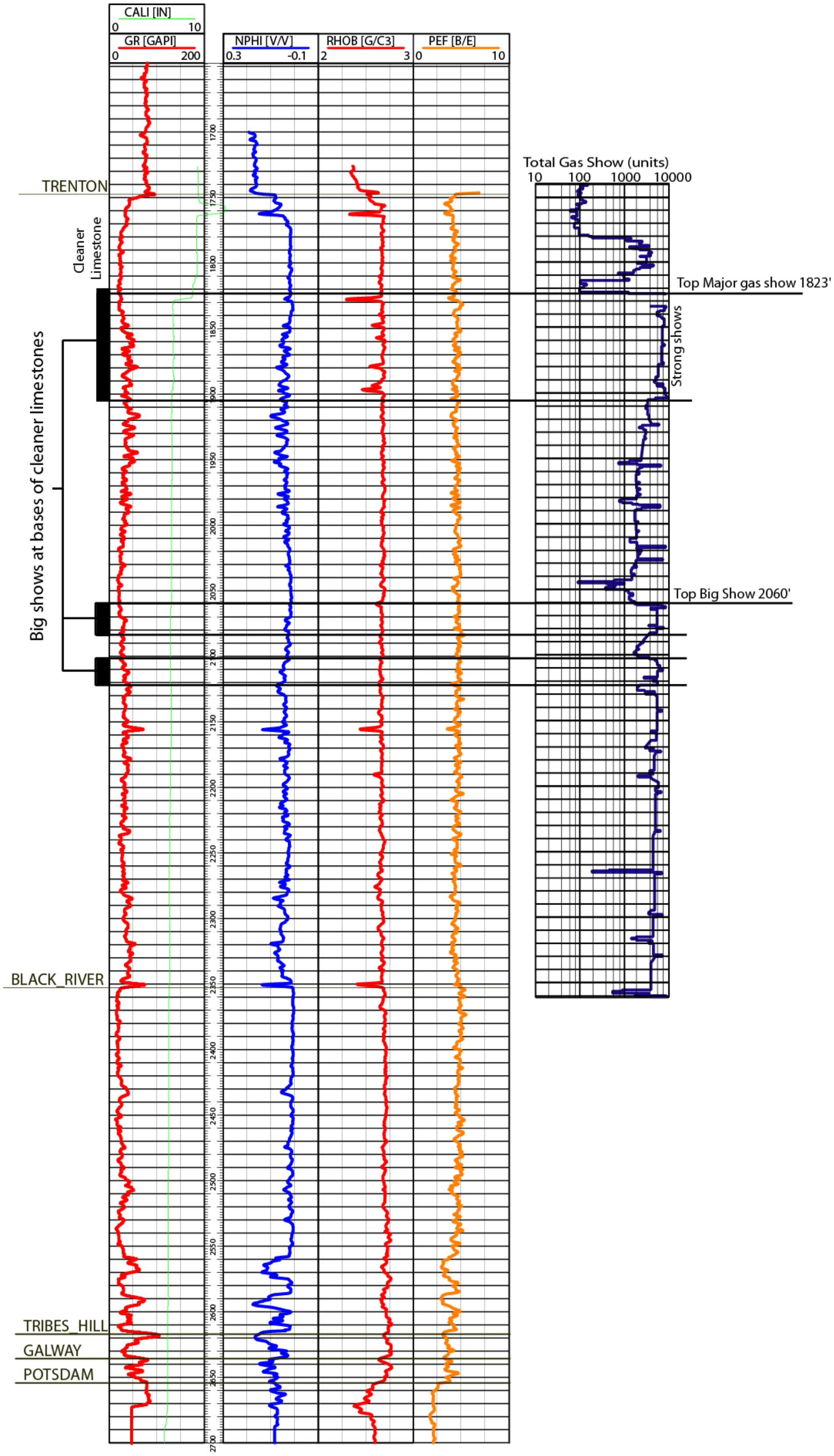


Figure 3. Logs and gas show from Huntley #1 well.

Section 3

WELL TEST

Apparently, none of the units where gas shows occurred flowed at economic rates during testing (Scott Gorham, Seneca Resources, personal communication). This is consistent with many other accounts of the Trenton Limestone reservoir. Very high pressured gas is encountered during initial drilling, but it very commonly blows down to sub-economic rates (a few mcf per day) within a few hours or days. In the Huntley #1 well, everything below the top of the Black River was interpreted to be tight or wet, including the basal sandstone of the Galway Formation, which had the only visible matrix porosity (Gorham, personal communication).

Section 4

GEOLOGIC SETTING

The Grenville Basement, which underlies New York State and much of the eastern United States, has been subjected to numerous tectonic events that produced several fault and fracture trends. The Grenville Orogeny occurred approximately 1.1 billion years ago (Moore, 1986), forming thrust faults and associated tear faults. After the Grenville Orogeny, North America was part of a supercontinent that underwent a long-lasting episode of rifting in the Late Precambrian (620-550 ma: Van Stahl, 2005) that resulted in numerous failed rift zones such as the Rome Trough, Reelfoot Rift, and others (Burke and Dewey, 1973; Thomas, 1991), some of which extend into New York. Along with the extensional faults were associated strike-slip transfer faults (Thomas, 1991). The faults formed during these early events were likely reactivated during subsequent tectonic events.

After the Late Precambrian rifting of the supercontinent, New York was situated on a passive margin developed over the New York Promontory (Thomas, 1991). The Middle-Cambrian Potsdam Sandstone (0-100 feet thick) rests unconformably on the rifted basement and is overlain by the Cambro-Ordovician Beekmantown Group carbonates and siliciclastics (Figure 4). In New York, the Beekmantown is composed of the Upper Cambrian Galway dolomitic sandstone and Little Falls Dolomite and the Lower Ordovician Tribes Hill Formation, which is a limestone in some places and a dolomite in others. Only the Galway and Tribes Hill are present in the study area.

The overlying Black River Group is primarily composed of muddy and fine-grained shallow marine carbonates. The Black River is overlain by the Trenton Group, which is composed of deeper-water argillaceous limestones and calcareous shales and high-energy shallow marine grainstones and packstones (Brett and Baird, 2002). The Trenton and Black River thin toward eastern New York on the Canajoharie Arch, where they are absent in some places, and thicken into the south-central part of the state where most of the recent production has occurred (Rickard, 1973). In this well, the Trenton Group carbonates are about 600 feet thick and the Black River Group is about 265 feet thick. The Trenton is capped by the Throughway Disconformity which is overlain by the Indian Castle Member of the Utica Shale.

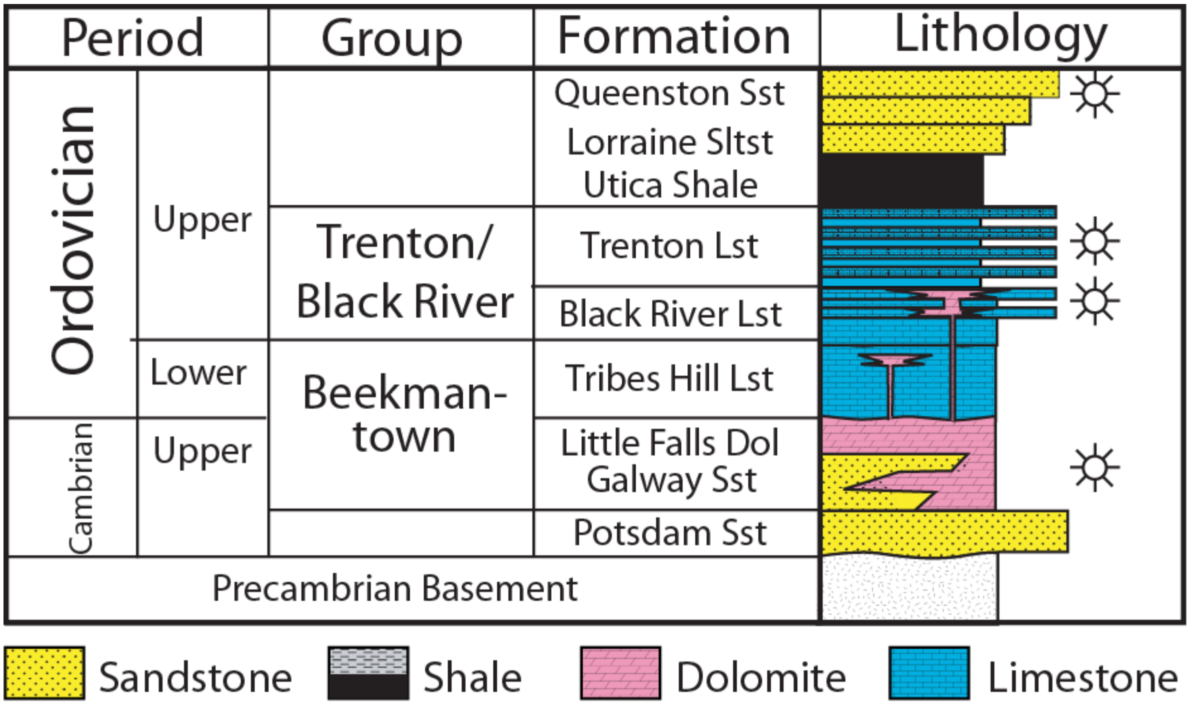
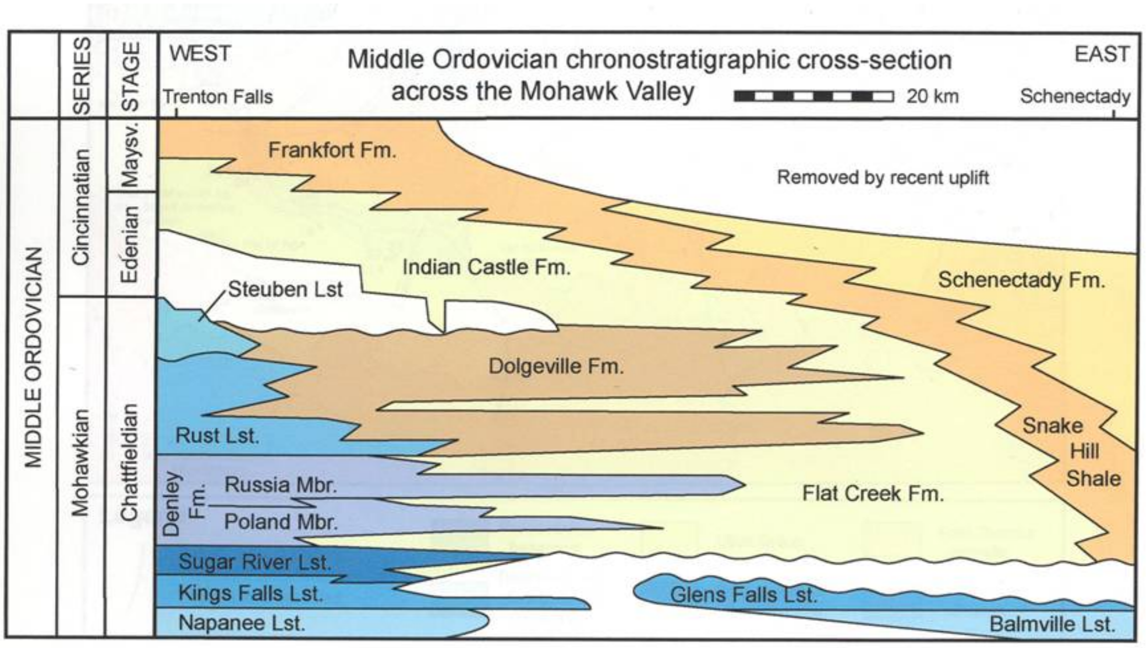


Figure 4. Stratigraphic names of Lower Paleozoic strata of central New York.



(Goldman, et al 1994)

Figure 5. Stratigraphic nomenclature and time-relationships between Trenton Group (Blue) and Utica Group (tan). The Huntley #1 well has stratigraphy similar to the left side of this diagram.

The Trenton Group is composed of seven formations. These limestones grade laterally into the Dolgeville Limestone and Shale to the east which is interbedded with and grades laterally into the Flat Creek Shale farther to the east (Figure 5). The Utica Shale is overlain by the Upper Ordovician Lorraine Siltstone and Queenston Sandstone, which are siliciclastics that prograded from the Taconic Mountains across most of New York in the Late Ordovician.

The Taconic Orogeny began in the Late Ordovician when an island arc collided with proto-North America to the east of present-day New York and continued throughout the Late Ordovician and into the Early Silurian (Ettensohn and Brett, 2002) (Figure 6). Both the Black River and Trenton Groups contain bentonite (volcanic ash) beds, some of which can be correlated for great distances (Kolata et al., 1996). Further evidence for tectonic activity at this time includes development of a foreland basin to the east, Late Ordovician extensional faulting in the foreland area of the Mohawk Valley (Bradley and Kidd, 1991) (Figure 7), spatial and temporal variations in differential subsidence in the Trenton Group, and the occurrence of seismites in the outcrops of Trenton- and Utica-aged rocks in New York, Kentucky, and Ohio (Pope et al., 1997; McLaughlin et al., 2002; Ettenshohn et al., 2002).

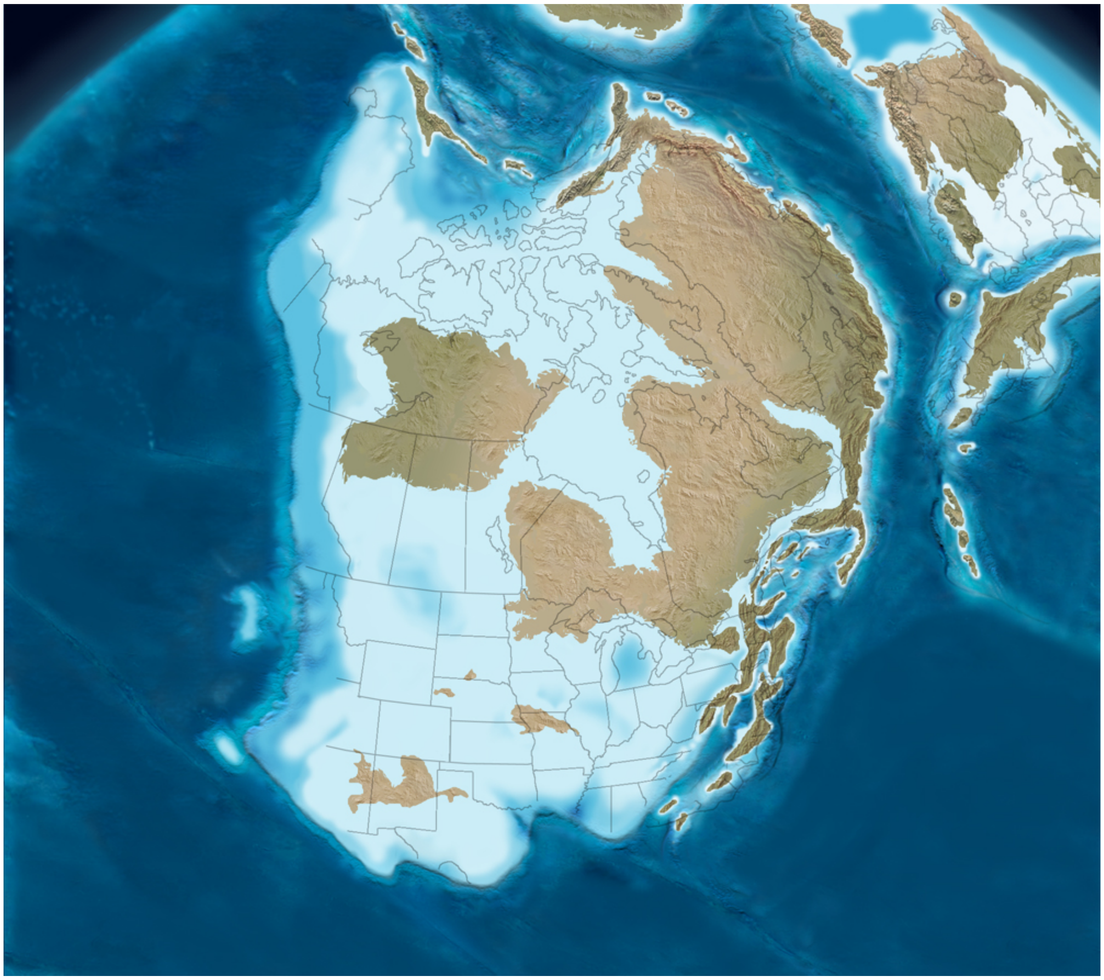


Figure 6. Late Ordovician Paleogeography showing Taconic Mountains forming to east and New York in Foreland Basin.

After deposition, the Trenton and Black River Groups of the study area were probably buried to a depth of several kilometers in the study area. CAI values from the Utica Shale range between 2.5 and 3.5, which suggest burial to a depth of approximately 3-5 kilometers (Weary et al., 2000). Maximum burial is likely to have occurred in the Devonian or Pennsylvanian. Current burial depths are less than one kilometer where the Huntley #1 well and all of the Trenton Limestone fields in New York occur, so there has been significant uplift and erosion since the Paleozoic.

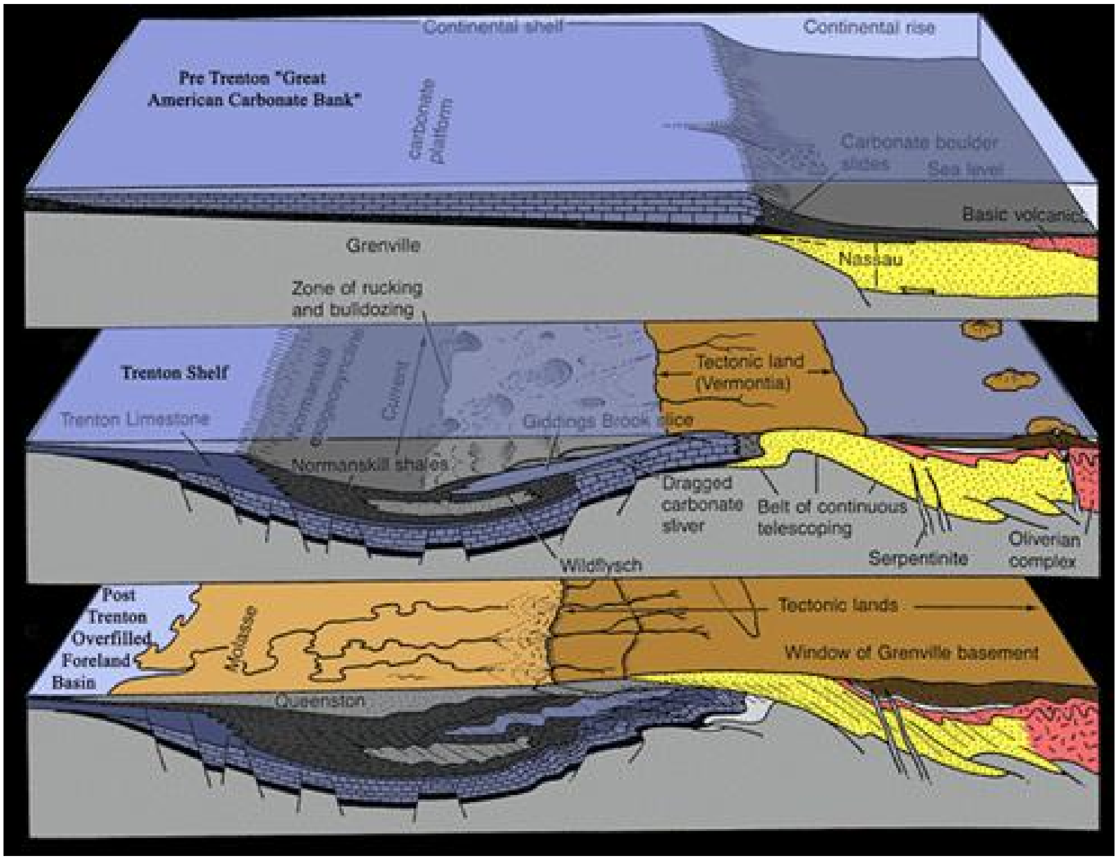


Figure 7. Block Model showing Late Ordovician tectonics and sedimentation in New York State. The Trenton Limestone was deposited during a time of active faulting and development of a foreland basin to the east. From Bird and Dewey, 1970.

Section 5
METHODS

The sidewall core locations were picked after the well had been drilled and logged. The cores were drilled by Schlumberger, who were to provide 160 cores for $85,000, along with the standard wireline logs, the mudlog, and the FMI log. Core locations were picked where there were gas shows and apparent porosity lobes on the logs (see Plate 2). Additional coring points were picked to ensure that all rock types in the well could be identified. Several more were taken in the Black River and Galway Formations, none of which had any gas shows but may be prospective in other parts of the basin.

Each plug was trimmed, polished, and the cut ends were sent out for thin sections. The ends of each plug were scanned at 600 dpi. (These scans are included on the plates that are numbered by their depth and in the images named by depth on the enclosed CD.)

Thin sections were made from 155 of the plugs. Half of each slide was stained with Alizarin red-S (which stains any CaCO3 red) and potassium ferrocyanide (which stains any iron-rich mineral blue) and cover-slipped. The thin sections were described and photographed by Rick Bray; these are recorded in Plates 6-160.

Ten samples with the most shale in them were sent to Humble Geochemical Services to see if they might have source rock potential.

The objectives of the petrographic study were to:

1. Assess the mineralogy, texture, and skeletal and non-skeletal components from the thin sections provided (Trenton and Black River Groups);
2. Identify important diagenetic features and develop a paragenetic sequence from the thin section analysis (Trenton and Black River Groups);
3. Interpret representative rock types, sedimentological features, and diagenetic features from the FMI (Trenton Group only); and
4. Establish the sequence stratigraphic context of the Trenton Group.

All thin sections are 1x2-inch format. Alizarin Red-S turns calcite red but does not alter dolomite, quartz, or clay. Potassium ferrocyanide stains iron-rich calcite and dolomite blue or purple. All thin sections are well prepared and provide excellent material for petrographic evaluation. Nevertheless, thin section sample density is irregular. Of the thin sections described, 107 are from the Trenton Group, 36 from the Black River Group, one from the Tribes Hill Formation, and thirteen from the Galway Formation.

Each of the plates for the plugs contains a scanned image of the polished plug ends; two photomicrographs, and semi-quantitative data on the lithology and fossils present (Plates 1761 to 2684). The photomicrographs document important textural, sedimentological, and diagenetic features.

Descriptions of the plugs and linking of plugs to the FMI were used to make a stratigraphic column (see Plates 3 and 4). Plugs were examined and linked to their FMI responses; un-sampled intervals were then interpreted based on their FMI responses. This, of course, could be a source of error, but there is confidence that the rock types picked are fairly accurate. Important sedimentological and diagenetic features are also indicated on the graphic column. One track records the relative percent of limestone as determined by examination of the FMI.

Semi-quantitative petrographic analyses are summarized in Plate 5, and the raw data is included as three Excel spreadsheets that enumerate mineralogy, fabric elements, and skeletal and non-skeletal allochems. The numerical data are visual estimates of the various attributes, which were collected from the thin sections. These semi-quantitative analyses represent the composition of the often heterogeneous thin section and include components of limestone and matrix-rich interbeds.

Section 6
TRENTON GROUP (1750-2352 feet)

6.1 Lithology

The Trenton Group is a series of limestones interbedded with calcareous shale beds (Plates 1827.5, 1837.5, 1846.5, 1856.5, 1902, 2044, 2222). All beds are relatively thin, invariably less than one foot thick. Limestone beds are generally thicker than the shaly beds.

The shaly beds typically include varying amounts of clays, detrital quartz silt, fine carbonate mud (micrite), pyrite, carbonate grains, organics, bitumen, and dolomite. These beds are impossible to discern on the FMI log and often difficult to define petrographically because bitumen and hydrocarbon residues often saturate and stain these strata, obscuring the original texture and fabric (Plate 2349). Some “shaly” beds contain K-bentonite and are important correlative, chronostratigraphic markers.

The limestone interbeds contain variable amounts of terrigenous clastic quartz and clay. Quartz, which usually occurs as silt, is also present as euhedral crystals replacing muddy carbonate matrix or skeletal grains or as void-filling chert cement. Chert is restricted to strata in the immediate vicinity of the Trenton/Black River contact (Plate 2349.5). Pyrite (Plate 2088, 2154), although present throughout the Trenton limestones, is more common in the finer-grained fabrics and muddy textures, probably deposited with higher organic content than the grain-rich rocks. Pyrite may be concentrated along, near, or on pressure solution features and may partially replace skeletal grains (Plate 2026).

Dolomitization is rare, and only one sample contains significant dolomite, which has replaced a muddy carbonate matrix (Plate 2054). Most dolomite occurs as isolated, non-ferroan rhombs (Plate 2046) replacing a carbonate mud. Ferroan replacement dolomite is rare (Plate 1877.5).

The lower portion of the Trenton is more regularly bedded than the upper portion. This lower stratigraphic interval represents a deeper depositional setting than the overlying Trenton beds. This is supported by petrographic analysis that records an increase in clay from approximately 2190-2350 feet.

6.2 Texture and Constituents

Carbonate depositional textures of the Trenton Group limestones include the spectrum from matrix-supported lime mudstones (Plates 2155.5, 2301) and wackestones (Plates 1762.5, 1847.5) to grain-supported, mud-rich packstones (Plate 1797), mud-deficient packstones (Plate 1896), and well-cemented grainstones (Plates 1830, 1895). One sample (Plate 2086) appears to have been locally biologically welded or consolidated during deposition, perhaps an instance of early algally mediated seafloor cementation rather than a true boundstone.

In general, the lower Trenton is muddier with fewer grainstones than the upper Trenton of the studied interval. Biogenic activity is apparently less in the lower Trenton. Burrows (Plates 1877.5, 2157) and nodular bedding, both of which are indicative of bioturbation, are most common in the upper Trenton interval.

Muddy sediments, including mudstones (Plate 2142), wackestones (Plate 1762.5), and mud-rich packstones (Plate 1816.5), are most numerous in the Trenton. Disarticulated and fragmented skeletal grains are contained in a dominantly fine-grained, micritic matrix. Post-depositional compaction and dewatering of these mud-rich sediments reduced volume by dissolution of the unstable matrix and grains, increased grain packing, and often created pressure-solution features such as stylolites (Plates 2205, 2222), microstylolites (Plate 1828.5), sutured and embayed contacts (Plates 1778, 2026), and grain fragmentation (Plate 1896).

Grain-dominated textures, especially grainstones (Plates 1826.5, 1827 1828, 1895) and mud-deficient packstones (Plates 1840, 1896), generally are thicker than the mud-supported textures. Grainstones (Plates 1826.5, 1828, 1895) are often well cemented very early, prior to the onset of significant compaction. The most common intergranular cement is calcite, usually occurring as syntaxial cement in these echinoderm-rich sediments. Blocky calcite spar, which is coeval and probably mineralogically identical to the syntaxial calcite, often cements other carbonate grains. Early cementation stabilized the sediments, protecting them from compactive forces during later burial. Nevertheless, rare mud-lean, grain-supported textures show evidence of compaction (Plates 1791,1855.5).

The dominant skeletal grains are echinoderms and brachiopods (Plates 1761, 1840, 1855.5, 1896). The echinoderms are most probably pelmatozoan (stalked) crinoids, common in Paleozoic seas. In some instances, the microstructure of the echinoderm stereom is well preserved (Plate 1826.5). All echinoderm skeletal elements occur as isolated ossicles because the echinoderm connective tissue decays immediately after death and disarticulation quickly follows. Echinoderm ossicles generally are the most common carbonate grains in coarse grain-supported textures (Plates 1791, 1895).

Several distinct brachiopod morphologies can be identified in the Trenton thin sections. Although crenulate valves are most common (Plates 2140, 2144), rarer punctate, costate (Plate 2055), and spinose (Plate 1878.5) species are identifiable. Brachiopod taxa probably include larger strophomenids and orthids, which are common soft-sediment, muddy-bottom dwellers. Smaller individuals may be ribbed, inarticulate species (Plate 2065). Although usually disarticulated and often fragmented, rare brachiopod valves remain articulated (Plate 1837.5, 2140).

Trilobites (Plates 1878.5, 2090, 2144) are ubiquitous although much less numerous than echinoderms and brachipods. Ostracodes (Plate 1892) and bryozoans (Plates 2140, 2191) are rare to sparse. Other skeletal grains include rare bivalve mollusks (Plates 2171), which are usually preserved as spar-filled molds or neomorphic spar, gastropods (Plates 1893, 2059), spicules, serpulids (Plate 1879), and phosphatic skeletal grains (Plates 1762, 2023). The phosphatic skeletal grains may be the remnants of brachiopods, trilobites, or conodonts. No corals or stromatoporoids were identified in the Trenton.

Intense biological, chemical, and mechanical activity may reduce carbonate skeletal grains to silt-sized grains or calci-silt (Plates 2031.5, 2046). Calci-silt may be an abundant constituent in many fine-grained carbonate and siliciclastic interbeds. These fine grains are transported in suspension as silt-sized particles and are especially evident in the muddy sediments of the lower Trenton interval.

Intraclasts are the dominant allochem in one thin section and are identifiable in a few other thin sections (Plates 1879, 1944, 2190). Peloids (Plate 1826), though generally rare, are sparse to common in one sample. It is not clear whether "peloids" are altered fecal pellets or rounded, micritized skeletal fragments. Rarely peloids are glauconite (Plate 1891). Micropeloids in clay-rich interbeds may be flocculated clays (Plates 1894, 1899, 1837.5). In contrast to the Trenton, peloids and micropeloids are more abundant in, and often characteristic of, the underlying Black River Group.

6.3 Sequence Stratigraphy

There are many small-scale cycles throughout the Trenton that have shaly bases and cleaner, limestone-rich caps (see alternating limestone/shaly limestone cycles throughout Trenton in Plate 3). These bundle into at least three larger-scale sequences that again have shaly bases and cleaner, limestone-rich caps (Plate 3). Many of the intervals with shows occur near the base of the clean limestone caps and the upper parts of the shale-rich intervals. The uppermost of these cleaner limestones is called the Steuben Limestone. This unit pinches out to the east where it is in facies relationship with the Dolgeville Limestone and the Utica Shale. This and the other cleaner limestone units may serve as seals over the underlying gas prone interbedded limestone and shale intervals. All fields in the Trenton Limestone play occur to the west of the pinch-out.

6.4 Porosity

The neutron and, to a lesser extent, the density log in the Huntley #1 well and many other Trenton wells across the state show some porosity in the shaly intervals of the Trenton. This porosity was a focus of the coring effort, as it appeared that the gas shows lined up with the more porous intervals. Pores are here divided into macroporosity and microporosity. Macroporosity should be visible in thin sections with a petrographic microscope and generally includes pores that are >1 or 2 microns in diameter. Microporosity is generally invisible with a petrographic microscope but can be seen with a scanning electron microscope and generally includes pores <1-2 microns in diameter. There was very little if any macroporosity in this well, but there is some microporosity in the clay-rich intervals. There may also be some porosity in micro-cracks.

Porosity was measured in all of the plugs. The plug porosity followed the log porosity very closely (Figure 3). The porous plugs were almost all plugs that had obvious clay content. Eight of the plugs with the highest porosity were viewed with a scanning electron microscope. Microporosity is visible at very high magnifications within the shaly parts of the samples.

6.5 Macroporosity

Petrographic examination of the thin sections reveals no macroporosity in these intervals. Grainstones, which were deposited with a high primary, intergranular porosity and excellent permeability characteristics, were thoroughly cemented (Plate 1896.3) with calcite cement. Any depositional macroporosity of matrix-rich rocks was completely eliminated by compaction (Plate 1797).

Cements completely fill any intraskeletal or intragranular porosity. Shelter voids (Plate 2059) and burrows (Plate 2157) are filled with cements, which in turn occluded any fractures (Plates 1899, 2092). Numerous open fractures in the thin sections were induced during coring, sample handling, or thin section preparation. Scant moldic porosity, which was created by dissolution, later was filled with cement (Plate 1833).

Absence of macroporosity cannot be attributed to sampling bias, as thin sections were concentrated in the apparent porous intervals. Thus, based on petrographic examination of 107 thin sections, one can only conclude that the Trenton lacks observable macroporosity. All primary and secondary macroporosity has been cemented and/or reduced by compaction.

6.6 Microporosity

Figures 8 to 15 show SEM photos from the Huntley #1 well. Most of the samples show some possible microporosity within the clay, and many show very small fractures or micro-cracks. These micro-cracks could be real, or they may have been induced during the coring and/or sample preparation. There also appears to be some microporosity in very isolated pores within some calcite crystals in Figure 6 from 1762 feet. The micro-pores do not appear to be very well connected in many of the samples, which would imply very low permeability. Permeability is controlled by the size of the pore throats that connect the pores. In this case, they appear to be very small or to not be connected at all in some cases. As a rule of thumb, pore throats smaller than approximately 0.5 microns are unlikely to flow gas.

The gas storage for this play may occur within the microporosity in the clays and, to a lesser extent, within the possible micro-cracks. It may total as much as 5 or even 10% porosity in the clay-rich intervals. Microporosity commonly has a high bound water percentage, so all of that 5-10% porosity may not be gas full.

Shows do not occur at every microporous interval, which suggests that there must be fractures, bedding plane partings, or some other higher permeability feature in order to get the gas to flow.

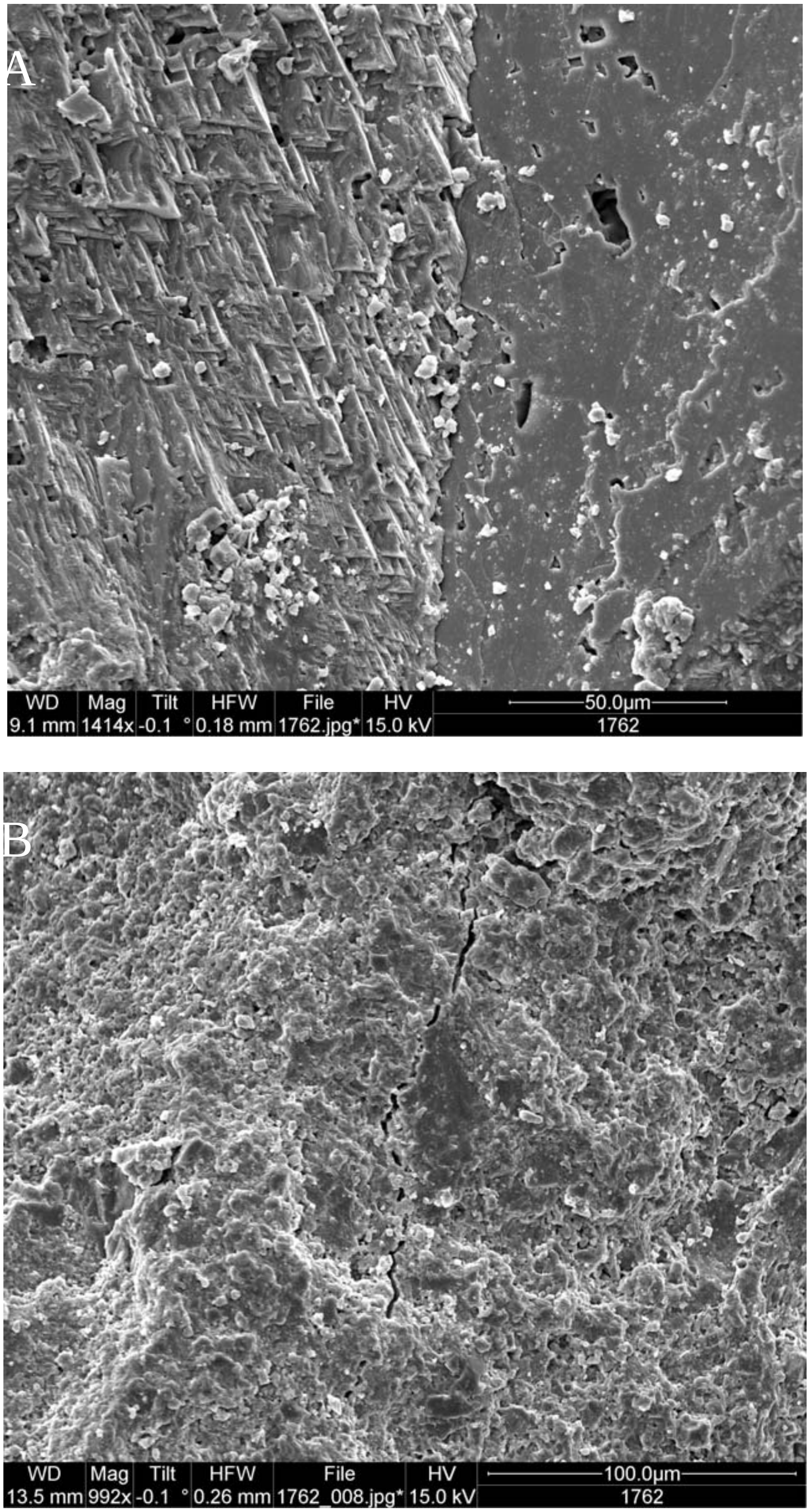


Figure 8. SEM photos from sample at 1762 ft. A) Calcite crystals with cleavage and possible mircopores. Possible micropores within calcite appear to be isolated. B) Microcrack and possible microporosity in clay.

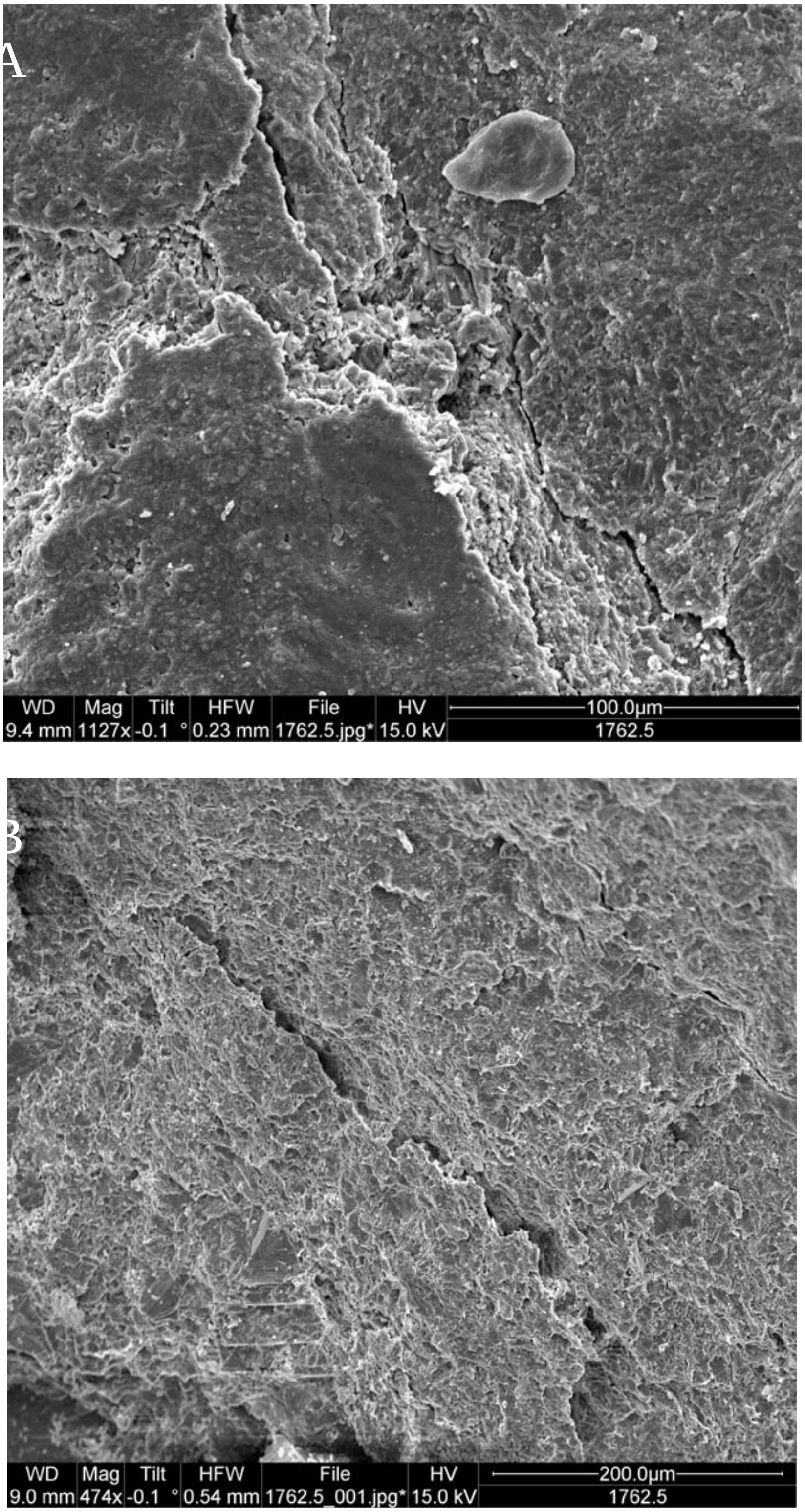


Figure 9. SEM Photos from sample 1762.5. A) Apparent fracture with some associated possible microporosity along it. B) Possibly microporous clay.

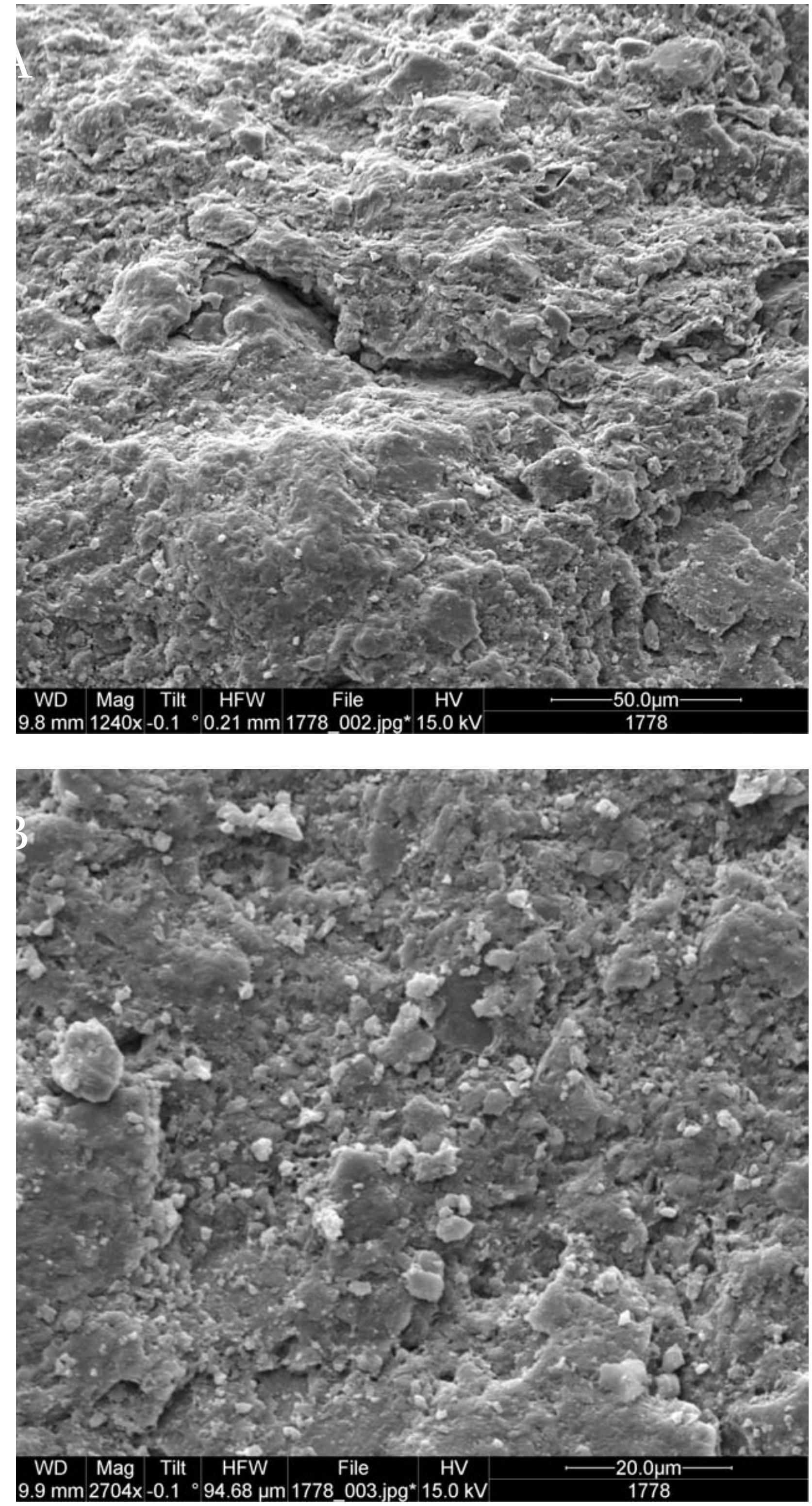


Figure 10. SEM photos from sample at 1778 feet. Both samples show possible very small micropores in shaly limestone. The pores appear to be about 1 micron in diameter.

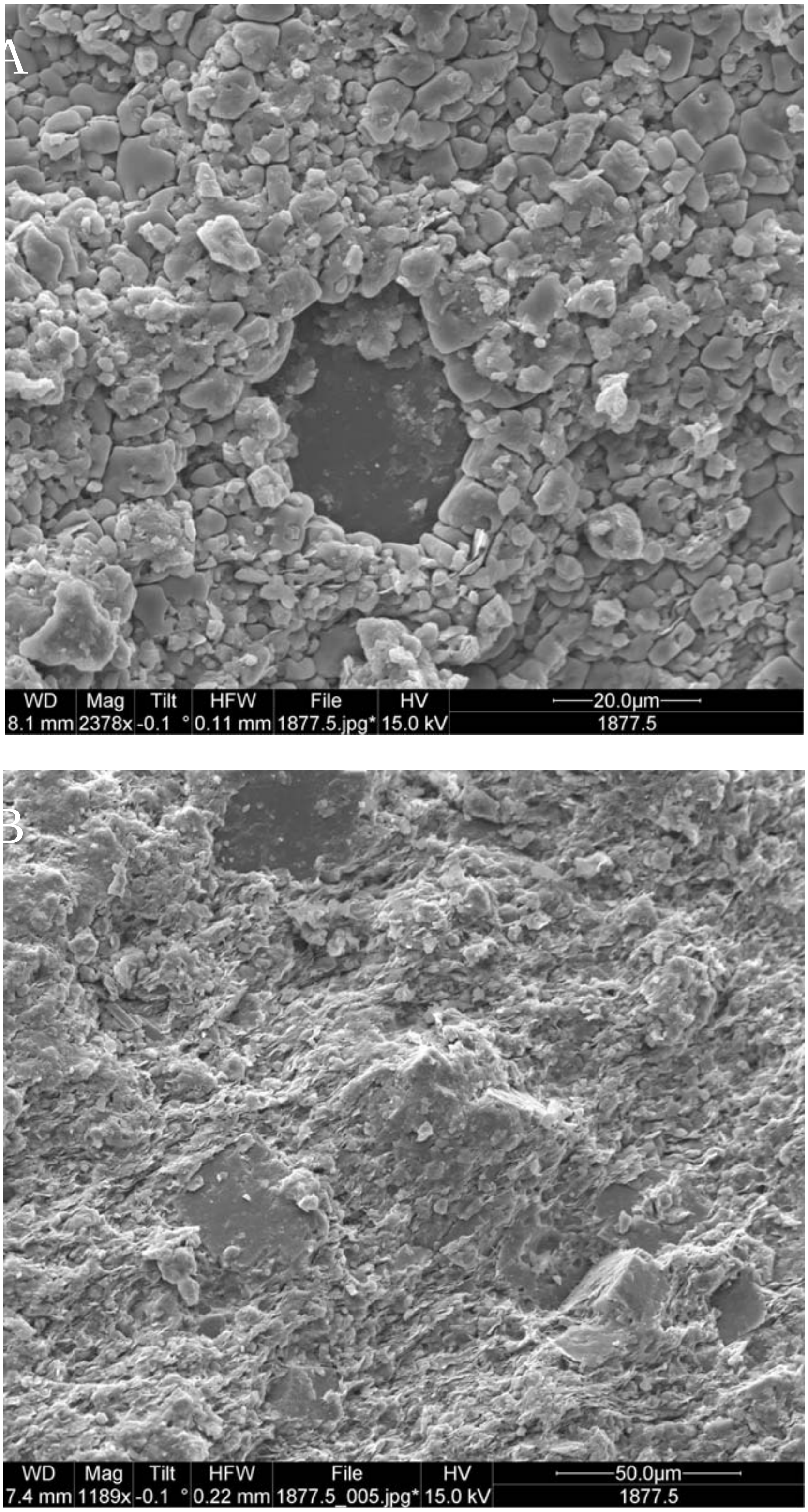


Figure 11. SEM photos from 1877.5 feet. A) Limestone with interesting etched pattern between calcite crystals. This may be microporosity, but it is hard to tell. B) Shale with some possible microporosity.

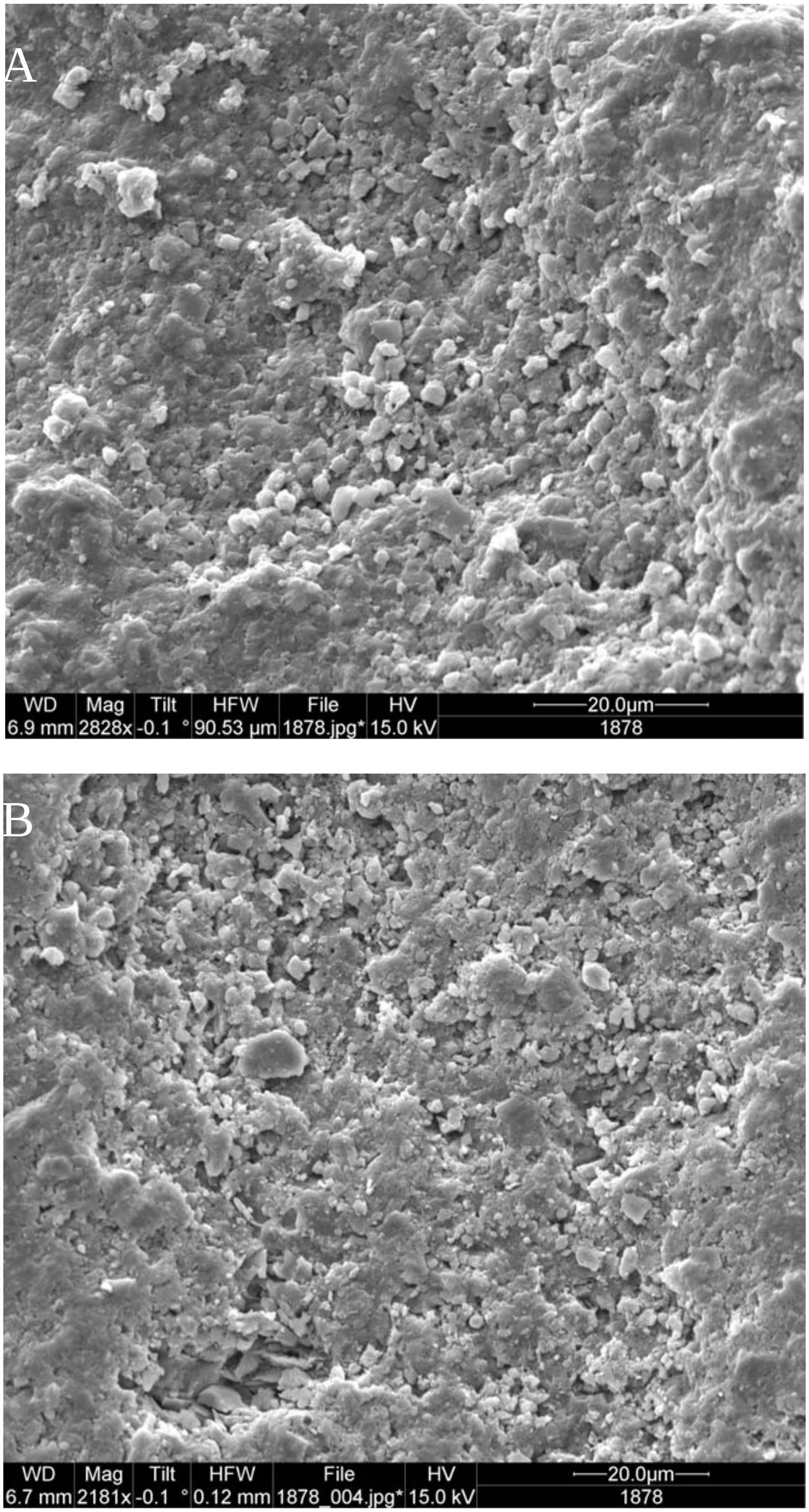


Figure 12. SEM samples from 1878 feet. A) Possible microporosity in shaly limestone. B) Possible microporosity in shaly limestone.

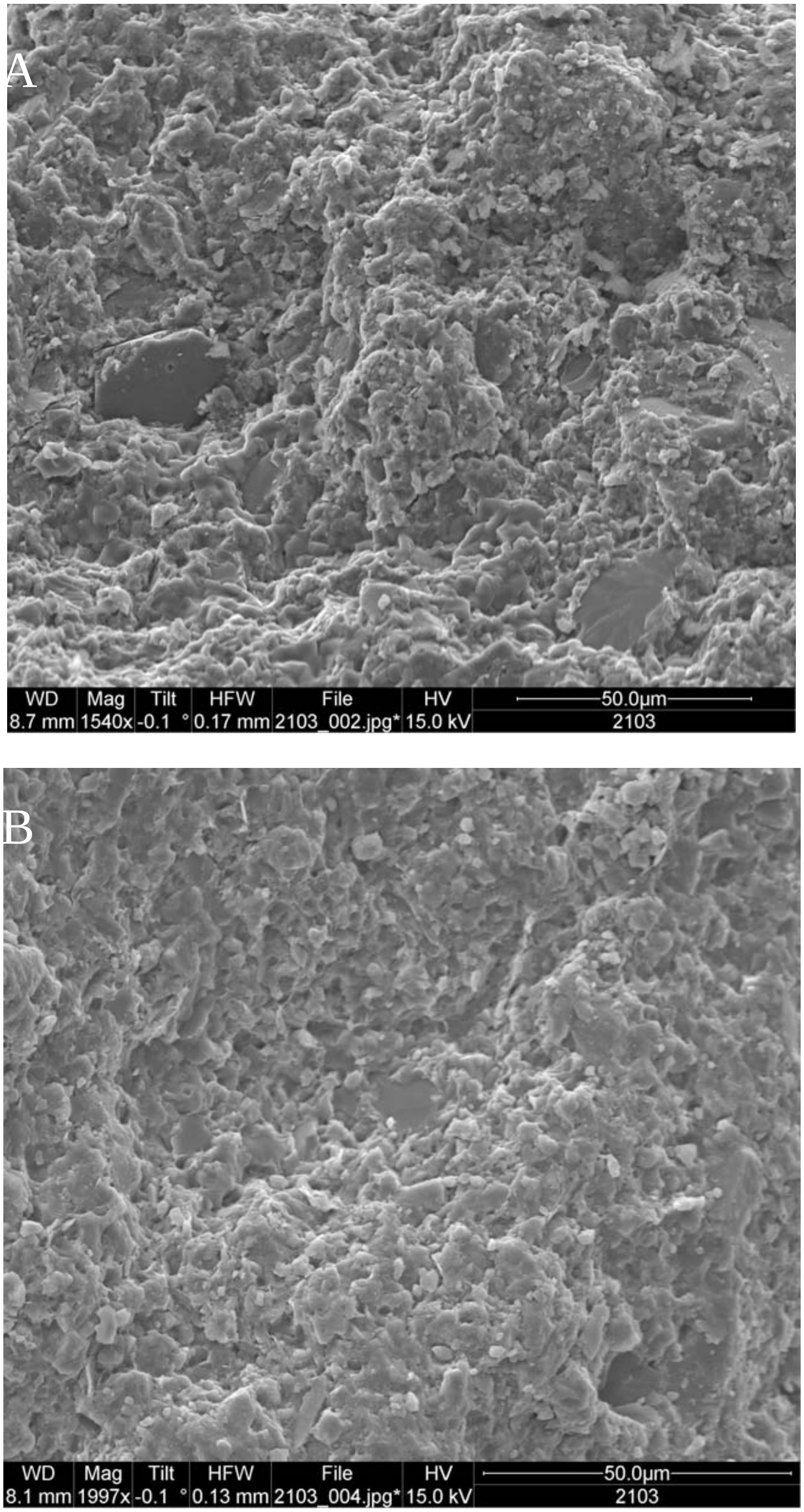


Figure 13. SEM Photos from 2103 feet. A) Possible microporosity in shaly limestone with larger calcite crystals. B) Possible microporosity in shaly limestone.

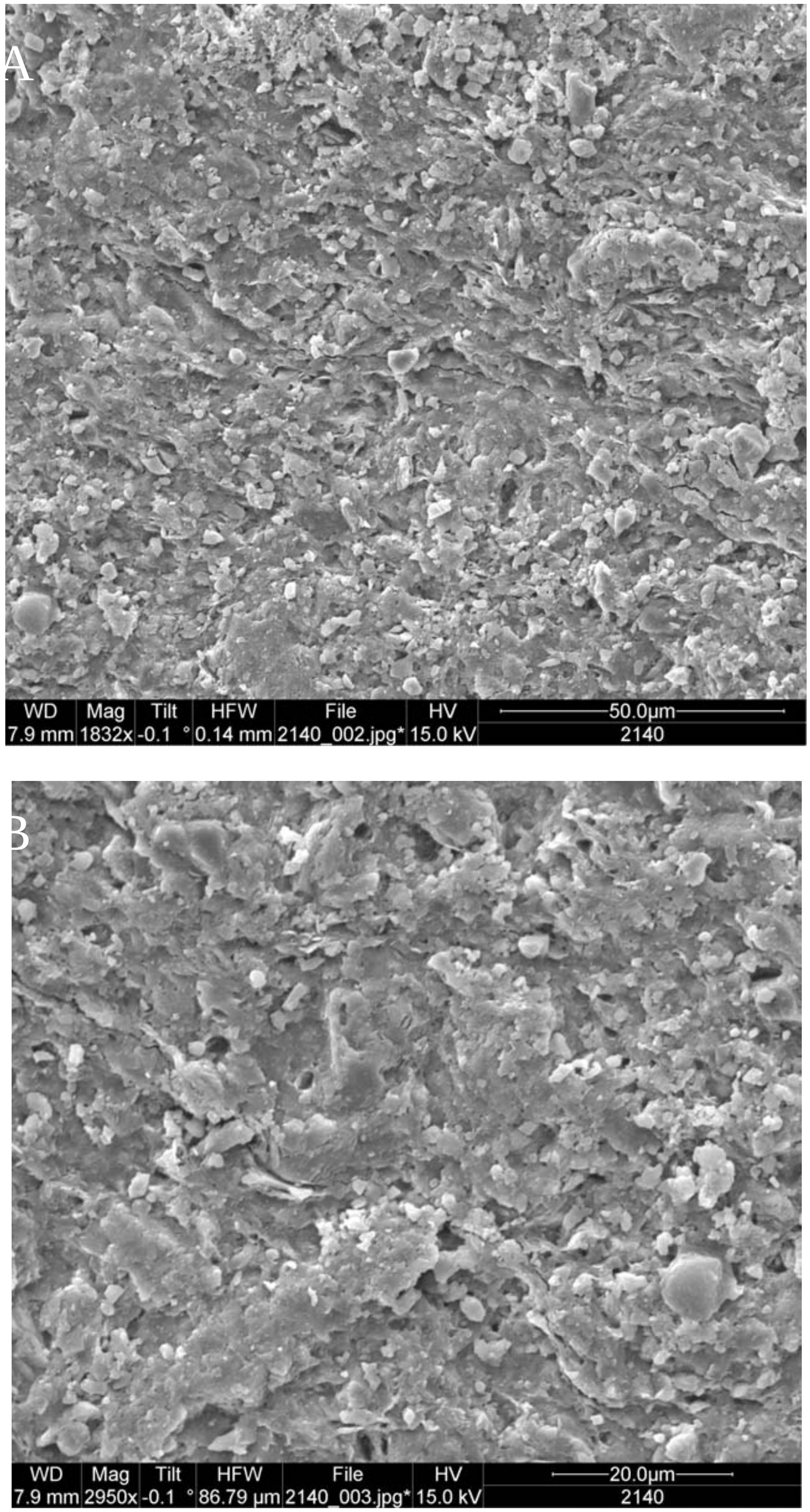


Figure 14. SEM Photos from 2140 feet. A) Shaly limestone with microcrack and possible microporosity. B) Close-up of previous with sinuous microcrack and possible microporosity.

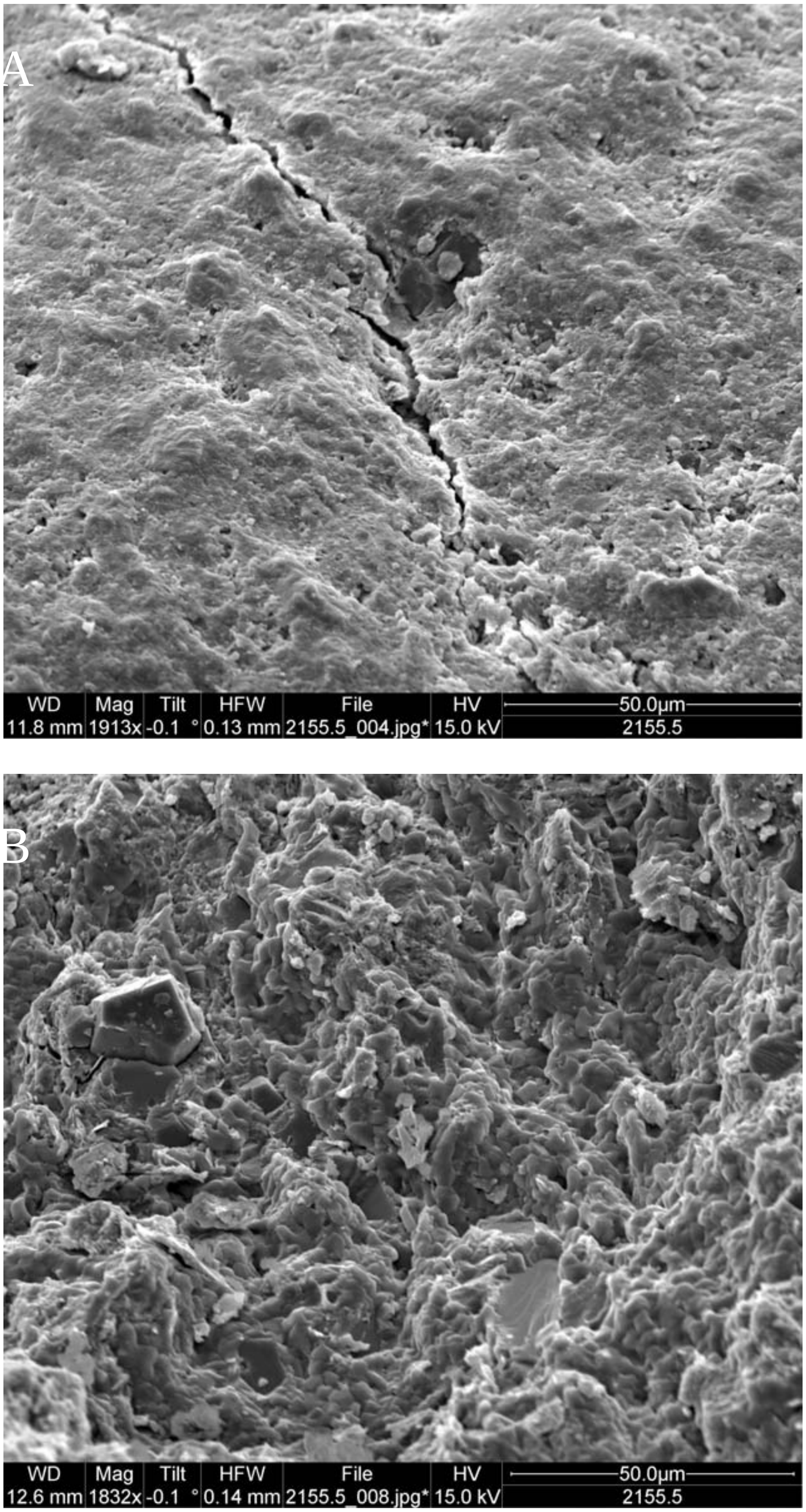


Figure 15. SEM photos from 2155 feet. A) Open *en echelon* microcracks. B) Possible microporosity in shaly limestone.

6.6 Shale Geochemistry

Source-rock analysis was performed on ten samples of the darker shales interbedded within the Trenton (Table 2). Samples were selected because they were in units where gas shows occurred and appeared to be the darkest shales. None of the TOC values were more than 1%.

HGS No.	Depth (ft.)	Sample Type	Leco TOC	S1	S2	S3	Tmax (^{o}C)	Cal. %Ro
05-3072-122176	1846	swc	0.20	0.06	0.02	0.23	394	-1.00
05-3072-122177	1847	swc	0.24	0.08	0.04	0.21	-1	-1.00
05-3072-122178	1857	swc	0.07	0.02	0.01	0.15	-1	-1.00
05-3072-122179	1878	swc	0.21	0.05	0.07	0.20	305	-1.00
05-3072-122180	1880	swc	0.05	0.03	0.03	0.20	-1	-1.00
05-3072-122181	1890	swc	0.11	0.04	0.02	0.18	305	-1.00
05-3072-122182	1892	swc	0.02	0.00	0.00	0.00	-1	-1.00
05-3072-122183	1893	swc	0.06	0.02	0.00	0.11	-1	-1.00
05-3072-122184	1927	swc	0.08	0.03	0.01	0.08	-1	-1.00

HGS No.	Depth (ft.)	HI	OI	S2/S3	S1/TOC	PI	Pyrogram
05-3072-122176	1846	10	115	0	30	0.75	n
05-3072-122177	1847	17	87	0	33	0.67	n
05-3072-122178	1857	14	214	0	29	0.67	n
05-3072-122179	1878	33	95	0	24	0.42	n
05-3072-122180	1880	60	400	0	60	0.50	n
05-3072-122181	1890	18	164	0	36	0.67	n
05-3072-122182	1892	0	0	-1	0	-1.00	f
05-3072-122183	1893	0	183	0	33	1.00	n
05-3072-122184	1927	13	100	0	38	0.75	n

Note: "-1" indicates not measured or meaningless ratio
* Tmax data not reliable due to poor S2 peak
TOC = weight percent organic carbon in rock
S1, S2 = mg hydrocarbons per gram of rock
S3 = mg carbon dioxide per gram of rock
Tmax = oC

HI = hydrogen index = S2 x 100 / TOC
OI = oxygen index = S3 x 100 / TOC
S1/TOC = normalized oil content = S1 x 100 / TOC
PI = production index = S1 / (S1+S2)
Cal. %Ro = calculated vitrinite reflectance based on Tmax
Measured %Ro = measured vitrinite reflectance Notes:
c = Rock-Eval analysis checked and

Pyrogram:
n=normal
ltS2sh = low temperature S2 shoulder
ltS2p = low temperature S2 peak
htS2p = high temperature S2 peak
f = flat S2 peak
na = printer malfunction pyrogram not available

Table 2. Shale Geochemistry from Humble Geochemical.

Section 7
LOG ANALYSIS

7.1 Neutron and Density Porosity

There are two zones in virtually all Trenton wells where the neutron porosity goes up but the density porosity (other than a few thin spikes) only goes up a very small amount (Figure 3; Plate 3). These zones occur in intervals where gamma radiation is higher, suggesting that they are mainly due to an increase in clay content. Neutron logs respond to hydrogen ions which occur in many clays. Many of the shows occur within these zones, suggesting a link between clay content and gas shows. Figure 3 shows that virtually every increase in neutron porosity is accompanied by an increase in gamma radiation. All of the gamma ray values have been plotted against neutron porosity values from the same depth, and the result is generally a linear trend. As gamma radiation increases, neutron porosity increases. This means that clay content is causing the apparent increase in neutron porosity. Note that in the Utica Shale, the density is slightly lower, but the neutron log shows significant porosity. The few outliers from the trend occur on what are interpreted to be bentonites. The neutron log is more sensitive to shale content than the density log. If the shows mostly occur where the shale content is high, and it appears that they do, then the gas is most likely related to the occurrence of shale beds. The SEM photos revealed some possible minor microporosity in the clays.

When the porosity of the plugs was measured, they were found to indeed be porous in the intervals that looked porous on the neutron log. This should not happen unless there is actually some porosity or unless the measured grain densities were inaccurate. Rocks are porous when the bulk density (measured by weighing and determining the volume of the plug) is less than the measured grain densities that are determined using a helium pycnometer. In the end, the porosity is likely to be very low and be higher than the measured density porosity and lower than the measured neutron porosity.

7.2 Bentonites

Bentonites are volcanic ash layers. There were volcanoes to the present-day east of the study area during Trenton-Black River deposition, and there are many volcanic ash beds preserved in the study interval. However, none of the plugs sampled bentonites that could be detected. The log signature of a bentonite that is thick enough to affect the logs is high gamma ray, low density (high density porosity), and high neutron porosity. These commonly occur as “spikes” on the log. If, however, the bentonite is thinner than about six inches, it may only affect one or two of the logs, or perhaps none of them. This appears to be the case in the Huntley #1 well. There are some spikes that are clearly bentonites, where the density, neutron, and gamma radiation all respond appropriately. Some of the gas shows may occur at the bedding plane boundaries between the bentonites and the limestone. Some of the spikes may in fact be thin shale beds, not bentonites. If they correlate from well to well, as many of these do, then they are likely to be bentonites.

Section 8
BLACK RIVER GROUP (2352-2618 Feet)

8.1 Lithology

On the FMI log and with the petrographic scope, one can easily and informally distinguish a distinctive, massive to bedded "upper" (2350-2379) and "lower" Black River (2379-2615). The former corresponds to the Lowville and perhaps younger stratigraphic units, which are composed of massive and bedded clay-deficient limestones and rare shaly breaks (Plates 2356, 2375). This "upper" unit contrasts with the "lower" Black River Group, the Pamelia (Plates 2679, 2413, 2456, 2566, 2609), which is composed of dolostone, interbedded limestones, and thin, shaly strata. The basal Pamelia, below approximately 2560 feet, contains more dolomite-rich intervals than the remainder of the section.

The depositional style of the Pamelia more closely resembles the bedding of the Trenton. Lenticular and nodular bedding is most conspicuous in the lower Black River. Similar to the Trenton, the basal Black River interval may represent deposition in a deeper setting than the upper Black River. Despite this similarity, the Black River was probably deposited in a shallower environment than the Trenton.

Although most beds are less than one foot thick throughout the Black River interval, one-foot-thick limestone beds are not uncommon. There is also the occasional two-foot-thick limestone bed. The carbonate contains little, disseminated, detrital clay. Clay is generally restricted to very thin seams and interbeds (Plates 2404, 2408). These detrital, clastic-rich strata have probably been thinned considerably by compaction. K-bentonite, an important chronostratigraphic marker, may be a constituent of some shaly beds, although this supposition was not tested.

Quartz silt and sand is not common in the upper Black River, Lowville and younger units, and is generally restricted to shaly interbeds (Plate 2342). The dolomitized intervals of the Pamelia contain much quartz sand, which is rounded and may be aeolian (Plate 2566). Much quartz in the Black River occurs as authigenic crystals (Plates 2352, 2372, 2377) and rare megaquartz cement and replacement (Plate 2350). The latter are especially conspicuous near the Trenton boundary. In contrast to the overlying Trenton, pyrite is very rare in the Black River (Plates 2413, 2432).

Dolomite generally occurs as fine (Plates 2404, 2466, 2532) to coarse (Plates 2354, 2366) crystalline replacement rhombs in the Black River interval. Dolomite may be concentrated or preferentially formed along pressure-solution features (Plates 2536, 2549). The dolomite of the Pamelia replaces lime-mud matrix (Plates 2570, 2609). Although the Pamelia may be extensively or completely dolomitized, dolomite is not abundant, nor does it completely or extensively replace carbonate above the Pamelia. Coarse saddle dolomite is very rare, occurring as cement (Plate 2364, 2369). There may have been some "overgrowth" of replacement dolomite during the saddle dolomite emplacement, although this is conjectural.

The Black River interval has many small V-shaped fractures (Plates 2358, 2404, 2536), which often are indicative of desiccation fractures. These fractures invariably are limited to the thin section and do not appear to be larger or tectonically induced. Some desiccation fractures may be cross-cut by later tectonic fractures (Plate 2358). Many desiccation fractures terminate at stylolites. Although such a relationship may indicate fracturing after the formation of the stylolite, an alternative explanation is that the plane of the stylolite represents a depositional surface and a hiatus in deposition (Plates 2375, 2377). Desiccation fractures are common in intertidal or shallow subtidal environments, which are exposed shortly after deposition and are distinguishable from tectonic fractures (Plates 2362, 2466).

8.2 Texture and Constituents

Carbonate depositional textures of the Black River Group range from mudstone
(Plates 2466, 2536) through grainstone (Plates 2372, 2456, 2579) but also include organically bound fabrics. Well-defined fenestrae are present at the very top of the Black River and may represent a thin, but diagnostic, microbial boundstone (Plate 2350). Poorly developed fenestral voids (e.g. 2549) are rare in the remainder of the Black River section.

The dominant grains in the uppermost Black River are non-skeletal micropeloids (Plates 2350, 2368), in contrast to the skeletal-dominated Trenton fabrics. The appearance of abundant micropeloids approximates the assigned and arbitrary break between informal upper Black River and lower Black River. Well-formed peloids (Plates 2372, 2447, 2456), which are differentiated on the basis of size, are a significant contributor to the suite of allochems, and they dominate the lower Black River strata. Not definitively fecal pellets, Black River peloids may be the internal molds of the zooecia of bryozoans (Plate 2389). Although non-skeletal grains are not immediately evident, indistinct clotted textures hint of a peloidal and micropeloidal origin of many intervals of the Black River limestone (Plates 2367, 2413, 2466 feet) and dolomite (Plate 2609). Other non-skeletal grains may locally dominate the carbonate grains suite. These include intraclasts (Plates 2389, 2404, 2447) and ooids (Plate 2579).

Skeletal grains are rarely important components of these characteristically muddy rocks of the Black River and generally are not a dominant rock-forming constituent. A typical Ordovician suite can be identified and includes echinoderms (Plate 2367), brachiopods (Plate 2352), and trilobites (Plate 2408). Bryozoans (Plate 2389), bivalve molluscs (Plate 2369), ostracods (Plate 2432), calcareous algae (Plate 2456), gastropods, and spicules (Plate 2413) are sparse to rare constituents of these generally matrix-dominated rocks.

Carbonate skeletal grains may be intensely abraded and comminuted, creating calcisilt (Plates 2351, 2366), which may be an important yet indistinct component of the fine-grained textures. Tetradium, a small tabulate coral that is prominently mentioned in the literature regarding the Black River, was not a conspicuous component of the skeletal suite. Tetradium was only identified in one sample (2389), occurring as the component in a small intraclast.

8.3 Porosity

Petrographic examination revealed no observable porosity in the thirty-six thin sections of the Black River Group. All primary and secondary porosity has been cemented and/or reduced by compaction. Loss of high depositional porosity of matrix-rich rocks (Plate 2413) was eliminated by compaction. Fenestrae, which are characteristic of the Lowville, are occluded by calcite and quartz cements (Plate 2350 feet).High primary, intergranular porosity of rare grainstones and packstones was thoroughly cemented (Plates 2546, 2579). Cements completely fill any intraskeletal or intragranular porosity (Plate 2389). Burrows (Plate 2408) are completely cemented.

What once may have been secondary, moldic porosity (Plates 2362) is entirely occluded by cement, typically calcite. Fractures (Plates 2368, 2375), either desiccation or tectonic, are thoroughly cemented. Open fractures are artifacts of coring, sample handling, or thin-section preparation.

Section 9

TRIBES HILL FORMATION (BEEKMANTOWN GROUP)

(2618-2635 feet)

Because only one sample (Plate 2630) represents the thin sliver of the Tribes Hill in the Huntley #1 well, little can be said. The lime mudstone in the one sample contains some clay laminae and fine replacement dolomite. There is no visible porosity.

Section 10

GALWAY FORMATION (2635-2686 feet)

Although at first inspection there is a gross resemblance to the sandy dolomite strata of the Pamelia, the Galway Formation contains no discrete limestone intervals. The Galway contains abundant detrital clastics and is often a dolomitic sandstone. Terrigenous clastic material may account for up to approximately 85% of the bulk composition of the Galway. The detrital clastic quartz and feldspar are rounded to subangular and poorly sorted (Plates 2636, 2656). In contrast to the Pamelia, the Galway contains significant amounts of detrital feldspar. Detrital matrix clays are often sericite and are probably the altered remnants of detrital feldspar. Heavy minerals (Plate 2656) and glauconite (Plate 2645) are also present.

Most commonly, the dolomite of the Galway is a replacement of carbonate matrix rather than a cement. Calcite occurs as unconsumed calcite matrix and poikilotopic cement. There are no identifiable skeletal grains in the Galway. There is no visible porosity in the dolomitic section of the Galway.

The lower Galway is a well-rounded, moderately well to well-sorted sandstone with little clay or carbonate. Only the beds immediately above the basement are non-porous (Plate 2684). Intergranular pores (Plate 2672) are the dominant type, accounting for up to 20 percent porosity. Primary porosity may be reduced to be entirely occluded by quartz overgrowth or quartz cement (Plates 2677, 2684).

Section 11

DETAILED DIAGENESIS OF THE TRENTON-BLACK RIVER

The following is a detailed description of the diagenesis of the Trenton and Black River Group carbonates in the Huntley #1 well, as revealed by the core plug thin sections. These are summarized in Figure 16.

After death and disarticulation of organisms, physical and biologic processes comminute and abrade skeletal elements. Similarly, non-skeletal carbonate grains are also subject to fragmentation and abrasion. Fragmentation creates smaller grains, which are more readily transported by weaker currents and rendered more susceptible to further size reduction and abrasion. Extensive fragmentation of allochems may provide abundant silt-sized carbonate grains or calcisilt. Disaggregation of calcareous algae is especially important in the production of carbonate mud or micrite, the dominant component of mud-supported carbonate textures and a constituent of many terrigeneous clastic-rich interbeds.

Various algae and fungi are responsible for micritization, which may begin during the life of some organisms and continue after death and disarticulation. Fungi and algae excavate galleries in the outer rim of skeletal material. These cavities are subsequently filled with micrite. Many generations of excavation and infilling create a thin micrite rim or envelope. Borings by algae, fungi, and other organisms weaken the carbonate skeleton, making them more susceptible to later fragmentation.

Early marine cements, though rare, may stabilize grainstones in the marine environment. Such cements require active movement of large volumes of fluids through a well-connected pore system. Although early marine cements may preserve primary intergranular porosity, later cementation and compaction entirely occlude all primary voids in the Trenton-Black River interval.

Some fabrics show evidence of early synsedimentary lithification, which is patchy and very irregularly distributed. Portions of some thin sections show little or no evidence of compaction, in contrast with similar fabrics in the same thin section that exhibit evidence of pressure solution. It appears that the early lithification may selectively consolidate muddy carbonate sediments that are deficient in detrital quartz silt and clay. Shaly, silty interbeds and terrigenous clastic-rich carbonates are more responsive to compaction.

Petrography reveals several carbonate hardgrounds which are evident in thin section and on the FMI. Numerous instances of intraclasts above grainstones can be identified on the FMI and are confirmed by thin section analysis. In addition, the top of the Black River Formation was probably lithified and bound during deposition. Numerous synsedimentary cavities are preserved in the microbial boundstone at the top of the Black River. Lithified sediments may be later exposed and eroded, either in the submarine or vadose environment.

Pyrite and glauconite, both iron-rich minerals, may form very shortly after deposition, especially in reducing sedimentary environments. Glauconite may be an alteration product of detrital clay.

Early pyrite that formed under reducing conditions contrasts with late pyrite, which may have a hydrothermal origin.

Undersaturated meteoric fluids, which passed through the carbonates, dissolved unstable mineralogies and produced moldic porosity. Calcite cement fills all moldic pores in the Trenton-Black River interval. The paucity of filled moldic pores indicates either a short residence time in the undersaturated meteoric environment or a reduced fluid flow. Later meteoric fluids, which were saturated in respect to calcite, precipitated large volumes of equant calcite, syntaxial calcite, and sparry calcite cement, especially evident in the mud- deficient grainstones. Sparry cements often exhibit conspicuous zonation, a response to changing pore fluid composition. Reducing meteoric pore fluids precipitate ferroan cements and may be responsible for the formation of pyrite.

Burial and compaction generate a host of diagenetic products. For example, overburden may fragment grains after burial. More important, pressure solution removes carbonate, effectively reducing the sediment/rock volume. Strata or lenses, which were not cemented early, most often manifest the effects of pressure solution. These features include embayed and sutured carbonate grains, wispy microstylolites, and low-amplitude stylolites. Overburden- and compaction-induced pressure solution not only dissolves carbonate grains and matrix, but also concentrates insoluble components, including organic residues, detrital quartz silt, sand, and clay. Concomitant with pressure solution is the formation of matrix dolomite, often localized near stylolites, and the precipitation of calcite cements from fluid mobilized from dissolution of carbonate grains and matrix. Pressure solution is an important agent that reduces porosity.

Petrographically observable fractures are most abundant in the Black River and much rarer in the Trenton. This distribution may indicate an episode of fracturing prior to deposition of the Trenton. Some V-shaped fractures are early desiccation cracks in exposed carbonate sediments. Compactional fractures, which are also early and were probably induced in semi-lithified sediments, are evident. Larger tectonic fractures can be distinguished from early fracturing events. There is no fracture porosity; calcite and dolomite cements fill all fractures.

Dolospar is the earliest of the burial cements, emplaced during one fracturing event. Saddle dolomite, though rare in the Trenton-Black River interval, may be conspicuously zoned and is a hydrothermal product.

Hydrocarbons were emplaced after the dolospar. Liquid hydrocarbons were converted to solid bitumen either during another fracturing event and the associated hydrothermal activity, or during burial. Curiously, many bituminous residues exhibit meniscus textures and may be fractured. In the former case, liquid hydrocarbons and air (or possibly another gas) must have filled the pores. Fracturing of the solid hydrocarbon residue occurred prior to the emplacement of the late cements.

Reactivation of fractures and renewed hydrothermal activity post-dated the conversion of liquid hydrocarbons to bitumen. This hydrothermal episode, which is distinct from the earlier event that precipitated the saddle dolomite, emplaced very coarse calcite cement—which invariably is non-ferroan—more pyrite, and finally quartz cement and replacement.

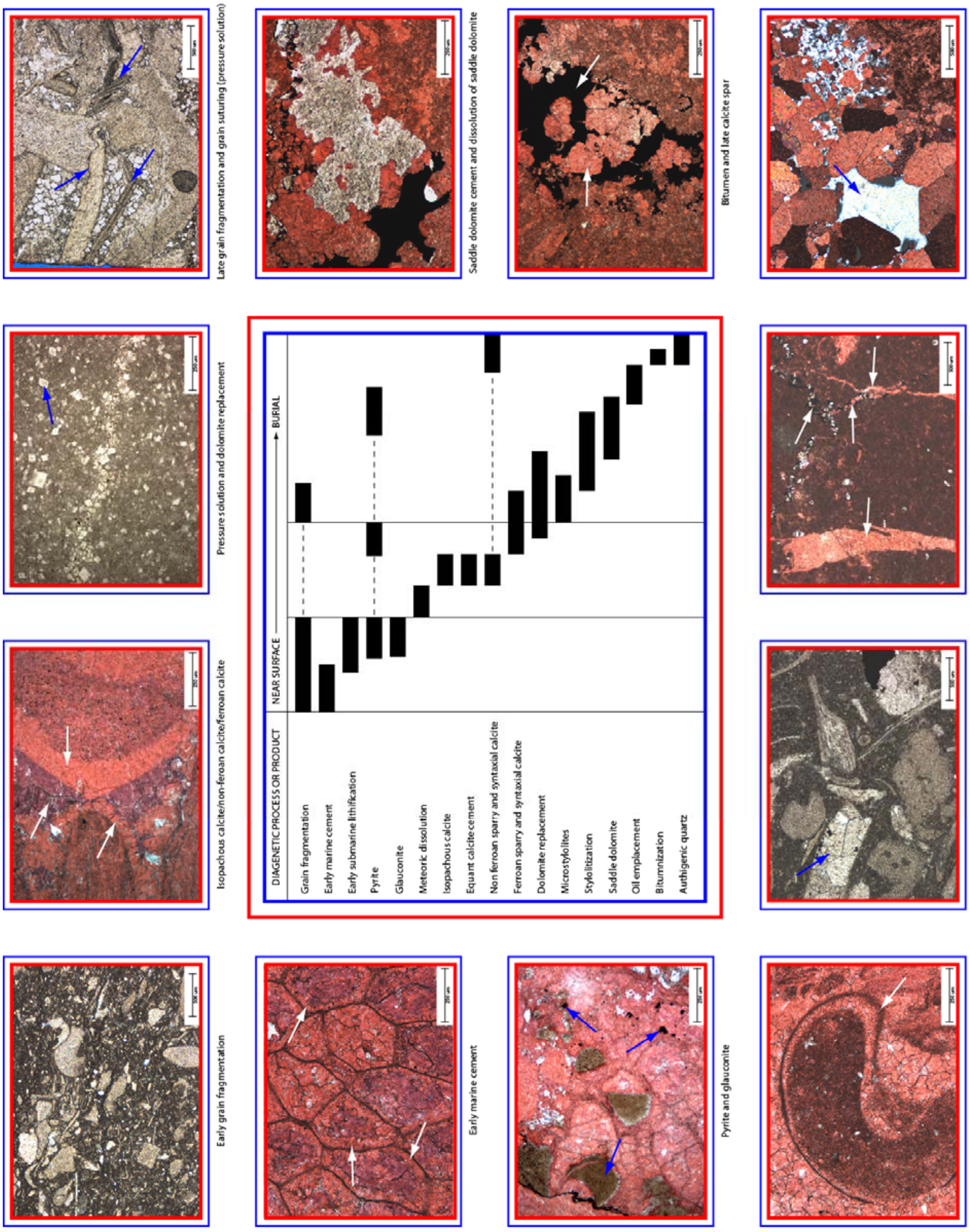


Figure 16. Paragenetic sequence of Trenton and Black River Groups.

Section 12
RESERVOIR CHARACTERIZATION AND INTERPRETATIONS

12.1 Bedding-plane Parting Model

So where does the gas come from? First, it is not a hydrothermal dolomite play like the prolific Trenton-Black River reservoirs to the south and west. There is a small amount of dolomite and a very small amount of saddle dolomite, but the intervals where the shows occurred are not dolomitized. It is not a matrix limestone play; there is virtually no porosity in the limestone in the interval where the shows occurred. There are few vertical fractures in the Huntley #1 well in the interval where the shows were, so in this well, it is not a vertical fracture play (although vertical fractures may be very important in wells that produce economic quantities of gas elsewhere in the trend).

The interpretation here is that most of the gas in this well and in many wells in the New York Trenton limestone play comes from open bedding plane partings or horizontal fractures. This is an idea that was first heard from Bill Zagorski of Great Lakes Energy (personal communication) and with which a few other operators also seem to agree. The bedding plane partings would be most likely to be open and have high-pressure gas where there is a stark contrast in lithology between shale and limestone or bentonites and limestone. The photograph in Figure 17 is of a Devonian bentonite and limestone, but it illustrates how partings between these lithologies might be open and prone to being filled with gas. Gradational contacts would be less likely to be pushed apart.

Figure 18 A-D is a schematic of how this play works. Figure 18A shows schematic Trenton stratigraphy. The high pressure of the gas holds the partings open (Figure 18B). When the partings are first penetrated (Figure 18 C) , the very high-pressure gas may cause blowouts and strong pressure kicks; as soon as the gas pressure decreases, the weight of the overburden causes the bedding-plane partings to close (Figure 18 D), and the rate drops to a few mcf per day.

There is very little direct evidence for the bedding-plane parting model, but this model best explains the data. The rapid decline rates are typical of fracture production. These high-pressure gas shows only seem to occur where the Trenton is buried to a depth of less than 2500 feet (Figure 1). Horizontal fractures or open bedding-plane partings are progressively less likely to occur with increasing burial depth, so they should be more common at shallow depths and progressively less common with increasing depth until they cease. The more technical explanation is that the maximum compressive stress is horizontal up to a depth of 2500-3000 feet and then becomes vertical below that. When the principal compressive stress is horizontal, as it is at the shallower depths, horizontal fractures or expansion of bedding plane partings will occur. When the principal compressive stress is vertical, vertical or near vertical fractures will form. The shows are most common in the intervals where there are interbedded shales, limestones, and bentonites. Again, these bedding-plane partings might be most easily opened where there is a stark contrast between a well-cemented limestone and a shale bed. Note that many porosity zones and gas shows line up with such high-contrast bedding (Plate 3).

The high mud weights needed to control the well suggest that the gas was at or very near lithostatic pressure. Lithostatic pressure varies slightly with the composition of the bedrock but is typically around 1.0 psi/foot (or 100 psi/100ft) which is the equivalent of about 19.2 lb/gal mud (see Table 3). The mud weight needed to control the well while drilling was 19.2 lb/gal. So the pressure of the gas may have been enough to prop open bedding planes and actually lift the overburden until it was penetrated by the drill bit which allowed the gas to escape and the bedding planes to close.

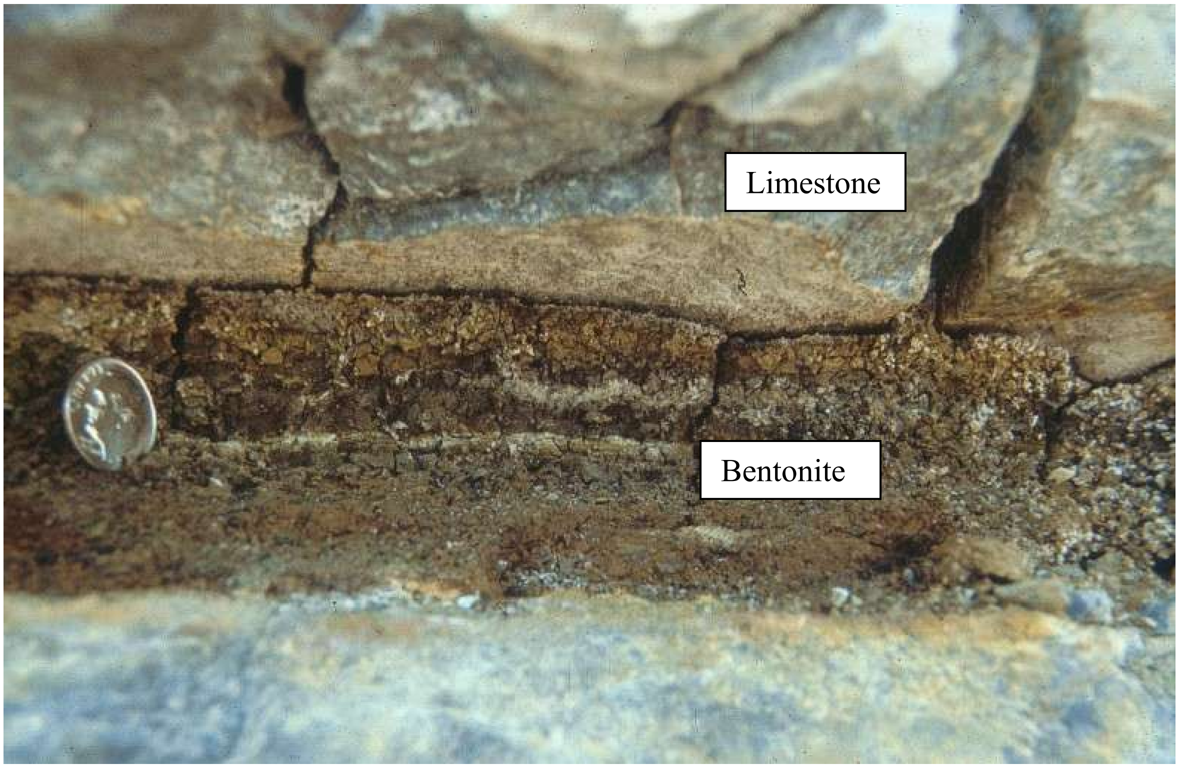


Figure 17. Bentonite and limestone with open parting between them (photo courtesy of Chuck Ver Straetten)

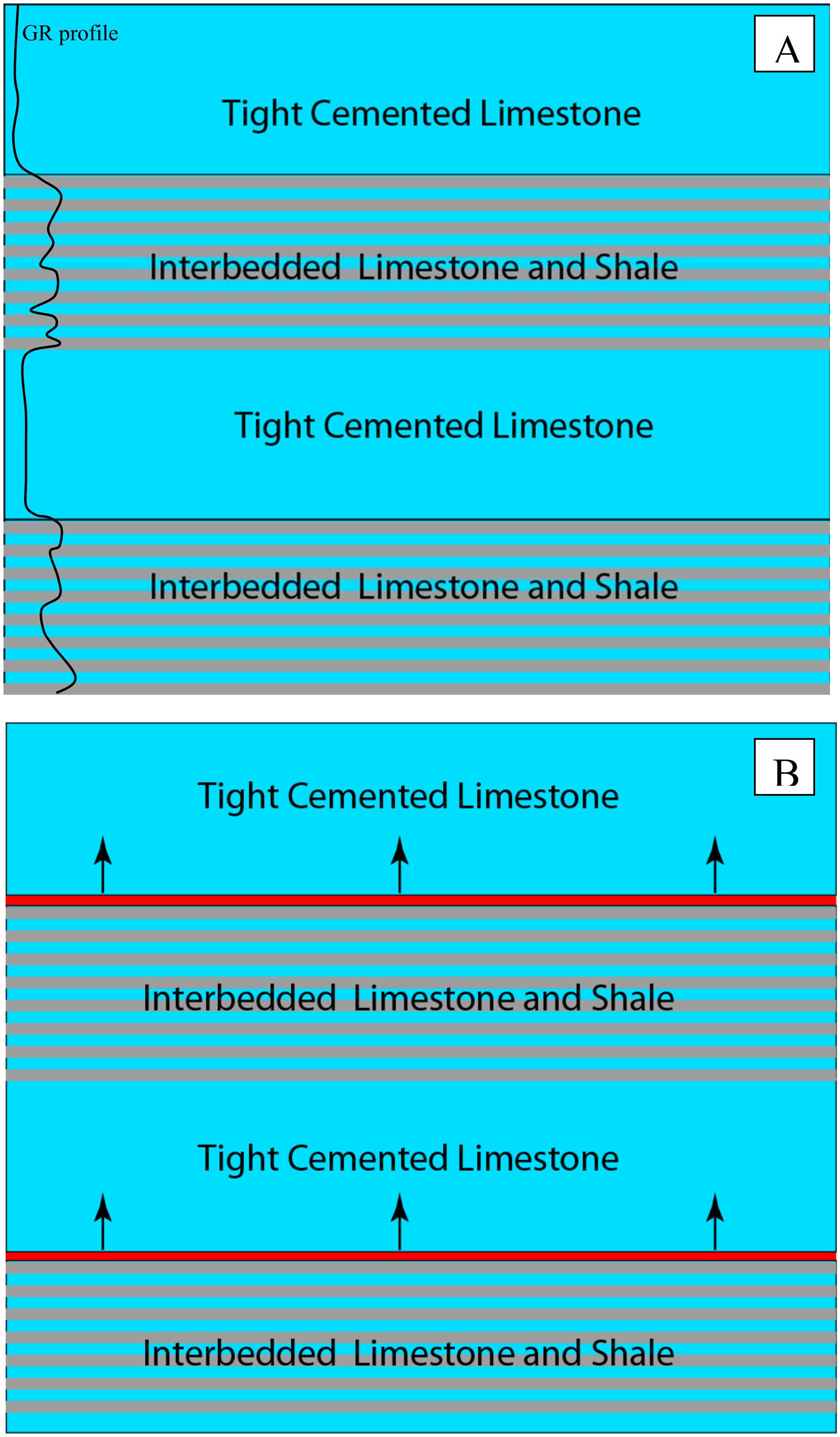


Figure 18. A) Schematic Trenton formation stratigraphy and gamma ray response. B) Gas that is right at lithostatic pressure lifts open bedding plane partings.

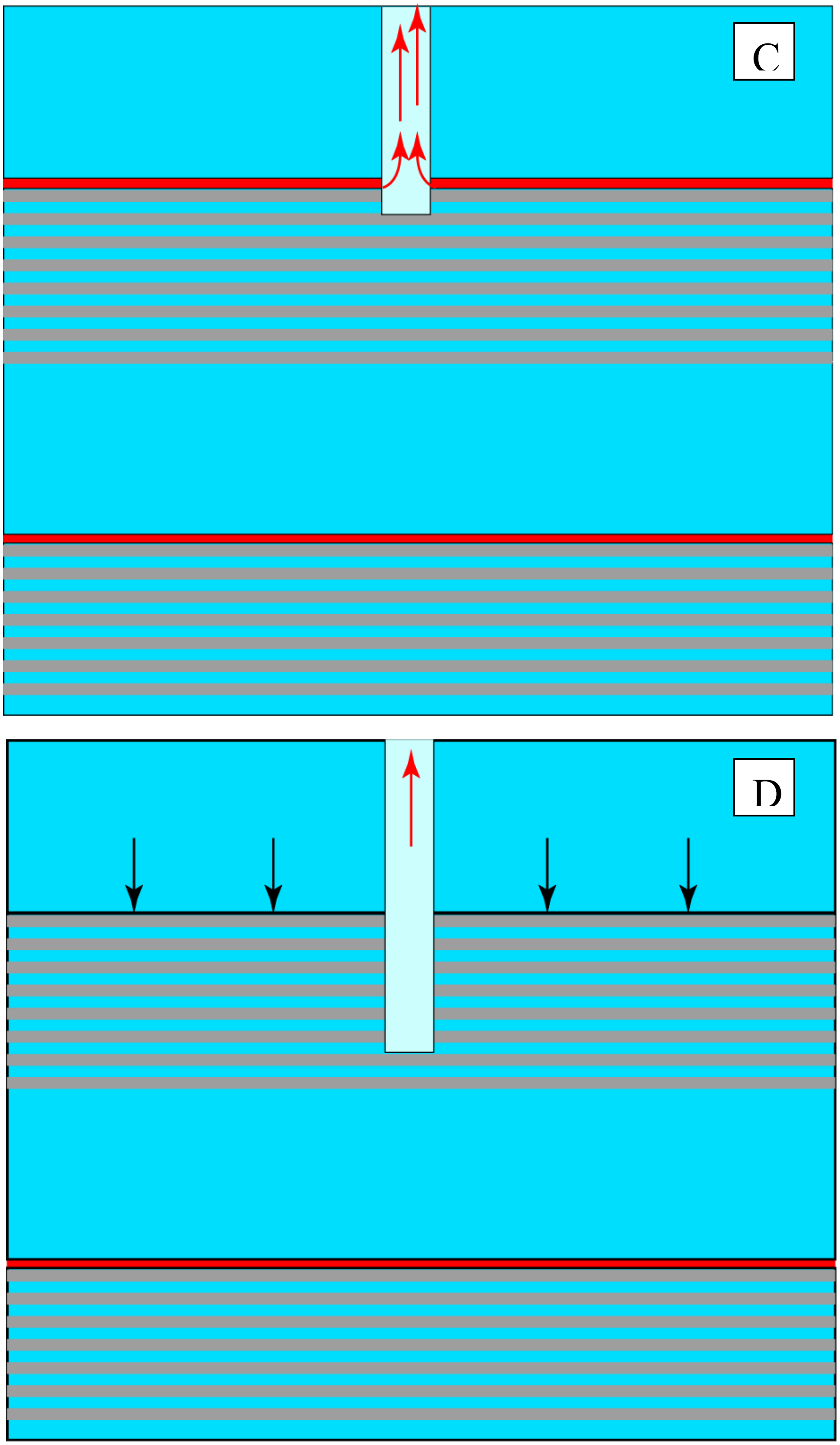


Figure 18. C) Well bore penetrates gas bearing bedding plane and high-pressure gas flows at high rate out of hole. D) As pressure decreases, bedding plane closes and flow decreases to very low rate.

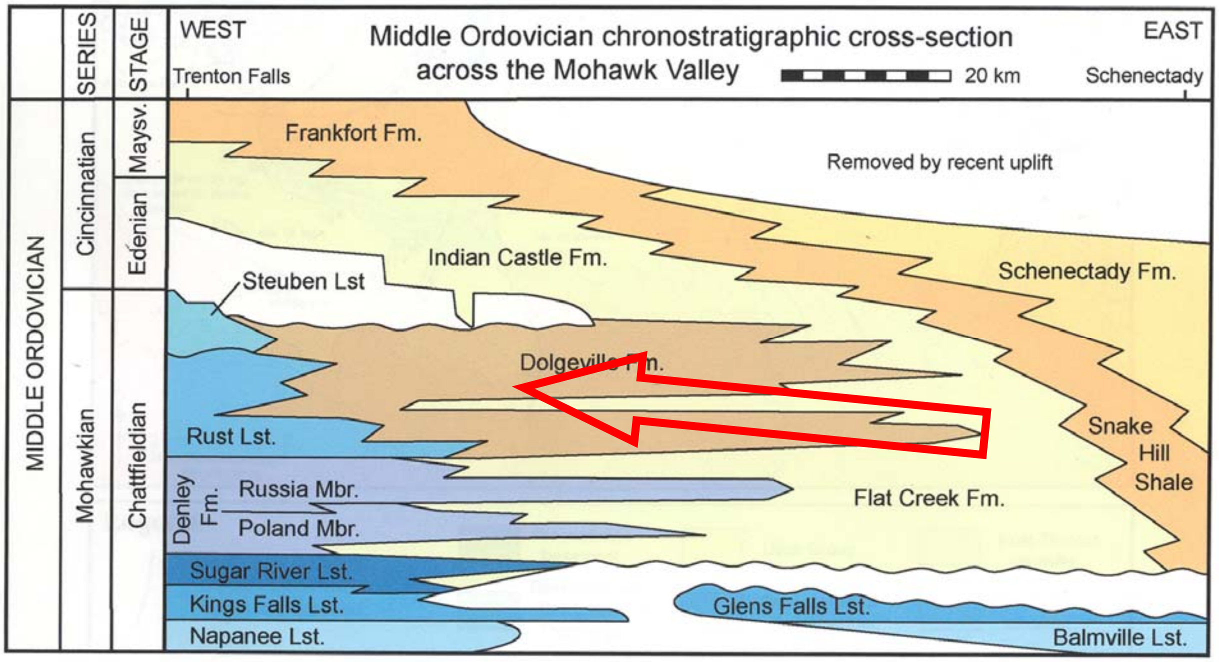


Figure 19. Utica Shale (Flat Creek and Indian Castle Formations) could be a source for the gas or much of it may come from interbedded organic-rich strata. Modified from Cross (2004) and Goldman et al, 1994.

12.2 Source of the Gas

The gas is either self-sourced from organic-rich shales in the Trenton or comes laterally from the time-equivalent section of the Utica Shale (Figure 19). Source-rock analysis was performed on ten samples of the darker shales interbedded within the Trenton (Table 3); all were found to have fairly low TOC values. It may be that the samples were not from the shales with the best source-rock potential, and that most or all of the gas is self-sourced. The gas may have migrated in laterally from the Utica. The number of fields increases towards the lateral contact with the Utica Shale, which supports this model.

If the gas is self-sourced, it may be that maturation of the source rock took place during deeper burial (up to 3-5 km), when temperatures and pressures were in the gas window. When the strata were buried at high pressures, the gas was probably primarily contained in the microporosity of the shale. As the Trenton was uplifted and unroofed, lithostatic pressure decreased and the gas expanded and pushed apart any weaknesses such as high-contrast bedding planes and fractures.

12.3 Prospect and Drilling Approach

The microporosity in the shale is likely to have very low associated permeability. Without fractures to assist, production rates from the shale will be negligible. If completions can be designed to keep the bedding-plane partings open during production, it might be possible to drill economic wells to this play. However, fracture or proppant jobs may be very difficult in these wells when the pressure is high and the depths are so shallow.

Zagorski (IOGANY presentation, Fall 2005) showed that wells drilled to the Trenton limestone in “grabens” or negative flower structures seemed to have production that held up better than wells not drilled into these structural features. Shown in Figure 20 is a seismic image of a structure similar to the one presented by Zagorski; his graben is virtually identical to those drilled for Black River hydrothermal dolomite reservoirs further to the southwest. Open fractures are more likely to form on the downthrown side of faults than they are on the upthrown side (Figure 21). It may be that wells that penetrate open vertical fractures can be economic in this play while those that only penetrate the bedding plane partings are not. The vertical fractures may connect enough of the bedding-plane partings and microporous shale units to yield economic quantities of gas.

These faults are best detected with seismic data. If it is established that only wells drilled in certain structural positions are economic, it will probably be necessary to acquire seismic data to identify good well locations. This adds considerable expense to each well, and it remains to be seen whether those costs can be recovered with “good” Trenton limestone wells. On the plus side, there may be hydrothermal dolomite plays underlying fractured Trenton in these features and/or Queenston plays above them so it may be possible to stack prospects.

Zagorski (IOGANY, Fall 2005) also suggested that most wells with shows had a strong show at the base of the cleaner limestone at the top of the Trenton (Figure 22, Plate 3); this is also where the Huntley #1 well blew out (Plates 2 and 3). This fits with the interpretation that the clean, tight limestones are seals over the overpressured gas in the partings between the shale and limestone. Shows may occur at many other intervals above and below this, but this zone consistently had shows in wells that flowed gas.

A drilling approach that will likely help reduce costs is to stop and flare each overpressured gas zone during drilling to determine whether the pressure holds up (Dick Beardsley, personal communication). If the pressure rapidly declines and the flow decreases to a few mcf after a short time, continue to drill; if the pressure and rate stay high enough to produce at an economic rate, it may be best to stop drilling and hook up the well. When the well has stopped flowing or flow has decreased to sub-economic rates, it may then make sense to come back and continue drilling to potential deeper targets.

If one were to choose a stratigraphic interval into which to drill a horizontal well, it would be in the shale-rich interval just below the Steuben Limestone, which is the uppermost clean limestone in the Trenton Formation (Figure 22). This shale-rich zone commonly has porosity in the neutron logs and is time-equivalent to the organic-rich Flat Creek Shale to the East which is also a possible drilling target in New York. Drilling horizontally through these overpressured horizons may be difficult, but if one were to attempt this approach, this is the zone that would be most appropriate. Major hydrofracturing jobs similar to those currently being done in the Barnett Shale and closer to home in the Marcellus Shale may help these wells to yield economic quantities of gas.

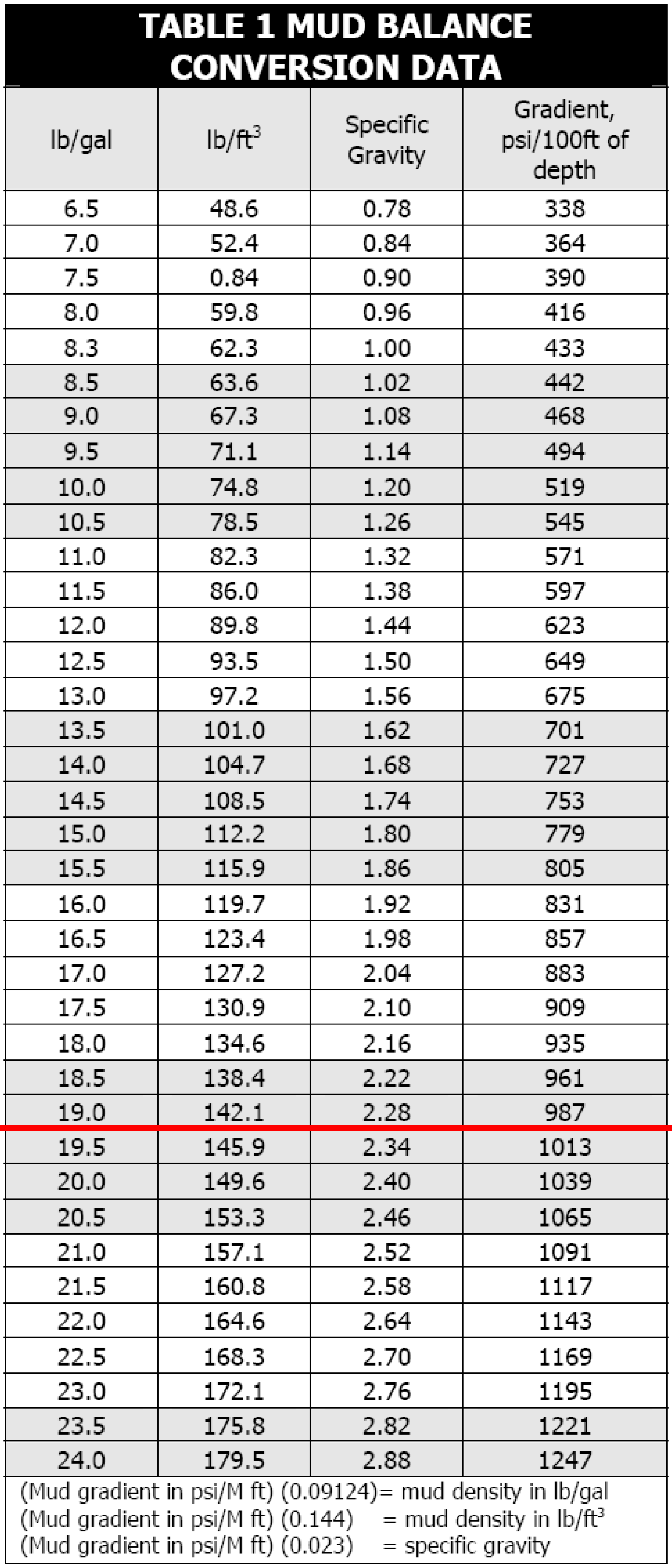


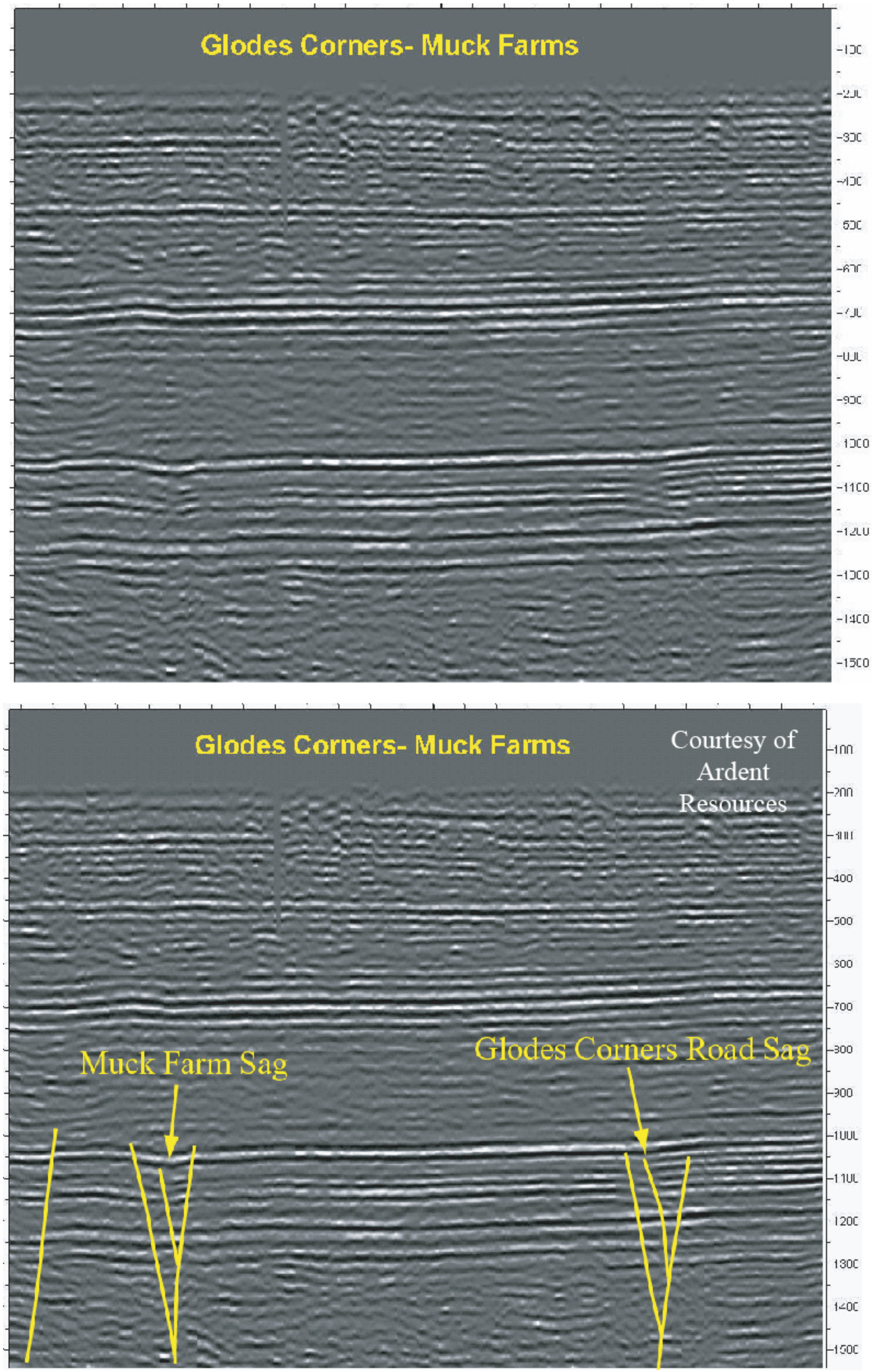
TABLE 1 MUD BALANCE CONVERSION DATA

lb/gal	lb/ft³	Specific Gravity	Gradient, psi/100ft of depth
6.5	48.6	0.78	338
7.0	52.4	0.84	364
7.5	0.84	0.90	390
8.0	59.8	0.96	416
8.3	62.3	1.00	433
8.5	63.6	1.02	442
9.0	67.3	1.08	468
9.5	71.1	1.14	494
10.0	74.8	1.20	519
10.5	78.5	1.26	545
11.0	82.3	1.32	571
11.5	86.0	1.38	597
12.0	89.8	1.44	623
12.5	93.5	1.50	649
13.0	97.2	1.56	675
13.5	101.0	1.62	701
14.0	104.7	1.68	727
14.5	108.5	1.74	753
15.0	112.2	1.80	779
15.5	115.9	1.86	805
16.0	119.7	1.92	831
16.5	123.4	1.98	857
17.0	127.2	2.04	883
17.5	130.9	2.10	909
18.0	134.6	2.16	935
18.5	138.4	2.22	961
19.0	142.1	2.28	987
19.5	145.9	2.34	1013
20.0	149.6	2.40	1039
20.5	153.3	2.46	1065
21.0	157.1	2.52	1091
21.5	160.8	2.58	1117
22.0	164.6	2.64	1143
22.5	168.3	2.70	1169
23.0	172.1	2.76	1195
23.5	175.8	2.82	1221
24.0	179.5	2.88	1247

(Mud gradient in psi/M ft) (0.09124)= mud density in lb/gal
(Mud gradient in psi/M ft) (0.144) = mud density in lb/ft³
(Mud gradient in psi/M ft) (0.023) = specific gravity

19.2 ≈ lithostatic

Table 3. Mud weight and gradient depth (from www.cetco.com/dpg/**pdf**/Testing%20-%20**Mud**%20Balance.**pdf)**.



Courtesy of Ardent Resources

Figure 20. Interpreted and uninterpreted siesmic line showing negative flower structures (sags) from Black River Play. Zagorski (2005) showed that the better Trenton limestone well in his working area was drilled into a similar sag. Open fractures more likely to occur on downthrown side of faults.

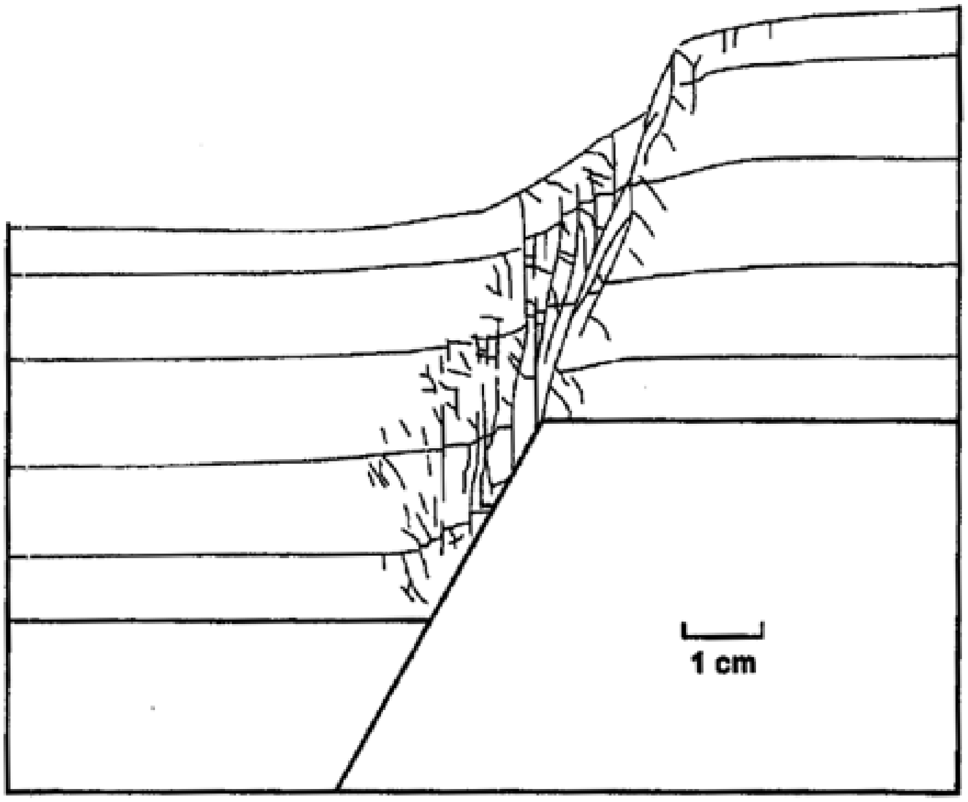


Figure 21. Preferential formation of vertical fractures on downthrown side of normal or transtensional fault (from Witnjack, 1990 by way of Davies, 2001).

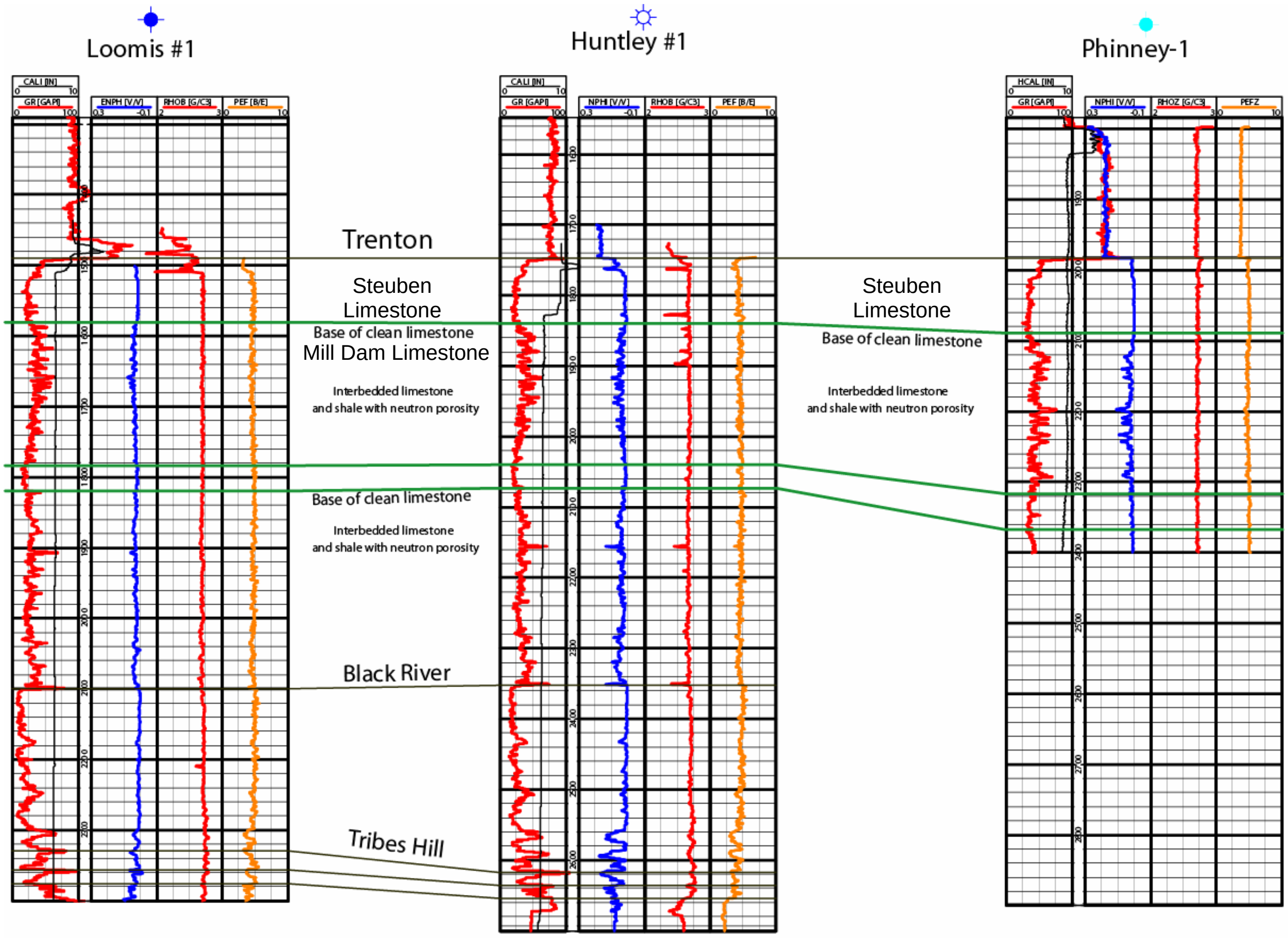


Figure 22. Cross section between three Seneca Resources wells. When gas shows occur, it is commonly at the base of the clean limestones noted on cross section. If horizontal wells were to be attempted, these zones would be the best targets. See Figure 2 for well locations.

12.4 Play Boundaries

There are two possible plays in the Trenton Limestone, the highly overpressured play discussed here and a possible more normally pressured play to the southwest. The highly overpressured play seems to only occur where the Steuben Limestone caps the Trenton and the formation is buried to less than 2500 feet (measured depth).

The Steuben Limestone caps the Trenton to the west, but pinches out to the east (Figure 23). There are no fields to the east of the Steuben pinch out, probably because the productive interval is no longer part of the Trenton but is considered to be Utica Shale. The Utica is not known to be highly overpressured so the Steuben seal may be what helps to generate the overpressure. Most of the larger fields occur where the Steuben Limestone is at least 75 or 100 feet thick.

The highly overpressured play appears to be bounded to the south by the line at which the Trenton is buried below a depth of 2500 feet (yellow line in Figure 24). At depths shallower than this, the pressure of the gas is equal to the lithostatic pressure and able to prop open bedding planes. At depths greater than about 2500 feet the lithostatic pressure exceeds the gas pressure and the horizontal partings are closed. As a consequence, no highly overpressured fields occur to the south of this line.

It is not known how far west the play extends, but there are few fields past the eastern end of Lake Ontario. The amount of gas may decrease to the west because it is farther from the Utica Shale source rock or perhaps the interbedded shales become less organic-rich to the west. The Trenton outcrop belt to the northeast would of course be the northern limit of the play. Any new wells testing this play are most likely to find gas within these boundaries.

There is also some potential at depths greater than 2500 feet, but it would probably be more normally pressured or perhaps slightly overpressured. Based on logs, there is still some good neutron porosity as well as density porosity on the logs within the Trenton. This may be a sign that there is porosity in the shales and that they might produce gas. The Trenton is not highly overpressured in this area so it may be easier to drill. Long horizontal wells with large frac jobs might be a good approach in this area as well. If it does work, there may be potential for hundreds if not thousands of wells. It may be viewed as an extension of the Utica Shale Play. The porosity in the shaly interbedded part of the Trenton improves as the overlying Steuben Limestone thins.

12.5 Potential

The Trenton Limestone play may actually be better viewed as an extension of the Utica Shale play. Like many shale plays today, it may be best approached with long horizontal wells and high volume frac jobs. If drilled and completed in this way, the Trenton will almost certainly produce gas, but it remains to be seen if there is a great enough volume of gas to be economic. Within the interbedded shale and limestone interval, much of the rock is limestone which probably has little or no gas in it. The potential for gas production probably increases from west to east toward the pinchout lateral facies change into the Utica.

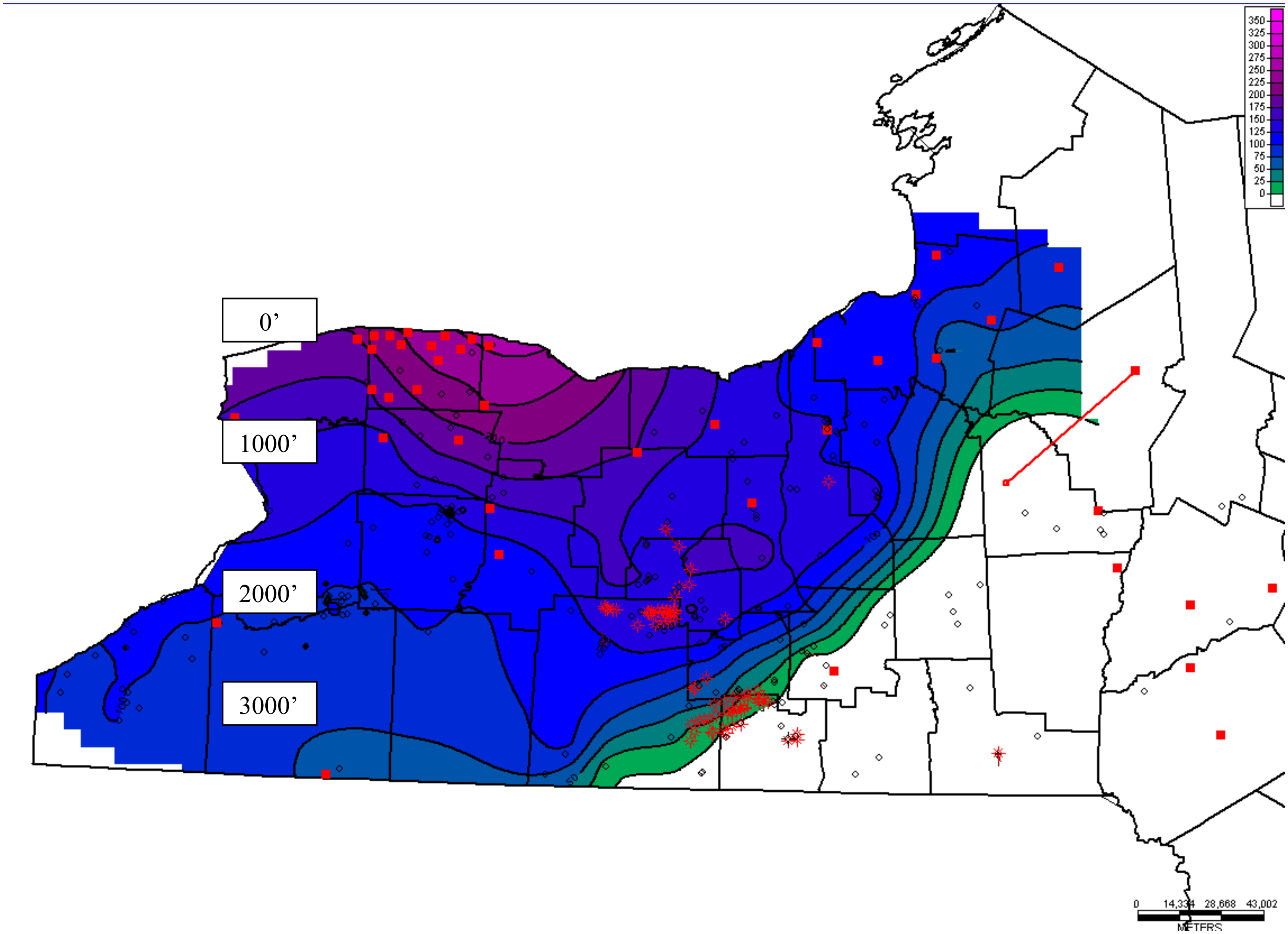
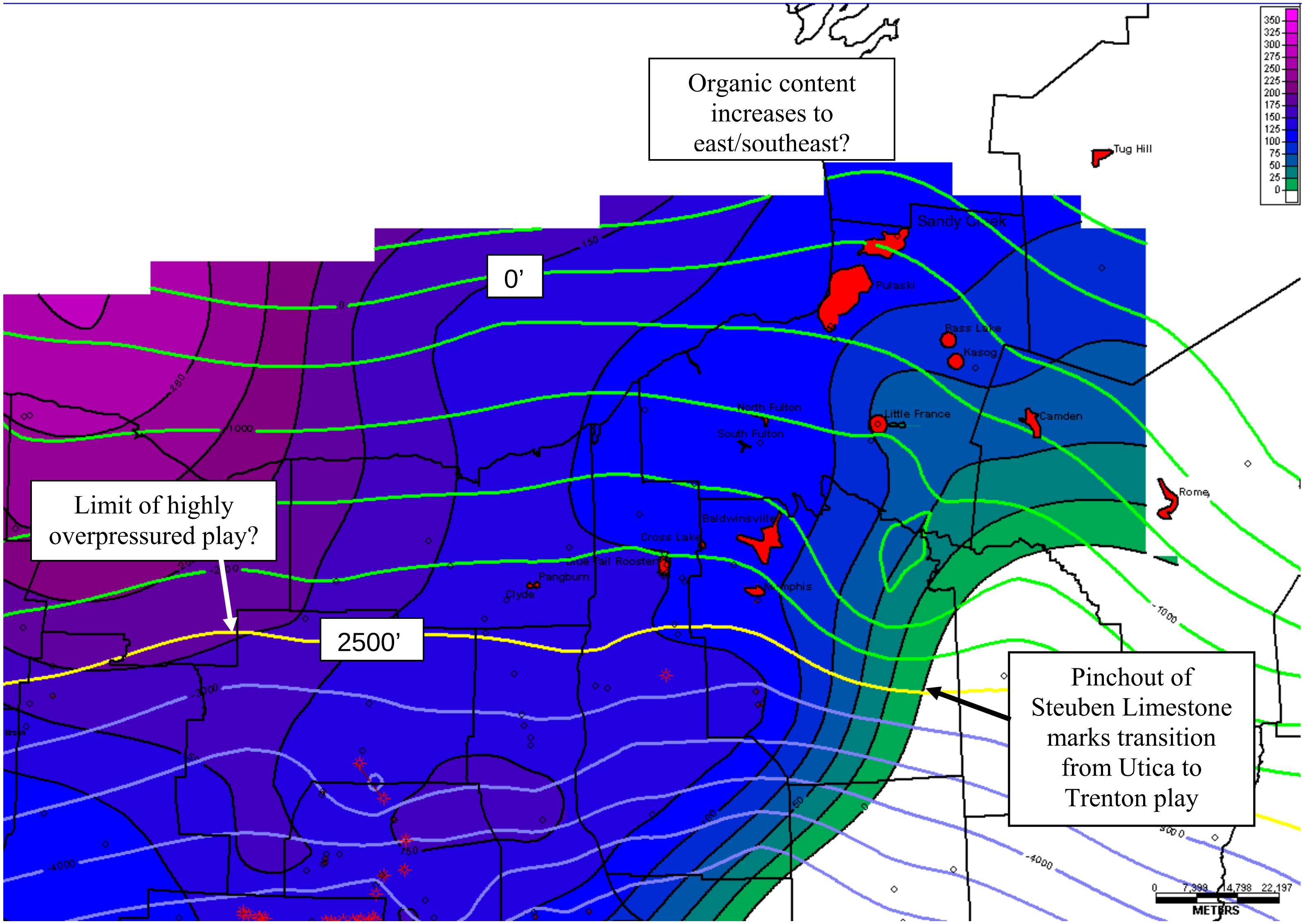


Figure 23. Isopach map of Steuben Limestone – pinchout to east may mark edge of Trenton Limestone play (and beginning of Utica Shale play?).



Organic content increases to east/southeast?

0’

Limit of highly overpressured play?

2500’

Pinchout of Steuben Limestone marks transition from Utica to Trenton play

Figure 24. Color-filled contours are isopach of Steuben Limestone at top of Trenton – no fields to east of pinchout. Color contour lines are burial depth to top Trenton (measured depth). Play boundaries delimited by outcrop belt to northeast, pinchout of Steuben Limestone to southeast, and ~2500 foot burial depth (yellow line) to south. Note that all fields occur to the north of the yellow line, and most of them where the Steuben is between 100 and 125 feet thick.

Section 13
CONCLUSIONS

The following facts were gleaned from the sidewall core study of the Trenton Limestone play around Lake Ontario in New York:

1. The Huntley #1 well had numerous extremely high-pressure gas shows in the Trenton Limestone. However, the well did not flow economic quantities of gas when later tested. This is similar to many Trenton wells in the area. Only a few have held up and produced economic quantities of gas.
2. These are not hydrothermal dolomite reservoirs. There is very little dolomite in the intervals that flowed gas.
3. There is virtually no macroporosity in the limestones. Samples were taken of many limestones that looked porous on the logs, and they had no visible porosity.
4. There does appear to be some microporosity visible with an SEM in the shaly interbeds. The micropores appear to be somewhat isolated, and permeability is interpreted to be very low.
5. There are few, if any, vertical fractures detectable on the FMI log in the zones that had gas shows in the Huntley #1 well.

The following are interpretations based on the data and discussions with geologists familiar with the play:

1. The overpressured gas is interpreted to occur in bedding-plane partings that are held open by the high pressure of the gas. After a short period of high-rate flow, the weight of the overburden causes the bedding plane partings to close.
2. The bedding plane partings are most likely to occur where there are sharp contacts between well-cemented cleaner limestones and shales or bentonites. Gradational contacts will be less likely to separate.
3. Wells with no vertical fractures, such as the Huntley #1 well, are likely to have production profiles with very high initial pressure and rates dropping off to sub-economic gas flow in a very short time. If no completion practices can be devised to keep the horizontal bedding planes open, wells with no vertical fractures may not be economic.
4. Wells with open vertical fractures may produce economic quantities of gas over longer periods of time. Open vertical fractures are most likely to occur on the downthrown side of extensional or transtensional faults. These features can be found using seismic data.

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Reservoir Characterization Group
at the New York State Museum

Plate 1. Black River/Trenton Fields and Dry Wells in New York State

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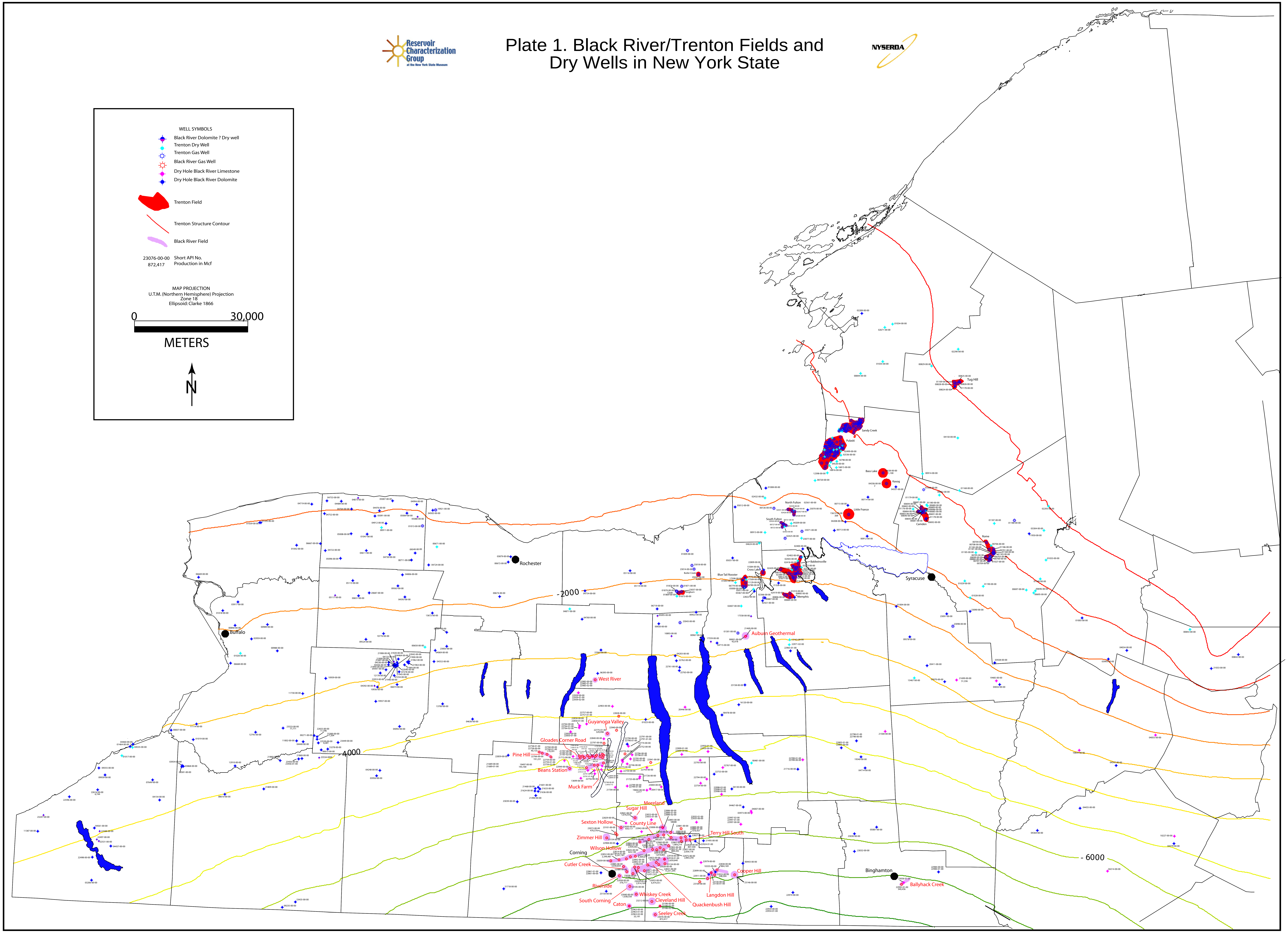

Reservoir Characterization Group
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Plate 2. Mudlog and Wireline Logs of the Huntley#1 well

NYSERDA

Huntley #1 Wireline Logs

Huntley #1 Mudlog

TRENTON LS @ 1725'

LS: DK GY, OFF WH, S&P, VF SM TXT, MICRO XTLN, HD,TRS CALC INCLU,TRS EMBD FOSS, TRS EMBD TRS PYR

TD FOR INTERMEDIATE CSG @1760'

BIT #5 8-3/4"HTC HR30C,JETS 3-12'S IN@1762'

LS: PRED LT GY, DK GY MOTT, MOD HD, DK LS PRED MICXTLN, LT GY OFF WH LS IS MORE COARSELY XTLN, TRS EMBD FOSS AND FOSS FRAG, ABDT OFF WH, TRNSL CALCT, SME W CLEAVGE BREAKS, POSS FRAC POR

SHUT WELL IN, NO VIS PRESSURE ON GAUGE, BUILD MW TO 10.0

INC MW TO 11.5

NOTE: WELL BLEW OUT @1812', SHUT WELL IN @1812', SHUT IN PRESSURE 1300 PSI, MIX 15.6 PPG KILL MUD

BULDING MWT TO 16.9 @1812'

DRL TO 1825', CIRC,CK FLOW, WELL FLOWING, INC MW TO 17.4

INC MW TO 18.0, SHUT PUMPS DWN GAS 1400U. INC MW TO 18.4, 10 STD ST GAS 235U

LS; PRED M GY, SME LT GY, SME MICORXLN, FRM TO HRD, PRED CALC CMT, SME TO TR FOSS, BRACH; TR, CLR TO TRNSL, QTZ XTL

LS; PRED M GY, SME LT GY, SME MICROXLN, FRM TO HRD, PRED CALC CMT, SME TO TR FOSS, BRACH; TR, CLR TO TRNSL, QTZ XTL

LS; PRED M GY, SME LT GY, SML, MICROXLN, RGH, FRM TO HRD, PRED CARB CMT, SOME TO TRACE FOSS, BRACH; TR, CLR TO TRNSL, QTZXTL, TR PYT. INTBD IN CALC

TOOH, REPAIR LEAK IN BOP

LS: PRED M GY, SME LT GY, MICROXLN, CRYPTOXLN IP, FRM TO HD, TRS FOSS FRAG, TRS FREE CALC

LS: PRED M GY, SME LT GY, MICROXLN, CRYPTOXLN IP, FRM TO HD, TRS FOSS FRAG, TRS FREE CALC

LS: PRED M GY, SME LT GY, OCC OFF WH, MICROXTLN, CRYPTOXLN IP, FRM TO HD, FREE CALC, SME W CLEV FRAC,TRS BRAC FOSS

LS: PRED M GY, SME LT GY, OCC OFF WH, MICROXTLN, CRYPTOXLN IP, FRM TO HD, FREE CALC, SME W CLEV FRAC,TRS BRAC FOSS

LS: PRED M GY, SME LT GY, OCC OFF WH, MICROXTLN, CRYPTOXLN IP, FRM TO HD, FREE CALC, SME W CLEV FRAC, TRS BRAC FOSS

GAS SHOW 2062' TO 2072' MAX GAS 9000U TOOH WORK ON BOP @2062'

LS: PRED M GY, DK GY, OCC LT GY,OFF WH, MICROXTLN, CRYPTOXTLN IP, FRM, HD,BLKY, CHNKY, TRS FREE CALC, TRS BRAC FOSS

LS: PRED M GY, DK GY, OCC LT GY,OFF WH, MICROXTLN, CRYPTOXTLN IP, FRM, HD, BLKY CHNKY,TRS FREE CALC, TRS BRAC FOSS

LS: PRED M GY, DK GY, OCC LT GY,OFF WH, MICROXTLN, CRYPTOXTLN IP, FRM, HD, BLKY CHNKY,TRS FREE CALC, TRS BRAC FOSS

LS: PRED M GY, DK GY, OCC LT GY,OFF WH, MICROXTLN, CRYPTOXTLN IP, FRM, HD, BLKY CHNKY,TRS FREE CALC, TRS BRAC FOSS

LS: PRED M GY, DK GY, OCC LT GY,OFF WH, MICROXTLN, CRYPTOXTLN IP, FRM, HD, BLKY CHNKY,TRS FREE CALC, TRS BRAC FOSS

LS: PRED M GY,BRNISH GY, DK GY, OCC LT GY,OFF WH, MICROXTLN, CRYPTOXTLN IP, FRM, HD, BLKY CHNKY,TRS FREE CALC, TRS BRAC FOSS

LS: PRED M GY, DK GY, OCC LT GY,OFF WH, MICROXTLN, CRYPTOXTLN IP, FRM, HD, BLKY CHNKY,TRS DOL

LS: PRED M GY, DK GY, OCC LT GY,OFF WH, MICROXTLN, CRYPTOXTLN IP, FRM, HD, BLKY CHNKY,INC DOL

REPAIR BOP

DOL: PRED M GY, BRNISH GY, OC LT GY, MICROXTLN, CRYPTOXTLN IP, FRM, HD, BLKY CHNKY, TRS FOSS FRAG, TRS INTBD CALC, TRS PYR XTL

DOL: PRED M GY, BRNISH GY, OC LT GY, MICROXTLN, CRYPTOXTLN IP, FRM, HD, BLKY CHNKY, TRS FOSS FRAG, TRS INTBD CALC

DOL: PRED M GY, BRNISH GY, OC LT GY, MICROXTLN, CRYPTOXTLN IP, FRM, HD, BLKY CHNKY, TRS FOSS FRAG, TRS VFGR SUBANG ,SUBRD,UNCONS SS GR

TOP OF POTSDAM 2564'

Plate 3. Huntley Trenton Logs, FMI and Interpreted Lithology

Plate 4. Huntley Black River Logs, FMI and Interpreted Lithology

Plate 5. Abundances of Fossils and Constituents with Logs and Mudlog

This Plate consists of relative abundances of various fossils and constituents estimated from thin sections. They are only accurate at the sample depths and there is likely to be much variation between samples that is not captured by the abundance graphs. There are some significant differences between the interpreted lithology from the mudlog and the actual rock types found in the plugs. Most of the gas shows in the Trenton occur where there is interbedded limestone and shale. Some thin shale beds may not have been sampled.